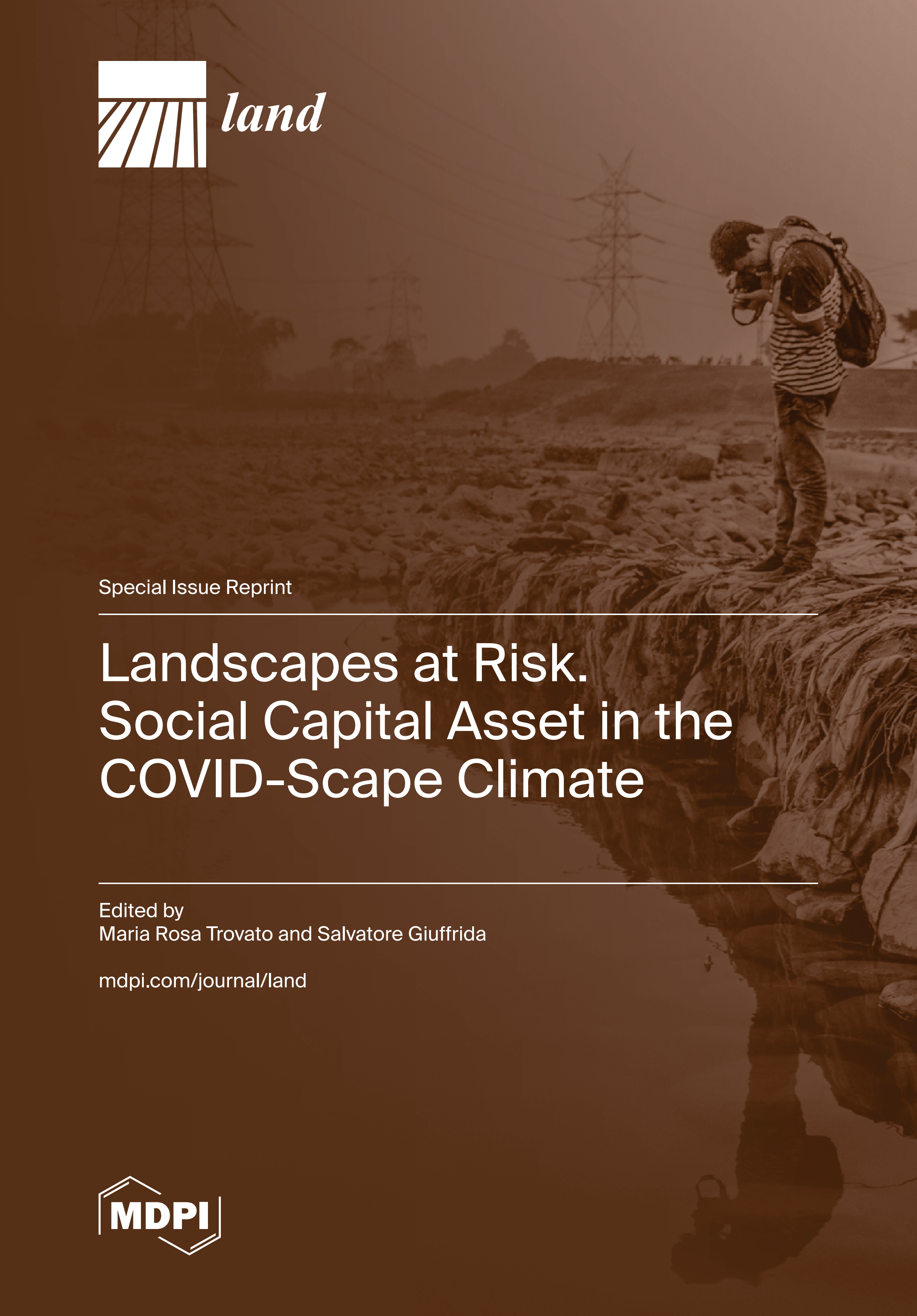

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Special Issue Reprint

Landscapes at Risk. Social Capital Asset in the COVID-Scape Climate

Edited by
Maria Rosa Trovato and Salvatore Giuffrida

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Guest Editors

Maria Rosa Trovato
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Contents

About the Editors

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Preface

The territory has been deprived of its own institutional dimension for too long. Based on the perspective of Luhmann's macrosystemic approach, the territory is characterized as a "unity-difference between the social system and the environment".

Hence, the fragmentation of the territory into components of the social system on the one hand and rejected parts on the other causes issues. While the former are linked by increasingly coherent and articulated forms of social communication, the latter, precisely because they are excluded from it, dissolve into the environment as a condition rather than a place or habitat.

Social communication, precisely because of its implicit connective function, delimits the space of sharing and inclusion, in which the subjects of this unity emerge and evolve; in contrast, that which is not part of this communicative process cannot be represented and symbolized by the prospects and destinies that are shared by the subjects of communication, thereby becoming its object, and remains in the ambiguous state of potentiality: either to be recovered to the condition of being a part of the social system or, on the contrary, to accumulate with others, sedimenting the condition of growing environmental risk.

Consequently, the question of at-risk landscapes concerns the co-presence, and therefore the competition, between being a subject and being an object of social communication, the asymmetry of which can allow the sociosystemic or environmental dimension to prevail, modifying the (communicative, not physical or geographical) delimitation of the landscape, which, as an entity identified in the sphere of intentional perception, is an over-subject of social communication and therefore, by definition, a social system.

With increasing complexity, the social system tends to divide into subsystems (political, legal, economic, cultural, educational, etc.), which aggregate by means of opposite codes. Each is characterized by a code that selects what is functional for its expansion and what instead hinders it, potentially coming into conflict with the other subsystems that aggregate through opposite codes.

The combination of these codes defines perceptions, knowledge, and awareness, which are aggregated into values and motivations, i.e., the content of evaluations and transformations of the territory.

Constitutive landscape categories that can be associated with social subsystems are, for example, 'natural-scape', 'urban-scape', and 'human-scape'. Just as the category of landscape, as an epiphenomenon of the social system, is the subject of social communication, so, conversely, are the categories of the natural-scape, urban-scape, and human-scape the objects of social communication.

These three dimensions of the environment are thus the result of the exclusion from social communication of important parts of natural, urban, and human capital, and, left to themselves, they accumulate, creating a risk that environmental fluctuations (floods, earthquakes, migrations) may affect the forms (sustainability, valorization, inclusion) of nature, the city, and communities. This is the conceptual scheme for defining landscape risk and thus identifying landscapes that are at risk.

The redefinition of the environment and environmental risk from the landscape and the concept of landscape risk implies not so much an anthropocentric or sociocentric approach, but rather an affirmation of the primacy of form (shape > scape) and its recognizability as the boundary between what is landscape and what is not, i.e., the environment.

The notion of environmental risk, outside the category of form, takes on a physicalist declination that has nothing in common with the nature of landscape risk.

The COVID-19 pandemic has highlighted the lack of an adequate and comprehensive approach to landscape and landscape risk. This awareness has led scholars to examine the relationship between social capital and the landscape as a whole. While the former has mainly been considered in its material, functional, economic, and ethical dimensions, the latter has been studied in its perceptual, psychological, cultural, and esthetic dimensions. Researchers in the field of "real estate landscape" have attempted to characterize the strong relationship between real estate capital, as a form of social fixed capital, and the way in which the choices of use and investment of real estate assets, as well as the instruments of territorial and urban policy, are progressively reflected in the forms of housing, the city, and the territory. In this sense, landscape constitutes not only the perceptual dimension, but also the cognitive and therefore formal or essential dimension of the territory, since it is precisely the different ways of being of the real estate asset that transcend its physical dimension and enter into the symbolic, for better or for worse, as the contributions collected here point out, albeit in different ways and using different languages. In the first case, the public, social, and inclusive dimensions of a built heritage that is integrated into the ecosystem components of the landscape prevail, which is the result of an evolutionary process of architectural language and settlement systems that are internally and externally coherent. In the second case, where the prospect of individual promotion exceeds the sphere of creativity—or even betrays it with destructive and dissipative actions in the form of natural capital—the communal and integrative dimension of the use and development of physical capital is lacking, the effects of which are reflected in the reduction in the formal and essential unity that the landscape has always represented, i.e., in the harmony between the abiotic, biotic, and anthropic components of the territory.

Moreover, scholars have shown how real estate capital can express this relationship to a monetary measure (market price) and an articulated and complex qualitative essence, which also includes the landscape. The current pandemic and future crises on a geopolitical scale have determined and will determine significant variations in the relationship between social capital and the landscape, i.e., two of the main existential dimensions of settled communities, which can be detected in their economic–monetary dimension. A new systemic perspective can support the development of a new vision of the relationship between humans and the landscape in its various dimensions, defining new territorial arrangements that are centered on a renewed relationship between attractors (dense areas or strong cities) and detractors or environmental obstacles (the plundered and abandoned parts of rural and inland areas, i.e., those that are not recognized by the dominant subsystem).

The following volume presents studies on the essence and possible resolution of the conflict between certain functions of the economic subsystem and landscape quality, with particular reference to the main criticalities that already existed before the pandemic and to the possibility—given the new constraints—of re-establishing their links in order to reduce landscape risk.

The issue of landscape risk has been studied at the territorial and urban scales. At the territorial level, researchers have proposed the pursuit of various objectives: the production of thematic maps and indices, as in the case of the inland areas of Sicily and Sardinia (Italy); the identification of tools to support analysis and evaluation for the planning of interventions to counteract the progressive spread of construction in rural areas, as in the case of Noto (Italy); the identification of an index to assess a country's performance in terms of economic, social, and environmental sustainability, also taking into account the relative risk of COVID-19, based on an integrated assessment method based on the Choquet integral (CI) mathematical framework and the multi-attribute ideal–real comparative analysis (MAIRCA); an analysis of the impact of the COVID-19 pandemic and the Russian–Ukrainian conflict on the agricultural sector and land use in the context of the European Union; the development of a participatory decision-making approach for the selection of joint valorization strategies for the terraced cultural landscapes of the Costa Viola (Italy); the creation of an integrated tool, the Heuristic Planning support system (HPSS), aimed at exploring green–blue strategies for the historic districts of the Borgata di Santa Lucia in Syracuse (Italy); and the identification of a methodological approach to support public administrations and private investors, based on an optimization algorithm that is aimed at reducing the gap between the costs estimated by technical experts and the actual costs. At the urban level, efforts have been made to identify proposals promoting innovation in planning processes to mitigate the effects of the pandemic and reduce exposure to future risks.

An interesting proposal analyzed the processes of "gentrification" and "degentrification" in the Itaewon area in South Korea using semantic network analysis. The literature review focused on the importance of the human landscape, highlighting how human and social capital and livability issues can guide the debate on urban development prospects in the post-COVID-19 era.

Some scholars have proposed tactical urbanism interventions as a tool for urban regeneration; others have proposed new key indicators of digitization to enable the measurement of the sustainability of the digital transition in urban planning.

Still, on an urban scale, some analyses have measured the impact of the pandemic and the Russian–Ukrainian conflict on the housing market in Northern Italy using a random forest feature importance analysis and multivariate regression; others have measured the economic impact of the perceived landscape on the prices of single-family houses in a Spanish Mediterranean urban area (Marbella).

This issue has also been analyzed from the perspective of the financial measures that were taken by governments to cope with the pandemic, the Russian–Ukrainian crisis, and the ecological transition. In light of the above, some researchers have proposed an approach for economic and energy assessments as a tool for evaluating policies from the public and private perspectives in the context of the financial package—the "Superbonus 110%"—that was established by the Italian government for energy retrofitting. Other researchers have proposed a comparative analysis between Italy and Spain on the transposition of European standards for energy communities and financial instruments. Another study analyzed the impact of external shocks on financing to promote GDP (Gross Domestic Product) convergence based on panel data approaches and convergence theory.

Maria Rosa Trovato and Salvatore Giuffrida

Guest Editors

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Editorial

Landscapes at Risk: Social Capital Assets in the COVID-Scape Climate

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1. Introduction

Up until the current pandemic, the terms "urban-scape" and "human-scape" have been meant, assumed, and practised as parallel dimensions of in territorial analysis, marginalising our knowledge about and evaluation of landscape risk [1–12]. This has always been associated, and often confused, with diverse forms of environmental risk, despite the fact that they both represent some of the most important components of risk, but not its essence [13,14].

The relationship between social capital and landscape deserves to be examined and represented in its entirety: as a matter of fact, while social capital has mainly been considered in terms of its material, functional, economic [15–20], and ethical dimensions, landscapes have been examined in terms of their perceptual, psychological, cultural, and aesthetic dimensions [21–28].

Significant attempts to define the strong relationship between capital and landscape have been conducted in the field of the "real estate-scape"—the asset of real estate capital, indeed, shows the relationship between a monetary measurement (price) and an articulated and complex qualitative essence, which represents all of the attributes the market price is associated with [29–34].

Sudden and widespread environmental fluctuations, such as the one created by the current pandemic, significantly influence the relationship between the two main existential dimensions of settled communities—social capital and landscape—and their possible representations by means of their economic–monetary dimension as well [35–38].

In view of a possible renewal of the relationship between people and the city-landscape system, highly differentiated scenarios of new territorial arrangements could unfold.

The ultimate aim of this territory renewal process, by virtue of the territory's institutional dimension, is to resolve the traditional opposition between our social system and the environment, according to Luhmann's macrosystemic approach [39].

From this perspective, this process should favour a renewed relationship between territorial attractors (dense areas and major cities) and environmental hindrances—the neglected parts of rural and state-owned territory, which are the main cause of environmental threats.

2. The Special Issue—Landscapes at Risk: Social Capital Assets in the COVID-Scape Climate

This volume presents studies on the nature of the conflict between some specific functions of the economic sub-system and landscape quality and the possibility of overcoming this conflict, with specific references to the main criticalities already present before the pandemic and to the possibility—prefigured by new restraints—of rebuilding the two sides' connections in order to reduce landscape risk. However its aspects may be articulated (natural/artificial, geological, agricultural, urban, industrial, archaeological, etc.), the landscape has an essential matrix built upon it being the "shape of the territory" and, as such, a "recognisable essence in the sphere of intentional perception". Therefore, landscape risk consists of the possible loosening or dissolution of this structural unity, due to the driving force of a non-integrated development of the territory.

The topic of landscape risk has been investigated at the territorial and urban scale. On a territorial scale, research has been conducted that pursues different aims: the identification of thematic maps and indices, as in the case of the Italian inland areas of Sicily, in Trovato and Nasca (List of Contribution, 1), and Sardinia, in Monsù Scolaro and Cappello (List of Contribution, 2); the identification of tools to support analyses and evaluations carried out for the planning of interventions to combat the progressive spread of buildings in rural areas, as in the case of Noto (Italy), with the identification of an index to assess Sicily's performance in terms of economic, social, and environmental sustainability, in Minioto et al. (List of Contribution, 3); the relative risk of COVID-19, considered using an integrated assessment method based on the Choquet Integral (CI) mathematical framework and on a Multi-Attribute Ideal-Real Comparative Analysis (MAIRCA), in Sica et al. (List of Contribution, 4); an analysis of the impacts of the COVID-19 pandemic and the Russian–Ukrainian conflict on the agricultural sector and land uses in the European Union, in Pereira Domingues Martinho (List of Contribution, 5); the construction of a participatory decision-making approach for the selection of shared valorisation strategies for the terraced cultural landscapes of the Costa Viola (Italy), in Della Spina et al. (List of Contribution, 6); the creation of an integrated tool, the Heuristic Planning Support System (HPSS), aimed at exploring green–blue strategies for the historical neighbourhood of the Borgata di Santa Lucia in Syracuse (Italy), in Trovato and Cappello (List of Contribution, 7); the identification of a methodological approach to support public administrators and private investors, based on an optimization algorithm intended to reduce the gap between the costs estimated by technical experts and actual costs, in Tajani et al. (List of Contribution, 8). On an urban scale, landscape risk has been used in research proposals to promote innovation in the planning processes established to mitigate the effects of the pandemic and to reduce peoples' exposure to future risks.

Interesting research by Han et al. (List of Contribution, 9) analysed the processes of "gentrification" and "degentrification" in the Itaewon area in South Korea by means of a semantic network analysis. A literature review on the importance of the human landscape, highlighting how human, social capital, and liveability issues can guide the debate on urban development prospects in the post COVID-19 era, is presented in Cilliers et al. (List of Contribution, 10).

Some scholars have proposed tactical urbanism interventions as a tool for urban regeneration, as in Rossitti et al. (List of Contribution, 11); others have established new key indicators of digitization to enable the measurement of digital transition sustainability in urban planning, as in the paper of Canesi and Marella (List of Contribution, 12).

Furthermore, on an urban scale, Gabrielli et al. have measured the effects of the pandemic and the Russian–Ukrainian conflict on the housing market in Northern Italy using a random forest feature importance analysis and a multivariate regression (List of Contribution, 13), while Castro Noblejas et al. have measured the economic impact of the perceived landscape on the prices of single-family houses in an urban Spanish Mediterranean area (Marbella) (List of Contribution, 14).

The topic of landscape risk was also analysed from the perspective of the financial measures implemented by governments to overcome the crises of the pandemic, the Russian–Ukrainian conflict, and climate change. From this perspective, Gotta et al. have proposed an approach that uses economic and energy assessments as a tool for evaluating policies from public and private perspectives in the context of the funding package "Superbonus 110%", established by the Italian government for energy retrofitting (List of Contribution, 15). Barbaro and Napoli proposed a comparative analysis between Italy and Spain on their adoption of European standards within their energy communities and financial tools (List of Contribution, 16). Pereira Domingues Martinho analysed the effects of external shocks on financing to promote GDP (gross domestic product) convergence based on panel data approaches and convergence theory (List of Contribution, 17).

Conflicts of Interest: The authors declare no conflicts of interest.

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Article

An Axiology of Weak Areas: The Estimation of an Index of Abandonment for the Definition of a Cognitive Tool to Support the Enhancement of Inland Areas in Sicily

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Abstract: The marginalization of areas due to a progressive increase in social, material, economic, and infrastructural vulnerability is a phenomenon that afflicts many countries today, and it is growing rapidly. Agenda 2030, in highlighting the need to identify measures to counter this phenomenon, has promoted the development of a growing awareness of addressing this issue that cannot be postponed. With this in mind, in Italy, a map of inland areas was produced by the Interministerial Committee for Economic Planning and Sustainable Development (ICEPSD), a publication aimed at measuring the extent of the phenomenon and support the development of specific strategies that collectively define the National Strategy for Inland Areas (NSIA). In this study, starting from a critical analysis of the classification of areas in the National Strategy for Inner Areas, we propose a new cognitive tool of the phenomenon of abandonment developed from the perspective of an axiological approach of marginal areas. This tool is based on the mapping of an abandonment index I_a on QGIS with reference to the clusters of municipalities identified based on the quartiles of its values. This index was estimated as an aggregate weighted sum of the components identified because of the Principal Component Analysis (PCA) used to analyze the indicators of different forms of territorial capital of weak areas.

Keywords: inland area; territorial capital; axiological approach; principal component analysis (PCA); abandonment index; map of abandonment; National Strategy for Inner Areas (NSIA); vulnerability of territories; resilience of territories; National Recovery and Resilience Plan (NRRP)

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1. Introduction

The marginalization of abundant areas due to the progressive increase in social, material, economic, and infrastructural vulnerability is a complex phenomenon that requires an urgent response, one which can no longer be postponed [1–8].

The 2030 Agenda for Sustainable Development [9] provides general measures on less developed areas with reference to "Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable", and in particular, targets 11.1, 11.2, 11.4, 11.6, 11.a and 11.c [10].

The European Commission, with Europe 2020 [11], promotes "smart, sustainable and inclusive growth" and greater economic and social policy coordination between the European Union and member states. Inclusive growth must promote an economy with a high employment rate, and must foster social and territorial cohesion.

Moving in this direction is the long-term vision for the EU's rural areas [12], an initiative that creates a new momentum for rural areas, home to 30 percent of the EU's population, building on new opportunities created by the EU's green and digital transitions and on lessons learned from the experience of the pandemic effects of COVID-19 [13,14].

The Commission's communication proposes a negotiation among citizens and other stakeholders in rural areas to create a rural pact and rural action plan aimed at making them stronger, more connected, resilient, and prosperous.

Laws have been enacted in Italy to support weak areas, such as Law No. 97 "New Provisions for Mountain Areas" of 31 January 1994, for the preservation and enhancement of mountain areas, which are of preeminent national interest" [15]; Law No. 158 "Measures for the support and enhancement of small municipalities, as well as provisions for the redevelopment and recovery of the historic centers of the same municipalities" of 6 October 2017 [16], aims to support, through incentives for development, small municipalities, although, to date, it has been cumbersome to implement. In order to facilitate better implementation of the policies proposed by Law No. 158, the Italian Ministry of the Interior issued the Decree of 10 August 2020, namely "Definition of parameters for determining the types of small municipalities eligible for funding under Law No. 158" of 6 October 2017 [16].

The report "Historic Centers and the Future of the Country" by the National Association of Historic Artistic Centers (NAHAC) and the Center for Economic and Social Research of the Building Market (CESRBM) [17] provides an analysis of the vulnerability/resilience ratio of the 109 historic centers of the Italian capital province, using the rankings of the main 8000 Census indices [18] processed by National Institute of Statistics (NIS) on population dynamics, household composition, aging of residents, integration of foreigners, housing adequacy and employment.

Comparisons of key demographic indices on the built heritage and economic activities at the scale of the historic center, municipal area and related values at the national scale are offered in the report. This study identified some guidelines aimed at the defense of historic centers, their preservation and enhancement, highlighting the urgency of defining a national policy to support the regions and municipalities, and the ineffectiveness of some of the instruments aimed at small historic centers in inland areas proposed by the previously mentioned Law No. 97.

In Italy, the National Strategy for Inner Areas (NSIA), which has been promoted by the Agency for Territorial Cohesion since 2013, provides support measures for territories affected by structural processes of depopulation and abandonment (1077 Italian municipalities, and just over 2 million inhabitants) [19].

The NSIA supports fragile territories, distant from the main centers of supply of essential services and too often left to their own devices, which, however, cover a total of 60 percent of the entire surface area of the national territory, 52% of the municipalities and 22 percent of the population.

In terms of financial support for actions to support weak areas, several packages have been introduced over time.

The legislative package on cohesion policy 2014–2020 (Italy, England, France) introduces important changes: strengthened coordination of the programming of the four EU funds linked to the Common Strategic Framework 2014–2020 in a single strategy document, and close coherence with the goals of the Europe 2020 "Strategy for Smart, Inclusive and Sustainable Growth" [20]. Following this, the 2021–2027 Partnership Agreement strengthened the use of European Development and Investment Funds (EIS) in pursuit of the Union's Strategy for Smart, Sustainable and Inclusive Growth [21].

The Italian National Recovery and Resilience Plan (NRRP) funded by the European Union-NextGeneration EU, with reference to the implementation to Mission No. 5 "Inclusion and Cohesion" [22] has provided funding of 100–400 million euros from the Fund for Development and Cohesion (FSC) for "special interventions for territorial cohesion", "National Strategy for Inner Areas, and "strengthening of community social services and infrastructure".

The goal is to provide social services to at least two million citizens residing in inland areas, including at least 900,000 in southern regions, for which a minimum share of 40% of the total investment is reserved.

The amount of funding allocated for inland areas in Italy represents an important opportunity to be able to significantly promote their protection, conservation, and enhancement [23].

Funding will be disbursable based on the characterization of inland areas proposed by the Interministerial Committee for Economic Planning and Sustainable Development (ICEPSD).

The map of inland areas is an important knowledge base for strategy planning and intervention planning.

In this regard, ICEPSD has updated the first version of the map of inland areas from 2014, with a new version that is from 2020, which will support the Partnership Agreement 2021–2027.

The beneficiaries of funding will be all municipalities identified as intermediate, peripheral or ultra-peripheral areas in the proposed new mapping.

The cognitive support produced by ICEPSD is based on a characterization of inland areas with reference to the distance matrix, centers of service provision, demographic indicators, and some indicators of socio-economic and structural condition of the territories. It, in classifying areas into pole, belt, peripheral, and ultra-peripheral primarily based on the distance matrix and the level of services offered, provides cognitive support for the development of the National Strategy of Inland Areas, which may be incapable of detecting the residual values of territory. As a consequence of this, it may be unable to detect the residual resilience of these areas [24,25], contributing to the selection of inefficient strategies for them.

If the basic tool for promoting the implementation of specific policies and for allocating funding is unable to capture the values and/or dis-values of areas [25], it could contribute to making the former ineffective and the latter inefficient.

In order to improve the cognitive support for the development of strategies to support weak areas, the research from a critical analysis of the ICEPSD classification of inland areas proposes to develop one from the perspective of an axiological approach.

This approach is aimed at interpreting the values and/or dis-values of abandoned areas in order to explore their residual worth and support decisionmakers in the complex process of reinterpreting their values [26].

In this regard, the research will propose a new cognitive framework of the geography of abandonment, i.e., a new map of the phenomenon based on the representation in QGIS of an index of abandonment estimated in this study for the inland areas of Sicily, Italy.

The index will be constructed based on the characterization of the main forms of territorial capital, namely, human, urban, economic, infrastructural, natural, cultural, and environmental capital. Given the numerosity of the indicators, in order to arrive at the most representative set of indicators, and thus to reduce the complexity of the representation of the different forms of territorial capital, a methodological approach widely used in the literature for this purpose will be used, namely, Principal Component Analysis [27–31]. The abandonment index will be estimated as an aggregate weighted sum of the components identified as a result of Principal Component Analysis (PCA) [4] implemented on the values of the different forms of territorial capital of weak areas.

The paper is organized in the following sections:

- Section 2 proposes a survey of the phenomenon of abandonment;
- Section 3 introduces the case study: Area Classification in the National Strategy for Inland Areas;
- Section 4 illustrates the methodological approach;
- Section 5 reports the results;
- Section 6 proposes some reflections on the results, i.e., the abandonment map based on the aggregate index estimated in this study and some comparisons with the classification of areas for the National Strategy of Inner Areas; it then identifies the limits and the lines of future development of this research;
- Section 7 proposes a summary of the proposed research.

2. A Survey of the Phenomenon of Abandonment

Abandonment, obsolescence, indifference, and disaffection pervade many aspects of our existence. They affect spaces, landscapes, territories, artifacts, emotions, technology, consumer goods, lifestyles, and thoughts. The rapid evolution of contemporary culture increasingly results in the loss of usefulness, wear and tear, and outgrowth of places, landscapes, and territories generating the condition of abandonment and obsolescence [32,33].

The condition of abandonment can be characterized in several manners: a physical sense, i.e., when one leaves a place; virtual when it is the result of a mental and affective process; social when territories are characterized by the progressive reduction of personal services and the concentration of phenomena, such as poverty, unemployment, low education, etc.; functional as a result of the divestment of activities and functions; and political as a result of inefficient or deliberately inequitable economic-social planning and governance in favor of some territories or portions of territories and to the detriment of others. An example of the latter point could be the weakening of the welfare state, which has resulted in the dismantling of important territorial principles due to the state's inability to keep them alive because of the progressive loss of population or the absence of an adequate level of infrastructure to support them.

The process that leads to abandonment in most cases is multi-dimensional in nature, i.e., several concurring causes generate it.

Today, more than 50% of the world's population lives in urban areas, and several studies predict that this percentage will increase to 75%.

The migration of population to urban areas at the expense of less urbanized areas, a shift brought about by increased job opportunities and service provision, climate change or natural disasters, is of a significant magnitude that is expected to grow in the coming years.

The concentration of populations, functions, services, technologies, and knowledge in coastal or urbanized areas at the expense of rural and inland areas has resulted in an asymmetry of territorial values, with strong polarization toward the former and abandonment in the latter [34]. While the attractiveness of urban areas is an advantage from the standpoint of territorial competitiveness, this is leading to strong pressures that have contributed to an imbalance in urban values.

In fact, urban areas, as a result of this, are more exposed to the effects related to climate change, such as those due to the generation of heat islands [35] and are affected by real environmental emergencies such as those generated by a progressive decrease in area quality and the problematic issue of waste management [36–38].

The UN World Urbanization Prospects 2018 report highlights the worsening phenomenon of land abandonment [39]. The current geography of land abandonment, according to this report, is that about two-thirds of the world's population by 2050 will dwell in large cities, especially in countries such as India, China, and Nigeria [40]. Their locational choice will be dictated by increased access to services, education, and employment [41].

The most populated urban territories currently are North America (82%), South America (81%), Europe (74%) and Oceania (68%) [42–44].

About 50% of the world's population resides in cities with fewer than 500,000 inhabitants, while 1 in 8 people live in one of 33 cities with more than 10 million.

Four types of depopulating regions (*shrinking regions*) have been identified in Europe (Figure 1): industrial areas in economic decline, mainly in Western Europe; peripheral depopulated areas typical of Northern Europe; areas that have experienced or are experiencing political transformations such as those in Eastern Europe; and rural areas in Southern Europe that are structurally weak with sharply declining fertility rates [45–49].

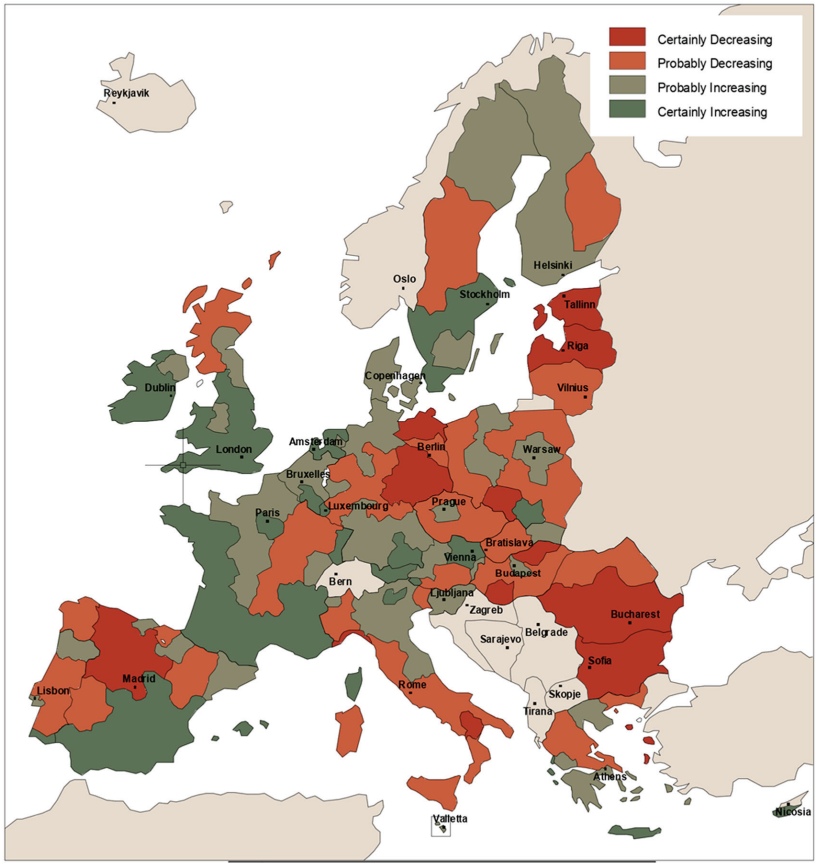

Figure 1. Typology of the "shrinking regions" (2005–2030). (Authors' elaboration based on EUROSTAT data [50]).

In Europe, population decline is associated with internal migration, so that from the 1960s onward, the population has become increasingly concentrated in the major urban centers, while the more inland, rural areas are losing ground [51].

In addition, many European cities are undergoing a reduction in their populations, giving rise to the phenomenon of *shrinking cities* [52–57] (Figures 2 and 3).

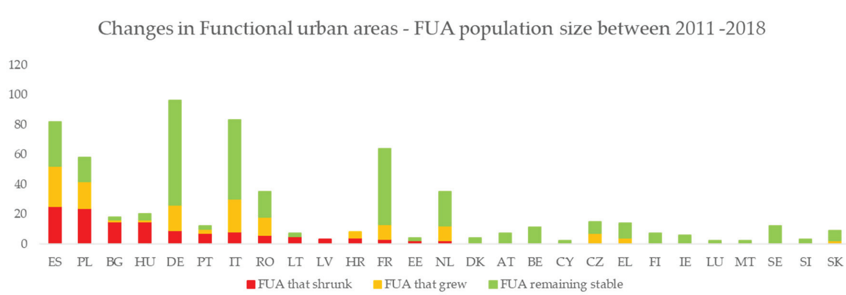

Figure 2. Changes in Functional Urban Areas-FUA population size between 2011 and 2018. (Authors' elaboration based on Joint Research Centre data [50]).

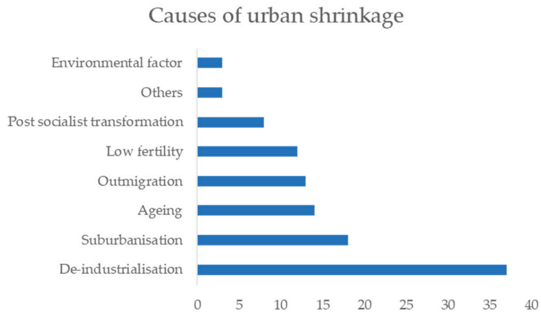

Figure 3. Causes of urban shrinkage. (Authors' elaboration based on Joint Research Centre data [58]).

Data on population decline, old-age index, birth rate, and registry de-registrants provide a mapping for Europe of the extent of the phenomenon of abandonment at the territorial and urban scale [59].

In Europe, between 2001 and 2020, the EU population (with reference to EU27) increased from 429 million to 447 million, a growth rate of 4 percent, although in 2020 [60], there was the highest rate of the population over 65 years old compared to the population aged 15–64 years old, at 32%; the number of live births in the EU has declined at a relatively constant rate from 2001 to 2020 [61].

In Italy between 2020 and 2021, the population decreased by 0.6 percent; this figure was definitely affected by the COVID-19 pandemic; the rate of over-65s compared to the population aged 15–64 is 37% [61], about five percentage points above the European average. Overall in 20 years the percentage of older Europeans has risen from representing 22.5% of the population to 32 percent [62]; the number of live births has experienced decreases of 25% between 2001 and 2020 [63]; the number of people cancelled from the civil registry for foreign countries has grown by 16.1 percent compared to 2018 [64].

During the period from 2010 to 2019, immigration of both foreign nationals (from within and outside the EU) and nationals returning to their country of origin increased in all member states except Italy, where immigration decreased during the same period.

Data show a higher level of quality of life in small Italian municipalities than in large cities, but they continue to depopulate in favor of urban areas [65].

In recent years, small municipalities have lost more than 74,000 inhabitants [66]. The entire south of Italy along with Genoa and parts of Piedmont are expected to lose population, while Emilia Romagna, Trentino and the Milan metropolitan area are expected to grow [67].

In Sardinia, National Institute of Statistics (NIS) data show a decrease in population over the past 60 years of more than 73,000 in inland municipalities, while it has grown by 293,000 in coastal municipalities. In the next 50 years, Sardinia will have 340,000 fewer inhabitants, most of which will be lost from inland municipalities [68].

The phenomenon of abandonment results in underutilization of all forms of territorial capital, namely, human, urban, economic, infrastructure, cultural, natural, and environmental capital [69–74].

The need to identify a new development process capable of interconnecting abandoned and marginalized areas with dense, attractive and congested areas meets the need for a rebalancing necessary for an improved functioning of the territorial system as a whole [75–78].

In fact, the urban areas, strong, dominant, catalysts of flows of "matter (natural resources), energy (labor) and information (technology)" have progressively extracted more and more from the weak areas, transforming them into "environment" in the Luhmanian sense [79,80].

As a result of this, weak areas have been dominated and ousted from both urban and land systems.

Urban areas now increasingly need to integrate weak areas for a twofold reason: because new flows of matter, energy and information [81,82] will have to support their development, and because they will have to manage their carrying capacity to improve their internal resilience [25,83–92].

The human, urban, natural, cultural-historical, infrastructural, and economic heritage characterized by people, housing, buildings, hamlets, resources, infrastructure and services, the small productive fabric [93] of weak areas, turns out to be in most cases looted, debased and abandoned. The heritage complex of a territory should contribute to the formation of its identity. It should represent the infrastructure supporting the very existence of a territory and that is a precondition for its development. The marginalization of weak areas and disaffection with the heritage complex that within them work together to generate the crisis of local identity and territories.

Identity is a complex issue, especially in a society such as the contemporary one marked by major upheavals and the great crises of this time, such as climate, pandemic, wars, poverty, injustice [94], and multidimensional and value dissimilarities. A reinterpretation of individual, collective and territorial identities could support overcoming these crises and promote development in contemporary societies.

In this perspective, the complex heritage of weak areas can become a resource, an opportunity for territories [95].

A reinterpretation of territorial values could reverse the gradual process that has led to disaffection and loss of identity, promoting a process of affection and renewed identity capable of interconnecting weak areas and urban areas. The creation of a territorial system in which weak areas can be included would promote not only their recovery but also the development and enhancement of urban areas. The perspective of an axiological approach [96,97] to support this study is instrumental in detecting territorial values and/or disvalues in order to support their reinterpretation.

3. Materials

The inland areas selected by the proposed classification for the NSIA are seventy-two, comprising a total of 1077 municipalities, covering approximately 2,072,718 inhabitants [19].

Inland areas are the most peripheral Italian municipalities in terms of access to essential services (e.g., health, education, and mobility). For the characterization of inland areas, "pole" municipalities are identified as a priority, i.e., those municipalities that offer the following services (alone or together with their neighbors):

- Higher education: an upper secondary school offered with at least one high school (scientific or classical) and either a technical or a vocational institute;
- Health services: at least one hospital with a Level I Emergency Department of Acceptance (EDA);
- Rail transportation services: a railway station of at least silver type, corresponding to medium-small facilities.

The data base supporting the NSIA classification contains not only information on instrumental criteria for characterizing "pole" areas, but also those on resident population, housing density per square kilometer, and some structural indicators, service supply indicators, service demand indicators, and social context indicators. A description of the indicators supporting the NSIA classification has been provided in Appendix A.

Municipalities are classified as "belt", "intermediate", "peripheral", and "ultra-peripheral", that is, with levels of peripherality gradually increasing with distance from the "pole" municipality.

In February 2022, ICEPSD updated this methodological framework, further refining the tool that serves to monitor the peripherality of the different territories that make up the country.

For the new classification, the basic approach has remained unchanged; in particular, the criterion for identifying the "pole" is the services present, but the distances from the "pole" for identifying the different types of inland areas have been reshaped, and metropolitan cities have not been assigned a priori to the "pole" category, as had happened (although for very few cases) in the 2014 classification. There are 389 municipalities that fall under the NSIA classification for the nine metropolitan areas of Sicily (Figure 4).

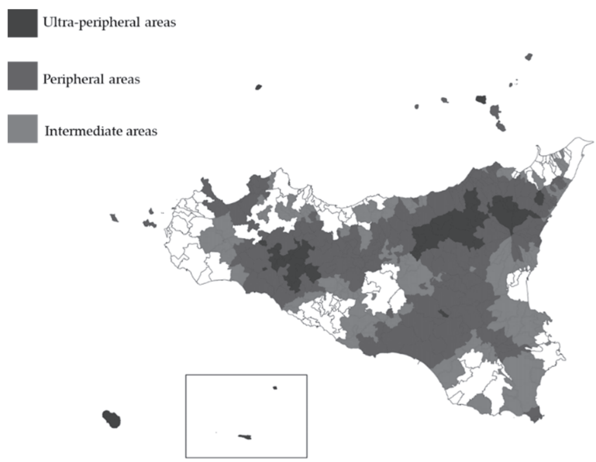

Figure 4. NSIA classification for inland areas of Sicily. (Authors' elaboration based on NSIA data).

They are characterized by 14 "pole" municipalities (4% of the total), 65 "belt" (17% of the total), 119 "intermediate" (31% of the total), 157 "peripheral" (40% of the total) and 34 "ultra-peripheral" (9 percent of the total). Intermediate, peripheral, and ultra-peripheral areas account for 80% of those falling under this classification. These areas cover a territory with an area of 19,541 square kilometers, in which 2,312,007 inhabitants reside. The percentage of municipalities falling in the NSIA classification (Figure 5) for the different metropolitan cities shows a greater concentration of the ultra-peripheral, peripheral, and intermediate typology for Messina, the absence of municipalities in the ultra-peripheral typology for Caltanissetta and Syracuse, and of municipalities falling in only intermediate areas for Ragusa.

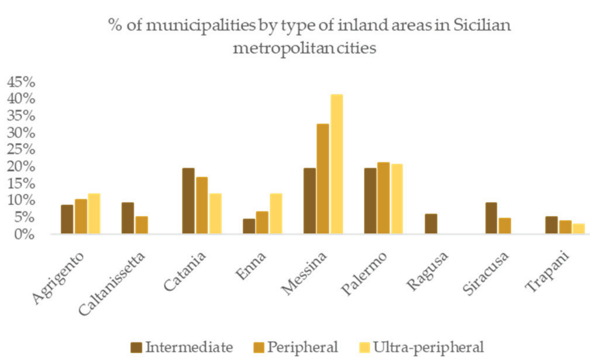

Figure 5. Percentages of municipalities by type of inland areas in Sicilian metropolitan cities. (Authors' elaboration from NSIA data).

With reference to land area, there is a greater extension of the ultra-peripheral type in the metropolitan cities of Messina and Enna, of the peripheral type in the metropolitan area of Caltanissetta, and of the intermediate type in the metropolitan area of Ragusa (Figure 6).

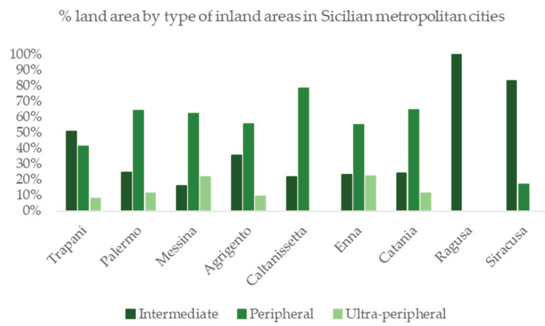

Figure 6. Percentage of land area by type of inland areas in Sicilian metropolitan cities. (Authors' elaboration from NSIA data).

There is a greater concentration of the resident population in the ultra-peripheral type in the metropolitan areas of Enna, in the peripheral type in the metropolitan area of Caltanissetta, and following almost at the same percentage of population, the metropolitan areas of Trapani, Palermo, Messina, and Agrigento, and in the intermediate type for the metropolitan area of Ragusa (Figure 7).

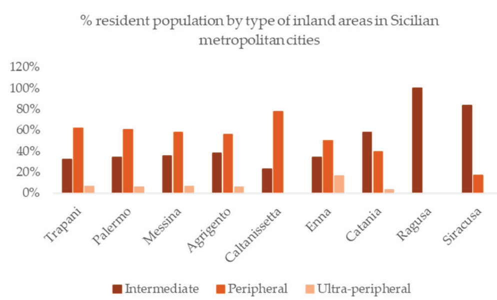

Figure 7. Percentage of resident population by type of inland areas in Sicilian metropolitan cities. (Authors' elaboration from NSIA data).

In summary, the NSIA classification identifies the most disadvantaged territory as a consequence of the number of municipalities falling in the peripheral and ultra-peripheral areas, by the extension of these areas, and by the percentage of population residing in the metropolitan area of Messina; the least disadvantaged territory with reference to the presence of only one type of area, the intermediate one, characterized by slight marginality, by its extension and by the percentage of population residing the metropolitan area of Ragusa. In terms of least disadvantage, after Ragusa is the metropolitan area of Syracuse.

The NSIA classification certainly represents a good cognitive base to support the enhancement of the territories characterized by abandonment; it has been instrumental in identifying the plan of needs, the order of priorities, the supporting policy, strategies, and funding. The different levels of remoteness/peripherality, in order to best achieve the set goal, require specific efforts of policies, from the ordinary one to rethink the organization of services (schools and health) even in the most distant, often mountainous territories, to the additional one based on conditionality, multi-level governance, participation and linkage to the result.

We question whether the cognitive framework proposed by the NSIA classification, one developed from the perspective of an approach to marginality substantiated by distance from attractive poles and the level of service provision, can effectively support the development of appropriate policies and strategies for abandonment territories. Geographic distance is certainly an important aspect of a geography of abandonment, but it is not exhaustive. In fact, an area could be economically strong or culturally/environmentally relevant even if it is far from the main attractor, or it could be economically weak and poorly culturally/environmentally relevant even if it is close to the main attractor.

Also, it must be remembered that the level of service provision is a condition that arises from political choices, in some cases short-sighted or oriented by the hegemonic power of the strong city, or characterized by selective ignorance, generating fractures and inequality between city and territory and favoring the progressive deterioration of the latter in favor of the former. In the perspective of an axiological approach of abandoned areas, one aimed at interpreting their values and/or disvalues, the definition of a cognitive process aimed at detecting the residual capacity of worth and supporting the process of reinterpreting value is an important issue [98].

From this perspective, the cognitive framework should integrate all the components of territorial capital that represent the value and valence capacity of these areas. In this regard, we propose a cognitive process of inland areas (i.e., a mapping of the phenomenon of abandonment), aimed at generating their mapping based on the values of the different components of the forms of territorial capital. In this regard, in the following section we will introduce the different forms of territorial capital that we consider relevant to this study.

4. Methods

In order to propose a new cognitive process developed from the perspective of an axiology of abandoned areas, we propose a methodological approach consisting of the following steps (Figure 8):

- Identification of the forms of territorial capital;
- Construction of a geodatabase of variables characterizing the forms of territorial capital;
- Standardization of all input variables to z-scores (each with a mean of 0 and a standard deviation of 1);
- Mapping with QGIS support of clusters of municipalities on the basis of quartiles of values of indicators of the forms of territorial capital;
- Comparison of the clusters of municipalities based on the quartiles of the indicators of territorial capital forms and the NSIA classification;
- Principal Component Analysis;
- Estimation of an aggregate index of abandonment I_a;
- Ranking of Sicilian municipalities based on their abandonment index;
- Cluster mapping with QGIS support of municipalities on the basis of quartiles of abandonment index I_a values.

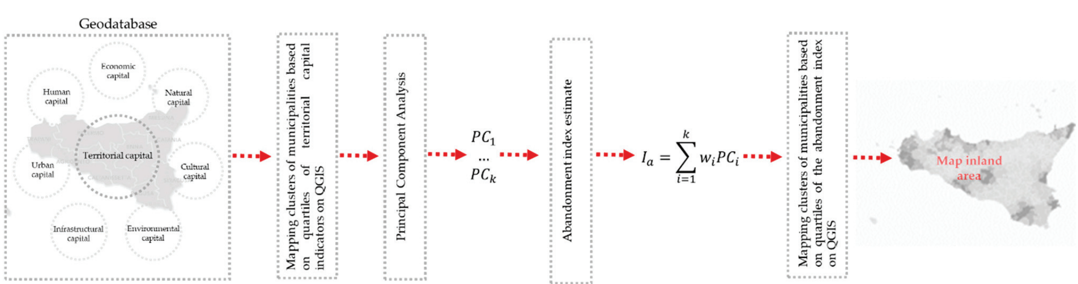

Figure 8. Flowchart of the methodological approach.

4.1. *Shapes of the Territorial Capital*

The concept of territorial capital was first proposed by the Organization for Economic Cooperation and Development (OECD) in the 2001 Territorial Outlook report [99] as a set of localized assets (natural, human, man-made, organizational, relational, and cognitive) that constitute the competitive potential of a given territory. It can also be considered as the set of elements, again part of the territory itself, that can act as a constraint or strength, in direct proportion to the ideas of those who intend to act on it to make the most of its opportunities [100,101]. It can be seen as the fulcrum between forces of the past, present, and future, but one which is also affected by the inside and outside of the territory that changes due to elements from different epochs and at different times that have been created and consolidated in the territory itself. The term "territory" refers to a proximity to a system of localized externalities, both from the point of view of proximity to the market and resources and as proximity to a localized system of production, knowledge, and traditions. The term "capital" is to be understood as a set of assets that can be used to increase well-being and competitiveness [102–107].

The main forms of territorial capital can be summarized in the following forms of capital: human, urban, economic-productive, infrastructure, cultural, environmental, and social.

Human capital can be identified as an individual's productivity potential, including health, education, work experience and skills [108].

Human capital as defined by the OECD can be regarded as a synthesis of "knowledge, skills, competencies and attributes embodied by individuals that facilitate the creation of personal, social and economic well-being" [109,110].

There are several methodological approaches in the literature for estimating the monetary value of human capital: cost-based approach [111], income-based approach [112], education-based approach [113], and the knowledge-based approach [114].

Among the best-known approaches proposed in the literature for estimating human capital is the Jorgenson-Fraumeni approach [115].

It, in fact, allows for the appropriate determination of its estimates, based on the present value of discounted income over its life cycle, taking into account possible variations in earnings (including due to experience), additional education that may be acquired, differential patterns of labor force participation and mortality [116].

Urban capital can be understood as the set of urban characteristics of the territory, i.e., the housing-city-landscape system, in which the housing stock is representative of a specific component of the social capital, i.e., the fixed capital.

Economic-productive capital can be understood as being the structure that enables the support of local economies and the productive capacity of a territory.

Infrastructural capital can be understood as the fixed capital accumulated in infrastructure and facilities, considered as a whole and with reference to the externalities arising from them [117–119].

Environmental capital can be understood as the set of conditions and resources of the natural environment, including geographical location [120–122].

Cultural and identity capital can be understood as the set of historical-cultural heritage, both tangible (monuments, landscapes, etc.) and intangible [123].

Social capital with reference to the definition proposed by Putman can be understood as "trust, norms governing coexistence, networks of civic associationism, elements that improve the efficiency of social organization by promoting initiatives taken together" [124]. Referring to Coleman's definition, social capital would consist of the "set of social relationships that the individual is able to use in order to achieve a goal of his or her own" [125,126].

Based on these definitions, the indicators represented of the different components of territorial capital, namely human, urban, economic, infrastructure, natural, cultural, and environmental capital, were selected.

The Geodataset of the Territorial Capital

The variables selected to characterize the different forms of territorial capital with reference to the different official databases are presented below, in Table 1 for human capital, Table 2 for urban capital, Table 3 for economic capital, Table 4 for infrastructural capital, Table 5 for natural capital, Table 6 for cultural capital, and Table 7 for environmental capital.

Table 1. Human capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
1	HC1	Resident population 15–64 years	Pop.	a
2	HC2	Annual average change rate of resident population	%	b
3	HC3	Average 10-year change rate of resident population	%	c
4	HC4	Old age index	Index	c
5	HC5	Index of structure of the working population	Index	d
6	HC6	Employment rate	%	d
7	HC7	Index of employment turnover	%	c
8	HC8	Incidence of young people outside the labor market and training	%	c
9	HC9	Percentage of foreign population	%	a
10	HC10	Italian/foreign employment ratio	%	c
11	HC11	Italian/foreign school attendance ratio	%	c
12	HC12	Italian/foreign independent employment relationship	%	c
13	HC13	Male/female employment ratio	%	c
14	HC14	Percentage of population with average income	%	e
15	HC15	Graduate rate	%	f
16	HC16	High school graduate rate	%	f

Table 2. Urban capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
17	UC1	Degree of urbanization according to Eurostat classification	Index	g
18	UC2	Change in the unused rate of buildings	points %	c
19	UC3	Change in the index of under-utilisation of dwellings	points %	c
20	UC4	Change in the unused rate of dwellings in built-up areas	points %	c
21	UC5	Percentage change in average house purchase price	points %	c
22	UC6	Human density	pop/s.k.	h
23	UC7	Incidence of resident population in scattered households	%	c
24	UC8	Index of dispersion of dwellings	Index (0–1)	h
25	UC9	Concentration index of the typologies of use of the buildings	Index (0–10,000)	d
26	UC10	Compactness index of urban areas	%	i
27	UC11	Fragmentation index of the urban landscape	m./s.m.	i
28	UC12	Index of under-utilisation of dwellings	%	c
29	UC13	Index of building expansion in towns and villages	%	c
30	UC14	Index of residential attractiveness	Index	h
31	UC15	Urban green (non-agricultural) per capita	s.m./inhab.	d
32	UC16	Index of crowding of dwellings	%	c
33	UC17	Unused buildings rate (Potential use of buildings)	%	c
34	UC18	Unused rate of dwellings in built-up areas	%	c
35	UC19	Housing exclusion index (Incidence of improper housing)	%	c
36	UC20	Incidence of residential buildings in a poor state of preservation	%	c
37	UC21	Index of availability of services in the dwelling	%	c
38	UC22	Average age of recent housing stock	n. of years	c

Table 3. Economic capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
39	EC1	Change in unemployment rate	points %	c
40	EC2	Change in economic dynamism index	Index	g
41	EC3	Index of economic dynamism	Index	g
42	EC4	Unemployment rate	%	c
43	EC5	Youth unemployment rate	%	c
44	EC6	Concentration index of employees in economic sectors	Index (0–10,000)	d
45	EC7	Gini index	Index (0–1)	h
46	EC8	Number of agricultural and zootechnical holdings	n.	l
47	EC9	Number of active enterprises	n.	l
48	EC10	Number of agricultural holdings and production of animal products, hunting and related services	n.	l

Table 4. Infrastructural capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
49	IC1	Average travel time		
50	IC2	Private mobility (private use)	%	c
51	IC3	Density of fixed retail trade	Local units/s.k.	d
52	IC4	Daily mobility for study or work	%	c
53	IC5	Mobility index (commuting for work)	Index	h
54	IC6	Self-containment index (commuting for work purposes)	Index	h
55	IC7	Residential mobility	%	c
56	IC8	Rate of compound accommodation function	Index	h
57	IC9	Number of stadiums	Number	h
58	IC10	Number of amusement and entertainment hubs	Number	h
59	IC11	Number of commercial hubs	Number	h
60	IC12	Digital divide from fixed and mobile network	%	d
61	IC13	Road accessibility index for shopping centres	Ranking (0–4)	d
62	IC14	Rail index	Track (0/1)	d
63	IC15	Accessibility index at railway stations	Ranking (0–4)	h
64	IC16	Ordinary hospital beds per 10,000 inhabitants	n. per 10,000 inhab.	d
65	IC17	Dynamism of public institutions	Index	h
66	IC18	Ordinary pharmacies per 10,000 inhabitants	n. per 10,000 inhab.	d
67	IC19	Public mobility	%	c
68	IC20	Pre-school, primary and secondary school buildings	n.	n
69	IC21	Health facilities	n.	o

Table 5. Natural capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
70	NC1	Protected areas	yes/no	p
71	NC2	Natura 2000 network (SCI/SAC/SPZ)	yes/no	p
72	NC3	Number of parks and gardens	n.	p
73	NC4	Average agricultural value	n.	q
74	NC5	Percentage of utilized agricultural area (AA) in total agricultural area	%	r

Table 6. Cultural capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
75	CC1	Number of state cultural sites	n.	h
76	CC2	Total number of cultural assets	n.	s
77	CC3	Total number of architectural assets	n.	s
78	CC4	Number of historical parks and gardens	n.	s
79	CC5	Number of museums, galleries, and archaeological sites	n.	s

Table 7. Environmental capital indicators.

Ref.	Variable	Definition	U. m.	Data Sources
80	EVC1	Seismic hazard	Index	t
81	EVC2	Surface of soil consumed in areas of high and very high seismic hazard	ha	i
82	EVC3	High and very high proportion of the municipal surface is hazardous due to landslide HP-H3 + H4	%	i
83	EVC4	Resident population at risk in high and very high landslide hazard areas-H3 + H4	Pop	i
84	EVC5	Soil surface consumed in areas with high and very high landslide hazards-H3 + H4	ha	i
85	EVC6	Percentage of municipal area with high hydraulic hazard H3	%	i
86	EVC7	Resident population at risk in areas of high hydraulic hazard-H3	Pop	i
87	EVC8	Soil surface consumed in areas with high hydraulic hazard-H3	ha	i
88	EVC9	Soil consumed per capita	s.m./inhab.	i
89	EV10	Altitude of the center	m.	g

The official databases from which data on different forms of territorial capital were extracted are as follows:

(a) National Institute of Statistics dataset: Population and households 2022 [127];

(b) National Institute of Statistics dataset: Demo.ISTAT 2002–2019 [128];

(c) National Institute of Statistics dataset: 8 milaCensus [129];

(d) Dataset of the Department of Economic Planning and Policy Coordination: Urban Index [130];

(e) National Institute of Statistic dataset: Economic conditions of households [131];

(f) National Institute of Statistics dataset: Education, work and travel for work [132];

(g) National Institute of Statistics dataset: Main geographical statistics of municipalities [133];

(h) "PRIN Postmetropolitan Atlas" dataset [134];

(i) Superior Institute for Environmental Protection and Research dataset [135];

(l) National Institute of Statistics dataset: Statistical atlas of municipalities. [136];

(m) Agency for Territorial Cohesion Dataset. National Strategies for Internal Areas: Classification Internal Areas [19];

(n) Italian Municipalities Dataset: Schools [137];

(o) Italian Ministry of Health Dataset [138];

(p) National Institute of Statistics dataset: Indicators [139];

(q) Income revenue authority dataset: Average Agricultural Value [140];

(r) National Institute of Statistics dataset: Census of agriculture [141];

(s) Sicilian Region Dataset: Museums galleries and archaeological sites [142];

(t) National Institute of Geophysics and Volcanology dataset [143];

(v) National Institute of Statistics dataset: Territorial bases and census variables [144];

4.2. Principal Components Analysis

Principal component analysis (PCA) is a statistical technique for dimension reduction. It is a technique aimed at deriving, from a set of correlated numerical variables, a smaller set of "artificial" orthogonal variables" [145]. It is used when there are many interrelated variables within a dataset and the analyst would like to reduce their number, losing the least amount of information possible.

The PCA aims to maximize variance by calculating the weight to be given to each starting variable in order to concentrate them into one or more new variables (called principal components) that are formed of linear combinations of the starting variables.

In PCA we denote by the term "information" the total variability of the original input variables, that is, the sum of the variances of the original variables. The central point of PCA is the so-called spectral decomposition (or decomposition into eigenvalues and eigenvectors, or eigen decomposition) of the sample variance/covariance matrix. This decomposition makes it possible to calculate the eigenvalues and eigenvectors of the covariance matrix. The eigenvalues (in descending order of value) represent the amount of total variability observed on the original variables, "explained" (or "expressed") by each principal component; the eigenvectors, on the other hand, represent the corresponding (orthogonal) directions of maximum variability extracted from the principal components.

PCA is a widely used technique. The main steps of the variable reduction process are as follows:

1. Standardization of all input variables into z-scores (each with a mean of 0 and standard deviation 1)
2. Selection of the number of components based on the unrotated solution, i.e., the initial solution using the Kaiser Criterion (all components corresponding to an eigenvalue equal to or greater than 1 should be included in the final model) [146] or the screen plot (the number of components to be extracted is that which coincides with the change in slope, i.e., the elbow of the curve, after which the break generally tends to flatten) [147];
3. Rotation of the initial PCA solution (Varimax rotation);

4. Selection of the number of components based on the rotated solution, according to the Kaiser or screen plot criterion;
5. Interpretation of the resulting components;
6. Combination of the selected component scores into a univariate score;
7. Standardization of the resulting scores to a mean of 0 and a standard deviation of 1.

Simulation Software

There are several software applications used to process PCA. We used the statistical software SPSS. This software allows us to select the number of significant components with the help of the screen plot.

4.3. Abandonment Index-I_a

In this study, PCA will allow the identification of indicators, that is, of a reduced set of those originally selected for the characterization of different forms of territorial capital. The new indicators will make it possible to identify an index of abandonment for marginal areas of Sicily through the following formula (Equation (1)):

$$I_a = \sum_{i=1}^{k} w_i PC_i \tag{1}$$

where w_i represent the weights of the components identified with PCA, PC_i the value of the i-th component, and k the number of components identified.

By means of the neglect index estimated with Equation (1), it will be possible to rank Sicilian municipalities from best to worst.

4.4. The New Cognitive Tool of the Abandonment Phenomenon

A mapping of clusters of municipalities with QGIS support on the basis of quartiles of aggregate I_a index values will make it possible to represent the phenomenon of abandonment at the regional scale.

The new map of the phenomenon of abandonment for Sicilian municipalities will be able to be compared with the map of Internal Areas produced by the NSIA classification.

5. Results

Data on indicators for different forms of territorial capital were extracted from the official databases previously referred to, and an instrumental geo-database was constructed for them for the analyses that will lead to the definition of an index of abandonment and a mapping of the abandonment phenomenon.

5.1. Cluster of Municipalities Based on Quartiles of Indicator Values of Different Forms of Territorial Capital

The indicators selected for characterizing the different components of territorial capital were normalized and with QGIS support, cluster maps of municipalities were generated based on the quartiles of these indicators. This made it possible to highlight the performance of each municipality for the different indicators of the different forms of territorial capital. The municipalities for which the analysis was conducted are those that fall within the Intermediate, Peripheral and Ultra-peripheral areas in the NSIA classification.

Clusters of municipalities based on quartiles of indicators on human capital and cultural capital are shown in Figure 9. In the box in Figure 9 and for all the figures that will be presented subsequently regarding the indicator maps for the different forms of territorial capital, the Pelagic Islands are shown.

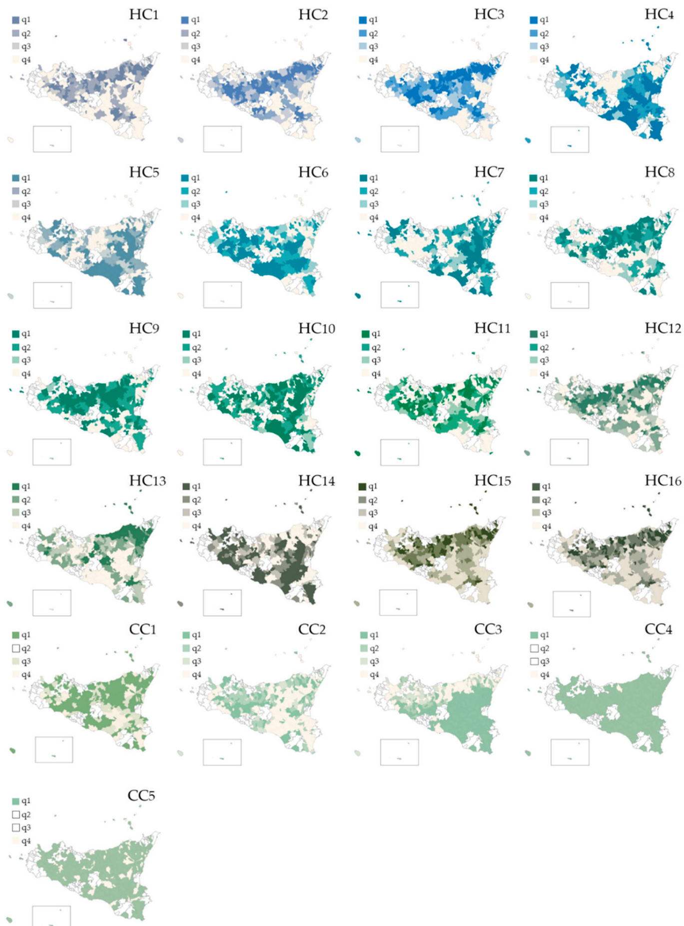

Figure 9. Mapping Human and Cultural Capital Indicators. (Authors' elaboration).

With reference to the first quartile, Figure 9 shows: the presence of small clusters of municipalities predominantly falling in the north-central area of Sicily for HC1, HC2, and HC3; clusters of municipalities predominantly falling in the south-eastern area of Sicily for HC4, and HC5; clusters of municipalities predominantly falling in the south-central area of Sicily for HC6; clusters of municipalities predominantly falling in the eastern area of Sicily for HC7; clusters of municipalities predominantly falling in the north-eastern area of Sicily for HC8; clusters of municipalities predominantly falling in the north-central area of Sicily for HC9; clusters of municipalities predominantly falling in the eastern area of Sicily for HC10; clusters of municipalities predominantly falling in the north-central area of Sicily for HC11 and HC12; clusters of municipalities predominantly falling in the northeastern area of Sicily for HC13; clusters of municipalities predominantly falling in the southern and east-central areas of Sicily for HC14; and small clusters of municipalities predominantly falling in the north-central and northeastern areas of Sicily for HC15 and HC16.

With reference to the second quartile, Figure 9 shows: the presence of clusters of municipalities predominantly falling in the north-central area of Sicily for HC1, HC2, and HC3; clusters of municipalities predominantly falling in the east-central area of Sicily for HC4, HC5, HC6, and HC7; clusters of municipalities predominantly falling in the north-eastern area of Sicily for HC8; clusters of municipalities predominantly falling in the central and eastern areas of Sicily for HC9; small clusters of municipalities predominantly falling in the central-northern area of Sicily for HC10; clusters of municipalities predominantly falling in the southeastern area of Sicily for HC11; clusters of municipalities predominantly falling in the central and southeastern areas of Sicily for HC12; small clusters of municipalities predominantly falling in the central and southeastern areas of Sicily for HC13 and HC14; and clusters of municipalities predominantly falling in the central-northern and northeastern areas of Sicily for HC15 and HC16.

With reference to the third quartile, Figure 9 shows: the presence of small clusters of municipalities falling in the central area of Sicily for HC1; clusters of municipalities predominantly falling in the central area of Sicily for HC2, HC3, HC4, HC5, and HC6; clusters of municipalities predominantly falling in the south-central area of Sicily for HC7 and HC8; small clusters of municipalities falling in the central area of Sicily for HC9; clusters of municipalities predominantly falling in the central and eastern areas of Sicily for HC10 and HC11; clusters of municipalities predominantly southern and central-eastern areas of Sicily for HC12; clusters of municipalities predominantly falling in the central and eastern-southern areas of Sicily for HC13; small clusters of municipalities predominantly falling in the central-northern area of Sicily for HC14; and clusters of municipalities predominantly falling in the central and northern-eastern areas of Sicily for HC15 and HC16.

With reference to the fourth quartile, Figure 9 shows: the presence of clusters of municipalities predominantly falling in the south-central and eastern areas of Sicily for HC1 and HC2; clusters of municipalities predominantly falling in the south-eastern and north-western areas of Sicily for HC3; clusters of municipalities predominantly falling in the central-northern area of Sicily for HC4, HC5, HC6, and HC7; clusters of municipalities predominantly falling in the central-southern area of Sicily for HC8; clusters of municipalities predominantly falling in the southern and northeastern areas of Sicily for HC9; clusters of municipalities predominantly falling in the central and northeastern area of Sicily for HC10; clusters of municipalities predominantly falling in the eastern area of Sicily for HC11 and HC12; clusters of municipalities predominantly falling in the central-southern area of Sicily for HC13; clusters of municipalities predominantly falling in the northern and southeastern areas of Sicily for HC14; and clusters of municipalities predominantly falling in the central-southern and eastern areas of Sicily for HC15 and HC16.

With reference to the first quartile, Figure 9 shows the presence of clusters of municipalities predominantly falling in the north-central area and partially in the southern area of Sicily for CC1; small clusters of municipalities predominantly falling in the central and southeastern areas of Sicily for CC2; clusters of municipalities falling in almost all of Sicily except the metropolitan area of Trapani and (partially) in those of Agrigento, Ragusa and Palermo for CC3; and clusters of municipalities falling in almost all of Sicily for CC4 and CC5.

With reference to the second quartile, Figure 9 shows: no clusters of municipalities for CC1; small clusters of municipalities mainly falling in the north-central area of Sicily for CC2; small clusters of municipalities mainly falling in the west-central area of Sicily for CC3; no clusters of municipalities for CC4 and CC5.

With reference to the third quartile, Figure 9 shows: the presence of small clusters of municipalities falling in the central area of Sicily for CC1; small clusters of municipalities predominantly falling in the central area of Sicily for CC2; small clusters of municipalities predominantly falling in the central-western area of Sicily for CC3; and no clusters of municipalities for CC4 and CC5.

With reference to the fourth quartile, Figure 9 of small clusters of municipalities falling in almost the entire territory of Sicily with a higher concentration in the central-southern-eastern area for CC1 and CC2; clusters of municipalities predominantly falling in the northern area of Sicily for CC3; two small clusters of municipalities falling in the metropolitan cities of Palermo and Catania for CC4; and small clusters of municipalities falling in almost the entire territory of Sicily for CC5.

With reference to the first quartile, Figure 10 shows clusters of municipalities predominantly falling in the south-eastern area of Sicily for UC1; small clusters of municipalities predominantly falling in the east-central area of Sicily for UC2, UC3, and UC4; clusters of municipalities predominantly falling in the central area of Sicily for UC5; clusters of municipalities predominantly falling in the north-central and east-central areas of Sicily for UC6; small clusters of municipalities falling mainly in the southern and eastern areas of Sicily for UC7, UC8; small clusters of municipalities falling mainly in the north-central area of Sicily for UC9; clusters of municipalities falling mainly in the eastern area of Sicily for UC10; clusters of municipalities falling mainly in the southern and eastern areas of Sicily for UC11; clusters of municipalities falling mainly in the eastern area of Sicily for UC12; clusters of municipalities predominantly falling in the central-northern area of Sicily for UC13; clusters of municipalities predominantly falling in the central area of Sicily for UC14; clusters of municipalities predominantly falling in the central and northern-eastern area of Sicily for UC15; small clusters of municipalities predominantly falling in the central-northern area of Sicily for UC16; clusters of municipalities predominantly falling in the central and southern-eastern areas of Sicily for UC17; clusters of municipalities predominantly falling in the central-eastern area of Sicily for UC18; small clusters of municipalities predominantly falling in the central-northern area of Sicily for UC19; small clusters of municipalities predominantly falling in the eastern area of Sicily for UC20; small clusters of municipalities predominantly falling in the central-northern and southern areas of Sicily for UC21; small clusters of municipalities predominantly falling in the central area of Sicily for UC22.

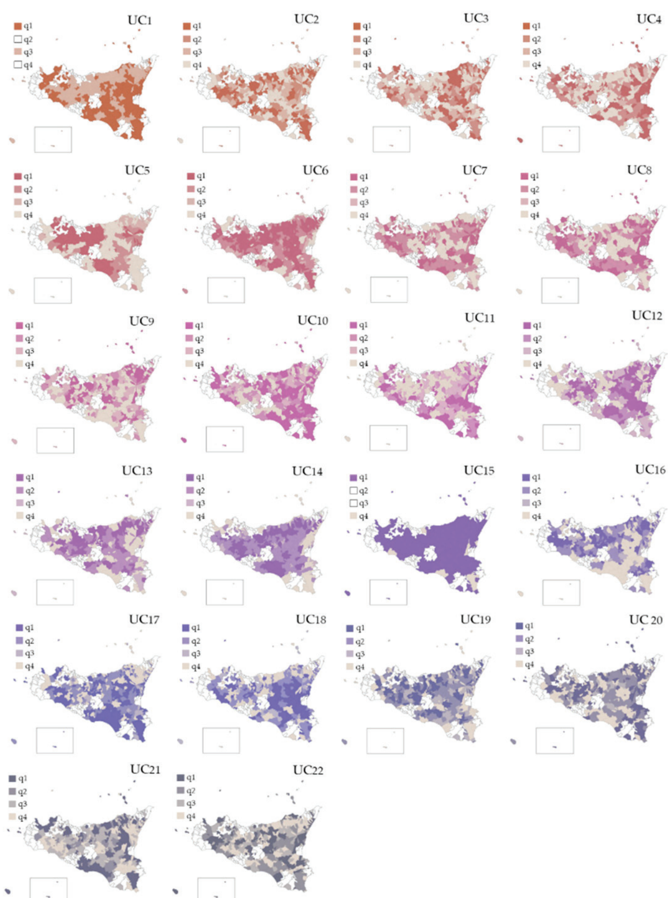

Figure 10. Mapping Urban Capital Indicators. (Authors' elaboration).

With reference to the second quartile, Figure 10 shows: the presence of clusters of municipalities predominantly falling in the north-central area of Sicily for UC1; small clusters of municipalities predominantly falling in the northern and southern areas of Sicily for UC2; small clusters of municipalities predominantly falling in the eastern area of Sicily for UC3, UC4 and UC5; clusters of municipalities predominantly falling in the central area of Sicily for UC6, UC7 and UC8; small clusters of municipalities predominantly falling in the central area of Sicily for UC9 and UC10; small clusters of municipalities predominantly falling in the southern area of Sicily for UC11; clusters of municipalities predominantly falling in the central area of Sicily for UC12, UC13, and UC14; no municipalities in the second quartile for UC15; and small clusters of municipalities predominantly falling in the north-central area of Sicily for UC16, UC17, UC18, UC19, UC20, UC21, and UC22.

With reference to the third quartile, Figure 10 shows: no municipalities in the third quartile for UC1; small clusters of municipalities predominantly falling in the central area of Sicily for UC2, UC3, UC4, and UC5; small clusters of municipalities predominantly falling in the southern area of Sicily for UC6; small clusters of municipalities predominantly falling in the central area of Sicily for UC7, UC8, UC9, UC10, and UC11; small clusters of municipalities predominantly falling in the southern and eastern area of Sicily for UC12; small clusters of municipalities predominantly falling in the eastern area of Sicily for UC13; small clusters of municipalities predominantly falling in the central area of Sicily for UC14; no municipalities in the second third for UC15; small clusters of municipalities predominantly falling in the central area of Sicily for UC16, UC17, UC18, UC19, UC20, UC21, and UC22.

With reference to the fourth quartile, Figure 10 shows: no municipalities in the second quartile for UC1; clusters of municipalities predominantly falling in the central and north-eastern areas of Sicily for UC2, UC3 and UC4; clusters of municipalities predominantly falling in the eastern and southwestern areas of Sicily for UC5; small clusters of municipalities predominantly falling in the eastern area of Sicily for UC6; clusters of municipalities predominantly falling in the eastern and central coastal areas of Sicily for UC7, UC8, and UC9; small clusters of municipalities predominantly falling in the central and eastern-northern coastal areas of Sicily for UC10; clusters of municipalities predominantly falling in the central and eastern-northern coastal areas of Sicily for UC11 and UC12; clusters of municipalities predominantly falling in the central and eastern coastal areas of Sicily for UC13; clusters of municipalities predominantly falling in the eastern coastal area of Sicily for UC14; small clusters of municipalities predominantly falling in the southern and eastern coastal areas of Sicily for UC15; clusters of municipalities predominantly falling in the central-eastern area of Sicily for UC16; clusters of municipalities predominantly falling in the central-northern area of Sicily for UC17 and UC18; clusters of municipalities predominantly falling in the eastern area of Sicily for UC19; clusters of municipalities predominantly falling in the central area of Sicily for UC20; clusters of municipalities predominantly falling in the central-eastern and southern-western areas of Sicily for UC21; and clusters of municipalities predominantly falling in the central area of Sicily for UC22.

With reference to the first quartile, Figure 11 shows the presence of clusters of municipalities predominantly falling in the central area of Sicily for EC1; small clusters of municipalities predominantly falling in the north-eastern and south-central areas of Sicily for EC2, EC3, and EC4; clusters of municipalities predominantly falling in the north-eastern and south-eastern area of Sicily for EC5; clusters of municipalities predominantly falling in the central and southeastern area of Sicily for EC6; small clusters of municipalities predominantly falling in the north-eastern area of Sicily for EC7 and EC8; and small clusters of municipalities predominantly falling in the central and north-eastern areas of Sicily for EC9 and EC10.

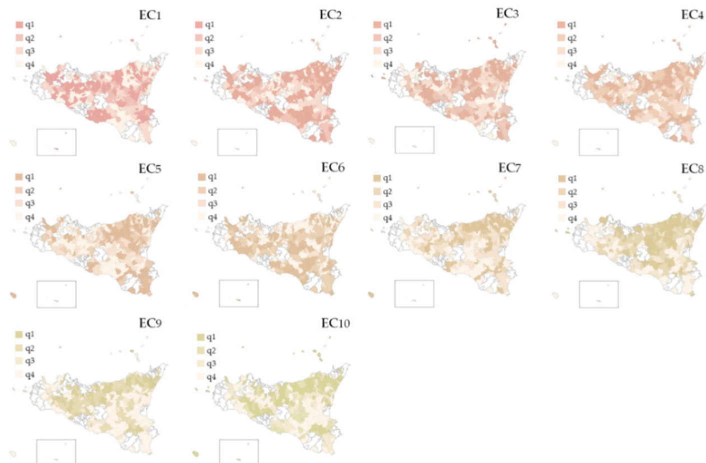

Figure 11. Mapping Economic Capital Indicators. (Authors' elaboration).

With reference to the second quartile, Figure 11 shows clusters of municipalities predominantly falling in the central area of Sicily for EC1; small clusters of municipalities predominantly falling in the central and southern areas of Sicily for EC2; clusters of municipalities predominantly falling in the central and southeastern areas of Sicily for EC3; clusters of municipalities predominantly falling in the central and northeastern areas of Sicily for EC4; clusters of municipalities predominantly falling in the north-eastern area of Sicily for EC5; clusters of municipalities predominantly falling in the central and south-eastern areas of Sicily for EC6; small clusters of municipalities predominantly falling in the central area of Sicily for EC7; and clusters of municipalities predominantly falling in the central and north-eastern areas of Sicily for EC8, EC9 and EC10.

With reference to the third quartile, Figure 11 shows: the presence of small clusters of co-municipalities predominantly falling in the central area of Sicily for EC1, EC2, EC3, EC4, and EC5; small clusters of municipalities predominantly falling in the central and eastern-southern areas of Sicily for EC6; clusters of municipalities predominantly falling in the central and eastern areas of Sicily for EC7 and EC8; small clusters of municipalities predominantly falling in the central area of Sicily for EC9; and clusters of municipalities predominantly falling in the central and eastern-southern areas of Sicily for EC10.

With reference to the fourth quartile, Figure 11 shows: the presence of clusters of municipalities predominantly falling in the southern and northeastern areas of Sicily for EC1; small clusters of municipalities predominantly falling in the central area of Sicily for EC2, EC3, and EC4; clusters of municipalities predominantly falling in the central-southern area of Sicily for EC5; clusters of municipalities predominantly falling in the north-central area of Sicily for EC6; clusters of municipalities predominantly falling in the central and southern areas of Sicily for EC7; clusters of municipalities predominantly falling in the south-central area of Sicily for EC8; and clusters of municipalities predominantly falling in the east-central area of Sicily for EC9 and EC10.

With reference to the first quartile, Figure 12 shows: the presence of clusters of municipalities predominantly falling in the central-southern and eastern areas of Sicily for IC1; small clusters of municipalities falling mainly in the central area of Sicily for IC2; clusters of municipalities predominantly falling in the eastern and western areas of Sicily for IC3; clusters of municipalities predominantly falling in the central-southern and eastern areas of Sicily for IC4; clusters of municipalities falling predominantly in the north-eastern and southern areas of Sicily for IC5; clusters of municipalities falling predominantly in the eastern area of Sicily for IC6; clusters of municipalities falling predominantly in the north-central area of Sicily for IC7; clusters of municipalities falling in almost all of Sicily except the metropolitan area of Trapani and partially in those of Agrigento, Ragusa and Palermo for IC8, IC9, IC10 and IC11; small clusters municipalities predominantly falling in the southern, north-central and east-central areas of Sicily for IC12; clusters of municipalities predominantly falling in the south-central and northeastern areas of Sicily for IC13; clusters of municipalities falling in almost all of Sicily except the metropolitan area of Trapani and partially in those of Agrigento, Ragusa and Palermo for IC14; clusters of municipalities predominantly falling in the south-central and northeastern areas of Sicily for IC15; clusters of municipalities predominantly falling in the north-central and eastern area of Sicily for IC16; small clusters of municipalities falling predominantly in the central and northeastern areas of Sicily for IC17; clusters of municipalities falling predominantly in the central and southern area of Sicily for IC18 and IC19; small clusters of municipalities falling predominantly in the central and southeastern areas of Sicily for IC20; and clusters of municipalities falling in almost all of Sicily except the metropolitan area of Trapani and partially in those of Agrigento, Ragusa and Palermo for IC21.

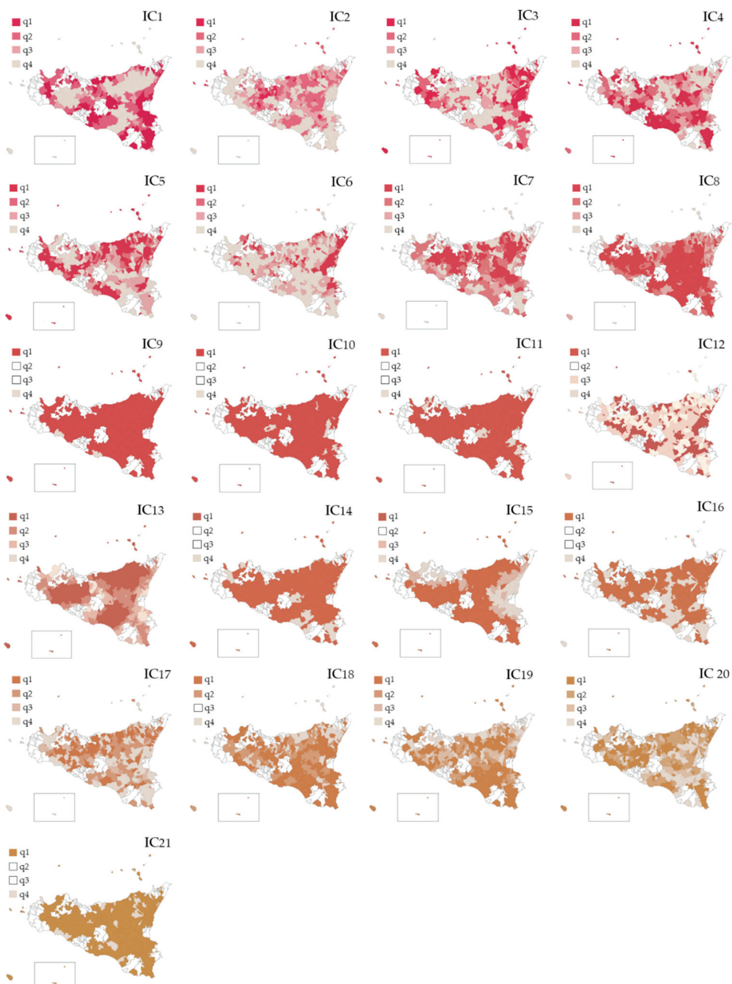

Figure 12. Mapping of Infrastructure Capital indicators. (Authors' elaboration).

With reference to the second quartile, Figure 12 shows: clusters of municipalities predominantly falling in the central and eastern areas of Sicily for IC1; small clusters of municipalities predominantly falling in the central area of Sicily for IC2; clusters of municipalities predominantly falling in the central-western and eastern areas of Sicily for IC3; clusters of municipalities predominantly falling in the central area of Sicily for IC4; small clusters of municipalities predominantly falling in the north-central area of Sicily for IC5; small clusters of municipalities predominantly falling in the north-western area of Sicily for IC6; clusters of municipalities predominantly falling in the central and southern areas of Sicily for IC7; clusters of municipalities predominantly falling in the southern and northern area of Sicily for IC8; no municipalities falling in the second quartile for IC9, IC10, and IC11; no municipalities falling in the second quartile for IC12; clusters of municipalities falling in the central and eastern area of Sicily for IC13; no municipalities falling in the second quartile for IC14, IC15, and IC16; clusters of municipalities predominantly falling in the central-northern and southern areas for IC17; small clusters of municipalities predominantly falling in the central area for IC18 and IC19; small clusters of municipalities predominantly falling in the central-western and eastern-northern areas of Sicily for IC20; and no municipalities falling in the second quartile for IC21.

With reference to the third quartile, Figure 12 shows: the presence small clusters of municipalities predominantly falling in the central area of Sicily for IC1; small clusters of municipalities predominantly falling in the central and north-eastern areas of Sicily for IC2, IC3 and IC4; clusters of municipalities predominantly falling in the central and eastern-southern areas of Sicily for IC5; small clusters of municipalities predominantly falling in the central and eastern areas of Sicily for IC6; small clusters of municipalities predominantly falling in the central and southern-eastern areas of Sicily for IC7; small clusters of municipalities predominantly falling in the northern-eastern area of Sicily for IC8; no municipalities in the third for IC9, IC10 and IC11; clusters of municipalities predominantly falling in the central-southern area of Sicily for IC12; small clusters of municipalities predominantly falling in the central-southern and eastern areas of Sicily for IC13; no municipalities in the third for IC14; clusters of municipalities predominantly falling in the central-western and eastern areas of Sicily for IC15; no municipalities in the third for IC16; small clusters of municipalities predominantly falling in the central-southern area of Sicily for IC17; small clusters of municipalities predominantly falling in the northern-eastern and southern-western areas of Sicily for IC18; small clusters of municipalities predominantly falling in the northern area of Sicily for IC19; small clusters of municipalities predominantly falling in the central-eastern area of Sicily for IC20; and no municipalities in the third for IC21.

With reference to the fourth quartile, Figure 12 shows: clusters of municipalities predominantly falling in the north-central, south-eastern and west-central areas of Sicily for IC1; clusters of municipalities predominantly falling in the southern and eastern areas of Sicily for IC2; clusters of municipalities predominantly falling in the central area of Sicily for IC3; clusters of municipalities predominantly falling in the central-northern area of Sicily for IC4; clusters of municipalities predominantly falling in the central-southern area of Sicily for IC5; clusters of municipalities predominantly falling in the central-southern and northeastern areas of Sicily for IC6; small clusters of clusters of municipalities predominantly falling in the northern-eastern and southern areas of Sicily for IC7; small clusters of municipalities predominantly falling in the northern-eastern area of Sicily for IC8; small clusters of municipalities predominantly falling in the southern-western area of Sicily for IC9; small clusters of municipalities predominantly falling in the central area of Sicily for IC10; small clusters of municipalities predominantly falling in the central and eastern areas of Sicily for IC11; small clusters of municipalities predominantly falling in the central and northeastern areas of Sicily for IC12; small clusters of municipalities predominantly falling in the central and eastern areas of Sicily for IC13; small clusters of municipalities predominantly falling in the southern-eastern and northern area of Sicily for IC14; and clusters of municipalities predominantly falling in the central-eastern and northwestern area of Sicily for IC15; clusters of municipalities predominantly falling in the central and southern areas of Sicily for IC16 and IC17; small clusters of municipalities predominantly falling in the northern-eastern and central-western areas of Sicily for IC18 and IC19; clusters of municipalities predominantly falling in the central-eastern area of Sicily for IC20; and small clusters of municipalities predominantly falling in the northern-eastern and southern areas of Sicily for IC21.

With reference to the first quartile, Figure 13 shows: the presence of clusters of municipalities predominantly falling in the central and northeastern areas of Sicily for NC1; small clusters of municipalities predominantly falling in the central and northeastern areas of Sicily for NC2; clusters of municipalities falling in almost all of Sicily with the exception of the Trapani metropolitan area and partially in those of Agrigento, Catania, Messina, Palermo, and Ragusa for NC3; clusters of municipalities predominantly falling in the central and southeastern central areas of Sicily for NC4; and small clusters of municipalities predominantly falling in the northern, eastern, and south-central area of Sicily for NC5.

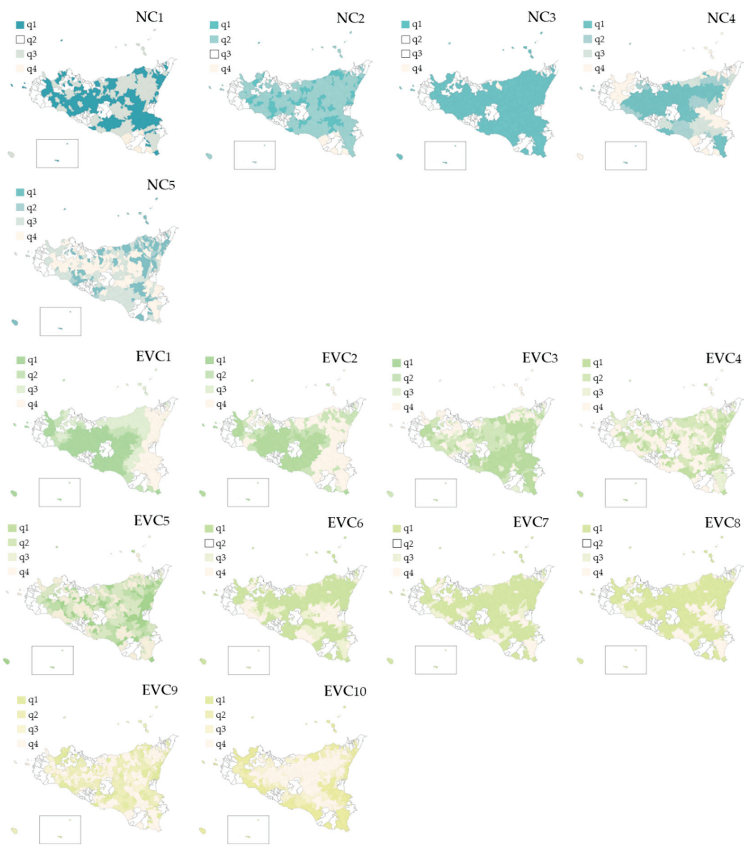

Figure 13. Mapping of Natural and Environmental Capital indicators. (Authors' elaboration).

With reference to the second quartile, Figure 13 shows: no municipalities falling in the second quartile NC1; clusters of municipalities falling throughout Sicily with a lower concentration in the metropolitan cities of Agrigento, Palermo, Ragusa, and Trapani and NC2; no municipalities falling in the second quartile for NC3; clusters of municipalities falling in the central and southeastern areas of Sicily for NC4; and small clusters of municipalities predominantly falling in the northern, eastern, and south-central areas of Sicily for NC5.

With reference to the third quartile, Figure 13 shows: no municipalities falling in the second quartile for NC1; no municipalities falling in the third quartile for NC2 and NC3; clusters of municipalities falling in the eastern area of Sicily for NC4; and small clusters of municipalities predominantly falling in the southern and north-central areas of Sicily for NC5.

With reference to the fourth quartile, Figure 13 shows: clusters of municipalities predominantly falling in the southern-eastern area of Sicily for NC1 and NC2; small clusters of municipalities predominantly in the metropolitan cities of Messina and Catania for NC3; clusters of municipalities in the eastern and northwestern areas of Sicily for NC4; and small clusters of municipalities predominantly falling in the central and eastern areas of Sicily for NC5.

With reference to the first quartile, Figure 13 shows: clusters of municipalities predominantly falling in the central and southern areas of Sicily for EVC1 and EVC2; clusters of municipalities predominantly falling in the eastern and central-western areas for EVC3; small clusters of municipalities predominantly falling in the eastern and central areas of Sicily for EVC4 and EVC5; clusters of municipalities predominantly in the north-central and east-south areas for EVC6, EVC7 and EVC8; small clusters of municipalities predominantly falling in the eastern, south-central and north-western areas of Sicily for EVC9; and small clusters of municipalities predominantly falling in the coastal area of Sicily for EVC10.

With reference to the second quartile, Figure 13 shows: the presence of small clusters scattered predominantly in the central area of Sicily for EVC1; small clusters of municipalities scattered predominantly in the north-central and south-central areas of Sicily for EVC2; clusters of municipalities falling predominantly in the central area of Sicily for EVC3; small clusters of municipalities predominantly falling in the north-central and eastern areas of Sicily for EVC4 and EVC5; no municipalities falling in the second quartile for EVC6, EVC7, and EVC8; small clusters of municipalities predominantly falling in the central and eastern area of Sicily for EVC9; and small clusters of municipalities predominantly falling in the south-central and eastern areas of Sicily for EVC10.

With reference to the third quartile, Figure 13 shows: the presence of clusters of municipalities predominantly falling in the northern and central-eastern areas of Sicily for EVC1; small clusters of municipalities scattered predominantly in the northern-eastern and southern-eastern areas of Sicily for EVC2; small clusters of municipalities of municipalities falling predominantly in the central and northern-eastern areas of Sicily for EVC3; small clusters of municipalities in the central and eastern areas of Sicily for EVC4; the presence of clusters of municipalities falling in the central and northeastern areas of Sicily for EVC5; small clusters of municipalities predominantly falling in the central area of Sicily for EVC6; no municipalities falling in the second quartile for EVC7 and EVC8; small clusters of municipalities predominantly falling in the central and eastern areas of Sicily for EVC9; and small clusters of municipalities predominantly falling in the central-southern and eastern areas of Sicily for EVC10.

With reference to the fourth quartile, Figure 13 shows: the presence of clusters of municipalities predominantly in the eastern area of Sicily for EVC1; clusters of municipalities predominantly falling in the northern and eastern areas of Sicily for EVC2; clusters of municipalities predominantly falling in the central-western and north-central-eastern areas of Sicily for EVC3; clusters of municipalities predominantly falling in the central area of Sicily EVC4; clusters of municipalities predominantly falling in the southern and north-central areas of Sicily for EVC5; clusters of municipalities predominantly falling in the southern and east-central areas of Sicily for EVC6; small clusters of municipalities predominantly falling in the southern, west-central, and east-central areas of Sicily for EVC7 and EVC8; clusters of municipalities predominantly falling in the eastern and west-central areas of Sicily for EVC9; clusters of municipalities falling in the central area of Sicily for EVC10.

5.2. Comparison of Clusters of Municipalities Based on the Quartiles of Territorial Capital Indicators and the Types of Areas in the NSIA Classification

Clusters of municipalities with reference to indicator quartiles for different forms of territorial capital were compared with the different types of areas proposed by the NSIA classification, particularly with peripheral, intermediate, and ultra-peripheral areas.

Municipalities, according to the NSIA classification, are characterized on the basis of their marginality, graded with reference to certain socio-economic indicators and distance from the reference pole.

The analysis proposed in this study is based on the indicators representing the level/value of different forms of territorial capital, and also including those supporting the NSIA classification, including distance to the pole, and shows substantial differences in municipalities clustered based on indicator performance and the characterization of municipalities by levels of marginality.

With reference to the types of areas in the NSIA classification, the intermediate one is characterized by lower marginality, and therefore municipalities falling under it should show the best indicator performance, the ultra-peripheral one the worst performance, and the peripheral one an intermediate performance between the two.

Comparing the performance of the indicators of territorial capital forms for the nine metropolitan areas in Sicily and the types of areas in the NSIA classification, it is possible to always highlight municipalities belonging to the clusters by quartiles that fall into the different types of NSIA areas.

An example may better clarify what we have noticed. We highlight in this section the comparison between clusters of municipalities based on quartiles of human and natural capital indicators, and the NSIA classification (Figure 14), and propose the same comparison for indicators of all other forms of capital in Appendix A.2.

With reference to the HC1 indicator, the municipalities for the different metropolitan areas of Sicily falling in the fourth quartile are those characterized by a higher level/value of the indicator; we would have expected to find these municipalities among those characterized by less marginality, but this is not the case, as the municipalities belonging to this cluster can be classified according to NSIA as intermediate, peripheral and ultra-peripheral areas.

From this, it is possible to highlight that even municipalities with high HC1 performance may fall with reference to NSIA classification into areas characterized by high marginality, such as ultra-peripheral areas.

Again, with reference to HC1, we detect the highest percentage of municipalities falling in the third quartile of the indicator that with reference to the NSIA classification fall in ultra-peripheral areas, which are characterized by high marginality. In addition, there is a high percentage of municipalities falling in the second and first quartiles of the indicator that with reference to NSIA fall in intermediate and peripheral areas, thus characterized by low or medium marginality.

In general, for all indicators considered to characterize the different forms of capital it is possible to find that the municipalities in the quartile clusters can always be classified according to the three types of NSIA areas. From this it is possible to show that in most cases high performance of indicators could correspond to high marginality for NSIA classification, or, vice versa, low performance of indicators could correspond to low marginality, and again medium-low and medium-high performance of indicators could correspond to low, medium, and high marginality.

Figure 14. *Cont.*

Figure 14. *Cont.*

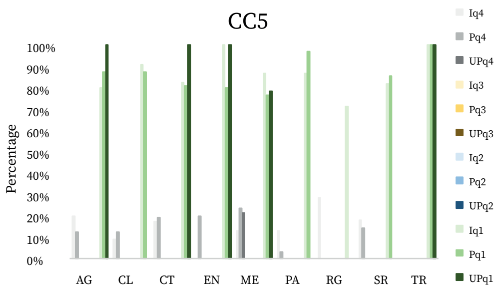

Figure 14. Comparison of the percentages of municipalities for different metropolitan cities in Sicily based on the quartiles of indicators for human and cultural capital, and the NSIA classification. (Authors' elaboration).

The absence of total convergence between the classifications, the NSIA one, and the one with reference to clusters of municipalities on the basis of quartiles of indicators for different forms of capital, highlights the former's inability to be able to capture the values of different areas.

The approach underlying the attribution in a certain level of marginality to areas proposed by the NSIA classification fails to capture the distinctiveness of their values and/or dis-values. There is a risk that it provides a mapping of abandonment incapable of adequately supporting the planning of interventions aimed at reducing their marginalization and promoting the development of strategies aimed at enhancing the areas.

In this regard, this research proposes a new mapping of abandonment based on an index estimated with reference to the values and/or dis-values of indicators of different forms of territorial capital.

5.3. Principal Component Analysis of Territorial Capital Indicators

We selected 89 indicators for the characterization of different forms of territorial capital. Given the presence of many interrelated variables, PCA can be used. PCA was conducted with the help of SPSS statistical software, and it is instrumental in reducing the dimension and arriving at the estimation of the abandonment index more efficiently.

With the help of the statistical software, the non-rotated solution was produced and then the rotated solution using the Rotation-Varimax method with Kaiser normalization, and the components were selected based on the screen plot (Figure 15).

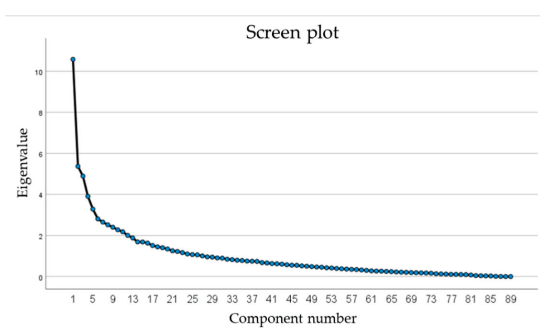

Figure 15. Screen plot rotated solution using the Rotation-Varimax method.

The rotated solution was obtained after 34 iterations and identified 27 components that in total explained 73.5 % of the total variance (Table A1 in Appendix B).

For each component, based on the variables in it, we gave a name. The 27 components and their designations are given below:

- PC1 (HC2, HC3, UC13, UC14, IC8) called Attractiveness 1;
- PC2 (HC1, UC6, EC9, IC17) called Attractiveness 2;
- PC3 (EC2, EC3, EC4, EC8, IC1) called Economy 1;
- PC4 (HC6, HC14) called Economy 2;
- PC5 (IC6, IC16, CC1) called Facilities 1;
- PC6 (UC21, IC13, IC15) called Facilities 2;
- PC7 (EC10, NC1, NC2, NC4) called Natural heritage and agricultural activity;
- PC8 (UC7, UC8, UC11) called Urbanization 1;
- PC9 (IC2, IC4, IC5) called Mobility;
- PC10 (HC9, HC11, HC12) called Foreigners;
- PC11 (NC3, CC2, CC3, CC4) called Cultural heritage;
- PC12 (UC9, UC15, IC3) called Functional mix;
- PC13 (EVC1, EVC2, EVC6, EVC7, EVC8) called Hydraulic and seismic hazards;
- PC14 (HC4, HC5, HC7, UC1, IC18, EVC9) called Population and urbanization;
- PC15 (HC15, HC16) called Education;
- PC16 (EVC3, EVC4, EVC5) called Landslide Hazard;
- PC17 (UC12, UC16, UC17) called Dwellings 1;
- PC18 (UC17, IC12) called Facilities 3;
- PC19 (UC4, UC18, UC20, UC22, EVC10) called Urbanization 2;
- PC20 (IC10, IC11, IC20) called Facilities 4;
- PC21(HC8, HC13) called Employment 1;
- PC22 (HC10, EC6) called Employment 2;
- PC23 (IC9, IC21, CC5) called Facilities 5;
- PC24 (UC3, UC5, UC19) called Dwellings 2;
- PC25 (UC10, EC1, EC5, EC7) called Economy 3;
- PC26 (IC7, IC14, IC19) called Transport;
- PC27 (UC2, NC5) called Urban and agricultural land use.

The PCA made it possible to reduce the number of variables representing the different forms of territorial capital from 87 to 27. The new variables considered next in the analysis are: Attractiveness 1, Attractiveness 2, Economy 1, Economy 2, Facilities 1, Facilities 2, Natural heritage and agricultural activity, Urbanization 1, Mobility, Foreigners, Cultural heritage, Functional mix, Hydraulic and seismic hazards, Population and urbanization, Education, Landslide Hazard, Dwellings 1, Facilities 3, Urbanization 2, Facilities 4, Employment 1, Employment 2, Facilities 5, Dwellings 2, Economy 3, Transport, and Urban and agricultural land use.

5.4. Estimated Aggregate Index of Abandonment-I_a

Based on the components identified with the help of the PCA and through Equation (1) previously presented, the abandonment index I_a was estimated for the marginal areas of Sicily

Based on this calculation, all Sicilian municipalities under study were ranked, i.e., those falling in the intermediate, peripheral, and outermost NSIA areas. The ranking of the municipalities is shown in Table A2 in Appendix B. The clusters of municipalities based on quartiles, for the different metropolitan areas in Sicily are presented in Table A3 in Appendix B. Based on the quartiles of the estimated abandonment index, four classes of abandonment were defined, low, medium, medium-high and high. Municipalities falling into the fourth quartile are those characterized by a low level of abandonment, those falling into the third quartile are characterized by a medium level of abandonment, those falling into the second quartile are characterized by a medium-high level of abandonment, and those falling into the first quartile are characterized by a high level of abandonment.

Figure 16 shows the number of municipalities for the nine Sicilian metropolitan cities that fall into the different classes of abandonment. Figure 16 shows a high number of municipalities falling in the high I_a class for the metropolitan cities of Palermo and Messina. The latter also has the highest number of municipalities falling in the medium-high I_a class.

From this it can be inferred that these two metropolitan cities are those most affected by the phenomenon of abandonment. The Ragusa metropolitan area is the only one that has no municipalities in the medium-high and high class.

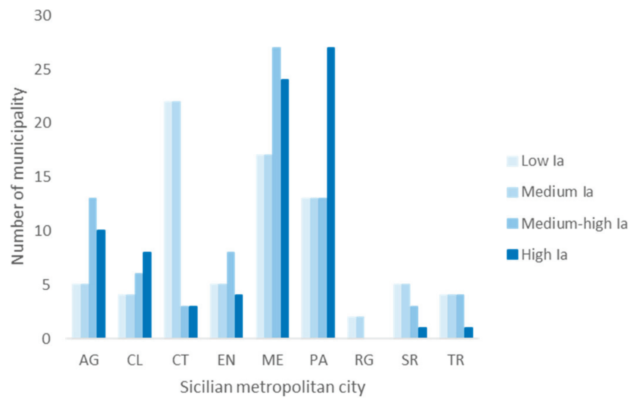

Figure 16. Number of municipalities by class of abandonment in Sicilian metropolitan cities. (Authors' elaboration).

In order to highlight the areas most affected by the phenomenon of abandonment, a map of clusters of municipalities defined on the basis of quartiles of the abandonment index was produced with QGIS (Figure 17).

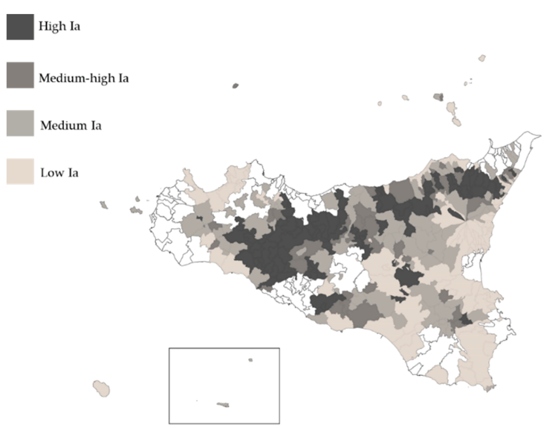

Figure 17. Abandonment map for municipalities in Sicilian metropolitan cities. (Authors' elaboration).

The map shows clusters of municipalities with a low level of abandonment in the central-eastern and western areas of Sicily; clusters of municipalities with a medium level of abandonment in the central and northeastern areas of Sicily; clusters of municipalities with a medium-high level of abandonment in the central and northeastern areas of Sicily; and clusters of municipalities with another level of abandonment in the central-northern area of Sicily. The abandonment mapping produced in this study on the basis of the estimated abandonment index will be compared in the following section with those of inland areas according to SNAI. The purpose is to highlight the convergences and divergences of the two classifications. The purpose of this comparison is to test whether abandonment mapping, i.e., the cognitive support of abandonment adopted so far, is able to effectively support policies and strategies aimed at reducing and containing this phenomenon.

6. Discussion

By comparing the two maps, the one of the classifications of inland areas according to SNAI and the one obtained as a result of this study on the basis of the estimated abandonment index I_a in the perspective of an axiology of weak areas, marked differences can be highlighted.

In the map according to the NSIA classification (Figure 18a) the ultra-peripheral areas highlighted by the darker gray color, to which correspond the areas characterized by the highest level of marginality, fall in the central and northern areas of Sicily, the Pelagic islands, and the island of Pantelleria and Salina. In the new map (Figure 18b) the areas characterized by an I_a belonging to the high class, highlighted by darker gray, fall in the central and northern areas of Sicily. Between the two maps there is a convergence for the location of the areas affected by the phenomenon of abandonment, but divergences with reference to the extent of the areas affected, more extensive in the case of the new map and a different characterization for the Pelagic islands, the island of Pantelleria and Salina.

In the map according to the NSIA classification (Figure 18a) the peripheral areas highlighted by gray, to which correspond the areas characterized by an intermediate level of marginality, affect large portions of the Sicilian territory mainly in the central, eastern-northern, and western-northern areas and in the southern areas of Sicily, the Aeolian and Egadi islands. In the new map (Figure 18b) the areas characterized by an I_a belonging to the medium-high class, highlighted by gray, fall in the central and northern areas of Sicily, the Aeolian and Egadi islands. Between the two maps there is still a convergence for the location of the areas affected by the abandonment phenomenon, as well as divergences with reference to the extent of the areas affected, which are smaller in the case of the new map and a different characterization of the Aeolian and Egadi.

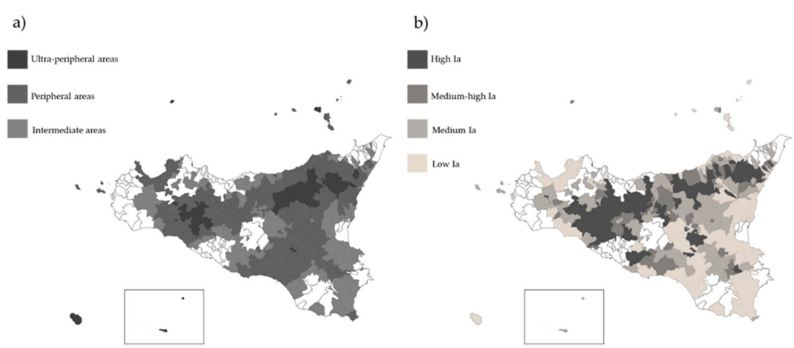

Figure 18. Comparison between the NSIA classification of inland areas and that based on the abandonment index I_a. (**a**) highlights the map of interen areas based on the classification of the NSIA; (**b**) highlights the map constructed based on the abandonment index. (Authors' elaboration).

In the map according to the NSIA classification (Figure 18a) the intermediate areas highlighted by the light gray color, to which correspond the areas characterized by a low level of marginality, cover large portions of the Sicilian territory, mainly in the central and eastern areas of Sicily. In the new map (Figure 18b) the areas characterized by an I_a belonging to the medium class, are highlighted by lighter gray, and fall in the central area of Sicily, the Pelagic and Egadi islands. Between the two maps there is still a partial convergence for the location of the areas affected by the phenomenon of abandonment with reference to the central areas, but also divergences with reference to the extent of the areas affected, smaller in the case of the new map and a different characterization of the Pelagic and Egadi islands.

Based on the fourth class of I_a, i.e., the low class, highlighted by very light gray, the new map (Figure 18b) highlights extensive portions of Sicilian territory predominantly falling in the eastern, southern and northern areas, the island of Pantelleria and the Aeolian

Islands. These areas are identified in the NSIA classification as intermediate and peripheral, while the former characterization could be considered congruent with the low class of I_a, the latter certainly highlights a discordance between the two maps.

Going into more detail, a comparison of the percentages of municipalities between the two classifications, the one with reference to I_a, and the NSIA classification, reveals strong divergences. The municipalities falling in the fourth quartile of I_a, and thus belonging to the high class of abandonment, in the NSIA classification can be classified as intermediate, peripheral, and ultra-peripheral areas, as is highlighted in Figure 19a. In particular, it is noted that: the metropolitan cities of Agrigento, Enna and Messina are characterized by municipalities that can be classified in the three types of NSIA areas; the metropolitan cities of Caltanissetta, Catania and Palermo are characterized by municipalities that can be classified in two types of NSIA areas; and the metropolitan cities of Syracuse and Trapani are characterized by municipalities that according to the NSIA belong to the peripheral area for the former and to the intermediate area for the latter.

This detects a divergence, in that areas with profoundly different levels of marginality for the NSIA classification fall in the same class of I_a high. More importantly, it is possible to highlight municipalities with high levels of marginality, such as those falling in the ultra-peripheral areas of the NSIA classification, while falling in the fourth quartile in the estimated I_a index. This highlights a criticality of the NSIA classification in detecting the actual status in terms of marginality of municipalities.

A convergence between the two classifications is detectable for the Ragusa metropolitan area, which for the NSIA classification is characterized only by intermediate areas and for which no municipality falling in I_a high can be detected.

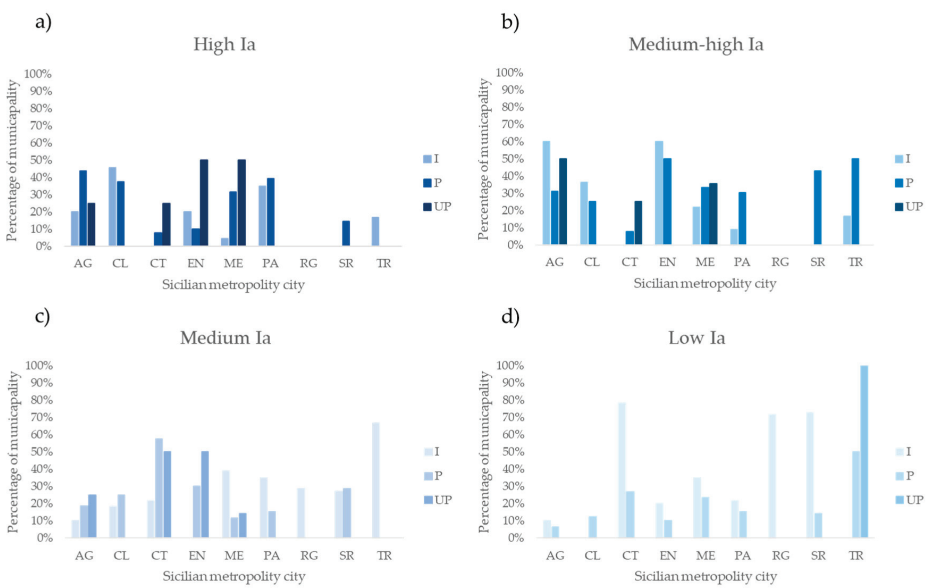

Figure 19. Percentage of municipalities in Sicilian metropolitan cities by classes of abandonment and membership in SNAI internal area types: (**a**) Low I_a; (**b**) Medium I_a; (**c**) Medium-high I_a; (**d**) High I_a. (Authors' elaboration).

The same divergences can be detected by comparing the NSIA classification with that for I_a Medium-high, Medium and Low (Figure 19a–d). Again, the only convergence detected between the two classifications still concerns the Ragusa metropolitan area, for which there are absent municipalities falling in the I_a Medium-high class, and present municipalities falling in the Medium and High class, considering the latter range of values likely to be similar to those of an intermediate area, which is the only type of area provided for Ragusa in the SNAI classification.

For the Region of Sicily, four areas have been identified for which an area strategy has been identified in order to counter the phenomenon of abandonment and promote measures aimed at territorial rebalancing. The proposed supporting policies are place-based and provide directions for promoting the SDGs [9] in these areas. The strategies are mainly based on Citizen Empowerment for Health, Active Land Protection, Renewable Energy Production, Rural System Development, Supporting Local Businesses and Crafts to Promote Employment, Enhancing Territorial Accessibility and Mobility, Improving Tourism Supply, Reducing Digital Device, Promoting Local Community Participation, Community Services and Social Infrastructure, Enhancing Human Capital, Partnerships, Sustainable Communities [148,149].

The four areas identified according to the NSIA classification of inland areas are Calatino, Madonie, Nebrodi and Val Simeto. These areas are characterized by the territorial contiguity of municipalities that have joined the Framework Program Agreements. The different areas include municipalities that can be classified according to NSIA as intermediate areas, peripheral and ultra-peripheral, and in some cases, as in the case of the Madonie and the Val di Simeto even those falling within the belt areas. For example, with reference to the case of the Nebrodi area strategy (Table 8), it includes nineteen municipalities falling within the Messina metropolitan area. The municipalities in the Messina metropolitan area adhering to the Framework Agreement with reference to the NSIA classification are characterized: four as intermediate areas, thirteen as peripheral areas, and two as ultra-peripheral areas. With reference to the abandonment index estimated in this study, four of them fall in the first quartile; eleven in the second quartile; three municipalities fall in the third quartile and only one municipality falling in the quartile.

Table 8. The municipalities belonging to the Nebrodi area strategy.

Metropolitan Area	Nebrodi Area Strategy	NSIA	*Ia*
ME	Tusa	I	q2
ME	Pettineo	I	q1
ME	Castel di Lucio	P	q1
ME	Mistretta	P	q2
ME	Reitano	I	q2
ME	Santo Stefano di Camastra	I	q3
ME	Caronia	P	q2
ME	San Fratello	P	q3
ME	Militello Rosmarino	P	q2
ME	Sant’Agata di Militello	P	q4
ME	Alcara Li Fusi	UP	q1
ME	Longi	UP	q2
ME	San Marco D’Alunzio	P	q3
ME	Mirto	P	q2
ME	Naso	P	q2
ME	San Salvatore di Fitalia	P	q1
ME	Castell’Umberto	P	q2
ME	Tortorici	P	q2
ME	Galati Marmettino	P	q2

Again, as in all the other areas identified, the municipalities participating in the area strategy are characterized by territorial contiguity. They belong to the same territorial sub-area as the metropolitan area of Messina.

The NSIA Classification can be seen as a cognitive tool to support networking among municipalities, in this case supported the identification of a mix of municipalities characterized by different levels of marginality, in which 21 percent fall in intermediate areas, 685 in peripheral areas and 11 percent in ultra-peripheral areas. The network selected in this case integrates municipalities with strongly marked marginalities, others with less marked marginalities, and still others with small marginalities. If strategies were effectively selected for this network, it could foster those complementarities among municipalities capable of generating a territorial unity that could achieve greater enhancement than a single municipality could achieve.

The classification according to the index of abandonment estimated in this study developed from the perspective of an axiological approach highlights, in a more pronounced way the possibility of generating a network on the basis of the complementarity of municipalities. For the case of the Nebrodi area, we show that 21% of the municipalities fall in the first quartile of I_a, 58% in the second quartile of I_a, 16% in the third quartile and 5% in the fourth quartile of I_a. Again, a main pole is detected, which is represented by the municipality or municipalities with the highest I_a perfomance on the base are connected those with progressively worse performance thus defining the network.

According to this perspective, the measure of the values and/or disvalues of municipalities, i.e., the measure of their residual worthiness identified in the index I_a is possible to more effectively support the selection of municipalities that will be able to fall within a functional area and to support the creation of a network. Classification on the basis of the abandonment index I_a will be able to support the decision maker in identifying an area unit and creating specific development strategies.

The mapping of inland areas proposed by NSIA represents the official cognitive tool to counter the marginalization and abandonment of territories. Italy among European countries is the first country that has produced a reconnaissance of the state of abandonment of the territory, proposing a unified framework to develop strategies to counter this phenomenon. This mapping is the basis for the allocation of financial resources provided in Mission 5, Component 3, Investment 1 of the Italian National Recovery and Resilience Plan (NRP) [22]. It represents the financial tool to support the implementation of policies aimed at reducing social distress and fragility, increasing the number of service recipients, increasing the quality of supply, and facilitating connections and accessibility to territories and services.

In Europe, other countries have promoted policies aimed at territorial rebalancing and finding funding to support it. For example, France a promoted in 2014 "*Revitalisation des centres-bourges*" [150] which represents the first national program aimed at intervening in the imbalances that affected small and medium-sized cities, which until then had been excluded from national urban policies that were mainly directed at *grandes villes*. Later, in order to improve the level of policy implementation with reference to the peculiarities of the areas of action, France proposed other programs such as the "*Action Coeur de Ville*" in 2018 [151], which is aimed at improving the living conditions of the inhabitants of medium-sized centers and consolidating the leading role of these centers in the development of the territory. In 2020, France proposed the program "*Petites villes de demain*" nel 2020 [152], aimed at improving the living conditions of the inhabitants of small towns and surrounding areas by supporting communities in identifying dynamic trajectories for their ecological transition.

Other countries, such as Switzerland, adopted a New Regional Policy (NRP) in 2008 [153] to support mountain and border regions and rural areas, promoting improved hard and soft location factors of regions, promotion of innovation, value creation and competitiveness in a sustainable way [154–157].

In this way, the NRP contributes to the creation and retention of jobs in the targeted areas, to compensate for regional disparities, and to maintain decentralized settlement structures in Switzerland. The NRP also promotes European territorial cooperation in line with the Interreg, ESPON, URBACT and INTERACT programs [158].

In Spain, the issue of depressed areas due to their depopulation and socio-economic decline was initially addressed by some regions, such as Castilla-La Mancha, which in 2016 approved the definition of five geo-graphic areas with specific development needs [159], as well as the initiation of procedures for the implementation of integrated territorial investments, i.e., tools to facilitate support for integrated actions in an area, allowing the combination of funding related to different thematic objectives and various operational programs supported by the various European Structural and Investment Funds (EIFs).

Subsequently, the Spanish Council of Ministers on March 29, 2019 approved the General Guidelines for a National Strategy to Address the Demographic Challenge by mapping demographic depopulation, aging, and the effects of population fluctuation and setting the following goals [160]: ensure full territorial connectivity; ensure adequate provision of basic services to the entire population; incorporate demographic impact and perspective in the preparation of laws, plans and investment programs; regulatory and administrative simplification, for small municipalities; enhance the image and reputation of territories most affected by demographic risks; strengthen public-private collaboration; and align the Strategy's action lines with the achievement of the Sustainable Development Goals and Agenda 2030.

Other interventions in favor of marginal areas are being planned in Spain under the impetus of a debate on the subject (which is quite heated), such as the program "El plan de España para evitar la despoblación rural", which is still being structured.

The mapping of inland areas proposed by NSIA to support the development of strategies aimed at combating abandonment of territories is a tool that as highlighted in this study has ample room for improvement. In this regard, our proposal for a new mapping based on an abandonment index moves in the direction of improving the formation of a knowledge base of the phenomenon of abandonment, instrumental in identifying strategies and improving the effectiveness of policies.

The main limitations of this study are mostly due to the quality of the data used in the analysis, which although extracted from official datasets, unfortunately refer to different periods. This factual criticality is also detectable for the data used to develop the NSIA classification of inland areas.

With this in mind, we will estimate the abandonment index again in the future once NSIA makes data on the 2021 Permanent Population and Housing Census available.

But more significantly, possible developments of this study will address the question of how this cognitive tool can support decision makers in generating the network of municipalities and supporting strategies in order to achieve more effective implementation of policies in favor of a rebalancing of the territory [161–163].

Future studies will look at the potential of this approach in supporting a territorial values-network-based pattern that can be developed with the support of network analysis, neural network or specific genetic algorithms, aimed at optimizing the selection of areas, strategies and improving the allocation of budgets to those areas.

The estimation of an abandonment index for marginal areas was developed from the perspective of a formative model, in which individual indicators are seen as the "cause" of the latent variable.

PCA for the construction of formative composite indices, as highlighted by Mazzotta and Pareto [164], is a good approach, as it is a powerful tool for complexity reduction and supports data visualization by supporting the researcher in identifying units of analysis with the same characteristics and allows for comparing empirical dimensions (factors) with theoretical dimensions (pillars) while highlighting redundant indicators [165].

Future developments in the estimation of an abandonment index for marginal areas will concern the estimation of weights for the aggregation of the different components. A sensitivity analysis of the index based on the different approaches to estimating the weights may improve its estimation. Further development may concern uncertainty analysis (UA) [166].

7. Conclusions

The marginalization of areas due to progressively increasing social, material, economic, and infrastructural vulnerability is a phenomenon that afflicts many countries today and is growing rapidly [167,168]. The 2030 Agenda highlighted the need to identify measures to support the least developed areas, particularly with reference to Goal 11 of the SDGs [9].

Under the impetus of the sustainability goals set by the 2030 Agenda, there has been a growing awareness among researchers and policymakers that this issue is no longer deferrable, and that it will have to be addressed while being aware of the complexity of the phenomenon. The debate on the issue of abandonment has developed mainly from the perspective of characterizing the phenomenon of abandonment, resulting in actions to measure its magnitude and determine its causes, and on identifying strategies and measures to counter it, and the related sources of funding to be allocated. In this perspective, Italy has equipped itself with a cognitive tool created by the Interministerial Committee for Economic Planning and Sustainable Development, namely the map of inland areas, aimed at to measure the extent and determine the causes of the phenomenon; an operational tool aimed at combating the phenomenon of abandonment aimed at identifying the strategies and interventions to be developed within the framework of the National Strategy for Inland Areas; and a financial tool aimed at supporting the implementation of the specific measures identified, namely the NRRP.

In this study starting from a critical analysis of the NSIA classification of inland areas, we have proposed a new cognitive tool of the phenomenon of abandonment, developed from the perspective of an axiological approach of marginal areas, which led to a mapping of the phenomenon of abandonment on the basis of an index of abandonment I_a. This index was defined on the basis of the value of the different forms of territorial capital of marginal areas, i.e., with reference to human, urban, economic, infrastructure, natural, cultural, and environmental capital. Given the large number of indicators of territorial capital, in order to arrive at the most representative set of indicators, and thus to reduce the complexity of representing the different forms of capital, it was necessary to resort to Principal Component Analysis. The latter supported the identification of twenty-seven components for the characterization of the abandonment index, which was estimated as an aggregate weighted sum of the different components.

The mapping of the abandonment index I_a on QGIS made it possible to identify a new cognitive tool of the abandonment phenomenon, capable of highlighting the values and/or dis-values of areas. The map provides clusters of municipalities based on quartiles of estimated index values. Mapping, in identifying the residual worthiness of areas, can be used for the development of strategies to support their resilience, improve the effectiveness of policies, and promote the efficient use of financial resources to be allocated. It, as amply evidenced in the proposed comparisons with the NSIA classification, can identify itself as a more effective cognitive tool to support the development of strategies to reduce abandonment and promote rebalancing. Certainly, in order to improve the result, we have arrived at, the limitations of this study will have to be overcome.

These limitations are mostly related to the quality of the data, which due to difficulties related to their retrievability refer to different periods, is an issue that can be resolved as soon as NIS makes available the data on the 2021 Permanent Population and Housing Census. Possible developments of this study will address the question of how this cognitive tool can support decision-makers in generating the network of municipalities and identifying strategies, supporting more effective implementation of policies aimed at reducing territorial imbalances.

Subsequent work, therefore, will address the potential of this approach to support a territorial values network-based pattern that can be developed with the support of network analysis, neural networks or specific genetic algorithms aimed at optimizing the selection of areas and strategies and improving the allocation of budgets to different areas.

Author Contributions: Conceptualization, M.R.T.; methodology, M.R.T.; software, M.R.T.; validation, M.R.T.; formal analysis, M.R.T.; investigation, M.R.T. and L.N.; resources, M.R.T.; data curation, M.R.T.; writing—original draft preparation, M.R.T.; writing—review and editing, M.R.T.; visualization, M.R.T. and L.N.; supervision, M.R.T.; project administration, M.R.T.; funding acquisition, M.R.T. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Appendix A.1. Details of the Indicators Supporting the NSIA Classification

Structure indicators:

- Housing structure: this indicator was chosen as a summary measure of the prevailing housing type: population centers, cores and scattered houses, and thus considered a proxy for the degree of urbanization;
- Population rate over 65 years old: this indicator was considered a proxy for the demographic environment.

Indicators of supply for services:

- Presence and type of upper secondary schools (varies between "No offer" and "Full offer", full offer includes high schools, technical and vocational colleges, and other types of high schools);
- Presence of banking services (no. bank branches × 1000 inhabitants);
- Presence of financial services for the citizens;
- Presence of health and emergency room facilities (varies between "No facilities" to "More than one facility");
- Presence of health facilities with at least 250 beds;
- Presence of health facilities with at least 120 beds;
- Presence of health facilities that are home to Level I EDA;
- Presence of a railway station of at least "Silver" type;
- Presence of state and non-state museums.

Indicators of demand for services:

- High school enrollment out of population aged 14–18 years.
- Context indicators (Source: Istat):
- Share of motor vehicle accidents × 1000 vehicles on the road (proxy for congestion level).

Appendix A.2. Comparison of the Performance of Indicators of Territorial Capital Forms by Sicilian Metropolitan Cities and the Types of Areas in the NSIA Classification

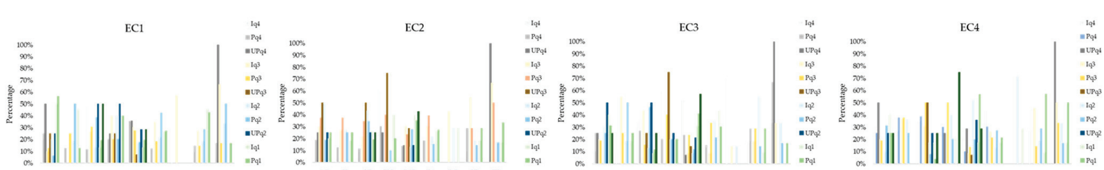

Figure A1. *Cont.*

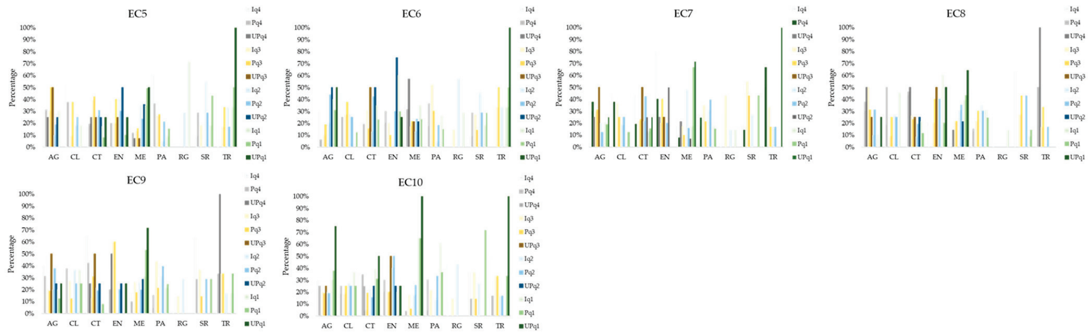

Figure A1. Comparison of the percentages of municipalities for different metropolitan cities in Sicily based on the quartiles of indicators for economic capital, and the NSIA classification. (Authors' elaboration).

Figure A2. Comparison of the percentages of municipalities for different metropolitan cities in Sicily based on the quartiles of indicators for urban capital, and the NSIA classification. (Authors' elaboration).

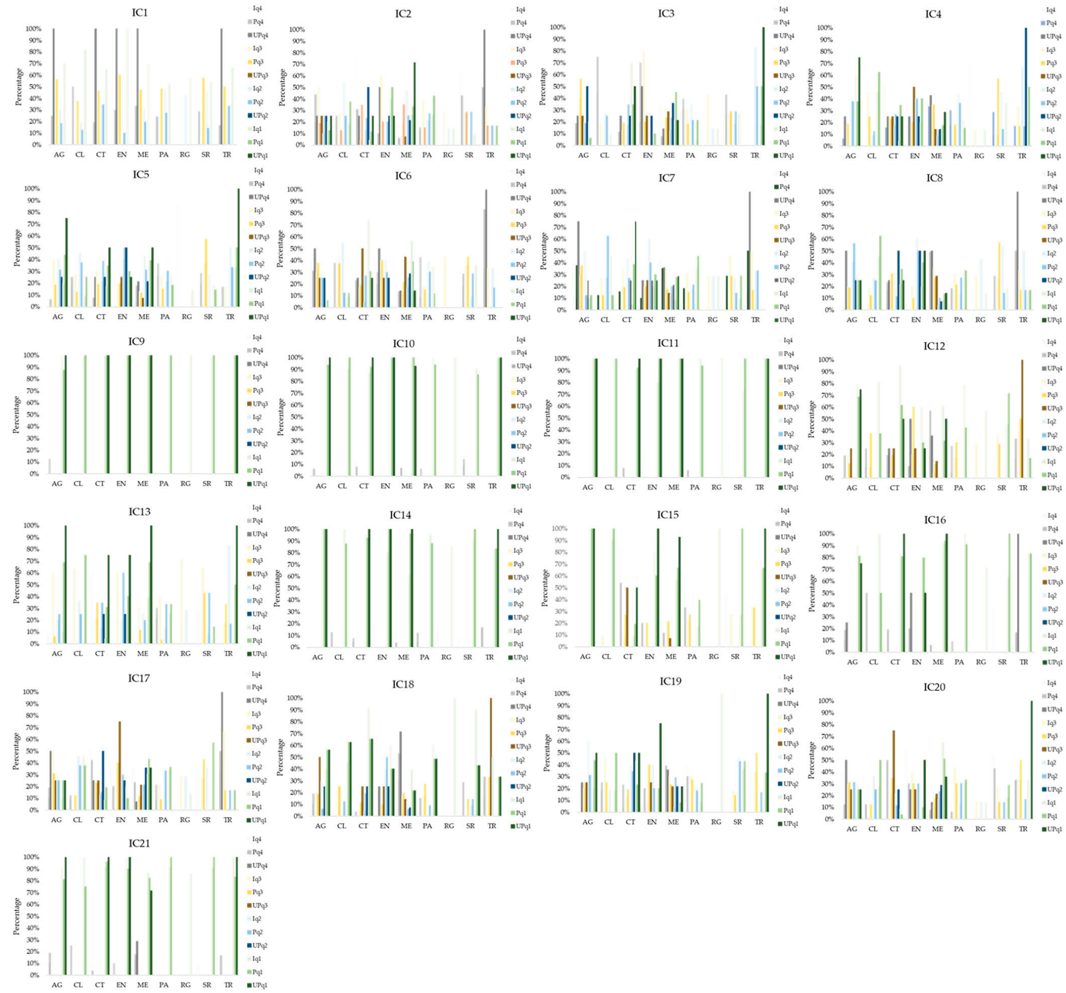

Figure A3. Comparison of the percentages of municipalities for different metropolitan cities in Sicily based on the quartiles of indicators for infrastructural capital, and the NSIA classification. (Authors' elaboration).

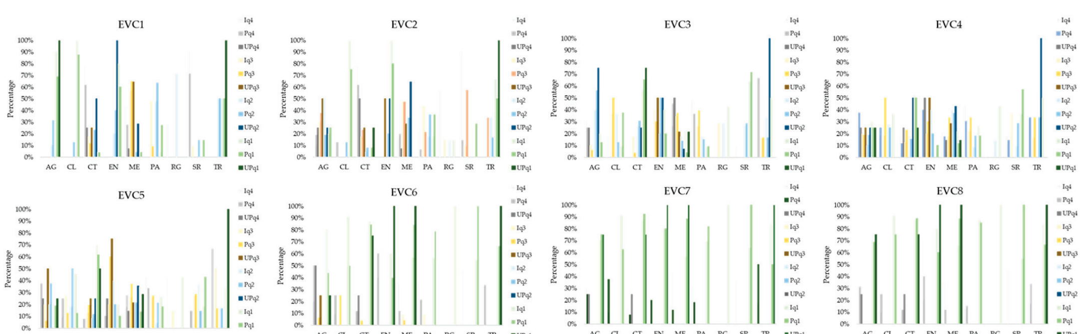

Figure A4. *Cont.*

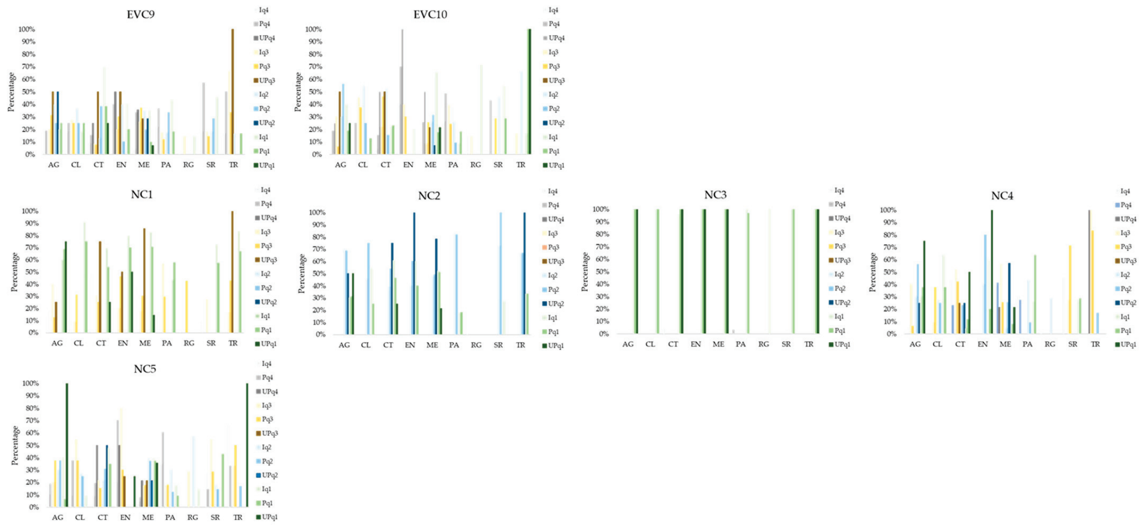

Figure A4. Comparison of the percentages of municipalities for different metropolitan cities in Sicily based on the quartiles of indicators for environmental and natural capital, and the NSIA classification. (Authors' elaboration).

Appendix B

Results on PCA: Total Variance Explored

Table A1. Ranking of municipalities based on abandonment index for nine metropolitan cities in Sicily.

Total Variance Explained									
Component	**Eigenvalues**			**Sums of Extraction Squares**			**Sums of Squares of Rotation**		
	Total	**% Variance**	**% Cumulative**	**Total**	**% Variance**	**% Cumulative**	**Total**	**% Variance**	**% Cumulative**
1	10.582	11.890	11.890	10.582	11.890	11.890	5.207	5.851	5.851
2	5.368	6.032	17.922	5.368	6.032	17.922	4.693	5.273	11.123
3	4.894	5.498	23.420	4.894	5.498	23.420	4.240	4.764	15.888
4	3.907	4.390	27.811	3.907	4.390	27.811	3.950	4.439	20.327
5	3.286	3.692	31.503	3.286	3.692	31.503	2.989	3.359	23.685
6	2.811	3.158	34.661	2.811	3.158	34.661	2.959	3.325	27.010
7	2.653	2.981	37.642	2.653	2.981	37.642	2.922	3.284	30.294
8	2.522	2.833	40.476	2.522	2.833	40.476	2.770	3.112	33.406
9	2.404	2.701	43.177	2.404	2.701	43.177	2.434	2.735	36.140
10	2.279	2.560	45.737	2.279	2.560	45.737	2.362	2.654	38.795
11	2.181	2.450	48.187	2.181	2.450	48.187	2.308	2.593	41.388
12	2.006	2.254	50.441	2.006	2.254	50.441	2.264	2.544	43.932
13	1.883	2.116	52.558	1.883	2.116	52.558	2.220	2.495	46.427
14	1.687	1.896	54.454	1.687	1.896	54.454	2.220	2.495	48.922
15	1.684	1.892	56.346	1.684	1.892	56.346	2.148	2.413	51.335
16	1.632	1.834	58.179	1.632	1.834	58.179	2.097	2.356	53.691
17	1.511	1.698	59.877	1.511	1.698	59.877	2.003	2.251	55.942
18	1.448	1.626	61.504	1.448	1.626	61.504	1.941	2.181	58.123
19	1.405	1.579	63.083	1.405	1.579	63.083	1.661	1.867	59.989
20	1.344	1.510	64.593	1.344	1.510	64.593	1.627	1.828	61.818
21	1.254	1.409	66.002	1.254	1.409	66.002	1.599	1.796	63.614
22	1.222	1.373	67.375	1.222	1.373	67.375	1.558	1.750	65,364
23	1.169	1.313	68.688	1.169	1.313	68.688	1.530	1.719	67.083
24	1.100	1.236	69.924	1.100	1.236	69.924	1.503	1.689	68.772
25	1.070	1.202	71.126	1.070	1.202	71.126	1.483	1.666	70.438
26	1.057	1.188	72.314	1.057	1.188	72.314	1.389	1.560	71.998
27	1.006	1.130	73.445	1.006	1.130	73.445	1.288	1.447	73.445

Table A2. Ranking of municipalities based on abandonment index for nine metropolitan cities in Sicily.

Ranking	Metropolitan City	Municipality	Ranking	Metropolitan City	Municipality	Ranking	Metropolitan City	Municipality
1	Ragusa	Vittoria	**104**	Messina	Itala	**207**	Palermo	Mezzojuso
2	Palermo	Carini	**105**	Siracusa	Sortino	**208**	Agrigento	Montallegro
3	Trapani	Pantelleria	**106**	Catania	Maniace	**209**	Caltanisetta	Resuttano
4	Catania	Acireale	**107**	Trapani	Calatafimi-Segesta	**210**	Messina	Mirto
5	Ragusa	Acate	**108**	Trapani	Salemi	**211**	Messina	Longi
6	Catania	Belpasso	**109**	Messina	Forza d'Agrò	**212**	Palermo	Castellana Sicula
7	Ragusa	Scicli	**110**	Palermo	San Cipirello	**213**	Palermo	Baucina
8	Catania	Camporotondo Etneo	**111**	Messina	Rometta	**214**	Messina	Moio Alcantara
9	Catania	Aci Castello	**112**	Catania	Piedimonte Etneo	**215**	Messina	Alì
10	Siracusa	Augusta	**113**	Palermo	Marineo	**216**	Messina	Mistretta
11	Catania	Mascalucia	**114**	Catania	Adrano	**217**	Caltanisetta	Milena
12	Palermo	Isola delle Femmine	**115**	Messina	Motta Camastra	**218**	Enna	Gagliano Castelferrato
13	Messina	Taormina	**116**	Palermo	Piana degli Albanesi	**219**	Messina	Santa Domenica Vittoria
14	Siracusa	Noto	**117**	Enna	Nicosia	**220**	Messina	Librizzi
15	Catania	San Giovanni la Punta	**118**	Messina	Montagnareale	**221**	Messina	Reitano
16	Catania	Pedara	**119**	Catania	Licodia Eubea	**222**	Agrigento	Lucca Sicula
17	Catania	Aci Sant'Antonio	**120**	Messina	Scaletta Zanclea	**223**	Siracusa	Ferla
18	Catania	Caltagirone	**121**	Palermo	Castelbuono	**224**	Catania	Maletto
19	Siracusa	Melilli	**122**	Messina	Nizza di Sicilia	**225**	Enna	Valguarnera Caropepe
20	Siracusa	Lentini	**123**	Messina	Leni	**226**	Agrigento	Santo Stefano Quisquina
21	Catania	Viagrande	**124**	Catania	Vizzini	**227**	Messina	Galati Mamertino
22	Catania	San Pietro Clarenza	**125**	Catania	Randazzo	**228**	Messina	Antillo
23	Catania	Giarre	**126**	Palermo	Corleone	**229**	Agrigento	Camastra
24	Catania	Aci Catena	**127**	Enna	Agira	**230**	Agrigento	Naro
25	Catania	Trecastagni	**128**	Messina	Roccavaldina	**231**	Messina	Gallodoro
26	Ragusa	Ispica	**129**	Messina	Sant'Angelo di Brolo	**232**	Messina	Francavilla di Sicilia
27	Messina	Letojanni	**130**	Caltanisetta	Niscemi	**233**	Palermo	Gratteri
28	Catania	Tremestieri Etneo	**131**	Trapani	Santa Ninfa	**234**	Enna	Villarosa
29	Catania	Gravina di Catania	**132**	Agrigento	Lampedusa e Linosa	**235**	Palermo	Contessa Entellina
30	Caltanisetta	Gela	**133**	Ragusa	Giarratana	**236**	Agrigento	Cattolica Eraclea
31	Catania	Mascali	**134**	Enna	Troina	**237**	Palermo	Ventimiglia di Sicilia
32	Palermo	Cinisi	**135**	Messina	San Fratello	**238**	Palermo	Bompietro
33	Messina	Capo d'Orlando	**136**	Palermo	San Giuseppe Jato	**239**	Catania	San Cono
34	Messina	Torrenova	**137**	Siracusa	Francofonte	**240**	Palermo	Ciminna
35	Messina	Patti	**138**	Ragusa	Monterosso Almo	**241**	Siracusa	Cassaro
36	Catania	Aci Bonaccorsi	**139**	Catania	Grammichele	**242**	Messina	San Salvatore di Fitalia
37	Catania	Valverde	**140**	Catania	Mineo	**243**	Palermo	Caltavuturo
38	Palermo	Capaci	**141**	Messina	Monforte San Giorgio	**244**	Palermo	Bisacquino
39	Trapani	Alcamo	**142**	Caltanisetta	Mussomeli	**245**	Agrigento	Calamonaci

Table A2. *Cont.*

Ranking	Metropolitan City	Municipality	Ranking	Metropolitan City	Municipality	Ranking	Metropolitan City	Municipality
40	Messina	Acquedolci	**143**	Agrigento	Santa Margherita di Belice	**246**	Palermo	Vicari
41	Palermo	Partinico	**144**	Messina	San Marco d'Alunzio	**247**	Trapani	Vita
42	Palermo	Borgetto	**145**	Palermo	Cefalà Diana	**248**	Messina	Alcara li Fusi
43	Catania	Nicolosi	**146**	Palermo	Villafrati	**249**	Palermo	Campofiorito
44	Enna	Enna	**147**	Catania	Linguaglossa	**250**	Palermo	Castronovo di Sicilia
45	Siracusa	Avola	**148**	Enna	Leonforte	**251**	Messina	Cesarò
46	Messina	Lipari	**149**	Catania	Sant'Alfio	**252**	Palermo	Blufi
47	Messina	Santa Teresa di Riva	**150**	Enna	Nissoria	**253**	Messina	Novara di Sicilia
48	Palermo	Torretta	**151**	Caltanisetta	Serradifalco	**254**	Palermo	Isnello
49	Messina	Giardini-Naxos	**152**	Catania	Castel di Iudica	**255**	Messina	Roccella Valdemone
50	Siracusa	Carlentini	**153**	Siracusa	Portopalo di Capo Passero	**256**	Agrigento	Caltabellotta
51	Catania	Ragalna	**154**	Caltanisetta	Delia	**257**	Agrigento	Burgio
52	Agrigento	Sciacca	**155**	Catania	Raddusa	**258**	Palermo	Lercara Friddi
53	Messina	Sant'Agata di Militello	**156**	Palermo	San Mauro Castelverde	**259**	Messina	Castel di Lucio
54	Catania	Riposto	**157**	Messina	Castell'Umberto	**260**	Messina	Casalvecchio Siculo
55	Messina	Sant'Alessio Siculo	**158**	Messina	Castroreale	**261**	Agrigento	Bivona
56	Catania	Ramacca	**159**	Palermo	Collesano	**262**	Palermo	Roccapalumba
57	Agrigento	Canicattì	**160**	Trapani	Poggioreale	**263**	Agrigento	Villafranca Sicula
58	Trapani	San Vito Lo Capo	**161**	Agrigento	Sambuca di Sicilia	**264**	Messina	Pettineo
59	Palermo	Terrasini	**162**	Trapani	Salaparuta	**265**	Messina	Montalbano Elicona
60	Messina	Brolo	**163**	Trapani	Favignana	**266**	Messina	Fondachelli-Fantina
61	Messina	Piraino	**164**	Palermo	Petralia Sottana	**267**	Caltanisetta	Montedoro
62	Messina	Alì Terme	**165**	Palermo	Pollina	**268**	Palermo	Polizzi Generosa
63	Messina	Furnari	**166**	Enna	Centuripe	**269**	Enna	Sperlinga
64	Trapani	Castellammare del Golfo	**167**	Messina	Naso	**270**	Caltanisetta	Vallelunga Pratameno
65	Ragusa	Pozzallo	**168**	Caltanisetta	Mazzarino	**271**	Messina	Frazzanò
66	Messina	Gaggi	**169**	AG	San Giovanni Gemini	**272**	Palermo	Roccamena
67	Enna	Piazza Armerina	**170**	Palermo	Camporeale	**273**	Caltanisetta	Campofranco
68	Siracusa	Rosolini	**171**	Enna	Regalbuto	**274**	Palermo	Giuliana
69	Messina	Savoca	**172**	Agrigento	Palma di Montechiaro	**275**	Palermo	Alia
70	Catania	Santa Venerina	**173**	Caltanisetta	Riesi	**276**	Messina	Malvagna
71	Catania	Santa Maria di Licodia	**174**	Messina	Sinagra	**277**	Caltanisetta	Sutera
72	Messina	Capri Leone	**175**	Agrigento	Cammarata	**278**	Palermo	Palazzo Adriano
73	Siracusa	Solarino	**176**	Palermo	Ustica	**279**	Messina	Basicò
74	Messina	Gioiosa Marea	**177**	Enna	Assoro	**280**	Messina	Raccuja
75	Siracusa	Pachino	**178**	Messina	Graniti	**281**	Enna	Aidone
76	Messina	Roccalumera	**179**	Siracusa	Buccheri	**282**	Palermo	Alimena
77	Palermo	Bolognetta	**180**	Catania	Militello in Val di Catania	**283**	Messina	Ucria
78	Palermo	Giardinello	**181**	Trapani	Gibellina	**284**	Enna	Cerami
79	Siracusa	Palazzolo Acreide	**182**	Messina	Santa Marina Salina	**285**	Palermo	Valledolmo
80	Catania	Palagonia	**183**	Palermo	Petralia Soprana	**286**	Caltanisetta	Acquaviva Platani

Table A2. *Cont.*

Ranking	Metropolitan City	Municipality	Ranking	Metropolitan City	Municipality	Ranking	Metropolitan City	Municipality
81	Palermo	Trappeto	**184**	Messina	Ficarra	**287**	Palermo	Campofelice di Fitalia
82	Messina	Furci Siculo	**185**	Enna	Catenanuova	**288**	Palermo	Montemaggiore Belsito
83	Palermo	Balestrate	**186**	Messina	Caronia	**289**	Messina	Tripi
84	Catania	Fiumefreddo di Sicilia	**187**	Enna	Calascibetta	**290**	Caltanisetta	Villalba
85	Catania	Zafferana Etnea	**188**	Enna	Barrafranca	**291**	Agrigento	Sant'Angelo Muxaro
86	Agrigento	Menfi	**189**	Siracusa	Buscemi	**292**	Catania	Mirabella Imbaccari
87	Palermo	Santa Cristina Gela	**190**	Messina	Tortorici	**293**	Messina	San Teodoro
88	Catania	Mazzarrone	**191**	Agrigento	Campobello di Licata	**294**	Palermo	Prizzi
89	Catania	Biancavilla	**192**	Messina	Mazzarrà Sant'Andrea	**295**	Agrigento	San Biagio Platani
90	Catania	Bronte	**193**	Agrigento	Montevago	**296**	Caltanisetta	Bompensiere
91	Palermo	Montelepre	**194**	Catania	Castiglione di Sicilia	**297**	Agrigento	Cianciana
92	Agrigento	Licata	**195**	Caltanisetta	Sommatino	**298**	Palermo	Aliminusa
93	Trapani	Partanna	**196**	Palermo	Godrano	**299**	Messina	Mongiuffi Melia
94	Catania	Milo	**197**	Caltanisetta	Butera	**300**	Messina	Mandanici
95	Messina	Santo Stefano di Camastra	**198**	Agrigento	Ravanusa	**301**	Messina	Capizzi
96	Messina	Castelmola	**199**	Messina	Militello Rosmarino	**302**	Palermo	Chiusa Sclafani
97	Catania	Scordia	**200**	Messina	Fiumedinisi	**303**	Catania	San Michele di Ganzaria
98	Siracusa	Canicattini Bagni	**201**	Agrigento	Casteltermini	**304**	Messina	Roccafiorita
99	Palermo	Belmonte Mezzagno	**202**	Palermo	Geraci Siculo	**305**	Messina	Floresta
100	Agrigento	Ribera	**203**	Messina	Tusa	**306**	Caltanisetta	Marianopoli
101	Messina	Malfa	**204**	Messina	San Piero Patti	**307**	Messina	Limina
102	Catania	Paternò	**205**	Palermo	Gangi	**308**	Palermo	Sclafani Bagni
103	Catania	Calatabiano	**206**	Messina	Pagliara	**309**	Messina	Motta d'Affermo
						310	Agrigento	Alessandria della Rocca

Table A3. Cluster of municipalities based on quartiles of the abandonment index for nine metropolitan cities in Sicily.

Metropolitan City	q1	Metropolitan City	q2	Metropolitan City	q3	Metropolitan City	q4
AG	Cattolica Eraclea	AG	Camastra	AG	Menfi	AG	Canicattì
AG	Sant'Angelo Muxaro	AG	Campobello di Licata	AG	Licata	AG	Sciacca
AG	Alessandria della Rocca	AG	Casteltermini	AG	Ribera	CL	Gela
AG	Burgio	AG	Montallegro	AG	Santa Margherita di Belice	CT	Aci Bonaccorsi
AG	Calamonaci	AG	Naro	AG	Lampedusa e Linosa	CT	Aci Castello

Table A3. *Cont.*

Metropolitan City	q1	Metropolitan City	q2	Metropolitan City	q3	Metropolitan City	q4
AG	Caltabellotta	AG	Palma di Montechiaro	CL	Delia	CT	Aci Catena
AG	Cianciana	AG	Cammarata	CL	Serradifalco	CT	Acireale
AG	San Biagio Platani	AG	Montevago	CL	Mussomeli	CT	Aci Sant'Antonio
AG	Villafranca Sicula	AG	Ravanusa	CL	Niscemi	CT	Belpasso
AG	Bivona	AG	Sambuca di Sicilia	CT	Biancavilla	CT	Camporotondo Etneo
CL	Acquaviva Platani	AG	San Giovanni Gemini	CT	Licodia Eubea	CT	Gravina di Catania
CL	Bompensiere	AG	Lucca Sicula	CT	Paternò	CT	Mascalucia
CL	Campofranco	AG	Santo Stefano Quisquina	CT	Scordia	CT	San Giovanni la Punta
CL	Montedoro	CL	Milena	CT	Mazzarrone	CT	San Pietro Clarenza
CL	Sutera	CL	Resuttano	CT	Adrano	CT	Santa Maria di Licodia
CL	Marianopoli	CL	Riesi	CT	Bronte	CT	Santa Venerina
CL	Vallelunga Pratameno	CL	Sommatino	CT	Calatabiano	CT	Trecastagni
CL	Villalba	CL	Butera	CT	Castel di Iudica	CT	Tremestieri Etneo
CT	San Cono	CL	Mazzarino	CT	Fiumefreddo di Sicilia	CT	Valverde
CT	San Michele di Ganzaria	CT	Maletto	CT	Grammichele	CT	Viagrande
CT	Mirabella Imbaccari	CT	Militello in Val di Catania	CT	Linguaglossa	CT	Ragalna
EN	Villarosa	CT	Castiglione di Sicilia	CT	Milo	CT	Caltagirone
EN	Aidone	EN	Barrafranca	CT	Mineo	CT	Giarre
EN	Cerami	EN	Calascibetta	CT	Palagonia	CT	Mascali
EN	Sperlinga	EN	Catenanuova	CT	Piedimonte Etneo	CT	Nicolosi
ME	Pettineo	EN	Assoro	CT	Raddusa	CT	Pedara
ME	Basicò	EN	Centuripe	CT	Sant'Alfio	CT	Ramacca
ME	Casalvecchio Siculo	EN	Gagliano Castelferrato	CT	Vizzini	CT	Riposto
ME	Castel di Lucio	EN	Regalbuto	CT	Zafferana Etnea	EN	Enna
ME	Fondachelli-Fantina	EN	Valguarnera Caropepe	CT	Randazzo	EN	Piazza Armerina
ME	Frazzanò	ME	Castroreale	CT	Maniace	ME	Alì Terme
ME	Limina	ME	Mazzarrà Sant'Andrea	EN	Agira	ME	Brolo
ME	Mandanici	ME	Pagliara	EN	Leonforte	ME	Furnari
ME	Mongiuffi Melia	ME	Reitano	EN	Nissoria	ME	Letojanni
ME	Montalbano Elicona	ME	Tusa	EN	Nicosia	ME	Patti
ME	Motta d'Affermo	ME	Alì	EN	Troina	ME	Roccalumera

Table A3. *Cont.*

Metropolitan City	q1	Metropolitan City	q2	Metropolitan City	q3	Metropolitan City	q4
ME	Novara di Sicilia	ME	Caronia	ME	Furci Siculo	ME	Santa Teresa di Riva
ME	Raccuja	ME	Castell'Umberto	ME	Itala	ME	Taormina
ME	Roccafiorita	ME	Ficarra	ME	Monforte San Giorgio	ME	Acquedolci
ME	San Salvatore di Fitalia	ME	Fiumedinisi	ME	Montagnareale	ME	Capo d'Orlando
ME	Tripi	ME	Francavilla di Sicilia	ME	Nizza di Sicilia	ME	Capri Leone
ME	Ucria	ME	Galati Mamertino	ME	Roccavaldina	ME	Gaggi
ME	Alcara li Fusi	ME	Gallodoro	ME	Rometta	ME	Giardini-Naxos
ME	Capizzi	ME	Graniti	ME	Santo Stefano di Camastra	ME	Gioiosa Marea
ME	Cesarò	ME	Librizzi	ME	Scaletta Zanclea	ME	Lipari
ME	Floresta	ME	Militello Rosmarino	ME	Castelmola	ME	Piraino
ME	Malvagna	ME	Mirto	ME	Forza d'Agrò	ME	Sant'Agata di Militello
ME	Roccella Valdemone	ME	Mistretta	ME	Motta Camastra	ME	Sant'Alessio Siculo
ME	San Teodoro	ME	Naso	ME	San Fratello	ME	Savoca
PA	Alimena	ME	San Piero Patti	ME	San Marco d'Alunzio	ME	Torrenova
PA	Aliminusa	ME	Sinagra	ME	Sant'Angelo di Brolo	PA	Bolognetta
PA	Caltavuturo	ME	Tortorici	ME	Leni	PA	Borgetto
PA	Gratteri	ME	Antillo	ME	Malfa	PA	Capaci
PA	Isnello	ME	Longi	PA	Belmonte Mezzagno	PA	Isola delle Femmine
PA	Montemaggiore Belsito	ME	Moio Alcantara	PA	Castelbuono	PA	Torretta
PA	Ventimiglia di Sicilia	ME	Santa Domenica Vittoria	PA	Marineo	PA	Carini
PA	Blufi	ME	Santa Marina Salina	PA	Piana degli Albanesi	PA	Cinisi
PA	Alia	PA	Collesano	PA	San Cipirello	PA	Giardinello
PA	Bompietro	PA	Pollina	PA	San Giuseppe Jato	PA	Partinico
PA	Campofelice di Fitalia	PA	Baucina	PA	Santa Cristina Gela	PA	Terrasini
PA	Castronovo di Sicilia	PA	Camporeale	PA	Villafrati	RG	Acate
PA	Ciminna	PA	Castellana Sicula	PA	Balestrate	RG	Ispica
PA	Contessa Entellina	PA	Gangi	PA	Cefalà Diana	RG	Pozzallo
PA	Lercara Friddi	PA	Geraci Siculo	PA	Corleone	RG	Scicli
PA	Polizzi Generosa	PA	Godrano	PA	Montelepre	RG	Vittoria
PA	Roccamena	PA	Mezzojuso	PA	Trappeto	SR	Augusta
PA	Roccapalumba	PA	Petralia Soprana	RG	Giarratana	SR	Avola

Table A3. *Cont.*

Metropolitan City	q1	Metropolitan City	q2	Metropolitan City	q3	Metropolitan City	q4
PA	Sclafani Bagni	PA	Petralia Sottana	RG	Monterosso Almo	SR	Carlentini
PA	Valledolmo	PA	San Mauro Castelverde	SR	Canicattini Bagni	SR	Lentini
PA	Vicari	PA	Ustica	SR	Francofonte	SR	Melilli
PA	Bisacquino	SR	Buccheri	SR	Sortino	SR	Noto
PA	Campofiorito	SR	Buscemi	SR	Palazzolo Acreide	SR	Rosolini
PA	Chiusa Sclafani	SR	Ferla	SR	Portopalo di Capo Passero	SR	Solarino
PA	Giuliana	TP	Gibellina	TP	Calatafimi-Segesta	SR	Pachino
PA	Palazzo Adriano	TP	Favignana	TP	Partanna	TP	Alcamo
PA	Prizzi	TP	Poggioreale	TP	Salemi	TP	Castellammare del Golfo
SR	Cassaro	TP	Salaparuta	TP	Santa Ninfa	TP	San Vito Lo Capo
TP	Vita					TP	Pantelleria

AG-Agrigento; CL-Caltanisetta; CT-Catania; EN-Enna, PA-Palermo; ME-Messina; RG-Ragusa; SR-Siracusa; TP-Trapani.

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Article

The Realms of Abandonment: Measures and Interpretations of Landscape Value/Risk in Northern Sardinia (Italy)

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Abstract: This contribution is part of the context of studies on the prospects of eco-oriented territorial rebalancing involving the settlement networks of inland areas. These are characterised by the contrast between socio-territorial disadvantage issues and opportunities to reuse physical resources within the broader framework of territorial regeneration and the revitalisation of local identities. In Italy, the region of Sardinia represents one of the most suitable operational contexts for the study of this relationship due to the presence of a natural context that dominates the urbanised areas and a deep, and in some ways still intact, cultural identity. Between nature and culture lies the issue of urban settlement structures, which are progressively being emptied due to depopulation and abandonment, and which require responses to revitalise territories integrated with the now inescapable ecological–environmental needs. This study proposes the formation of an initial platform of indicators to describe the effects of land abandonment through a multidimensional approach to highlight the potentials and weaknesses of the natural, urban, and socio-cultural heritage. The scale of observation and comparison concerns urban centres and small towns in the province of Sassari in the Region of Sardinia (Italy). The creation of an integrated set of maps highlighting deficiencies, vocations, and unexpressed potentials are the first results of the observation methodology adopted; these residual potentials can be used to design possible redevelopment and regeneration strategies based on the specific vocations of territories and urban settlements.

Keywords: culture and society; abandonment risk; strategic urban planning; land recovery

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1. Landscapes and Interconnected Risks

The landscape is one of the most important references—in terms of its scale and complexity—for 'judging' territorial phenomena of natural and/or anthropogenic origin. This study deals with the representation of landscape risk, manifested in the various forms of abandonment, in a sub-regional territorial context strongly characterised by tensions between certain development drivers and the enduring socio-economic order still preserved in the slow and coherent evolution of settlement forms. The anthropic dimension of the landscape highlights the vocations and unexpressed potentials of territories, which can be traced back to the sphere of values based on which local disadvantages are selected; the landscape risk results from the asymmetry between territorial resources and the location of the population, in short, the degree and forms of abandonment. This aspect of landscape risk is now increasingly and irreversibly linked to the growing anthropogenic pressure resulting from lifestyles based on productive efficiency rather than the resilience of ecological and natural systems.

1.1. Nature and Culture of Landscapes

The concept of the landscape encompasses a wide range of knowledge, which, while contributing to different interpretations and representations, attempts to regulate the dialectic between natural structure and anthropic transformations [1], summarised in the terms 'pristine landscape' (Urlandschaft) and 'cultural landscape' (Kulturlandschaft) [2].

Sauer, with his physiognomic approach, provides an interesting integrated interpretation: the landscape has an 'organic quality' because it is a part of the real territory with recognisable characteristics. A landscape can be defined as 'an area consisting of a distinct association of forms, both physical and cultural' [3]. The natural landscape is the landscape as it existed before human intervention. It consists of a collection of natural landforms: mountains; hills; plains; plateaus; lakes and watercourses; vegetation; and other landscape elements [4]. The cultural landscape, on the other hand, is that which has been modified by human use (agriculture and grazing), its economic exploitation (factories, industries, and production sites), or its modification (settlements and urbanity of various origins and types); in 1992, the United Nations recognised human interactions with natural landscapes as cultural landscapes. [5].

As a reference for functional classifications for protection, conservation, and development actions of settled communities, further degrees of relationship between anthropic action and the original spatial order can be taken: (1) built landscape; (2) organically developed landscape; (3) associative landscape. In 2000, the European Landscape Convention reaffirmed the perceptual component of landscape as a discriminating factor that allows us to reconstruct both the interactions between nature and living species and the deep, often hidden, processes of transformation [6,7] and to interpret their modes of interaction [8,9].

Landscape culture, understood as the ability to distinguish and combine its components in several dimensions, is embodied in a holistic view through the coupling of different landscape systems [10]. It is through these systems that man perceives and evaluates their existence and, at the same time, interacts with them by transforming and creating them [11].

The 'culture of the landscape' implies the inseparability of its material and immaterial dimensions in the progressive affirmation of a territorial identity whose character derives from the action of natural and human factors and their interrelationships [12].

1.2. The Environmental Issues and the Landscape Risk

Territorial dynamics, driven by the progressive evolution of lifestyles and increasing anthropogenic pressures, raise the question of the compatibility between consolidated historical forms (natural and artificial) and the current transformations required by territories in global competition; these transformations have reached such proportions that they are leading to the progressive alteration and impoverishment of the original natural and identity characteristics of landscapes [13].

The growing availability of technology has boosted humanity's capacity to modify the natural landscape, which, however, does not become the cultural landscape due to irreversible large-scale transformations with definitive consequences for the climatic and ecosystemic order [14]. The World Economic Forum's Global Risk Report 2023 points out that landscape degradation leads to diminishing natural resources, collapsing local economies, increased conflict and forced migration [15]. In Italy, as elsewhere, the uncontrolled growth of cities and their expansion into the countryside has profoundly altered the landscape, resulting in enormous land consumption, reduced biodiversity, and increased energy use [16].

Today, the processes of land use and exploitation, superimposed on the depopulation and abandonment of sites, have consequences at different scales, both urban and territorial. The combination of demographic dynamics and deindustrialisation processes has created several abandoned landscapes that still contain resources—natural and man-made—from which the regeneration and urban reconnection of these places could start, also in the broader context of the ecological transition strategy outlined in the United Nations (UN) 2030 Agenda for Sustainable Development (SDGs) [17,18].

The condition of abandonment implies the presence of a substantial endowment of unused assets whose vocations (intrinsic characteristics) and unexpressed potentials (extrinsic or contextual characteristics) redefine the ways of 'implementing urban and territorial planning a new state of necessity capable of seizing a historic opportunity for concrete transformation' [19]. Thus, derelict goods and places offer innovative planning opportunities to reconnect pre-existing resources with people and lifestyles [20].

This implies a broader vision of a common landscape restoration plan and an awareness of embodied resources as legacies of past eras and lifestyles. From the perspective of possible cross-sectoral and multi-level cooperation between stakeholders and institutional decision-makers, interlinked landscape risks could be addressed, promoting effective interventions across institutional, political, and national boundaries and restoring productive conditions for long-term resilient areas [21].

1.3. Contents and Aims

This paper proposes the construction of a queryable database that, through a series of parameters on the state of the main components of the territory of Northern Sardinia (Figure 1), describes the detailed vitality/abandonment conditions of the municipal units with reference to natural, urban, and socio-cultural aspects.

Figure 1. Framing of the territories under analysis. (Our processing).

Using spatial analysis tools (GIS) and starting from the official data available on the portals of the competent national institutions—public bodies and institutions that provide aggregated data for specific uses—this study provides analyses aimed at a synthetic reading of the natural, urban, and socio-cultural components of the area under study, through indices and maps at different levels of aggregation. The summary results identify criticalities and potentials that can support subsequent planning and related revitalisation actions for specific areas and urban centres [22,23].

Therefore, the title recalls the double value of the proposed methodology: on the one hand, a container of knowledge useful to represent the value of the landscape—here understood as the set of physical systems (abiotic and biotic components and built apparatuses) and flow systems (the established communities, their quality of life and their economic-productive characteristics)—the area analysed; on the other hand, a survey of landscape risk, here reduced to the concept of abandonment of structures that have modified the natural landscape but that, being without function, do not even constitute a cultural landscape. The model then provides measures of the degree of landscape value and the degree of abandonment, which, interpreted through a correlation of their different components, provide a basis of useful information for planning rehabilitation and revitalisation at different scales.

This paper is divided into six parts: Section 2 (Materials) provides a general description of the study context in terms of the main measures of the degree of abandonment and, more generally, of the landscape's environmental, material, and socio-economic vulnerability; Section 3 (Method) describes the procedure via which the most relevant information was selected and aggregated in order to construct the most representative synthetic indices of the study context in terms of landscape risk; Section 4 (Application and Results) presents the results and the main interpretations of the natural, urban, and socio-economic contexts in an organic way; Section 5 (Discussion) discusses the results through comparisons and correlations between landscape risk and the drivers of abandonment; Section 6 (Conclusions) summarises the main lines of this study, indicates some of its limitations, and outlines the main perspectives.

2. Materials

Sardinia covers an area of 24,100 square kilometres and is the second-largest island in Italy. It is made up of 377 municipalities divided into four provinces, the capital of which is Cagliari.

Sardinia's geographical position, eccentric with respect to the main Mediterranean routes, has favoured the development of indigenous flora and fauna that has evolved, being protected from contamination and hybridisation [24].

For this reason, too, Sardinia has always been sparsely populated. It experienced a period of intense demographic growth between 1920 and the second post-war period, maintaining the highest birth rate in Italy, but with the beginning of the 21st century, the trend reversed [25]. Between 1991 and 2001, there was a decrease of only 2%, which shows considerable stability of the population, to some extent reproducing the Italian trend (Figure 2).

The case study of Sardinia stands out as a particular case within the European macro issue of depopulation and shrinking cities. The phenomenon appears to be rather complex, difficult to define unambiguously and interrelated with external factors that depend entirely on the context in which it occurs, taking on very different connotations and dynamics [26]. For this reason, it is very difficult to compare different methodologies, which, in order to be valid, must be based on knowledge of the specific characteristics of the reference context [27]. The effects of depopulation and the abandonment of large parts of cities draw attention to the opportunities offered by the availability of living and working spaces to be rewritten, economies to be reinvented, and social plots to be reconstructed for the formation of a new culture of urban and territorial planning that takes into account these dynamics, which are no longer unprecedented [28].

The Sardinian region, thanks to its isolation, has preserved a landscape that is still very natural and precious in the face of the crisis that more 'consumed' regions are facing. At the same time, however, the sparse population increases the risk of shrinkage, and the inadequacy of services, especially accessibility, aggravates the situation of small inland communities.

In Italy, as part of the National Reform Programme (PNR), the 2014–2020 Partnership Agreement defined the National Strategy for Inner Areas (SNAI) in 2014, with the aim of defining an organic governance framework to halt the demographic decline and relaunching the economic development of territories [29]. In total, the SNAI identifies 124 project areas covering 1904 Italian municipalities. Initially, Sardinia was included in the SNAI with two experimental areas—Alta Marmilla and Gennargentu Mandrolisai—to which two other areas—Barbagia and Valle del Cedrino—were added. The number of municipalities included in the four areas identified is 318, representing 84% of the total number of municipalities in the region [30,31].

The demographic dynamics reflect the crisis of production and the agricultural and pastoral settlement that manifested itself in the last decade of the 20th century. In fact, the population moved towards the more integrated economies of the province of Cagliari and towards the eastern coasts, attracted by the demand expressed by the tourist sector in these areas (Figure 3) [32,33].

Figure 2. Annual intercensual variation in Italy and Sardinia (**a**); detailed analysis of the four provinces of the region of Sardinia of population growth from 1861 to 2011 (**b**); and comparison between cancellations and new arrivals by year (**c**). (Our processing).

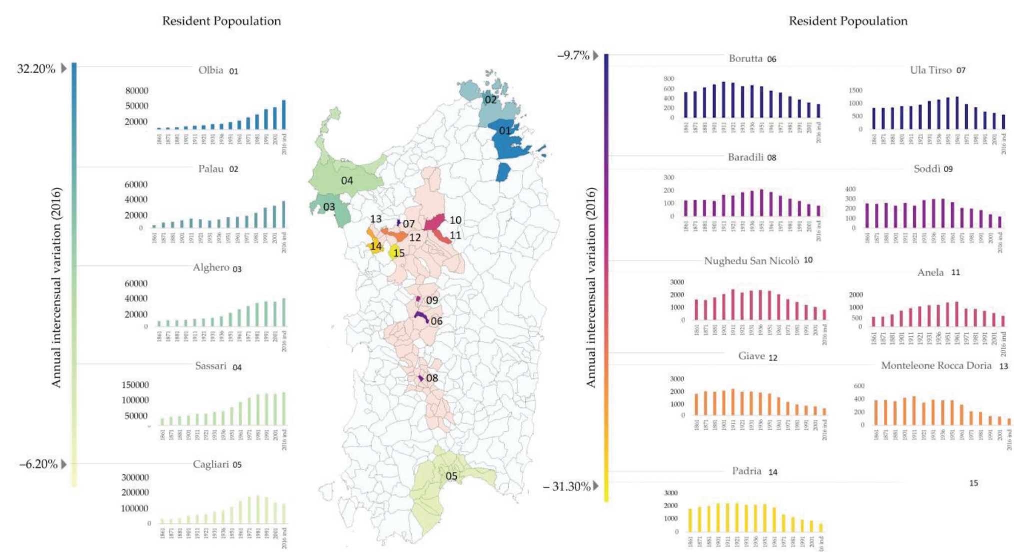
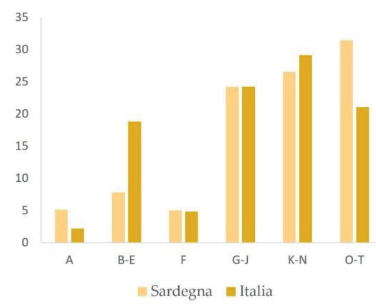


Figure 3. Annual intercensual variation of the most significant growing municipalities (**left**) and the municipalities most at risk of depopulation (**right**) in the region of Sardinia. (Our processing).

The economy of Sardinia today is mainly based on the tertiary sector (78% of the workforce), driven by tourism and the seaside. The primary sector accounts for 6.2% of employment and is mainly based on sheep farming. The manufacturing sector, represented by the metallurgical (Porto Torres), chemical (Ottana), and petrochemical (Olbia and Cagliari) industries, accounts for the rest of the workforce (Figure 4) [34].

	Sardinia incidence		%	Italy incidence		%
	2005	2014	13-14	2005	2014	13-14
agricolture	6.9	3.9	−7.8	3.8	3.3	−4.6
total industry	9.6	19.7	11.6	25.9	26.8	-2.4
extractions	**0.3**	**0.5**	**47.7**	**0.5**	**0.7**	**25.2**
manifacture	5.6	4.6	−3.4	16.6	19.4	1.1
energy, gas	1.1	12	24.9	4.8	3.5	−20.2
water, waste	0.7	0.8	−7	1.1	1.1	−5.7
construction	1.9	1.8	−13	2.8	2	−2.8
total services	83.5	76.3	2.9	70.3	69.9	-3.2
trade	8.7	2.7	-19	6	4.7	−17.3
transport	9.1	5.8	20.8	7.4	7.4	0.3
real estate	**36.5**	**35.4**	**−5.7**	**29.6**	**31.6**	**−2.7**
PA, compulsory insurance	16.1	18	21.2	9.1	8.1	−4.2
other services	13	14.4	5.6	18.2	18.1	−0.6

(**a**)



(**b**)

Figure 4. Articulation of the three economic macro-sectors and the incidences of industries in percentage (**a**) and with respect to ATECO economic activity classifications (**b**), where (A) agriculture, forestry, and fishing; (B–E) mining, manufacturing, energy, and water supply; (F) construction; (G–J) trade, transportation, accommodation and catering, information, and communication; (K–N) financial, insurance, real estate, professional, and scientific and support services; (O–T) public administration, education, health, and other. (Our processing).

After the Second World War, the 'Rebirth Plan' was devised to improve the socio-economic situation of the island, which was in a deep state of backwardness. Launched in 1962, it financed various entrepreneurial and industrial initiatives until 1975 [35]. However, the plan did not have the desired results, mainly because the establishment of petrochemical industries did not act as a driving force for the entire region, and social structures did not follow the political intentions of the plan's creators. To this day, Sardinia suffers from organisational, infrastructural, and productive difficulties due both to the wrong choices made in those years and to a socio-cultural structure that has changed little since the 1950s [36].

Local economies are unable to compete with global markets, and employment opportunities in the inland areas are diminishing; the result is the abandonment of areas and small villages. The productive landscapes of the past become landscapes of abandonment as people migrate to the coasts, where seasonal tourism attracts both inland inhabitants and new residents. In this way, the primary services of the interior disappear while those of the coast are strengthened, a region that resembles a 'crater, empty in the centre and full on the sides, like an empty shell' [37].

Case of Study

This study focuses on the province of Sassari, in northern Sardinia, which is the area most affected by the demographic flows and socio-economic changes described. This area has been analysed and described in terms of its natural, urban, social, and economic systems.

In 2016, the Province of Sassari acquired (Regional Law No. 2 of 4 February 2016) the territories of the municipalities of the former Province of Olbia Tempio, becoming one of the largest provinces in Italy with an area of 7692 square kilometres divided into 92 municipalities (Figure 5a). It is the most populous province in the region, with a total population of 493,788 inhabitants (Figure 5b,c).

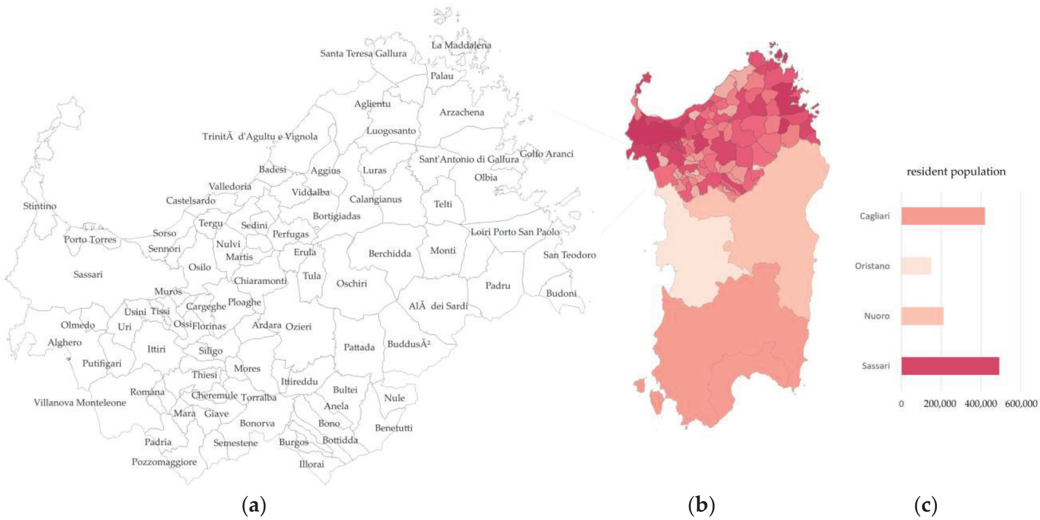


Figure 5. (**a**) Map of the provincial municipalities to be analysed; (**b**) ranking of the population per municipality in Sassari compared to the total of the other provinces in the area; in this representation, the average colour of Sassari province shown in the graph (**c**) is detailed by municipality based on a corresponding shade; (**c**) population of the four provinces in Sardinia. (Our processing).

This is probably due to the better quality of transport and travel services to and from the island: the province of Sassari is home to two of Sardinia's three airports (Olbia and Fertilia–Alghero) and two of its three ports (Olbia and Porto Torres).

In terms of landscape, this area is characterised by rugged coastlines with different geological features and colours, while the northeastern area is predominantly mountainous, with the famous granite reliefs of Gallura.

This part of the region, Gallura, can be considered a separate entity in economic and demographic contrast to the rest of the island and is, therefore, interesting to study. Since the 1960s, the historical region of Gallura has been internationally renowned for its cork and granite industries, which in the last two decades have become less competitive on international markets due to transport costs, leaving large areas of the territory to be profoundly altered and abandoned. Disused production sites and quarries that are no longer in use are a threat to the landscape—they do not represent either the natural landscape or the cultural landscape but rather disturbing elements for both categories, which can, however, be transformed.

3. Method

3.1. General Premises

This work is part of a more general research path concerning the identification of ecologically oriented regeneration processes of the urban-building heritage of fragile territories [38–40]. It explores the spatial framework with reference to the four general categories of the natural, urban, social, and economic systems; each of them is observed in detail through different levels of depth [41,42].

This observation is structured according to a hierarchical scheme that organises the elementary spatial units (iUs) extracted from official sources. At the last level of the work breakdown structure (WBS) are the IUs that express more synthetic characteristics and capabilities that can be directly attributed to the four previous systems [43].

The result is the formation of a searchable information system for the calculation of complex indices to compare municipalities in the province by correlating different aspects—natural, urban, social, and economic—describing the territorial structure observed.

The aim of this knowledge framework is to support policies aimed at redressing the territorial handicaps resulting from the asymmetric development between coastal and inland areas, the latter often suffering from the conditions of inaccessibility of small centres located in inaccessible areas. In these areas, local communities still express a strong attachment to the territory and to the endogenous principles of sustainable development, places rich in natural, social and cultural resources, but at the same time facing significant risks of abandonment.

3.2. Sources and Data

The objective of 'Recovering Abandoned Landscapes' requires a reliable information base for comparing different information spatial units (iUs) to select similar or converging groups.

These relationships could be used to delineate spatial areas with similar problems and a similar potential for recovery.

Data sources are as follows:

1. With reference to the natural context, the Territorial Landscape Plan (PPTR) of the Region of Sardinia, the Geological and the Land Use Map from 2008, accessible on https://www.sardegnageoportale.it/ (accessed on 2 February 2023). The first shows the structure of the main systems with reference to the land aggregations that form homogeneous landscapes, while the two maps provide quantitative information on the abiotic and biotic components;
2. The database of the Italian National Statistics Institute (NSI) from 2011, with specific reference to the entire database on the details of the municipality and to the Census Section (CS) for the basic information on social, economic, and urban system aspects; the '8000 Censuses' sections, which offer an ordered selection of general databases for the purpose of presenting the phenomenon of social vulnerability; the 'Italy in detail' section, which includes the main municipal data of civil interest of the NSI (geographical, demographic, register, economic-productive, employment, patrimonial, etc.), important for the section dedicated to the urban system; the portals of the 'Italian Municipalities', which make it easier to consult data on demographic and income dynamics to describe the social system and aspects of income distribution; the Statistical Atlas of Municipalities (2011), with specific reference to ATECO (2007) data describing the production system of the territory;
3. The database of the Italian Real Estate Market Observatory (REMO)—by the Revenue Agency—provides general information on the structure of real estate; REMO data refer to the period from 2006 to 2022 and are aggregated in
    - the Microzones (MZ), consisting of five main classes aggregating 34 subsets distinguishing historical centres, semi-central and peripheral areas, industrial or craft areas, coastal and rural areas;
    - residential buildings, economic dwellings, boxes, industrial buildings, typical buildings, laboratories, warehouses, shops, offices, structured offices, villas, and cottages (by a topology);
4. The database of the Regional Plan of Mining Activities (PRAE), which lists the mining concessions and authorisations of the companies operating in Sardinia (updated to 2004): the PRAE also identifies active and inactive (i.e., upgraded or abandoned) quarries. This information tool has made it possible to measure both the degree of exploitation and anthropisation of the territory to produce traditional buildings and the possibilities for reactivating this production chain as an important part of local identities underlying a consolidated building culture.

The remaining data relating to climate, some production system specifications (i.e., for the agricultural system, PDO, and PGI products), and the wealth distribution index (Gini index) have been extracted from the platforms certifico.com and urbanindex.it (referring to 2018 and 2015, respectively).

3.3. The Model

The proposed model coordinates information units at different levels of description and evaluation. The information apparatus is structured in the form of a database in which the records (rows) are the territorial units (tU) that carry the information, and the fields (columns) are the attributes, i.e., the information units (iU). The attributes are divided into denoted and connotated; the former is of a mainly descriptive type, and the latter is of a mainly evaluative type. The latter are, in fact, representations of the value of everything from the point of view of the previously identified criteria that describe its capacity to be valuable.

3.3.1. Territorial Units

The information base consists of three different databases (Figure 6):

1. The first works at the municipal scale with the details of the NSI CS and consists of 5170 $tU_{NSI}CS$ and 140 $iU_{NSI}CS$ (the information units provided by the NSI database);
2. The second consists of the areas identified by the MZs coming from the Real Estate Market Observatory (ReMO) of the National Revenue Agency (NRA), which extends to the 92 municipalities under study, forming a database of 3814 $tU_{ReMO}MZ$. Since the latter distinguish historical centres, zones of the first and second expansion, commercial and industrial zones, peripheral and coastal zones, and rural areas, through the functions of spatial association, the CS belonging to each MZ has been identified in order to be able to enrich the territorial real estate information (Real Estate Territorial Information) with the socio-economic and building information (Socio-economic Building Information) coming from the NSI at the retail of CS, thus being able to link heterogeneous levels of information related to different systems. This intermediate information apparatus consists of two sub-databases that coordinate a total of 5170 tUs and 1020 iUs (30 $iU_{NSI}CS$ for each of the 34 ReMO MZs);
3. The third database consists of the Municipalities bounded by the NSI in 2023 and according to the 2011 survey. It uses the aggregations of the iUs attributed to each tUs of the two above-mentioned databases and elaborations made on the basis of the available thematic maps. The last database, which represents the entire set of observations and indices for all municipalities and is the main basis of the evaluation model, is composed of 92 $tU_{NSI}M$ (rows) and a total of 527 $iU_{NSI}M$ (columns).

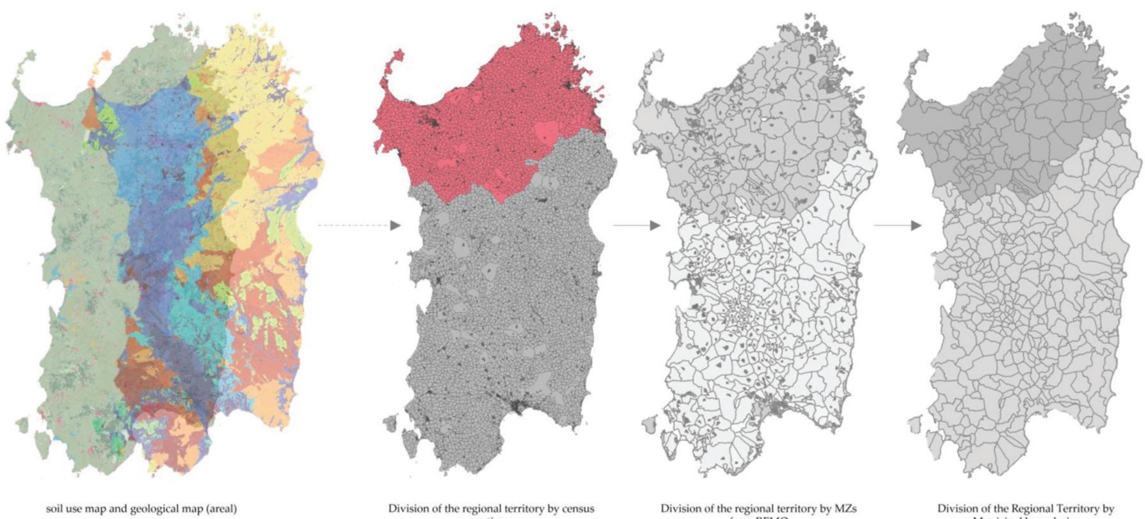


Figure 6. Overlapping of available data in shapefile format and comparison between the different territorial units over the whole Sardinian regional territory. (Our processing).

3.3.2. The MAVT-Based Model

A model of multicriteria analysis based on the Multi-Attribute Value Theory (MAVT) [44–47] has been developed to characterise and compare the different main tUs on the basis of different value capacities, i.e., on the basis of different evaluation criteria. This capacity is expressed in the attitudes of the territories towards ecologically oriented redevelopment by each of the tUs that make it up.

The evaluation model used here is part of the operational research tools within the multidimensional analysis referred to by the tools that support shared decision-making processes, extending the knowledge of the utility sphere to the value sphere [48]. The first concerns mainly functional aspects, and the second also includes variables that refer more or less directly to ethical and aesthetic values [49].

The proposed model coordinates the cognitive process by means of a Work Breakdown Structure (WBS) [50,51], that is, a scheme of progressive unbundling of the main criteria in iUs that increasingly detailed information up to the information sources represented by different measures.

At all levels of aggregation, each iU is assigned a weighting factor that measures its importance in relation to those of the same group.

The WBS scheme is represented in the dendrogram of Figure 7. Each tU is characterised by a score that summarises its evaluation from the four points of view that outline its natural, urban, social, and economic profile.

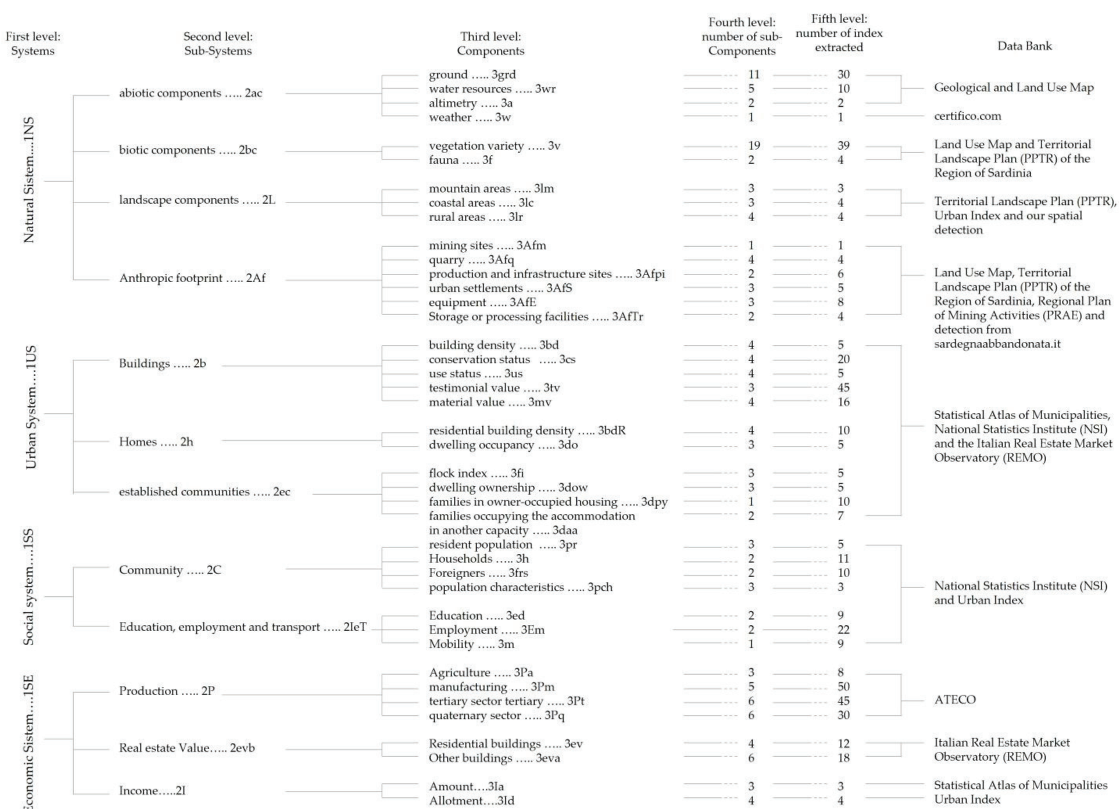


Figure 7. Dendrogram representing the distribution of the indices from the first to the third level of the WBS. (Our processing).

3.3.3. Attributes: Measurements and Valuations

In the proposed model, the attributes are the iUs that have a specific explanatory capacity at each of the WBS levels at which they are placed. The first level represents the value of the municipality from the point of view of each system. At the second level, the attribute expresses the aggregate value of the main components into which these systems can be disaggregated. Similarly, at the third level, the attribute expresses the sub-components and at the fourth level, the relative specifications for type and quality. Finally, the fifth level contains the measurements of the selected information units of the database from which the whole system is drawn.

The evaluation path starts from the level of maximum disaggregation, which contains the elementary ones. Each of them consists of the manifestation of a phenomenon expressed via a specific unit of measurement. At this level, the k_{th} ($k = 1, 2, \ldots, m; m = 92$) tU is evaluated from the point of view of each i_{th} ($i = 1, 2, \ldots, n; n = 527$) elementary attribute iU, by means of a value function $v_{ki}\left(\alpha_{iU_i}\right)$. This value is a score that varies for all evaluation functions in a range from 0 to 2, the minimum and maximum value, respectively; a score of 1 is a sufficient condition.

These functions increase or decrease depending on whether the observation concerns an event considered as a value or a disvalue.

The total value of each tU is then given by the sum of the products of all the attributes for the relative weights applied, starting from the elementary level up to that of maximum aggregation:

$$V_k = \sum_{i=1}^{n} w_i v_{iU_i} \quad (1)$$

where w_i is the attributed weight of the i_{th}, and v_{iU_i} is the score of the k_{th} tU related to attribute iU_i.

For the application of Equation (1), it is necessary that

$$\sum_{i=1}^{n} w_i = 1 \quad (2)$$

The (1) refers to the aggregation of level 5 of the model where each elementary iU is transformed into a standard score and associated with it is an elementary weight. This elementary weight is calculated as the product of the weights at the higher levels, as follows:

$$w_i = w_h w_g w_f w_e \quad (3)$$

where w_h is the weight of the corresponding ius group at level 4; w_g is the weight of the corresponding iUs group at level 3; w_f is the weight of the corresponding iUs group at level 2; w_e is the weight of the corresponding iUs group at level 1.

This standard additive aggregation process is supported by the assumption of mutual independence of preferences between attributes.

3.4. Phases of Use of the Model

The model supports the critical analysis of the context studied in two phases: 1. identification of landscape-territorial vocations (landscapes); 2. definition of the main forms of landscape risk (abandonments); 3. identification of the main drivers of landscape risk and invariants of its resilience (drivers of abandonment).

1. The first coordinates are the set of databases consulted in a hierarchical model in which each unit of information finds its place in each of the four systems mentioned above; on the basis of this information, detailed and synthetic index maps are produced in order to describe and consequently evaluate the municipal territories from the point of view of the four systems studied;

2. The second phase focuses on the aspects of abandonment by defining specific measurement indicators; the mapping of indices allows us to understand aspects of asymmetry between significantly different areas of the territory;
3. The third phase, based on the results of the previous two phases, describes the relationships between structural aspects (Natural System and Urban System) and anthropic aspects (Social System and Economic System) in an attempt to identify, measure, and represent landscape risk in terms of its main drivers.

4. Application and Results

4.1. Landscape(s)

4.1.1. Natural System

With reference to the above-mentioned definition of landscape risk, the natural system is examined here in terms of its physical components (abiotic and biotic), landscape structural values, and the extent and intensity of anthropogenic erosion (number of mining or production facilities or, more importantly, for environmental recharging, disposal, and processing plants, landfills, etc.).

The abiotic components are represented through the sub-components ground, elevation, water resources, and climate.

Considering the limitations of data availability and management, the aggregated indices of the soil sub-component summarise information on the presence of geotopes of greater or lesser historical and physical value, as well as the landscape and cultural uniqueness they represent [52].

Thus, the elementary iUs of the fifth level are aggregated to the fourth level by clusters of geotopes with homogeneous characteristics in terms of the amount of historical information they contain and/or the quality of their physico-chemical characteristics. The clusters are as follows:

1. Granitoid complex;
2. Rocks and haplitic groups;
3. Plateau basalts;
4. Sediments:
    4.1. Water bodies;
    4.2. Related to gravity;
    4.3. Historical succession.

These UIs, which are included in the fourth level of the dendrogram, are then aggregated to the *ground* component at the third level. In this case, weights are assigned based on the landscape and cultural potential identified in the geotope clusters. Thus, the value attributed to the diversity (and hence the richness) of the geotopes identified for each municipality at the fourth level is reversed at the third level, where specificity is more important than quantity: the fewer the different geotopes, the greater the value of their identity in terms of characterising both the landscape and the towns and cities that have been created and developed with the gradual consolidation of the technologies and techniques used for stone working.

The biotic components are divided into fauna and vegetation. The vegetation sub-component is described at the fourth level based on the grouping of the most common spontaneous or cultivated botanical species, considering their importance in terms of development patterns and lifestyles aimed at reconciling livelihood needs and biodiversity.

The landscape components refer to the sub-components of the coastal, mountain and rural areas, which are assessed according to their importance in terms of type and quality (i.e., in the case of coastal areas, the development of the coastline and the surface area of the municipality, as well as the distance from the urban centre to the coast).

The anthropic footprint is calculated based on the environmental footprint of anthropogenic—development patterns, such as production and urban settlements, infrastructure systems, large equipment, waste storage or transformation, and mining sites.

The resulting ranking places the municipality of Berchidda in the first place (Figure 8). Berchidda, similar to many other municipalities in Sardinia, is characterised by the relevance of the value of the natural system, as the score is strongly influenced by the reduced anthropisation. Only a few municipalities, including Esporlatu, Semestene, and Romana, have built-up areas that almost coincide with the boundaries of the whole agglomeration, and these are indeed at the bottom of the ranking.

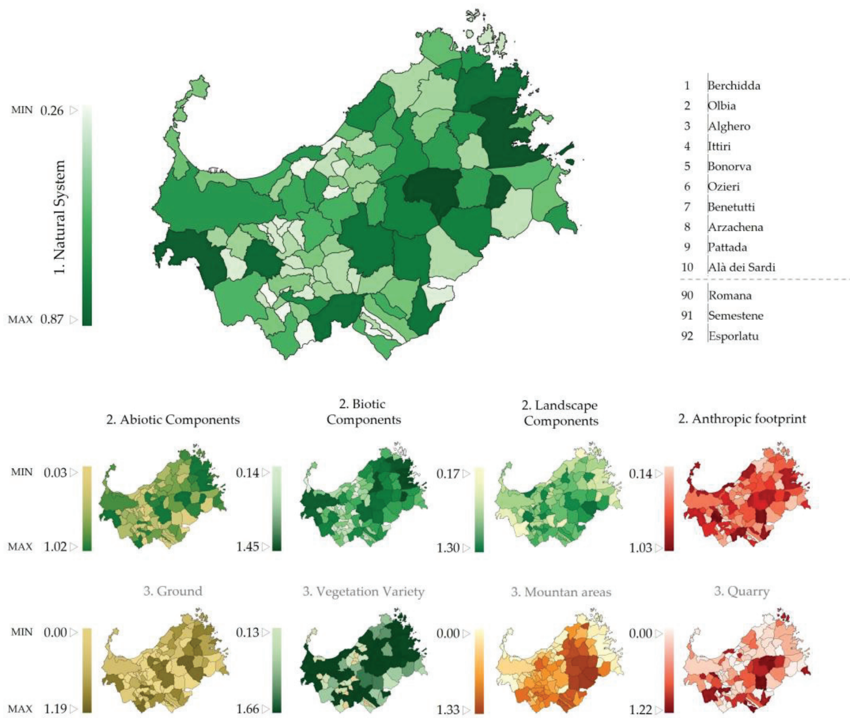


Figure 8. Map and ranking of the scores of the municipalities in the Natural System with mapping of the aggregate values at the second level and of certain sub-components at the third level considered most significant. (Our processing).

It is also noticeable that all coastal municipalities, apart from Olbia, Alghero, Arzachena, and Palau, generally score lower than inland ones. In this case, the landscape values are partly offset by the fact that large parts of the territory retain intact natural features of high value, which are sufficient to compensate for the anthropic imprint.

4.1.2. Urban System

The Urban System is interpreted as an open and organised system, defined in its forms by the flows of matter, people, and energy, from the interpolation of which its quality is derived [53].

To this end, the components of the urban system selected and identified here are the built heritage, the housing system, and the settled communities.

The built heritage (buildings) in its physical–quantitative (materials) and qualitative (culture) aspects is investigated through the sub-components that characterise it, such as building density, state of preservation, state of use, testimonial, and material value (referring respectively to the age of the buildings and the technological and material coherence of their formal apparatus).

Each of the sub-components aggregates its attributes with reference to the above-mentioned MZs del ReMO.

The set of attributes of the housing sub-component refers exclusively to the 'home' dimension (the space of the person); at the third level, this iU aggregates those present at the fourth, related to the above-mentioned MZs, as to housing density and occupancy rate.

The last component of the urban system is intended to describe the established communities (ideally the energy flows of the area) in quantitative (crowding index) and qualitative terms. From this point of view, the elements taken into consideration aim to assess the integrity of the identity of a community, representative of the territory to which it belongs. These elements are the family as a 'referent' and the house as a 'signifier', i.e., as an identity value that expresses precisely the degree of rootedness in the territory of origin.

The system's overall score (Figure 9) aggregates the three components, giving greater weight to the built heritage, valuing the physical and symbolic support with which communities identify themselves, and the relationship between owners/tenants for the significance highlighted above.

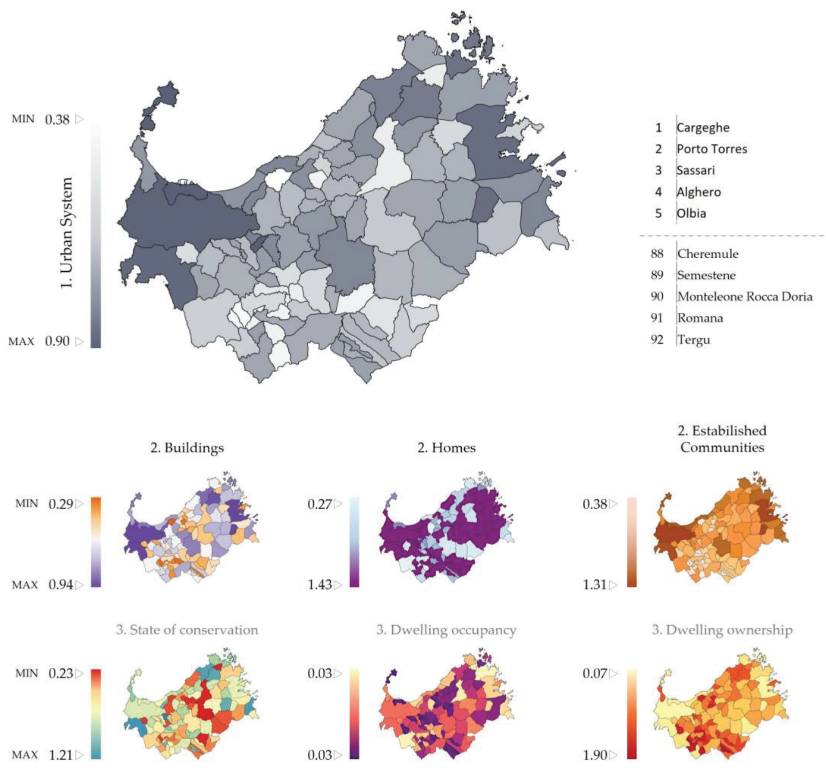


Figure 9. Map and ranking of the scores of the municipalities in the Urban System with mapping of the aggregate values at the second level and of certain sub-components at the third level considered most significant. (Our processing).

In a study focusing on the areas of northern Sardinia, the latter is of considerable importance. Except for Cargeghe, which is ranked first because of the historical and monumental value of the village and its good state of conservation, municipalities, such as Porto Torres, Stintino and La Maddalena, also rank high because they are among the few coastal centres not affected by significant processes of replacement of the original population.

The condition of inland municipalities is different, with an overall low level of building conservation and a high rate of building abandonment.

4.1.3. Social System

The components of the social system that are considered relevant here in order to represent the balance between the different territories relate, in general, to the way in which territorial wealth is more or less accessible to all.

Thus, the description of the communities settled in the municipalities under study aims at identifying the demographic dimension of the local social realities (communities) and the set of skills (employment and education) of the inhabitants.

In particular, in the communities component, the subcomponent of the resident population represents the demographic consistency of the settlement (population density) in relation to its greater or lesser attractiveness (intercensuary variation), while the household subcomponent represents a variety of aspects, among which those related to the risk of abandonment of areas were considered the most important; among these, the presence and consistency of family units (taken as a positive value), the presence of young single-parent families, elderly people living alone, etc. (taken as a negative value).

The heterogeneity of the sub-component (similar percentages of men and women, residents and non-residents, young and old) was considered important as a potential reserve of ability in view of the revitalisation processes of less vibrant urban centres.

The education and employment component, on the other hand, aggregates information on the level of education, employment and mobility services for the study and work of the resident population.

In terms of the overall score, Olbia, Ozieri, Pattada, Thiesi, and Sassari are in the top five (Figure 10).

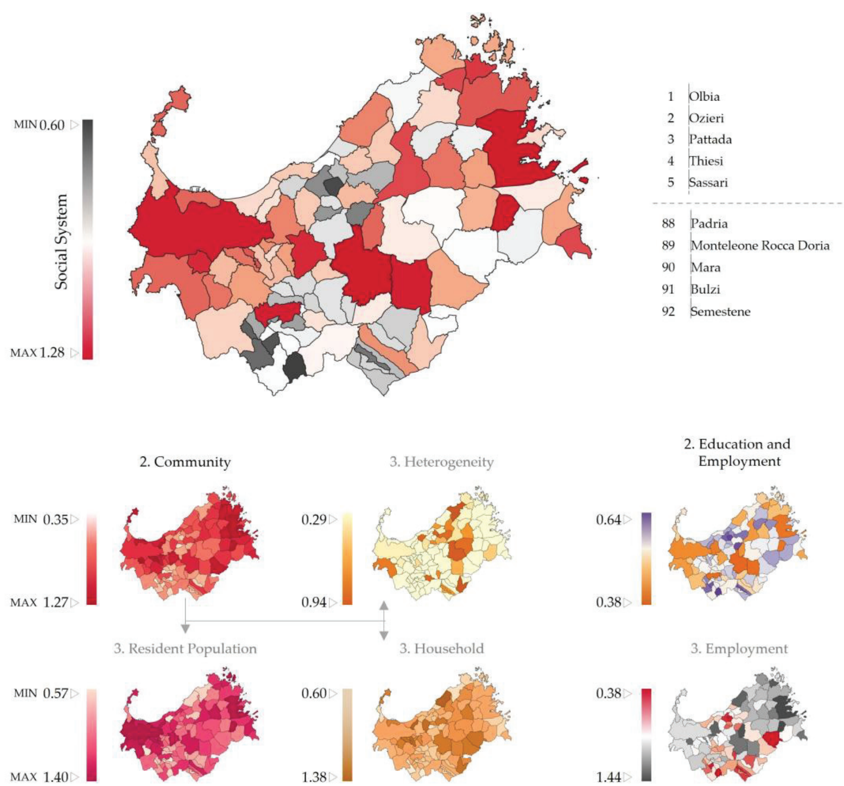


Figure 10. Map and ranking of the scores of the municipalities in the Social System with mapping of the aggregate values at the second level and of certain sub-components at the third level considered most significant. (Our processing).

Here, too, the score is conditioned by the size of the municipality and, thus, by the total number of inhabitants. The largest social realities are also those where economies of scale multiply, thus offering the greatest opportunities for development. As a result, they attract a heterogeneous population which, while enriching opportunities, reduces local identities and the sense of belonging.

4.1.4. Economic System

The economic system, in a general sense, represents the set of elements (actors, resources, technologies, knowledge) and their relations that give rise to the production of wealth, its exchange, use, and accumulation. The forms that this wealth takes in terms of satisfying individual and collective needs are described by the set of observations produced by the above-mentioned National Statistical Institutes, grouped into the three sub-components of production: the presence and size of entrepreneurial activity in the various sectors (primary, with specific reference to the extractive sector, secondary, and tertiary); the city (economic buildings value); the real estate sector and the people (income), in terms of personal income and its distribution.

The overall assessment places Olbia, Ozieri, and Sassari in the top two places, while Padria, Monteleone Rocca Doria, Mara, Bulzi, and Semestene are again in the lower part of the ranking (Figure 11).

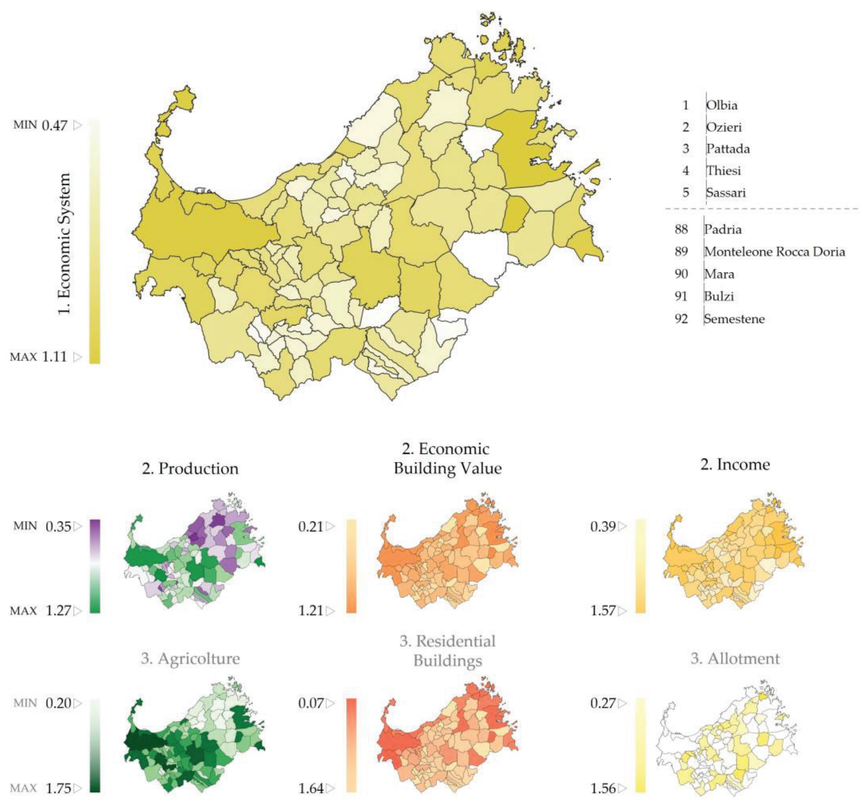


Figure 11. Map and ranking of the scores of the municipalities in the Economic System with mapping of the aggregate values at the second level and of certain sub-components at the third level considered most significant. (Our processing).

The production subsystem is more substantial on the western side, with the exception of Olbia and Budoni. The municipality of Olbia registers 8876 companies (5% of the regional total and 37% of the provincial total), with a higher growth rate than other areas of the region [54].

With regard to the value accumulated in the real estate sector, the survey highlights the disparity between the prices recorded by ReMo in the most prestigious coastal towns, particularly in the residential sector, and those in the inland municipalities. This disparity is due to the part of the property market that does not respond to internal or regional demand (or even to external demand in general) but is chosen by that part of the Italian and foreign population that is able to pay thirty times more for a property near the sea than in inland towns.

Confirming this, the survey shows that the amount of income, apart from the lower levels that characterise the flat inland areas, is basically the same between the coastal and mountain areas, suggesting that the value accumulated in luxury housing does not represent a share of the local income surplus, but rather that this asset is a container for the excess liquidity generated elsewhere.

4.2. Abandonment(s)

Due to its heterogeneity, landscape risk is presented according to the different forms of land abandonment. The abandonment is considered according to the two main dimensions of local identity, the collective and the individual. The former presents the phenomenon in its entirety with reference to economic and urban systems, and the latter with reference to the residential and family dimension.

4.2.1. The Collective Dimension: Land Abandonment

As explained in the Materials chapter, the causes of demographic decline are mainly to be found in the economic substitution of the original productive dimensions by the markets of the new modernity. The forms of land abandonment identified, therefore, concern the following:

1. Stone economies, given by the ratio between the total area of inactive quarries and the total area of active quarries within the boundaries of each municipality;
2. Agricultural economies, given by the ratio of the inverse of the agricultural area in use to the total agricultural area;
3. Industrial settlements, given by the number of disused industrial buildings (taken from the website sardegnaabbandonata.it [55]) out of the total municipal territory;
4. Built heritage, given by the total number of unused buildings out of the total number of buildings.

From the analysis carried out, it can be seen that the condition of abandonment of the territory mainly affects the inland areas, with the exception of the municipalities of Golfo Aranci and Palau, which, although they are poles of tourist attraction, do not have significant manufacturing structures and activities; similarly, the two municipalities of Trinità D'Agultu e Vignola and Badesi, precisely because they belong to the Gallura district, fully express the typical features common to the inland areas despite the significant landscape value of their waterfronts (Figure 12).

The thematic maps describing the dimension of abandonment in relation to the four economic systems mentioned above show the profound transformation of the economy of many centres in northern Sardinia, which is becoming increasingly tertiarised, confirmed by generalised population growth.

The demographic dynamic that has affected the whole of Sardinia, with a marked and constant increase from the fifties to the eighties and a subsequent slowdown until the first decade of this century, is reflected, to a greater or lesser extent, with due differences, in all the municipalities mentioned above, which moreover represent the dynamics of recent decades.

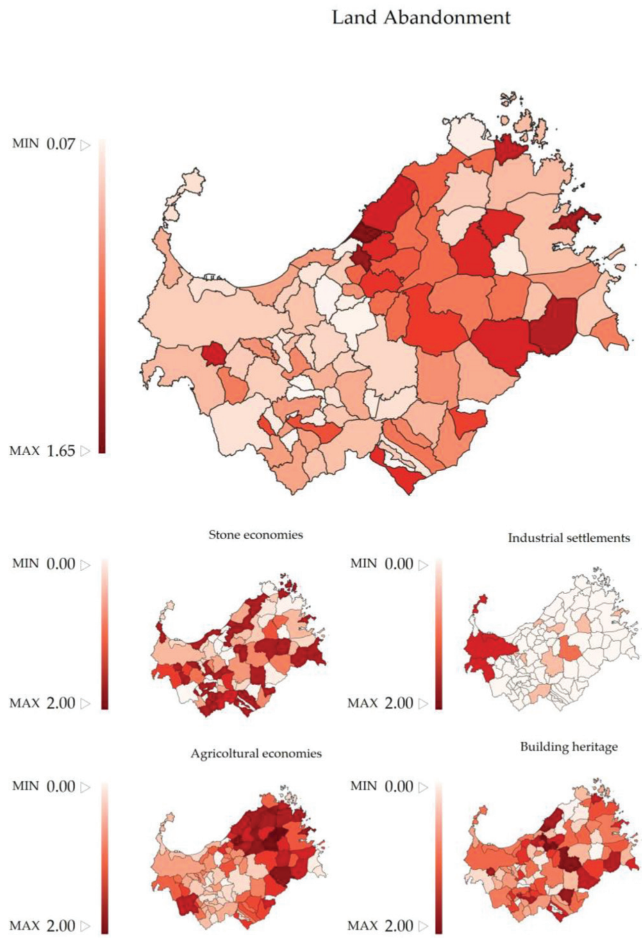


Figure 12. Mapping of the forms of abandonment concerning the collective dimension with a histogram by classes of abandonment of the built heritage in coastal and inland areas. (Our processing).

4.2.2. The Individual Dimension: Home Abandonment

The dimension of home abandonment was investigated with reference to:

1. Dwellings—disused ones compared to total dwellings;
2. Historic centres—residential buildings not in use in historic centres in relation to the total;
3. Dwelling ownership—rented or otherwise occupied dwellings compared with owner-occupied ones;
4. Thinning—the number of residents per dwelling.

The resulting map is almost complementary to the previous one and shows that the lowest rates of utilisation of the housing stock are in the above-mentioned Aglientu, Trinità d'Agultu e Vignola, Badesi, Golfo Aranci, Palau, Stintino, and in the other municipalities on the east coast (Arzachena, Loiri Porto San Paolo, San Teodoro, and Budoni), except for Monteleone Rocca Doria (Figure 13). In these municipalities, with the exception of Monteleone Rocca Doria, the population is growing, with a change in lifestyle, a better redistribution of the urban population between historical centres and expansion areas, and a more organic relationship between owned and rented housing.

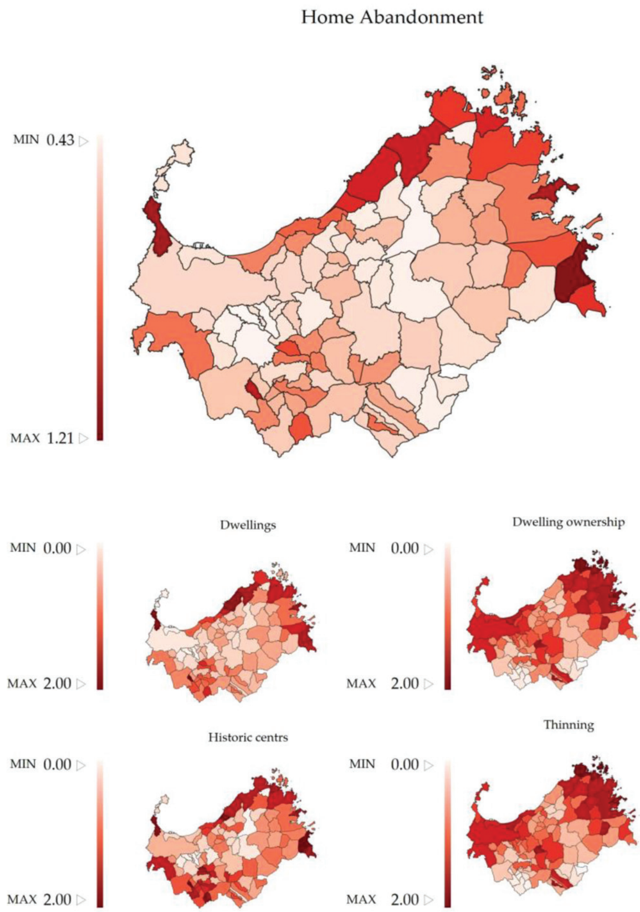


Figure 13. Mapping of the forms of abandonment in relation to each dimension, with histograms by classes of the degree of thinning and occupancy of dwellings in coastal and inland areas. (Our processing).

In particular, the ratio between the number of inhabitants and the number of dwellings does not deviate from the Italian average (1.89) of the recording values of 1.34, 1.67, and 1.93 for the three quartiles calculated.

In order to better understand the above, the demographic dynamics and property prices of the above municipalities have also been examined in comparison with other municipalities that are considered to be useful points of comparison.

Figure 14a shows the population dynamics that highlight the apparent contradiction between population growth and the state of low housing use. An overview of the entire province of Sassari from the point of view of real estate quotations (Figure 14b) highlights the considerable gap between the high number of municipalities (67), in which average real estate quotations fluctuate between 525 and 920 €/sq.m., and the extreme variability of quotations among the remaining 25 where quotations vary from 920 to 16,000 €/sq.m. This disproportion indicates the impact on the housing economies of the tourist accommodation sector due to the exceptional characteristics of the Sardinian coastal landscape. This asymmetry has, therefore, led to a complete reinterpretation of the living experience and the relationship between home ownership and use.

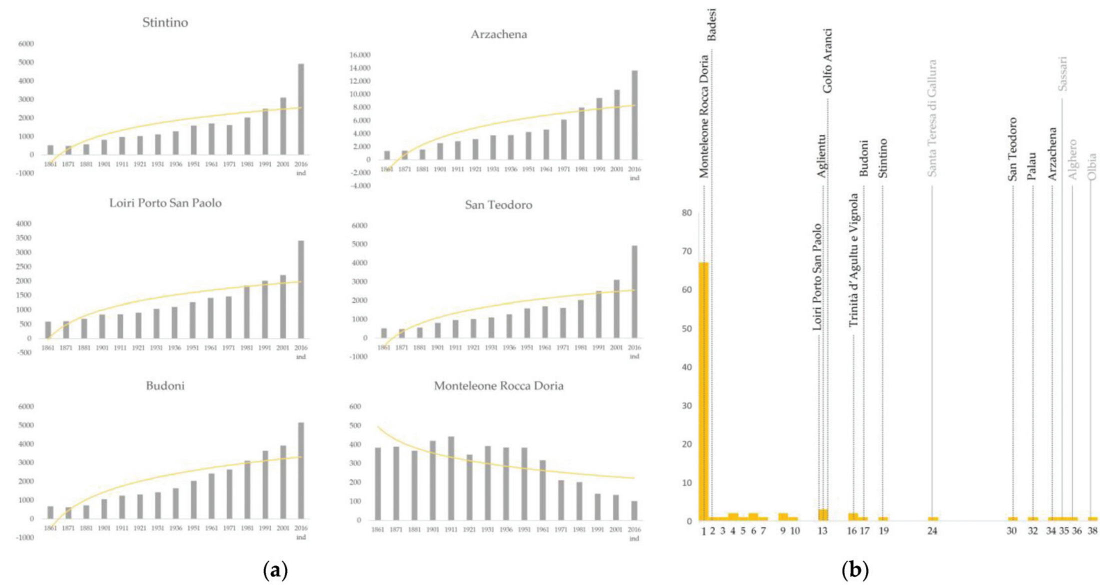


Figure 14. (**a**) Demographic evolution in the towns mostly representing the home abandonment; *x*-axis, years; *y*-axis, population; (**b**) histogram with classification of economic values of dwellings; *x*-axis, real estate prices classes, from the lowest class (525–919 Euro/sq.m) to the highest (15,902–16,295 Euro/sq.m); *y*-axis, number of municipalities per class. (Our processing).

4.3. Interpretation: Drivers of Abandonment

This final part uses the extensive analysis carried out in the previous phases to support considerations aimed at identifying the drivers of abandonment between the iUs, built through the proposed model and attributable to the four systems.

To identify the different declinations of the degree of abandonment in a heterogeneous territorial context, the findings of the two previous analyses were compared with the main drivers of abandonment taken here as the main dimension of landscape risk.

These analyses and the resulting interpretations have revealed a dual register of the phenomenon of abandonment, which affects inland and coastal areas differently, showing, in some cases, different and sometimes divergent trends.

The drivers were selected from the iUs of the different levels of the analysis on the Urban Social and Economic system and with reference to the two different dimensions, collective and individual, described above.

With regard to the collective dimension of abandonment, i.e., the phenomenon caused by general structural changes, this study looked at the following:

- The productive system, in terms of the relationship between the causes and effects of land abandonment (quarries, agricultural land). The greater efficiency in the use of the productive potential of local assets indicates a certain resistance to abandonment in both clusters, but more so in the coastal areas, both because of their greater dynamism and because of the location of some important productive settlements (Figure 15a);
- The landscape components: although with a very low index of determination, both coastal and mountain communities show an increasing tendency to land abandonment. Because of the value of the landscape, communities seem to opt for the possibility of exploiting local resources (Figure 15b);
- The characteristics of settled communities in terms of density, heterogeneity, and occupation of dwellings. In this case, the two clusters interpret the relationship between the abandonment index and social integration differently. Coastal areas

are, on average, more socially integrated and seem to resist abandonment, unlike mountain communities (Figure 15c).

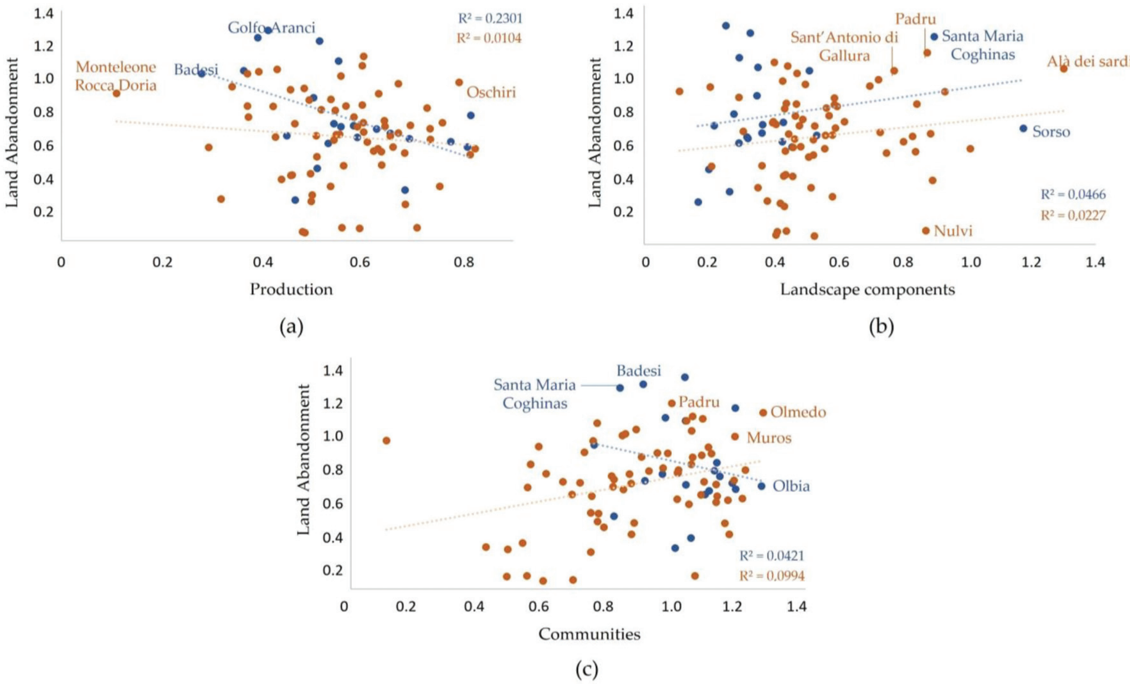


Figure 15. Correlations between the index of land abandonment and the drivers of the structure of the production apparatus (**a**), the drivers of landscape components (**b**) and the value of the characteristics of settled communities (**c**) in coastal areas (blue) and inland areas (orange). (Our processing).

Regarding the individual dimension of abandonment, the identified drivers are as follows:

- The characteristics of the urban housing system in terms of the state of conservation and the heritage value of the buildings. In mountain areas, the degree of abandonment is higher for buildings in a poor state of preservation, while in coastal areas, on the contrary, the tendency to abandon houses increases for those in a very good state of preservation due to the seasonal use of the buildings. The heritage value constitutes a driver of resilience in both clusters, showing how urban identity tends to create a stable link between the population and the house (Figure 16a);
- The economy of the settled communities in terms of income and employment levels. The two clusters are very different in these two respects; the richer coastal areas confirm one of the main risks of abandonment due to the friction between the traditional economy of local production and the newer economy of services linked to seasonal tourism; in fact, while the richer inland communities maintain the link with housing, the opposite is the case in the coastal areas, precisely because of the preponderance of housing used by non-residents (Figure 16b);
- The characteristics of households in terms of the number of members and the relationship between households and housing are measured by the percentage of owner-occupied dwellings. For both clusters, the size of the household is an element of resilience that is more evident in the interior; on the contrary, the relationship between the abandonment rate and the number of households living in rented accommodation outlines divergent trends in the two clusters; in coastal areas, the tendency towards

abandonment denotes those cities where the high number of rented households in relation to the total is justified by the low number of inhabitants and high market prices of dwellings, as well as the presence of temporary work and study opportunities; in inland areas, the resilience to abandonment denotes a more complex urban reality, as in Cargeghe and Luogosanto, where a wider range of economic activities and more job opportunities seem to incentivise renting (Figure 16c).

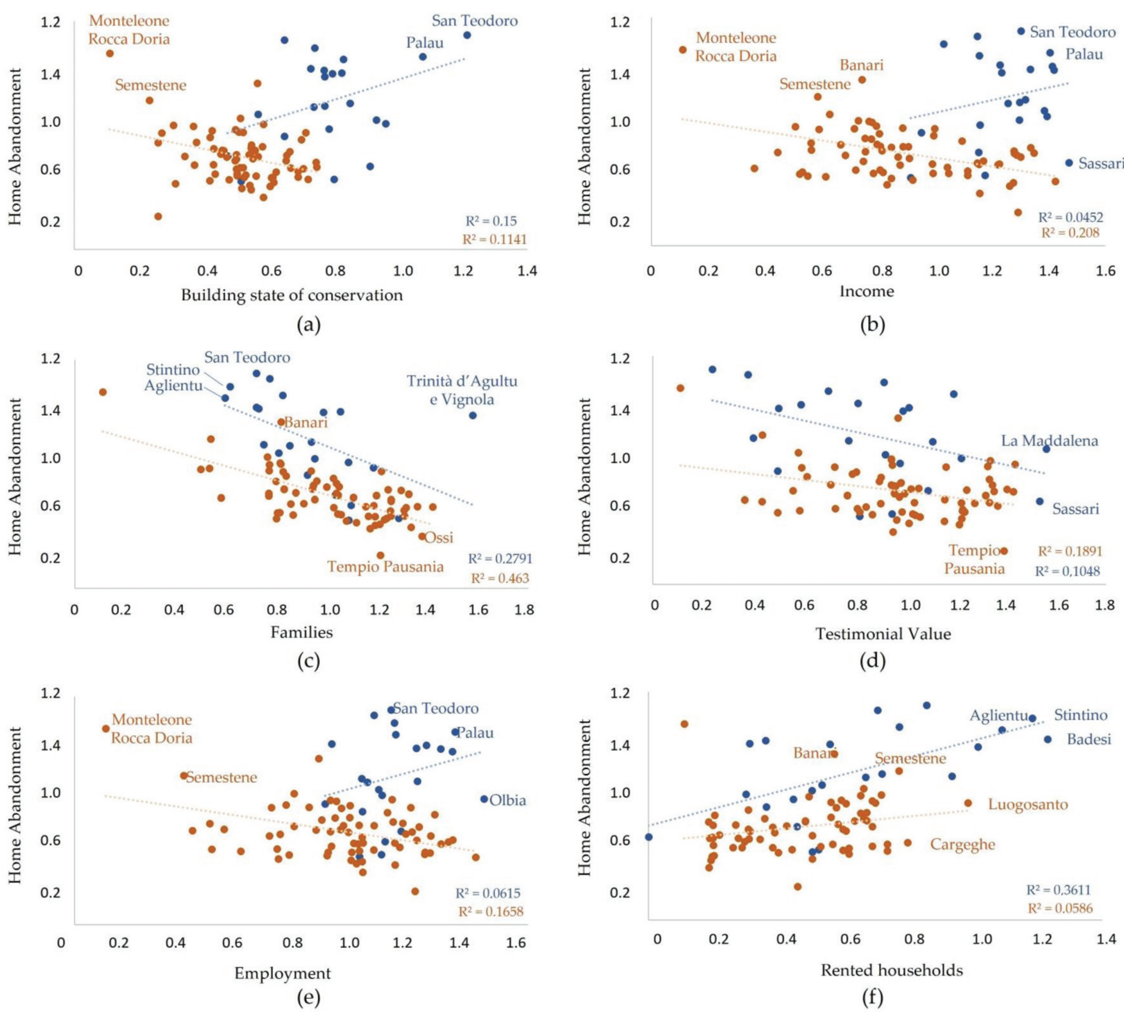


Figure 16. Correlations between the index of home abandonment and its drivers with specific reference to the state of preservation of buildings (**a**) and their testimonial value (**d**), the income of settled communities (**b**), their level of occupation (**e**), the composition of households (**c**), and the number of households in rented flats (**f**) in coastal areas (blue) and inland areas (orange). (Our processing).

5. Discussion

The research is part of the studies and policies for the revitalisation of disadvantaged territories that characterise both national and European territories [56–60].

In Sardinia, scientific interest seems to focus on the demographic malaise (SMD) and the difficulty in accessing basic services (DAS) [61,62], similar to Italy, where studies focus sectorially on depopulation—interpreted only in quantitative terms—[63], on the poor management of the economic resources of the 'public machine' to effectively support development projects [64] or even on the insufficient access to services that characterise inland areas [65].

In Europe, many countries have promoted policies aimed at territorial rebalancing and the identification of specific funding to support the improvement of the quality of life in small towns, such as in France with the 'Revitalisation des centres-bourges' and the 'Petites villes de demain' promoted in 2014 and 2020, respectively [66,67], or geographical areas (mountain, rural and border) with specific development needs [68].

The proposed study prefigures a broadening of the scientific and operational interest in territorial disadvantage, according to a further meaning of abandonment that in a holistic vision of the components that build the landscape can lead to more articulated solutions and directions, with respect to a very complex reality [69].

The first phase provided integrated knowledge aimed at identifying potentialities and criticalities of both the original physical conformation (geological, water etc.) and cultural transformations (productive, urban, etc. settlements) of the analysed context. The articulation of the abandonment concept, addressed in the second phase, constituted one of the main focuses of this research, declined with reference to the two dimensions of associated life, the home and the territory.

These are represented by specific indices measuring eight different aspects of abandonment identified as a result of the observations in the previous phase. The third phase defined the incidence of the drivers of abandonment by highlighting the different declinations of landscape risk in a heterogeneous territorial context; one of the two interpretations refers to the manifestations of impoverishment and territorial disadvantage characterising the hinterland; the other refers to the overlapping of the real estate and service sectors on a barely cohesive productive economy.

The results obtained are in keeping with the representations produced by the National Atlas of Rural Territory [70], which, with specific reference to the areas of northern Sardinia, identifies marginal areas as affected by differentiated criticalities that induce the abandonment of homes and towns, tourist areas, and areas in agricultural decline that induce land abandonment. Several studies on the national territory have highlighted this dichotomy between marginalisation and development [71].

The sharability of this conoscitive and evaluative path consists in the application of a model based on a WBS, easily traceable top–down and bottom–up, whose criteria are ordered in a structure articulated in four systems (natural, urban, economic, and social). The methodology and tools used make the model flexible and extendable to other contexts, as well as integrate additional data to complete the knowledge dashboard [72].

The limitations of the proposed model include, for example, the lack of useful data to understand the physical–geographical constraints of the territories (e.g., orographic analysis), updated dataset coming also from other institutions [73], and network analysis with reference to the measurement of accessibility [74,75].

Since these data need to be updated and contextualised with respect to the proposed articulation of the criteria, we will postpone a more detailed analysis to a monothematic study on accessibility.

Another aspect that makes it difficult to immediately understand the results of the proposed mappings consists in the heterogeneity of the main tUs in terms of size and density (surface area, population, the extent of the built heritage, etc.), which is combined with the many salient features of these territorial units, in particular, the prevailing natural, urban, economic, and social characterisation.

The general perspective of the presented study is to extend the methodology applied to the entire regional territory in order to

- support wide area planning in identifying development strategies that originate predominantly from their own territorial capacities in order to foster forms of autonomy consistent with the profile outlined by the measures implemented against the COVID-19 pandemic [76];
- address territorial rebalancing strategies that can mend the dichotomy between inland and coastal areas [77–80];
- reinterpret abandoned industrial, productive, and urban sites by recognising them as resources with a high capacity to generate new development paths for local communities, according to a holistic vision that integrates environment, society, and economy, as proposed by the new Regional Development Plan (RDP) 2020–2024 [81–83] and also in line with the objectives of the SDGs [84].

6. Conclusions

The aim of this study was to provide a framework for observing and interpreting landscape risk at the provincial level, with reference to the phenomenon of abandonment of the most important territorial components in northern Sardinia. The complexity of the causes of abandonment and the heterogeneity that characterises the various territorial units that make up the study area made it necessary to construct a structured information model with reference to the natural, urban, economic, and social systems. The model supports an initial overall assessment of the studied context, as well as a subsequent differentiated evaluation by clusters of municipalities (inland and coastal areas) in which the two dimensions of abandonment (land and home) were represented.

The model is a cross-sectional query tool of a database, the contents of which are also evaluation indices built for the specific purpose of representing abandonment. The context studied, consisting of 92 tUs (municipalities), is characterised by 527 iUs between observations and indices, grouped with reference to the main territorial systems.

Through a differentiated analysis of the two clusters of municipalities, this study has highlighted convergent and divergent trends that reveal, on the one hand, the profound transformation of coastal areas and, on the other hand, elements of the resilience of inland areas, which could be useful to drive future large area planning. Coastal areas show elements of risk of landscape abandonment due to trends typical of areas where the link between the agricultural economy and local production and the housing system is interrupted by the emergence of transitory service economies. The former is characterised by long-term investments and slow processes of mutual adaptation, the latter by sudden and irreversible transformations due to tourism development. On the contrary, inland areas manifest the typical features of local communities characterised by a strong connection to places where economic and family structures tend to retain the population and keep alive the housing and economic heritage consolidated by the combination of the characteristics of the land and the organisation of work.

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Article

A Sensitivity Index to Perform the Territorial Sustainability in Uncertain Decision-Making Conditions

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Abstract: The issue of sustainability is central to development strategies. Although this alignment is acknowledged and shared world-wide, territorial development in a sustainable light must also take the ongoing COVID-19 pandemic into consideration, specifically by evaluating the effects of COVID-19 on the global health, social order, and economic-environmental system. The research suggests a sensitivity index to gauge the degree of territorial sustainability taking the COVID-19 pandemic's impacts into account. A study set of countries, as identified by the Organization for Economic Co-operation and Development (OECD), is used to test the developed index. The index evaluates a country's performance in terms of economic, social, and environmental sustainability while also considering the relative risk of COVID-19. The proposed index measures territorial sustainability from a variety of angles by enabling comparisons between the circumstances before and after current shocks in the socioeconomic and environmental performance frames by pandemic emergency. The index was created using an integrated assessment method that was based on the *Choquet* Integral (CI) mathematical framework and Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA). The study establishes a unique and up-scaling methodology for constructing the sensitivity index, significantly advancing the suggestions for sustainable accounting under uncertain circumstances at the territorial scale. Adopting indices that quantify territorial sustainability under uncertainty may help guide policy decisions from an investment programming viewpoint, particularly when it comes to allocating financial resources to the economic sectors most impacted by shock events such as the COVID-19 pandemic.

Keywords: sustainable development; COVID-19; sensitivity index; integrated framework; *Choquet* Integral; Multi-Attributive Ideal-Real Comparative Analysis; OECD countries

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1. Introduction

By 2019, the COVID-19 pandemic had begun to damage nations' development and growth dynamics world-wide, as well as the attainment of the 17 sustainable objectives established in the United Nations' Agenda 2030 [1,2]. According to the World Economic Forum's International Monetary Fund (IMF) estimate for 2020, the global economic-social and environmental assets will suffer the worst crisis since the "Great Depression" of 1929 [3].

Since the emergency broadened to a world-wide scale (2020–2021), the pandemic had significant effects on people's psychophysical health and sociality [4,5], national economic-productive performance [6], ecosystems condition [7], and climate change [8]. Inhibitions for halting the pandemic's spread had an impact on social contacts [9], which also had an effect on the country's manufacturing industry. Similar to the IMF report (2020), the global economy's growth outlook for 2020 shrank by 3%, as opposed to a forecast for 3.3% economic growth. Global gross domestic product (GDP) decreased by 1.8% in the first quarter of 2020 compared to the same period in 2019 [3]. Instead, the pandemic revealed important functional connections between the state of the biophysical ecosystems. Particularly during the lockdown periods, there was a rise in biodiversity, a supply of ecological services, and an improvement in air quality [10]. Air pollution and greenhouse gas emissions significantly reduced as a result of decreased human activity. According to Le Quéré et al. (2020), daily CO_2 emissions worldwide decreased 17% from the average level in 2019 [11].

The tourism industry, use of renewable energy sources, and educational system were all affected to an equal extent (World Economic Outlook, 2020). Even if the usage of renewable energy sources has risen, the World Travel and Tourism Council (WTTC) and the International Energy Agency (IEA) said that millions of jobs were at risk and that energy output had drastically decreased, respectively [12,13]. As a tactical move by industrialized nations to control the spread of the pandemic at the local level, the breakdown of the educational process in schools and higher education institutions reinforced the socio-economic disparities among students and their households significantly [14,15].

The highlighted impacts occur from exposure to a risk, such as a disturbance or stressor, which affects the important economic, social, and environmental elements that define the territory as a multidimensionally complex and fragile frame [6]. The United Nations (UN) asserted in its World Economic Situation and Prospects report for 2022 that efforts to stop the pandemic from spreading globally should serve as a roadmap for each nation to develop more resilient, egalitarian, and inclusive economies that are driven by sustainability objectives, encouraging investments to revive global trade, and lowering vulnerability to unexpected events [16].

This study suggests a sensitivity index that may be used to assess a territory's long-term performance as well as its relative trends before and after an emergency outbreak. The creation of the index is intended within an integrated framework that takes into account sustainability and the risk associated with the COVID-19 pandemic. The framework is organized in accordance with the Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA) methodology. The latter was linked with the logical-mathematical ideas of Choquet's Integral (CI) for the aim of creating indices [17].

By utilizing the potential of each practical approach, the suggested evaluation model (MAIRCA-CI) integrates the MAIRCA phases with those of CI. In order to handle and resolve multi-criteria analysis instances where there is uncertainty, MAIRCA is based on a linear computational algorithm. It is primarily adaptable with other instruments, and it has a straightforward mathematical structure, which enables analysis that bridges the gap between ideal and empirical assessments [18]. As opposed to aggregative strategies based on geometric and arithmetic means, the CI enables the construction of indices by including the dependencies between assessment criteria for each alternative, establishing a mutual function between components, and adjusting the weighting parameter.

The remaining sections of the work are as follows: Section 2 highlights sustainable accounting in the context of vulnerability as discussed in the reference literature; Section 3 discusses the materials underlying the integrated process for index construction, specifically the description of the MAIRCA (3.1) and Choquet (3.2) approaches; Section 4 illustrates the logical-operational characteristics of the evaluation models used as a starting point for the definition of the integrated evaluation model (MAIRCA-CI); Section 5 includes the case-study; Section 6 details the findings and Section 7 presents the study's conclusion.

2. Reviewing the Relevant Studies

In several ways, the vulnerability discussion broadens public awareness [19,20]. In the international scientific literature, attempts to assess the sustainability of a territory can also be examined in relation to its relationship with unforeseen interactions [21–24]. Multiple studies looked at the sudden shifts in territorial systems brought on by temperature trends, variations in the frequency and intensity of rain, and increasing susceptibility to natural disasters [25–30]. A growing agreement identifies that understanding of the effects and responses by the affected system must go beyond disruptions and stressors, and places the majority of the blame for vulnerability on the dynamics of the human–environment system under uncertain conditions [31]. Vulnerability must be taken into account with respect to the system as well as the numerous linkages that might influence its condition [32].

Robust vulnerability analyses are required, and the relationship between scientific issues and the needs of decision-making is improving [32]. The literature supports the application of vulnerability analysis when it: (i) refers to the coupled human–environment system and relative conditions; (ii) identifies some components affecting the vulnerability of the system; (iii) measures the degree of vulnerability of a specific location; (iv) makes it simpler to identify critical points that suggest decision makers' actions; and (v) suggests the applicability of both quantitative and qualitative methodological approaches to manage information [19,20].

Regarding (v), the Risk-Hazard (RH) and Pressure-And-Release (PAR) models seem to be the most effective ways to demonstrate vulnerability [32]. RH seeks to understand how a risk affects an entity based on its sensitivity to the risk event and its exposure to it. The risk in the PAR model is intended to be a function of the perturbation, stressor, and vulnerability of the exposed unit. The assessment of the situations that might lead to hazard events and the requirement to comprehend vulnerability are the main points [33].

The sensitivity to stressors and perturbations differs between the two models. The political economy, especially social structures and institutions, are not addressed by the RH in terms of modifying exposure causes and effects, and the PAR does not address the human–environment system vulnerability from an integrated viewpoint [33].

The implementation of assessment techniques and tools based on multi-criteria logic, taking into account many and diverse variables within the same decision-making environment, is recommended by the literature to overcome the conceptual limitations of RH-PAR. The Analytic Hierarchy Process, Goal Programming, and the Multi-Attributive Ideal-Real Comparative Analysis for solving ranking cases between alternatives are a few examples of appropriate evaluation methods and tools to support the sustainability implementation in planning/design practices that were reviewed by Morano et al. in 2021 [34]. The creation of composite indicators for gauging socioeconomic well-being and the relative variation following unexpected occurrences have also been covered in the reference literature [35–43]. Long et al. (2020) depicted the sustainable performance of an islands-set in China referring to ecological wellbeing performance by the integration of the Three-Dimensional Ecological Footprint and Urban-Scale Human Development Index [35]. Shah et al. (2019) used the Energy Security and Environmental Sustainability Index, which combines energy and environmental indicators, to monitor energy security and environmental sustainability of South Asian countries [36]. Hansuebsai et al. (2020) introduced an environmental performance index to evaluate the activities of a printing house based on three impacts: carbon footprint, volatile organic compound emissions, and waste [37]. Richter and Behnisch (2019) combined geostatistical methods (landscape structure metrics, spatial multi-criteria assessment, weighting approaches) and a multitude of data related to environmental concerns. Based on the multi-criteria assessment, an index of landscape functions was calculated [38]. Tokimatsu et al. (2018) showed how the sustainability indicator Genuine Savings can be endogenized within a general equilibrium model and used as a criterion for judging the impacts of such policies in terms of future well-being [39]. Lind (2019) referred to the Human Development Index, published annually since 1990 by the United Nations Development Programme, to reflect 'development' as evident in the actual progression of life expectancy, education, and income in the world [40]. Kalimeris et al. (2020) explored the relevance of three welfare indicators—the Human Development Index, the Index of Sustainable Economic Welfare, and the Genuine Progress Indicator—as a basis for evaluating the dependency of welfare and its major engine, the economy, on natural resources [41]. Pais et al. (2019) assessed sustainable development for 28 Organization for Economic Co-operation and Development countries by computing a comparable Genuine progress indicator [42]. Vukoszavlyev (2019) studied the connection of innovation in 126 countries by different well-being indicators and whether there are differences among geographical regions with respect to the Global Innovation Index [43].

These primary implementations focus on three main goals: (i) monitoring of the environment with energy usage [35,36,43,44]; (ii) study of the long-term consequences of territorial policies aimed (for example) at reducing the risk of natural catastrophes [37–39,45–50]; and (iii) tracking the economic growth at the country level in relation to the well-being status and ecosystem condition [39–43]. In the latter, the creation of sensitivity indices was put to the test in an effort to enhance knowledge of vulnerability and future forecasts of it in territorial analysis techniques. Many people in both fields concentrated on calculating the geometric and mathematical means; others, however, relied on the application of operational strategies widely used in game and decision theory, for example, the Choquet Integral.

3. Materials

The suggested methodological framework aims to express the performance related to territorial sustainability and, in particular, it is capable of describing the adaptability of sustainable territorial development assets to changes in the economic, social, and environmental conditions, taking into account before/after the COVID-19 pandemic conditions. In order to promote robust and dynamic decision-making systems for territorial development from a sustainable viewpoint, the suggested protocol of multi-criteria matrix aims to present a sensitivity evaluation index.

As previously stated, the suggested index is realized in accordance with the logical-operative flow of the MAIRCA combined with the CI. The following lists the stages for the MAIRCA (3.1) and CI (3.2) techniques.

3.1. The MAIRCA Method for Gap Analysis Implementation

Professor Dragan Pamučar of the Belgrade Defence University defined the MAIRCA approach [51]. It is based on the logical-operational notion of a "ideal solution" that is connected to the evaluation issue to be addressed [52], and it is often utilized and tested in a variety of decision settings, as well as in combination with various multi-criteria and geographic analytic approaches. In particular, Gigović et al. (2016) used geographic information systems and the MAIRCA technique to solve a scenario of choosing between two locations without a clear functional purpose for the development of new infrastructure [53]. In order to decrease the number of road fatalities, Pamučar et al. (2018) used an integrated evaluation procedure that used the Full Consistency Method and the MAIRCA when allocating level crossings [18]. By defining priorities for selection using the MAIRCA technique coupled with fuzzy principles, Pamučar et al. (2019) analyzed six potential territorial regions to identify the landing site of vehicles in combat operations [54]. In 2018, Badi and Ballem combined MAIRCA with the Best-Worst Method (BWM) [55]; Chatterjee et al. coupled MAIRCA with the Analytic Network Process [56]; in 2019, Ulutaş combined MAIRCA with Step-Wise Weight Assessment Ratio Analysis. To determine the ideal staffing level for an organization's IT department [57], Aycin (2020) created the inter-criteria correlation (CRITIC) and MAIRCA methods [58], Arsić et al. (2019) conducted a multi-criteria evaluation with the adoption of BWM and MAIRCA methods [59]. In the research by Chatterjee et al. (2020), the MAIRCA method was used to evaluate environmentally friendly lightweight materials in terms of their performance in the automotive manufacturing sector [60].

Given the numerous implementations of the MAIRCA approach throughout the final decade of the twenty-first century, it is efficient in measuring the gaps for several choices in multiple contexts. The general evaluative scenario may have the optimal solution represented by that with the smallest total gap value [51,53].

The MAICA is very adaptable to various decision-scenarios due to its implementation capability in conjunction with other tools. In general, the MAIRCA is composed of operational matrix phases that are sequential and may be used as a guide for structuring decision-making analysis in terms of problem identification, impact assessment, values elicitation, information synthesis, applying the results to enhance decision-making, and challenging thinking. In order to gather appropriate data and support the single stage effectively so that it respects the nature of the decision scenario of reference, the integration of these stages with additional technologies is frequently necessary.

The six sequential steps that make up the MAIRCA approach stand out are as follows [18].

3.1.1. Step 1: Criteria Identification and Creating Initial Decision Matrix

Having identified which criteria C_i (with $i = 1, \ldots, n$) to include in the evaluation of alternatives A_j (with j = 1, ... , m), the values of the assessment criteria for each alternative are organized in a matrix (X) of the type:

$$X = \begin{bmatrix} A_1 \\ \ldots \\ A_m \end{bmatrix} \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \begin{bmatrix} C_1 & \ldots & C_n \end{bmatrix} \quad (1)$$

3.1.2. Step 2: Determining the Alternative Priorities

Once the matrix (X) has been constructed, the principle of ordering alternatives is established. The Pamučar axiom of the MAIRCA method consists in the absence of a priority law to be applied in the process of selecting and ordering between alternatives [18]. Each alternative is of equal importance to the others.

The priority of the j-th alternative $\left(Pr_{A_j}\right)$ is calculated according to the following algebraic equalities (2):

$$Pr_{A_j} = \frac{1}{m}; \sum_{j=1}^{m} Pr_{A_j} = 1 \quad (2)$$

3.1.3. Step 3: Construction of the Theoretical Rating Matrix

The elements of the Theoretical Rating Matrix $\left(T_p\right)$ are obtained considering the priority factors of j-th alternative with respect to the i-th criterion. Specifically, the elements $t_{p_{ij}}$ of T_p are obtained by multiplying the priorities Pr_{A_j} by the corresponding weight factor $\left(w_j\right)$. The matrix T_p [m × m] takes on the following algebraic configuration (3):

$$\mathrm{T_p} = \begin{bmatrix} \mathrm{Pr_{A_1}} \cdot \mathrm{w_1} & \cdots & \mathrm{Pr_{A_1}} \cdot \mathrm{w_m} \\ \vdots & \ddots & \vdots \\ \mathrm{Pr_{A_m}} \cdot \mathrm{w_1} & \cdots & \mathrm{Pr_{A_m}} \cdot \mathrm{w_m} \end{bmatrix} \quad (3)$$

3.1.4. Step 4: Defining the Real Rating Matrix

The matrix T_r is derived from the combination of the matrix T_p and that of the initial decision (X). Equations (4) and (5) evaluate the T_r elements in accordance with the greatest and lowest values of the j-th alternative to the i-th criterion, respectively. The generic component $t_{r_{ij}}$ of T_r is considered the weighted average value of the results from the (4) and (5).

$$\mathrm{t_{r_{ij}}} = \mathrm{t_{p_{ij}}} \cdot \frac{\left(\mathrm{x_{ij}} - \mathrm{x_{ij}^-}\right)}{\left(\mathrm{x_{ij}^+} - \mathrm{x_{ij}^-}\right)} \quad (4)$$

$$\mathrm{t_{r_{ij}}} = \mathrm{t_{p_{ij}}} \cdot \frac{\left(\mathrm{x_{ij}} - \mathrm{x_{ij}^+}\right)}{\left(\mathrm{x_{ij}^-} - \mathrm{x_{ij}^+}\right)} \quad (5)$$

In (4) and (5), x_{ij}^+ is the highest value of the numerical series relating to the criterion (C_i) by which A_j is assessed $[x_{ij}^+ = max(x_1, x_2, \cdots, x_m)]$; meanwhile x_{ij}^- identifies the corresponding lowest value $[x_{ij}^- = min(x_1, x_2, \cdots, x_m)]$.

3.1.5. Step 5: Computation of Total Gap Matrix

The difference between the matrix X e T_r gives the Total Gap Matrix (G) which assumes an algebraic configuration of the type:

$$G = T_p - T_r = \begin{bmatrix} g_{11} & \cdots & g_{1n} \\ \vdots & \ddots & \vdots \\ g_{1m} & \cdots & g_{mn} \end{bmatrix}$$

The value of g_{ij} in G matrix is commensurate with the difference between the T_p e T_r, i.e., the matrices representing respectively the reference value of the i-th criterion with respect to the j-th alternative ($t_{p_{ij}}$), and the corresponding real value as a result of evaluations carried out on the basis of pre-established reference targets ($t_{r_{ij}}$).

3.1.6. Step 6: Final Value of the Alternatives

In view of the (G) matrix, it is possible to derive the final score (Q_j) for the alternative (A_j) on the basis of the relative differences in values in T_p e T_r for each criterion C_i (con i = 1, . . . , *n*). The parameter (Q_j) can be calculated by means of the geometric series such as Equation (6) below:

$$Q_j = \sum_{i=1}^{n} g_{ij} \tag{6}$$

From the Q_j values it is possible to identify the alternative (A_j) whose performance characteristics differ, significantly or not, from the target values of each criterion (C_i). When the differential between $t_{p_{ij}}$ e $t_{r_{ij}}$ of the alternative A_j tends to zero, the A_j is performing in consideration of the (C_i).

In order to overcome Jean-Pierre Brans' problems with prioritizing techniques amongst alternatives, the MAIRCA approach was created [61], but the lack of thresholds for preference and/or indifference in the aggregate of the gaps of each choice is one of its limitations in terms of compensation. Due to the interaction between the components and the mutual numerical differential, the Choquet Integral (CI) stands out as an aggregation operator from weighted average operators to close this gap. The CI and the associated stages for the development of composite evaluation indices enabling the prioritizing of alternatives based on the relative trade-offs of each criterion are discussed in the next sub-section. The CI's description is relevant to Section 4 in regard to the MAIRCA-CI evaluation framework.

3.2. The Choquet Integral

The most popular weighted average operators are generalized in Choquet integrals. Choquet's measures appear to be practical modeling tools for the mutual interdependencies in interacting decision systems, as in the Decision Theory. Murofushi and Soneda investigate reciprocity between the components in more detail [62,63]. As a gauge of the relative weight of the various assessment criteria, they employed the Shapley value. Grabisch and Roubens noticed the idea of using indices to quantify the significance and degree of interaction between subsets, and they subsequently applied it to the multi-criteria analysis theory [64,65].

The implementation of CI developed in the twenty-first century. In complex decision-making systems, Meyer and Ponthière used the CI to express individual preferences [66–69]. In order to create indices based on interactions between performance indicators and pre-established reference objectives, Carraro et al. (2013) employed the CI [70]. Merad et al. (2013), Bertin et al. (2018), Bottero et al. (2015) and (2018), Branke et al. (2016), and Campagnolo et al. (2018) all conducted similar exercises [71–76]. Grabisch et al. (2008) used CI together with participative methodologies to determine how much each evaluation criterion should matter in light of stakeholder assessments [77].

In light of the literature references, a baseline operation is discernible. The following is an explanation.

Given a set N = {l, 2, . . . , n}—i.e., a finite set of *n* interacting elements, the components of N may represent decision agents, or even criteria characterizing a multi-criteria decision problem. A discrete Choquet measure on the set N is a function $\mu : P(N) \rightarrow [0, 1]$ that satisfies the following two conditions, the boundary (1) and monotony condition (2), respectively:

1. μ (0) = 0; μ(D) = 1;
2. for any S, T⊆D, S⊆T⊆D → $\mu(S) \leq \mu(T) \leq \mu(D)$.

The quantity μ(S), with S ⊆ N, represents the value of the coalition S without the other elements in N\S. The μ(T) refers to the Choquet measure in a subset T of the analysis-domain D, whereas the μ(D) concerns the Choquet measure on the analysis-domain border.

If $\mu(i)$ represents the weight of *i*, in 1992 Murofushi proposed the use of an importance index within the framework of the multi-criteria decision theory. The same was introduced in 1953 by Shapley in Game Theory, defining the Shapley power index [62,78].

Shapley's power index (or Shapley's value) for each element $i \in N$ ($\theta_\mu^{(i)}$) is measured by means of the following Equation (7):

$$\theta_\mu^{(i)} = \sum_{T \subseteq N \setminus i} \frac{(n-1-t)!t!}{n!} \left[\mu\,(T \cup i) - \mu\,(T)\right] = \\ = \frac{1}{n} \sum_{t=0}^{n-1} \binom{n-1}{t}^{-1} \sum_{T \subseteq N \setminus i} \left[\mu\,(T \cup i) - \mu\,(T)\right] \quad (7)$$

The (7) can take on a compact algebraic connotation as that follows (8):

$$\theta_\mu^{(i)} = \frac{1}{|N|!} \sum_{\pi \in \pi_N} \mu(CI(\pi, i) \cup \{i\}) - \mu(CI(\pi, i)) \quad (8)$$

The Shapley value of an element *i* expresses the contribution of *i* to all possible coalitions (π) with other components. Shapley values, for any element *i* in N, are always positive, assuming values between [0÷1].

Based on the Shapley value of each element $\mu\left(x_{(i)}\right)$ it is possible to define the corresponding Choquet integral $C_\mu(x)$ as follows (9):

$$C_\mu(x) = \sum_{i=1}^{n} x_{(i)} \left[\theta\left(x_{(i)}\right) - \theta\left(x_{(i+1)}\right)\right] = x_{(i)} \left[\theta\left(x_{(i)}\right) - \theta\left(x_{(i+1)}\right)\right] = \theta\left(x_{(i)}\right)\left[x_{(i)} - x_{(i-1)}\right] \quad (9)$$

4. The MAIRCA-CI Model

For the purpose of creating assessment indices with which to quantify the variability of the reference decision scenario from a sustainable perspective, the suggested model incorporates the MAIRCA properties together with those that distinguish the CI. The Shapley value and Choquet measure will be used, respectively, for the assignment of weights to each analytical element and for the formulation of a sensitivity index, as per the methodological framework of MAIRCA, which has been agreed to be kept. The methodologically integrated approach (MAIRCA-CI) put forward facilitates the assessment of the territorial circumstances in regard to any potential discrepancy of their sustainable frame brought on by unforeseen occurrences such as the COVID-19 pandemic. Public and private decision-makers can greatly benefit from the monitoring of sustainability levels even in the face of abrupt changes in socioeconomic and environmental systems when restructuring strategic development assets to be used at the territorial scale and, as a result, when redistributing available financial resources among development projects.

Following are the phases that define the proposed MAIRCA-CI assessment model's flow:

Step 1: Criteria identification and creating initial decision matrix (X);

Step 2: Determining the Priorities of Alternatives (Pr_{A_j}) and weights factors by means of Shapley measure. Construction of the Theoretical and Real Rating Matrix (T_p, T_r);

Step 3: Computation of Total Gap Matrix (G) and Index construction with Choquet integral.

The theoretical and practical premises supporting the suggested paradigm of analysis include:

- linear ordering of the assessment criteria so that they may be compared in a predetermined order *i* (where $i = 1, \ldots, n$) in accordance with the set of criteria's consistency (of index *i*);
- evaluation of each criterion's weighting elements using the Shapley measure, which considers the i-th criterion's varying degree of coupling with the other criteria of order ($i - 1$). The preferences of possible stakeholders in the decision-making process are not taken into account while applying the Shapley formula;
- decision-makers' preferences are not used to determine how each alternative is weighted; rather, an egalitarian significance factor is used to do so.
- The following subsections detail each stage.

4.1. Criteria Identification and Creating Initial Decision Matrix (X)

The sustainable assessment of each potential alternative is conducted using the proper evaluation criteria and performance indicators to quantify and qualitatively analyze each criterion. The criteria and relative indicators should be chosen in accordance with the following factors: (i) the particulars of the evaluation case to be solved; (ii) the sustainability dimensions to be examined for each alternative; and (iii) the likelihood of measuring each criterion via a particular indicator in relation to the availability of geo-referenced and NOR data, information systems, and the analysis scale of reference. The criteria C_i (with $i = 1, \ldots, n$) screened according to the principles of inclusion/exclusion illustrated above found elements in the initial decision matrix X where the indicators values for each criterion (matrix columns) can be organized in correspondence to each alternative A_j (with $j = 1, \ldots, m$). The initial decision matrix takes on a configuration of the type in (1).

In order to be able to compare each j-th alternative to the other, it is necessary to normalize the values of X, so as to obtain the $\overline{X}$ in which to include the results by the normalization practice. The normalization process must respect both the theoretical framework and the properties of available data.

There are several ways to put it into practice [79,80]. The "Min-Max" normalization intended for the suggested technique of analysis is recommended, whereby the normalized indicators (I_n) have an identical range [0, 1] by subtracting the minimum value and dividing by the range of indicator values *i* as follows:

$$I_n = \frac{x_i - \min_i x}{\max_i x - \min_i x} \tag{10}$$

In (10), x_i is the value of the indicator referred to the i-th criterion, $\min_i x$ the minimum of the numerical series relative to the i-th indicator; $\max_i x$ refers to the maximum of the series itself.

4.2. Determining the Priorities of Alternatives and Weights Factors by Means of Shapley Measure. Construction of the Theoretical and Real Rating Matrix (T_p,T_r)

Starting by the X-matrix we proceed to the construction of the Theoretical Rating Matrix (T_p) of which each element $t_{p_{ij}}$ is obtained by multiplying the priority factor of the single alternative by the weight of the i-th criterion. The i-weights are estimated using the Shapley measure (see Equation (7)). By integrating (7) into (2), T_p is reshaped as follows:

$$T_p = \begin{bmatrix} Pr_{A_1} \cdot \theta_\mu^{(1)} & \cdots & Pr_{A_1} \cdot \theta_\mu^{(m)} \\ \vdots & \ddots & \vdots \\ Pr_{A_m} \cdot \theta_\mu^{(1)} & \cdots & Pr_{A_m} \cdot \theta_\mu^{(m)} \end{bmatrix} \quad (11)$$

namely,

$$T_p = \begin{bmatrix} Pr_{A_1} \\ \cdots \\ Pr_{A_m} \end{bmatrix} \cdot \begin{bmatrix} \theta_\mu^{(1)} & \ldots & \theta_\mu^{(m)} \end{bmatrix} \quad (12)$$

The $\theta_\mu^{(i)}$ are calculated on the basis of the amount of the criteria. Equation (8) in Section 4 is used for their assessment. On the basis of the values of T_p it is possible, then, to realize the Real Rating Matrix T_r as described within Step 4 of 4.1 in Section 4.

4.3. Computation of Total Gap Matrix (G) and Index Construction with Choquet Measurement

The last step of the proposed analysis model is the construction of the Total Gap Matrix (G) based on the difference between the average of the values extracted from (4) and (5) with the values of the initial evaluation matrix constructed within Step 1. As function of the differentials related to the matrix G, valuation indices are determined for the j-th alternative. By using the Choquet measurement and the algebraic formulation (9) in Section 4, the evaluation index *j* is created.

5. Case-Study

The aim is to assess and analyze the degree of sustainable development of OECD nations in light of the socio-economic and environmental consequences of the COVID-19 pandemic crisis. Each nation must pay close attention to the execution of investments targeted at attaining the sustainable development goals of the Agenda 2030, according to international governmental and other legal measures for the post-COVID-19 recovery period. By gathering information pertaining to the second quarter of 2020, the influence of COVID-19 on the performance of sustainable development within the triple profile of economic-social and environmental for 35 OECD nations was examined (1. Australia, 2. Austria, 3. Belgium, 4. Canada, 5. Chile, 6. Colombia, 7. Czech Republic, 8. Denmark, 9. Estonia, 10. Finland, 11. France, 12. Germany, 13. Greece, 14. Hungary, 15. Iceland, 16. Ireland, 17. Israel, 18. Italy, 19. Japan, 20. Korea, 21. Latvia, 22. Lithuania, 23. Luxembourg, 24. Mexico, 25. Netherlands, 26. New Zealand, 27. Norway, 28. Poland, 29. Portugal, 30. Slovak Republic, 31. Slovenia, 32. Spain, 33. Sweden, 34. Switzerland, 35. Turkey).

The three processes at the core of the MAIRCA-CI integrated assessment model (see Section 4) are used to advance the case study's development in terms of:

Step 1: Defining sustainability criteria and creating the initial study-set evaluation matrix;

Step 2: Weighting the evaluation sustainability criteria;

Step 3: Constructing the sensitivity index with *Choquet* measurement.

Each of the steps above is devolved into a subsection as follows.

5.1. Defining Sustainability Criteria and Creating the Initial Study-Set Evaluation Matrix

To ascertain the sustainable level for the countries under study, acceptable criteria and corresponding performance indicators must be identified while putting up the first decision matrix. The OECD, European Union, and United Nations sustainable development goals were used to generate the sustainable development indicators for OECD nations. The OECD database's Green Growth Indicators were specifically taken into account. The 35 OECD nations are included in the database [81].

The case study's indicators were chosen using clear sustainability benchmarks to highlight the essential elements of green growth: (1) environmental protection; (2) economic productivity; and (3) social well-being. For each significant aspect, indicators characteristic of the reference dimension are considered, such as production-based CO_2 emissions (C1), real GDP per capita (C2), and life expectancy at birth (C3). Through comparable units of measurement, such as tons for C1, dollars for C2, and years for C3, the indicators under consideration are related to measurable things. These metrics were chosen to monitor nations' advancements toward green growth in support of territorial decision-making frameworks. It makes sense to assume that, based on the particular evaluative scenario, further and more indications may also be used.

In addition to the sustainability indicators (C1, C2, C3), the Inform COVID-19 Risk Index (C4) is also taken into consideration as an additional performance indicator to identify countries at risk from health and humanitarian impacts of COVID-19 that could overwhelm current national response capacity, and therefore lead to a need for additional international assistance. The adoption of C4 for each nation supports giving early reaction measures for the key pandemic consequences priority. The following website has information about C4: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-COVID-19 (last accessed: 20 December 2022).

Table 1 provides the initial decision matrix with C1, C2, C3, and C4 values for each of the 35 countries analyzed. Table 2 contains the values numbers of Table 1 normalized by means of the algebraic expression (10) in Section 4 in order to standardize data to the same measurement scale.

Table 1. Initial decision matrix of alternatives assessed under the four criteria.

	Production-Based CO_2 Emissions [Tonnes]	**Real GDP per Capita [USD]**	**Life Expectancy at Birth [Years]**	**Inform COVID-19 Risk Index [0–10]**
Australia	375.98	46,225.27	83.64	2.10
Austria	57.27	48,737.82	81.77	3.00
Belgium	83.31	44,906.81	81.86	2.80
Canada	523.19	43,446.19	82.67	2.00
Chile	79.74	21,662.19	80.42	3.10
Colombia	70.35	12,524.04	77.53	4.30
Czech Republic	84.34	36,059.28	79.57	3.40
Denmark	25.57	52,109.98	81.11	2.10
Estonia	8.60	33,214.55	78.89	3.00
Finland	35.70	44,480.50	82.14	2.10
France	258.23	41,170.83	82.86	3.00
Germany	585.26	47,499.52	81.57	2.20
Greece	46.59	26,536.37	82.47	3.30
Hungary	43.63	30,473.28	77.04	3.40
Iceland	1.47	52,977.67	83.22	2.50
Ireland	31.63	88,490.38	82.51	3.00
Israel	57.97	39,534.71	83.19	2.70
Italy	280.37	35,211.43	83.71	3.20
Japan	1.024.07	40,416.16	84.79	2.30
Korea	570.74	41,654.84	83.20	4.80
Latvia	6.37	28,294.46	75.46	3.40
Lithuania	10.79	35,362.04	76.11	2.80
Luxembourg	7.48	104,591.30	82.47	0.00
Mexico	381.00	16,989.68	75.24	3.70
Netherlands	134.71	52,493.26	82.49	2.50
New Zealand	33.10	40,784.45	82.51	2.10
Norway	36.11	60,470.83	82.63	1.80
Poland	267.64	31,305.22	78.94	3.10
Portugal	37.33	30,997.88	82.29	2.80
Slovak Republic	26.50	31,640.41	77.72	3.30

Table 1. *Cont.*

	Production-Based CO_2 Emissions [Tonnes]	Real GDP per Capita [USD]	Life Expectancy at Birth [Years]	Inform COVID-19 Risk Index [0–10]
Slovenia	11.76	35,061.91	81.54	2.60
Spain	194.79	34,250.05	83.74	2.80
Sweden	32.14	50,412.39	83.03	2.20
Switzerland	34.12	66,240.84	83.97	1.90
Turkey	366.11	28,160.55	77.99	3.90

Table 2. Initial decision matrix, of which the values were normalized by means of formula (10) in Section 4.

	Production-Based CO_2 Emissions	Real GDP per Capita	Life Expectancy at Birth	Inform COVID-19 Risk Index
Australia	0.3662	0.3661	0.8796	0.4375
Austria	0.0546	0.3933	0.6838	0.6250
Belgium	0.0800	0.3517	0.6932	0.5833
Canada	0.5102	0.3359	0.7780	0.4167
Chile	0.0765	0.0993	0.5424	0.6458
Colombia	0.0674	0.0000	0.2398	0.8958
Czech Republic	0.0810	0.2556	0.4534	0.7083
Denmark	0.0236	0.4300	0.6147	0.4375
Estonia	0.0070	0.2247	0.3822	0.6250
Finland	0.0335	0.3471	0.7225	0.4375
France	0.2511	0.3112	0.7979	0.6250
Germany	0.5709	0.3799	0.6628	0.4583
Greece	0.0441	0.1522	0.7571	0.6875
Hungary	0.0412	0.1950	0.1885	0.7083
Iceland	0.0000	0.4394	0.8356	0.5208
Ireland	0.0295	0.8251	0.7613	0.6250
Israel	0.0553	0.2934	0.8325	0.5625
Italy	0.2727	0.2464	0.8869	0.6667
Japan	1.0000	0.3030	1.0000	0.4792
Korea	0.5567	0.3164	0.8335	1.0000
Latvia	0.0048	0.1713	0.0230	0.7083
Lithuania	0.0091	0.2481	0.0911	0.5833
Luxembourg	0.0059	1.0000	0.7571	0.0000
Mexico	0.3711	0.0485	0.0000	0.7708
Netherlands	0.1303	0.4341	0.7592	0.5208
New Zealand	0.0309	0.3070	0.7613	0.4375
Norway	0.0339	0.5208	0.7738	0.3750
Poland	0.2603	0.2040	0.3874	0.6458
Portugal	0.0351	0.2007	0.7382	0.5833
Slovak Republic	0.0245	0.2076	0.2597	0.6875
Slovenia	0.0101	0.2448	0.6597	0.5417
Spain	0.1890	0.2360	0.8901	0.5833
Sweden	0.0300	0.4115	0.8157	0.4583
Switzerland	0.0319	0.5835	0.9141	0.3958
Turkey	0.3566	0.1698	0.2880	0.8125

5.2. Weighting the Evaluation Sustainability Criteria

The Theoretical Rating Matrix (T_p) by estimating the priority factor (Pr_{A_j}) according to the number of reference alternatives (A_j) for the weight of each criterion. The estimation of the i-th weight (with i = 1, . . . , 4) is performed via Equation (8) of Section 3. Table 3 shows the theoretical rating matrix (T_p) related to the case study.

Table 3. The Theoretical Rating Matrix (T_p) where weight factors for each possible combination between the evaluation criteria were defined using the mathematical expression in Section 4.2.

T_p =		{**C1**}	{**C2**}			
	A_j	0.001429	0.000952	0.000952	0.000714	0.167

On the basis of the information included in the T_p, we proceed to create the Real Rating Matrix (T_r) via the mathematical formula described within Step 4 of 4.1 in Section 4. Table 4 presents the Tr specific of the case-study examined.

Table 4. The values of the Real Rating Matrix (T_r) for the case study. Each numerical element was defined by means of the formulas (4) and (5) in Section 3.1.

	C1	**C2**	**C3**	**C4**
Australia	0.001020	0.000811	0.000952	0.000031
	0.000409	0.000142	0.000000	0.000683
Austria	0.000135	−0.000653	−0.000661	−0.000311
	0.001293	0.000173	0.000291	0.000404
Belgium	0.000207	0.001169	0.000674	0.000248
	0.001221	0.000173	0.000278	0.000466
Canada	0.001429	0.000744	0.000800	0.000000
	0.000000	0.000208	0.000152	0.000714
Chile	0.000197	0.000220	0.000451	0.000342
	0.001231	0.000733	0.000502	0.000373
Colombia	0.000171	0.000000	0.000000	0.000714
	0.001257	0.000952	0.000952	0.000000
Czech Republic	0.000210	0.000566	0.000318	0.000435
	0.001381	0.000000	0.000635	0.000280
Denmark	0.000047	0.000952	0.000558	0.000031
	0.001381	0.000000	0.000395	0.000683
Estonia	0.000000	0.000498	0.000212	0.000311
	0.001429	0.000455	0.000740	0.000404
Finland	0.000075	0.082307	0.000136	−0.000009
	0.001353	−0.081355	0.000816	0.000723
France	0.000693	0.076181	0.000137	−0.000008
	0.000736	−0.075229	0.000815	0.000722
Germany	0.001601	0.087894	0.000135	−0.000009
	−0.000172	−0.086942	0.000817	0.000723
Greece	0.000105	0.049097	0.000137	−0.000007
	0.001323	−0.048144	0.000816	0.000722
Hungary	0.000097	0.056383	0.000127	−0.000007
	0.001331	−0.055430	0.000826	0.000722
Iceland	−0.000020	0.098033	0.000138	−0.000008
	0.001448	−0.097081	0.000814	0.000723
Ireland	0.000064	0.163759	0.000137	−0.000008
	0.001365	−0.162806	0.000816	0.000722
Israel	0.000137	0.073153	0.000138	−0.000008
	0.001292	−0.072201	0.000814	0.000722
Italy	0.000754	0.065152	0.000139	−0.000007
	0.000674	−0.064200	0.000813	0.000722
Japan	0.002819	0.074785	0.000141	−0.000009
	−0.001391	−0.073832	0.000811	0.000723
Korea	0.001561	0.077077	0.000138	−0.000005
	−0.000132	−0.076125	0.000814	0.000720
Latvia	−0.000006	0.052350	0.000124	−0.000007
	0.001435	−0.051398	0.000829	0.000722

Table 4. *Cont.*

	C1	C2	C3	C4
Lithuania	0.000006	0.065431	0.000125	−0.000008
	0.001422	−0.064478	0.000827	0.000722
Luxembourg	−0.000003	0.193558	0.000137	−0.000012
	0.001432	−0.192605	0.000816	0.000726
Mexico	0.001034	0.031428	0.000123	−0.000007
	0.000395	−0.030476	0.000829	0.000721
Netherlands	0.000350	0.097137	0.000137	−0.000008
	0.001078	−0.096184	0.000816	0.000723
New Zealand	0.000068	0.075466	0.000137	−0.000009
	0.001361	−0.074514	0.000816	0.000723
Norway	0.000076	0.111901	0.000137	−0.000009
	0.001352	−0.110949	0.000815	0.000724
Poland	0.000719	0.057923	0.000130	−0.000008
	0.000709	−0.056970	0.000822	0.000722
Portugal	0.000080	0.057354	0.000136	−0.000008
	0.001349	−0.056401	0.000816	0.000722
Slovak Republic	0.000050	0.058543	0.000128	−0.000007
	0.001379	−0.057591	0.000824	0.000722
Slovenia	0.000009	0.064875	0.000135	−0.000008
	0.001420	−0.063923	0.000817	0.000723
Spain	0.000517	0.063373	0.000139	−0.000008
	0.000912	−0.062420	0.000813	0.000722
Sweden	0.000065	0.093285	0.000138	−0.000009
	0.001363	−0.092333	0.000815	0.000723
Switzerland	0.000071	0.122580	0.000139	−0.000009
	0.001358	−0.121628	0.000813	0.000724
Turkey	0.000992	0.052103	0.000128	−0.000007
	0.000436	−0.051150	0.000824	0.000721

5.3. Constructing the Sensitivity Index with Choquet Measurement

The Total Gap Matrix (G) is shown in Table 5 as a prerequisite to the building of the assessment index of each country's sustainability level commensurate with the relevant degree of risk from COVID-19. The Choquet Integral is then used to define the sustainable evaluation index of the studied nations (see Section 3.2). The Choquet Integral adopts the following algebraic form in regard to the selected case study:

$$
\begin{aligned}
C_{\mu}(i) = \textstyle\sum_{i=1}^{35}(\{C1\}) \quad & *C1 + (\{C2\}) * C2 + (\{C3\}) * C3 + (\{C4\}) * C4 + (\{C1, C2\}) + (\{C1\}) \\
& + (\{C2\}) \times \min(C1, C2) + [(\{C1, C3\}) + (\{C1\}) + (\{C3\})] \times \min(C1, C3) \\
& + [(\{C1, C4\}) + (\{C1\}) + (\{C4\})] \times \min(C1, C4) \\
& + [(\{C2, C3\}) + (\{C2\}) + (\{C3\})] \times \min(C2, C3) \\
& + [(\{C2, C4\}) + (\{C2\}) + (\{C4\})] \times \min(C2, C4) \\
& + [(\{C3, C4\}) - (\{C3\}) - (\{C4\})] \times \min(C3, C4) + [1 - (\{C1, C2\}) - (\{C1, C3\}) \\
& - (\{C1, C4\}) - (\{C2, C3\}) - (\{C2, C4\}) - (\{C3, C4\}) + (\{C1\}) + (\{C2\}) + (\{C3\}) \\
& + (\{C4\})] \times \min(C1, C2, C3, C4)
\end{aligned} \tag{13}
$$

Table 5. The Total Gap Matrix (G) specifically for the case-study. Their elements (g_{ij}) are deduced from the difference between the normalized values of Table 2 and the average of each couple of values in Table 4.

	C1	C2	C3	C4
Australia	0.713218	0.850867	0.999524	0.043121
Austria	0.144473	0.818277	0.707969	0.347780
Belgium	0.137533	0.230172	0.472907	0.477904
Canada	0.146464	0.594059	0.333130	0.608339
Chile	0.137533	0.230367	0.472907	0.477904
Colombia	0.119280	−0.000476	−0.000476	0.999643
Czech Republic	0.146383	0.594252	0.333130	0.608339
Denmark	0.032267	0.999524	0.585167	0.043121
Estonia	−0.000714	0.522197	0.222244	0.434425
Finland	0.051937	0.806792	0.754358	0.043121
France	0.484396	0.723185	0.871264	0.434425
Germany	1.119901	0.883057	0.659636	0.086599
Greece	0.073108	0.353496	0.808410	0.564860
Hungary	0.067354	0.452948	−0.080540	0.608339
Iceland	−0.014571	1.021443	0.930715	0.217034
Ireland	0.044036	1.918547	0.813449	0.434425
Israel	0.095230	0.681854	0.925186	0.303991
Italy	0.527404	0.572641	1.011237	0.521382
Japan	1.972652	0.704120	1.186907	0.130078
Korea	1.091695	0.735411	0.927541	1.217034
Latvia	−0.005047	0.397908	−0.339219	0.608339
Lithuania	0.003545	0.576446	−0.233241	0.347469
Luxembourg	−0.002888	2.325280	0.807658	−0.869922
Mexico	0.722975	0.112333	−0.375701	0.738773
Netherlands	0.244360	1.009206	0.811322	0.217034
New Zealand	0.046886	0.713424	0.813678	0.043121
Norway	0.052743	1.210731	0.834226	−0.087314
Poland	0.502666	0.473964	0.230718	0.477904
Portugal	0.055113	0.466201	0.778636	0.347469
Slovak Republic	0.034068	0.482432	0.031196	0.564860
Slovenia	0.361099	0.548355	1.015164	0.347469
Spain	0.045021	0.956640	0.898683	0.086599
Sweden	0.048873	1.356490	1.053216	−0.043835
Switzerland	0.694021	0.394525	0.075269	0.825730
Turkey	0.048873	1.356490	1.053216	−0.043835

The {C1}, {C2}, {C3}, {C4}, {C1, C2}, {C1, C3}, {C1, C4}, {C2, C3}, {C2, C4}, {C3, C4} are in Table 3.

6. Discussion

The significance of the interdependencies between pandemic risk and sustainable level at territorial scale can be considered in light of the results (see Tables 5 and 6) obtained by the application of the proposed evaluation model.

The COVID-19 pandemic's effects on each of the 35 nations' partial (Table 5) and overall (Table 6) sustainability performance may be tractable through the MAIRCA-CI model. Even in the presence of uncertainty and variability in the reference decision-making environment, analysis of the numerical values in Tables 5 and 6 enables observations about the performance of each country from the perspective of economic, social, and environmental sustainability.

Table 6. The Table 6 expresses the Choquet Integral index of the 35-countries study. The specific value is obtained by the formula (13).

	$\mathbf{C_{\mu}(i)}$
Australia	1.0301
Austria	0.8259
Belgium	0.5993
Canada	0.7509
Chile	0.5999
Colombia	0.1280
Czech Republic	0.7508
Denmark	0.4008
Estonia	0.3896
Finland	0.4816
France	1.3527
Germany	1.0787
Greece	0.6714
Hungary	0.1758
Iceland	0.6151
Ireland	0.8870
Israel	0.7241
Italy	1.4570
Japan	1.3713
Korea	2.2938
Latvia	−0.2679
Lithuania	−0.1350
Luxembourg	−0.7043
Mexico	−0.0852
Netherlands	0.9129
New Zealand	0.4613
Norway	0.3644
Poland	0.9233
Portugal	0.5978
Slovak Republic	0.3178
Slovenia	1.0762
Spain	0.5829
Sweden	0.5264
Switzerland	0.7605
Turkey	0.5264

The Total Gap matrix of country values for each indicator is shown by Table 5. Each indicator's reading provides information on the change in performance, if any. Observe how a decrease in the danger of pandemic exposure is matched by a marked improvement in the nation's performance, first economically and then socially. Considering the real GDP per capita trade-off values in relation to those typical of COVID-19, for instance, in the countries of Luxembourg, Sweden, and Norway shows how exposure to dangerous occurrences may alter a region's level of productivity and innovation, thereby slowing down the nation's sustainable economic progress [43]. In addition, it is evident that high pandemic risk values correlate with decline in the community's social and physical well-being from the standpoint of social sustainability. Consider the situations of Colombia, Mexico, and Latvia as examples. This demonstrates how a territory's human development, as measured by social welfare within the community, may be influenced by exposure to the danger of population-destabilizing events, whether that exposure is high or low [40].

The performance of nations under each criterion in respect to their own degree of riskiness may also be analyzed using the suggested assessment model, but the MAIRCA-CI model enables a synthetic comparison of geographical realities. In fact, the synthetic index in Table 6 takes into consideration both the COVID-19 risk component and individual variations in sustainability performance. Note that it is a measure of the effect—whether favorable or unfavorable—on the potential for sustainable development in each country. It should go without saying that using a single numerical parameter makes it easier to carry out tasks targeted at resolving ranking situations in relation to the world-wide context of study. Comparisons across geographic realities can be restricted to the year of information retrieval or by calculating the index to a year earlier or before the zero-reference year; it is feasible to compare the loss or gain in sustainable performance by nation.

According to Table 6, Colombia, Hungary, Latvia, Lithuania, Mexico, and the Slovak Republic all saw variations in sustainability performance during the first quarter of 2020, with values for the indicators ranging from 20% to 85%.

The trend line of the index that summarizes each country's sustainability performance and that which refers to its unique risk factor via COVID are shown in Figure 1 as follows. The indicator values for the nations included in the study set are also shown.

The COVID-19 pandemic broke out in the second quarter of 2020, at which time the sustainability performances of the various nations were compared to those of the same quarter the year before. This is to emphasize the influence of the COVID-19 hazard on territorial performance, as in the case study examined, in comparison to a baseline setting free of pandemic risk. The suggested MAIRCA-CI assessment approach is used to reassess the sustainable assessment indices across the 35 research nations. The indices for 2020 and 2019 are suggested in Figure 2. For each country, the percentage difference between the indices is provided.

It is conceivable that some areas' economic, social, and environmental sustainability performance has significantly declined as a result of the information gathered. Some of the first nations to observe the pandemic's quick spread between 2019 and 2020 are France (−16.30%), Italy (−19.66%), and Korea (−27.58%). These circumstances should be explored in light of their insightful characteristics from an environmental, economic, and social point of view. However, depending on how risky they are in terms of COVID-19, as shown by their individual Inform COVID-19 Risk Index scores, there is a minor drop in their sustainability levels. Last but not least, there are examples of nations' own economic, social, and environmental sustainability improving, as in the situations of Luxembourg (+32.62%), Mexico (+14.09%), and Latvia (+12.72%), some of the last nations to be affected by the pandemic catastrophe at the start of the global emergency.

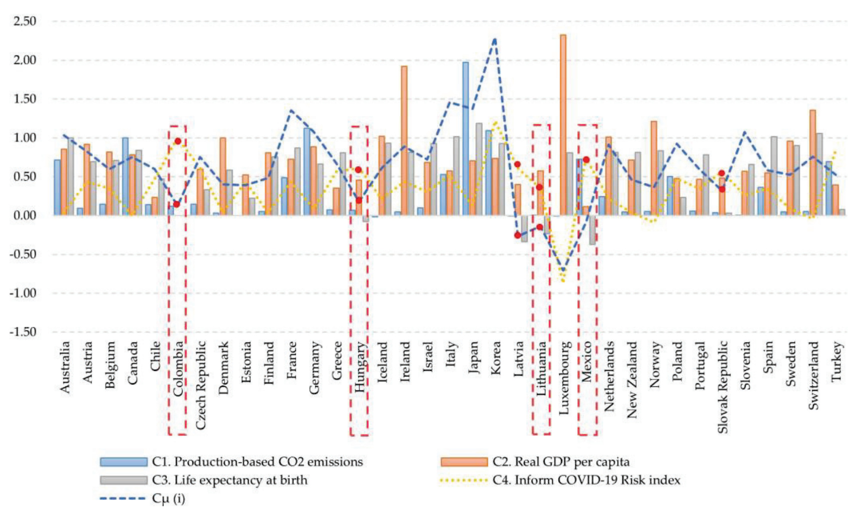

Figure 1. Evolution of the research nations' sustainability levels in respect to their own risk tolerance according to COVID-19. Examples of a strong relationship between territorial riskiness and sustainability are given.

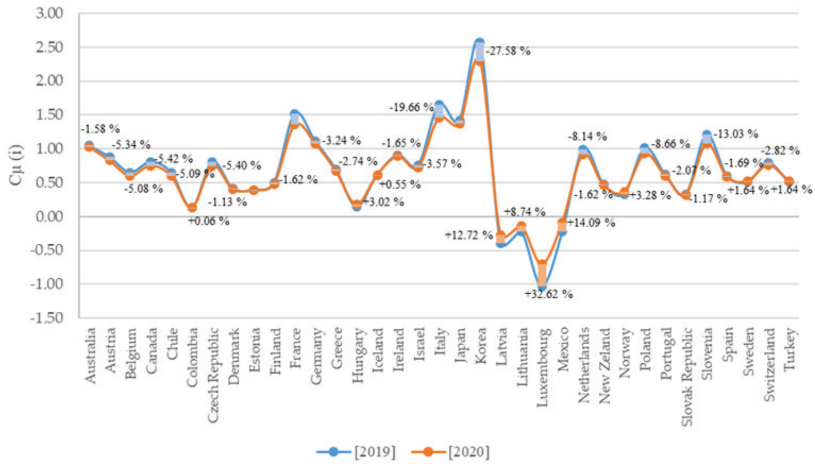

Figure 2. Alterations in the sustainability levels of the study nations, taking into account the corresponding evaluation indices between 2019 and 2020 using the suggested accounting method.

7. Conclusions

In light of the case study's findings, complex decision-making systems can benefit from simplification in their management and resolution due to the MAIRCA-CI model's multi-criteria nature, which enables it to simultaneously take into account various aspects and keys to reading the landscape within a single framework from a sustainability-sensitive perspective. The suggested sensitivity index is even framed as a tool capable of capturing recognized assessment criteria via the use of performance indicators accepted globally by organizations such as the OECD. The use of artificial risk indices of COVID-19, such as the one in the suggested case study, has also made it possible to qualify the suggested assessment model in a dynamic way, allowing for the adaptation and application of the algorithm in a variety of temporal scenarios, even during an epidemic emergency, in order to monitor the long-term viability of the study system. The construction of a synthetic assessment index with which to qualitatively convey the influence that the risk from COVID-19 had on the level of economic, social, and environmental sustainability of the region resulted from the integration of the MAIRCA model with the integral CI. Consequently, methods of monitoring and evaluation at a territorial level are made easier. In particular, policymakers may benefit from the monitoring and assessment phase of sustainability performance trends as they plan and allocate resources for spatial development projects. Understanding the nature of territorial sustainable development aids decision-makers in making sound financial resource allocations and adhering to a distribution criterion suitable for the economic, social, and environmental particularities of the target setting.

The choice of sustainability indicators to be used in the assessment phase, the use of indices that summarize the level of uncertainty related to the disasters in study, and the application of the technique at a scale other than territorial are all examples of research constraints. Regarding this final consideration, research focuses will include putting the proposed MAIRCA-CI model to the test at the city scale, taking a variety of indicators into consideration, and looking into the possibility of expressing the shocks through other measurement indices that are not necessarily qualitative but are more closely related to the dynamics of the relevant territorial/urban context.

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Impacts of the COVID-19 Pandemic and the Russia–Ukraine Conflict on Land Use across the World

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Abstract: The impacts of the COVID-19 pandemic and the Russia–Ukraine crisis on the world economy are real. However, these implications do not appear to be symmetric across countries and different economic sectors. Indeed, the consequences of these two shocks are more severe for some countries, regions and economic activities than for others. Considering the importance of the agricultural sector for global food security, it is important to understand the impacts of the pandemic and the conflict on the different dimensions of agriculture, namely land use. Given the scarcity of data for the last few years available from the various statistical databases, this research mainly considers the insights highlighted in the literature on the implications, in agricultural dimensions, of the most recent shocks. The study here presented shows that the Russia–Ukraine crisis has had more impact on land use changes than the pandemic, namely promoting adjustments in the decisions of farmers and policymakers to deal with constraints in agri-food chains. Nonetheless, the impacts of the conflict on land use were not totally explored.

Keywords: literature review; COVID-19 pandemic; russia–ukraine conflict; land use; food security

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1. Introduction

Land use is interrelated with ecosystem planning [1], sustainability dynamics [2], carbon balance [3] and sink [4], water management [5], habitat dynamics [6] and policy design [7]. Indeed, land use changes, namely those associated with urbanization, have had impacts on the ecological dimensions [8]. Urban land use management requires adjusted approaches to address the complexity of the variables involved [9]. Changes in land use over the last few decades has also had, jointly with other factors, environmental effects with consequences for global warming [10]. Specifically, these changes have impacted soil fertility [11], soil carbon management [12], wildlife populations [13], fish populations [14] and biodiversity [15].

The end of the Soviet Union brought, in the respective geographies, changes in the structure of land use as a consequence of transitions for market economies [16], affecting the agricultural dynamics [17], for example. Cropland abandonment was a reality after the Soviet collapse [18], with implications for rural development. The agricultural sector plays a determinant role for rural populations [19]. In addition to the framework here described, it is worth highlighting the importance of Russia and Ukraine for the grain markets [20], and their vulnerabilities to socioeconomic and environmental factors [21].

The COVID-19 pandemic and Russia–Ukraine conflict have had impacts on several sectors worldwide [22], and the implications on land use are no exception. The ways in which different countries deal with these shocks are different [23], and depend on their internal strategies. The COVID-19 pandemic, for instance, influenced military–political interactions in some contexts [24], as well as the conditions of health assistance [25], medical research [26] and business models [27]. The Russia–Ukraine crisis brought additional challenges to these contexts worldwide [28], specifically in the several dimensions related to human health [29]. The negative effects of this conflict are expected to be serious for healthcare [30], especially among the Ukrainian population [31].

Global warming, COVID-19 and the Russia–Ukraine conflict have become the main concerns of various international stakeholders related to food security [32], due to the impacts on the food supply chains [33] and the uncertainty generated [34]. Some of these contexts, such as those associated with the pandemic, are involved in discussions that are not always unanimous [35].

The scenario described above highlights the relevance of the current contexts associated with climate change, the pandemic and the Russia–Ukraine crisis on the various dimensions of sustainability and across different economic sectors, including land use and agricultural performance. In any case, the most serious challenge seems to be dealing with the constraints on the grain production of leading producers and their respective supply chains. These barriers, reinforced by the conflict among Russia and Ukraine, bring additional concerns for the national and international organizations related to food security. New strategies must be designed to deal with this threat. The land use and the agricultural organization worldwide require reassessments. From this perspective, this research aims to analyze the COVID-19 pandemic and Russia–Ukraine impacts on land use worldwide through a literature survey complemented with statistical assessment and bibliometric analysis.

2. Materials and Methods

To achieve the objectives proposed above, statistical information from Eurostat [36] was considered using monthly, disaggregated data, and a literature survey was carried out based on bibliometric analysis. For the literature review and bibliometric analysis, 316 documents were taken into account; these were obtained from the Scopus database [37], for the topics "COVID-19" and "land use" from a search performed on 1 September 2022. The literature review and bibliometric analysis were focused on the COVID-19 topic, because of the limited number of studies found on the topics Russia–Ukraine conflict/war/crisis and land use.

For the bibliometric analysis, procedures proposed by VOSviewer software [38–40] were followed. The literature review based on bibliometric assessments was conducted in a systematic way, following the research of Moher et al. [41] and Martinho [42–44].

The monthly statistical information was assessed for unknown structural breaks caused by the COVID-19 pandemic and Russia–Ukraine frameworks through the Quandt likelihood ratio (QLR) test; this is a changed version of the Chow test used to find break dates [45]. A structural break in a time series is verified when an abrupt change in a point of the series occurs. These changes may be a consequence of disturbances in the parameters of the framework that originates the data [46]. Testing for structural breaks is a crucial step for studies involving statistical information, particularly for recent time periods after the shocks of the COVID-19 pandemic [47] and the Russia–Ukraine conflict. On the other hand, the findings of these assessments may provide relevant information for several stakeholders, including policy and decision makers, specifically to inform about changes that deserve special attention, and more vulnerable parameters that need specific interventions by national and international organizations. In addition, failure to consider these changes in empirical research may lead to biased results and conclusions [48].

The structural breaks, assessed in the present study, are promoted by specific factors within the framework of the worldwide impacts of the pandemic and conflict. These specific determinants are interesting topics for future research. In this research, the aim was to identify the months since the beginning of the pandemic associated with structural breaks. The variables considered to test structural breaks were selected based on their relationships with land use, taking into account the multidimensional interlinkages of land management. Other variables could be considered, however, finding information on the recent time period is not an easy task.

3. Testing for Structural Breaks

We carried out the QLR test [49] to search for structural breaks (considering a critical value of 3.66 at 5%) in variables related to land use with monthly disaggregated data, following Torres-Reyna [45] and Stata software [46,50,51] procedures. The selection of the variables was dependent on the availability of statistical information for the most recent months worldwide. The intention was to capture the effects of the COVID-19 pandemic and the Russia–Ukraine crisis. In this way, a period from January 2020 (2020m1) until June 2022 (2022m6) was considered. The variables analyzed were the following for the current 27 European Union countries [36]: harmonized indices of consumer prices (HICP, monthly rate of change for all items); actual rentals for housing (ARH, index, 2015 = 100); construction confidence indicator (CCI, seasonally adjusted data, not calendar-adjusted data); and harmonized unemployment rates (HUR, percentage of the population in the labor force, seasonally adjusted data, not calendar-adjusted data, and total unemployment according to the International Labour Organization definition).

The beginning of the conflict between Russia and Ukraine seems to have had more effects, in terms of structural breaks, on the harmonized indices of consumer prices, construction confidence indicator and harmonized unemployment rates (Figures 1–3, respectively), than the pandemic. The structural breaks regarding rentals in the housing market occurred earlier with COVID-19, towards the end of 2020 (Figure 4). These findings may provide support for future studies that intend to consider monthly statistical information, since the beginning of the COVID-19 pandemic, in the European Union context. Overall, the impacts of the pandemic were not, in some circumstances, as severe for some indicators as the Russia–Ukraine crisis.

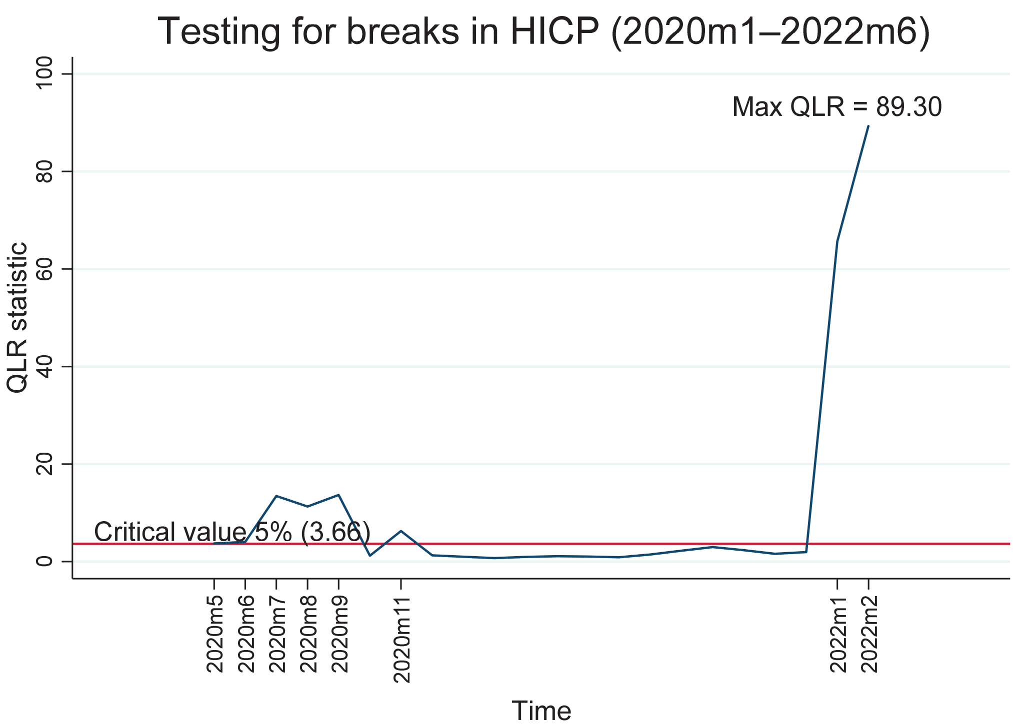

Figure 1. QLR test for the harmonized indices of consumer prices (HICP) over the period 2020m1–2022m6.

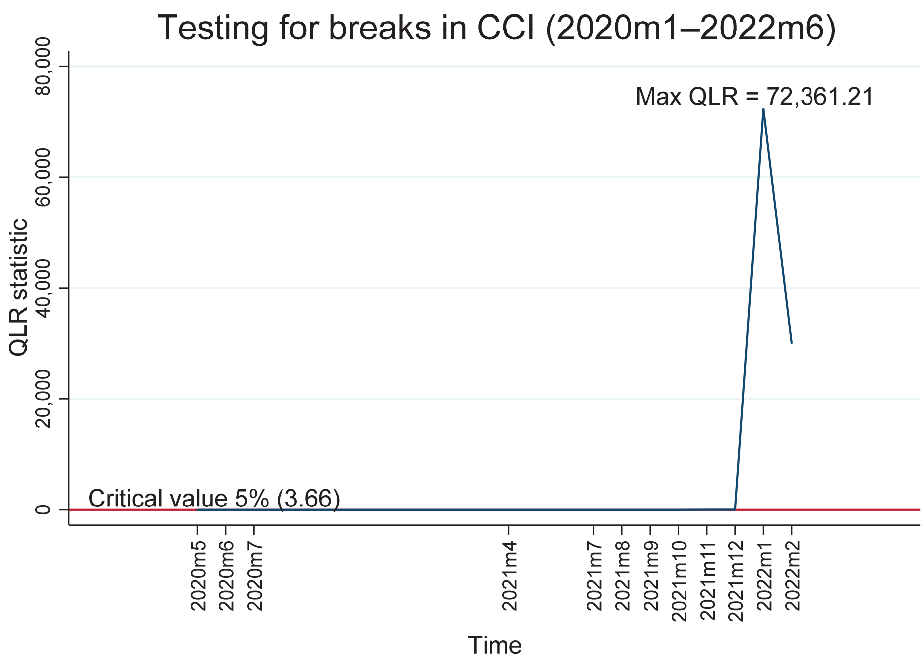

Figure 2. QLR test for the construction confidence indicator (CCI) over the period 2020m1–2022m6.

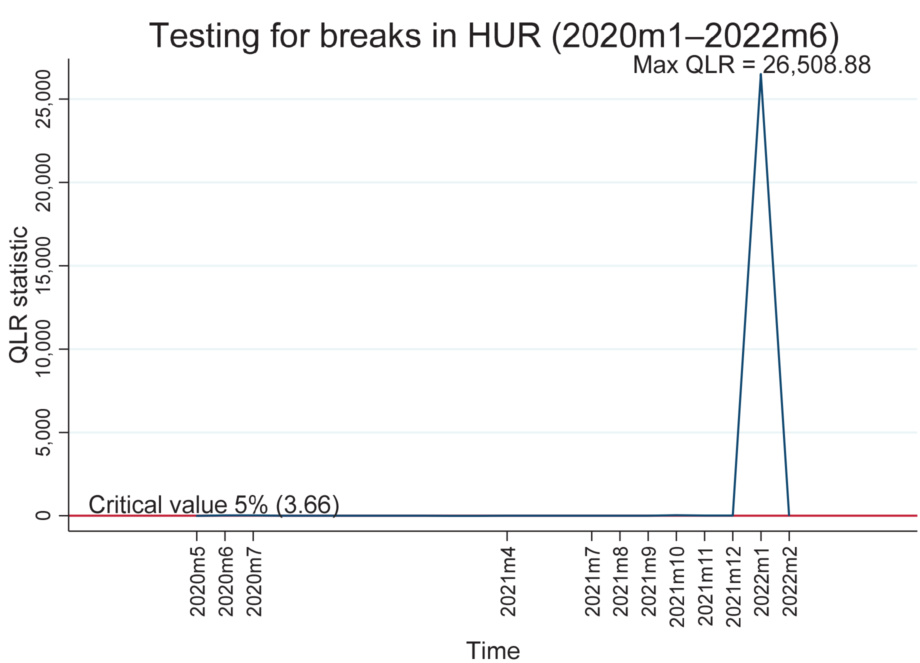

Figure 3. QLR test for the harmonized unemployment rates (HUR) over the period 2020m1–2022m6.

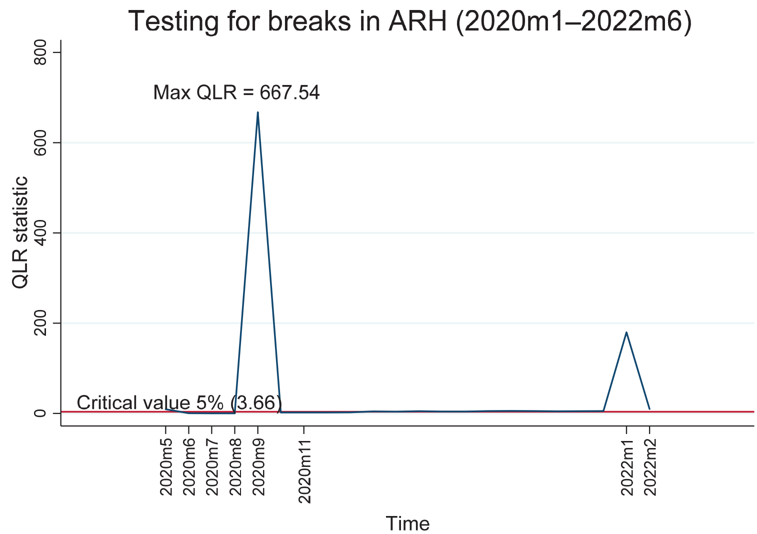

Figure 4. QLR test for the actual rentals for housing (ARH) over the period 2020m1–2022m6.

4. Bibliometric Assessment

Figure 5 and Table 1 show the metrics obtained with text data, considering terms as items. This information was found through binary counting, which means that the number of occurrences represents the number of documents in which the term appears. The information in Figure 6 and Table 2 was also obtained through text data and considers terms as items, but with full counting (the occurrences symbolize the total number of occurrences of a term in all documents). The dimension of the circles and respective labels in Figures 5 and 6 are proportional to the number of occurrences. In these figures, each color is associated with a cluster, and the proximity between the terms is related to the relatedness [39].

Table 1. Top 20 terms with the highest occurrences found in text data for the topics "COVID-19" and "land use", applying binary counting with 1 as the minimum number of occurrence of a term.

Terms	Occurrences	Average Publication Year	Average Citations	Average Normalized Citations
matter	11	2021	3	2
feature	10	2021	9	1
century	9	2022	1	0
sensing	8	2021	2	0
vehicle	8	2021	3	0
wave	7	2021	8	1
pollutant	6	2021	2	2
cluster	5	2021	4	1
disease risk	5	2021	10	1
insecurity	5	2021	4	1
island	5	2021	3	0
mix	5	2022	5	1
satellite	5	2021	4	1
temperature	5	2021	4	1
test	5	2021	14	2
accuracy	4	2022	4	1
actor	4	2022	2	0
agency	4	2021	16	1
body	4	2021	9	1
conference	4	2022	0	0

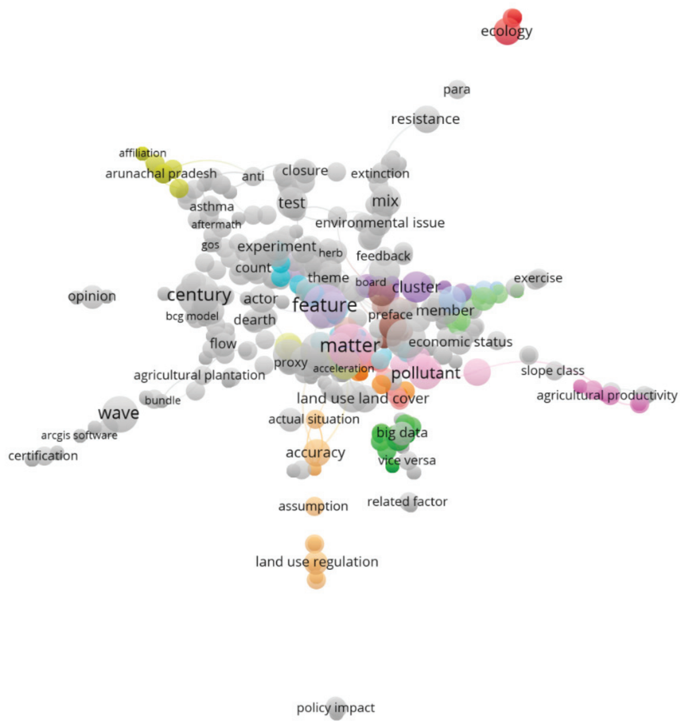

Figure 5. Network visualization map constructed from text data, considering terms as items, for the topics "COVID-19" and "land use", applying binary counting with 1 as the minimum number of occurrence of a term.

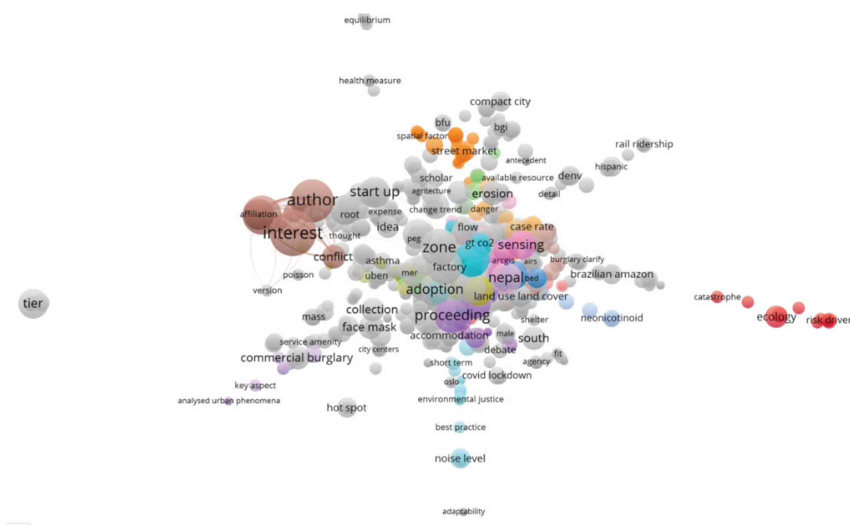

Figure 6. Network visualization map constructed from text data, considering terms as items, for the topics "COVID-19" and "land use", applying full counting with 1 as the minimum number of occurrence of a term.

Table 2. Top 20 terms with the highest occurrences found through text data for the topics "COVID-19" and "land use", applying full counting with 1 as the minimum number of occurrence of a term.

Terms	Occurrences	Average Publication Year	Average Citations	Average Normalized Citations
interest	26	2022	1	0
author	23	2022	1	0
declaration	19	2022	2	0
zone	17	2021	1	1
bioaerosol	15	2021	8	1
gtc yr	15	2020	611	15
proceeding	14	2021	0	0
adoption	13	2021	3	1
financial interest	12	2022	0	0
matter	12	2021	3	2
Nepal	12	2021	3	0
start up	12	2022	0	0
vehicle	12	2021	4	0
Africa	11	2021	3	1
awareness	11	2021	5	1
content	11	2020	9	0
personal relationship	11	2022	0	0
S. baicalensis	11	2020	10	0
soc	11	2022	0	0
temple	11	2022	0	0

In Tables 1 and 2, the average publication year is the average publication year of the documents where the terms appear, the average citations are the average number of citations obtained by the documents where the terms appear, and the average normalized citations were used to correct for the fact that older documents may have more citations than more recent papers [39].

The metrics in Figure 5 and Table 1 demonstrate that terms such as sensing, vehicle, wave, pollutant, disease risk, insecurity, island, temperature and test are among the items with the highest number of occurrences for binary counting (number of documents where the term appears at least once). Some of these terms also appear when considering the top 20 items for full counting (Figure 6 and Table 2), jointly with other terms; for example, Africa and personal relationship. These top 20 terms identified for binary and full counting reveal the concerns of the scientific community in some specific contexts, such as Africa, and with the several dimensions associated with the pandemic, namely those relatedwith impacts on human life.

Table 3 presents the bibliographic data and bibliographic coupling links used in this study. To identify the top 20 documents, the metric total link strength (total strength of the links associated with each document) was considered. These documents will be considered in the next section for a systematic literature review. The consideration of using bibliometric analysis to support a systematic literature survey has been previously considered, for example, by Martinho [42–44].

Table 3. Top 20 documents with the greatest total link strength found using bibliographic data and bibliographic coupling links for the topics "COVID-19" and "land use", applying full counting with 0 as the minimum number of citations of a document.

Documents	URL	Total Link Strength	Citations	Normalized Citations	Publication Year
ferreira m.n. (2021) [52]	https://doi.org/10.2305/iucn.ch.2021.parks-27-simnf.en	110	6	1	2021
lawler o.k. (2021) [53]	https://doi.org/10.1016/s2542-5196(21)00258-8	104	9	1	2021
wu t. (2021) [54]	https://doi.org/10.1007/s13280-020-01497-4	94	27	4	2021
shaer a. (2021d) [55]	https://doi.org/10.1080/17549175.2021.1995028	87	1	0	2021
talukder b. (2022) [56]	https://doi.org/10.1016/j.onehlt.2022.100416	86	0	0	2022

Table 3. *Cont.*

Documents	URL	Total Link Strength	Citations	Normalized Citations	Publication Year
rivera-ferre m.g. (2021) [57]	https://doi.org/10.1016/j.agsy.2021.103134	79	16	2	2021
roberts m. (2021) [58]	https://doi.org/10.1016/j.epidem.2021.100523	74	1	0	2021
shaer a. (2021a) [59]	https://doi.org/10.1016/j.jth.2021.101244	74	4	1	2021
shaer a. (2021c) [60]	https://doi.org/10.1016/j.cities.2021.103255	74	12	2	2021
plowright r.k. (2021) [61]	https://doi.org/10.1016/s2542-5196(21)00031-0	73	49	7	2021
white r.j. (2020) [62]	https://doi.org/10.1111/mam.12201	69	54	1	2020
albers h.j. (2020) [63]	https://doi.org/10.1007/s10640-020-00449-6	65	6	0	2020
mouratidis k. (2021) [64]	https://doi.org/10.1016/j.landusepol.2021.105772	60	11	2	2021
wang j. (2021) [65]	https://doi.org/10.3390/ijerph18147561	60	6	1	2021
reaser j.k. (2021) [66]	https://doi.org/10.1111/rec.13357	56	13	2	2021
shaer a. (2021b) [67]	https://doi.org/10.1016/j.tranpol.2021.08.016	54	2	0	2021
reaser j.k. (2022) [68]	https://doi.org/10.1111/conl.12869	53	2	3	2022
barbier e.b. (2021) [69]	https://doi.org/10.1016/j.jeem.2021.102451	53	4	1	2021
budiman i. (2021) [70]	https://doi.org/10.33396/1728-0869-2021-4-15-24	53	2	0	2021
wali b. (2021) [71]	https://doi.org/10.1016/j.healthplace.2021.102659	49	9	1	2021

5. Literature Review Based on Bibliometric Analysis

The relationships between the land use dynamics and the COVID-19 pandemic are multidimensional, as is highlighted in Table 4. In fact, the land use changes promoted by the need for urban expansion, climate change and farming intensification to deal with the increased demand for food have impacts on the host habitats of pathogens of infectious diseases. The consequence of this is the transmission of these diseases to the human population and their spread worldwide through transportation systems. On the other hand, these consequences have impacts on land use through feedback loops that are self-reinforced.

Table 4. Contributions from the top 20 documents with the highest total link strength.

Documents	Objectives	Insights about COVID-19 and Land Use
ferreira m.n. (2021) [52]	Overview of zoonotic diseases	Land use change influence the emergence of new zoonotic diseases
lawler o.k. (2021) [53]	Explore the feedback loops between the zoonotic diseases causes and consequences	Climate change and land use change are among the drivers of zoonotic diseases
wu t. (2021) [54]	Review how ecosystem change, meat consumption, urban expansion and connectivity among regions and countries are interrelated with the emerging infectious diseases	Meat consumption and land use change promote the pathogen transmissions from animals to humans
shaer a. (2021) [55]	Assess the impacts of the COVID-19 pandemic on active mobility of men and women in Iran	Active mobility during the pandemic was affected by the built environment
talukder b. (2022) [56]	Understand the factors that influenced the origin of COVID-19	Land use and land cover changes are among the planetary health drivers of the COVID-19 pandemic
rivera-ferre m.g. (2021) [57]	Analyze the feedback loops among the pandemics and the food systems	Food systems have impacts on land use changes and consequently on the pandemic
roberts m. (2021) [58]	Review the dimensions of wildlife–human interfaces and the appearance of infectious diseases	The emerging zoonotic diseases are promoted by anthropogenic factors, including the land use changes
shaer a. (2021) [59]	Analyze the changes in the factors that influence the active mobility of older adults in Iran during the pandemic	Land use characteristics are among the main factors that influence the active mobility during the crises
shaer a. (2021) [60]	Evaluate the implications of the pandemic on the active mobility in Iran	The conditions of the built environment are the main drivers of active travel

Table 4. *Cont.*

Documents	Objectives	Insights about COVID-19 and Land Use
plowright r.k. (2021) [61]	Investigate the relationships between land use changes and emerging zoonotic diseases from a landscape perspective	Multidisciplinary cooperation is needed to protect the landscape conditions that mitigate the risks of infectious transmissions from animals to humans
white r.j. (2020) [62]	Review land use changes and pathogen spillover	Forest degradation, urban expansion and farming intensification impacts the zoonotic diseases emergence and spread
albers h.j. (2020) [63]	Highlight potentialities to consider diseases spread dimensions in human behavior assessments	Multidisciplinary approaches are needed to address the human-environment relationships
mouratidis k. (2021) [64]	Evaluate the impacts of the pandemic on the quality of life	Land use was changed during the COVID-19 pandemic
wang j. (2021) [65]	Review built environment and COVID-19 risks	Built environment is interrelated with the transmission risks
reaser j.k. (2021) [66]	Assess ecological strategies to mitigate zoonotic diseases	Ecological restoration strategies may reduce the risks of pathogen spillover
shaer a. (2021) [67]	Analyze the mobility of older adults during the COVID-19 pandemic	The transportation framework impacted the mobility under pandemic conditions
reaser j.k. (2022) [68]	Investigate the landscape immunity framework	The environment is modified by changes in the land use and this impacts the relations among the pathogens and their hosts
barbier e.b. (2021) [69]	Assess the risks of diseases transmissions	Wildlife Habitat conservation is crucial to reduce the risks of infectious pathogen spread
budiman i. (2021) [70]	Review human–nature relationships	COVID-19 pandemic impacted the land use, namely the forest management
wali b. (2021) [71]	Investigate the relationships between pandemic consequences and built environment	Built environment has implications on the COVID-19 pandemic severity

These frameworks require adjusted policies designed and implemented by national institutions and international organizations, primarily to preserve and restore ecological conditions and landscape immunity. Land use management in cities and the respective built environment also impacts the conditions experienced by populations during the pandemic outbreak, specifically in terms of mobility; this deserves special attention from urban policy and decision makers.

6. The Main Results

The main objective of this research was to analyze the relationships between land use, the COVID-19 pandemic and the Russia–Ukraine crisis. To achieve this aim, a systematic review based on bibliometric analysis was carried out. For the bibliometric analysis, 316 documents were considered from the Scopus database in a search performed on 1 September 2022 for the topics “land use” and “COVID-19”. This study focused on these topics, because for the topics “land use” and Russia–Ukraine crisis/conflict/war the number of documents found was negligible. In addition, with statistical information from Eurostat, the structural breaks of some variables were tested. The variables selected to assess the structural breaks were those with available data for the recent months and that were in some way related to land use.

The structural breaks assessment shows that the Russia–Ukraine conflict had more impact on the prices, employment market and construction confidence indicator than the COVID-19 pandemic. The consequences of the pandemic were greater on the actual rentals for housing, however, not at the beginning. The bibliometric analysis carried out with text data (considering terms as items) and bibliographic data (bibliographic coupling as links and documents as links) highlights the relevance of the following terms for the scientific community: matter, feature, century, sensing, vehicle, wave, pollutant, disease risk, insecurity, temperature, test, zone, bioaerosol, Africa and awareness. The African context is, in fact, a concern for researchers and policymakers in the context of pandemic spread mitigation.

The literature review based on bibliometric analysis reveals the importance of land use changes for the emergence of the zoonotic diseases and spread. Indeed, deforestation, urban expansion and pressures on the food systems are among the main drivers of habitat loss for pathogens of infectious diseases, and their consequent transmission to the human population. This is particularly worrying as these frameworks may become self-reinforced processes through feedback loops, where the land use changes promote zoonotic disease emergence and the respective outbreaks may alter the land management.

The main findings are summarized in Figure 7.

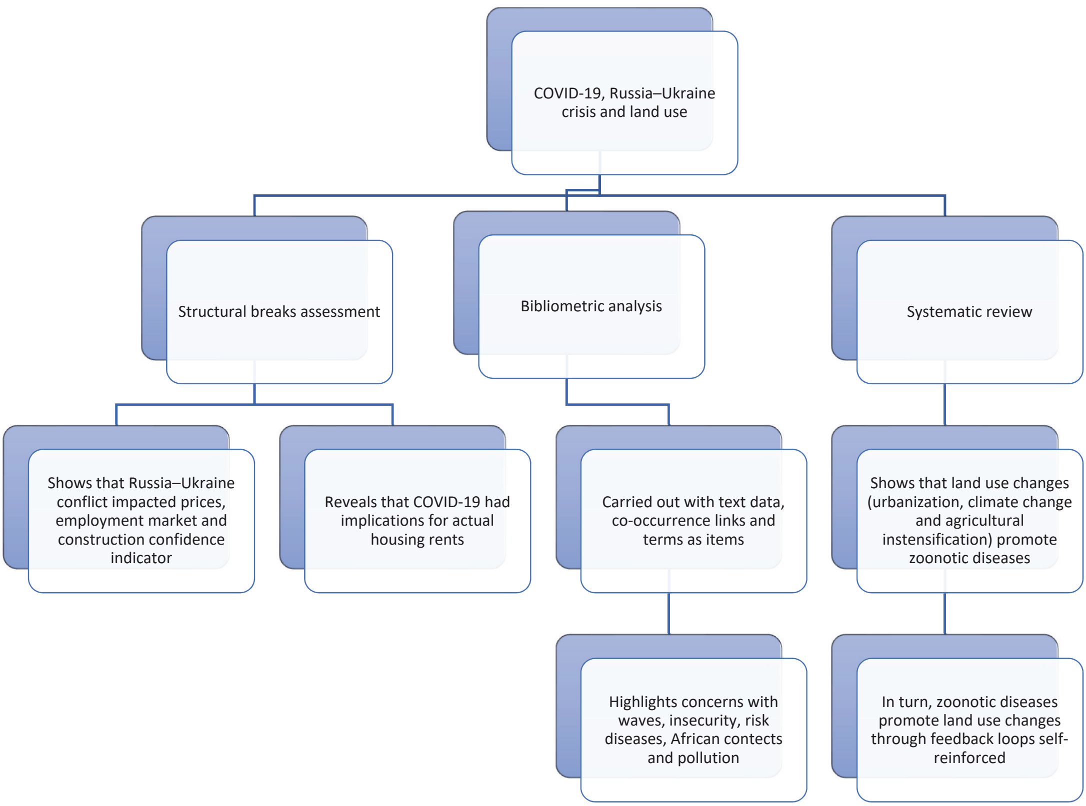

Figure 7. Main results of this research obtained via structural breaks analysis, bibliometric assessment and systematic literature review.

7. Discussion of the Main Findings

The impacts of the unexpected shocks on variables associated with several dimensions of human life and their interrelationships are, in general, worrying, and require specific and adjusted assessments [72]. This means that it is important to be aware of the possibilities of structural breaks in the statistical information considered for empirical studies, and to adequately deal with this possibility [73]. The COVID-19 pandemic had effects on the evolution of several indicators [74], as did the Russia–Ukraine conflict. Nonetheless, the existence of structural breaks during the COVID-19 pandemic was not verified in all variables [75,76], showing that there are sectors, activities and regions that are more vulnerable to these unexpected events. In any case, the presence of structural breaks requires adequate approaches that improve the robustness of the findings obtained [77].

Testing for structural breaks is important for several socioeconomic and environmental domains, including sustainability assessments [78], use of natural resources [79], social indicators [80], industry dynamics [81] and characteristics of agricultural markets [82]. The results obtained in this study are in agreement with those found in the scientific literature and highlighted above in this section. In fact, COVID-19 and the Russia–Ukraine conflict have had impacts on several variables, and this must be taken into account in assessments with statistical information from periods since the beginning of the pandemic.

The application of bibliometric analysis to carry out a systematic literature review has already been explored in the literature [42–44], but has not been fully explored in the topics covered here ("land use" and "COVID-19"), highlighting the novelty of this research. Indeed, bibliometric analysis allows one to find the most relevant items, namely documents, and this is particularly relevant when one intends to perform a literature review on topics where the availability of scientific literature on scientific platforms is numerous. Furthermore, bibliometric assessment also allows one to identify trends and gaps to be explored. The findings obtained with the bibliometric evaluation in this study highlight the concerns about the impacts of the pandemic on the different waves, the respective feelings of insecurity and the implications in other dimensions related, for example, to pollution and environmental changes. In turn, these findings reveal that there are topics that deserve further exploration, such as those associated with the Russia–Ukraine crisis and land use.

8. Conclusions, Practical Implications and Policy Recommendations

The COVID-19 pandemic and the Russia–Ukraine conflict have been external shocks for countries worldwide, with impacts on socioeconomic and environmental indicators. In these contexts, if the pandemic seemed to have serious implications for human life in its several dimensions, the Russia–Ukraine crisis brought unexpected socioeconomic consequences, namely those related to inflation and supply chains. This conflict seems to have different dynamics, with distinct effects from those associated with the pandemic. In fact, for the pandemic, there was a common enemy for all countries, but in the Russia–Ukraine conflict, the world is divided with different "enemies".

In addition, these shocks overshadow older challenges and, in some cases, exacerbate them. Concerns about climate change and land use, for example, were passed for a second plan during the pandemic, and this increased the problems associated with global warming. In practice, land use changes have increased the risks of zoonotic diseases and, on the other hand, pandemics promote changes in land use. International conflicts have negative effects on these processes. Particularly for the Ukraine context, the conflict has had severe impacts on land use management, for example, in the agricultural production. This deserves special attention, as Ukraine produced (Gross Production Value (constant 2014–2016 thousand I$)), in the period 2018–2020, about 2% of the total world's cereals and about 3–4% of the world's wheat [83].

In terms of practical implications, the present research highlights the urgent need to create a culture of ecological and landscape preservation and restoration, specifically to maintain habitats and biodiversity. On the other hand, statistical assessments conducted since the beginning of the pandemic should consider the structural breaks identified here. For policy recommendations, we suggest designing policies to break the self-reinforced processes by the national and international organizations, because the natural dynamics seem unable to mitigate the current trends of degradation. For future research, it is important to find alternative information to show the specific impacts of the Russia–Ukraine crisis and pandemic on land use worldwide.

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Data and Values: Axiological Interpretations of Building Sprawl Landscape Risk in the Rural Territory of Noto (Italy)

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Abstract: This research concerns the issue of landscape risk due to the progressive spread of construction in rural areas through the creation of a "site-specific" analysis and evaluation model and its application to the context of the municipal area of Noto (Italy). The phenomenon of construction in rural areas was facilitated by the regulatory evolution of the Sicilian Region, which supported the construction of artifacts in agricultural areas to boost cultivation and production, but which, for the most part, was intended for seasonal residential use. In particular, the municipal territory of Noto is characterized by remarkable landscape values, including very low building density, large portions of the territory remaining almost uncontaminated, and the widespread presence of cultural and ethno-anthropological assets. Consequently, the demand for localization in rural areas, now also driven by the tendency to decongest dense urban areas in order to contain the effects of the pandemic, is a phenomenon that must be countered, on the one hand, and addressed and regulated on the other. The objective of this study is to provide the local administration with a planning tool to determine permissible interventions in various areas of the landscape context. This has guided the process of representing the phenomenon in quantitative and spatial terms, and of evaluating the territory targeted. A large set of data, coordinated in a hierarchical set of indices by means of a multidimensional valuation approach, allows us to provide an orderly and robust representation of the resilience of the landscape at risk from building pressure while considering multiple perspectives.

Keywords: rural landscape; building pressure; landscape resilience

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1. Introduction

This paper deals with the issue of the urbanization of rural territory within landscape contexts, typically characterized by the delicate equilibrium of anthropological and natural values and leading to protection and land use policies. The research method and experiments converge toward the creation and application of a value-based information system strictly structured according two dimensions of the issue: on the one hand, the value of the landscape, on the other hand, the extent, intensity, and speed of the urbanization process.

1.1. Disciplinary Premises—Landscape Risk: Land Planning and Valuation

The evaluation of the impact on rural landscapes of the progressive extension of building activity in extra-urban areas raises various conceptual concerns. A coherent interdisciplinary sphere converges towards the formation of "command and control" patterns aimed at the process of increasing real estate capital, enhancing land capital, protecting natural capital and promoting cultural capital [1].

The two disciplinary areas involved are Spatial Planning and the Science of Value and Valuation; the latter—traditionally referred to as "Appraisal"—is currently subject to debate about the evolution of its disciplinary foundations and operational perspectives [2].

This research provides further elements that contribute to defining the conceptual and operational limits between the “order of values” and the “creativity of the design gesture” “in reason and truth”, i.e., through the systematization of an extensive and articulated information base and a coherent and traceable evaluative method, capable of justifying the regulatory direction that constructively integrates values and interests.

These two disciplinary areas, therefore, interpret the notions of territory and landscape from two different perspectives: Land Use Planning as systems of rules, and the Science of Valuation as systems of values. More generally: from the perspective of Land Use Planning, a landscape is the result of the progressive adaptation between artificial and natural space. It is the consequence of the way human [3] relationships are represented by institutions that rule territories; from the perspective of the Science of Valuations, a landscape is the shape of a territory, hence the more general cognitive and operational dimension that should inspire the formation of values at the basis of civil coexistence. The basic difference lies in the fact that the former has a positive and prescriptive view of the landscape, and the latter an axiological and normative view.

Both the positive dimension (which refers to the support of the physical and sociological sciences) of planning and the normative perspective (which searches for convergence between the efficiency and equity of land transformation processes) of assessment science defend the scientific soundness of landscape interpretation from the arbitrariness of planning choices and the relativism of the values that support them. These are all the more solid as they relate to “the prospect of a better world”, and thus, to the unamendable goals of landscape preservation, eco-socio-systemic sustainability, and territorial safety [4,5].

Scientific soundness is a success factor for participatory decision-making processes [6–11] that take into account the plurality of perspectives that accumulate around an issue, such as the one addressed here, which involves a broad spectrum of values, many of which are opposed [12].

In conceptual and methodological terms, the convergence between the “rules of value and evaluation” and the “(meta-)planning gesture” depends on sharing the notion of a landscape as a “Formal constitutive entity”, and as such, the reference of value judgments [13] and planning measures and the highest expression of the “value reality” of the territory.

These disciplinary directions reinforce and exceed the contents of the European Landscape Convention, proposed by the Council of Europe and signed in Florence in 2000 [14], which defines a landscape as “an essential aspect of the life framework of populations, contributing to the elaboration of local cultures and representing a fundamental component of Europe’s cultural and natural heritage”, no less than a fundamental economic resource; a landscape is rather an overall dimension of moral, civil and economic issues, not just an “expression of territory”. A profound rethinking of policies affecting the continuous modification of territories is now necessary.

The processes of landscape reworking are changing the faces of cities and territories day by day, creating landscapes in which it is increasingly difficult to trace the traditional codes or statutes of places that seem to be characterized by disorder, perhaps apparent in [15–30].

The market regulates the allocation of wealth, which the state turns into social value-stock aimed at reducing social subjects’ exposure to environmental fluctuation: the landscape constitutes axiological–normative and prescriptive–design references, according to which social systems are coordinated, to reduce environmental risk [31–44].

As it represents the shape of the land, the landscape stands out as the highest expression of the orderly combination of wealth and value [45–48]; the dichotomy between wealth and value is represented in the land’s shape through the interaction between the expansion of building stock and the value system of the rural landscape, as well [49–52]. Land use planning defines the sustainable enhancement goals, which agricultural policies achieve through the production of added value that can be captured and treasured in landscape value stocks.

1.2. Contents and Aims

The intense processes of urbanization that took place in Italy from the late 1960s have caused radical transformation of the Italian rural landscape. This has triggered profound changes not only in the localization of residential functions, but also in the whole organizational structure of the territory.

Associated with this long-term process are the medium- and short-term ones, respectively, the effects of the economic crisis of 2008–2012 and the effects of the distressed condition of all economies struggling with the pandemic. The latter led to a new course in economic policy and project-based planning. The former experiments with new forms of centralization and interventionism by the state, with the disbursement of substantial public funds to support the sectors most significantly linked to the ecological transition, but also the most strategic, i.e., those most capable of multiplying national income per unit of investment, due to the high degree of sectoral interdependence (construction, energy and culture). Project-based planning activates and experiments with new private–public partnerships and participative processes for the broadest possible involvement of stakeholders in order to produce public expenditure proposals within the envisaged timeframe in such a way that resources are not wasted. In this new socio-economic context, subsidies for sustainable building and the need to recover the small town centers of inland areas according to the Piano Nazionale Borghi (National Boroughs Plan) have also spurred interest in the intensification of urbanization in rural areas, a context lacking in urban and landscape constraints and with low resilience against the technological potential of the building and infrastructure sector, especially where publicly financed. In this recent situation, it is possible to delineate the risk of the new and exacerbated dimensions of the post-COVID rural landscape.

The aim of this research is to represent the extent and value of the impact that the gradual expansion of building production in suburban areas has on the rural landscape. The objectives are twofold: on the one hand, we aim to show the extent to which the landscape is able to bear the building load, and on the other hand, we present the reasons why building permits need to be gradually limited because of the resilience of the landscape units affected by farmland building [53–56].

The experimental context for this representation is the municipal territory of Noto (Italy), chosen from among the 21 municipalities in the province of Syracuse because of its considerable extension and the high value of the rural landscape at risk. The built heritage is mostly represented by Noto, one of the eight old towns in south-eastern Sicily declared a UNESCO heritage site in 2002; there are also 22 hamlets, 17 of which are in the hinterland and five along the coast (Figure 1).

Figure 1. Territorial framework of the municipality of Noto: (**a**) the province of Syracuse in the region of Sicily; (**b**) the municipalities in the provinces of Syracuse and Ragusa; (**c**) the territory of the municipality of Noto (our processing).

The excessive building production in the rural landscape has several reasons, including the shortcomings of the national legislation. In agricultural areas (defined as *Zone—E*), Italian Town Planning Legislation allows only developments that are functional to farming, including residential ones. However, this principle lacks detailed rules, except the definition of a maximum Floor Area Ratio (FAR) for residential buildings that allows approximately one dwelling per hectare.

In several cases, regional legislations, i.e., in Tuscany, have introduced more efficacious rules for regulating building activity in rural areas, but this is not the case in Sicily. There, Regional Law no. 71/1978 [57]—amended in 2002, repealed by Law no. 19/2020 [58] and reintroduced by Law no. 2 in 2021 [59]—loosens the limits on building in agricultural areas, triggering a process of progressive colonization of agricultural land. This process has taken place in the most evocative and uncontaminated rural areas, not sheltered by the protection measures that instead affect parks and reserves. Therefore, these areas are more exposed to landscape risk [60–62]. Regional law no. 71/1978 was originally intended as a tool for easing the development of agriculture by allowing the construction of the required facilities. However, its broad interpretation and several amendments have progressively allowed the sprawl of industrial buildings not related to agriculture, outside the planned industrial estates. The restriction to agricultural facilities was gradually repealed, even allowing commercial buildings or other activities funded by European and national funds.

The broad disciplinary field explored by this study is in trouble in terms of both its knowledge bases and the tools available for critical observation of the urbanization of rural areas. In fact, although this phenomenon has developed according to individual freedoms and within the limits of property rights, it has reached a vast scale, with redistributive effects of territorial wealth and significant impacts on landscape value [63].

Furthermore, the degree of almost total irreversibility of the building phenomenon, and moreover, attitudes to the obsolescence (physical, technological, functional, economic and typological) of building artifacts should discourage "tactical"—and thus, short-term—territorial policies, in favor of long-term strategies centered on resilient values that provide more support for the inertia than the dynamics of territories that are characterized by rarefied landscape connotations and are therefore easily attacked [64].

The concept of resilience, which has declined in the field of rural landscapes, is the convergence point of the cognitive and operational aspects of this study. Assuming that a landscape represents the shape of a territory, the persistence of it in the face of urban contamination is a factor that can be used to measure its resilience. This capacity can manifest as the aptitude of: maintaining recognizability even in the face of transformations incoherent with the original shape; metabolizing negative impacts by integrating them into the existing shape; and considering these transformations opportunities for the natural evolutionary course of the territorial identity.

According to the three dimensions of risk, "landscapes at risk" are affected by "landscape risk", the hazard of significant changes in the socio-economic structure, triggering irreversible transformations of the most vulnerable components of the unitary and recognizable shapes of the most exposed (valuable) parts of the territory.

As a consequence, support for the agricultural sector should focus on the conservation of agrarian capital components related to resistant and structural landscape components—the shape of the rural territory—that characterize the uniqueness of the cultural mosaic, and the work forces engaged in it, rather than its real estate contamination [65,66], together with the work forces originating from outside.

According to the aforementioned relationship between assessment and planning, this study interprets this type of landscape risk with reference to the category of territorial capital as the underlying potential of resilient formal landscape units. Spatial planning is responsible for increasing the volume of social capital if the added value, in terms of collective service flows, is integrated in the increase in the landscape value stock [67–80].

In fact, the progressive shift in real estate [81,82] interest from dense urban contexts to the countryside has triggered a phenomenon whose control is based on the representation of the landscape, articulated in successive phases (observation, the construction of information and the evaluation of both the rural landscape and the building phenomenon), carried out on the basis of official databases using methods and tools for turning the data into information and the latter into evaluations [83].

Although the urbanization of rural and/or agricultural areas [84–87] has taken place in the agricultural territory of Noto in accordance with the regulations in force, the quality of the unconstrained areas has increased their locational advantage, leading to a form of "sprawl" [88–100] that results in uncontrolled urban expansion with low population density, except in coastal areas [101–110].

The case of Noto was approached by integrating the interfaces and the capabilities of a spreadsheet and a Geographic Information System (GIS) into a multidimensional analysis and evaluation model in order to organize the mass of available data through an organic and oriented set of queries, interpretations and correlations aimed at understanding and representing the way in which the rural landscape has undergone this drift [111–116].

This study is divided into six parts. Section 2 describes some of the characteristics of the agricultural territory of Noto with reference to the provincial- and municipal-scale planning instruments in force; Section 3 presents the method used to approach the representation of the value of the landscape risk due to the combination of the evolution of buildings and the characteristics of the agricultural landscape; Section 4 describes the procedure by which the model was applied and the results in terms of the overall assessment of the resilience of agricultural land affected by building expansion; Section 5 discusses the results, highlighting the limitations of the model, prospects for further research and the possibilities of extending the model; Section 6 outlines the main conclusions.

1.3. Rural Landscape

In 2000, the European Landscape Convention provided a clear and broad definition of a landscape: "Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" [14].

UNESCO's World Heritage Committee already agreed, in 1992, on revised operational guidelines specifying that cultural landscapes can be protected in accordance with the 1972 World Heritage Convention [117–120]. In 1995, the Committee of Ministers of the Council of Europe adopted the Recommendation on the Integrated Conservation of Cultural Landscape Areas as Part of Landscape Policies [121]. With reference to this, ICOMOS proposed the following definition: "rural landscapes are terrestrial and aquatic areas co-produced by human-nature interaction used for the production of food and other renewable natural resources, via agriculture, animal husbandry and pastoralism, fishing and aquaculture, forestry, wild food gathering, hunting, and extraction of other resources, such as salt [122]. Rural landscapes are multifunctional resources. At the same time, all rural areas have cultural meanings attributed to them by people and communities: all rural areas are landscapes" [122].

A rural landscape, in terms of heritage, includes the tangible and intangible heritage of rural areas. It "encompasses physical attributes (productive land itself, morphology, water, infrastructure, vegetation, settlements, rural buildings and centers, vernacular architecture, transport, and trade networks) and wider physical, cultural, and environmental linkages and settings" [122].

It also includes "associated cultural knowledge, traditions, practices, expressions of local human communities' identity and belonging, and the cultural values and meanings attributed to those landscapes by past and contemporary people and communities" [122]. Rural landscape heritage encompasses technical, scientific, and practical knowledge related to human–nature relationships [123–125].

There are several definitions of rural landscapes in the literature, developed by authors of different disciplines, such as geography, landscape ecology, landscape aesthetics, rural tourism, social economics, and geographic information science.

In geography, the rural landscape is defined by some authors as: "a cultural landscape that transforms nature for agricultural purposes, rather than a natural landscape formed by geological, climatic and biological factors" [126,127]; as a landscape managed through local adaptation and historical traditional agricultural techniques, families and ways of life [128]; and as an area that is closely related to agriculture geographically and functionally [129].

In landscape ecology, Turner defined the rural landscape as a mosaic of a variety of landscape patches, providing species with a variety of broken spatial grid representations of living habitats, including grasslands, woodlands, arable land, roads and hedges [130]. Such an atomistic perspective has been integrated according to the different and somehow opposite perspective of landscape aesthetics, in which Antrop [131,132] defined the rural landscape as a collection of unique and identifiable structures that reflects a clear relationship between the constituent elements; these can be differently appreciated according multiple landscape experiences, which nowadays are mostly recreational, which cultural institutions try to drive toward low-impact practices. In fact, in rural tourism, van Zanten et al. [133] highlighted that the rural landscape offers a wide range of ecosystem services, such as recreation and tourism, connected to the aesthetic functions of cultural heritage.

As for the landscape's material and immaterial streams, in landscape ecology, Zasada et al. [134] also recognize the rural material and immaterial landscapes services (LS) that directly or indirectly meet human needs, such as food production, pollination, water regulation and recreation. Again, in social economics, Schaller et al. [135] highlight that the rural landscape provides not only private types of goods, but also a wide range of public services, which cumulate, creating the socio-economic asset of the rural economy. Such a complex conceptual, cognitive and operational entity is a representation of of geographic information science; in this field, Statuto et al. [136,137] and Picuno et al. [112] highlight that the rural landscape, as a result of the interaction between natural components and human activities in time and space, is a non-renewable resource that provides information about the overall state of the environment [138].

In Italy, the failure to introduce a legal definition of the concept of a rural landscape, has resulted, over the years, in the progressive exploitation, without limits, of the rural landscape, as well as the depreciation of the dimension of the rural landscape [139]. The prospect of considering the rural landscape as a special category of cultural landscape could promote its protection. Article 142 of the Cultural Heritage and Landscape Code (24/02/2004) [140] lists a number of areas protected by law. They are identified as naturalistic areas, mountain areas, parks and nature reserves, forests and woodlands and other wetlands of geological or archaeological interest. For these areas, the legislature assumes the cultural value of the portion of land and subjects it to a series of constraints that its maintainers must comply with. Providing for the inclusion of rural landscapes of cultural and historical interest within these areas would promote their protection. In this regard, in Italy, the Ministry of Culture has launched calls in all regions for the restoration and enhancement of architecture and rural landscapes, supported by funding under the National Recovery and Resilience Plan: Mission 1—Investment 2.2: "Protection and Enhancement of Architecture and Rural Landscape" (05/05/2021) [141]. A total of EUR 590 million has been earmarked to support nearly 4000 projects that will receive funding in line with the objectives of protecting the cultural heritage and characteristic elements of rural landscapes: rural buildings, water- or windmills, oil mills, cheese factories, rural schools, barns, shelters, stables, dryers, ovens, troughs, bridges, and dry-stone walls.

2. Materials—The Territory of Noto and its Landscape Risk

The province of Syracuse occupies part of the Val di Noto, the eastern administrative district of the three into which the region was divided from the Muslim period (10th century AD) to 1812.

The municipality of Noto is the largest of the 21 into which the provincial territory is divided, occupying just over a quarter of the territory (550 sq.km out of 2124 sq.km).

The province has numerous nature areas and protected reserves of international importance, including Pantalica, Vendicari, the Maddalena Peninsula, the Ciane River and Saline di Siracusa Nature Reserve, and Capo Passero Island.

It is one of the most complex and densely populated areas in the whole of Sicily and, while until the last century it was a predominantly agricultural area, today, the entire province has become an industrial hub specializing in the chemical, electrical and engineering sectors, even though the primary sector remains alive through differentiated cultivation with various and numerous aspects of agricultural excellence.

The urban and planning instruments on various scales, and the studies on the territory of Noto analyzed to support this study, are:

- The Provincial Territorial Plan of Syracuse (21 December 2021) [142].
- The Territorial Landscape Plan of Syracuse (finally approved on 20 October 2017) [143].
- The "Noto Dossier" from the National Atlas of Rural Territory (2010) [144].
- The Masterplan of the Municipality of Noto (28 June 2018) [145–147], within which the following are relevant:
    a. The Implementation Rules;
    b. The Agricultural Forest Study.

2.1. Provincial Territorial Plan of Syracuse (PTPS)

The PTPS classifies the different areas of the provincial territory according to their vocation, according to the number of denominations (DOC, PDO and PGI) that fall within each of them: PGI—red orange from Sicily; PGI—lemon from Syracuse; PGI—tomato from Pachino; PDO—extra virgin olive oil from Frigintini, Trigona Pancali, Monte Lauro and Valle del Tellaro; and PDO—Moscato di Noto from Eloro.

From the overlapping of the various denomination areas (DOC, DOP and IGP), the provincial agricultural territory is classified into the following categories: Important Agricultural Areas, Agricultural Areas, and Ordinary Agricultural Areas.

The PTPS employs the original criterion of the Sicilian Regional Legislation, according to which municipal master plans may allocate land used for specialized crops, irrigated or equipped with infrastructure and facilities to support agricultural activity, and for non-agricultural uses only in exceptional cases.

2.2. Territorial Landscape Plan of Syracuse (TLPS)

The Landscape Plan of the areas falling within the province of Syracuse takes into account the landscape and environmental values of the territory through:

- The analysis, protection and landscape enhancement of historical, natural and cultural resources;
- Urban and building development in harmony with the different levels of recognized value.

The general objectives of the TLPS concern the ecological stabilization of the soil and the protection of biodiversity for reducing landscape risk in its multiple units and for its sustainable enhancement.

The main measures of the TLPS are generally aimed at the seven fundamental components of the agricultural landscape: herbaceous crops; arboreal crops; vineyards; citrus groves; crop mosaics; and greenhouse crops. In general, the measures include converting and improving the existing cover (except for greenhouse crops); creating renaturation areas and ecological networks; maintaining compatibility with the conservation of historical and landscape heritage, educational–recreational, ecological and testimonial functions and the variety of germplasms; maintaining and restoring traditional soil morphology (dry stone walls and terracing); maintaining plant functionality; restoring historical residences; and mitigating the landscape impact of existing greenhouse crops, especially in areas of greater landscape value [148–150].

2.3. National Atlas for Rural Territory

The National Atlas of Rural Territory, drafted by the Ministry of Agriculture, Food and Forestry Policies, is a support tool for rural development policies; it is aimed at investigating and interpreting the different geographies of rural development, using tools to assess the impact of agricultural policies on territories according to the European directives.

The Rural Atlas focuses on development processes within the local dimension by identifying 600 Local Systems within which it identifies the stock of fixed social capital present in the rural space, such as agricultural landscapes and urban resources, accessibility conditions and human resources.

The following local landscapes (LLs) fall within the territory of Noto:

- LL 11: Tellaro River Valley;
- LL 12: Hyblean Plateaus;
- LL 13: Central Coastal Plain;
- LL 14: Plateaus of Rosolini;
- LL 15: Noto Clay Hills;
- LL 16: Tellaro Floodplain;
- LL 17: Lower Hyblean Mountains;
- LL 18: Eloro Coast and Vendicari Marshes;
- LL 19: Southern Marshes.

With reference to the subject of this study, Table 1 shows a summary of the salient features of the relationship between landscape values and the entity of urbanization of the territory, highlighted by the Atlas “Dossier Noto”.

Table 1. Landscape risk drivers according to the National Rural Land Atlas (our processing).

Local Landscapes	Agricultural Landscape	Geomorphological Landscape	Landscape Values	Settlement Issues	Critical Issues and Risk Factors
LL 11	Prevalence of dry arable, arboreal and irrigated areas.	Grey-blue marl; river alluvial soils on the valley floor.	Substantial integrity. Riverbed with riparian vegetation. Crag linking this LL to the Hyblean Plateaus.	Anthropic settlement is minimal due to the geomorphological conditions.	Minimal risks, due to punctual building settlement or infrastructural transformations, so as not to compromise the overall characteristics of the site.
LL 12	Scarcely anthropized; predominantly agrarian landscape with drystone walls and pasture land.	Alternations of yellowish-white or grey calcarenitic strata with sub-horizontal or south-easterly sloping terrain.	Scarce anthropization. Views of the valley incisions of Cava Grande, Manghisi, etc. Almost wild nature.	Settlements concentrated south of the plateaus and along the peripheral roads of municipalities like a spider’s web of building lines along the road network.	Risks due to the expansion and dispersion of urban centers and the establishment of activities alien to a landscape that only shows its qualities when observed and experienced ‘slowly’.

Table 1. *Cont.*

Local Landscapes	Agricultural Landscape	Geomorphological Landscape	Landscape Values	Settlement Issues	Critical Issues and Risk Factors
LL 13	Evocative, densely human-made agricultural landscape, characterised by the presence of citrus groves, almond groves and horticultural crops.	Presence of alluvial sediments and calcarenitic deposits. The plain is furrowed by the hydrographic network of the Cassibile River.	Integration of landscape and agriculture.	Urbanization of the coast with tourist settlements that tend to compact, thicken and lead to the formation of linear urban settlements.	Intense transformation and impoverishment of the landscape due to coastal settlements that will form an uninterrupted built barrier between the hinterland and the sea.
LL 14	Alternating dry arable land and extensive fallow land on rocky ground. Significant presence of carob trees.	Alternation of white-streak bio-calcarenites and yellowish marly limestone incised by quarries oriented in west–east direction.	The quarries are an element of both ecological and perceptive quality that opposes agricultural and urban anthropisation. Landscapes of the carob tree and networks of traditional drystone walls.	The built-up area of Rosolini tends to expand along the main roads.	Expansion of the built-up area of Rosolini with the formation of scattered settlements, which do not increase Rosolini's urban qualities but undermine the characteristics of the agrarian landscape.
LL 15	Hilly landscape of Noto. The countryside is covered with olive groves, almond groves and a few citrus orchards.	Presence of clay hills on which the center of Noto itself was settled.	Prevalence of the urban landscape of the baroque center of Noto, which has physical and visual relationships with the agrarian landscape and the crag of the Ibleo plateau to the north.	Countryside strongly anthropized by small rural aggregations and punctiform urbanization. Tendential expansion of the center of Noto along the hills to the north.	Breaking of physical and perceptive relations between the center of Noto and its territory. Recent widespread urbanization and fragmentation of the ecological continuity of the Asinaro river
LL 16	Contrast between the extensive almond groves along the river, with alternating horticultural crops, and the uncultivated rocky coastal strip.	Tellaro river valley: recent marshy bottoms and fluvial alluvium presence of marls. Marly uplands south of Rosolini.	Tellaro river with riparian vegetation; historical almond groves with a strong identity. Significant "hinge landscape" character.	The settlement system is limited to a sparse distribution of scattered buildings of an agricultural–rural nature.	Alterations to the environmental and ecological qualities of the Tellaro river
LL 17	Presence of intensive horticultural crops in the central and southern parts, and almond groves in the north.	Presence of marls, river rods and/or marshy bottoms. It also includes the small marly heights south of Rosolini.	Quality of the agrarian landscape, especially in the hilly area with a panoramic view towards the coastal plateau to the sea.	The purely rural character of this area is also found in the settlement system, consisting essentially of point dispersion in the suburban area, linked to agricultural activities.	The risks are due to intensive greenhouse cultivation that, although not pervasive, characterizes the central-southern part of the landscape.

Table 1. *Cont.*

Local Landscapes	Agricultural Landscape	Geomorphological Landscape	Landscape Values	Settlement Issues	Critical Issues and Risk Factors
LL 18	Presence of coastal marshes.	Alluvial soils and marshy bottoms; characterised by the marshes along the coast and yellow sand beaches.	Linked to the presence of the beaches and marshes that form the typical Mediterranean coastal environment. Characterised by the presence of architectural elements of high historical/testimonial value.	The landscape and environmental qualities of the area have triggered a strong coastal settlement process.	Presence of relevant and recent settlement proliferation in the southern part (S. Lorenzo coast). Significant process of building houses both scattered and aligned along the road or forming real allotments.
LL 19	Occupies the southern part of the Tavolato Ibleo, along the coast.	Alluvial soils, marshy bottoms and coastal marshes to the west. The coastal plateau presents stratifications of pinkish limestone and lava soils. Of particular note is the Portopalo crag.	Characterised by marshes, beaches and residual dunes, with their associated vegetation, and the typical Mediterranean coastal environment, especially the presence of the balza di Portopalo.	The settlement systems of the municipalities of Pachino and Portopalo and the village of Marzamemi extend into the suburban area with dispersed buildings, linked to agricultural and residential activities. Recently, the coast has been affected by intense building. The presence of greenhouses as far as the coast is also relevant.	The risks are due to the urban expansion of Pachino and Portopalo and the intensive use of agricultural land with greenhouse crops. Settlement pressure also affects the marsh areas.

3. Methods

3.1. Stages

This research crosses three distinguishable and integrated areas of investigation involved in research concerning the critical analysis and representation of the urbanization of rural territory: 1. assessment of the landscape values of the territorial context; 2. description of the urbanization of the rural territory; and 3. synthesis of the two findings, aimed at providing and mapping a landscape risk composite index.

The variety of data collected in the first two survey phases was reduced to comparable information units, sorted by subject and hierarchized by degree of depth. This made it possible to define appropriate evaluation indexes by correlating the results of cross-queries of the Regional Technical Cartography (RTC) [151] and the cadastre [152] databases: the former provided physical and quantitative data, and the latter qualitative and economic information. These phases, typically descriptive and evaluative, provide:

1. A landscape assessment of the territorial context, assuming the 420 Cadastral Sheets (CS) as the minimum information land units;
2. A critical representation of the phenomenon itself, in its extension and intensity, in space and time and with reference to the different units of information: the building units (BU), the land cadastral parcels (LCP) and the building cadastral parcels (BCP), available from the two above-mentioned sources.

3. According to a land use planning prospect, the synthesis of the two above cognitive-valuative findings in terms of the assessment of landscape risk from building development.

The method was developed as follows:

1. Creation of cartographic support for joint mapping of the territorial context and the buildings in three periods;
2. Organization of the data relating to the different units of information;
3. Characterization of the building dynamics in the rural territory;
4. Identification and classification of the territorial units, distinguishing the main units (cadastral sheets and sub-sheets) designated for representation, and subordinate units (land cadaster parcels, building cadaster units, buildings in the Regional Technical Map) designated for characterization of the main units;
5. Characterization of the main spatial units;
6. Construction of the evaluation functions of the spatial unit;
7. Construction of the evaluation functions of the building development phenomenon;
8. Construction of indices for the overall assessment of the landscape resilience of each main territorial unit against the pressure of building dynamics.

3.2. Data Sources

The two main data sources used for the analyses of landscape context and building dynamics in the rural territory were, respectively, the Cadaster database of the Revenue Agency and the Regional Technical Cartography database supporting the Regional Territorial Information System.

3.2.1. Revenue Agency Database

The data used to represent the many dimensions of the landscape value of the territory of Noto were obtained from the land cadaster (LC) and building cadaster (BC) databases.

The census archive of the LC contains the technical, dimensional, legal and economic information of each cadastral parcel, from which we extracted data on identification, location, surface area, quality of cultivation or use, productivity class and yield.

The census archive of the BC contains dimensional, technical–physical, legal and economic information of each urban property unit (UP) from which we extracted the data on identification, location, type (A—residential and office use, B—public use, C—commercial use, D—industrial and special commercial use, E—collective use), size (number of rooms, surface or volume units depending on the type) and rent class (only for property units in types A, B and C).

3.2.2. Regional Geographic Information System

The representation of the regional territory was organized into four types of interrelated and continuously updated product: technical cartography, thematic cartography, the territorial information system and aero-photogrammetric surveys.

Technical cartography on a 1:10,000 scale was used to record the development of the building stock in the years 2000, 2007 and 2012 in the study area.

Information useful for identifying the evolution of the building stock was included in the vectorial layer "B" of Regional Technical Cartography. The height of the buildings was missing in this representation, so only the area and number of buildings could be reported.

3.3. The Model

3.3.1. Tools

The model developed for the assessment of landscape risk due to diffuse building in rural areas coordinates the functions of a spreadsheet (SpSh) and a Geographic Information System (GIS) to represent the value: 1. of the built stock, in terms of consistency and location; 2. of the landscape, in terms of the qualitative–quantitative value of the territorial units recognized as having attributes of landscape value; and 3. of the landscape risk derived from the landscape contextualization of the building phenomenon.

GIS is a tool designed for the storage, archiving and analysis of land objects and phenomena whose geographic location is the original and primary reference (Aronoff, 1989); it is used for both the spatial calculation and the representation of the consequent cognitive and evaluative dimensions [153,154].

By means of spatial join functions, the characteristics of the building stock dynamics were associated with the landscape qualities of the territorial units analyzed.

SpSh: Through the spreadsheet functions, we made the multiple value attributes of the information-bearing spatial units comparable, and created four interlinked databases:

- The main database consisted of land cadaster (LC) data referring to 410 cadaster sheets (CS, records) delimiting the basic value-bearer land units for the representation of landscape risk; the attributes (fields) were associated with these units by combining the functions of landscape value assessment and building stock evolution indices.
- The second included building cadaster (BC) data extracted for the 95,075 land cadaster parcels (LCPs) and building cadaster parcels (BCPs) of Noto.
- The third included 33,243 real estate properties (REPs) from the BC.
- The fourth included 15,146 building units (Bus) from the Technical Cartography.

3.3.2. Concepts

The evolution of the cognitive potential of spatial information technologies over the past 30 years has also significantly influenced the methods of analysis, evaluation and planning and their synthesis [155–158].

The explanatory functions of the method adopted here support the organization and control of the process of obtaining critical knowledge of the phenomenon in terms of its internal and external coherence. Internal coherence is an attribute of validity of the functions of the progressive abstraction of knowledge from the denotative to the connotative level, i.e., representation by the values [159–162] of landscape risk; external coherence is an attribute of the appropriateness of the "representation by value" to its reference, i.e., to the concrete forms of territorial capital in the evolution of its volume and value [163].

This cognitive path consists in the progressive abstraction of the concreteness of data into indices and evaluations, whereby throughout the hierarchic pattern, the denotation, signification, connotation and interpretation functions of the information units are organized at different levels of detail and according to their degree of involvement in the building development process.

In essence, landscape assessment is the representation of the territory by means of value attributes assigned to its elementary units, and is thus made comparable through "signification relations", which refer to a value paradigm based on the category of territorial capital, and in its general dimension, social capital. Thus, the hierarchical collection and aggregation of information units, such as indices, measuring the multiple values of territorial units based on a unitary metric, are part of the additive utility approach of the Multi-Value Attribute Theory we refer to for the evaluation of both resilience and building pressure.

The latter performs both economic and symbolic functions [164], here represented through the interpretation of spatial information. The economic functions are measured with reference to the functional, productive and real estate characteristics of the different portions of the territory, and the symbolic ones with reference to the system of existing landscape constraints and the complexity of the cultivation mosaic [165].

3.3.3. Functions

The proposed model coordinates a hierarchical set of queries of the aforementioned databases to support the assessment of all landscape risk variables, individual and aggregated, according to two expressions (graphic and numerical) and referring to the territory and building dynamics, and their combination, in both factual and value terms.

Through the formation of specific indices, the ordered interpretation of landscape risk is represented in gradually more abstract form, and thus to a greater critical and evaluative degree. These representations converge in a final aggregate index that measures the resilience of the rural landscape, given by the impact that the driving forces of the building phenomenon exert on the value components of the rural landscape. This index is calculated via progressive reduction in the information spectrum, through which the two components (the building phenomenon and the rural landscape) are described and characterized through the ranks of denotation, connotation, and interpretation in which the different "Information Units" (IU) are placed (Figure 2).

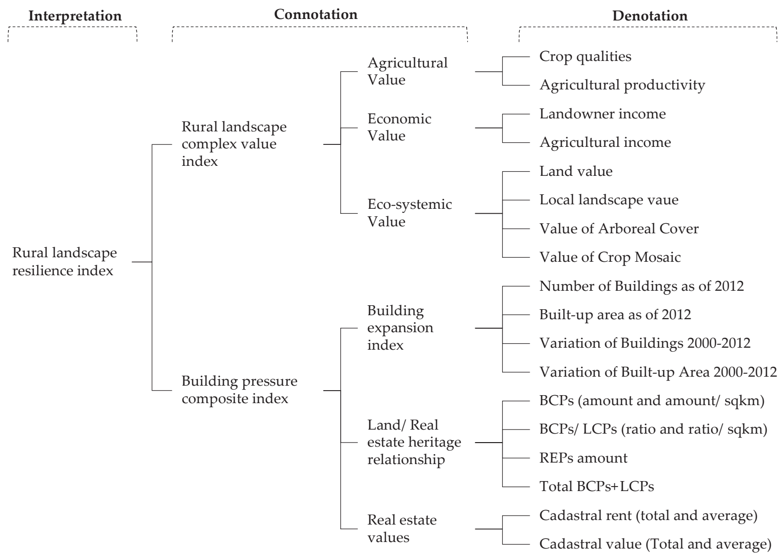

Figure 2. Dendrogram of the IUs in the denotation, connotation, and interpretation processes. The denotation level of the dendrogram reports the specific criteria for the assessment of the whole Rural Landscape Resilience Index (our processing).

Denotation describes the landscape context and building phenomenon for the purpose of their evaluation and interpretive synthesis in terms of landscape risk.

1. The landscape context, described and characterized with reference to the two databases:
    - The territorial and regulatory database (in support of the urban planning instrumentation in force) regulates land function and use on the basis of the identification of the forms of territorial capital with regard to their capacity to deliver service flows without eroding this capacity over time; moreover, it indicates constraints, for example, on building, where this may interfere with the extent and quality of intangible (landscape) services that the areas included in the protection strategies primarily and permanently are able to provide.
    - The real estate database, Land and Buildings Cadaster—LC and BC—which describes the territories and their purpose: "equalizing", aimed at transferring part of the land and real estate added value to the public through the tax levy on the "privileges" of land and urban renting, and "informational", in accordance with the civil functions of the cadaster, whose effectiveness is entrusted to the constant institutional updating process.
2. The building phenomenon, also described and characterized with reference to two spatial and real estate databases:

- Regional Technical Cartography, where the consistency and location characteristics of the existing buildings are surveyed; the description includes regulatory references contained in current planning instruments regarding land use and constraints.
- The database of the BC, the register of cadastral parcels of farmland on which buildings of different types and functions exist, which, in turn, consist of real estate properties (REP), some of which are characterized by functional independence and autonomous yield capacity; the REP was assumed as the minimum study unit of the second database.

The general contents of denotation functions are summarized in the last column of Figure 2.

Connotation is the transformation of observations made at the denotation level into value attributes. The elementary IUs were normalized by means of specific valuation functions and converted into dimensionless scores for the application of an additive model. This allowed the territorial units (TUs) to be characterised with gradually more concise scores of landscape quality and building impact.

An additive multi-criteria evaluation model based on the Multi-Attribute Value Theory was used [166–171], whereby each territorial unit was assigned a value with reference to the generic evaluation criterion:

$$V_h = \sum_{i=1}^{n} g_{ij}\lambda_j \quad (1)$$

under the condition that

$$\sum_{i=1}^{n} \lambda_j = 1 \quad (2)$$

where V_h is the evaluation of the landscape value or building pressure attributed to the h_{th} territorial unit by the weighted sum of the related i_{th} attributes, denoted as g_{ij}, in relation to the j_{th} value attributes, whose relative importance with respect to the others of the same set is measured by the weighting factor λ_j.

The weighting factor system is the interface between assessments and spatial policy decisions, and as such, represents the perspectives of the stakeholders involved. It should be noted, in this regard, that this study has a methodological and exploratory cognitive perspective and proposes a useful tool for representing and measuring landscape risk on a large scale [172,173]. Accordingly, the weight system applied here was established on the basis of the authors' expert knowledge, without any normative claim. In doing so, we outlined several hypotheses, choosing the one that best fits the shared knowledge of the area.

Interpretation is the synthesis of the results of the assessment, with the dual objective of combining, in a synthetic index, the connotations of the two risk components (landscape quality and building on agricultural land) and indicating the most significant correlations between the elements that constitute them.

The summary of the results is the degree to which the landscape value system is able to metabolize the impact of urbanization on the rural territory; this is the Landscape Resilience Value, calculated as the product of the Rural Landscape Complex Value Index and the Composite Building Pressure Index.

4. Application and Results

The Total Rural Landscape Resilience Value calculated for the 410 CFs is the result of the descriptive synthesis of 42 observations, the evaluation using 19 attributes, and the interpretation of the two indices measuring the Complex Rural Landscape Value and the Complex Building Pressure Value.

The following are the observation elements used for the subsequent rural landscape and building dynamics assessments with reference to the measures of agricultural value, economic value, and eco-socio-systemic value, respectively.

4.1. Denotations and Connotations

4.1.1. Rural Landscape

The valuations used for the structured connotation of the rural landscape are grouped into agricultural value, economic value and ecosystem value (Figure 2).

- *Agricultural Value Index*

This is an index of agricultural capital productivity and depends on the crop quality and land productivity class (from first (the best) to fifth (the worst)). Based on the queries of the LC census archive, the Agricultural Value Index is calculated as the average between the scores of the absolute value (in the whole CS) and the relative value (per area unit) of the weighted and normalized average productivity classes of all crop qualities: arable land, irrigated arable land, arboreal arable land, irrigated vegetable garden, vineyard, olive grove, orchard, irrigated orchard, citrus grove, irrigated citrus grove, cane grove, carob grove, almond grove, prickly pear, pasture, arboreal pasture, productive pasture, sterile pasture, ceded forest, tall forest, greenhouse, quarry, salt marsh and fish pond (Figure 3).

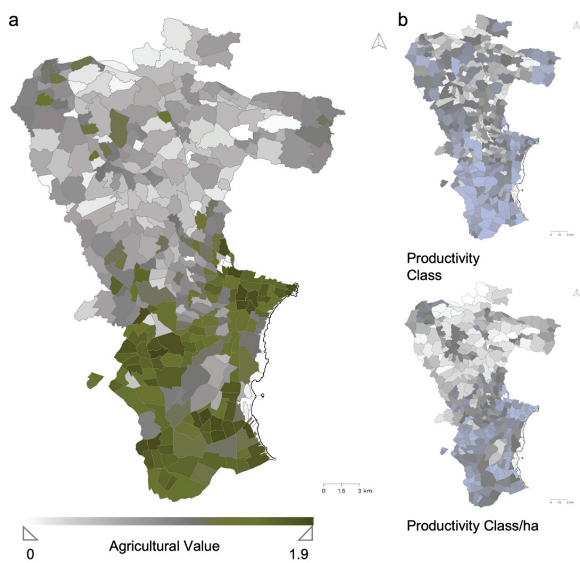

Figure 3. Maps of agricultural value: (**a**) connotation; (**b**) denotations (our processing).

- *Economic Value index*

This is an index that aggregates: 1. the income streams of the value of agricultural capital, agricultural income and land capital, and dominical income, and 2. the conventional stock land value and the average agricultural value for each quality of crop. Again, the value is the average of the normalized absolute and relative measurements (Figure 4).

- *Ecosystem value index*

This index aggregates local landscape values represented by the presence of typical crops and tree cover and the complexity of the cultivation landscape. The assessment results in an extensive and complex analysis summarized by the sequence of 15 maps, ordered with respect to the prevalent crop in each CS (Figure 5).

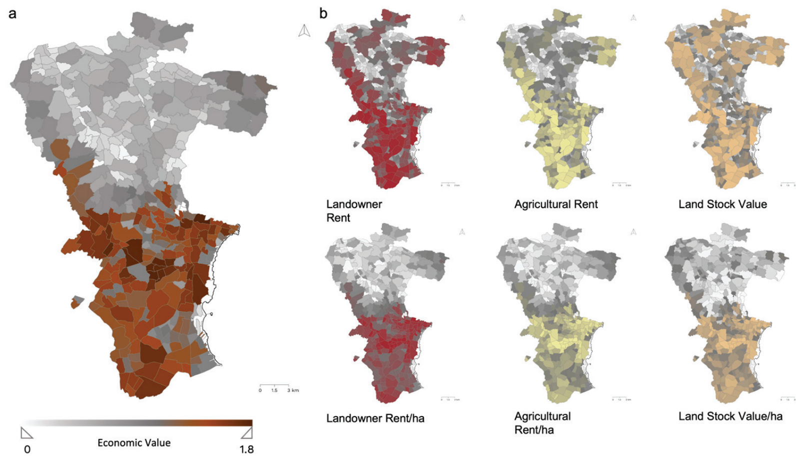

Figure 4. Maps of economic value: (**a**) connotation; (**b**) denotations (our processing).

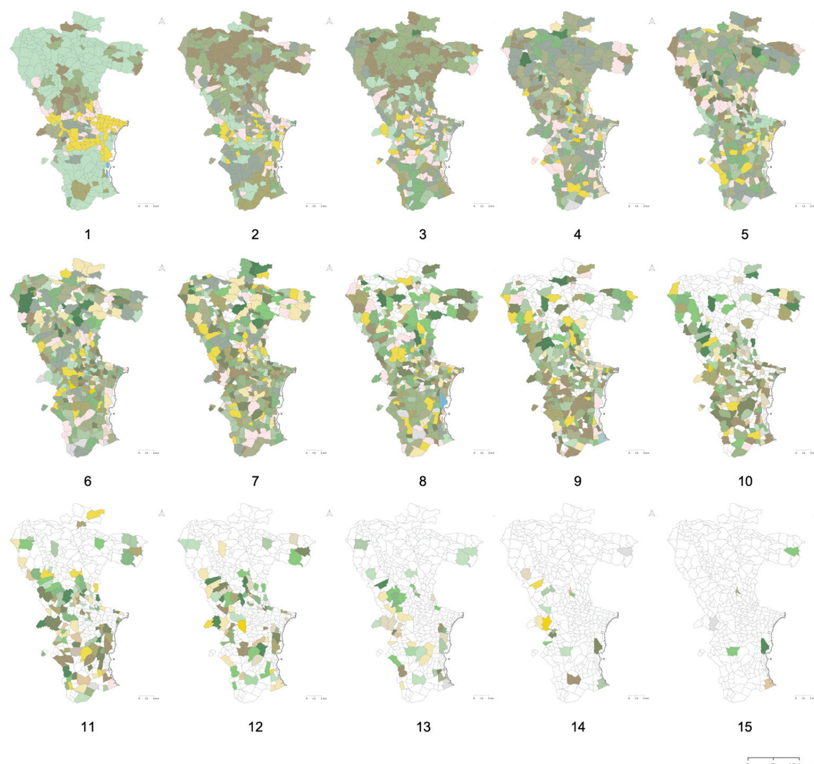

Figure 5. Denotations: agricultural mosaics in 15 maps by culture prevalence in the cadastral sheets (our processing).

Again, the value is given by the average of the normalized absolute and relative magnitudes (Figure 6).

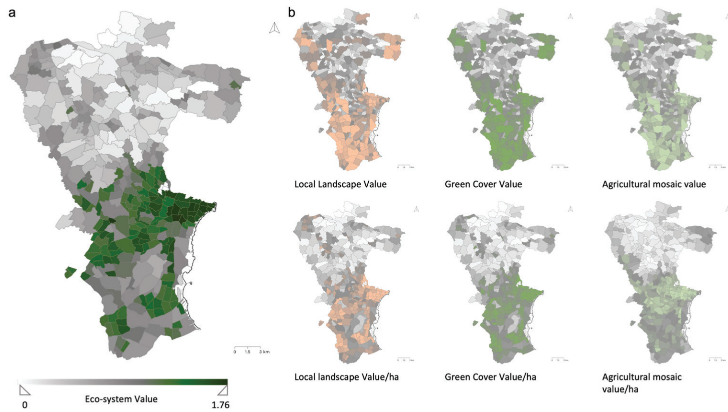

Figure 6. Maps of ecosystem value: (**a**) connotation; (**b**) denotations (our processing).

4.1.2. Building Dynamics

The value representation of the phenomenon of building expansion in rural areas is based on the change in real estate volume (number of buildings and occupied area) and the real estate value of the built heritage with reference to the three observations in 2000, 2007 and 2012. Figure 7 displays the three stages of progressive evolution over the whole municipal territory.

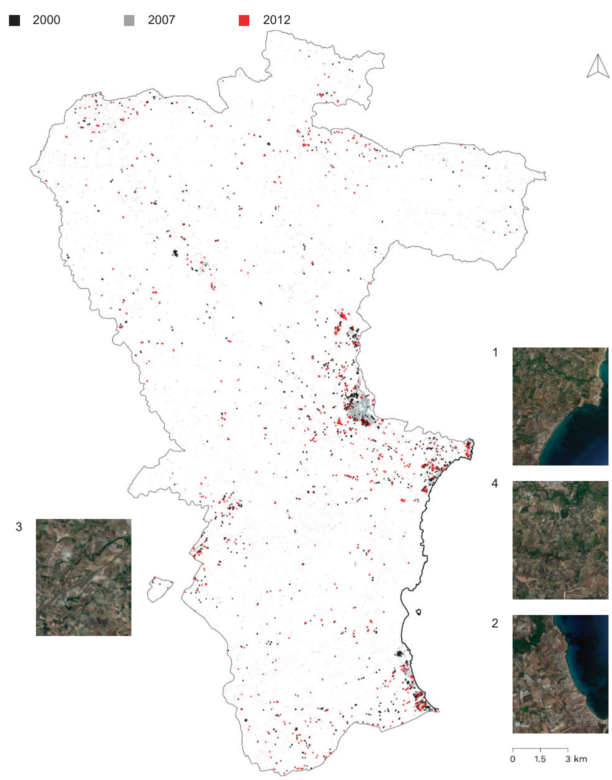

Figure 7. Visualization of the phenomenon of building expansion in the territory of Noto in 2000, 2007 and 2012 (our processing).

Figure 8 focuses on four sample areas, two inland and two coastal.

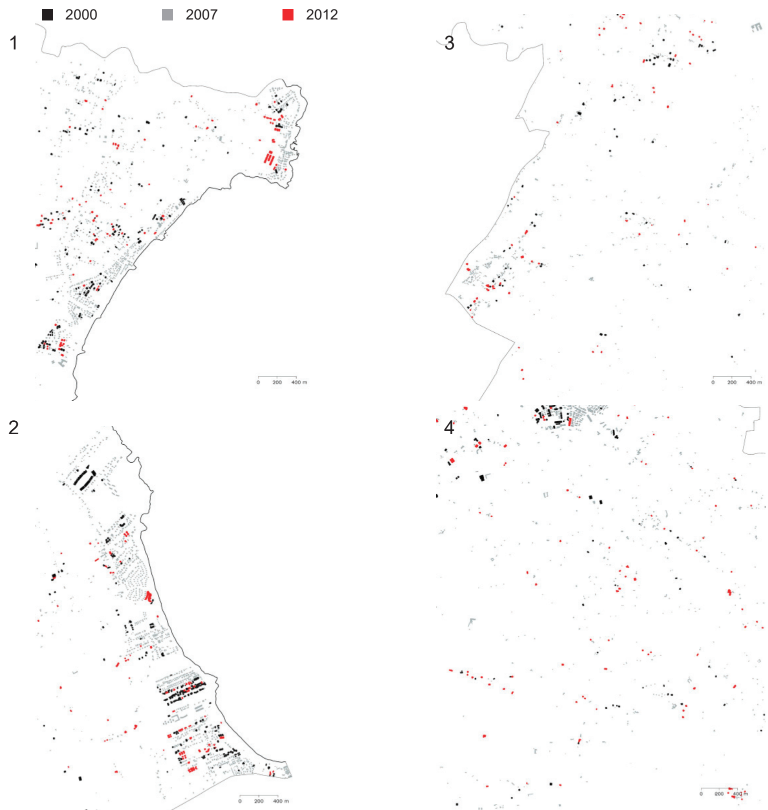

Figure 8. Observation of the phenomenon of building expansion in the rural area of Noto in four of the most susceptible areas in 2000, 2007 and 2012 (our processing).

As a premise of the following assessments, these observations were mapped with reference to the intensity of the phenomenon, as variations from 2000 to 2007, from 2007 to 2012, and over the entire observation period (from 2000 to 2012), as well as variations in the number of BUs (Figure 9) and in the area occupied by buildings (Figure 10) in each CS.

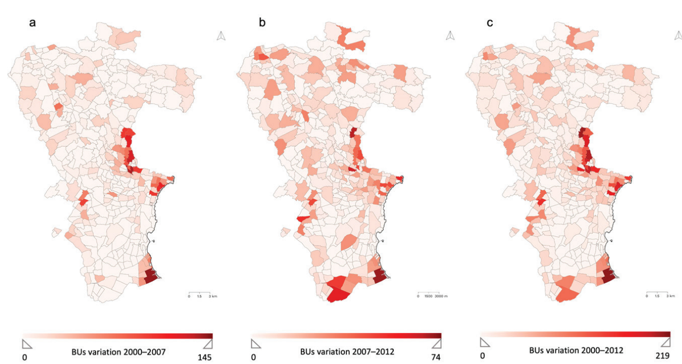

Figure 9. Mapping of the variation in BUs over the period observed: (**a**) 2000–2007; (**b**) 2007–2012; (**c**) 2000–2012 (our processing).

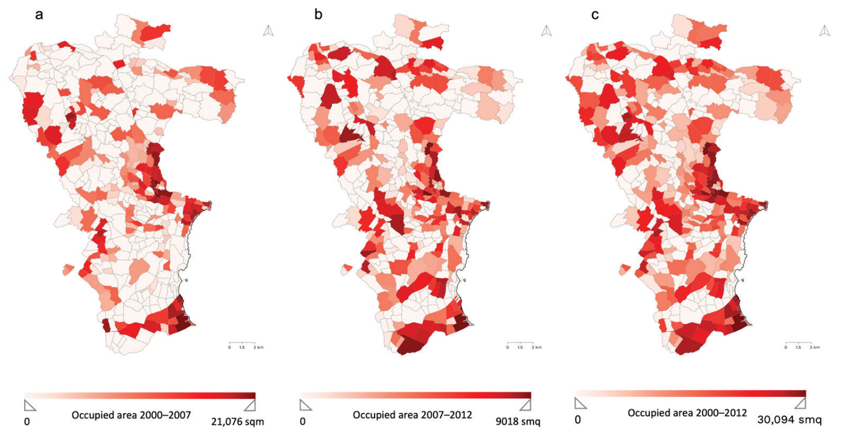

Figure 10. Mapping of the variation in occupied area over the period observed: (**a**) 2000–2007; (**b**) 2007–2012; (**c**) 2000–2012 (our processing).

- *Building development index*

Based on the above surveys, building expansion was represented with reference to building stock and its variation between 2000 and 2012 in terms of BUs and area occupied, and in both absolute and relative values, that is, taking into account the number of BUs in each CF and the ratio of the latter to the area of the CF (Figure 11).

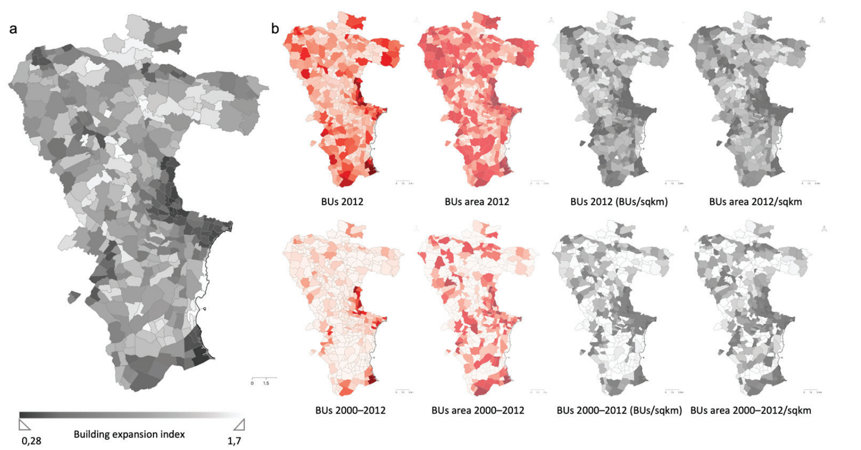

Figure 11. Mapping of the building expansion Index: (**a**) connotation; (**b**) denotation (our processing).

- *Index of the ratio of land and real estate assets*

The index of the balance between the extent of land and real estate assets was calculated with reference to the size of the two land capital stocks—real estate and land—and with reference to the absolute and relative (per unit area) BCPs (the ratio of BCPs to LCPs in absolute terms and per unit area), with reference to the number of LCPs to total CPs, and the area of BUs in absolute terms and per unit area (Figure 12).

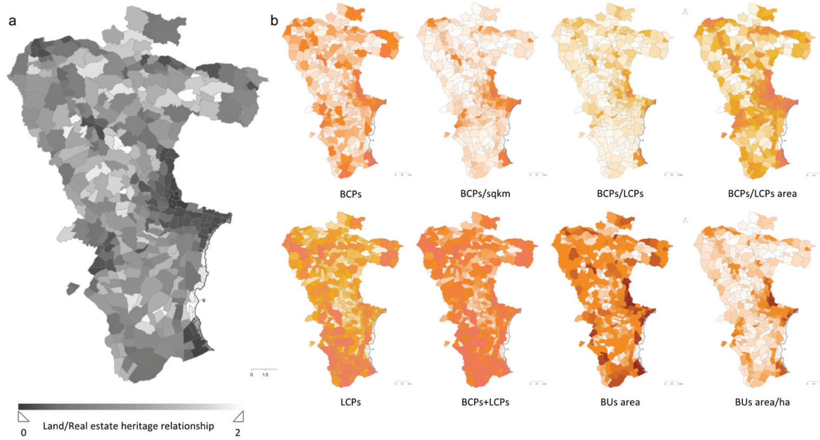

Figure 12. Mapping of the land/real estate heritage relationship: (**a**) connotation; (**b**) denotation (our processing).

- *Real estate value index*

The property value was represented on the basis of cadastral income and the cadastral value, in both cases in absolute terms and per unit area (Figure 13); the cadastral value was obtained by multiplying the cadastral income by a coefficient established by the Internal Revenue Service for each cadastral category.

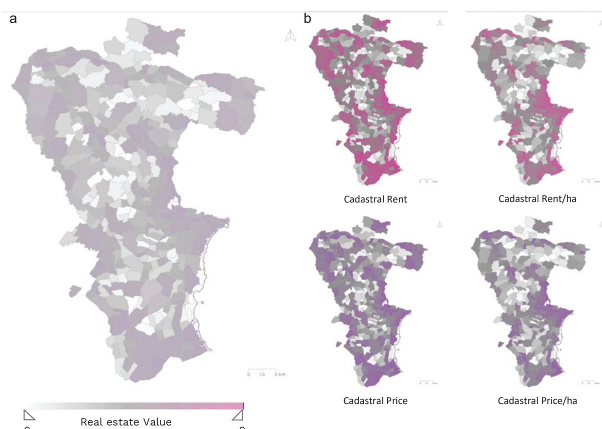

Figure 13. Mapping of the real estate value index: (**a**) connotation; (**b**) denotation (our processing).

4.2. Interpretation

The last level of the evaluation pyramid concerns the interpretation functions. These were conducted by first completing context assessments, and then, phenomenon assessments, via calculation of the Rural Landscape Complex Value Index and the Building Pressure Composite Index, respectively (Figure 14).

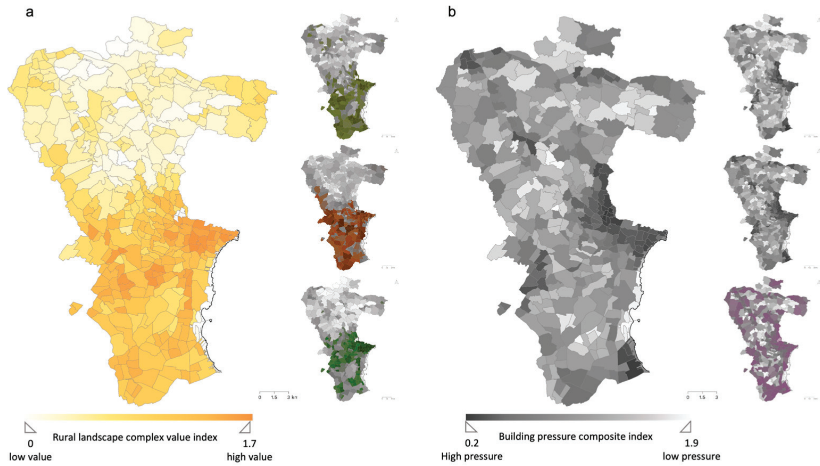

Figure 14. Interpretations and connotations. Mapping of: (**a**) Rural Landscape Complex Value Index; (**b**) Building Pressure Composite Index (our processing).

Finally, at the top of the pyramid of this integrated landscape risk assessment in rural areas, the Rural Landscape Resilience Index was calculated as a synthesis of the overall qualities of the landscape context and the quantitative and qualitative characteristics of the building phenomenon, combining the two previous indices (Figure 15b). In Figure 15a, TUs in the yellow gradations represent areas where building pressure is low and landscape value is high, and vice versa for units in the grey gradations.

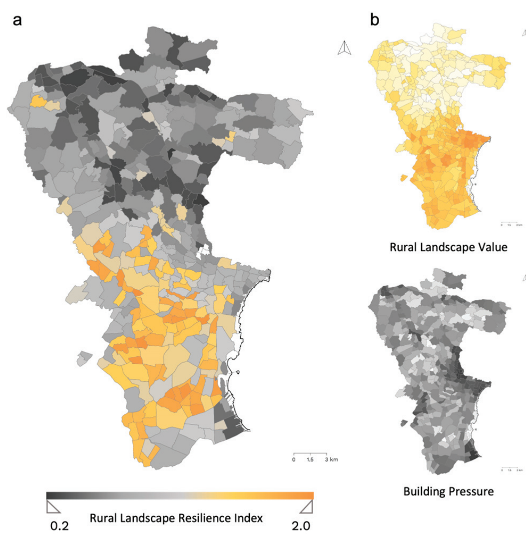

Figure 15. Mapping of the Rural Landscape Resilience Index: (**a**) interpretation; (**b**) connotations (our processing).

The final results of the description and evaluation process developed so far are a test of the consistency and validity of the proposed model, the ultimate purpose of which is to target future land policies, starting with the amendment of the law that currently regulates building in rural areas [174–182].

The progressive reduction in the broad information into synthetic assessment units—according to the typical positive/normative approach characterizing the science of valuation—has provided a synoptic and convergent representation of the two components of landscape risk, rural land quality and the extension of building development [183,184].

The latter is concentrated in areas close to the beach area, northwest of the municipality of Noto, toward the wooded areas inland and along the stretch of SS 115 connecting the municipalities of Noto and Rosolini.

In the areas of Lido di Noto and San Lorenzo, where landscape values have not yet been compromised, recreational motivations prevail, which are expressed in the demand for vacation homes.

Particularly exposed to this risk are the buffer areas of the Vendicari Reserve—in the former case, facilitated by the almost total absence of constraints—which allow the expansion of pre-existing buildings.

In the northwest area, in the hamlet of San Corrado di Fuori, there has been a phenomenon that is not very different but somewhat less pronounced, which has also occurred along the SS 115; here, investments in the complementary receptivity sector have been implemented instead, with the transformation of old farmhouses in a state of abandonment, in contexts characterized by the prevalence of typical features of the rural landscape as opposed to naturalistic ones, and thus, where arable crops, citrus and olive groves predominate.

Figure 16 shows a combination of the observation of built development and the assessment of landscape values. In this representation, the differential impact that dense and diffuse building has on the resilience of the landscape context is more evident, even when of significant value.

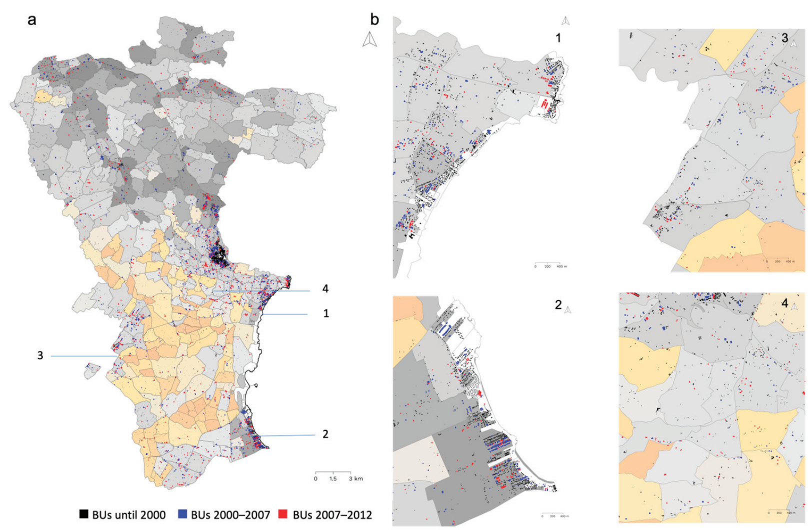

Figure 16. Visualization of the phenomenon of building expansion in a resilience index map: (**a**) in the entire municipality; (**b**) in four of the most sensitive areas in 2000, 2007 and 2012 (our processing).

The last step in this representation concerns the correlation between the variation in some of the most significant drivers of landscape risk and the combination of the two components of the Landscape Resilience Index. Figure 17 shows, on the x-axis, the Complex Landscape Value Index, and on the y-axis, the Composite Building Pressure Index; each CS is represented by a bubble whose size represents the value of the drivers (the title of each graph) correlated with the joint variation of the two components.

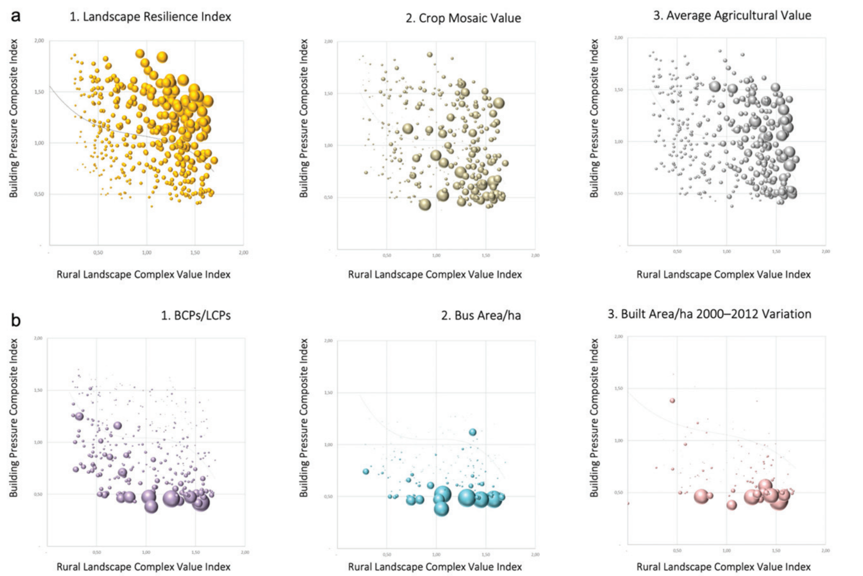

Figure 17. Correlations between: (**a**) landscape value drivers and landscape resilience conjoint components; (**b**) building pressure drivers and landscape resilience conjoint components. The drivers are indicated in the title graphs and their values represented by the bubbles' size (our processing).

5. Discussion

The results presented suggest several interpretations requiring specification and consolidation of the three main indices by homogeneous areas across the wide and articulated municipal landscape context of Noto.

In this experiment, further synthetic elaboration was carried out in order to discuss the general trends of the two main indices (supporting the calculation of the final one, the Landscape Resilience Index) from the perspective of some significant components: (a) the landscape value and (b) the pressure placed by building on rural territory.

These correlations are displayed by means of the graphs in Figure 17, reporting, on the x-axis, the Complex Landscape Value Index, and on the y-axis, the Composite Building Pressure Index; each territorial unit (CS) is represented by a bubble whose size represents the value of the drivers (the title of each graph) correlated with the joint variation of the two components.

Assuming the axis values as positive measures of appreciation, the generalized decreasing trend confirms that building pressure on land is most intense in areas of higher landscape value. This finding is assumed as the background of multiple possible correlations, including the following.

The graphs in (a) represent correlations related to the landscape context with reference to three of its most relevant dimensions: (a.1) overall resilience, (a.2) crop mosaic value and (a.3) agricultural value. As the two indices—the complex value in the abscissa, and the value of building pressure (taken as a positive value) in the ordinate—increase together:

a.1 Since the landscape resilience index (LRI) is calculated as a product of the other two, it increases proportionally along an ideal 'growth path' described by the vector exiting the origin of the axes, inclined by 45°; this is true from two complementary points of view, i.e., depending on the combination of the two indices (x and y). The territorial units at the top left and bottom right of the graph have approximately the same LRI, but the former denote low building pressure (appreciation is high) and a low landscape value, and vice versa.

a.2 The value of the crop mosaic grows more in line with the landscape value from the point of view of cultivation; this result denotes an understandable tendency for construction to focus on areas with the richest and most varied vegetation. Further investigation could also measure the hedonic price of the value of the crop mosaic, which can be taken as an aesthetic attribute.

a.3 Agricultural value is somewhat higher in the areas most affected by construction, consistent with the trend shown in a.2; this trend indicates the convergence of land and property rent.

The graphs in (b) display correlations related to building development with reference to three of the most relevant dimensions: (b.1) the cadastral stock, (b.2) the building volume and (b.3) the variation in building stock from 2000 to 2012. As the two indices increase together:

b.1 The property intensity, measured as the BCPs/LCPs ratio (building/land cadaster parcels), also increases as a function of landscape value; the level of attention in this index is important for providing some land policy elements inherent to the appropriateness of transferring land properties to the cadaster of buildings.

b.2 The BU area/ha increases according to the landscape value, as well; in this case, again, some landscape policy constraints should be triggered according to equalization tools, which can be used in order to discourage/encourage the worst/best building/landscape practices;

b.3 The building dynamics are more intense in the most valuable landscape areas, despite the real estate and economic–financial crisis that started in 2008, confirming the speculative expectations underlying rural landscape exploitation.

6. Conclusions

This contribution explored one of the most widespread aspects of landscape risk—building development in rural areas—through the observation of this phenomenon in the territory of the municipality of Noto, one of the most extensive in the Sicily region.

Through a hierarchical multidimensional analysis and evaluation model, based on the progressive abstraction of data into evaluations, the building phenomenon was represented in relation to landscape values regarding its territorial, economic–agricultural, economic–real estate and landscape components.

This research has shown to what extent and in what forms building development represents the primary driver of 1. economic–territorial imbalance and 2. landscape risk in areas typically characterised by a widespread landscape value, i.e., not depending on the presence of relevant landmarks but linked to the continuity and coherence between forms of production, working and living.

1. The attempt by regional policy to address the issue of the intra-generational solidarity arising from territorial imbalance has triggered significant building pressure on the most valuable areas of the rural landscape, putting them at risk of irreversible transformation. The latter consists, in essence, of the progressive abstraction of agricultural value—linked to the concreteness of land work and land rent—into real estate value, transforming a socio-economic model centered on production into one inspired by speculation and treasure. This has led to the progressive prevalence of the recreational dimension (holiday homes), which reduces the rural component in the picturesque frame of "dissipative functions", which are the exact opposite of the work activities that shaped this territory. The evolution of wealth distribution depends on changes in the origin and destination of added value. In the rural territory, wealth came from the primary sector, from work on the land, from the millennial evolution of widespread knowledge and from the transformation of surplus social product into the forms of the cultivated mosaic, and of a built heritage that consists of tension between natural, technological and economic constraints and the minimal needs of a life dedicated mainly to work in the fields. The current structural decline of the rural territory has disconnected the landscape value from agricultural production, leading

to the emergence of the manufacturing, construction, and tertiary sectors (particularly marketing, accommodation, catering and personal services). A radical change in the legislation regarding the extent of the rural area that can be used for production and residential buildings is needed.

2. The main sustainability issues concerning inter-generational solidarity are derived from the irreversibility of new buildings and the underlying property rights. The obsolescence of hasty construction, driven by purposes unrelated to the land and its original economic value, represents a profound and permanent modification of this territory and the very essence of its landscape. The resulting territorial scenario thus backfires against the very purpose of the legal framework, which, with the intention of supporting agricultural activity, facilitates building in rural areas; thus, it ends up supporting the real estate sector, which irreversibly impoverishes the territory from a physical–agronomic and cultural point of view. Finally, interpreting this phenomenon in the light of the fundamental dualities between wealth and value and between stock and stream magnitudes, the inversion of causal relationships can be outlined as follows: Agricultural activity has always provided sufficient economic energy to build and maintain towns, infrastructure, rural villages and agricultural complexes; consequently, tthe accumulation of wealth in the shapes of the durable capital has had in agricultural activity its origin, and in its surplus, its destination. Finally, the prospect of fostering agricultural production with a legislative measure that expands building activity reverses the traditional perspective by implying that the production of added value no longer creates capital but, rather, real estate speculation creates added value in terms of capital gains. Additionally, against the background of the new prospects of global climate change, outlined by the pandemic and military crises, rural landscape exploitation for short-term added value creation reflects an inadequate land economics vision that rejects the main and only possible approach to the ecological transition, the recovery of lifestyle moderation and the preservation of resource stock with a high information value cumulation.

This study shows that a radical change in current regional legislation is needed in order to clarify that agricultural land requires a higher level of protection than is currently provided. The study presented herein has the aim of improving the knowledge needed to support the required legislative change with data [185]. Further development could include the issues of hydrological hazards and landscape fragmentation, both relevant in the studied area. Finally, the proposed model, based on the abstraction of occurrences, is projected to be used on a municipal scale in all the municipalities of the province and region; furthermore, it allows us to aggregate the results at the level of the municipality for further critical analyses and assessments on a provincial and regional scale [186].

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Article

Sustainable Collaborative Strategies of Territorial Regeneration for the Cultural Enhancement of Unresolved Landscapes

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Abstract: The experience of adaptation and instability to a plurality of threats that question the life of human beings on the planet, from the post-pandemic to political conflicts, up to the danger looming in the background—the upheavals expected from climate change—impose a reflection that recognizes that landscape/cultural heritage plays a key role in preservation/enhancement as a specific resource for its "human-centered development", based on values included. These threats are challenges in which phenomena that require solidarity and common actions are faced, which should lead humans to cooperate to face them. The European Landscape Convention of 2000 attributed an important role to the landscape, as an "essential component of the life context of peoples". The phase of listening to the territory and participatory and co-design processes are necessary tools for understanding the expectations and perceptions of the communities, co-exploring possible new uses of the landscape, being capable of generating added value for all stakeholders, and adopting a "win-win" approach. From this perspective, this contribution poses the following research question: how to build collaborative processes capable of putting local institutions, businesses, and local communities in synergy, to identify enhancement strategies for the cultural landscape? This study explores the potential of an integrated, incremental, and adaptive decision-making approach, oriented toward the elaboration of shared choices aimed at the elaboration of territorial enhancement strategies attentive to the specificity of the multiple values and complex resources that characterize the cultural terraced landscapes of the Costa Viola (Italy). In particular, the interactions between different knowledge, approaches, and tools makes it possible to formulate scenarios, strategies, and actions, contributing to the creation of a richer and more complex context of knowledge of the territory and to the construction of bottom-up and situated transformation strategies, supported from a decision-making process attentive to the identification of values and an understanding of the needs of the local 'landscape community' who live and animate it.

Keywords: cultural terraced landscapes; complex values; multidimensional approach; strategic planning and decision making; multi-criteria decision analysis; regime multicriteria method

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1. Introduction

Over the centuries the concept of "landscape" has evolved assuming different meanings [1] that can be traced back to three interpretations: (i) of an aesthetic nature, the landscape as an image, with origins in romantic and late idealist philosophy; (ii) of a scientific nature, the landscape as a phenomenon, which coincides with the development of the natural sciences; (iii) systemic and interdisciplinary, the landscape according to an integrated and multidimensional approach.

The European Landscape Convention in 2000 (ELC) [2], in favor of the latter interpretation, defined the landscape as «a specific part of the territory, as perceived by the populations, whose character derives from the action of natural and/or human factors and from their interrelations» (ELC, art. 1) [2]. With this meaning, it is considered a complex system of relationships between human/social, natural/manufactured, and historical/cultural capital. Its quality, which is the result of the interaction of these factors and the expression of the identity of the populations, is decisive for individual and collective well-being as well as for the sustainable development of a territory. The benefits it unfolds include the environmental, cultural, social, and economic fields; however, they often lose in political decision-making processes as they are always difficult to communicate and measure. Furthermore, the Convention introduced elements of considerable complexity and innovation linked to the recognition of a fundamental right to use the landscape [3]. In fact, the signatory States of the Convention must play an active role in its transformation, since it "represents a key element of individual and social well-being, and that its protection, management, and planning entail rights and responsibilities for each individual" (ELC, art. 2) [2]. A great merit of the Convention is precisely the vision of the landscape as a collective good, with respect to which public institutions must assume specific responsibilities through a broader process of social responsibility, supported and animated by the population's participation in strategic choices and consequent actions. Therefore, the Convention introduced a completely new vision, above all with respect to the realization of individual and collective well-being, and concerning its ability to generate added value (not only economic), intrinsic or existential value. Central to this perspective is the ability to proceed with valorization, in its multiple dimensions and implications: aesthetic, economic, financial, cultural, and social.

Moreover, the ELC [2,3] attributed full conceptual autonomy and legal recognition to the landscape as a community asset to be safeguarded, managed, and planned, and as an "essential component of the life context of the populations, an expression of the diversity of their common heritage cultural and natural and foundation of their identity" (ELC, art. 5) [2]. For this reason, the Council of Europe encouraged the production of studies capable of assessing the complexity of landscapes «taking into account the specific values attributed by the populations concerned» by initiating public participation procedures and co-design (ELC, art. 6) [2], particularly oriented toward raising levels of well-being and quality of life.

Cultural landscape, the most recent heritage category introduced by UNESCO [4,5], defined as the result of the historical combination of the work of man and nature, is an essential component of European heritage and an indispensable element for the quality of life of communities. Thanks to its ability to connect nature and culture, the landscape constitutes «a structure within which it is possible to implement the principles of sustainable development, i.e., the pursuit of human well-being and the protection of the environment, through a development of a holistic approach» [6].

The first practical implication of this meaning is the extreme opening of the reference horizon: the landscape extends to the whole territory and it no longer concerns some of its circumscribed areas.

Consequently, attention cannot focus only on 'excellent landscapes', but must also extend to 'common', 'ordinary', and 'unresolved' or abandoned ones, which are in any case the cultural expression of the society that produced them and inhabits them. The consideration of ordinary and common landscapes opens up a previously unknown management and redevelopment planning perspective, especially in Italy, where the approach of conservative protection has always prevailed, functional to a monumentalizing vision of the landscape.

The landscape is the product of an incessant anthropic activity of transformation of the territory, whose negative effects on both the natural environment and on health have led to a revision of the traditional development model, which only had objectives of an economic nature, toward a circular development model [7], in which, in addition to economic growth, environmental and social aspects must also be considered. The landscape can therefore be defined as a construct of both a cultural and a social nature [8]. In this sense, the concept of landscape is inclusive: people are constantly involved in its creation.

The landscape is connoted in a strategic sense only if it derives from the expression of a collective planning intentionality, the result of a conscious elaboration process by the communities that inhabit and animate it, transforming it into a strategic construct [9,10].

Over the last three decades, the progressive opening up of planning to the themes of landscape and identity, from the perspective of sustainable local development, has undoubtedly contributed to redefining the forms and contents of territorial policies, partly renewing the planning instruments, but above all by enriching their theoretical–interpretative devices with new meanings and new approaches.

Moreover, the exceptional circumstances that the whole world is going through due to the COVID-19 pandemic impose a reflection that recognizes the landscape/cultural heritage as having a key role in preserving/enhancing as a specific resource for its "human-centered development", based on the values included. From this perspective, the contribution poses the following research question: how to build collaborative processes capable of putting local institutions, businesses, and local communities in synergy, to identify enhancement strategies for the cultural landscape?

In this direction, it is necessary to adopt a widely shared strategic vision that can trigger bottom-up co-design policies and actions in order to not undermine the development process that is intended to be triggered. The synergies or conflicts that can emerge in the participation and interaction in the regeneration processes between the different categories of stakeholders are necessary for the determination of alternative evolutionary scenarios [11].

An inclusive and prosperous landscape is aware of its cultural diversity and protects the rights of all its inhabitants [12]. Therefore, through the participation and involvement of interested parties in creating sustainable urban development, belonging and identity are promoted, contributing to the definition of policies in a "landscape for all". Participatory planning is seen as a "potential exercise to support decisions" [13]; in fact, more and more new forms of stakeholder involvement are being perfected, precisely to encourage better sharing of the interested parties in defining strategic choices.

The selection and articulation of the different phases, approaches, and evaluation techniques that characterize a decision-making process can help improve the final decision, allowing the inclusion of the different components that influence the choices and providing a transparent description [6,12–14].

The need for an effective use of resources in the planning of actions for the protection and enhancement of cultural landscapes calls for the need for integrated evaluation methodologies capable of involving knowledge and examining the different points of view and benefits of local stakeholders. Decision-making processes must be supported by transparent evaluation systems capable of explaining the complexities of the landscape and defining action priorities in a transparent and effective way according to shared common objectives. An integrated perspective can be based on a values approach [15,16] that recognizes the need to develop appropriate models for specific contexts through multi-methodological assessments, is useful to make explicit an incremental, flexible, and adaptive decision-making process, and is attentive to the complexity of the various detectable territorial components.

Evaluation, therefore, becomes a process of active participation, self-learning, the social construction of meaning, and of collective identity through which initial values are modified and new values are constructed/produced [15,16].

This contribution deals with the evaluation of the terraced cultural landscape. The objective of this study is to explore the potential of an integrated, incremental, and adaptive decision-making approach, oriented toward the elaboration and evaluation of co-designed and shared territorial enhancement strategies, and which is attentive to the specificity of the multiple values and resources attributable to the cultural landscapes terraced, with reference to the case study of the Costa Viola in Southern Italy.

In detail, the document is structured as follows: after an introduction to the research objectives and the presentation of the case study (Sections 2 and 3), Section 4 presents the multi-methodological framework, in which the methods and results for each step obtained are detailed; in the concluding Section 5 the results are analyzed, and research perspectives are identified.

2. Research Objectives

Public policy decisions are intrinsically multi-attribute problems characterized by multiple dimensions, with heterogeneous, often conflicting goals further exacerbated by an uncertain policy cycle and scarce public resources. This requires inclusive participatory decision-making that facilitates discussion and is able to include multiple points of view and different perspectives.

However, it should be noted that investments and management decisions for the enhancement and regeneration of cultural heritage are by their nature complex and involve high costs, which discourages investment by public and private subjects. Today, the importance of protecting agricultural cultural landscapes, and in particular of terraced cultural landscapes, collides with the uneconomic nature of traditional agricultural practices carried out in areas that are difficult to access and have a high hydrogeological risk.

The terraced landscape represents one of the most complex landscape systems, being made up of a multiplicity of elements and functions (ecological, historical–cultural, social, and economic).

On this front, the National Recovery and Resilience Plan (PNNR) and the NextGenerationEU program (NGEU), the temporary instruments designed to stimulate recovery and Italian economic growth, dedicate various investments and grants to the protection and enhancement of the immense cultural heritage of our country [17]. The measures envisaged by the PNNR, of unprecedented scope and ambition and never financed in Europe, provide resources for the protection and enhancement of architecture and the landscape aimed at preserving and enhancing rural and historical landscapes through the protection of tangible and intangible cultural heritage, and promoting initiatives and activities related to sustainable tourist-cultural use, enhancing local traditions and culture. The measures are inspired by a philosophy of environmental sustainability and strong digitization, as well as cooperation between public and private entities, and provide for specific investments to accelerate the ecological and digital transition, improve the training of male and female workers, and achieve greater gender equality, territorially and generationally [17].

In this context, it becomes urgent to support public strategic decisions through adequate evaluation methodologies, able on the one hand to manage the complexity of the interests at stake (not always consensual) of the stakeholders involved and on the other to evaluate the various intervention scenarios according to the different dimensions of sustainability (cultural, social, and economic).

This complexity needs to be addressed through appropriate evaluation approaches, which can effectively support public decisions regarding the investment and management of the cultural landscape.

In particular, this paper fits into this line of research by proposing a Multi-Criteria Decision Aid approach (MCDA), elaborated on with respect to specific objectives and criteria and capable of providing the public decision-maker with a multi-methodological framework, which is useful for classifying and deducing a ranking of preferability among alternative intervention strategies and scenarios. An integrated evaluation approach based on creative and collaborative tools [8,13,14] for the territorial regeneration of the vulnerable 'unresolved' landscapes, such as terraced landscape of the Costa Viola in Southern Italy, is capable of triggering new values and adding value to the community development of the territory concerned. In this sense, it represents an effective tool for managing landscape transformations, is capable of governing the territory, involving multiple sectors and skills at various levels, and of integrating the preferences and needs of the community through a process of co-design and co-evaluation of a more shared desirable future.

The international initiatives for the protection of terraced landscapes (World Alliance for Terraced Landscapes), agricultural cultural landscapes [18], and the protection of biodiversity [19] highlight the importance of rural cultural landscapes for sustainable development [20]. Furthermore, terraced landscapes are considered an effective example of a resilient system built over the centuries [21]. They are a resilient territorial system that has been able to respond flexibly and dynamically to external pressures (economic, social, and ecological), using their self-organizing capacity to continuously evolve while preserving their structure and identity.

Evaluation is the basis of the dialogue between knowledge and values, it is capable to translate this dialogue into the selection of objectives and actions, the identification of key values and their meanings, the exploration of opportunities and the construction of alternatives, analyzing the possible impacts and effects, and supporting the management of complex systems with multiple priorities.

The dialogue between experts in the landscape community and the integration of these different values in the decision-making process generates greater feelings of consensus and trust in public decisions [12] and the reduction of conflicts [13]. In this context, the evaluation process, through the integrated multi-methodological approach used and applied to this case study, integrates the contribution of different knowledge and is based on the sharing of responsibilities among the various stakeholders and on the concertation of design choices through the complementarity between experiences and skills of different domains.

3. Case Study

The theme of the landscape as a "common good" [22], according to the definition of Historic Urban Landscape (HUL) [23], has been explored as a field of investigation and experimentation for an innovative model of local development to be implemented for the terraced landscape of the Costa Viola (CV), in which the values that characterize the concept of HUL persist. The HUL represents the most recent contribution to the international debate on the identification, conservation, enhancement, and management of cultural heritage [22,23].

The complex landscape, the object of study (Figure 1), is characterized not only by the presence of immense material and immaterial cultural heritage but also by a heritage of biodiversity to be safeguarded and valorized.

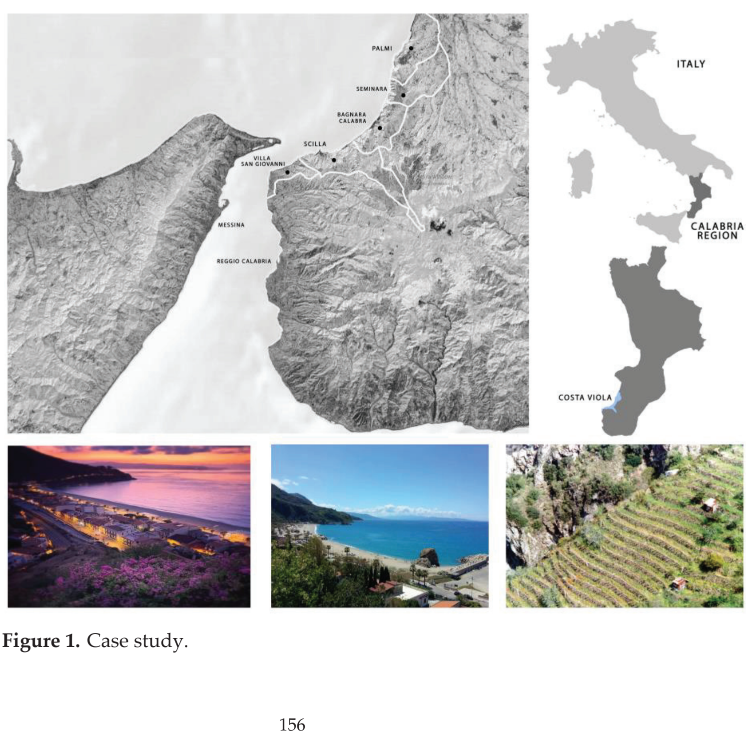

Figure 1. Case study.

The significance of the CV cultural landscape results from the stratification of intangible and tangible cultural components representative of different periods of history and vividly characterized by the relationship with the morphology and the hydrography of the territory.

The Calabrian terraced landscape of the CV is located in Southern Calabria in the territory of the province of Reggio Calabria. The CV is a Special Protection Area (SPA) whose territory has a total area of 29,425.00 hectares [24–26].

The coastal territory extends for about 35 km between the Strait of Messina and the lower Tyrrhenian Sea and includes territories facing the sea and, behind it, the vast hinterland of the Aspromonte Park. The coast, squeezed between the sea and the mountains, is dominated by high and jagged coasts, with an altitude between 0 and 500 m [26].

The structure and shape of the landscape have been modified by the presence of local communities that have developed their social and productive life near the sea, exploiting its resources (agriculture and fishing). The mountain ranges facing the sea alternate sandy and gravel coasts with hilly plateaus largely shaped by the agriculture that has settled on the mountainsides; the entire coastal strip is dotted with rural houses, defensive works, and watchtowers that characterize the territory producing results of extraordinary landscape value.

It is a cultural landscape that, in the past, has traditionally performed socio-economic, ecological–environmental, and cultural functions for the historically settled local communities, which has profoundly modified the natural structure of the soils, transforming them into a system of terraces.

This landscape, characterized by multiple and complex values, has undergone a slow process of abandonment by the local communities in recent decades, which historically have consolidated and preserved the territory, drawing benefits and comforts from it. The changed conditions and the socio-economic opportunities have determined, as for other traditional agricultural landscapes, the loss of the economic value deriving from the productivity of the terraced soils, which tend to re-naturalize, causing a loss of stability of the slopes. At the same time, the most profitable activities in the tourism sector, which indirectly use the landscape as the main element of economic attractiveness, risk further depleting local ecological resources due to seasonal environmental pressure.

The hydrogeological risk and the irreversible loss of the cultural and identity values inherent in the landscape, here as in other terraced areas, make it urgent to implement a shared regeneration strategy [26]. The terraced landscape, the result of countless individual modifications over the centuries, must be considered a “common good” [20,22] functional to the well-being and sustainable development of the communities that inhabit it. It is, therefore, necessary to adopt a widely shared strategic vision that can trigger enhancement and recovery actions widely supported by the private sector, restoring the conveniences linked to landscape maintenance [27]. The evaluation of the benefits generated by the landscape, beyond the economic, requires evaluation approaches capable of making explicit the values and their relationships, evaluating the impacts of the design actions to identify the intervention priorities, and monitoring the achievement of shared objectives.

4. Materials and Methods

The proposed methodological path is structured in three phases (Table 1):

1 Knowledge of the Historic Urban Landscape being studied, through the approaches of Hard and Soft Systems Analysis [28–32].
2 Identification of strategic actions and alternative scenarios through tools such as Customer, Actors, Transformation process, Weltanschauung, Owner/s Environmental constraints (CATWOE) [33] and Strategic Options Development and Analysis (SODA) [34].
3 Assessment of alternative scenarios through the multi-criteria method of Regime [35,36].

The evaluation approach was conceived in successive steps. For each step, the most appropriate analysis and evaluation methodologies and techniques were therefore selected, being able to support the pre-established results of the decision-making process according to the emerging problems and considering the characteristics and emerging problems in the study context. In particular, considering the CV as a Historic Urban Landscape, an expression of the practices of ordinary life, and of the relationships and links between the specific context and those who live in it, have been selected for each of the phases of the decision-making process techniques that are consistent with the Systems Thinking approach (ST) [28–31].

Table 1. Steps of the methodological framework.

Steps	Methods	Results
1. Landscape Knowledge	Hard Analysis Fishbone Diagram Soft Analysis	Context/Indicator Analysis Criticism and Potential Map Stakeholder
2. Scenarios Definition	CATWOE SODA Analysis Domain Analysis Central Analysis	Community Preferences Cognitive Maps Strategic Actions
3. Scenarios Assessment	Regime multicriteria	Preferable Scenario

The ST is a way of thinking aimed at solving complex problems related to the uncertainty of the real world. Indeed, ST analyzes the impacts and behaviors of each element and how it interacts with the entire system. If the world is a set of highly interconnected and hierarchically organized technical and social entities, then it is possible to produce observable behaviors by stakeholders, who are subjects directly interested or influenced by such behaviors.

In this sense, ST, or Systems Thinking approach, is a tool for describing a system as a whole, highlighting its dynamic nature and the interaction that takes place between its elements.

To better understand what ST is and how to be able to think in systems to improve the strategic positioning of an organization or to guide its organizational transformation, it is necessary to carry out some insights into the discipline at its base, which can be represented as a collection of tools and methods, as well as a profound new philosophy of thought.

This philosophy concerns the following fundamental aspects:

- the ability (sensitivity) to be able to observe and grasp the "circular" nature of the world in which we live;
- awareness of the role of the structure of "systems" in determining the situations we are confronted with;
- the understanding that there are potential unintended consequences to the actions we take.

The ST is therefore also a diagnostic tool applied to problem-solving, because it allows, through a rigorous approach, to analyze problems more accurately and completely before acting.

One could therefore define "Thinking for Systems" as thinking approaches for systemic analysis that allow us to give the right answers to vital questions for the organization since, even before reaching hasty conclusions (pursuing the modern need to have—too much—to quickly provide the "right answers"), one is able to identify the right questions to ask/ask in the analysis of the problems under examination.

The art of seeing the forest and not the single tree: thinking in systems, therefore, means moving from the mere and simple analysis of the individual components of a system toward the understanding of the whole system in its entirety and in its emerging properties. Additionally, once the system has been defined, one can move from the observation of the events (or of the data connected to them) toward the identification of the patterns of behavior over time of the phenomena of interest, and from there to the underlying structures that generate them.

The ability to understand and modify those "structures" that are not operating at their best (including our mental models or perceptions) allows us to expand the selection of choices available and thus create more effective long-term solutions to chronic problems.

The ST, therefore, expands the range of choices available for solving a problem, broadening our capacity for analysis and articulation in an innovative and different way. At the same time, the principles of Systems Thinking make us aware that there are no optimal or even perfect solutions: the choices we make will impact other parts of the system. By anticipating the impacts of each such trade-off, we can minimize its severity or even use it to our advantage.

Not surprisingly, the power of Systems Thinking approach has also recently been recognized by the OECD (Organization for Economic Co-operation and Development) [37,38], which, in one of its latest reports, identified the need to use this paradigm if we want to successfully solve the challenges of the 21st century.

The OECD is not alone in recognizing the benefits of Systems Thinking as a skill that helps solve problems more effectively. The World Bank has also promoted this methodology in two very different fields: as a model for more effective education and as a methodology to better evaluate investment policies in education and training around the world.

According to the ST approach, decision problems are by their nature complex; they can influence habits, behaviors, and practices. These problems can therefore be better understood and analyzed by considering the reciprocal relationships, the bonds, and the interactions between the elements that make up the totality of the system and the other systems, in a cyclic rather than a linear process. The experience is considered complementary to the observation and the landscape is interpreted as an expression of the collective memory, as an explanation of the wider cultural context [39,40].

It is therefore widely believed that ST is a fundamental approach to managing the complexity of the problems facing the world in the coming decades.

ST is applied by a wide variety of disciplines as it enables decision makers and managers of all types and at all levels to deal with the subtleties and confusion of the complex situations they face. As a decision support system, the ST is used in the field of planning and management of territorial systems, landscape and urban planning, feasibility studies, strategic planning, and construction of alternative scenarios, as in the decision-making context of the study addressed in this research [6,8,10,13,16,28–31].

In particular, the combination of techniques such as Soft Systems Analysis and Hard Systems Analysis [28–32] has made it possible to structure a learning process aimed at understanding the specificities of the context perceived by the main and various categories of local stakeholders, being actively involved in the decision-making process, and determining how to improve the definition of the components of the decision-making problem under examination.

In the first phase, through Hard Systems Analysis, this study made it possible to structure a synthetic and objective cognitive framework relating to specific thematic areas and problems of the terraced cultural landscape of the CV and identifying measurable and representative issues of the specific problems. Subsequently, the critical issues and potential of the territory were then identified according to some potential actions that were structured according to a Fishbone diagram [41].

In the first phase, through the Hard Systems Analysis, this study made it possible to structure a synthetic and objective cognitive framework of the terraced cultural landscape of the CV with reference to specific thematic areas, identifying measurable and representative issues of the specific problems.

However, applied to a situation such as that of the Costa Viola, which is characterized by complex problems that follow non-linear logics, the "hard" approach proved to be insufficient to produce useful results for understanding the different components which must be considered. In fact, in many real-life situations, it can be difficult to describe the decision problem in a way that can be easily addressed. For these reasons, it is possible to integrate the "hard" approach with the "soft" one and resort to Soft Systems Analysis, which allows tackling unstructured problems where the objectives cannot be easily specified and the relevant data are not identified. The integration of these two approaches makes it possible to structure issues more attentively to the multiple dimensions of a decision-making context, in which the combination of "hard" and "soft" data provides a rich and articulated picture of emerging issues and significant characteristics for the present case.

In the next phase, through the Soft Systems Analysis, the "soft" data collection phase was conducted starting from the definition of an identification map of the stakeholders involved in the decision-making process through the Institutional Analysis (IA) technique [42]. In structuring an IA process it is necessary to identify alternative solutions and criteria that are shared by the stakeholders and that reflect the hierarchy of preferences and interests of the various actors in the landscape community. To identify the point of view of the stakeholders, the CATWOE approach (C-customers, A-actors, O-owners, E-environmental constraints) [33] was used, which was particularly suitable for analyzing the roots of the decision-making problem, offering the interviewees the opportunity to express their opinions in a profound and reasoned way.

The soft data collection was built through the realization of exemplified in-depth interviews using the CATWOE approach, which made it possible to facilitate the sharing of information as well as the interactions between the actors involved in the theme of the regeneration of the historic terraced landscape of the CV. CATWOE is a decision aid technique typical of Soft Systems Analysis which refers to the Soft Systems methodology formulated by Checkland in 1981 [32].

The phase of identifying and processing the perception of problems, preferences, and possible solutions expressed by the community was developed through the application of the strategic options development and analysis (SODA) approach [34]. The SODA approach allows for the elaboration of cognitive maps starting from the verbal protocol of an exemplified in-depth interview and the analysis of preferences by elaborating the relative orders of preference useful for identifying shared visions and actions.

The SODA analysis, together with the analysis of the plans and programs in place in the area, contributed to the elaboration of five alternative intervention scenarios.

Finally, the last phase presented the Regime method [35,36], the multi-criteria methodology elaborated based on the knowledge acquired and the experiences presented in the previous phases. The Regime method was applied to the evaluation of the terraced landscape of the CV to classify the identified shared scenarios.

The methods, tools, and results of applying the proposed methodology for each phase of the multi-methodological assessment framework are described in the next section.

5. Application and Results

The proposed decision-making process made it possible to structure a learning process aimed at understanding the specifics of the study context, in which, for each of the phases, the techniques most consistent with the Systems Thinking approach were selected.

5.1. Knowledge Phase: Hard Systems Analysis

In the preliminary cognitive phase of the decision-making process, a Hard Systems Analysis (HSA) was used, characterized by the acquisition of objective and measurable "hard data" [30,32]. The HSA made it possible to acquire a reference cognitive framework, which was useful for defining a set of qualitative and quantitative indicators structured according to specific thematic areas. The hard data were extracted from various institutional databases (national, regional, provincial, and municipal) of public and private entities operating in the area, from territorial analyses, planning and programming tools, and bibliographic research [43].

This made it possible to structure a synthetic and objective cognitive framework of the territory in question, organized by thematic areas, with respect to which a set of indicators were identified among those most representative of the problems of the study context and able to indicate the mutations of the phenomena and related changes over time. The information framework was structured with reference to specific thematic areas: population; economy; tourism; transport; infrastructure; agriculture; soil and subsoil, hydrosphere; cultural and landscape heritage; and services for the citizen.

As considerations on the sidelines of the study of existing programming and design tools, it should be noted that there is a lack of an overall and unitary vision of the entire CV site. What emerged from this analysis was not only the lack of coordination of the projects in the temporal planning and the territorial space, or between the various municipalities of the CV landscape, but also the lack of integration of the projects concerning the different resources and landscape components, as well as compared with the entire local system. Therefore, the analysis of this planning shows how, in reality, the projects related to the different landscape dimensions are not realized according to the landscape system, neither its components nor its dynamics. In any case, the existing lines of development that emerged from the planning in force were identified in order to understand the evolution of the landscape system, and to consequently propose a project scenario shared with the CV community. In fact, making explicit the guidelines in place allows you to compare the current state of affairs with a more advantageous vision and to define the trajectories toward which to direct the management of the site. From this perspective, specific scenarios were then developed and then evaluated, as described in the following sections.

Finally, starting from the analysis of the set of selected indicators the "criticalities" and "potentialities" of the territory were identified according to the possible intervention actions, structured and classified according to the Fishbone diagram [41]. The actions were therefore classified taking into account their relevance, highlighted through a specific and appropriate evaluation scale (High relevance, Medium relevance, or Low relevance), to which a chromatic scale was associated (see Tables 2 and 3)

Table 2. Criticality.

POPULATION	ECONOMY	TOURISM	TRANSPORT
Demographic decrease.	Lack of management, enhancement, and integration policy for economic activities.	Tourist seasonality.	Inadequacy of public transport.
Low level of education.	Progressive abandonment of economic activities such as agriculture and crafts.	Low quality of the tourist offerings.	The main use of private transport.
	Quite high unemployment rate.	Poor enhancement of the various tourist attractions.	Insufficiency of the road network.
		Inadequate tourist services.	Large tourist bus turnout.
		Outdated accommodation facilities.	Lack of integration between the different types of infrastructure and transport.
		Touch and go tourism.	Lack of parking.
		Unqualified personnel.	
AGRICULTURE	**SOIL, SUBSOIL, AND HYDROSPHERE**	**CULTURAL AND LANDSCAPE HERITAGE**	**SERVICES FOR THE CITIZEN**
Abandonment of agricultural activities.	Presence of areas with high hydrogeological risk.	Lack of management, protection, and enhancement policy for the landscape resource.	Absence of social recreational facilities.
Poor valorization of organic products.	Rise of numerous empty houses.	Lack of an integrated program of knowledge and enhancement of cultural heritage.	The concentration of events and demonstrations in the summer months.
		Threat to the conservation of biodiversity.	
		Bad management of cultural heritage.	
		Abandonment of proto-industrial buildings (mills, etc.).	
		Poor maintenance of paths and mule tracks.	

Legend:

High relevance
Medium relevance
Low relevance

Table 3. Potentiality.

POPULATION	ECONOMY	TOURISM	TRANSPORT
	Tourism: economic sector in constant growth.	Tourist attraction.	Maritime transport.
	Presence of traditional local economic activities	Presence of uncontaminated landscapes and authentic places.	
		The annual increase in arrivals.	
		Typical products.	
		Natural–historical and hiking trails.	
AGRICULTURE	**SOIL, SUBSOIL, AND HYDROSPHERE**	**CULTURAL AND LANDSCAPE HERITAGE**	**SERVICES FOR THE CITIZEN**
Typical agricultural products.	Forest and vegetation cover most of the territory.	Presence of proto-industrial heritage.	Presence of centers of local history and culture.
Costa Viola products: IGP wine.	Architectural heritage largely before 1945.	Presence of significant biodiversity systems.	Presence of school facilities.
Unused agricultural areas.	Possibility of exploiting water for the production of electricity.	Presence of numerous Nature Reserves.	
		Typical products.	
Legend:		Cultural and religious events.	
High relevance			
Medium relevance			
Low relevance			

Therefore, through the preliminary cognitive phase of the HSA, the problems of the study context were now clearly defined, and it was, therefore, possible to structure and clearly define the objectives oriented according to development strategies shared with all the actors involved.

5.2. Knowledge Phase: Institutional Analysis

However, the "hard" approach, applied to a situation such as the Costa Viola, which is characterized by complex problems that follow non-linear logic, proved to be insufficient to produce useful results for understanding the different components that must be considered. In fact, in many real situations, it can be difficult to describe the decision problem in a way that can be easily addressed. For these reasons, it is possible to integrate the "hard" approach with the "soft" one and resort to Soft Systems Analysis, which allows for tackling unstructured problems where the objectives cannot be easily specified and the relevant data are not identified. The integration of these two approaches makes it possible to structure issues more attentively to the multiple dimensions of a decision-making context, in which the combination of "hard" and "soft" data provides a rich and articulated framework of emerging issues and significant characteristics for the case under consideration.

The "soft" data collection phase was conducted starting from the definition of an identification map of the various actors involved in the decision-making process through the Institutional Analysis [42].

The Institutional Analysis [42] supported the analysis and identification of available endogenous human, social, and environmental resources, as well as the identification of social and economic perceptions of the community, which was useful for identifying alternative solutions and the criteria which expressed the preferences and reflected the hierarchy of interests of the different groups that make up the CV landscape community.

Through the Institutional Analysis [42] it was possible to define an identification map of the various stakeholders involved in the decision-making process through an analysis of the context and its evolution over time. In particular, through the study of the history of the CV, it was possible to trace who were and who are the dominant and significant figures for the local culture and the characteristics of the places.

They have been recognized among the institutions operating in the area, the representatives of the dominant economic sectors, the main users, the experts, the locally organized groups, and the influential associations. Through the analysis of the main actors involved, it was possible to understand how the options to be built should be aimed at the specific interests of the community, taking into consideration the preferences of the actors representing a particular condition or a more general need. An Institutional Analysis oriented in this way made it possible to increase the cognitive framework and improve the selection of tools through which to develop alternative scenarios.

The stakeholders were divided into three main groups: the promoters (institutions, experts, and universities), the operators (production activities, accommodation businesses, and associations), and the users (citizens and tourists).

The first group included institutions and experts with a high degree of influence in choices oriented toward the pursuit of one's objectives.

In the second group were classified the operators of the dominant economic sectors, operators of productive and hospitality activities, but also the associations, i.e., those who have a high degree of interest and a significant influence in the choices.

Finally, the addressees of public policies, to be involved in the formulation of the same policies as citizens and tourists, who have a high interest but a low influence, were classified in the third group.

5.3. Strategic Actions Identification Phase: Soft Systems Analysis

The Institutional Analysis [42] supported the analysis and identification of available endogenous human, social, and environmental resources, as well as the identification of perceptions. To identify the stakeholder point of view, in-depth interviews were carried out using the CATWOE approach [33], a decision-aid technique typical of Soft Systems Analysis [40]. The CATWOE is a useful tool for structuring the interview and for exploring the decision-making problem from multiple points of view.

The understanding of the issues and the identification of possible strategies are articulated according to the following points:

- Customers: Who could obtain advantages or disadvantages?
- Actors: Who performs the transformations?
- Transformation process: What is proposed in terms of input and output?
- Weltanschauung: Which vision makes the proposed activity meaningful?
- Owners: Who could oppose this activity?
- Environmental constraints: Which environmental constraints could be conditioning?

The model proposed for the landscape of the Costa Viola enriches the points of the CATWOE by inserting two others, considered significant for describing some aspects of the problem more clearly, to integrate the information already obtained through the analysis of the "hard" data and explained with the Fishbone diagrams (see Tables 2 and 3).

- Criticality: What are the major critical issues?
- Potentiality: What are the greatest potentialities?

The stakeholder interviews respected the CATWOE's eight interpretative questions.

The interview was, therefore, structured on the basis of some issues considered significant for the sustainable development project of the Historic Terraced Landscape of the CV, to bring out the perception of the critical issues and potential, and identifying future scenarios of transformation and related implementation strategies.

The elaboration phase of the perceptions of the problems, the preferences, and the possible solutions made explicit by the community was structured through the application of the Strategic Options Development and Analysis (SODA) approach [34].

The method makes it possible to structure, from a formal and methodological point of view, and adequately analyze the qualitative data starting from the cognitive maps and the verbal contents of the interviews. The elaboration of cognitive maps allows a mental representation and serves to acquire, codify, memorize, recall, and decode a system of concepts and to identify the relationships between them, to communicate the nature of the decision-making problem in question and the related implications.

Operationally, the verbal protocol according to the CATWOE model with the eight interview questions was administered to each group of stakeholders. The eight questions making up the interview were associated with the concepts of criticality, potentiality, actions, future visions, obstacles, actors, environmental limits, and an identifying color.

Contextually, using the Decision Explorer3.1 software, the relative cognitive map was elaborated for each group of stakeholders (institutions, hoteliers, restaurateurs and traders, experts, associations, agricultural producers, tourists, and citizens).

Finally, the analysis and comparison of the results of the domain analysis and the central analysis allowed the formulation of the structure of the preferences of the different stakeholders involved. The preferences identified, and made explicit by the landscape community, made it possible to outline future shared visions, strategic actions, and enhancement scenarios of the Historic Terraced Landscape of the CV.

Five alternative "scenarios" were constructed for possible landscape enhancement and regeneration, and consisted of a set of "strategic actions" integrated with each other with respect to the interdependencies that characterized the reference territorial system.

The "scenarios" were constructed with reference to three territorial dimensions (cultural heritage, natural heritage, and infrastructure of the territorial system) and made explicit through "strategic actions" that responded to three "strategic objectives", identified in relation to the same identifying components of the landscape:

- To Protect and Enhance the Cultural Heritage;
- To Protect and Enhance the Natural Heritage;
- To Improve and Strengthen the Infrastructural System.

Specifically, the general objectives were identified by analyzing the study context and taking into account the coding of the in-depth interviews considering the preferences expressed by the community. While the strategic actions were aimed at an effectively integrated valorization of the territory, they constituted specific, punctual, and local interventions relating to the complex territorial system and were conceived to trigger dynamics of development and sustainable management, which introduced new sap to "restore" the denied values of the territory and promote an effectively integrated enhancement of the landscape.

5.4. The Multi-Criteria Evaluation

In the research applied to the study context, in order to arrive at a synthetic evaluation, a Multi-Criteria Decision Analysis (MCDA) [44,45] was adopted, which was able to help find answers regarding the identification of intervention priorities within the development guidelines in the study context and which allowed a ranking of preferability among the different identified scenarios.

Multi-criteria methods appear capable of grasping the multiplicity of values at stake that planning aimed at achieving sustainable development must take into consideration.

Within the large family of multicriteria analyses, Regime's method is a discrete MCDA method [44,45] capable of reflecting the plurality of values, and therefore able to express the quantitative/qualitative approach for the evaluation of the complex social value of the intervention alternatives, such as of the future scenarios identified for the Historic Terraced Landscape of the Costa Viola in this specific case.

The MCDA analysis, and the discrete method of Regime [35,44] in particular, have been proposed as perspectives capable of helping to find answers regarding the identification of intervention priorities within the guidelines of development in the context of this study.

Regime's multi-criteria method is, in particular, a discrete multi-criteria evaluation method capable of managing qualitative and quantitative data. It is a tool suitable for planning problems characterized by great uncertainty and complexity regarding existing territorial, social, and economic structures and their interrelationships [42,46].

It is a decision support method which, in addition to the possibility of considering data of different natures (quantitative and qualitative), offers the opportunity to assign different weights to the identified criteria, manage conflicts between objectives, and deduce priorities between options alternatives.

The Regime method, in fact, is able to manage data of mixed types (binary, ordinary, cardinal, and categorical). It can be considered a qualitative method since the information on the preferences of the Decision Makers (DM), which then represent the weights, have only an ordinal (qualitative) definition, while the criteria can also be defined in a quantitative form [35,36]. From a methodological point of view, the method is based on the generalization of the agreement analysis, which in turn is a generalization of the pairwise comparison.

From an operational point of view, it is necessary to define: the impact matrix and the weight vector, which derive from the preferences expressed by the Decision Maker(s) on the order of importance of the weights [35,47–50].

The impact matrix summarized the effect of each action on each evaluation criterion, the weights, and the relative importance assumed by the evaluation criteria.

By comparing all the alternatives in pairs with respect to each evaluation criterion, it was possible to identify the concordance and discordance sets that served as a basis for arriving at the net concordance index, with regard to which it was necessary to focus above all on the sign that presented. This is because weights were also involved in the evaluation process, on which we only had ordinal information. The ranking of the alternatives was based on an aggregate probability linked to the sign of the net agreement index, which was expressed as a performance score.

The inputs required by the Regime method were the list of evaluation criteria and the vector of weights.

The output produced by the model was the ranking of preferences for every single alternative based on the "net index of a concordance".

For the synthetic evaluation of the Costa Viola landscape, the multi-criteria analysis of the Regime was elaborated with reference to three objectives and five criteria, deducing a ranking of preferences among the future scenarios shared by the "community" of the Costa Viola landscape. It also developed a sensitivity analysis to verify the "robustness" of the final results obtained.

The "scenarios" shared by the Costa Viola community were constructed with reference to three territorial dimensions (cultural heritage, natural heritage, and infrastructure of the territorial system) explicated through "strategic actions" that responded to three "strategic objectives", identified in relation to the same identifying components of the landscape.

In order to arrive at a summary assessment that allowed for the identification of a ranking of preferability among the various future scenarios proposed, the assessment was structured taking into account the three reference objectives, such as:

- Protect and Enhance the Cultural Heritage;
- Protect and Enhance the Natural Heritage;
- Improve and Strengthen the Territorial System.

Additionally, six criteria, for each of which the impacts were assessed:

- Archaeological Heritage;
- Built Heritage;
- Historical Landscape;
- Natural Heritage;
- Infrastructure System;
- Socio-Economic System.

The Guidelines from UNESCO 2011 [23] were used for the scenarios' impact assessment.

From an operational point of view, the overall impact assessment was obtained by combining the "intensity of change" with the "effects of the change produced".

A five-point impact assessment scale (no change, negligible change, marginal change, moderate change, and major change) was used to evaluate the impact of the scenarios with respect to the "intensity of change".

For the evaluation of the "effects of the change produced", positive and negative, a five-point impact evaluation scale was used; for this purpose, a five-point impact rating scale (from "very high" to "negligible") was used.

Considering the UNESCO proposal [23], for each scenario an overall assessment of the impacts was defined with reference to each strategic action and six evaluation criteria (archaeological heritage, built heritage, historical landscape, natural heritage, infrastructural system, and social economic) [19].

Note that a certain strategic action can be common to several scenarios (see Table 4); empty boxes indicate that the scenario was not affected by the corresponding strategic action. Since the impact assessment regards each strategic action, the effect (expressed on a scale from "very strong" to "weak") was identical for each scenario containing that strategic action (see Table 5). Note that the impacts are all positive and, for ease of reading, the empty boxes indicate "zero impacts".

Table 4. Cultural Heritage strategic actions.

Objective I: To Safeguard and Enhance the Cultural Heritage						
		SCENARIOS				
n.	**Strategic Actions**	**A**	**B**	**C**	**D**	**E**
a1.1	Restoration of Agriculture Mosaics through the support of agricultural and non-agricultural activities	☐		☐	☐	
a1.2	Restoration of the terracing system and its irrigation system	☐		☐	☐	☐
a1.3	Safeguard and recovery of the forest system, connected to the system of terraces and its supply chain	☐		☐	☐	
a1.4	Protection of the distributed ancient settlements			☐	☐	
a1.5	Redevelopment of settlements and environment			☐	☐	
a1.6	Strengthening of the tourist accommodation and tourism services in the inner areas: identification of different well-equipped poles (central reception and information services; promotion and sale of localproducts; interchange station among the tourist buses, etc.)			☐	☐	☐
a1.7	Integrated redevelopment of the main rural network of mule and trails (Rural Service) and complementary infrastructure to the main rural tracks (hiking trails)			☐	☐	☐
a1.8	Safeguard of the centralized ancient settlements				☐	
a1.9	Consolidation and integration of territorial polarities consisting of historical and architectural interest assets			☐	☐	
a1.10	Integrated safeguard and enhancement of the historical architecture of civilian type and defensive military (such as watchtowers and defense along the coast)			☐	☐	
a1.11	Promotion of cultural network made up of the numerous historical-architectural assets spread throughout the area, aimed at a tourist-cultural circuit, also of a scholastic nature			☐	☐	
a1.12	Enhancement of the religious tourism circuit				☐	
a1.13	Enhancement of the museum circuit				☐	
a1.14	Enhancement of the archaeological tourist circuit			☐	☐	
a1.15	Enhancement or the early industrial architecture circuit	☐		☐	☐	

Table 5. Cultural Heritage impacts evaluation.

Strategic Actions	Criteria						SCENARIOS				
	Arch. Heritage	Built Heritage	Historical Heritage	Natural Heritage	Infrastr. System	Soc. Ecosystem	A	B	C	D	E
a1.1			VS	S		S	☐		☐	☐	
a1.2			VS	S		M	☐		☐	☐	☐
a1.3			S	VS		M	☐		☐	☐	
a1.4		VS	S						☐	☐	
a1.5		VS	VS	M					☐	☐	
a1.6					S	VS			☐	☐	☐
a1.7			M		M	W			☐	☐	☐
a1.8		VS	S							☐	
a1.9	S	VS	M			VS			☐	☐	
a1.10		VS	M			M			☐	☐	
a1.11		S	M			M			☐	☐	
a1.12		S	M			S				☐	
a1.13		S	M			VS				☐	
a1.14	VS					S			☐	☐	
a1.15		S	M			M	☐		☐	☐	

VS—Very Strong; S—Strong; M—Moderate; W—Weak.

In detail, the scenarios were compared by applying the multi-criteria Regime method [35,36,48] and using the DEFINITE 2.0 software (DEcision on a FINITE set of alternatives) [51].

In the preliminary summary assessment, the three objectives were assigned the same weight (0.33 for each objective, with the sum of the weights equal to 1.00), and the criteria were assigned a weight obtained by dividing the weight of the objective by the number of criteria (equal to six), i.e., assigning a weight of 0.055 to each evaluation criterion (see Table 6).

The assessment returned the following preference rankings:

- The first ranking, with equal weights for all objectives.
- The second constituted a set of rankings obtained by attributing, in turn, to each objective a greater weight than the others and equal weighting to the two remaining objectives; in this way, a sensitivity analysis of the rankings was carried out as the weights varied.

The rankings obtained agree in identifying the following ranking of preferability among the scenarios:

- First position: Scenario D (score 1.00).
- Second position: Scenario E (score 0.75).
- Third position: Scenario C (score 0.50).
- Fourth position: Scenario A (score 0.25).
- Fifth position: Scenario B (score 0.00).

By applying the Regime method, the final result was reached, in which Scenario D was the most performing and which received the greatest consensus from the Costa Viola landscape community, highlighting the reasons that contributed to determining this preferability through the elaboration of an appropriate sensitivity analysis, which also explained the "robustness" of the alternative.

This final result also highlights that the preference for Scenario D is due to the performance of the scenario and that the results are not sensitive to the different attribution of the weights assigned to the objectives but only to the characteristics of the other scenarios.

Table 6. Multicriteria evaluation: Ranking scenarios.

(a) Equal Weight to the Three Objectives		**(b) Greater Weight for Objective: to Protect and to Enhance the Cultural Heritage**	
	Regime		*Regime*
Scenario D	1.00	Scenario D	1.00
Scenario E	0.75	Scenario E	0.75
Scenario C	0.50	Scenario C	0.50
Scenario A	0.25	Scenario A	0.25
Scenario B	0.00	Scenario B	0.00
(c) Greater Weight for Objective: to Improve and to Reinforce the Infrastructure System		**(d) Greater Weight for Objective: to Protect and to Enhance the Natural Heritage**	
	Regime		*Regime*
Scenario D	1.00	Scenario D	1.00
Scenario E	0.75	Scenario E	0.75
Scenario C	0.50	Scenario C	0.50
Scenario A	0.25	Scenario A	0.25
Scenario B	0.00	Scenario B	0.00

6. Conclusions

The "structural invariants" of the landscape of the Costa Viola site, as essential resources of the territory, represent the potential generators of sustainable and lasting wealth; these fundamental resources of the territory determine self-sustainable development that depends on the projects, and on their strategy in particular.

The evaluation process thus makes it possible to "hold together" the different territorial components in order to restore the integrity of the landscape and to establish how the transformation of the territory can be regulated [45]. An integrated approach relating to strategic planning and a coordinated set of different methodologies of knowledge and construction of bottom-up paths for the identification of values and understanding of needs has a high degree of operational effectiveness: the conservation and enhancement of the landscape is an activity which by its nature tends to oppose the processes of reductive simplification and homologation, which weaken territorial identities [2,14,15,35,44].

The combined use of different methodologies and multidimensional assessments allows one to outline a conscious and shared transformation and enhancement project that is consistent with the principles underlying the HUL approach [4,5,19,23,37,38,52,53], and to re-capitalize the "landscape as heritage" to build an ethical development in respect of the multiple material and immaterial components of the place, or rather to enhance the legacy of the past to produce new wealth, non-destructive of consolidated values, but capable of determining territorial added value [54–57].

In particular, the application of multi-criteria evaluation methods appears indispensable in the evaluation process as tools capable of building participation, making explicit the transparency of decisions, and also guiding "ethical" decisions of conservation, enhancement, and "construction" of the Historic Landscape Urban [23,58,59].

It is therefore appropriate that the strategic planning scenario is composed of projects based on the recognition of heritage values [12,14,46–49,53,58–60]. In conclusion, the evaluation process, supported by MCDA, demonstrates strategic value on three different levels:

- supports the feasibility of strategic landscape planning, as the multi-criteria approach is able to understand the complexity of the landscape and promote planning for its enhancement, favoring the implementation of integrated projects;
- it can favor the implementation of regional programming to which the strategic projects themselves must refer in order to be financed, thus also encouraging coherence in the transclarity of the plans and programs;
- makes the pursuit of landscape quality objectives operational, by virtue of which the European Convention aims to design landscapes as an expression of shared values.

Furthermore, the evaluation approach contributes to making operational the guidelines proposed by UNESCO and to implementing integrated and shared intervention strategies, also in line with what is indicated by the European Landscape Convention [2], which widens and solicits attention to all landscape typologies, as well as to all elements of urban structure, including social and cultural practices and values, economic processes, and intangible dimensions of heritage, as well as those related to diversity and identity [61–63].

Furthermore, as a landscape that maintains an active social role in contemporary society, closely associated with a traditional way of life and in which the evolutionary process continues over time, it is necessary to implement processes of valorization and the promotion of good governance, through the relational involvement of the local community, and which requires integrated and shared strategies capable of improving local deliberative democracy as a basis for shared actions in a long-term vision aimed at the development and effective construction of public decisions [12,22,27,29,45,48,52,54].

In conclusion, it can be said that the proposed evaluation structure represents a useful tool for managing the transformations of the terraced landscape, capable of governing the territory with a multi-dimensional approach, i.e., involving many sectors, skills, and decision-making levels [12,13,22,48,49,52,53]. According to this approach, scientific research and techniques do not have the task of defining optimal choices once and for all, but can be an important support for an interactive decision-making process involving various actors—citizens, administrations, and entrepreneurs—within some important shared values, what ultimately makes "local society" as is now sanctioned by all official documents, among which the European Landscape Convention, signed in Florence in 2000, stands out [2].

Finally, the work carried out opens up future research lines in the construction of an Integrated Spatial Decision Support System based on the assessment of ecosystem services and the landscape, which could be capable of providing increasingly accurate estimates of impacts on a spatial and economic scale, and of integrating the preferences and needs of the community for the "collaborative" construction of a desirable future [12,47,49,52,53,64].

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Article

Climate Adaptation Heuristic Planning Support System (HPSS): Green-Blue Strategies to Support the Ecological Transition of Historic Centres

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Abstract: The issue of climate has posed major and urgent challenges for the global community. The European Green Deal sets out a new growth strategy aimed at turning the European Union into a just and prosperous society, with a modern, resource-efficient, and competitive economy, which will no longer generate net greenhouse gas emissions by 2050. Cities in this context are committed on several fronts to rapid adaptation to improve their resilience capacity. The historic centre is the most vulnerable part of a city, with a reduced capacity for adaptation, but also the densest of values, which increase the complexity of the challenge. This study proposes an integrated tool, Heuristic Planning Support System (HPSS), aimed at exploring green-blue strategies for the historic centre. The tool is integrated with classic Planning Support System (PSS), a decision process conducted from the perspective of heuristic approach and Geographic Information System (GIS). It comprises modules for technical assessment, environmental assessment Life Cycle Assessment (LCA), economic assessment Life Cycle Cost (LCC), Life Cycle Revenues (LCR), and Discounted Cash Flow Analysis (DCFA) extended to the life cycle of specific interventions, the Multi-Attribute Value Theory (MAVT) for the assessment of energy, environmental, identity, landscape, and economic values. The development of a tool to support the ecological transition of historic centres stems from the initiative of researchers at the University of Catania, who developed it based on the preferences expressed by a group of decision makers, that is, a group of local administrators, scholars, and professionals. The proposed tool supports the exploration of green-blue strategies identified by decision makers and the development of the plan for the historic district of Borgata di Santa Lucia in Syracuse.

Keywords: green roof; Building Integrated Photovoltaic—BIPV; life-cycle assessment; life-cycle cost; life-cycle revenue; CO_2 emission reduction; cost-effectiveness analysis; financial feasibility; value-focused thinking; MAVT; Borgata di Santa Lucia in Syracuse

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1. Introduction

The challenges facing cities have changed dramatically in recent years. Issues such as digital transition, climate change, biodiversity loss, resource scarcity, migratory movements, demographic change, pandemics, social inequalities, and rapidly changing economies are at the heart of the debate [1–5].

The need for an epochal change in the economic and social framework has become increasingly apparent because of the exacerbation of the consequences of climate change, the increasing alarm cry from the scientific world, and a new general public awareness of the situation [6–14].

In this regard, in fact, in 2019, the European Commission made public the European Green Deal, which defines a new growth strategy aimed at transforming the European Union (EU) into a just and prosperous society, equipped with a modern, resource-efficient, and competitive economy, which will no longer generate net greenhouse gas emissions by 2050, and where economic growth will be decoupled from resource use. The European Green Deal proposed by the European Commission [15] promotes an acceleration of the implementation of the principles of sustainability set out by the Bruntland Commission (more than three decades ago) [16], the United Nations Conference on Sustainable Development in 1992 [17], the Kyoto Agreement in 1997 [18], the United Nations Conference on Sustainable Development-or Rio + 20 in 2012 [19,20], the Millennium Development Goals in 2015 [21], and the Conference of the Parties–21 (COP-21-Paris Agreement) [22].

The European Commission has outlined several objectives, policies, and key actions to be developed by the EU and the Member States [23,24]. The main objectives are the improvement of health and quality of life of European citizens, the protection of nature, and the transformation of the current economic model without anyone being excluded from this process or left behind. Coordinating the transition from a linear economy model, based on extraction, production, distribution, and use and disposal (where all end-of-life products are transformed into waste at the expense of the environment and with the risk of consumption of all existing raw materials), to a circular economy model, in which the production and consumption system exploits natural raw materials that can be recycled or reused [25] by extending the life cycle of products, minimising waste and environmental impact, means promoting such an ecological transition process, which is instrumental in pursuing these objectives.

Given that 75% of the European population lives in cities and that buildings account for about 40% of the EU's energy consumption and 36% of CO_2 production [23], the Green Deal, from the perspective of a circular economy, promotes the reduction of the use of resources and CO_2 emissions, the recycling of materials, and the reuse of the existing building stock.

Under the impetus of the Green Deal, a Horizon 2020-Green Deal call entitled "Building and renovating in an energy and resource efficient way" was launched, which promoted a series of research aimed at promoting the general guidelines proposed by the European Commission and influencing urban renewal and building renovation [26,27].

These actions, together with others, such as the political price of energy, digitalisation, etc., would allow the European Union to meet the challenge of improving energy efficiency and, at the same time, ensuring high level of employment, given that the envisaged increasing investment in the construction sector, which generates around 9% of European Gross Domestic Product (GDP), would foster the creation of 18 million jobs [23,28].

Although the social and economic repercussions of the COVID-19 pandemic in 2020 have, on the one hand, led to a setback for environmental policies, on the other, they have brought about a strong boost to European ecological policies, triggering the largest financial and implementation stimulus package ever funded in Europe, which has been instrumental in implementing those actions aimed at pursuing the objectives set out in the Green Deal and the Sustainable Development Goals (SDGs). The objective is a more environmentally friendly, digital, and resilient Europe.

The Next-Generation EU [29], within this framework, is a temporary instrument designed to respond to the economic and social damage generated by the pandemic, whose declared objective is to combat the climate crisis, recognized as the main threat of our time, and, through this challenge, to relaunch a new economy, reduce vulnerability, increase social capital, and steer Europe towards a new development perspective based on decarbonisation, the circular economy, and new patterns of production and consumption.

Next-Generation EU is the main tool used to promote recovery and resilience. It requires member states to allocate 37% of the funds of their National Recovery and Resilience Plans (NRRP) or Recovery and Resilience Plan (RRP) projects related to ecological transition.

This choice denotes the willingness to take the opportunity provided by the extraordinary funds of the Recovery Fund to accelerate the green transition. The ecological transition will need to be accompanied and supported by the digital process and administrative logic, to which a further 20% of the entire RRP budget is allocated.

What is innovative in the context of ecological transition, which is so massively adopted by institutions compared, for example, to the concept of sustainable development, is the firm awareness of the need for change, which implicit in the transition term itself: it is necessary not only to adapt our system to a more sustainable approach, but also to change it. Our economy must be restructured in such a way that respects, preserves, and values the entire planet that hosts us.

Cities are playing a leading role in action to reduce global CO_2 emissions and improve quality and increase the quantity of natural heritage. They represent one of the privileged contexts in which to implement the ecological transition process to achieve the objectives by 2050 [30–38].

Measures to improve the efficiency of the existing real estate and the creation of green infrastructure, in contexts characterized by a high concentration of historic and cultural heritage, raise several issues from technical, technological, economic–financial, social, environmental, cultural-identity, administrative, and political points of view.

There are many trade-offs generated by interventions to implement ecological transition in the historic centre. While the latter represents the most vulnerable and inelastic portion of the city, it is characterised by interlinked and stratified values that must be protected as representative of a place and its identity.

Is the ecological transition possible for old towns? Surely it must be possible, provided that a perspective capable of integrating all the elements previously mentioned is adopted.

From a thermodynamic perspective, the historic centre is not a closed system, whose order represents a mortal equilibrium, but an open system characterized by disorder, by flows of energy, matter, and information that allow it to “transire” (to pass) to a new state with enhanced resilience.

The information flows that cross through the historic centre must be able to mediate the trade-offs and identify the convergences related to the interventions necessary for the pursuit of the 2050 objectives [39–42].

The ecological transition of the historic centre is a multi-goal, multi-strategic, multi-layer, multi-stakeholder, and complex value process.

In view of this special condition, the ecological transition must be implemented based on integrated information processes. The adoption of a heuristic perspective can help public and private decision makers identify solutions that are most likely to work or be corrected [43–46].

For this purpose, this study’s objective is to define an integrated instrument finalized for the exploration of the green-blue strategies and the design layouts at the scale of the single building units, and at the urban scale of the historic district of the Borgata di Santa Lucia in Syracuse.

The district of Borgata di Santa Lucia is the second historic centre of the city of Syracuse. It has developed in more recent times than the other and older old town, namely Ortigia. The latter is the main nucleus of the UNESCO Site “Syracuse and the Necropolis rock of Pantalica” and is subject to strict constraints of protection and conservation that make it incompatible with interventions aimed at favouring the ecological transition. The district of Borgata di Santa Lucia is subject to less stringent constraints than Ortigia, offering greater opportunities for adaptation to combat climate change. Our research group has been working for five years to build a detailed database for this neighbourhood, and now we have a level of information that allows us to develop a tool to support its ecological transition.

The proposed tool is a particular Planning Support System (PSS), which is generally used for long-range problems and strategic issues and may even be designed explicitly to facilitate group interaction and discussion [47].

The PSS proposed in this study has been developed through the integration of different tools such as the Geographic Information System (GIS), a Decision System Support (DSS) based on Value-Focused Thinking [48], and some computer-based models that allow one to analyse and evaluate the data contained in a database developed in an Excel environment.

The proposed instrument integrates economic and environmental assessment, that related to the perception of the urban landscape and the identity of the context [49].

In this case, the proposed tool helps to explore the range of possible decisions and planning choices that are a priori unknown. Since the tool is developed from a heuristic perspective, it has been called Heuristic Planning Support System (HPSS).

The outcomes integrate complex information, such as the system of architectural-urban constraints, the cost-effectiveness also extended to environmental externalities, and the financial feasibility and multi-criteria analysis with reference to energy-environmental, identity, landscape, and economic criteria.

The paper is organised into the following sections:

Section 2 introduces an overview of the ecological transition critical issues in the historic centres; Section 3 illustrates the Heuristic Planning Support System (HPSS) tool and its components; Section 4 introduces the case study of the historic district of Borgata di Santa Lucia in Syracuse; Section 5 reports and discusses the results; Sections 6 and 7 proposes some reflections on the adopted HPSS tool, synthesizes the results, and identifies the lines of future development of this research.

2. An Overview on the Ecological Transition Critical Issues in the Historic Centres

The ecological transition of historic centres is more complex than in other parts of the city, and this makes this challenge more challenging.

Ecological transition critical issues in the historic centres can be summarized based on general and specific questions (Table 1).

Table 1. Ecological transition critical issues in the historic centres.

Critical Issues	Specific Critical Issues
Built environment	Typological and technological heterogeneity of the building heritage Poor adaptability and low levels of energy performance of building units Vulnerability of the building stock [50] Housing obsolescence Constraints for the protection of specific features
Human environment	Social vulnerability [38,39] due to the concentration in these contexts of the weakest social groups such as the elderly, immigrants, and families and the unfulfilled or insufficient process of social inclusion [51]
Economic and financial profile of subjects and real estate assets	Fragmentation of property ownership Concentration of income ranges in the medium–low type Concentration of buildings for rent Low awareness of the existence of financial instruments, such as incentive systems developed by national taxation to support the energy upgrading of buildings [52] Limited access, due to the specific characteristics of the built environment, to the benefits provided by the incentive system [53–55]
Natural environment	High population density Reduced endowment of natural capital [56] Reduced resilience to the effects of climate change
Administrative	Difficult technological and technical compatibility of the interventions with architectural and urban constraints [57–61]
Identity	Poor compatibility of energy efficiency interventions with the quality of the urban landscape and the historical–cultural and aesthetic values
Political	Difficulty to manage effectively the transition from a linear model to a circular one [62–69]

3. Methods

3.1. Planning Support System (PSS)

Among the tools proposed in the literature is the Planning Support System (PSS), which is widely used as planning support from a strategic perspective. [70].

PSS is a relatively recent tool, emerging on the planning scene in the mid-1990s as a geo-technology tool entirely dedicated to supporting and improving specific planning tasks [71,72].

This tool is connected to the Geographic Information System (GIS), but while the latter is a general-purpose tool for acquiring, storing, manipulating, analysing, and displaying geo-referenced data and applicable to many different problems, PSS is focused on supporting planning tasks.

In most cases, the PSS includes a GIS, especially if the planning task requires spatial data. The PSS is related to the Spatial Decision Support System (SDSS). The former generally pays particular attention to strategic and long-term problems. SDSSs are generally designed to support short-term policymaking by isolated individuals or business organisations [73,74].

The main function of the SDSS is supporting the operational decision-making process; the PSS aims to support the strategic planning activity [75].

The PSS usually consists of a combination of theory, data, information, knowledge, methods, and tools that are configured as an integrated framework with a shared graphic user's interface [76].

Many consider PSS a valuable support tools that will enable planners to better manage the complexity of planning processes, leading to better quality plans and saving time and resources [77].

The definition of PSS has evolved over time. Harris and Batty [71] were the first to define the PSS by combining a range of computer-based methods and models into an integrated system used to support a particular planning function [78–80].

Batty (1995) [71] has suggested that PSS was a subset of geo-computer technologies, dedicated to supporting those involved in design, exploring, representing, analysing, visualizing, predicting, prescribing, designing, implementing, monitoring, and discussing the issues associated with the need to plan. Klosterman [72,81], Brail, and Klosterman [82] suggest that PSS have matured as integrated information systems and software structures that synthesize the three components of traditional DSS—information, models, and visualization—and deliver them to the public sphere.

Geertman and Stillwell [83] considered PSSs as tools based on geographic information technology incorporating a suite of components (theories, data, information, knowledge, methods, tools, and meta-information) collectively supporting certain specific parts of a single planning task. Brail [84], instead, pointed out that many PSSs are developed and used to provide projections in the future or could support an estimate of the impacts arising from any form of development. There is no unambiguous and rigorous definition of PSS, but according to Klosterman and Pettit [85], all definitions tend to match the same type of functionality within this category of support tools. Many researchers see the PSS as a tool to improve knowledge and information management in planning processes. These functions provide enormous help to those involved in managing the ever-increasing complexity of planning activities.

Regarding the new developments of the PSS, Klosterman believes that it can integrate and expand the main components of the traditional DSS, and therefore also those of the SDSS, effectively supporting the planning and decision-making process at the same time [72,81].

This is only partially true, as a PSS in its classical structure alone can meet the needs of planning support, provided that the decision process is set beforehand, namely the set of alternatives is known.

Most decision-making problems investigated in the literature consider the set of alternatives as "dates". In fact, as pointed out by several authors [85], the decision-making analysis focuses mainly on how to choose an alternative without considering how it was defined.

Scholars on organizational behaviour maintain that the decisional process is much less systematic than what is established by the rational–normative model, which means that it is based on absolute rationality, as it takes for granted that decision makers apply several rational criteria during the decision-making process, which is also considered rational. Such special conditions are rare and circumscribed. Decisions are made with limited rationality; that is, decision makers are only able to recognize a limited number of alternatives and are only aware of some of the consequences of each alternative [86–88].

Heuristic processes are used to find answers and solutions that are most likely to work or be correct.

The process aimed at supporting the ecological transition of the Borgata district of S. Lucia can be considered as having limited rationality.

The decision-making process is not known; that is, the set of alternatives to be placed at the base of the decision is not given, and in this case it must itself be explored according to a heuristic approach.

In addition, a heuristic approach can also support the development of a heterodox perspective of the issue. In this perspective, the development of the decision-making process can integrate other perspectives besides the economic–financial one, such as the historical–cultural, architectural–urban, and environmental ones. Hence, there is a need to define a PSS that incorporates this heuristic perspective, namely a Heuristic Planning Support System (HPSS).

3.2. Heuristic Planning Support System (HPSS)

The ecological transition process of historic centres, due to its multi-objective, multi-strategic, multi-layer, and multi-stakeholder nature and complex values, can be implemented efficiently only if supported by a strategic perspective of the energy–environmental issue, by a heuristic approach, and by appropriate tools.

The tools should foster the exploration of objectives and strategies, identify potential trade-offs and convergences, mediate trade-offs based on multi-scale and multi-attribute evaluation, and support the identification of integrated strategies and a set of unknown and a priori established alternatives.

The process of exploring objectives/strategies and alternatives can be supported by a specific integrated tool that, because of the heuristic nature of the approach, can be defined as a Heuristic Planning Support System (HPSS). We have developed this tool HPSS, which will be presented in this section (Figure 1).

The HPSS tool proposed in this study consists of several modules:

A. The module supporting the identification of decision-making is based on value-focused thinking.
B. The analysis module integrates different levels of analysis aimed at:
    - The construction of a geodatabase, developed with the help of specific software, referring to the characteristics of building units and building and urban planning constraints; the characteristics of potential interventions from a technical and economic point of view (revenues and direct costs of interventions, revenues and environmental costs of interventions); and energy (the energy needs (Q) and primary energy (PE), environmental (GHH emission);
    - Supporting multi-criterial analysis.
C. The evaluation module integrates different levels of data built in the previous module and outputs the verification of technical feasibility, economic and financial feasibility, and the aggregate assessment of interventions with reference to the criteria selected by decision makers.
D. The planning module allows one to visualize, for any level of objective and strategy the decision makers want to explore, the performance of interventions with reference to individual and aggregate building units, and their localization in the study context.

Below are the specifications for the different modules integrated in the HPSS.

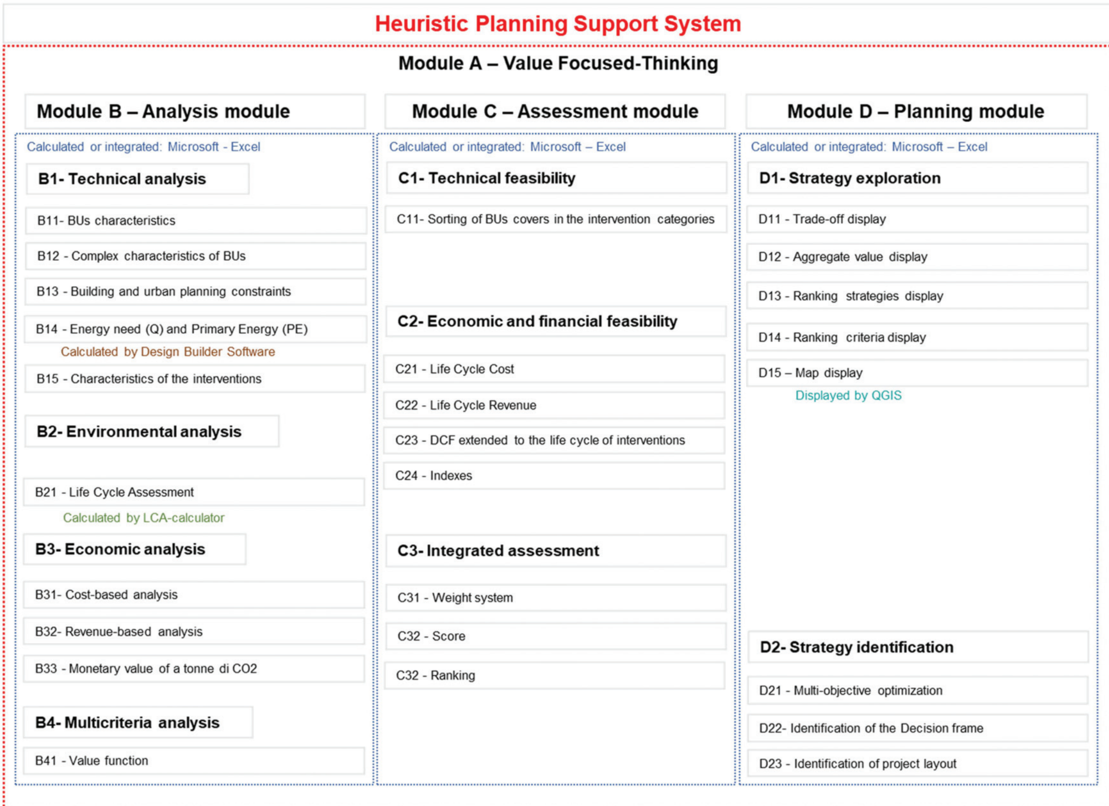


Figure 1. Heuristic Planning Support System (our processing).

3.2.1. Module A—Decision Process in the Perspective of Heuristic Approach. Value-Focused Thinking (VFT)

A rational decision-making model assumes that the decision maker has complete or perfect information about alternatives, time, cognitive abilities, and resources to evaluate each choice over the others. From this perspective, it is assumed that individuals are able to make choices that will maximize the benefits and minimize any cost.

In a rational decision-making model, factors that cannot be quantified, such as ethical concerns or the value of altruism, personal feelings, loyalty, or a sense of obligation, are excluded.

The objectivity of the rational decision-making model determines a bias towards preference for facts, data, and analyses that integrate intuition or desires.

Researchers who have criticized the rational decision-making model have pointed out that it has unrealistic assumptions regarding the quantity of available information, which is rarely complete or perfect; the difficulty in accessing information; the fact that it takes too long to access information; the availability of adequate resources to access resources; and limitations in the ability of individuals to conduct analysis and think through competing alternatives.

Individuals will manifest greater limitations in making rational choices as the complexity of the decision increases.

Some researchers in the field of behavioural economics have tried to explain why human behaviour often goes against pure economic rationality.

From this perspective, Herbert A. Simon [89] proposed the theory of limited rationality, which represents a more holistic way of understanding decision-making.

Decision-making in the context of limited rationality can still be considered rational, as decision makers act rationally based on limited information.

In fact, given the limited capacity and resources of decision makers to achieve the optimal solution, they can apply their rationality to a set of choices that have already been limited by the lack of complete information and resources, reaching a satisfactory solution rather than an optimal one. The theory of limited rationality, therefore, is not a theory of irrationality.

With reference to the need to renounce unrealistic assumptions such as omniscience and the optimization of rational theories, Simon defined two cognitive styles of decision makers: maximising and satisficers [90].

The former tries to make an optimal decision, the latter simply tries to find a solution that is "quite good" [91].

The theory of limited rationality can be applied to decision-making in the context uncertainty, where not all alternatives, consequences, and probabilities are known.

Gerd Gigerenzer argues that simple heuristics, that is, experiential problem-solving techniques, can converge towards better decision-making results than those based on more accurate processes and seeking the optimal solution, for which a lot of information is required.

Various heuristics can be characterized by specific organizational principles.

Gigerenzer et al., 1999 [92] proposed three main organizational principles, called Building Blocks (BB): search rules, stop rules, and decision rules.

Based on the building blocks highlighted and developed by Gigerenzer et al., 1999 [92], Gigerenzer and Selten, 2001 [93], and Gigerenzer and Gaissmaier, 2011 [94], four main heuristics can be identified: Minimalist, Take the best, Tallying, and Mapping.

The *Minimalist* heuristic proposed by Gigerenzer et al., 1999 [92] is a model of decision-making based on a single reason. This heuristic is characterized by a minimum amount of information which is necessary to decide. It considers only a random goal (BB-search rule) for which the scores of the alternatives (BB-stop rule) are compared. The alternative, which records the highest value, represents the one with the highest value for the decision maker (BB-decision rules).

Even the heuristic *Take the best* [92,94] supports a model of decision-making based on a single reason, then, on a single objective (BB-search rule).

In this case, the minimum amount of information is not considered, but the preferences of the decision maker are.

The heuristic compares all the scores of the alternatives (BB-search rule and stop rule) and identifies the one that maximizes the goal.

The alternative that registers the highest value represents the one that has the highest value for the decision maker (BB-decision rules).

The two heuristics *Tallying* and *Mapping* belong to the trade-off decision-making class [94]. Both heuristics consider multiple goals in random order (BB-search rule), ignoring preference information.

The stop rule in both cases provides for a break in the count when the alternative with the highest score is identified for each goal.

The *Tallying* heuristic chooses the alternative with the highest positive value for all objectives (BB-stop rule) [95].

The *Mapping* heuristic identifies all the alternatives that are above the median score in a goal (building block-stop rule) and chooses the preferred alternative from most goals (BB-decision rule) [94].

In the literature, the question of how small-information decision-making strategies (heuristic or intuitive decision-making) can influence the outcome of a decision has been widely discussed by many researchers [96–100]. These studies investigate the effects on decision making and ignore information about objectives, preferences, or assessments.

There are many studies in the literature that have developed heuristics to support the solutions to problems with high complexity, such as the integration of wind energy and other renewable energy resources in electrical systems [101], the search for parking spaces [102], water management [103], health [104], and information technology [105] and management [106].

The adoption of a heuristic perspective of the generation of alternatives, as a decision process, is more suitable for the purpose of this study.

We propose in this study an iterative heuristic belonging to the class of the decision-making trade-off, with a multi-objective search rule (such as the heuristics Tallying and Mapping). It integrates information about decision makers' preferences such as the Take-the-best heuristic. Our heuristic considers n-tuple shared objectives identified based on the preferences of the decision makers, and for each of them, it compares all the aggregated scores of the alternatives evaluated based on a set of criteria (BB-search rule and stop rule), identifying the one that registers the highest value for the decision maker (BB-decision rules).

From the perspective of a heterodox approach, this heuristic allows one to compare all the aggregated scores of the alternatives evaluated based on a set of criteria with reference to the economic profile, that is, its economic and financial performance (BB-sub-search rule and the stop sub-rule), and with reference to an integrated profile, that is, its performance related to other aspects besides the economic (BB-sub-search rule and stop sub-rule), identifying the highest value for the decision maker for the two profiles (BB-sub-decision rules for each profile).

In order to ensure that all relevant and important information in the decision-making process can be identified, that is, objectives, strategies, and alternatives, we have selected from among the approaches proposed by Operations Research, the Value-focused-thinking one.

This approach is considered a best practice from the decision analysis literature and has all the potential to effectively support the modelling phase of the decision problem as well as the project one, which deserves to be explored carefully, highlighting that, starting from the structuring of the objectives, it is possible to analyse different strategies and actions.

Value-focused thinking is an approach that starts by identifying values and then uses these values to evaluate and improve the set of alternatives provided to decision makers [48,107].

Value-focused thinking describes and illustrates concepts and procedures to create better alternatives for decision problems, identifying decision opportunities, and using fundamental values to guide and integrate decision-making activities [108].

The use of this technique is appropriate when dealing with conflicting objectives, complex alternatives, and major sources of uncertainty.

Value-focused thinking can lead to better decisions because

- It results in a better set of objectives to evaluate the alternatives, as generating objectives is an explicit purpose of Value-focused thinking;
- It facilitates the creation of alternatives, some of which might be better than those initially selected as potential ones;
- It proactively defines decision opportunities that are more attractive to deal with than the decision problems forced upon us.

The key concepts of Value-focused thinking are values, attributes, objective functions, alternatives, and decision frame.

From these concepts, the following phases can be derived: identification of values, generation of objectives, specification of attributes, quantification of values, creation of alternatives, and identification of project alternatives.

The process aims at identifying a series of objectives that can be structured based on the concatenation of several tools, such as focus groups, questionnaires, and decision conferences.

Decision-making conferences are work meetings supported by facilitators, aimed at problem-solving, including expert conflict resolution [109].

In the field of organizational planning, Schuman and Rohrbaugh, 1991 [110], highlight various purposes of a decision conference, such as definition of objectives, organizational priorities, budget allocation, strategic plans, etc.

Phillips, 2006 [111], states that a decision conference can support the participants' shared understanding of the issues under discussion and the generation of a common purpose. Schuman and Rohrbaugh, 1991 [109], point out that a decision conference can be identified as an ideal arena for reaching consensus on complex and unstructured issues and can succeed in reaching a consensus decision.

The decision makers throughout this process (Figure 2) were invited to express an order of preference for each n-tuple of objectives and at different levels.

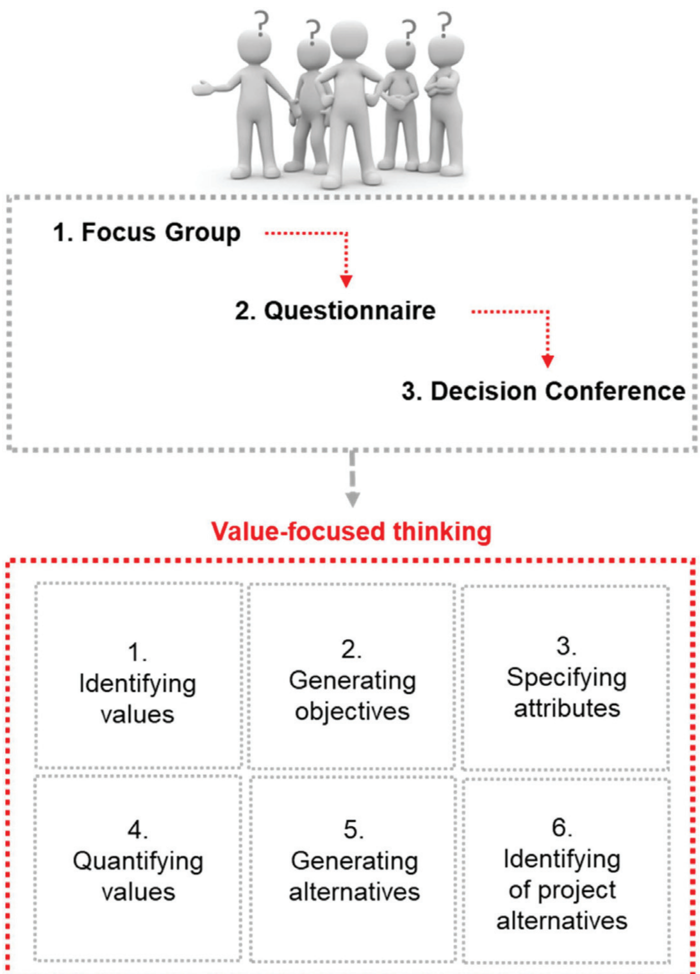


Figure 2. The process flow chart for identifying preference structures (our processing).

In this case, both goals and strategies can be explored in their respective domains based on decision makers' preferences, highlighting trade-offs, and convergences. Their exploration can support the identification of the decision frame and shared type by fostering the identification of a rational and feasible structure of preferences compared to the ones characterized by limited and uncertain rationality.

3.2.2. Module B—Analysis Module

The analysis module is instrumental for the construction of the database, as it integrates basic information and the outputs of technical, energy, environmental, economic, and multi-criterial analysis.

The database contains data on the basic real estate characteristics of BUs and the complex real estate characteristics, building and town planning constraints, and the characteristics of potential interventions from technical, energy (the energy needs (Q), primary energy (EP), environmental (GHG emission), and economic (direct revenues and costs, environmental revenues, and costs of interventions) points of view.

Technical Analysis

The BUs database was constructed based on data collected through survey forms about the characteristics of real estate. The detected characteristics of real estate are: dimensional, positional extrinsic or localization, the use of different floors, positional intrinsic, technological, architectural, state of conservation, and energy.

The data on building and urban planning constraints derived from the General Zoning Plan and the Detailed Plan are integrated into specific records in Excel.

The data on the real estate characteristics exported in csv are elaborated in QGIS for the estimation of complex characteristics for the BUs, that is, the shading, the visibility of the interventions from the road, and the degree of fragmentation of the roofs.

The outputs produced by this analysis phase are integrated into specific records in Excel.

The selection of potential interventions was conducted through the administration of a questionnaire to decision makers.

The decision makers identified two main types of interventions that specifically concern the roofs of BUs, namely the green roof and the installation of photovoltaic panels.

The solutions to the installation of photovoltaic panels have been selected with reference to the "Guidelines for the improvement of energy efficiency in cultural heritage. Architecture, historical and urban centres and nuclei", published by the Ministry of Cultural Heritage and Activities (MIBAC) [112], which are a useful tool to guide energy-improvement interventions for cultural heritage.

The guidelines for the insertion of photovoltaic panels on the roofs of historic buildings include the use of integrated roof solutions; the arrangement of the panels in a continuous line, above the eaves line, over the entire length of the roof, or possibly covering the whole surface of the pitched roof with the best exposure; and the choice of colours of the photovoltaic panels that match the existing roof colours.

The selected solutions for photovoltaics differ in terms of being installed with 1.5 kW, 3 kW, and 6 kW power; producibility (kWh) with reference to the site and its characteristics, i.e., azimuth angle (South, East–West) and tilt (0°–30°) [113]; grid-connected stand-alone systems with accumulation and connected to the network; and use of monocrystalline silicon and BIPV.

The HEMERA System has been selected for the BIPV solution [114].

The selected green roof solutions are grouped as referring to the roof type as follows: A1 for pitched roofs with extensive greening; B1 for flat, non-walk-on roofs with extensive greening; and B2 for flat, walk-on roofs with intensive greening.

These solutions were built for each type of intervention in the records on the technical, energy, environmental, and economic characteristics, which are instrumental to conducting the support analyses.

DesignBuilder Software was used to estimate the energy characteristics of the interventions. It complies with EN 15316, UNITS 11300 parts 1–4 [115] and is used to estimate the energy need (Q) and the primary energy (PE) for heating, cooling, and domestic hot water (DHW) in the different categories of intervention.

Environmental Analysis

A life-cycle assessment (LCA) was carried out to estimate the environmental characteristics of the interventions.

LCA is a methodology used to assess the environmental impacts associated with all the phases of the life cycle of a product and specifically in this study for the interventions under assessment. LCA is an instrumental methodology for estimating the carbon footprint related to the emission of GHGs generated at all stages of the product/intervention life, namely: extraction, processing, and transport of building materials; construction and demolition of buildings; direct energy consumption from buildings; and waste disposal.

In this study, LCA was implemented using LCA-calculator [116,117], a software that is widely used in the literature to support product/intervention carbon footprint estimation. It is used to estimate and compare, with other studies, the direct and indirect CO_2 emissions from all phases of the product/intervention life cycle [118].

LCA-calculator software performs LCA according to International Organization for Standardization (ISO) 2006. It uses eco-invent reference database v2.2. It estimates the carbon incorporated in materials and material production processes in accordance with ISO 14020 and ISO 14040, as well as ISO 14025. The software outputs an aggregate measure of the GWP (Global Warming Potential) of all 100-year emissions, expressed in kg CO_2 equivalent, calculated based on the characteristic factors provided by the IPCC [119].

The environmental analysis of the interventions is shown in Appendix A.1. Environmental Assessment.

Economic Analysis

For the estimation of the economic characteristics of the interventions, the following analyses were conducted: cost-based analysis, revenue-based analysis, analysis of the monetary value of a tonne of CO_2, and analysis of the costs and revenues extended to the life cycle of the interventions, that is, the Life Cycle Costing and Life Cycle Revenue.

The cost-based analysis was conducted based on surveys on the regional price of public works in the Sicily Region in 2019 and, alternatively, on that of the Emilia-Romagna Region 2018 or on estimates requested by established companies in the sector.

The costs for the design and supervision were calculated as a percentage of the costs of work; the annual maintenance costs [120] were calculated as the differentiated percentages for each type of work.

The environmental costs related to the life cycle of the photovoltaic plant and the green roof can be estimated by multiplying the negative externality determined based on the LCA by the monetary value of a tonne of CO_2.

The environmental benefits related to the life cycle of the photovoltaic plant and green roof can be estimated by multiplying the positive externality determined based on the LCA by the monetary value of a tonne of CO_2.

The Monetary Value of Tonnes of CO_2

The estimation of the monetary value of a tonne of CO_2 allows for the calculation of the monetary value of externalities produced in the life cycle by the interventions analysed in this study: photovoltaic system and green roof.

The monetary value of one tonne of CO_2 was determined based on data collected in an analysis of the literature review on the subject proposed in the article of Trovato et al., 2020 [121].

The monetary value of a tonne of CO_2 can be estimated based on two different approaches: the social cost of carbon (SCC) and the marginal cost of abatement (MAC) curve [122,123].

The first approach measures the long-term damage caused by the CO_2 emissions produced each year. The second approach, through the construction of the curve of the marginal cost of abatement (MAC), allows the following to be identified: the cost of the last unit of CO_2 abated for a defined level of abatement; the total abatement costs estimated through the integral of the abatement cost curve; and the average abatement cost obtained by dividing the total abatement cost by the quantity of abated emissions [124].

The level of reliability offered by climate change forecasting models generates uncertainty about the assessment of impacts, resulting in poor availability of data to support the SCC estimation, which can only be estimated for certain types of impacts.

Nevertheless, climate change forecasting models are considered a good approach for estimating the monetary value of the CO_2 emissions related to climate change impacts.

The review of the literature on SCC estimation reported in the article by Trovato et al. [121] highlights, among the best practices, three different integrated assessment models (IAM) [125], which were proposed by the Interagency Working Group (IWG), namely: DICE (Dynamic Integrated Climate–Economy model), developed by William Nordhaus (Yale University) [126]; FUND (Framework for Uncertainty, Negotiation, and Distribution model), originally developed by Richard Tol (University of Sussex); and PAGE (Policy Analysis of the Greenhouse Effect model), developed by Chris Hope (University of Cambridge).

These models are based on a discount rate of 3% [127] to estimate different SCC values, based on the DICE-2010R model of $40 per ton of CO_2; based on the FUND3.8 model of $22 per ton of CO_2; based on the PAGE09 model of $74 per ton of CO_2.

Other SCC estimates proposed in the literature include one proposed by the OECD [128] and the European Union survey, and one proposed by Ricke K. et al. [129], which showed different values from those estimated by the Interagency Working Group.

In the first case, the estimate of the SCC led to identification with reference to 2014, with a value of CO_2 emissions of $56 per ton and with reference to 2025 of $115 per ton. In the second case, the estimate of the SCC led to the identification of a range CO_2 emission values of $177–805 per ton.

The second approach, namely MAC, is used in the European Union in the emissions trading system, namely the EU ETS. A monetary value of EUR 40/tonne CO_2-eq has been estimated using MAC until 2020 [130], for which no further estimates are currently available.

To identify a monetary value of CO_2 emissions and thus support the estimation of the monetary value of externalities produced by interventions in their life cycle with reference to literature data, with reference to the two approaches (SCC and MAC), and with reference to the 3.3% social discount rate set for Italy from the Cost–Benefit Analysis Guidelines [131–133], we have chosen to confirm the value of 40 EUR /ton of CO_2-eq identified in the article Trovato et al. [121], which is close to the average value of the SCC values calculated by the IWG models. This choice is due to the absence in the literature of further estimates on the monetary value of one ton of CO_2 emissions.

Life Cycle Cost

In the field of building processes, the role of cost components is based on various elements constituting the feasibility of an intervention, including the construction process (Life Cycle Costing in construction), the life cycle (whole global costing), and management (Life Cycle Costing) [134].

The Global Cost formula according to the LCC approach is expressed by the following Equation (1) [135–137]:

$$C_G = C_I + \sum_{s=1}^{t} \frac{(C_M + C_r)}{(1+r)^t} + \sum_{v=1}^{n} \frac{\left(C_{dm} + C_{dp} - V_r\right)}{(1+r)^n} \quad (1)$$

where C_G is the life cycle cost; C_I is the investment costs; C_M is the maintenance cost; C_r is the replacement cost; C_{dm} is the cost of dismantling and C_{dp} is the disposal cost; V_r is the residual value; t is the year in which the cost occurred and N the number of years of the whole period considered for the analysis; and r is the discount rate. The "traditional" LCC methodology is a tool for measuring economic but not environmental performance. The economic and environmental assessment of interventions can also be conducted based on the integration of LCA and LCC [138–140].

For the assessment of the environmental impacts produced by interventions [141–147], it is necessary to provide a more in-depth analysis in order to identify the individual effects to be computed in the LCA. Environmental assessment can be integrated into the classic LCC formula. The new LCC formula considers the negative externalities related to the increase in CO_2 emissions (Equation (2)).

$$C_G = \sum_{s=1}^{t} \frac{(C_M + C_r)}{(1+r)^t} + \sum_{v=1}^{n} \frac{\left(C_{dm} + C_{dp} - V_r\right)}{(1+r)^n} + \sum_{z=1}^{q} \frac{IR_{CO_2}}{(1+r)^q} \quad (2)$$

Life Cycle Revenue

Revenues related to interventions can also be analysed from a life-long perspective.

They mainly concern the energy savings and CO_2 emission reductions determined by LCA both for the photovoltaic system and for the green roof (Equation (3)).

$$R_G = \sum_{i=1}^{T} \frac{ES}{(1+r)^T} + \sum_{j=1}^{N} \frac{RE_{CO_2}}{(1+r)^N} \quad (3)$$

ES represents energy saving, RE_{CO_2} the reduction of CO_2 emissions throughout the life cycle.

In the case of a green roof, the environmental benefits may also concern the benefits related to the absorption of pollution, and therefore it would be correct to add $\sum_{k=1}^{Q} \frac{AP}{(1+r)^Q}$, where AP represents the absorption of pollution offered by the green roof.

In the database estimating both the Life Cycle Costing-based analysis and the Life Cycle Revenue-based analysis, it is necessary to integrate the records of the results of the LCA for the types of photovoltaic plants and the green roof with the records related to the cost and revenue analysis.

The economic analysis extended to the life cycle of the interventions is reported in Appendix A.2 Economic Assessment.

Multicriteria Analysis

In the database, it is possible to integrate information in order to define specific value profiles. Value profiles are instrumental to characterize decision makers' preferences. In this regard, decision makers should identify a set of criteria that are instrumental to characterize their preferences on interventions aimed at combating the effects of climate change in the historic centre.

The multicriterial approach used for modelling decision makers' preferences is Multi-Attribute Value Theory (MAVT). It is an additive MCDA approach.

The MAVT is an algorithm that is widely used in the literature to support decision-making in numerous problems [148–151], and for this reason, we will report only some information. This will allow the reader to analyse a set of alternatives even from a perspective characterized by conflicting objectives.

Operationally, in this algorithm, the main objective is divided into secondary objectives in order to structure the decision problem through a hierarchy of first- and second-level criteria and defining a tree structure called the tree of criteria, from the higher-order criterion to the leaf criterion, or that of a lower level.

For each criterion, a value function is constructed that represents how the incremental value changes as the performance level of the alternative changes. As a rule, the value function has a range of variation between 0 and 1.

For each criterion, a weight is set representing the importance attached to it by the decision maker [148,152].

The system of weights normally follows the rule of having a sum equal to one.

Each alternative in decision-making is assessed based on the standard additive aggregation rule (Equation (4)) [148], which provides an aggregate measure of the value of the alternative with reference to its performance on each criterion:

$$V(a) = \sum_{k=1}^{s} w_i v_i(a) \tag{4}$$

where s is the number of criteria, w_i is the weight of the criterion i, and $v_i(a)$ is the value function for the criterion that reflects the performance of the alternative a with respect to the criterion i.

A MAVT module has been integrated in Excel to build value functions for each identified criterion.

All the estimated data in the various technical, energy, environmental, economic, and value profiles analyses can be collected in specific records in Excel. These records support the assessments conducted in Module C.

The different database records, either as basic data or as output of the analysis processes, can be used for spatial analysis in QGIS. The visualization of thematic maps of the analysis results is instrumental to increase the awareness of decision makers on the issue under analysis.

3.2.3. Module C—Assessment Module

The evaluation module offers tools to support the exploration of goals and strategies. This module consists of several operational tools to produce as outputs the technical feasibility, economic-financial feasibility, and the integrated assessment of interventions based on the MAVT approach.

Technical Feasibility

For the technical feasibility of the interventions on the individual BUs, logical propositions of this type are built if 'the characteristics of the BUs, the building and urban constraints, energy demand are...', and then 'BUs will be allocated in the intervention category...'.

Logical propositions allow the data query to help to sort the BUs into different intervention categories.

Database query outputs can be integrated into QGIS to support BUs' spatial analysis of each intervention category.

Economic and Financial Feasibility

The economic and financial evaluation is instrumental to verify the feasibility of the interventions.

A tool aimed at verifying the economic and financial feasibility has been defined with reference to the Discounted Cash Flow Analysis (DCFA) [153,154] integrated into the life cycle of interventions.

This tool integrates the information contained in module B for all the components of the DCFA, including those related to the life cycle of the interventions [155,156], i.e., Life Cycle Costing and Life Cycle Revenue.

It also incorporates a series of investment assessment criteria aimed at verifying economic and financial feasibility (Appendix A.3. Investment assessment criteria).

Integrated Assessment

The MAVT module integrated in Excel allows one to measure the aggregate value for each type of intervention or with reference to aggregate types of intervention, producing their ranking.

3.2.4. Module D—Planning Module

The planning module aggregates all the information contained in the previous modules. Additionally, in this case, the database can be interrogated on the basis of logical propositions of the type "If. . . , then. . . ".

This module helps the decision maker to explore the performance of interventions with reference to any n-tuple of objectives, strategies, and their levels.

This module offers different visualizations of the effects induced by different queries, some developed directly in Excel, and others with the help of QGIS:

- Paired comparison of criteria to highlight trade-offs and convergence between them;
- Comparison between the four criteria, supported by a polygon built on the basis of their assessments, whose size and symmetry with respect to the axes help decision makers identify their effects and the prevailing direction;
- Aggregate score of criteria assessments and their ranking;
- Comparison of performance between criteria;
- Spatialization of interventions in the neighbourhood.

4. Study Area

The exploration of green-blue strategies and alternatives at the scale of individual building units and at the urban scale with the HPSS tool was conducted for the historic district of the Borgata di Santa Lucia in Syracuse. The aim was to identify a design layout to facilitate the ecological transition of the district by integrating energy-environmental needs with those of identity, the historic urban landscape, and its constraints, aimed at their protection and conservation.

The Borgata di Santa Lucia is the second historic centre, in addition to Ortigia, in Syracuse.

We have selected this sample area because it is subject to a regime of constraints that are less stringent than those provided for in the urban planning tools for the historic centre Ortigia.

Ortigia, moreover, is part of the UNESCO Site "Syracuse and the Rocky Necropolis of Pantalica"; for this historic centre, the constraints of protection and conservation of the specificity of this site make it incompatible the interventions aimed at favouring its ecological transition.

The Borgata di Santa Lucia consists of the portion of urban territory between Via Torino to the east, Via Piave to the west, Viale Teocrito to the north, and the coast of "the long rocks—Riva port Lakio" to the south. In the ancient Greek period, it was part of Akradina, which, according to historians, included the territory between the area of Umbertina and the current via Maria Politi Laudien.

The Borgata di Santa Lucia is of great scientific and operational interest for development as a unitary urban entity within the vast program of social and civil reform started with the demolition of the walls that encircled the ancient nucleus of Ortigia around 1865.

The construction of the district began in 1886; before that date, this area was used for agricultural purposes. The first buildings were aimed at meeting the demand for residency for the less well-off population.

The neighbourhood occupies an area of 637,806 square metres. The population settled with reference to the last ISTAT census of 2011 [157] in the village of S. Lucia is 7674 inhabitants. The total number of buildings in the neighbourhood is 1876. The number of empty dwellings is 1295. The real estate is characterized by a number of buildings with a single floor of 635 units, two floors of 675 units, three floors of 245 units, four floors of 106 units, and for a greater number of four floors of 215 units [157].

Apart from some phenomena of building degradation and some out-of-scale replacements, the appreciable level of widespread architectural quality and the strategic value of the district in terms of its positional and landscape characteristics and low building density give rise to positive prospects of heritage, social, and identity regeneration.

5. Results

In a first phase of the process was organized with the support of the professional associations of architects and engineers of Syracuse, a "Focus Group" on the platform GoTowebinar (19 July 2021) which were invited to participate local administrators, scholars, professions, and industry enterprises. In this event, the question of actions to promote the ecological transition in the historic centres was introduced and discussed, and in particular, the case of the Borgata di Santa Lucia was introduced. One hundred and fifty participants attended this event.

At the end of the event, a questionnaire was administered to all participants.

Professional orders have made a link available on the relevant websites for those who did not participate in the Focus Group to fill out the questionnaire. At the end of this first process, 180 questionnaires were collected.

This first administration of the questionnaire was a pre-test for the drafting of a slightly modified structure of a second questionnaire that was administered at the end of a second Focus Group, organized with the support of the professional associations of architects and engineers on the platform GoTowebinar (13 September 2021). In addition, local administrators, scholars, professions, and industry enterprises were invited to participate in this second event. Two hundred participants took part in this event and completed a questionnaire at the end of it.

The link on the websites of the professional orders allowed the number of the surveyed questionnaires for this second phase to increase to 248.

In a third phase, two Decision Conferences were organized to detect the preferences of decision makers. These two events were held in compliance with the measures taken by the government to combat the spread of COVID-19.

In the first Decision Conference (19 October 2021), the results of the second questionnaire were presented. Only twelve subjects (three local administrators, two architects, two engineers, two members of civic and environmental associations, two scholars, and one industry enterprise) participated in the Decision Conference due to the restrictions due to the pandemic, as well as two facilitators.

Access to the event for all other interested parties was guaranteed through the GoTowebinar platform.

The second Decision Conference (3 November 2021) was attended by the same stakeholders as the first one, which in this study represents the group of decision makers. Again, other stakeholders participated via the GoTowebinar platform.

In the first Decision Conference, the decision makers identified four main objectives: improving the energy efficiency of BUs (Ev), fostering the production of electricity from renewable sources (E), protecting the historical-cultural identity (I), and the quality of the urban landscape of the neighbourhood (L).

The decision makers were then invited to give an order of preference for each objective (Ev), (E), (I), (L), and for each n-tuple of objectives (Ev, E), (Ev, L), (Ev, I), (E, L), (E, L), (I, L), (Ev, E, I), (Ev, E, L), (Ev, I, L), (E, I, L), (E, Ev, I, L).

As a result of the first Decision Conference, they provided the following orders of partial shared preference:

$$I \succ L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \tag{5}$$

$$I \succcurlyeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \tag{6}$$

$$I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \tag{7}$$

$$(I, L) \succ Ev,\ I \simeq L,\ I \succ Ev,\ L \succ EvI \succ E,\ L \succ E,\ Ev \succ E \tag{8}$$

$$\begin{gathered}(I, L) \succcurlyeq Ev_{lh},\ I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \\ l_h \leq threshold\ not\ known\end{gathered} \tag{9}$$

$$(I, L,) \succ (Ev, E),\ (I, L) \succcurlyeq Ev,\ I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \tag{10}$$

$$(I, L,\ Ev) \succ E,\ (I, L) \succcurlyeq Ev,\ I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \tag{11}$$

$$\begin{array}{c}(I, L,\ Ev) \succcurlyeq E_{l_i},\ (I, L) \succcurlyeq Ev,\ I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \\ l_i \leq threshold\ not\ known\end{array} \tag{12}$$

In the second Decision Conference, the decision makers confirmed the choice of the four criteria, and they were again invited to give an order of preference for each objective and for each n-tuple of objectives.

They provided the following orders of partial shared preference:

$$\begin{array}{c}(I, L) \succcurlyeq \left(Ev_{lh}, E_{l_i}\right)(I, L) \succcurlyeq Ev,\ I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \\ l_h \leq threshold\ not\ known,\ l_i \leq threshold\ not\ known\end{array} \tag{13}$$

The decision makers from the stage of identification of the objectives were aware of the convergent nature of some of them and the divergent nature of some other ones. Their declared preferences reflect their inability to simultaneously manage objectives of a different nature.

The above process is uncertain and characterized by limited rationality. The preference structure of decision makers in this case is uncertain. It can be identified as the output of a process of exploration of the effects of these objectives.

In the second Decision Conference, the decision makers were invited to outline a set of strategies and levels of strategies with reference to the selected objectives. The decision makers initially identified two main strategies: green and blue.

The green strategy (G) favours green roof interventions on BU roofs.

The blue strategy (B) favours the interventions that include the installation of photovoltaic systems in the roofs of BUs.

Subsequently, the decision makers stated that they also wanted to explore a hybrid strategy aimed at pursuing the green-blue strategy (G-B).

The decision makers were invited to declare a partial order of preference on strategies, and they provided the following information:

- $strategy\ G \succ Stategy\ B$
- $strategy\ G - B \succ Stategy\ G \succ Strategy\ B$

Based on this information, an exploration of the objectives and strategies selected by the decision makers can be supported through the database integrating the analysis and evaluation modules.

The decision makers were invited to identify a set of criteria from which they derived their preferences for interventions aimed at combating the effects of climate change in the historic centre, and they identified the following: identity, landscape, energy-environmental, and economic.

Through module B of analysis and module C of evaluation, the instrumental information to analyse the actions activated from the various selected strategies can be produced.

The database contains all the information on BUs, technical, environmental, and economic interventions, and querying the database gives as output the technical feasibility, the economic and financial feasibility, and an integrated assessment, which provides a qualitative analysis of the performance of the interventions with reference to four selected criteria.

Based on the preferences of the decision makers, the first exploration concerns the green strategy. This strategy, with reference to the preference of the decision makers (Equation (9)), selects actions that promote the energy efficiency of BUs (green roof solution). These solutions are perceived by decision makers in a more convergent way in terms of identity and landscape.

The green strategy was explored from a baseline scenario of zero (state of fact), promoting different levels of action implementation, from a minimum to a maximum level, considering the maximum green roof area that can be installed on BUs roofs. In total, 12 levels of implementation of the green strategy were explored.

The economic evaluation of actions implementing different levels of the green strategy, based on the DCFA extended to the life cycle, identifies the best performance at level 12 for all analysed green solutions.

The NPVs for the different levels of green strategy highlight their economic profiles (Figure 3) with reference to the individual green solutions and the total mix of solutions that can be installed on the roofs of the neighbourhood based on technical feasibility.

Economic assessment (EA)

	A1	B1	B2	Tot
1	0	0	0	0
2	0	0	3,822	3,822
3	1,394	0	5,332	6,727
4	16,956	0	110,169	127,125
5	100,883	0	236,263	337,146
6	124,460	0	296,787	421,247
7	278,345	4,460	467,880	750,686
8	334,446	7,504	492,016	833,966
9	541,254	133,131	510,704	1,185,090
10	859,769	290,897	705,346	1,856,012
11	957,441	343,154	772,439	2,073,034
12	1,033,941	392,671	772,439	2,199,051

Ranking of the levels of the green strategies for the different solutions

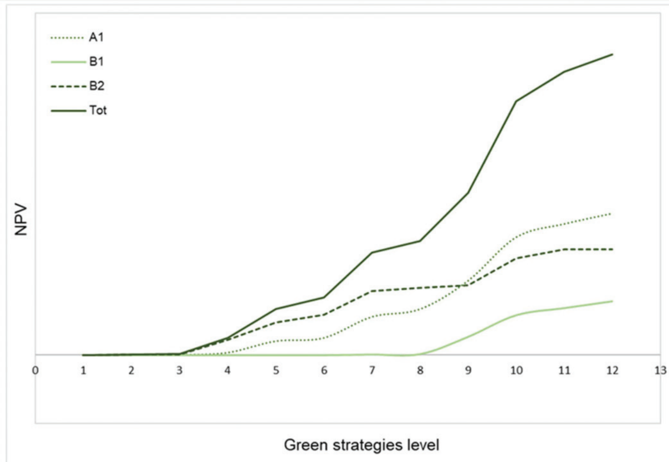


Figure 3. Ranking of interventions for the different levels of green strategy based on the NPV–NPV in the different levels of the green strategy.

The economic criterion is one of the criteria identified by decision makers, whose performance will have to be compared to the aggregate one with reference to the four criteria considered.

Module D allows one to produce for each query the visualization of the outputs of the MAVT module integrated in the tool, with reference to the criteria at the different levels of strategies.

The weight system has been defined by the decision makers based on an iteration process supported by the visualizations offered by module D.

The decision makers, based on the visualizations of the criteria values at the different levels of green strategy, have identified the set of weights and the level of trade-offs they can consider acceptable.

The visualization to support the selection of weights consists of two different control modes: the bubble size in the left (A) diagrams of Figure 4 that measures the values of the criteria in the different strategies, and the paired comparison between the values of the criteria in the right (B) diagrams of Figure 4, which is instrumental to highlight the trade-offs and the convergences between them.

Module D allows one to produce for each query, through the MAVT module integrated in the tool, the visualization of the outputs of the integrated evaluation based on an aggregate score of the evaluations on the four criteria and provides a ranking for the different levels of the strategy. The integrated evaluation makes it possible to identify the best level of the green strategy with reference to the four criteria, which in this case is represented by level 11 (Figure 5).

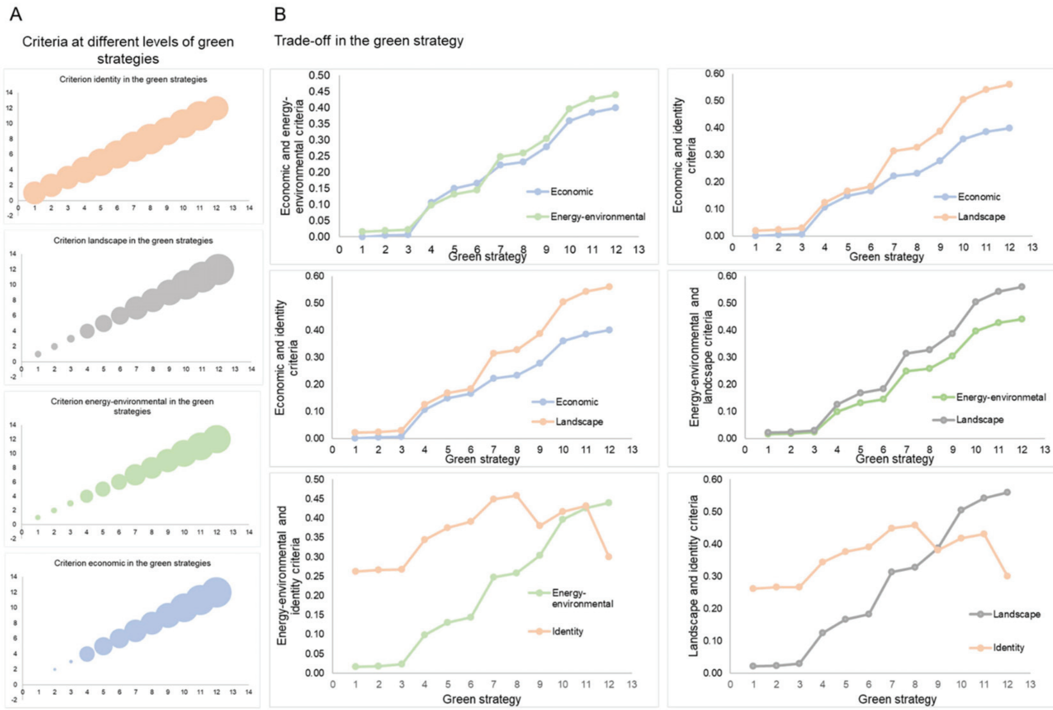


Figure 4. (**A**). Values of the criteria for the different levels of green strategy. (**B**). Trade-off between the criteria for the set of weights selected by the decision makers.

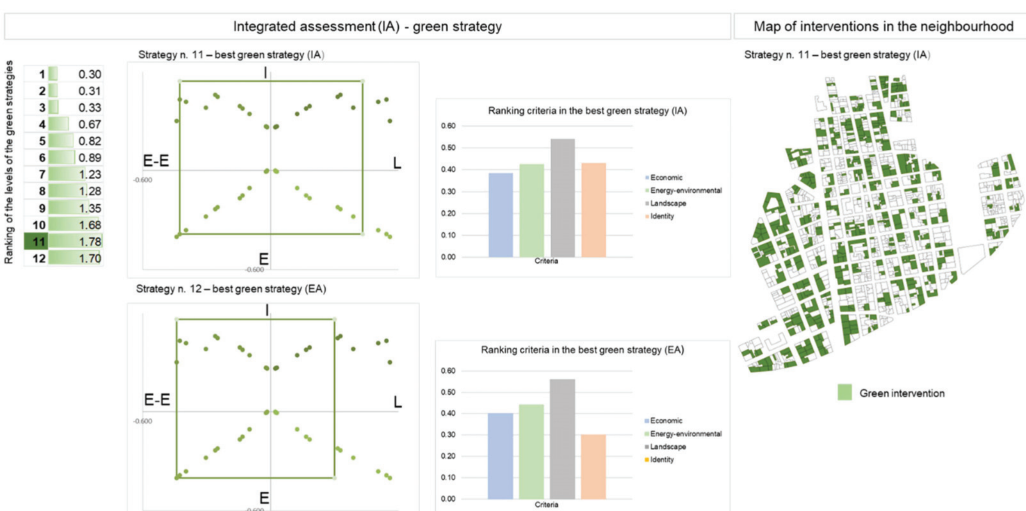


Figure 5. Ranking of the levels of the green strategy based on the aggregate assessment; comparison between the two levels of the strategy in economic terms and the integrated assessment; visualization of the ranking of the criteria for the best economic level and the integrated evaluation; map displaying the best level of the green strategy.

Strategy 12, which turned out to be better from an economic point of view, offers an overall performance of the four criteria lower than strategy 11. Module D allows one to compare the two levels of strategies based on the area of the polygon representing the aggregate assessment of the four criteria and on its position in relation to the axes as well.

In this case, the area of the polygon for level 12 is slightly smaller than for level 11. The position of the polygon in the four quadrants supports the identification of the effects of the strategy level on the paired criteria.

In this case, the comparison shows for level 12 a position of the polygon that less symmetrical than for level 11.

Level 12 of the green strategy shows impacts of intensity comparable to level 11 for criteria E, E–E, and L, but lower intensity for criterion I. The latter criterion, as can be seen from the structure of decision makers' preferences and from the weight system, has a greater importance than all the others.

Therefore, level 11 is preferable because it performs better for criterion I with equal values of E–E, E, and L, and it is consequently more consistent with the preference structure declared by the decision makers.

In addition, module D allows one to visualize, through the integrations of the information obtained on QGIS, the map of green interventions on BUs in the neighbourhood, supporting decision makers throughout the control of the distribution and dislocation of interventions.

The mix of green interventions for the best strategy from the point of view of the aggregate assessment consists of 463 interventions of type A1, 148 interventions of type B1, and 297 interventions of type B2. A total of eighty-four per cent of BUs roofs were used for green solutions for strategy level 11, of which forty-three per cent were from solution A1, fourteen per cent were from solution B1, and twenty-seven per cent were from solution B2.

Subsequently, based on the preferences of the decision makers, a second exploration concerned the blue strategy. This strategy, with reference to the preference of decision makers (Equation (12)), promotes action to encourage the production of energy from renewable sources by installing traditional photovoltaic panels or BIPV on the roofs of BUs. This solution is perceived by decision makers as more divergent in terms of identity and landscape.

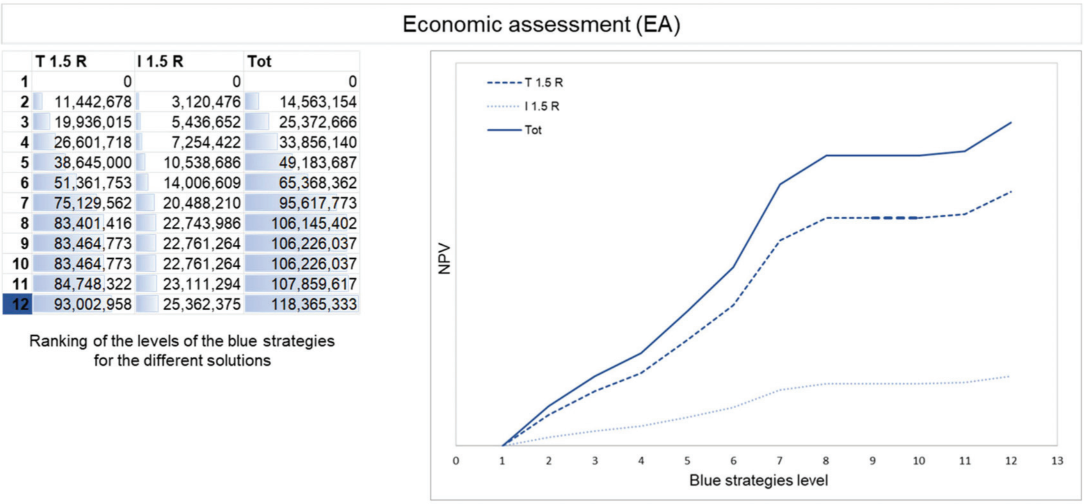
The blue strategy was explored from a baseline scenario of zero (state of fact), promoting different levels of implementation of the action, from a minimum level up to a maximum level that considers the maximum surface area of the BUS roofs on which it is possible to install photovoltaic systems.

The decision makers selected between the photovoltaics power options analysed 1.5 kw for both traditional and integrated technology, as this has been considered the most compatible one, due to the high degree of fragmentation of BU properties.

In total, 12 levels of implementation of blue strategies were explored in this case. The economic evaluation of actions implementing different levels of the blue strategy, based on the DCFA extended to the life cycle, identifies the best performance at level 12 for all blue solutions (traditional and integrated) under analysis. The NPVs for the different levels of the blue strategy highlight their economic profiles (Figure 6) with reference to the individual blue solutions and the total mix of solutions that can be allocated on the roofs of the district on the basis of technical feasibility.

Here, too, the economic performance of the various levels of the blue strategy is compared to the aggregate performance of the four criteria considered.

The visualizations shown by module D support the selection of weights by means of two different control modes: the bubble size on the left-side (A) diagrams in Figure 7 measures the values of the criteria in the different strategies; the paired comparison between the values of the criteria in the right-side (B) diagrams of Figure 7 are instrumental to highlight the trade-offs and the convergences between them.



	T 1.5 R	I 1.5 R	Tot
1	0	0	0
2	11,442,678	3,120,476	14,563,154
3	19,936,015	5,436,652	25,372,666
4	26,601,718	7,254,422	33,856,140
5	38,645,000	10,538,686	49,183,687
6	51,361,753	14,006,609	65,368,362
7	75,129,562	20,488,210	95,617,773
8	83,401,416	22,743,986	106,145,402
9	83,464,773	22,761,264	106,226,037
10	83,464,773	22,761,264	106,226,037
11	84,748,322	23,111,294	107,859,617
12	93,002,958	25,362,375	118,365,333

Figure 6. Ranking of interventions for the different levels of the blue strategy based on the NPV–NPV in the different levels of the blue strategy.

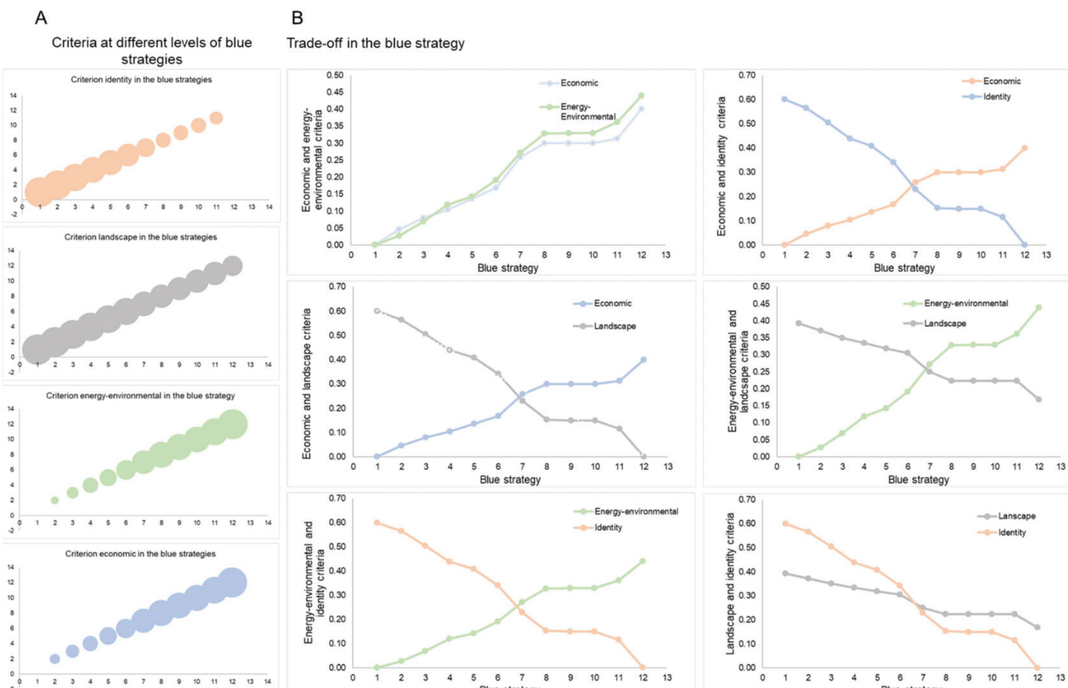


Figure 7. (**A**). Values of the criteria for the different levels of the blue strategy. (**B**). Trade-off between the criteria for the set of weights selected by the decision makers.

The integrated assessment allows one to identify the best level of the blue strategy with reference to the four criteria, which in this case is represented by level 11 for all the installed powers and for the different types of photovoltaic panels (Figure 8). Strategy 12, which turned out to be the best from an economic point of view, offers an overall performance in terms of the four criteria that is lower than strategy 11. The comparison of the two levels of the blue strategies based on the area of the polygon and its position with respect to the axes shows that a score for level 12 is slightly lower than that for level 11, with impacts with the same trend, which is moved further forward towards the criteria E–E and E but with different intensities.

Both levels of the blue strategy increase criteria E and E–E, to a greater extent for level 12 of the blue strategy than for level 11, but level 11 increases criteria L and I more significantly. Criterion I for level 12 is zero, which is not acceptable regarding the preferences of decision makers, because the mix of photovoltaic panel solutions is more balanced in level 11, enabling better performance for criteria L and I.

The BIPV solution is considered more compatible in terms of identity and is capable of improving the quality of the urban landscape, as its installation requires a refurbishment intervention of the roofs.

Level 11 of the blue strategy is therefore preferable because it is more consistent with the preference structure declared by decision makers.

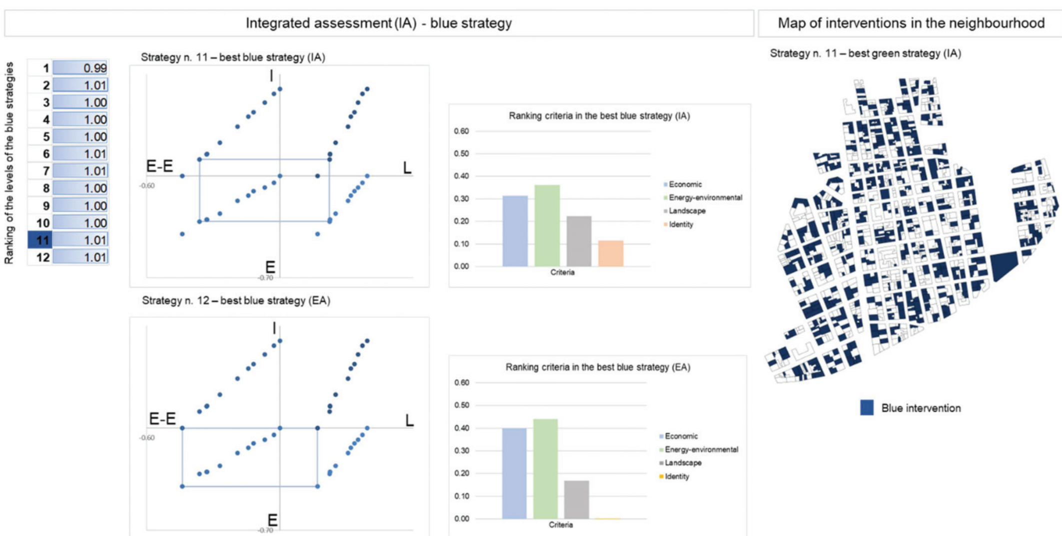


Figure 8. Ranking of the levels of the blue strategy based on the aggregate assessment; comparison between the two levels of the strategy in economic terms and the integrated assessment; visualization of the ranking of the criteria for the best economic level and the integrated evaluation; map displaying the best level of the blue strategy.

Additionally, in this case, the mapping of green interventions on BUs in the neighbourhood supports the decision makers in the control action of the distribution and the dislocation of interventions.

The mix of blue interventions provides the best strategy in terms of aggregate evaluation and consists of 377 interventions of type T 1.5 (traditional photovoltaics) and 289 interventions of type I 1.5 (BIPV). Sixty-two per cent of BUs roofs are used in blue solutions for strategy level 11, of which twenty-seven per cent are used in solution T 1.5 and thirty-five per cent in solution I 1.5.

Subsequently, based on the preferences of the decision makers, a third exploration concerned the green-blue strategy. This strategy, with reference to the preference of decision makers (Equation (13)), promotes integrated actions to improve the energy efficiency of buses (green roof solution) and to foster the production of energy from renewable sources with the installation of traditional photovoltaic panels or BIPV on BUs roofs. The green-blue strategy has been explored starting from a baseline scenario of zero (state of fact), promoting consistency with the preferences of the decision makers and giving priority to the allocation of green interventions rather than the blue ones.

In total, 12 implementation levels for the green-blue strategy were explored in this case as well.

Strategy 12 is the best from an economic point of view, as it is characterised by the increased use of BUs roofs for blue solutions, but it offers an overall performance in terms of the four criteria that is lower than strategy 9, which is the best regarding the integrated assessment.

The position of the polygon in the four quadrants that supports the identification of the effects of the strategy level on the paired criteria highlights a less symmetrical position of the polygon for the green-blue strategy level 12 compared to level 9, and impacts all criteria at lower intensity, particularly for criteria I (Figure 9).

Figure 9. Ranking of the levels of the green-blue strategy based on the aggregate assessment; comparison between the two levels of the strategy in economic terms and the integrated assessment; visualization of the ranking of the criteria for the best economic level and of the integrated evaluation; map displaying the best level of the green-blue strategy.

Level 9 of the green-blue strategy is characterised by a mix of green and blue interventions with 195 interventions of type A1, 124 interventions of type solution B1, 198 interventions of type B2, 68 interventions of type T solution I 1.5, and interventions of type 209 solution I 1.5 (Figure 9). Seventy-four per cent of Bus roofs are used, of which forty-eight per cent are used for green solutions (18% A1, 12% B1, and 18% B2) and twenty-six per cent for blue solutions (6% T 1.5 and 20% I 1.5). Some Bus roofs are used for both green and blue interventions, with a roof utilization index of 1.58%. Twenty-six per cent of Bus roofs remain unused.

6. Discussion

The general objective of promoting the ecological transition of the Borgata district of S. Lucia in order to combat climate change poses several aesthetic, symbolic, functional, and identity issues of the urban landscape in its historic centre overlooking the sea surrounding the island of Ortigia. It also poses technical issues, related to the compatibility of energy efficiency interventions with the green roof system and the production of energy from renewable sources with the installation of photovoltaic panels, and economic issues, concerning the actual feasibility of interventions in a situation that is a priori considered less convenient, especially in the context of a life-cycle assessment [121].

The decision makers have difficulty expressing their preferences, as this process is characterised by uncertainty. This uncertainty is mostly due to the poor ability to divide the overall objective into sub-objectives, but above all to the difficulty of managing a multi-objective problem and a low level of awareness of the effects related to potential scenarios.

At the beginning of this research, when we administered a questionnaire to stakeholders aimed at defining sub-objectives and strategies to support interventions in the historic centre, the answers highlighted different and often contradictory perceptions of the issue. Certainly, from the early stages, the issue of energy efficiency and the production of energy from renewable sources was clear to the stakeholders, but it was not clear how the latter could be implemented in a vulnerable context and characterized by numerous constraints.

The decision makers were aware that some of the objectives identified (Ev, E, I, and L) had a convergent and divergent nature, but for this reason they were unable to manage them simultaneously.

The process was uncertain and characterized by limited rationality. The preference structure of decision makers was uncertain and in some cases contradictory.

Our group began to build the database in Excel over five years ago, and about 15 units worked on it. We had the database and the know-how to build a tool capable of integrating technical, environmental, energy, and economic analyses of interventions in order to support the exploration of sub-objectives and strategies, aimed at reducing uncertainty and helping structure the preferences of decision makers.

Due to the heuristic nature of the process under analysis, we realized that decision makers needed a tool to support the definition of an a priori unknown decision frame that is instrumental to managing a multi-objective process, and we aimed at planning actions capable of jointly maximizing these objectives.

Hence, there is a need to define a tool, such as HPSS, that integrates the classic PSS, developed as a planning support from a strategic perspective; the decision process, from the perspective of heuristic approach; and the GIS.

Module D made it possible to identify, through a process of iteration and subsequent adjustment, the system of weights that best corresponded to the preferences that were gradually identified in the process and to explore the performance of interventions with reference to any n-tuple of objectives, strategies, and their selected levels.

The visualization offered by the module has accompanied decision makers in the long and difficult process of identifying a system of preferences that they might consider acceptable. It helps decision makers to compare the performance of the pairs of criteria in order to highlight and analyse the trade-offs and the convergence between them; compare the performance of the four criteria, with the help of a polygon built on the basis of their assessments, whose size and symmetry with respect to the axes help decision makers to identify the effects and the prevailing direction of them; identify the best level of strategies on the basis of the aggregate score of the criteria assessments and their ranking; and check the allocation of interventions in the neighbourhood.

Based on the partial order of preferences, 12 levels of implementation of the green strategy were primarily explored, because the green objective was perceived as more convergent with that of the identity and urban quality of the landscape. Subsequently, based on the economic assessment, the decision makers chose to explore 12 levels of implementation of the blue strategy, which they considered to be the most cost-effective overall, as evidenced by the results of the evaluation criteria of targeted investments, but less convergent with the objective of preserving the identity and quality of the landscape.

Based on the results obtained from the exploration of green and blue strategies, the decision makers expressed the need to explore an integrated green-blue strategy.

The prospect of a green-blue strategy began to be perceived as the one that could best combine the energy-environmental and economic issues with those of the protection of the identity and quality of the landscape.

The exploration of the 12 levels of the green-blue strategy showed better performance on all criteria considered, with levels of effectiveness in terms of achievement of the highest targets.

Based on the comparison of the rankings of the criteria for the best levels of the green, blue, and green-blue strategies (Figure 10), it is possible to highlight that the latter offers the best performance for all criteria and therefore is preferable to the others.

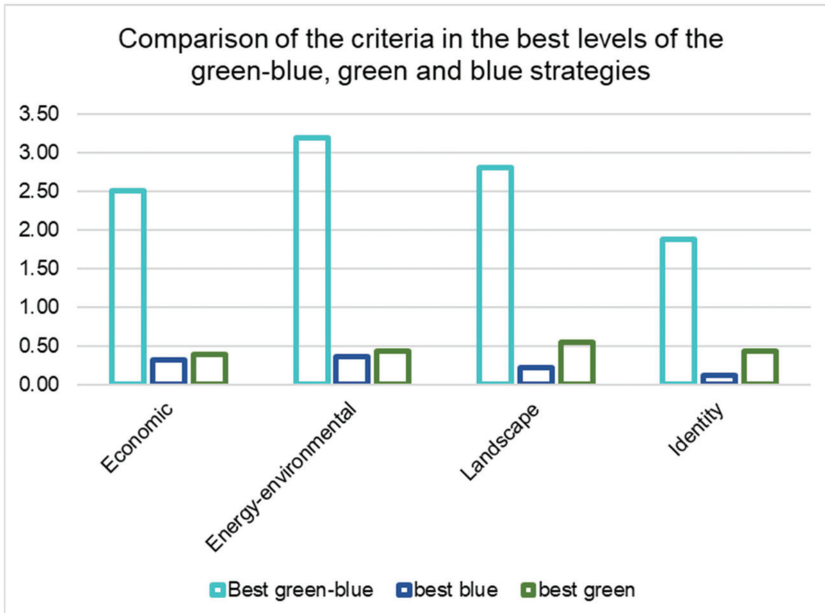


Figure 10. Comparison of criteria for the best level of strategies explored.

The decision makers selecting the green-blue strategy as the best ones are aware of having to sacrifice part of the economic profitability offered by the blue one, as well as the fact that it is more profitable than the green one.

They are also aware of the importance of the economic criterion but acknowledge that the others are perhaps more important regarding the issue of ecological transition and the specific reference context, a historic neighbourhood, with all the complexities that derive from it.

Based on the results obtained from the exploration of green, blue, and green-blue strategies, decision makers were able to identify an order of preference with reference to the objectives *Ev*, *E*, *I*, and *L* (Equation (14)).

$$\begin{gathered}(I, L) \succcurlyeq \left(Ev_{lh}, E_{l_i}\right)(I, L) \succcurlyeq Ev,\ I \simeq L,\ I \succ Ev,\ L \succ Ev,\ I \succ E,\ L \succ E,\ Ev \succ E \\ Ev_{lh},\ l_h \leq threshold,\ E_{l_i},\ l_i \leq threshold \\ \max\,(I,\ L)\end{gathered} \tag{14}$$

They primarily pursue the objective of the protection of the identity and quality of the landscape, and the energy efficiency of BUs and the production of energy from renewable sources is subject to the identification of a certain threshold of theirs that jointly maximizes *I* and *L*.

Now that the decision frame is defined, the decision makers are able to define a structure of preference from which it is possible to derive the choice of the interventions aimed at promoting the ecological transition of the neighbourhood of Borgata di S. Lucia.

Further analyses using the HPSS tool can be conducted to identify the project layout for the district with an even better performance. In this regard, other combinations of systems can be explored in addition to grid-connected ones, such as stand-alone systems with accumulation and connected to the network; other installed powers; or a mix of installed power, in addition to 1.5 kw. The decision makers selected this phase in order to optimize the process of ecological transition of the neighbourhood.

7. Conclusions

The issue of climate has posed major and urgent challenges to the global community. Cities in this context are committed on several fronts to rapid adaptation in order to improve their resilience capacity.

In this regard, the ecological transition of cities is a process that will have to be implemented quickly, given the urgency of the underlying issue.

Cities are engaged in several actions aimed at increasing the energy efficiency of buildings, increasing their green infrastructure endowment, and producing energy from renewable sources, in order to meet the target of zero net greenhouse gas emissions by 2050 [23].

Such actions are characterized by different levels of complexity in relation to the specific context in which they are generally and locally implemented in relation to the particularities of the urban fabric involved. The historic centres represent the most vulnerable part of the city, with a reduced capacity for adaptation, but also those denser of interconnected and stratified values that must be protected.

The issue of "transire" (to pass) to a new state with enhanced resilience, for the old town, represents a more challenging task that can be tackled only with the support of specific tools capable of combining multi-dimensional, multi-scale, multi-objective, multi-strategic, multi-layer, multi-stakeholder, and complex values. The HPSS tool developed and proposed in this study combines the classic PSS developed as a support for planning in a strategic perspective with the decision process in the perspective of heuristic approach and the GIS [158–161].

The HPSS tool responds to the need to encourage the exploration of objectives and strategies in a context such as the operational planning of interventions to mitigate the effects of climate change in the historic centre.

This process is characterised by limited rationality, namely the difficulty of public decision makers to recognize a set of actions that can be considered efficient from the point of view of achieving the objective and therefore known a priori.

The exploratory capacity of the instrument helps to divide the general objective into sub-objectives and identify the trade-offs related to the often divergent nature of the energy-environmental objectives, urban landscape, identity, and economics; it also allows us to measure the aggregate value produced by the specific strategy and by the different levels of the considered strategy and favours the comparison between different strategies.

The tool integrates several evaluation processes, i.e., technical, environmental, economic multicriterial, and instrumental, to facilitate the exploration of objectives and strategies.

The stakeholder group can be extended; indeed, in a subsequent phase of research, we also intend to integrate the local community.

The ecological transition of cities, and especially of historic centres, is a process that can only be implemented with the active involvement of citizens.

The Agenda 2030 with reference to Objective 11 "Sustainable Cities and Communities" promotes the involvement of citizens in the city planning process [20].

The operation of a wide audience of stakeholders can be resolved with the promotion of new forms of partnership, as indicated in Agenda 2030 with reference to Objective 17 "Partnership by Objectives".

The inclusiveness of the process and the partnership with reference to objectives 11 and 17 of the SDGs are instrumental to pursue goal 13, "Combating climate change".

In this context, The New Charter of Leipzig also promotes participatory planning and management of cities as well, based on participatory decision-making processes [48,162–167] and partnerships between public actors, the public and private sectors, and civil society.

In this perspective, the promotion of the approach of placemaking [168,169] can improve a neighbourhood and a city, as it is capable of capitalizing on the resources, inspiration, and potentials of a local community, translating them into the creation of quality public spaces that contribute to people's health, happiness, and well-being [170].

Communities can collectively reinvent public spaces and strengthen the connection between people and places, supported by creative models that are capable of integrating physical, cultural, and social that define and their continually evolve a place [171].

The tool proposed in this study is still certainly an instrument that will have to be refined. The database for the historic district of Borgata di S. Lucia was built in different phases of research, in which the quality and richness of information gradually improved.

There is still ample room for improvement of the database, which comprises sections related to calculating the energy needs (Q) and primary energy (PE) for heating; Cooling different types of BUs (building units); LCA for green roofs with intensive greening, for which the data are currently partial; LCA for traditional photovoltaics; and BIPV, for which the data are currently partial.

Other integrations may include exploring other blue solutions, such as district- and block-scale centralized plants or the creation of Energy Communities.

In another research study, we are developing a detailed 3D model of the Borgata of S. Lucia in order to identify the mitigation measures for the Urban Heat Island (UHI) [140].

The results of this research could converge in the database, and other functions could be developed to enrich the proposed tool.

The future development of this research will be aimed at resolving the questions raised above. An in-depth study of the green roof literature with intensive greening will provide a better information framework to improve the proposed tool [172,173].

The proposed HPPS is a tool that can be used to support planning in other contexts, cities, and other historic centres, once integrated into the relevant database.

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Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

PSS	Planning Support System
HPSS	Heuristic Planning Support System
SDGs	Sustainable Development Goals
NRRP	National Recovery and Resilience Plan
RRP	Recovery and Resilience Plan
BB	Building Blocks
VFT	Value-focused thinking
DCFA	Discounted Cash Flow Analysis
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCR	Life Cycle Revenue
Building Integrated Photovoltaic	BIPV
SCC	Social Cost of Carbon
MAC	Marginal Cost of Abatement
MAVT	Multi-Attribute Value Theory

Appendix A

Appendix A.1. Environmental Assessment

The energy simulation software "DesignBuilder" has been used to model some types of BUs for construction technology, geometric characteristics, and technological solutions in a Mediterranean climate in order to assess the performance and potentials for improvement concerning the greening of the roofs.

DesignBuilder, which provides a graphical interface for the Energy Plus numeric code [174], has been used to assess energy needs (Q) and primary energy (PE) for space heating and cooling.

The air conditioning system was set to operate at a temperature of 19 °C during the heating period (1 December–31 March) and 26 °C during the cooling period (1 June–30 September). Internal gains were considered with reference to an occupation density of 0.05 people/sqm and a lighting and equipment power density of 4.5 W/sqm. Moreover, concerning air quality, an air exchange rate of 0.5 vol/h^{-1} was used.

The model created in DesignBuilder for a BU in reinforced concrete with standard construction technology and geometric characteristics in the district Borgata di S. Lucia, Syracuse showed a 11.2% reduction in energy demand for the heating period and a 34.2% reduction for the cooling period.

The carbon footprint was calculated only for the extensive green roof intervention. The carbon footprints of the materials were calculated using the unit impact value (in kg CO_2 eq/kg of product) obtained from the eco-invent database.

For the intervention of an intensive green roof, the carbon footprint was estimated based on analysis of the literature review [175–193].

The extensive green roof intervention is characterized by a low additional load, as it does not require any additional structural reinforcement and is therefore particularly suitable for existing building structures. The types of vegetation used are moss, sedum, grass, and succulent plants (foliar area index 5.0/sqm), which are very common plants and are suitable to be used on an extensive green roof in a Mediterranean climate [194].

They are small plants that grow on the ground rather than upwards, providing good roof cover and membrane protection [195].

The substrate consists of a thin layer (10 cm) of porous soil: typically, a mixture of sand, clay, mineral aggregates, and organic matter. The soil is placed above the filtering layer, which is made with a geotextile fabric that filters the soil granules to prevent them from filling up the draining layer [196].

The green roof life cycle is reported in Table A1.

Table A1. Green roof life cycle phases.

Green Roof Life Cycle Phases	Carbon Footprint (kg CO_2 eq/m^2)
CO_2 embodied in green roof	29.67
Transportation	8.69
Usage	0.18
Carbon sequestration	–0.91
Net CO_2 equivalent emissions	37.63

For the calculation of the carbon footprints of photovoltaic panels, a figure from the literature was taken as reference, i.e., 0.045 kg CO_2-eq kwh [197–202], which is a partial database, since, between the different stages of the life cycle, it takes into account transport, installation, and operation as data, but in-depth analyses for the estimation of CO_2 emissions related to the disposal phase are yet not available.

Appendix A.2. Economic Assessment

The cost-based analysis and revenue-based analysis were conducted for all interventions, namely green roof solution A, B, C, and D and photovoltaic/BIPV.

Costs were taken into account for the calculation of C_G: C_I is the investment cost, C_M is the maintenance cost, C_r is the replacement cost, C_{dm} is the cost of dismantling and C_{dp} is the disposal cost (and the related environmental costs of the intervention), and V_r was considered zero.

Revenues were considered for the calculation of R_G, with energy savings at current unit prices of electricity, and the government incentives calculated as a percentage of the work, with reference to a 50% incentive provided for the renovation of the house [203], as these interventions alone do not fall under the 110% Eco-bonus [204] and the environmental benefits associated with the intervention. Records of C_G and R_G in the various interventions were created, whose data are expressed in terms of EUR /square metre to facilitate interoperability between the data in the database.

The costs for green roof solutions are A 191.91 EUR/sqm, B 157.68 EUR/sqm, C 181.10 EUR/sqm and D 308.66 EUR/sqm, and for the traditional photovoltaics, 1.5 kw 292.55 EUR/sqm, 3 kw 244.78 EUR/sq m, 6 kw 220.87 EUR/sqm. The costs for BIPV are 1.5 kw 370.92 EUR/sqm, 3 kw 358.52 EUR/sqm, and 6 kw 549.75 EUR/sqm.

The revenues for green roof solutions are A 16.50 EUR/sqm, B 14.28 EUR/sqm, C 17.11 EUR/sqm, and D 17.11 EUR/sqm. The revenues for traditional photovoltaics are 1.5 kw 38.02 EUR/sqm, 3 kw 36.01 EUR/sqm, and 6 kw 34.96 EUR/sqm. The revenues for BIPV are 1.5 kw 33.38 EUR/sqm, 3 kw 32.94 EUR/sqm, and 6 kw 43.15 EUR/sqm.

Based on the data integrated in the database for C_G and R_G, it is possible to determine all the economic indices [205].

The automatic procedure allows us to calculate the cost-effectiveness also extended to environmental externalities and financial feasibility for each type.

Appendix A.3. Investment Economic Assessment Criteria

1. The net present value (NPV) is the sum of the incoming and outgoing cash flows, that is, revenues (R) and costs (C), over a defined time horizon (T), discounted at the discount rate r. NPV is less than, equal to, or more than the (net) future value (FV) if the discount rate (r) [206] is more than, equal to, or less than 0; NPV is expected to be significantly positive in the case of a private player:

$$NPV = \sum_{i=0}^{T} \frac{R_i - C_i}{(1+r)^i} \geq 0 \quad \text{(A1)}$$

2. The total rate of return (TRR) is the more significant index of profitability and is expressed as the ratio between NPV and the present cost. TRR should be greater than the opportunity cost of capital c_k.

$$TRR = \frac{\sum_{i=0}^{T} \frac{R_i - C_i}{(1+r)^i}}{\sum_{i=0}^{T} \frac{C_i}{(1+r)^i}} \geq c_k \quad \text{(A2)}$$

3. The internal rate of return (IRR) is the discount rate r_{IRR} at which $NPV = 0$, that is, the maximum rate of return that can be extracted by an investment. It only depends on the distribution of the stream along the time horizon of the investment:

$$\sum_{i=0}^{T} \frac{R_i - C_i}{(1 + r_{IRR})^i} = 0 \quad \text{(A3)}$$

4. The external rate of return (ERR)—also called modified internal rate of return (MIRR)—refers to both the cost of the investment and the interest on the reinvested cash and is calculated based on an interest rate external to the investment at which net (positive) cash flows generated by the investment over its time horizon can be invested or borrowed r^* (Minimum Attractive Rate of Return—MARR or hurdle rate). The external rate of return r_e^* is the rate at which the investment costs discounted at the rate r equal the future value at time T of the positive cash flows ($CF_{i(>0)}$) deferred at the rate r^*, given $CF_i = R_i - C_i$. In other words, ERR is the IRR of an ideal investment whose unique cost is the initial investment cost calculated as the NPV at the rate r of the negative cash flows over the time horizon T and whose unique revenue is the future value (at year T) of the positive cash flows at the rate r^*. IRR is r_e^*.

$$\sum_{i=0}^{T} \frac{CF_{i(<0)}}{(1 + r_e^*)^i} = \sum_{i=0}^{T} CF_{T-1(>0)} (1 + r^*)^{T-i} \quad \text{(A4)}$$

5. The elasticity (E_r) is the marginal NPV at the discount rate r:

$$E_r = \frac{\frac{\delta NPV_r}{NPV_r}}{\frac{\delta r}{r_r}} \quad \text{(A5)}$$

6. The discounted payback period (DPP) is the number of years it takes to break even from undertaking the investment cost (I_0) by discounting future cash flows and recognizing the time value of money ($r > 0$) [207,208]; the higher the discount rate, the longer the DPP. More simply, a payback period (PP) can be calculated without taking into account the time preference rate ($r = 0$) [209]. In general, PP is the ratio between the total investment cost and the annual constant or average cash flow. Often, the variability of the cash flow over the lifetime of the project reduces the reliability of the formulas usually implemented for DPP, so a more general formula can be proposed considering $NPV(i)$, and then:

$$DPP = i_{NPV(i)=0} \quad \text{(A6)}$$

7. The average period at the rate r (P_r) [210–213] is a sort of time elasticity and can be considered as the average period of deferment of the i_{th} annual net discounted cash flows (CF_i) given the discount factor:

$$P_r = \frac{\sum_{i=0}^{T} \frac{iCF_i}{(1+r)^i}}{\sum_{i=0}^{T} \frac{CF_i}{(1+r)^i}} \quad \text{(A7)}$$

The discount rate r is an important indicator of the intertemporal solidarity [214–219] practiced with the implementation of the project, and it enables two different and complementary prospects, the private one as the means and the public one as the ends.

Concerning the first one, the discount rate can be assumed to be the well-known weighted average cost of capital ($WACC$), referring to the funds in terms of debt (D) and equity (E);

$$WACC = \frac{i_d D + i_e E}{D + E} \tag{A8}$$

where i_d is the interest rate for debt and i_e is the opportunity cost of equity, which respectively, refer to the active and passive interest rates charged to households and consumers, according to the statistics of Bank Italia (2021), set at 4.66% (over 5 years loan life) and 0.12%, assuming a leverage of 50% and $WACC$ of 2.39%.

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Article

The Effective Use of National Recovery and Resilience Plan Funding: A Methodological Approach for the Optimal Assessment of the Initiative Costs

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Abstract: With reference to the National Recovery and Resilience Plan (NRRP), the financial budget provided for a specific project constitutes a fundamental constraint to be taken into account in the selection phase of the initiatives to be carried out. In the present research, a methodological approach based on an optimization algorithm that allows one to minimize the differential between the assessed costs and the budget provided for the project, has been defined. The methodology is organized in three phases and, by borrowing the logic of the Operational Research, aims to minimize the gap between the costs assessed by the expert technician and the final costs, in order to fit the preliminary set budget. In this sense, the developed tool constitutes an effective support for Public Administrations and private investors for choosing the investments to be implemented, in order to identify the best initiatives in which to allocate the public funding, by preventing needless waste of limited financial resources that could be invested in alternative interventions, and to generate further benefits for the communities.

Keywords: construction costs; costs assessment; NRRP; methodological approach; budget of the project; optimization algorithm

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1. Introduction

Within the project life cycle, the assessment of the construction costs is included in several steps, from the first phase of project idea conception to the final phase of its disposal, with different purposes. In this sense, the ex ante evaluation of the intervention costs aims at determining the most likely expenses associated with the different operations of which the initiative is composed; the ongoing or in itinere evaluation intends both to determine the costs of the work variants during construction, and to verify the costs for ensuring the down payments at each step of the workings; the ex post evaluation aims to verify the adequacy of the costs incurred, and to assess the costs of the physical and functional adjustments.

With reference to the different subjects involved in the construction process, the goals for which the construction cost assessment is implemented are multiple: (i) for the client (contracting authority in the cases of public works), the determination of the expenditure order of magnitude, the definition of the financial plan of the works and the determination of the monetary amount to be considered for the awarding contracts; (ii) for the company, the quantification of the bidding in the tender, the determination of the payments plan and the organization of the building site and the succession of operations to be carried out; (iii) for the designer, the comparison between the project alternatives for the choice of the "best" project and the calibration of the best solution by balancing needs, requirements and performances in line with the budget constraint.

By taking into account the goals for which the assessment is developed, the subjects implement different tools for determining the construction costs, which are official price lists or price analysis for the client and their own price lists for the companies.

In this way, the contracting authority formulates a "generally valid" value judgment-based on the prices included in the lists normally used in the reference market, in which the amounts are derived considering the normal skills of an ordinary entrepreneur operating in the specific market. On the other hand, the company draws up a "specifically valid" judgment, strictly correlated to its own skills and specificities on the basis of its own price lists.

Within all phases of the project, the intervention costs valuation plays a central role and, simultaneously with the progressive increase in the detail of the different stages of the conception and subsequent design, the ex ante assessment is improved, becoming more precise and reliable.

In the Italian context, starting from a roughly broad summary estimation in which the overall cost order of magnitude and the amounts related to the main categories of the works to be carried out are determined, the three design levels admit a progressively decreasing error tolerance concurrently with the greatest project detail level and the improvement of the tools used to assess the costs. In fact, the art. 23 of the Public Works Procurement Code Legislative Decree No. 50/2016 [1] governs the articulation of the design according to three levels of subsequent technical in-depth analysis, in the *technical and economic feasibility project*, the *definitive project* and the *executive project*. Then, it clarifies the main goals that, in general terms, the design process intends to pursue in terms of: (a) meeting the needs of the community; (b) architectural and technical functional and relationship quality in the reference context; (c) compliance with environmental, urbanistic and protection for cultural and landscape asset standards, and with the provisions of the legislation on the protection of health and safety; (d) limited land use; (e) compliance with hydrogeological, seismic and forestry constraints as well as other existing constraints; (f) energy saving and efficiency in the construction and subsequent project activity as well as the assessment of the life cycle and maintainability; (g) compatibility with pre-existing archaeological sites; (h) rationalization of design activities and related checks through the progressive use of specific electronic methods and tools such as modeling for buildings and infrastructures; (i) geological, geomorphological, hydrogeological compatibility of the work; (j) accessibility and adaptability in accordance with the provisions in force on architectural barriers.

Therefore, the assessment of public project construction costs blindly follows the increase in technical detail that characterizes the different design levels. From a synthetic assessment, the analytical cost quantification is carried out by implementing the Metric Estimative Computation procedure, i.e., by associating the unit prices taken from the official regional price lists to the quantities of the different processing categories envisaged by the project.

In this sense, according to the Italian legislative reference, the definitive project is aimed at fully identifying the works to be carried out, in compliance with the needs, criteria, constraints, addresses and indications established by the contracting authority, for the required authorizations and approvals issue, the definitive quantification of the cost limit for the construction and the relative time schedule.

The executive project is intended for determining, in detail, the works to be carried out and the relative expected cost, in order to identify each intervention element in terms of form, typology, quality, size and price.

These two design steps provide for the analytical estimation of the construction costs to obtain a more precise ex ante evaluation of the costs to be incurred for the implementation of the initiative.

The first design level, instead, consistently with the limited in-depth analysis of the developed documents, includes the summary costs estimation, carried out starting from the costs of similar interventions performed in an adjacent spatial horizon (i.e., close to the intervention area) and in a recent period to that of evaluation. The contents of the technical and economic feasibility project have been defined by the guidelines of the Superior Council of Public Works approved on 29 July 2021 and, currently, referred to the elaboration of the technical and economic feasibility project for the award of contracts of National Recovery and Resilience Plan (NRRP) and National Plan of Complementary Investments (NPCI) works and interventions [2].

In the context of the Next Generation EU [3], aimed at promoting a "sustainable, uniform, inclusive and equitable recovery" following the crisis caused by the COVID-19 pandemic, in Italy, the NRRP definitively approved the Council's Implementation Decision on 13 July 2021 [4]; this provides a synthetic framework of reforms and measures to be implemented from 2021 to 2026 within the six pillars identified in the European Green Deal [5], i.e., green transition, digital transformation, social and territorial cohesion, health, policies for the next generation and sustainable, smart and inclusive growth.

The Italian NRRP foresees investments for a total of EUR 222.1 billion, of which EUR 191.5 billion are financed by the European Union through the Recovery and Resilience Facility (68.9 billion are non-repayable grants and 122.6 billion are loans), and a further 30.6 billion of national resources are part of a complementary fund, financed through the multiyear budget variance. In Figure 1, the summary of the structure of NRRP with the identification of the six investment sectors and the set monetary amount provided for the national plan, is reported.

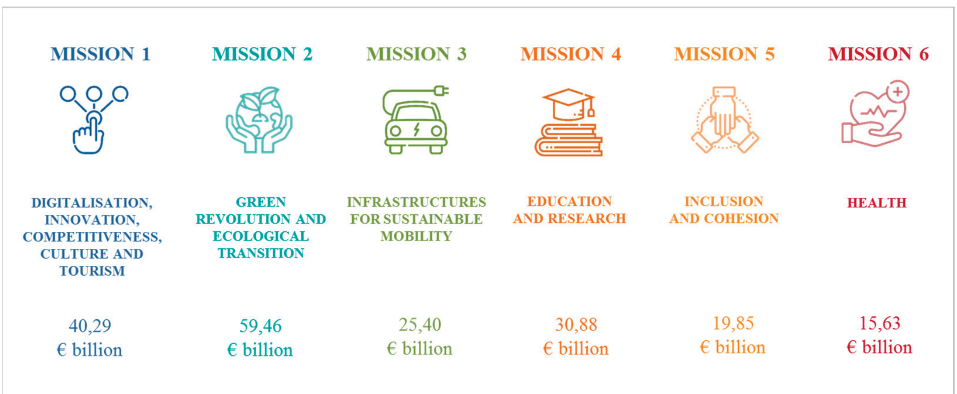

Figure 1. Summary of the NRRP structure.

In the context of the mentioned six main strategic missions upon which the national plan is developed, the construction sector plays a fundamental role in the success of the NRRP and the planning of effective investments is a fundamental aspect to be considered for an efficient use of the funds allocated. In this sense, relevant importance has been attributed to the technical and economic feasibility project which, according to the provisions of the Simplification Decree of 2021 (Law No. 108/2021 [6]), can constitute the document on the basis of which to entrust the executive design and execution of the works financed by the NRRP and the NPCI.

Currently, the guidelines for the drafting of the technical and economic feasibility project represent the only reference that defines the contents of this design level document: hence, its importance overcomes the NRRP projects context. Among the 19 documents in which this design level is divided, the project costs assessment has to be implemented through an estimative computation, in relation to the intervention size, typology and category. In particular, the reference guidelines specify that the analytic costs estimation replacement with an adequate synthetic one, able to justify the adequacy and appropriateness of the assessed costs, is allowed.

Within the phases of the project, an effective assessment of the intervention costs in all the stages assumes a significant role in avoiding, as much as possible, (i) the failure of initiatives to be implemented in the territory, deriving from the occurrence of unexpected events that cause the unforeseen increase in costs, and (ii) the transformation initiative start-up and subsequent interruption associated with incorrect ex ante costs assessments not validated during the construction.

In the framework outlined and focused on the development and the selection of initiatives to be financed through the NRRP funding, the ex ante, in itinere and ex post valuations of the construction costs allow one, respectively, to adequately estimate the project costs in relation to the fixed expenditure budget, to monitor the costs progressively incurred with those estimated and determine the variants monetary amounts and to verify the congruity of the costs paid with those assessed, in order to effectively use the available and limited resources.

In the context of the NRRP, the role played by the urban requalification is crucial: in fact, Mission 5 Component 2 (Investment 2.1), entitled "Investments in urban regeneration projects, aimed at reducing situations of marginalization and social degradation", concerns the projects regarding (i) the reuse and the refurbishment of existing public areas and buildings, including the demolition of structures illegally carried out by private individuals in the absence of, or total divergence from, the building permit, (ii) the improvement of the quality of the urban decor and of the social and environmental tissue, (iii) the development of social and cultural, educational and didactic services, (iv) the promotion of cultural and sporting activities. In this sense, the initiatives aimed at the rehabilitation of occupied/built up urban areas are included among the most relevant territorial management mechanisms: conscious land use involves the definition of urban planning strategies that promote the renovation of the exciting property asset (real estate enhancement) and the functional reconversion of degraded and underused areas (urban regeneration). Within the decision processes for the development of effective territorial policies, the assessment of intervention costs represents a key step for the successful initiatives implementation: in the mentioned topic, the "Monumental Budget Busters" represent a considerable phenomenon that concerns the overbudget construction projects, both in terms of duration and required amount of money, for which an "inadequate" or "unreliable" preliminary intervention cost assessment had been carried out. In the precious opportunity given by the PNRR, these situations should be avoided, in order to properly use the financial resources and to generate important benefits for the communities.

2. Research Objectives

The increasing need to define assessment tools and techniques able to support decision-making processes in the optimization of the allocation of foreseen financial resources and in the design and selection of projects highlights the role of the evaluation to orient Public Administrations in planning choices.

The compliance with the fixed financial constraint constitutes a fundamental issue in the preliminary intervention costs evaluation, connected to the cogence to carry out "high quality" projects. Thus, the variation between estimated costs and incurred costs, possibly due to in itinere variants, should not cause the lowering of performance level of the design solution (e.g., in terms of materials, constructive techniques and decrease in technological and qualitative standards). Within the scientific debate on the valid use of NRRP funding allocated for the urban requalification, the use of assessment tools for the "appropriate" compliance with the project budget determines the urgency to define effective methods for the optimal assessment of the initiative costs, able to provide a reliable reference in the ex ante evaluation phases.

In this perspective, the present research proposes a methodological approach that intends to facilitate the definition and the calculation of investment costs in the technical and economic feasibility projects level, as provided by the legislative references in force in the Italian context, in particular by the Procurement Code. The aim of the research is to highlight the key role played by the assessment discipline—during the first design phases—in the determination of the total costs, that have to be consistent with—and as close as possible to—the expenditure budget provided by the Public Administration. For this goal, an optimization algorithm that borrows the logic of the Operational Research is defined, that allows one to minimize the differential between the costs assessed by the expert technician and the a priori budget of the project. Given the set cost limit, for each category of work, the developed methodology allows one to reduce, as much as possible, the gap between the costs derived from official price lists taken as a reference for the assessment and the final costs.

The potentialities of the proposed assessment tool, firstly, concern the disaggregation of the project into single work categories, whose costs are optimized by implementing the developed methodological approach. This aspect represents an important innovation of the methodology: in fact, in the reference literature there are several applications of methods for the optimization of the cost assessment. The algorithm of Branch and Bound (B&B) [7–10] is an example of these methods: in particular, starting from a set budget to be divided among different projects to be carried out on the territory, the algorithm allows one to identify the initiatives for which the difference between the set budget and the sum of the respective total intervention costs is minimized. In this sense, the B&B algorithm allows one to determine only a priority list of the interventions, whereas the reliability of the costs assessed for each considered project is not verified.

Conversely, the methodology proposed in the present research optimizes the costs of each work categories, in order to carry out a reliable assessment of the intervention costs in the preliminary phase and to allow their remodulation according to the fixed budget and the reference official price lists.

With reference to the city of Rome (Italy), two urban regeneration projects related to public housing (*Tor Bella Monaca*) and public community services (*Santa Maria della Pietà* monumental complex) are selected as case studies. Specifically, following the identification of the relevant consistencies of each intervention, the main categories of works are determined. Then, for each of these, the construction costs are assessed by consulting the official reference price lists ordinarily used by local market operators. The application of the optimization algorithm makes it possible to verify the consistency between the estimated construction costs and the preliminarily set budget, by aiming to the effective management of available financial resources.

In the context of the funding allocated by NRRP for urban redevelopment, the proposed methodological approach represents a valuable support for the decision-making processes of Public Administrations, as it is able to define optimal modalities of using the available monetary resources. Furthermore, the model could facilitate the selection phase of the projects most consistent with the objectives of the plan and capable of determining greater benefits for the community. With reference to private entities, the optimization tool can be used to verify the feasibility of the investment, given an initial expenditure budget, the different categories of planned work and project consistencies. In this sense, the analysis points out the valuer role in the successful transformation initiative since the early design phases within the project life cycle. The valuer is able to assess the intervention costs by consulting valid and consistent sources, in order to define feasible and profitable solutions and to avoid failures and waste of significant economic resources. Therefore, the strong relationship that should be established between the design and the evaluation phases clearly emerges with the purpose to adequately use public funding. In addition, it highlights the increasing need to reach the interdisciplinarity among the different issues involved in a planning process. Moreover, already in the technical and economic feasibility project, several feasibility aspects (technical, environmental, financial, economic, procedural) are considered and explored in order to provide an overall analysis of the project and to identify any critical issues that do not ensure the convenience of the initiative. It is evident that the intervention cost topic assumes a relevant importance for the development of the next design levels, as the set budget constitutes a limitation and an essential condition to be taken into account.

The structure of the paper is organized as follows: in Section 3, the background related on the cost assessment method is illustrated; in Section 4, the methodology proposed in the paper is explained; in Section 5, the case studies related to the two urban regeneration projects referring to the *Tor Bella Monaca* public housing compendium and the *Santa Maria della Pietà* monumental complex are reported, and a concise framework of the funding provided for the city of Rome aimed at describing the context in which the case studies are included is outlined, the application of the optimization algorithm is discussed and the outcomes are presented. In Section 6, the conclusions of the research are drawn, and potential future developments are listed.

3. Background

During the recent decades, the need to implement accurate and robust cost assessments has been growing and closely linked to the requirement to effectively use the scarce national economic resources available to public entities, to adequately invest European funding and the financial resources of private partners involved in initiatives aimed at the urban territory development.

The thorough project cost assessment has been known as a major challenge that could influence project performance and its ultimate success: in this sense, a valuer needs to have expertise in converting the early scope of the project into costs [11], especially with reference to the different levels of project progress.

The risks of exceeding the costs paid compared to the estimated costs are very frequent in the construction sector, and an effective cost control process should allow one to limit significant differentials between the two cost items (assessed costs and incurred costs). This is also associate to the need to minimize the uncertainty related to cost variations and/or the occurrence of new unforeseen operations, to which significant increases in costs may be connected. The analysis of the risks associated with an increase in the project costs is performed to identify likely mitigation measures of the risks [12]. It is clear that the cost overrun, i.e., the increase in project cost that causes high variation compared to the estimation results and to the fixed budget, can significantly reduce the feasibility of the entire initiative. In the framework pointed out, the intervention global cost analysis—often used interchangeably with the term project life cycle cost [13,14]—and the cost monitoring in all the project phases represent essential steps for financial planning and management and for the determination of the resource requirements and budgets.

Furthermore, the cost assessments can orient the intervention implementation modalities, allowing one to select those that are consistent with the established spending limits and to reject the design solutions that are not convenient as too expensive (the so-called "white elephant" investments) [15–17].

With reference to the NRRP resources, the cogency to increase the quality of cost estimates through improved consistency and transparency of methods, assumptions and reporting, is currently predominant, and is strongly linked to the need not to waste the allocated resources, but to use them in the best possible way.

In general terms, the cost represents a fundamental element for the development of all the chosen processes, starting from the first phases of the building cycle up to its conclusion, at different scales. An accurate cost analysis is based on information data quality and long-term forecasts, indicating that data uncertainty is very often associated with Life Cycle Cost (LCC) methods [18–21], due to the limited level of detail that concerns the first design steps in line with the still not in-depth technical project definition. In fact, the scarce availability and reliability of the input data that usually characterizes the early stages of a project cycle in which the technical study of the project is limited, increases the uncertainty of the output [22].

To the lack of reliable information, among the main reasons for the uncertainty of the estimated costs, Sesana and Salvalai [23] have added the difficulty of predicting temporal factors over a long period (future operating, maintenance and demolition costs and discount rates and inflation rates). In addition, the authors have identified the variability of construction costs of the same component or material (depending on the company, quantity and availability in the specific context, etc.) as a key factor to be taken into account. In this sense, the uncertainty is endemic to Whole life Cost (WLC), as, by definition, it deals with the future, which is unknown. This contingency is worsening by the difficulty in obtaining the appropriate level of information and data and, thus, various risk assessment techniques applicable to WLC (sensitivity analysis, probability-based techniques, fuzzy approaches, etc.) have been mostly implemented in order to assess the uncertainty in WLC modelling. In accordance with this goal, Ilg et al. have provided a comprehensive overview of the uncertainties in LCC [24], by systematizing the uncertainty types and concluding that their variety makes it difficult to provide a simple and meaningful categorization [25]. To overcome the problem of unreliable and inconsistent data, El-Haram et al. [26] have developed a framework for collecting WLC data in building projects, and Wu et al. [27] have analyzed the impact of reliability on the improvement of WLC performance.

In the situations with different project alternatives, the WLC represents a valid support tool in the decision-making processes, and, although the approach can be conducted at any stage of the project, the potential of its effective use is maximum during early design stages, mainly because most, if not all, options are open to consideration [28,29].

It should be outlined that, in the referenced literature, the WLC is described as a wider notion than LCC; therefore, vice versa, the LCC can be considered as part of WLC, as the LCC is defined as costs of an asset or its parts throughout its life cycle, whereas the whole life costs concern all significant and relevant initial and future costs and benefits of an asset throughout its life cycle [30]. In this sense, the LCC methodology focuses exclusively on costs, whereas the WLC approach covers both costs and benefits during the lifetime of a project, and includes other costs, such as non-construction cost. The RICS professional guidance [31] clarifies the difference between LCC and WLC, by pointing out that LCC focuses only on the construction, maintenance, operation and disposal of the asset, whereas WLC also includes client and user costs, such as project financing, land, income and external costs (those not born by parties to the construction contract–such as tenants). However, the guide highlights that the same rules and procedures can be applied equally to WLC and LCC.

In brief, with reference to the life cycle of a project, the Life Cycle Costing Analysis (LCCA) represents an evaluation method. It allows one to determine the overall intervention costs, taking into account the investment costs (intervention preparation/promotion, site inspections, design, land acquisition and related legal, notary and administrative expenses, clean up and/or reclamation, construction, expenses related to the sale and/or lease, marketing, etc.) and all the costs that be incurred for its use (the operating costs of management and ordinary and extraordinary maintenance and of operation and replacement), including end-of-life costs, for example, those related to the disposal of the asset, or the residual value, positive or negative, that the asset has at the end of its useful life.

The main goal of LCCA implementation concerns the assessment of the project costs related to alternatives, in order to select the project solutions able to ensure the lowest overall cost consistent with its quality and function. Thus, during the last few decades, the WLC approach has considerably diverged from the traditional practice, according to which the construction investment and procurement decision were based on initial capital costs [32]. Currently the choices are addressed towards the design solutions characterized by higher initial costs and lower management costs. It is evident that an inverse functional correlation between the construction costs and the operating costs is established: the more accurate and detailed the design is, the higher construction costs and savings in the management phase will be.

An effective decision-making process that includes the life cycle costs among the "choice criteria" proposes that the LCCA should be performed early in the design phase, while there is still a chance to refine the design to ensure a reduction in costs [33].

The life cycle cost performance is regulated by Section 5—entitled "Buildings and constructed assets. Service life planning"—of the ISO 15686-5 standard [34], in which requirements and guidelines for the development of the economic evaluation technique of a new construction or an existing asset, by considering both immediate and long-term costs and benefits, are included. The relevance of the LCCA concerns the support provided by the analysis for design choices in various contexts, from individual products or components, to the entire building system, to an entire new construction project and to a renovation project of an existing property [35–37].

In theoretical terms, in fact, the LCC methodology aims at orienting the assessment of the economic benefits associated with the initiative, addressing the choice of the solution with higher initial cost and lower maintenance and management costs. Through this methodology, the single design solution is analyzed or the different project alternatives, in terms of materials and technological solutions, are assessed, in order to determine different costs in the building life cycle ant to guide the selection processes. Based on the goals of the parties involved in transformation operations (ex novo realization, property enhancement, energy retrofit, urban redevelopment, etc.), the LCCA should be implemented from the early stages of planning, to avoid costs for any future redesign [38]. The analysis should be adapted to the different steps of the project life cycle for the costs forecast, the alternative solutions analysis, the short-term costs estimation and the cycle cost management identification [39–42].

In 2007, The National Audit Office [43] published a guide for the implementation of a whole life costing analysis, identifying among the fundamental principles on which the success of a construction contract is based, the active participation of the client during all phases of project design, construction and management.

In the existing literature related to the concept of computation in decision-making mechanisms, the automation processes have been very often implemented for the determination of the market value (property valuation) [44–47]. However, the assessment of the cost value has been less studied in this way. The present research intends to fill the current gap, by defining a methodological approach for the optimal assessment of the initiative costs, given the fixed budget and the disaggregation of the projects into work categories.

4. Method

In order to define the methodological approach aimed at minimizing the differential between the estimated construction costs and the set project budget, the computational three-phase articulation is explained:

Phase (1) the analytic description of each single initiative into work categories, for which the quantities and relative units of measurement must be defined;

Phase (2) the assessment of the construction costs of each single work category, by consulting appropriate official price lists (named "official costs");

Phase (3) for each work category, the comparison between the official costs and those determined through the implementation of the optimization algorithm (named "optimal costs").

In Figure 2, a summary of the method operative logic is reported.

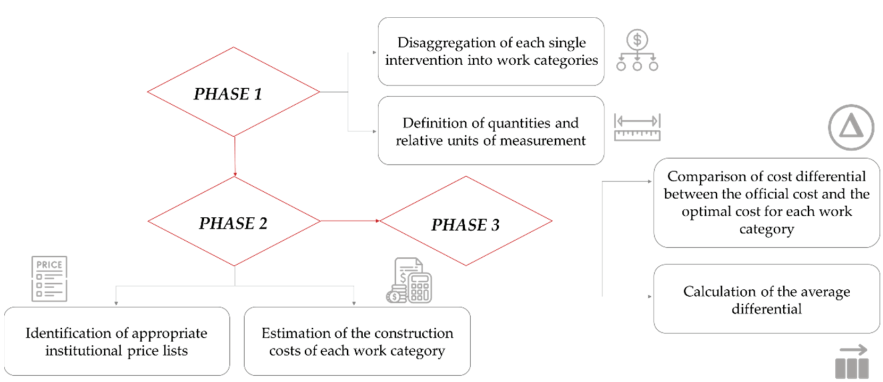

Figure 2. Computational phase articulation of the assessment method.

The proposed model borrows the operative logics of goal programming techniques, which support the definition of the optimal allocation of scarce resources that can be utilized for alternative uses. In this sense, a goal programming problem is characterized by the (i) resources available in limited quantities and for which different uses are provided (variable); (ii) constraints to the use of resources; (iii) objective functions, in order to assess the contribution that any possible use of resources contributes towards achieving a fixed objective [48].

In the case in which n available resources can be utilized for z possible uses, with f assumed to be the return function to minimize (min) or maximize (max) in line with the decision maker goal, and $a_1, a_2, a_3, \ldots, a_z$ allocated as the variables that represent the possible uses of the resources, the mathematical form can be defined as follows:

$$\min(\text{o} \max) f\,(a_1, a_2, a_3, \ldots, a_z) \quad (1)$$

The constraint system to achieve the objective can be summarized as shown in (2)

$$\begin{gathered} x_{11}a_1 + x_{12}a_2 + \ldots\ x_{1z}a_n \leq b_1 \\ x_{21}a_1 + x_{22}a_2 + \ldots\ x_{2z}a_n \leq b_2 \\ x_{n1}a_1 + x_{n2}a_2 + \ldots\ x_{nz}a_n \leq b_n \end{gathered} \quad (2)$$

In detail, by indicating with x_{ij}—whereby $i = 1, \ldots, n$ and $j = 1, \ldots, z$—the absorption rate of the i-th resource in the j-th use are considered unified, with b_i representing the amount of the i-th available resource, $\Sigma\, x_{ij}a_i \leq b_i$.

With reference to the present analysis, for the model, the resources in limited quantity are the available monetary amounts, the alternative uses are identified by the different work categories in which the entire initiative can be analytically divided, and the constraint is represented by the preliminary set budget provided for the project. The objective concerns the simultaneous compliance with the budget and the fulfilment of the adequate quality standards of the final project, in order to ensure the high intervention level.

For the purpose of structuring the optimization algorithm, the main components to be considered in formalizing the mathematical expression of the developed methodological approach are defined and listed below:

C_i = the construction costs of the i-th initiative;

$D_i = a_i \cdot C_i$ = the indirect costs of the i-th initiative;

a_i = incidence of indirect costs (contingency, technical expenses, VAT), determined in percentage on the construction costs;

n = the number of initiatives to be financed;

$B_{TOT} = \sum_{i=1}^{n} (C_i + D_i)$ = the total provided budget;

q_{ij} = the quantity related to the j-th work category of the i-th initiative;

k_{ij} = the unitary official cost, i.e., the unitary construction cost of the j-th category of work of the i-th initiative, estimated from institutional price lists;

k^*_{ij} = the unitary optimal cost, i.e., the unitary construction cost of the j-th work category of the i-th initiative (variable of the model);

m = the number of work categories (different for each i-th initiative).

In Table 1 the summary of the variables, constraints and objective function of proposed algorithm is reported.

The optimization algorithm, which is able to define compromise solutions between architectural design and the expenditure budget, should be determined for each category of work, such as to preserve the aim of the planned quality of the initiatives.

It should be observed that, in the situation where for each i-th initiative a specific budget is planned, for each of them the algorithm will be implemented; otherwise, the indexation with "i" and the corresponding summation disappear, and only the indexation in "j" remains.

Table 1. The optimization algorithm.

Variables	k_{ij}^{*}
Constraints	$\sum_{i=1}^{n}\sum_{j=1}^{m}\left[(1+a_i)\cdot\left(k_{ij}^{*}\cdot q_{ij}\right)\right] \leq B_{TOT}$
	$0 < k_{ij}^{*} \leq k_{ij}$
Objective function	$\min \sum_{i=1}^{n}\sum_{j=1}^{m}\left(k_{ij}-k_{ij}^{*}\right)$

The main advantages of the developed methodological approach concern, firstly, the ease and flexibility of the tool application in any geographical national context and for different goals, due to the computational three-phase articulation. Moreover, the method can be used for the rapid verification of the intervention costs and their remodulation in order to fit the preliminary set budget, starting from the disaggregation of total investment into work categories and "acting" on each of them for the optimization of the initiative costs.

5. Case Studies

Within the NRRP goals, and with particular reference to the capital of Italy (the city of Rome), the need to activate processes for the recovery and the function reconversion of degraded and unused urban areas is central and strongly considered in the political and scientific debate for the definition of territorial planning policies and practices.

Furthermore, in recent years in the metropolitan area of Rome, numerous urban transformation initiatives have been planned, given the increased funding, amounting to about EUR 8.2 billion [49]. In addition to funds from the NRRP, the city of Rome will benefit from investments for the organization of the Jubilee 2025 [50] and the likely EXPO in 2030 [51]. The investments will affect all areas of the city and will concern several initiative typologies: e.g., road infrastructure, public transport, management of water resources, improvement of the maintenance conditions of existing property asset (both residential and non-residential) [52].

With reference to the NRRP, the plan is divided into 16 components, grouped into six missions. In fact, in the implementation of Mission 5 Component 2 (M5C2; social infrastructure, families, community and third sector) and of the "Integrated Plans" project strategies, the Decree Law No. 152 of 6 November 2021, converted into Law No. 233 of 29 December 2021 [53,54], allocates funds up to a total of EUR 2493.79 million for the period 2022–2026 and, in particular for the metropolitan city of Rome, assigns EUR 330,311,511 for the same years. The specific investment, M5C2, is aimed at improving the suburbs of the metropolitan cities and, in general, large urban areas characterized by a relevant state of decay and degradation, in order to introduce new services for communities and to upgrade logistics infrastructures, by transforming the most vulnerable territories into new sustainable areas of "smart cities". Furthermore, the initiatives provided for by Article 21 of Decree Law No. 152 of 2021, with amendments by Law No. 233 of 2021, pursue the following goals: i) to encourage better social inclusion by reducing marginalization and situations of social decay; ii) to promote urban regeneration through the eco-sustainable recovery of buildings and public areas, the energy and water efficiency of existing property asset and the reduction in soil consumption; iii) to support projects related to smart cities, with particular reference to transport and energy consumption. In order to strengthen the initiatives for the Integrated Plans, within the "Resilience Italy Fund", an additional EUR 272 million has been allocated for the implementation of the strategies referred to in the Integrated Plans for municipalities projects. This fund, which is to be managed in the context of the European Investment Bank, aims to attract private financing for urban regeneration projects. The main goal is to promote the development and implementation of long-term urban investments, by creating new and alternative lending channels and innovative models for urban transformation projects, combining public resources with private resources [55].

In the context outlined, the metropolitan city of Rome should identify, within the limits of the resources allocated, the projects that can be financed. In this sense, the projects should present an opportunity to regenerate the territories and, consistently with the international sustainability objectives, to improve the quality of life and the resilience level of the city ecosystems. In particular, the first criterion to be considered in the decision-making processes regards the compliance with the legal limit of the Index of Social and Material Vulnerability [56,57]. The Index is a summary measure of the level of social and material vulnerability calculated for the Italian municipalities, capable of expressing different aspects of multidimensional natural phenomena with a single value in order to facilitate territorial and temporal comparisons and the monitoring of socioeconomic issues. The second criterion concerns the existence of a widespread and integrated multiyear planning of public and private interventions where the realization of public works related to the implementation planning tools has not been completed, or is unimplemented for lack of public resources, or for the lack of private interventions activation.

The interventions to be selected must be fully consistent with the strategic axes of the NRRP and the goals of the 2030 Agenda [58], and they are aimed at the sustainable development of the city.

As mentioned before, in the present research, the application of the defined optimization algorithm to two different projects to be realized in the city of Rome is carried out. The two urban regeneration interventions were selected according to the criteria for the selection of the projects among those proposed, and they are consistent with those provided for the NRRP funds. The two initiatives considered are located in two different city of Rome portions: the *Santa Maria della Pietà* monumental compendium in the northwest of the city, and the public housing asset of *Tor Bella Monaca* in the east of the city of Rome. In Figure 3, the localization of the two urban transformation areas is shown. Currently, the redevelopment projects in the two areas have already been defined: through the allocated funds, they will be integrated, and the realization process will be implemented. The finalization of the considered projects will allow one to take significant benefits from the NRRP funding uses, by assigning them to two important and densely populated city areas that, currently, need to be totally restored.

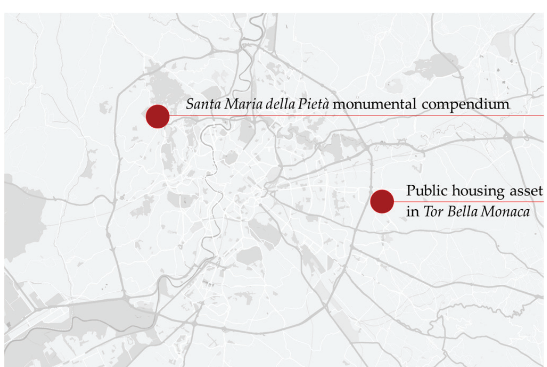

Figure 3. Localization of the two urban transformation areas considered in the analysis within the city of Rome.

5.1. Santa Maria Della Pietà

The *Santa Maria della Pietà* area is located in the northwest of the city of Rome. The area of intervention is surrounded by the *Agro Romano*, with parks and reserves of natural, historical and artistic interest, as well as by the agricultural areas, interspersed with numerous orographic incisions. The adjacent urban areas were developed in the 1950s, and have suffered a process of uncontrolled expansion. In fact, since their foundation, numerous urban transformations have been carried out, resulting in the construction of multiple building typologies, including public housing built in the 1980s and 1990s, alternating with private residential properties, which are often spontaneous and/or illegal.

In Figure 4, the monumental compendium of *Santa Maria della Pietà*, the main transport systems and the surrounding residential neighborhoods are shown.

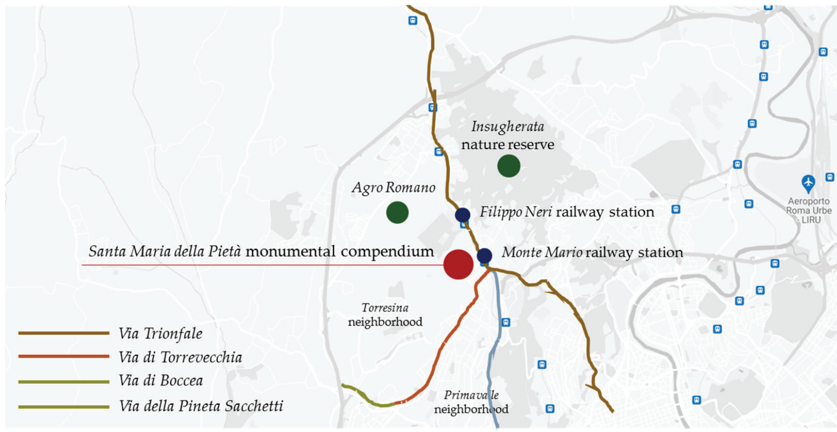

Figure 4. *Santa Maria della Pietà* monumental compendium, surrounding residential neighborhoods and main road axes.

The initiative provided for the monumental compendium of *Santa Maria della Pietà* is included in a program of interventions related to the health and well-being of the communities, intended as a state of physical, mental and psychological well-being, aimed at improving and spreading the culture of social inclusion, assistance and collective, community and generational integration.

As shown in Figure 5, the monumental compendium is organized in pavilions spread throughout the external park area in which different functions will be included, consistent with the structure of the pavilions and with the overall project solution.

For the pavilions to be transformed (Nos. 5, 6, 7, 16, 18, 23, 24, 25, 28, 31 and 41 in Figure 5), significant redevelopment works are planned in accordance with the original conformation of the building and the monumental constraints on the whole complex.

The project provides for refurbishment interventions, which involve a complete structural and systems renovation of the buildings and their functional reconversion, in compliance with the existing monumental constraint on the complex in which they are located. For the determination of the construction costs related to each pavilion, appropriate official price lists [59–63] have been considered. In particular, by analyzing the index items of the price list, the most appropriate one, i.e., the most similar intervention, has been selected and the unitary construction cost has been identified. These official costs have been validated and adjusted by analyzing the maintenance state of each pavilion and the functions envisaged by the project and, firstly, updated on the basis of the ISTAT revaluation coefficients for construction costs.

The summary calculation of construction cost was performed by considering the main work categories that contribute to defining the project, and attributing to each of them an appropriate value, which includes the sum of the expenses to be incurred for the category of work considered.

Figure 5. Pavilions of the *Santa Maria della Pietà* monumental compendium to be transformed.

5.2. *Tor Bella Monaca*

The *Tor Bella Monaca* neighborhood extends in the eastern quadrant of the city of Rome. It was built since the 1970s as numerous economic and social housing plans have been settled. In the neighborhood, the total number of inhabitants is approximately equal to 27,947: in particular, the urban built-up area is characterized by 2,012,293 m^3 of total volume and 77.7 hectares.

Residential buildings are mostly publicly owned: 4004 housing units belong to the city of Rome and about 1500 to the "Aziende Territoriali per l'Edilizia Residenziale Pubblica" (ATER Roma).

By considering the large consistence of the neighborhood, social gathering places are lacking, and widespread degradation of public spaces and housing can be observed. Furthermore, the urban area is poorly connected by local public transportation (there are only few bus lines), whereas there are different schools. In Figure 6 the localization of the *Tor Bella Monaca* neighborhood and the main existing infrastructure is reported.

The buildings considered in the redevelopment project are bordered on one side by a middle traffic road (on the west side) and to the east by the *Agro Romano*. In addition to the physical transformation of the buildings, the initiative aims to social objectives aimed at improving the entire surrounding area through the desirable cultural and economic revitalization with the promotion of shared initiatives for local development and the encouragement of new job creation. To this end, the transformation initiative provides for different interventions related to the building rehabilitation, the seismic adaptation, the energy efficiency, the removal of architectural barriers, the enhancement and regeneration of public space and the creation of park areas.

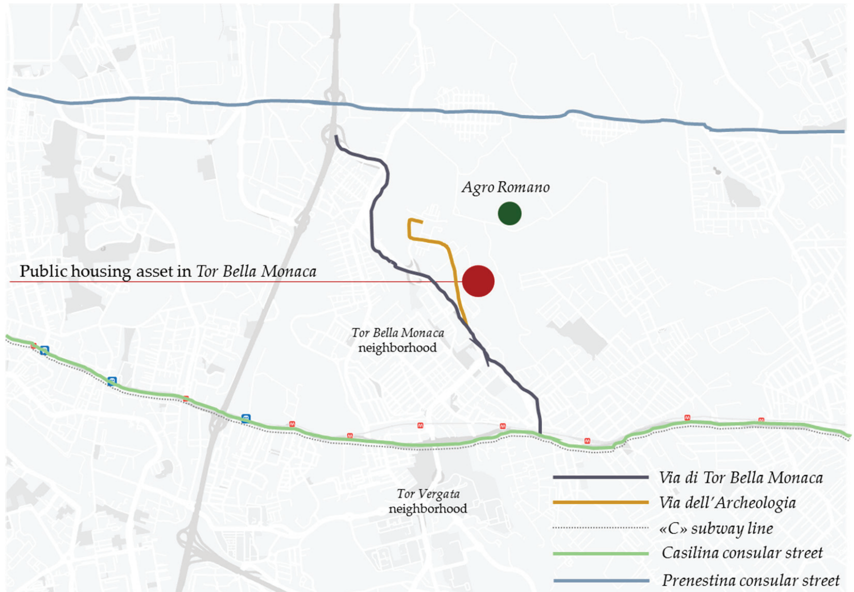

Figure 6. *Tor Bella Monaca* neighborhood and main road axes.

With reference to the buildings–named "North" and "South" in Figure 7 -, the most relevant interventions concern the first three levels: in particular, for the basement floor (Floor −1), the rehabilitation of the parking area with the expansion of covered parking spaces and the closure of internal crossing roads for safety reasons, are planned; for the ground and first floors (Floors 0 and 1) recovery operations aimed at diversifying the intended uses (currently only residential one is included) by introducing commercial activities and artist workshops are provided. For these two floors, a new organization of housing types and the insertion of collective spaces and services for the neighborhood are also defined. Finally, from the second floor to the seventh (Floors 2–7), "light" renovations are assumed, and they will concern the recovery of technological systems and on the envelope for energy efficiency (replacement of windows and doors and new envelope with insulation). In addition, the redevelopment of the courtyards of the buildings is also planned, with the inclusion of new functions such as a suburban museum and coworking spaces, as well as the complete renovation of green public spaces.

The construction costs for public residences, also established by the regional regulations No. 27/2006 [64] and implemented in the present analysis, can be attributed to three types of interventions. The first type is *primary recovery*, which tends to the renewal of the functionality and seismic safety of the building and concerns the common parts and includes the static consolidation of the load-bearing structures, by considering the foundations, the rehabilitation of masonry, stairs, roofs and the common parts of the installations and connections. The second type is *secondary recovery*, which tends to the habitability of individual dwellings rehabilitation and concerns a systematic set of works including functional reorganization, introduction of accessory elements, equipment and adaptation of facilities as well as restoration of the parts affected by the primary rehabilitation. The last type is *extraordinary maintenance*, as defined by Article 3(b) of the Italian DPR No. 380/2001 [65], which concerns the works and the modifications necessary to renovate and replace building parts, including structural parts, as well as to create and integrate the sanitation and technological systems, without varying the overall building volume and not involving significant urban changes in the intended use that would determine an increase in the urban planning load.

Figure 7. *Tor Bella Monaca* North and South Buildings.

Furthermore, the Regional Law No. 27/2006 indicates the parametric starting values, which have been appropriately updated and remodulated.

Therefore, the costs used for the three categories of intervention are as follows: EUR 580.28/m^2 for primary recovery, EUR 322.40/m^2 for secondary recovery, EUR 359.21/m^2 for extraordinary maintenance.

5.3. Application of the Optimization Algorithm

Borrowing the principles of the Operational Research, the proposed model has been applied in the analysis by implementing the simplex algorithm through the Linear Interactive Discrete Optimizer software (LINDO). For the case studies selected, the total budget provided by the Public Administration is EUR 82,538,000. By considering an incidence of the indirect costs (a_i) equal to 25%, the optimization algorithm defined in Table 1 has been applied. In this situation n = 2, whereas m = 103 (11 work categories for *Santa Maria della Pietà* monumental compendium and 92 for *Tor Bella Monaca* public housing compendium). It should be highlighted that in the model q_{ij} is the GFA for j-th work category of the i-th initiative. Therefore, the official costs are equal to ($k_{ij} \cdot q_{ij}$), with the unitary cost of each category of work estimated through institutional price lists and the optimal costs are assessed by applying the developed algorithm, equal to ($k_{ij}{}^* \cdot q_{ij}$), in which $k_{ij}{}^*$—which is the variable of the model—represents the unitary optimal cost for j-th work category of the i-th initiative.

Table S1 in Supplementary File reports, for each of the two initiatives, the intervention typologies, the GFA, the optimal costs estimated by the model and the official costs determined through appropriate price lists, the percentage differential (Δ) between the official costs and the optimal costs for each intervention, the total construction costs and the total initiative costs. As evidenced by Table S1, if the optimization model were not applied and the assessed costs (i.e., official costs) were considered, the preliminary set budget would not be respected: in fact, the total costs for the two initiatives would be equal to EUR 85,871,770, higher than the set budget for the two initiatives.

The implementation of the proposed model, on the other hand, allows one to verify the financial constraint imposed: in fact, the total costs of the two initiatives are equal to EUR 82,538,000. Furthermore, as it can be observed from the fifth column of Table S1, a very limited differential value between the official costs and the optimal costs for each category of work is ensured, with an average value equal to 4.7%: only for four work categories does the Δ reach up to 8%, whereas for 40 work categories it is lower than 4%.

In Table 2, the most relevant results are reported: in particular, for the two analyzed initiatives, the total construction costs, the indirect costs and the total initiative costs, calculated by consulting appropriate official price lists and through the implementation of the optimization algorithm, are shown in aggregate form. The disaggregation of the costs is specifically carried out in Table S1.

Table 2. Brief framework of the main findings obtained.

***Santa Maria della Pietà* Monumental Compendium**			
	Optimal Cost (EUR, €)	**Official Cost (EUR, €)**	**Δ (%)**
TOTAL CONSTRUCTION COSTS (EUR, €)	**26,318,869**	**26,994,980**	**−2.50**
INDIRECT COSTS (EUR, €)	**6,579,717**	**6,748,745**	**−2.50**
TOTAL INITIATIVE COSTS (EUR, €)	**32,898,586**	**33,743,725**	**−2.50**
***Tor Bella Monaca* public housing compendium**			
TOTAL INITIATIVE COSTS (EUR, €)	**39,711,474.68**	**41,702,435.73**	**−4.77**
INDIRECT COSTS (EUR, €)	**9,927,868.67**	**10,425,608.93**	**−4.77**
TOTAL INITIATIVE COSTS (EUR, €)	**49,639,343.35**	**52,128,044.66**	**−4.77**
TOTAL COSTS OF THE TWO INITIATIVES	**82,537,929.6**	**85,871,769.7**	**−3.88**

In order to test the proposed model potentialities, the first attempts in terms of modifications of work category costs, that could be carried out for compliance with the set budget are shown in Table 3 for *Santa Maria della Pietà* monumental compendium initiative. In Table 3, the monetary amounts in correspondence of the highest work category costs or for the largest quantity to be realized are changed to fit the preliminary expenditure limit. Regarding the situation in which the developed model had not been implemented, and the empirical procedure was applied, the decrease in construction costs would have determined a reduction in quality standard of the final project. Thus, the validity of the proposed model is represented by the design solutions optimization, for which a reduction in intervention costs does not correspond with a decline in the qualitative standards of the overall project. In this sense, the constraint of the simultaneous compliance with the budget and the fulfilment of the adequate quality standards of the final project is guaranteed.

It should be observed that for the compliance with the budget, the work category costs have to be reduced, up to 35% for the items characterized by the highest total costs, due to the largest GFA or to the highest unitary costs, by determining a reduction in quality standards of the final project.

Table 3. Costs obtained by implementing an empirical procedure for the intervention of *Santa Maria della Pietà* monumental compendium.

Pavilion (No.)	GFA (m^2)	Official Cost (EUR, €)	Empirical Cost (EUR, €)	Δ (%)
5	1688	2,236,146	2,000,000	−12%
6	1629	738,263	650,000	−14%
7	1350	2,744,754	2,400,000	−14%
16	2140	3,220,400	2,750,000	−17%
18	2370	3,733,540	3,150,000	−19%
23	1500	2,398,174	2,050,000	−17%
24	396	869,360	840,000	−3%
25	740	1,649,528	1,550,000	−6%
28	3790	4,873,469	3,610,000	−35%
31	1900	2,855,072	2,450,000	−17%
41	750	1,676,274	1,550,000	−8%
TOTAL CONSTRUCTION COSTS (EUR, €)		**26,994,980**	**23,000,000**	
INDIRECT COSTS (EUR, €)		**6,748,745**	**5,750,000**	
TOTAL INITIATIVE COSTS (EUR, €)		**33,743,725**	**28,750,000**	

Another possible and empirical solution to satisfy the defined constraints using a non-optimizing procedure, may involve the only one reduction in the work category highest construction costs, leaving unchanged the other items costs. However, this would determine an even more significant decrease in costs for this work category, i.e., a relevant decreasing of the qualitative level of this component of the project and, in general terms, of the entire initiative.

6. Conclusions

During recent years, several construction, promotion and development operations have contributed towards the definition and spread of process control systems capable of identifying the main variables that influence the success of a territorial initiative. In particular, feasibility analyses play a key role for the correct planning of cash flows and for a clear determination of project management techniques throughout the entire project life cycle [66,67].

The growing attention for methodological approaches able to virtuously relate the decision-making phase before the project [68], the construction one and the management step demonstrates the current cogency of integration among the different stages of the project in order to support the choices processes of Public Administrations and to effectively manage funding. In this sense, the compliance with the project budget constitutes a fundamental aspect to be taken into account in each life cycle cost assessment phase to prevent needless waste of financial resources, which are limited, and whose use is subtracted from alternative investment resources that could generate benefits for the communities. In this regard, effective project evaluations developed by expert and competent technicians associated with a valid system for monitoring the results obtained in the different steps of the project cycle ensure, as much as possible, the success of the initiative with respect to the realistic goals set. The assessments should neglect overly optimistic forecasts, and the project, consistent with the technical analysis, should be complete and clear and consistent with urban planning and legal requirements. Furthermore, a correct evaluation of the total costs of the project must explain the exposure to risk, identifying the main "critical" variables that could affect the conditions of intervention feasibility, both in the construction and management phases and, possibly, by identifying appropriate mitigation and control measures. The assessment of the project costs allows one to rationally direct the use of public resources and, in the case of Public Private Partnership procedures, including private procedures, to legitimize the choices and to make the decision-making processes transparent and reliable [69].

In the framework related to the selection of interventions to be financed through the NRRP funding, the need to develop valid assessment tools to support decision-making processes for optimizing the allocation of foreseen financial resources is relevant. In the present research a methodological approach based on an optimization algorithm that allows one to minimize the differential between the construction cost assessed by the expert technicians and the a priori budget of the project, has been defined. Starting from the organization of the entire initiative in categories of work, the methodology logic allows one to identify the compromise solution in terms of costs, able to ensure the compliance with the set project budget.

The proposed methodology has been implemented to two urban regeneration initiatives related to public housings (*Tor Bella Monaca*) and public community services (*Santa Maria della Pietà* monumental complex) located in the city of Rome (Italy). The application has highlighted the potential of the developed model, which is able to minimize the differential between the initial assessed costs and the final costs that effectively satisfy the budget constraint.

In order to appropriately manage and use the available financial resources, e.g., the funding allocated by NRRP for urban regeneration or, generally, the public funds aimed at the territorial development, the methodological approach could support the Public Administrations decision-making processes related to the selection phase of the projects most consistent with the planned goals, also according to the cost terms. On the other hand, the methodology could guide private investors in choices mechanisms, to verify the feasibility of the initiative, by considering the initial expenditure limit.

Thus, the developed model could be used in itinere for the costs assessment, in order to monitor the variation of the differential between the official costs and the optimal costs for each intervention, and to highlight the influence of the possible construction variants on the costs. In this sense, this practical implication of the model could allow one to manage any excessive cost increase that can occur during the executive phases, such as those that exceed the preliminary set budget.

Further insight provided by the present research concerns the implementation of the proposed methodological approach to several initiatives, in order to test its effectiveness in other contexts. In addition, the results obtained should be validated and updated through analytic cost assessments in correspondence of the following design steps, for which more detailed investigations must be carried out.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land11101812/s1. Table S1: Summary of the *Santa Maria della Pietà* monumental compendium and *Tor Bella Monaca* public housing compendium initiatives: identification of the GFA, of the optimal costs and the official costs, and the percentage differential (Δ) between the official costs and the optimal costs for each intervention.

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Article

Degentrification? Different Aspects of Gentrification before and after the COVID-19 Pandemic

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Abstract: The purpose of this study is to explore the aspects of "gentrification" and "degentrification" other than economic factors. To this end, this study focused on the gentrification situations occurring before and after the COVID-19 pandemic in the Itaewon area, South Korea, by using semantic network analysis. We analyzed news articles on the gentrification phenomenon in the Itaewon area reported in South Korea. As a result, gentrification in the Itaewon area is divided into four stages. The first stage of gentrification (2010~2014) is initial stage of gentrification. Gentrification stage 2 (2015~2017) is the period of commercialization as a gentrification growth stage. The first stage of degentrification (2018~2019) is the maturation period of gentrification. The second stage of degentrification (2019~30 June 2020) is the period of the COVID-19 pandemic. The results confirm the existing theoretical frameworks while building a more nuanced definition through operationalizing gentrification and degentrification. As with the etymology of the term, the degentrification phenomenon can only be revealed when the gentrification phenomenon is prominently displayed. This study has an implication in that it tried to phenomenologically examine the specific phenomenon of the next stage of gentrification through the term "degentrification".

Keywords: gentrification; degentrification; COVID-19; Itaewon; Seoul; semantic network analysis

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1. Introduction

1.1. Background and Objective

Over the last few decades, the issue of "gentrification" has spread to many academic disciplines. Gentrification is a term originally proposed by Glass [1] which usually is used to describe the processes and spatial changes in many metropolitan cities, with the suburbanization reversing around the old city center, the return of the middle class to the city center, and the push of the working class and the common people [2–4]. In other words, gentrification was defined as the process of social, economic, cultural, physical, and demographic transformation of a neighborhood with the influx of capital [5].

As this theory has been around for a long time in the academic field, there also have been proclamations about the demise or death of gentrification since at least the early 1990s. In Western countries, it has led to the deidealization of gentrification over time, which is also defined a "super gentrification", "rural gentrification" and "commercial led gentrification", "cultural led gentrification", and "tourism gentrification" [6,7]. This suggests that gentrification is a complex intertwined problem of macroscopic perspectives, based on a micro approach to behavior among relevant stakeholders and social, economic, and spatial restructuring.

In relation to gentrification, the following five harmful phenomena are mainly explained: residential relocation; exclusion; transformation of public, social, and commercial spaces; polarization; and homogenization [8]. Gentrification is mainly used in a negative sense both semantically and analytically. In this context, how should the opposite phenomenon of gentrification appear and be explained?

The purpose of this study is to explore the aspects of "gentrification" and "degentrification" beyond the economic factors. To this end, this study focused on the gentrification situations occurring before and after COVID-19 pandemic in Itaewon area, South Korea. The world is embroiled in the COVID-19 pandemic with unprecedented uncertainty. The climate change emergency lurks right behind and has great potential to further disrupt the travel and tourism industry or spawn new forms of privileged transnational travel and mobility. Restrictions on travel mean that many of the gentrification processes in this special issue have been suspended or are questionable [9–11].

The Itaewon area was formed by various political, economic, and cultural contexts of Korean society. Especially, Itaewon has a parallel with the process of town-centered development of Seoul city government after the 1960s, and it has established the identity as the consumption space by neoliberalism formally introduced after the 2000s. Moreover, based on the historical practice called the "US military government", Itaewon obtains its own unique placeness as a foreigner's place and a place combined with various cultures. In particular, during the COVID-19 pandemic, there was a time when the number of confirmed cases was concentrated mainly on visitors to the LGBTQ (lesbian, gay, bisexual, transgender, queer or questioning) club located in Itaewon area. This has also caused a misconception about LGBTQ people, and in addition, the number of visitors has decreased rapidly compared to other areas due to the COVID-19. By examining the several phenomena related to gentrification and degentrification before and after COVID-19 in Itaewon area, we would like to take a brief look at how the COVID-19 pandemic, which is a completely different aspect from the past pandemics and financial crisis, has affected gentrification.

To examine phases and aspects of how gentrification affects the Itaewon area, this study focused on "semantic network analysis" that applied big data and social network analysis. This provides a useful perspective for explaining micro behavior and macrosocial structures by examining the behavior of individual actors in the context of the macroscopic structure constructed through the connections and interactions between the micro behaviors. Through analysis of big data, this study has an implication in comprehensively examining the macro and micro aspects of rise and demise of the gentrification phenomenon. By doing so, we delineate how the gentrification and degentrification phenomenon was broadly reflected in the landscape of South Korea, how it is being developed, and what the differences between each stage are. By entering into critical debates on gentrification, we expect to present implications for the conceptual definition of "degentrification".

1.2. Historical and Geographical Landscape of Itaewon

The Itaewon area was formed by different authorities and is organized as an urban space by the effect of the United States, government, and capital, while the media plays a role in producing governmental ideology, interpellating minorities as others and excluding them. The discourses on the urban space tend to mask the problems of the urban space for the reproduction of capital [12,13].

The area's commercialization has been accelerated by speculative real estate agents, who are hunting for empty spots and reselling them at higher premiums to tentative leaseholders who anticipate the commercial success of the new business operations. Cultural entrepreneurs, who have imbued cultural aspirations into Itaewon, now face pressure from speculative investments. In the three neighborhoods examined above, rents for commercial properties have spiked rapidly in recent months [14,15]. The beginning of speculative real estate is heralded not only by the increase in rents but also by the creation of premiums, which did not exist before. As the burgeoning commercial facilities penetrated into these neighborhoods, the engagement of speculative real estate agents has instigated landlords to increase rents or to create premiums [13,16].

The urban cultural regeneration models detailed above do not explain Itaewon's experience. As a "disgraceful" place within national territory, cultural regeneration models of beautification of sites with an emphasis on historical legitimacy and nationalistic sentiment cannot be applied to Itaewon [12,14]. It was once designated as a cultural district to boost international tourism during the 1980s and 1990s, as Korea hosted international events such as the 1988 Seoul Olympics and the 2002 Korea–Japan World Cup [14,17]. However, the effects on urban regeneration were limited due to the lack of supporting programs. In addition, with the rise of other shopping districts and tourist sites, Itaewon lost its competitiveness to other tourist districts.

Since 2010, groups of younger artists have started settling in Itaewon, not as implanted artists but as residents and entrepreneurs. These groups have appeared as important cultural producers for mediating spatial and economic regeneration in Itaewon. There are two important pull factors that attract younger artists and entrepreneurs to Itaewon. First, cheap rents have provided them with affordable spaces for their shops and workshops. Next, urban authenticity, in terms of the neighborhood's gritty character resulting from deferred urban redevelopment, as well as the area's cultural diversity, has attracted them. In Itaewon, three different locations have been transformed into culturally vibrant neighborhoods around the same time by groups of cultural entrepreneurs (see Figure 1).

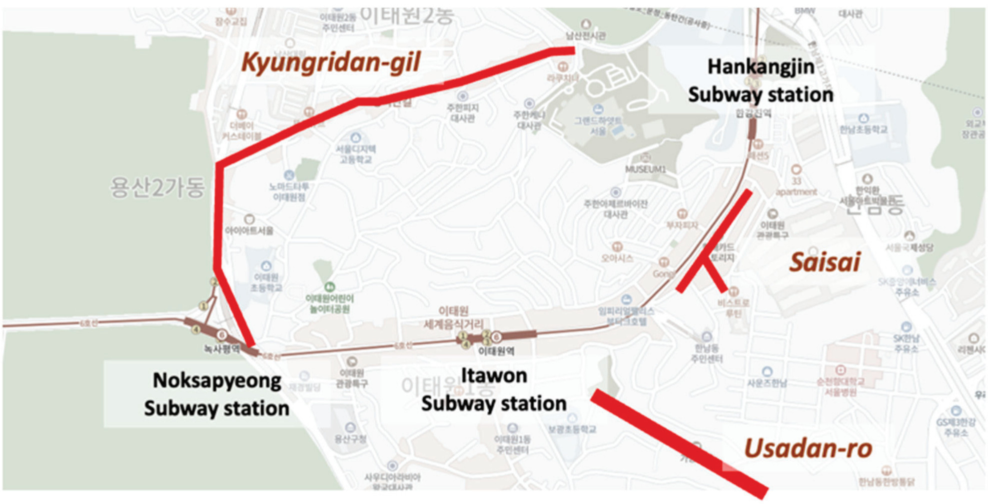

Figure 1. Map of Itaewon.

Given the fact that each group named its place by reflecting locational features such as road name and address, the locations in which the groups resided implicate historical connections between places and characters of cultural entrepreneurs: Kyungridan-gil in the proximity to military facilities and middle-class residential area has small restaurants and cafes; the nearby upper-middle-class residential area comprises high-end and stylish clothes shops managed mainly by professional designers; and Usadan-ro, where a central mosque is located and many Muslim migrant workers and lower classes reside, has many artists and cultural entrepreneurs pursuing hippies' loose lifestyle and dissident cultures. Beyond locational differences, however, there are common socioeconomic structural backdrops behind those young cultural entrepreneurs' activities, the reasons as to why they entered Itaewon, and the similar consequences they face as a result of their newfound popularity.

Since 2017, reports have started appearing that retail businesses in Itaewon are struggling with soaring rents and the economic downturn [18,19]. The situation in the Itaewon area has changed more radically after the COVID-19 pandemic. In South Korea, after the first patient was discovered on 20 January 2020, the social crisis of the first epidemic prevailed between February and April due to the group infection of the Shincheonji Church. On 11 May, there were 79 cases linked with the clubs in Itaewon. Seoul's LGBTQ community feared an antigay backlash as several media outlets identified at least one of the bars as a gay bar. Social media users have been tracking and threatening to stop "immoral activity" in some clubs [20].

2. Factors of Gentrification and Degentrification

The gentrification phenomenon has been appearing in completely different forms and phenomena by various actors in different urban living environments [21]. Since today's gentrification has a wide variety of content and spatial scope, it is necessary to consider complexity and chaos rather than looking at it from a fragmentary perspective. Therefore, it must be emphasized again that it is very difficult to explain the gentrification phenomenon in a concise and simplified way [22,23].

There are several explanations among scholars as to what triggers gentrification. The first factor is demographic change. Because this is by migration, it is important to distinguish between voluntary and involuntary migration to a place of residence [24]. This means that the lower the income level [21,25–30], the more involuntary migration occurs, and involuntary migration is inevitable depending on race [23,26,28,29] and social class [25,31–33]. In addition, changes in education [23,26,28,29,33,34], occupation [2,29,34–38], period of residence [25,34,38], household composition [25,26,34,35,37,39], population density [21,37,39–42], number of residents, number of households, and average family size can be seen as major factors affecting population change [43]. The essence of residential decentralization is a phenomenon that arises from the desire of urban residents to find a homogeneous group in various aspects within a heterogeneous urban society. Accordingly, the high-income class wants to move back to a specific area of the city center in consideration of the improvement of the city's physical environment, fame, and investment value. In this way, the distribution of housing among the classes occurs because the access to the housing market differs according to socio-economic status [24,44]. Furthermore, Marcuse [41] classified displacement in the phenomenon of gentrification into involuntary displacement of direct residence, chain displacement, exclusive displacement, and migration pressure.

Second, deindustrialization and changes in industrial structure are also factors. When the industrial structure of a specific region changes to a cultural center [45–48], the working class, such as manufacturing, shifts to culture and services, finance, and office work, and enters the middle class, and as cultural and leisure activities increase, their housing demand begins to appear [49–51]. Zukin [30] and Bridge and Dowling [52] argue that the change and ripple effect of gentrification is the reallocation of space according to the unique personality of the floating population and the advanced consumption preferences of the middle class. The shift from manufacturing to service industry leads to changes in the industrial structure of cities [47,48] and eventually leads to postindustrial cities, where spatial structural changes due to industrial structural changes are transformed to suit the preferences of the middle and upper classes and their consumption patterns [27,42,53].

The third factor is changes in housing selection priority. Newman and Wyly (2006) [37] found that rent and residential environment affect migration due to gentrification. In addition, house ownership, industrial location and residential area [53], self-ownership rate and rent rate [43], the rate of change in the official land price [43,53], and the sale price and area [24] are housing factors that are closely related to the rent gap. The rent gap [54,55] is a theory that has contributed to the explanation of traditional gentrification, which is the gap between the level of potential land rent and the actual land rent capitalized in current land uses. Tullock [56,57] argued that as the economy turned into a monopoly due to rent-seeking behavior, potential profits were generated and unproductive methods such as looting and lobbying were mobilized to sustain them. Smith [58] also argued that the government should intervene in the market to form an appropriate price for the land market, but the rent-seeking actors involved (from landlords to urban planners, bankers, and real estate investors) are the ones that cause the rent gap.

Lastly, changes in policy are also main factors. Newman and Wyly [37] pointed out that local government support and housing policies affect migration due to gentrification, and Kim [43] found that gentrification is formed according to changes in the housing supply rate, local tax revenue, and financial independence [24,59]. These policies are implemented under the tacit belief that economic activities and high-income classes can be clustered in the downtown area by promoting redevelopment in the downtown area, thereby realizing long-term agglomeration benefits [60]. Lee [61] argued that gentrification would not be able to bring about rapid changes in speed and scale without the intervention of the government. Shaw and Hagemans [62] questioned whether gentrification, which is ultimately the adjustment of capital and class, can lead to actual social mixing by inducing gentrification policies to promote redevelopment or urban regeneration. Social mix is rooted in the region's historical geography and is difficult to understand as the main concept of a form of redevelopment disguised as gentrification. In this respect, Bridge et al. [63] viewed gentrification as a problem of class and space and emphasized social ethics. Therefore, it can be seen that the gentrification policy must ultimately be linked to social mixing.

Summarizing the above discussion, it can be seen that the factors that form gentrification are diverse and intricately intertwined. In this respect, many scholars believe that a complete explanation of gentrification is impossible, that these factors are a part of gentrification, and that gentrification can be defined as factors such as production and consumption, supply and demand, economy and culture, and structure and subject.

On the other hand, studies on the factors and phenomena of degentrification are remarkably lacking. Smith [58] pointed out the processes of gentrification in the late 1980s and early 1990s as "a ruthless shakeout of small landlords, developers, marginal real estate agencies, and other gentrification-related businesses between 1989 and 1993" came to be characterized as "degentrification". In the 2008 global financial crisis, there were predictions of degentrification in North America and Europe, but as Hochstenbach and Mustered [64] argue, the crisis impacted gentrification processes but did not lead to degentrification. In 2020 with the COVID-19 pandemic, the media outlets began proclaiming the occurrence of the "degentrification" phenomenon in several cities such as New York City and London [65].

Most of the literature dealing with the phenomenon of "degentrification" regards the standard scale as an economic phenomenon. "Degentrification" has been accepted as the fact that after the inflow of capital reaches its peak due to the gentrification phenomenon in a certain area, facing various economic situations, the rent in that area falls again. However, since the process of gentrification itself has been based on many factors such as economic and cultural phenomena, "degentrification" cannot be also regarded as a simple economic phenomenon which is the opposite of one of the many factors of gentrification. The question is becoming: how can we define and explain the "degentrification" phenomenon? Is this only embracing the meaning of the death of gentrification?

3. Methods

3.1. Data Selection

In this study, data selection and text mining were performed using the Textom program to generate text frequency calculation and semantic network analysis matrix. Textom is a big data analysis solution using text mining technology that collects and refines data in the web environment and can even process matrix data generation. It supports data collection, purification, and analysis in various languages such as Korean, Chinese, and English. Textom provides 1-way and 2-way purification/analysis methods that can process not only collected data but also retained data. Analysis results can be applied to various statistical analysis programs such as SPSS, UCINet, NodeXL, NetMiner, Pajek, and Gephi. Textom is a program developed by a Korean-based company and is useful and meticulous for analyzing Korean-language articles and big data. Therefore, Textom has been used for big data-based trend analysis when Korean is used as the main keyword in various fields [66–69]. Using text frequency lists, Textom identifies keywords in the text, selects the necessary words, and generates a matrix. It follows the social network view that special meanings will occur when keywords are combined into specific behaviors and identifies the frequency with which keywords occur at the same time [70]. In addition, Textom can delete data that are not related to the research subject from the collected data and refine words that combine words that have been used but have the same meaning.

We analyzed news articles on the gentrification phenomenon in the Itaewon area reported in South Korea. The mass media, including newspapers, play an important role by reflecting the way the public perceives public issues, which in turn leads to an understanding of the population's issues [71,72]. The unit of analysis is an individual news article. Random sampling was used to select articles that refer to the gentrification in relation to the Itaewon area by titles and texts. The data analysis period was limited to eight years from 1 January 2010 to 30 June 2021, to examine recent aspects of the region of Itaewon. The year 2010 is when the issue of gentrification began in earnest, starting with Kyungridan-gil in the Itaewon area. Kyungridan-gil was the place where chefs who had been studying and working abroad in search of a relatively cheap rent compared to the main commercial area of Itaewon since around 2010 started their restaurant. Along with this, several popular celebrities opened restaurants here; Kyungridan-gil became the hottest place on social media [73,74]. The search terms were "Itaewon", "gentrification", and their derivatives. As a result, we retrieved a total of 1324 news articles. The exclusion criteria were articles not directly related to spaces and articles that overlapped with other articles. Finally, a total of 510 articles were included in the analysis.

After the data collected through the Textom package were firstly subjected to hypotheses in the system, they were repeatedly purified by the researchers using MS-EXCEL. The refinement criteria were first deleted when there was an unnecessarily long postposition or modifier. Second, keywords with similar concepts such as "measures", "alternatives", and "plans" were integrated into one word and refined. Third, keywords that can be used as a single word in terms of content, such as "contract renewal application", were used without spaces, and finally, unnecessary symbols and special characters were deleted for core keyword analysis.

3.2. Semantic Network Analysis

Semantic network analysis enables structural analysis of how words are used and placed on specific topics [67]. It is advantageous to extract formalized information from unstructured data to visualize the semantics and patterns of the communication process.

Based on the final data, keyword frequency was extracted by using Textom, and term frequency (TF)–inverse document frequency (IDF) and degree centrality were analyzed together. Degree centrality is linkage centrality, which is a statistical figure that examines key keywords by identifying how many keywords (nodes) are associated with other keywords (nodes). TF-IDF is a product of TF multiplied by IDF, which is a statistical value that weights how important a keyword (node) is in a particular document [75]. $TF_{i,j}$ is the value obtained by dividing the number of times keyword t_i appears in article d_j by the number of times occupied by all keywords. IDF_i is the total number of articles divided by the number of articles with keyword t_i, and $TFIDF_{i,j}$ is the product of $TF_{i,j}$ and IDF_i. This is formulated as follows:

$$TF_{ij} = \frac{n_{i,j}}{\sum_k n_{k,j}}$$

$\sum_k n_{k,j}$: number of times all keywords appeared in article d_j.
$n_{i,j}$: number of times keyword t_i appeared in article d_j.

$$IDF_i = log\frac{|D|}{|d_j : t_i \in d_j|}$$

$|d_j : t_i \in d_j|$: number of articles in which t_i is suggested.
$|D|$: total number of articles.

$$TFIDF_{i,j} = TF_{i,j} \times IDF_i$$

3.3. Phases of Gentrification and Degentrification

In this study, related articles on gentrification and degentrification were collected annually from 2010 to June 2021, and the process of reviewing the contents presented as key keywords was repeated. Through this process, each year was divided into years in which similar key keywords were presented, and the four-stage formation period was set as shown in Table 1.

Table 1. Phases of gentrification and degentrification aspects of Itaewon area.

	Gentrification		**Degentrification**	
	Phase 1 (2010~2014)	**Phase 2 (2015~2017)**	**Phase 1 (2018~2019)**	**Phase 2 (2020~2021 June 30)**
Articles	30	257	182	42

4. Results

4.1. Gentrification

4.1.1. Gentrification Stage 1 (2010~2014)

Itaewon's first stage of gentrification is from 2010 to 2014. Itaewon has long been known as the most exotic space in Seoul [76]. The change of place in the Itaewon area has accelerated since 2010 and has rapidly expanded not only along the roadside but also along the local alleys. Usadan-ro, Hoenamu-ro, and Kyungridan-gil in Itaewon-dong became popular among young people in their 20s and 30s, and the scenery of the alleyways changed rapidly. While Itaewon's 1 and 2 dongs are the center of restaurants serving a variety of cuisines from around the world, the Hannam-dong area is characterized by high-end commercialization [77].

During this period, a total of 30 articles related to Itaewon gentrification were searched. The most mentioned keywords were Cities (106), followed by Space (81), People (68), Cafe (64), Market (53), Kyungridan-gil (45), Restaurant (43 times), Life (39 times), House (38 times), Culture (37 times), Project/Society (34 times), Usadan village (30 times), and Merchant/World/Gentrification (27 times). The others were listed in the order of Progress, Rearrangement, Exploitation, Street, Itaewon-ro, Redevelopment, and Merchants Association (Table 2).

In addition, the major weighted keywords of TFIDF show that Cities (159.49979) had the highest weight, followed by Space (151.32899), Market (130.62735), Cafe (120.86908), People (116.0029), etc.

Figure 2 visualizes the semantic network between key keywords for the first phase of gentrification. First, the key keywords with the highest connection-centricity were Cities (0.04976), Spaces (0.03723), People (0.03520), and Cafe (0.03148). The keywords with the lowest connection density and the outermost network were Workshop (0.00947), Deterioration (0.01015), Program/Merchants Association (0.01049), and Refurbishment/ Redevelopment/Neighborhood (0.01083). Keywords that act as mediators were Art (0.02335), Artist (0.02301), and Culture/Project (0.01726).

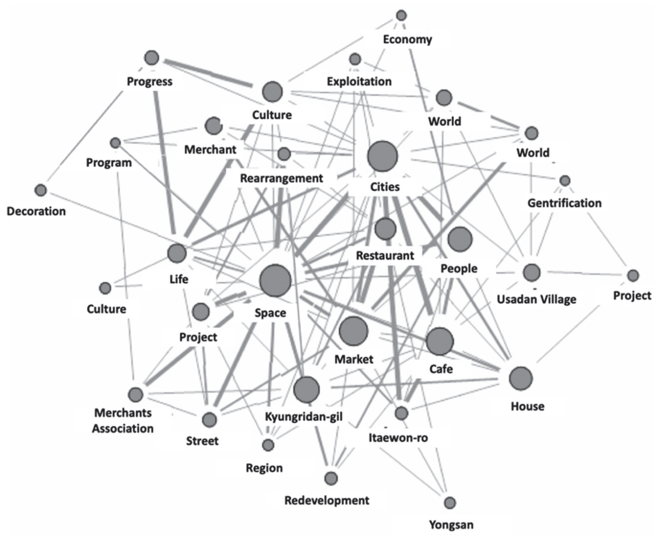

Figure 2. Gentrification stage 1: semantic network between core keywords.

Table 2. Keyword frequency, TF-IDF, and connection centrality for gentrification phase 1.

Keyword	Frequency	TF-IDF	Degree Centrality
Cities	106	159.49979	0.0574
Space	81	151.32899	0.04487
People	68	116.0029	0.04284
Cafe	64	120.86908	0.03912
Market	53	130.62735	0.0337
Kyungridan-gil	45	111.09374	0.02625
Restaurant	41	99.19598	0.03065
Life	39	95.0371	0.02761
House	38	105.69581	0.02761
Culture	37	88.79877	0.0249
Project	34	82.56045	0.0249
Society	34	82.56045	0.02795
Usadan village	30	89.29343	0.02185
Merchant	27	85.6054	0.02151
World	27	76.92106	0.02287
Gentrification	27	74.25238	0.02355
Progress	25	75.75643	0.02151
Rearrangement	24	71.33878	0.01847
Exploitation	23	70.47831	0.02185
Street	23	68.77383	0.01982
Itaewon-ro	22	72.11069	0.01779
Redevelopment	21	69.3571	0.01813
Merchants Association	20	65.2002	0.01881

4.1.2. Gentrification Stage 2 (2015~2017)

The second phase of gentrification is from 2015 to 2016. The change of place in Itaewon began to be explained as a gentrification phenomenon around 2015, and the mass media rushed to pour out negative reports about gentrification [78]. The gist of the report is that the gentrifier, the party who brought change to the alleyways in the Itaewon area, is rather expelled from the space created by him because of the market logic [79,80].

During this period, a total of 257 articles related to Itaewon gentrification were presented. The most mentioned keyword was Gentrification (714 times), followed by Kyungridan-gil (579 times), Rent (572 times), Legal System (380 times), Region (361 times), People (338 times), Landlords (325 times), Resident (289 times), Cities (245 times), Tenant (214 times), Shop (197 times), Building (181 times), Solution (159 times), Restaurant (146 times), Business District (124 times), House (105 times), Space (99 times), Village Community (95 times), Merchant (85 times), Business (84 times), Development (74 times), Neighborhood (72 times), Artist (59 times), Cafe (47 times), Usadan-ro (46 times), Itaewon-ro (43 times), and Tourists (36 times). Other keywords were mentioned less than 10 times, including Impression, Real Estate, Alley, and Capital (Table 3).

In addition, when looking at the key keywords with high weight of TFIDF, Legal System (2191.35427) was the highest. The next highest were Kyungridan-gil (1337.84999), Rent (1328.14593), Gentrification (1320.42446), Region (1162.13754), People (1047.74408), Cities (941.40322), Shops (875.55199), Tenants (873.28925), etc.

This stage can be said to be the stage leading to commercialization as Gyeongridan-gil became famous and the influx of floating population and tourists was frequent. As the rent rises and the residents move to another place, it is crowded during the day, but at night it becomes an unpopular neighborhood, and the vitality of the city slowly disappears. Therefore, in the third stage, it can be seen that the keywords "Legal System", "Kyungridan-gil", and "Rent" are significant.

Figure 3 visualizes the semantic network between key keywords for the second phase of gentrification. First, the core keywords with the highest connection-centricity were gentrification (0.06004), Kyungridan-gil (0.05837), Region (0.04426), Rent (0.04283), People (0.04153), Landlords (0.03119), and Residents (0.02847). The keywords with the lowest connection density and the outermost network were Impression (0.00897), Alley (0.01306), Usadan-ro (0.01349), Itaewon-ro (0.01355), Real Estate (0.01442), Merchant (0.01541), Legal System (0.01652), Artist (0.01708), Cafes (0.01733), Tourists (0.01745), and Business District (0.01900). Keywords that act as mediators between the center and the edge of the network were Solution (0.02321), Buildings (0.02389), and Tenants (0.02500).

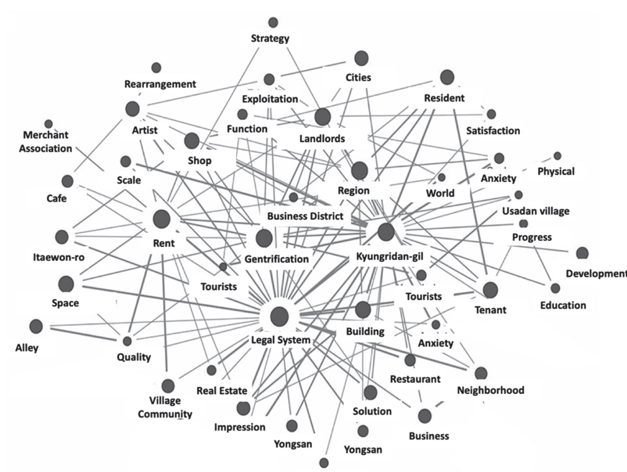

Figure 3. Gentrification stage 2: semantic network between core keywords.

Table 3. Keyword frequency, TF-IDF, and connection centrality for gentrification phase 2.

Keyword	Frequency	TF-IDF	Degree Centrality
Gentrification	714	1320.42446	0.06768
Kyungridan-gil	579	1337.84999	0.06601
Rent	572	1328.14593	0.05047
Legal System	380	2191.35427	0.02416
Region	361	1162.13754	0.0519
People	338	1057.52408	0.04917
Landlords	325	1015.81554	0.03883
Resident	289	848.32343	0.03611
Cities	245	941.40322	0.03549
Tenant	214	873.28925	0.03264
Shop	197	875.55199	0.03382
Building	181	800.78084	0.03153
Solution	159	752.4419	0.03085
Restaurant	146	789.09596	0.03128
Business District	124	736.34226	0.02664
House	105	715.49348	0.03153
Space	99	700.58404	0.03079
Village Community	95	732.8817	0.02806
Merchant	85	686.92663	0.02305
Business	84	663.31044	0.02856
Development	74	638.46138	0.02961
Neighborhood	72	672.18338	0.02751
Artist	59	637.87564	0.02472
Cafe	47	621.79934	0.02497
Usadan-ro	46	647.253	0.02113
Itaewon-ro	43	618.92086	0.02119
Tourists	36	590.58873	0.02509
Impression	9	551.39004	0.01661
Real Estate	8	553.16989	0.02206
Alley	6	609.35231	0.0207

4.2. Degentrification

4.2.1. Degentrification Stage 1 (2018–2019)

The first phase of degentrification in the Itaewon area is from 2018 to 2019. This period is also the maturity stage of gentrification, and conflicts between stakeholders are prominent due to the increase in rent. Accordingly, key keywords such as Win–Win Agreements, Commercial Rental Protection Law, and Ordinances appear in this period [80]. In 2018, Itaewon was the only place in Seoul with a vacancy rate of 30% or higher for small shopping districts. This is mostly because the U.S. Forces Korea and the United Nations Command relocated from Yongsan in 2018. The excessive increase in rents of building owners accelerated gentrification and reduced vitality.

A total of 181 articles related to Itaewon gentrification were published during this period. The most mentioned keyword is overwhelmingly Gentrification (674 times), followed by Rent (541 times), Policy System (272 times), Urban Regeneration (187 times), Conservation (184 times), Region (167 times), Mall Building (111 times), Win–Win Agreement (101 times), Landlords (100 times), Tenants (95 times), Seoul (86 times), Residents (75 times), Self-Employed (71 times), Business District (69 times), Increase (68 times), Solutions (53 times), Development (52 times), Merchant (49 times), Cites (47 times), Kyungridan-gil (46 times), Space (45 times), Shopping Mall Lease Protection Law (44 times), Citizen (43 times), Restaurant (42 times), Contract Request for Renewal (39 times). Other keywords, such as Ordinance, Franchise, Government, Periphery, Prevention, are referred to at a frequency of 20 times or less (Table 4).

Table 4. Keyword frequency, TF-IDF, connection centrality for degentrification phase 1.

Keyword	Frequency	TF-IDF	Degree Centrality
Gentrification	674	729.16495	0.11275
Rent	541	714.71068	0.06702
Policy System	272	1571.44059	0.03173
Urban Regeneration	187	1022.1241	0.04366
Conservation	184	915.89354	0.03124
Region	167	766.69672	0.04679
Mall Building	111	798.40457	0.04391
Win–Win Agreement	101	869.82454	0.03741
Landlord	100	761.3875	0.04251
Tenants	95	769.48601	0.03354
Seoul	86	753.36017	0.04448
Residents	75	697.81563	0.03774
Self-Employed	71	688.85683	0.0407
Business District	69	725.87493	0.03667
Increase	68	631.52053	0.02524
Solutions	53	595.49895	0.03231
Development	52	616.97693	0.03535
Merchant	49	587.86474	0.02754
Cites	47	668.28026	0.03486
Kyungridan-gil	46	650.88591	0.0277
Space	45	628.52175	0.03116
Shopping Mall Lease Protection Law	44	555.49266	0.02318
Citizen	43	543.97974	0.03108
Restaurant	42	534.91906	0.02787
Contract Request for Renewal	39	558.70392	0.02047
Ordinance	14	529.67429	0.02195
Franchise	9	505.59233	0.02326
Government	8	445.82139	0.02466
Periphery	7	445.77608	0.02376
Prevention	6	410.91671	0.02063

In addition, when looking at the key keywords with high weight of TFIDF, Policy System (1571.44059) was the highest, followed by Urban Regeneration (1022.1241), Conservation (906.11354), Win–Win Agreement (869.82454), Mall Building (798.40457), Tenant (769.48601), Landlord (761.3875), and Seoul (753.36017).

South Korea has been promoting urban regeneration policies as part of urban renewal and revitalization of alleyways, which also affects the Itaewon area. Accordingly, if gentrification in the extension of urban regeneration proceeds, the area will become livelier, the average income of the residents will increase, and the residents' sense of belonging and self-esteem for the area may increase. However, the question is whether the participation of local residents, the main body of urban regeneration, is actually taking place, and the land price rises excessively due to the influx of the middle class, tourists, and the participation of large external capital, which inevitably destroys the existing local ecosystem. The above proves that "Policy System", "Urban Regeneration", and "Preservation" were derived as keywords with high weight in TFIDF during this period.

Figure 4 shows the semantic network between key keywords related to the third stage of gentrification. The core keywords with the highest connection-centeredness were Gentrification (0.10511), Rent (0.05938), Region (0.03915), Seoul (0.03684), Mall Building (0.03627), Urban Regeneration (0.03602), and Landlords (0.03487). The keywords with the lowest connection density and the outermost network were Contract Renewal Application (0.01283), Prevention (0.01299), Ordinance (0.01431), Mall Lease Protection Law (0.01554), Franchise (0.01562), and Periphery (0.01612). The keywords that act as mediators between the center and the edge of the network were Business District (0.02903), Win–Win Agreements (0.02977), Development (0.02771), and Solution (0.02467).

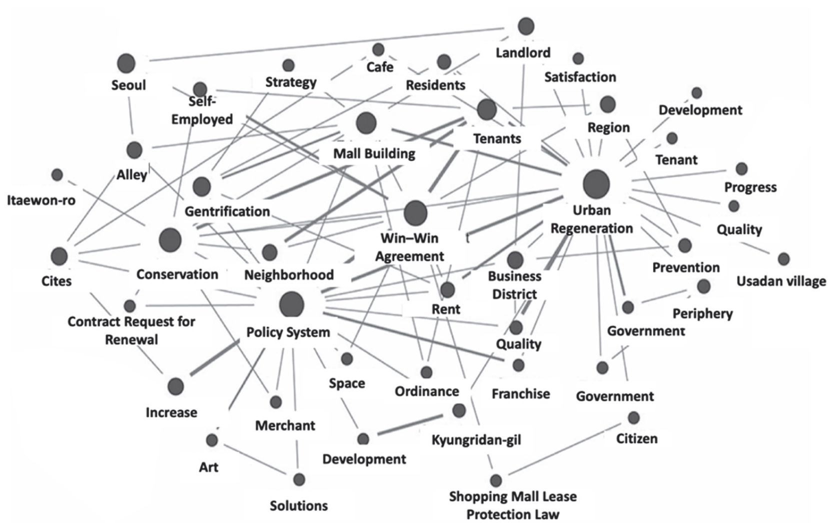

Figure 4. Degentrification stage 1: semantic network between core keywords.

4.2.2. Degentrification Stage 2 (2020~30 June 2021)

In the Itaewon commercial district, vacancy increased due to a rise in rent (gentrification). In 2018, the U.S. military base in Yongsan faced a crisis, and in 2020, it faced the worst situation with COVID-19. Entering this period, small business owners and self-employed people demanded diversified and fundamental measures such as tax and rental benefits for them, saying that the difficulties caused by the government measures so far have been aggravating and the economic damage is huge [81].

A total of 42 articles during this period were searched. The most mentioned keyword was Gentrification (272 times), followed by Merchants (218 times), Rent (203 times), COVID-19 (154 times), Vacant (139 times), Young People (119 times), Demise (112 times), Confirmed Case (103 times), Club (99 times), Policy System (48 times), Kyungridan-gil (35 times), Alley (28 times), Yongsan (24 times), and Real Estate (20 times). Other keywords, namely

LGBTQ, Real Estate, Gallery, Entrance, Substitution, and Situation, were mentioned fewer than 10 times (Table 5).

Table 5. Keyword frequency, TF-IDF, connection centrality for degentrification phase 2.

Keyword	Frequency	TF-IDF	Degree Centrality
Gentrification	272	120.82718	0.20406
Merchants	218	140.09776	0.09692
Rent	203	142.56889	0.06121
COVID-19	154	259.48406	0.06121
Vacant	139	195.43662	0.03442
Young People	119	59.71147	0.04781
Demise	112	107.82718	0.03889
Confirmed Case	103	93.01781	0.03889
Club	99	81.94703	0.03442
Policy System	48	183.99034	0.03442
Kyungridan-gil	35	169.57873	0.03442
Alley	28	157.21789	0.03889
Yongsan	24	78.91408	0.02996
Real Estate	20	150.16922	0.03889
LGBTQ	8	49.21775	0.02549
Gallery	7	38.15527	0.02103
Entrance	7	35.21872	0.03442
Substitution	5	29.09983	0.03442
Situation	4	25.11274	0.03442

Looking at the key keywords with high weight of TFIDF, COVID-19 (259.48406) showed the highest weight, followed by Vacant (185.65662), Policy System (174.21034), Kyungridan-gil (169.67873), Alley (157.21789), Real Estate (150.16922), Rent (142.56889), Merchants (140.09776), Gentrification (120.82718), Demise (107.82718), Confirmed Case (93.01781), Club (81.94703), and Yongsan (78.91408). Unlike the keyword frequency, it can be seen that the keywords for "COVID-19" and "Vacant" are the most important.

Figure 5 shows the semantic network between key keywords for the fourth stage of gentrification. First, the key keywords with the highest connection-centeredness were Gentrification (0.19642) and Merchants (0.08928). The keywords with the lowest connection density and the outermost of the network are Club/Policy System/Kyungridan-gil (0.01339) and LGBTQ (0.01785). Keywords that play a mediating role between the center and the edge of the network were Rent/COVID-19 (0.05357) and Demise/Confirmed Case/Alley/Real Estate (0.03125).

In this period, merchants complained that gentrification was the root cause of the real threat to the alley economy before COVID-19. Most of the self-employed are still suffering from gentrification and being hit directly by the COVID-19, but still cannot afford the high rent. In fact, a survey found that the most difficult thing for small business owners is rent. According to the results of a survey conducted by the Federation of Small Businesses on the management situation of small business owners after the COVID-19 crisis, 69.9% of the respondents chose "rent" as "the most burdensome of business expenses" [81].

Figure 5. Degentrification stage 2: semantic network between core keywords.

5. Discussion

In this study, the gentrification phase of Itaewon was analyzed by dividing it into a gentrification phase and a degentrification phase. It can be seen that there is a significant correlation between the frequency of media and SNS exposure as a sign of commercialization, popularity, and attractiveness of a region as a sign of gentrification. Based on the analysis, an empirical analysis of the Itaewon area was reviewed to summarize the list of phenomena and corresponding indicators found in the process of commercial gentrification and degentrification (Table 6).

Based on the above analysis results, the characteristics of degentrification are summarized as follows: First of all, the COVID-19 pandemic is likely to be the most important cause of degentrification, which is ultimately the root cause of the rent increase during the previous maturity of gentrification. After all, it is said that degentrification due to the COVID-19 pandemic is possible only in areas where there has been a phenomenon of maximization of gentrification. The pandemic situation would accelerate degentrification, but there is a limit to addressing the economic recession caused by the COVID-19 pandemic in places where there has been no gentrification as "degentrification". In particular, in the case of Itaewon, in 2020, the so-called "degentrification" aspect was noticeable due to the COVID-19 confirmed cases of visitors to the clubs including for LGBTQ in the area. Some media outlets referred to this club as a "gay club" or described the confirmed person as a homosexual in articles, and speculation about the gender identity of the COVID-19 confirmed person arose.

Second, looking at the analysis results of this study, the first stage of gentrification is a step inducing urban revitalization, and there is a positive aspect of providing a better environment to underdeveloped areas. The period of entering the degentrification stage is also the period when the vacancy rate increases. Looking at the semantic network between key keywords by stage, policy-related keywords to solve gentrification start to appear as central keywords from 2018, when degentrification begins. This is related to the culture-driven gentrification by gentrifiers, and it can be seen that the first and second degentrification periods had negative aspects as an issue about real estate as major keywords such as "rent" and "demise" appeared. New small business owners (tenants), a new cultural class lacking economic capital, are being highlighted as another victim of gentrification due to rising real estate prices and rents brought about by large developers who have begun to enter as the mass media pays attention to the area.

Table 6. Gentrification and degentrification characteristics and possible indicators of Itaewon area.

			Characteristics	Possible Indicators
Gentrification	Signs of escalation		First appearance in the press in 2001 2009: appearance of foreigners entering shops 2013–1015: article exposure frequency surge	News articles and SNS exposure frequency
	Factors in escalation		Expansion of Itaewon commercial district, Haebangchon urban regeneration area selection, Itaewon Special Tourism Zone Project, Yongsan Park Construction Plan	Creative producer Public project
	Progress in earnest	Rent Entitlement	Rapidly expanding commercial area since 2011 Rent has risen significantly since 2012 (50% increase in rent from 2011 to 2016)	Increase in official land price and rent
		Real estate transaction	The transaction volume of detached houses and apartments has surged since 2013 (160% increase in actual transaction price in Itaewon-dong in 2013–2015) Increase in rental demand (2011~2016)	A surge in real estate transactions Change of store tenants
		Business change	Business increase in 2011~2016	Increase in the number of businesses
		Industry change	Decrease in neighborhood stores Significant increase in general restaurants (2010~2015, 12 times) The trend of expanding the scope of the site to the back road	Decreased in the number of neighborhood stores Increase in restaurants
		Resident population	Decline in the resident population (January 2012–May 2014 decreased by about 480 people)	Decline in the resident population
		etc.	Increase in foot traffic	Increase in foot traffic
Degentrification	Maturity stage of gentrification		Vacancy rate increasing trend Increase in absentee landlords (change to nonresident owners of buildings)	Public policy Increased in vacancy rate Composite/new construction Tourist Franchise
	Demise of gentrification		COVID-19 Order to ban gathering (no business) for all entertainment facilities in Seoul	Rapid decrease in foot traffic Public policy

Third, what should be noted is that the target area of gentrification is "transitioned" to the adjacent area. In the case of the Itaewon area, as the gentrification phenomenon accelerated from 2013, and rents went up indefinitely, the vacancy rate in Itaewon increased and the surrounding areas suffered gentrification. This suggests that just as cities show cycles of growth and decline, gentrification also has cycles as an extension of downtown revitalization. In other words, gentrification is transferred in the process of moving to a new space or an adjacent area by displaced residents to the site where gentrification occurred and settling elsewhere, and the gentrifier also loses interest in the area and voluntarily migrates to a new space or adjacent area.

Lastly, the phenomenon of gentrification appeared in a wide variety of ways, as Beauregard [3] illustrates this as a "confusing and complex phenomenon". The concept of gentrification is now more complex and widespread on a global scale as time and space expand under the inevitable effects of neoliberalism. There is also the peculiarity of South Korea. In South Korea, the term gentrification, which has been disputed, has led to definitions that reflect various characteristics [24]. In response, the Korean National Institute of Korean Language (KMA) proposed the term "being driven out of a nest (둥지내몰림)" in Korean to substitute for the term "gentrification" [78]. Most of the characteristics of gentrification in South Korea are commercialization, in which residential facilities are converted to commercial facilities such as cafes and restaurants. The Korean-style gentrification phenomenon was initially due to the revitalization of the downtown area through the input of public policies such as urban regeneration and commercialization of existing commercial areas and neighboring facilities through rapid capital inflow in the process of urban regeneration. Tenants and residents who contributed to the revitalization of the commercial area were displaced. In addition, the residential area has lost its meaning as a place of life for local residents and has been turned into a tourist attraction for outsiders. Moreover, voluntary migration of gentrifiers and indigenous peoples occurred simultaneously over time. In the end, in order to prevent the decline of the local community and the deterioration of the quality of life of the residents due to the collapse of the local community, the government invests in the urban regeneration project in connection with the leading area in the vicinity of the area.

6. Conclusions

This study attempted to improve the consciousness of issues requiring a clear conceptual approach to degentrification by a case study of the Itaewon area. The Itaewon area has been formed by different authorities and has been organized as an urban space by the effect of the United States, government, and capital. The discourses on the urban space tend to mask the problems of the urban space for the reproduction of capital. Therefore, it is necessary to try to reveal an ideological illusion hidden behind those discourses. Using semantic network analysis, this study analyzed the main keywords and the meaning network difference between main keywords related to gentrification in national newspapers in South Korea. In doing this, what matters is how the keywords are connected, what keywords are located in the center of the overall network, and which keywords play a mediating role between the keywords [82].

As a result, gentrification in the Itaewon area is divided into four stages. The first stage of gentrification (2010~2014) is the initial stage of gentrification, and the main keywords are "Space" and "Life". Gentrification stage 2 (2015~2017) is the period of commercialization as a gentrification growth stage, and the main keywords are "City", "Space", "Art", "Market", "Region", "People", etc. The first stage of degentrification (2018~2019) is the maturation period of gentrification, and the main keywords are "Legal System", "Seoul", "Rental", etc. The second stage of degentrification (2019~30 June 2020) is the period of the COVID-19 pandemic, and the main keywords are "Gentrification", "COVID-19", and "Demise".

The results have confirmed the existing theoretical frameworks while building a more nuanced definition through operationalizing gentrification and degentrification. As with the etymology of the term, the degentrification phenomenon can only be revealed when the gentrification phenomenon is prominently displayed. Although various factors of gentrification have been studied, in terms of degentrification, in the end, rent was found to be the most important factor even in the COVID-19 pandemic situation.

Meanwhile, since the study site is located in South Korea, there is a limitation to generalizing the results. This should have to be proven by criticism and disproving it through future follow-up studies. The gentrification phenomenon in South Korea has been revisited through the input of public policy such as urban regeneration, and the existing commercial and neighboring facilities were commercialized by the rapid capital entry in the process of urban growth. The tenants and indigenous people who contributed to the revitalization of business were displaced. In addition, housing lost its meaning as a place of life for local residents and became a tourist destination for outsiders. In the process, space has changed and the identity of the area was damaged. Moreover, over time, the spontaneous migration of the gentrifiers and the local residents took place simultaneously. Eventually, in order to prevent the collapse of the local community and the deterioration of the quality of life of the residents, the government began urban regeneration projects.

This study has an implication in that it tried to phenomenologically examine the specific phenomenon of the next stage of gentrification through the term "degentrification".

The point is that when gentrification is used politically for urban regeneration, another policy will be created to alleviate the negative phenomenon of gentrification. Urban regeneration literally means revitalizing the life of a city, and it is not only improving the visible physical environment but also revitalizing the functions of the invisible city as a whole. Rather, deep reflection on whether urban regeneration has induced gentrification and contributed to its decline under the plausible cause of urban regeneration is required.

This study also provides overall implications on how to measure the process of gentrification/degentrification and reflect the results on gentrification policies and programs. The case of the Itaewon area shows that gentrification researchers need to provide a way to reflect empirical results practically in gentrification policy and programs. Given that gentrification and degentrification occur very rapidly and in a complex way, careful interpretation of empirical results should be emphasized by researchers.

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Article

From Urban-Scape to Human-Scape: COVID-19 Trends That will Shape Future City Centres

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Abstract: The COVID-19 pandemic did not only impact all spheres of life but came abruptly to redefine our understanding of the urban-scape. With changing user-values and user-needs, there is a renewed realisation of the importance of the human-scape and how human capital, social issues, and liveability considerations will progressively lead urban development discussions. The urban-scape risk is far more complex and fragile than previously anticipated, with the future of the city centre dependent on our ability to successfully manage the transition from an urban-scape to a human-scape. This research employed a narrative review methodology to reflect on COVID-19 trends that will shape future city centres, based on expert contributions pertaining to (1) the community sector, (2) the public sector, and (3) the private sector within the Sydney Metropolitan area of Australia. The research highlighted the changing human-scape needs and associated impacts of (1) changing movement patterns, (2) changing social infrastructure, and (3) increasing multifunctionality, which will be crucial factors in shaping attractive (future) city centres. The research contributes to the notion that future city centres will embrace and prioritise the human-scape in a response to 'build back better', and accordingly, identified how the human-scape can be articulated in broader spatial planning approaches to create attractive future city centres.

Keywords: urban-scape; COVID-19; cities; changing landscape; social capital; public transport; university campus; private business; communities; Sydney

1. Introduction: COVID-19 Changing Business-as-Usual for Cities and Sectors

The fragility of the city centre has recently been highlighted by the COVID-scape and the broad range of challenges and changeable unknowns it abruptly introduced. Changing societal needs and associated work-life patterns have emerged on a global scale as a result of the worldwide COVID-19 pandemic response and lockdown restrictions put in place. The impacts of the COVID-19 pandemic have introduced various challenges, but also opportunities for communities and future development efforts [1]. It has emphasised that social issues will progressively lead urban development discussions and echoed the findings of previous research that stated that the balance between the natural and built environments will continuously be negotiated in terms of liveability considerations [2]. During the past 18 months, cities across the globe have witnessed how the human-scape has drastically changed to conform to new ways of working and moving to such an extent that some scholars are now questioning the future of the city centre [3]. The contemporary urban-scape is being challenged by the current COVID-19 trends, and while the risks of the feasibility of the contemporary city centre are being highlighted, the current trends also provide a unique opportunity to reflect on the role of the urban-scape, the changing human-scape, and how we can transition to create attractive future city centres.

This research reflected on the trends and impacts of COVID-19 responses based on three different perspectives, informed by expert contributions with lived experiences in the Australian metropolitan city of Sydney from respective stakeholder groups inclusive of (1) the community, (2) the public, and (3) private sectors, as elaborated accordingly.

1.1. The Community Sector, a University Campus

This perspective includes the views of an expert with lived experiences, working in the community sector in Sydney and reflecting on the impacts of the COVID-19 pandemic on the higher education environment as applied to the University of Technology Sydney (UTS), located in the city centre of Sydney. The city campus is located near Sydney Central Station in Sydney and spread over five precincts, with the main campus located in Broadway, Haymarket, and Blackfriars, a sports hub in Moore Park, and an industrial centre in Botany close to the international airport. The location of UTS enhances its accessibility and reach and is a reason why UTS enrols close to 46,000 students each year from across the globe. This community sector saw an abrupt change in March 2020, when the COVID-19 pandemic started, and the university initiated a campus-wide lockdown. Face-to-face teaching transitioned to online and virtual learning, as business-as-usual was not possible under the restrictions on movement and social interaction The location coefficient that benefitted UTS was no longer part of the equation for attracting students, and industry collaboration and student experiences had to be redefined to fit the virtual environment. Changing work-life patterns and new ways of working (and learning) highlighted the role that the city centre previous played to sustain this community sector, but also raised questions relating to the future role of the city centre and whether it would be valued for its agglomeration economies alone.

1.2. The Public Sector, a Public Transport Network

This perspective includes the views of an expert with lived experiences, working in the public sector in Sydney and reflecting on the impacts of the COVID-19 pandemic on the Transport for NSW (New South Wales, Australia) network. Transport for NSW leads the development of a safe, efficient, integrated transport system that keeps people and goods moving, connects communities, and shapes the future of our cities and regional centres. It is responsible for strategy, planning, policy, regulation, funding allocation, and other non-service-delivery functions for all modes of transport in NSW including road, rail, ferry, light rail, point to point, regional air, cycling, and walking. With over 25,000 people working across NSW, it focuses on improving the customer experience and contracting public and private operators to deliver transport services on its behalf. This public sector has experienced the impacts that the COVID-19 pandemic brought along, specifically in terms of the vastly adjusted movement patterns. The city centre, which used to be the central connection hub with linking transport corridors and supporting infrastructure and services, was forced to a near standstill as part of lockdown regulations. This public sector's focus shifted from moving large groups of people as efficiently as possible to moving large groups of people as safely as possible, providing flexibility and choice through public infrastructure.

1.3. The Private Sector, an Advisory Consultancy for Built Environment Infrastructure

This perspective includes the views of an expert with lived experiences, working in the private sector in Sydney and reflecting on the impacts of the COVID-19 pandemic on the Ontoit Global Pty Ltd. Group (Sydney, Australia). Ontoit is a medium-sized independent infrastructure advisory and project management consultancy services business with over 70 staff members. It delivers services across nine different service sectors and has both public and private sector clients. Their consultancy work supports the major infrastructure market along the eastern seaboard of Australia [4]. Ontoit has offices in the major cities along the eastern seaboard of Australia, which are all strategically located close to transport and entertainment precincts. The COVID-19 pandemic shifted the Ontoit approach from face-to-face interaction (which was always considered a strong contributor to business culture, particularly in multidisciplinary organisations) to online and hybrid interaction. During the COVID-19 pandemic, this private sector had to adapt to virtual interaction and new ways of working, which in some instances were considered to be more beneficial in terms of time and resource management, thus questioning the future of the city centre as economic hub, which to some extent could be mimicked in the virtual environment.

2. Literature Review: The Notion of Urban-Scape and Human-Scape

Urban-scape dynamics have always been shaped by complex interactions across social, economic, and political factors, including population distribution, flows of wealth, and infrastructure requirements. As a result, city centres embodied a sense of unique human entrepreneurship, economic dynamism, and evolving multiculturalism [5]. The COVID-19 pandemic disrupted the urban-scape and the very core of urban living, from social distancing measures to lockdown responses, to destabilized local economies [6]. City centres are now challenged to respond in an attempt to reclaim the attractive urban-scape, along with its vibrant, humanized communities. It is no easy task, as the contemporary role and function of city centres have been challenged by technological advances [5] and communication innovations which now offer tantalising possibilities for transcending traditional social and geographical barriers [7]. These new advances in communication technologies and supporting metropolitan transport systems allows citizens to now stay selectively in touch, while disconnecting from the city at large [8]. This brings along a totally new understanding of efficiency (costs) and justice (equity), which underpins the performance of the contemporary city. It reopens the discussion of the five basic dimensions for the performance of a city, drafted by Lynch [9] namely: (1) how form affects vitality, (2) how form affects human sense, (3) the degree to which the form fits the requirements of people, (4) how people are to access activities and services, and (5) how much control people have over services, activities, and spaces. The COVID-19 pandemic reiterated the importance of the human-scape that was acknowledged by Lynch (1981) [9] but became overshadowed by agglomeration economies and related technology-driven production processes of the contemporary city centre [5]. The COVID-19 pandemic also brought forth a new understanding of changing societal needs and highlighted the fragility of cities when the human-scape is disrupted. Research furthermore showed that urban fragility is a crucial consideration for modern cities that are committed to coping with growing external pressures (from the environment) and internal tensions (within the social system) [10]. Urban fragility would continue to play an even bigger part in managing post-COVID city centres with the growing awareness of the importance of the human-scape as an integral part of the urban-scape. The importance of the human-scape is no new phenomenon, drawing back to the work of Jacobs, who identified more than half a century ago what the potential and real failures will be when the human dimensions of the city were not considered, accounted for, and valorised [11]. Human needs are thus the core basis and foundation on which urban futures should be usefully envisaged, and the recognition of how the human-scape intertwines with the urban-scape underpins an appreciation of the growing complexity of city centres [10] and the different layers and interactions that need to be considered [12]. While human-scape refers to the social and cultural system, and how humans socially interact with their physical environment, the urban-scape relates to the physical environment or 'landscape' of the built environment. The relationship between the urban-scape and the human-scape manifests through the complementary and conflicting impacts that they have upon each other, through public health improvements, social cohesion, social equality, and economic systems measuring urban capital [10].

The challenge, however, is that the urban-scape is traditionally known to be a slow-changing environment, while its hosting societies, the human-scape, are increasingly becoming more dynamic [2]. A slow-changing urban-scape must respond to fast-changing needs of the human-scape, brought along by the increasingly dynamic (and changing) needs and preferences with regard to social, sustainability, and economic issues, and further inflated challenges brought along by the COVID-19 pandemic. Recent developments emphasised the urgency of previous calls to foreground human needs at the heart of urban societal futures [11] and rethink the current policy and governance approaches that primarily focus on economic, technical, and environmental imperatives at national scales.

What is evident is the significance of urban identity, distinctiveness, and meaning that is increasingly being highlighted [13], especially when considering the transition from urban-scape to human-scape. Urban identities are informed by the "perceived uniqueness of a place" [14] and are formed by a range of "multiple and mutual relations in between context and content" [13]. The need for urban identity draws on a deep human need for associations with significant places [15]. Persistent identity has three distinctive components, namely the physical setting, the activities, and the experiences linked to that place [16]. The future cities of the post-COVID reality would need to revisit the notion of urban identity and uniqueness, and facilitate the transition from the urban-scape to the human-scape in a quest to reclaim the attractiveness city centres.

3. Contextualising Urban Identity: The Australian Context

From an Australian perspective, urban planning has progressively established a modern geospatial capability, which is known for its economic, social, and environmental well-being [17]. The human-scape has become increasingly recognised as part of the urban identity, and as a result, Australia is home to some of the most liveable cities in the world, according to the Global Liveability Index of 2021 [18], which evaluated 140 global cities based on a liveability score, inclusive of 30 qualitative and quantitative factors across five categories including stability, healthcare, culture and environment, education, and infrastructure.

The PwC Australia's Future of Work Report [19] showed that Australian city centres attract over 39% of staff employed by the professional and financial services industries who have a 'high' to 'very high' capability of being able to work remotely, as illustrated in Table 1.

With the introduction of COVID-19 and city-wide lockdown responses put in place in early 2020, the geospatial economic model also saw a fast change in terms of composition, since the traditional urban-scape could no longer provide the qualities that were needed to host and sustain the human-scape or business-as-usual [12]. The attractiveness of the city became much less important than attracting and retaining staff. Apart from the majority of professional and financial services industries retracting from the city centres, leaving the urban-scape without function or identity, other urban land-use changes were also evident during the time of the pandemic. Open space and quality outdoor environments within the urban-scape became crucial for well-being, and the benefits and attractiveness of these spaces were widely recognised in Australia, as in other global cities [20–22].

There was a renewed recognition of the importance of the urban-scape to provide social experiences [23], infrastructure, and spaces to support physical and mental health [24,25], flexible and safe transport modes [26], and access to digital infrastructure [27,28] as part of basic human rights for urban living and enhanced liveability. A new definition of essential tasks [29], the importance of transportation for global and geographically remote cities such as Sydney [30], changing travel patterns [30], and the decentralisation of the urban centres driven by the drastic change in user-values and user-needs [31,32] further challenged the contemporary city centres. Limited mobility, remote working, and prioritising the health agenda became the new normal within the urban-scape, turning planning theories and our understanding of the morphology of cities upside down [20]. Even urban density, which was previously not considered a risk factor [33], was now reconsidered as a driver of infection rates within the urban-scape [34], adding to the list of new vulnerabilities that were introduced as part of the 'new normal' in cities [35].

Table 1. Capacity of city centre workers with capability to work from home.

Industry	% of CBD Employment	WFH Capability
Professional, Scientific, and Technical Services	21.14%	High
Financial and Insurance Services	17.63%	Very High
Public Administration and Safety	13.90%	Low
Accommodation and Food Services	7.33%	Very Low
Education and Training	4.97%	Very Low
Retail Trade	4.77%	Medium
Administrative and Support Services	4.72%	Low
Information Media and Telecommunications	4.17%	Medium
Health Care and Social Assistance	4.01%	Very Low
Construction	3.31%	Low
Rental, Hiring, and Real Estate Services	2.46%	Medium
Mining	2.45%	Low
Transport, Postal, and Warehousing	2.26%	Low
Other Services	1.81%	Very Low
Electricity, Gas, Water, and Waste Services	1.67%	Low
Arts and Recreation Services	1.52%	Very Low
Manufacturing	1.04%	Low
Wholesale Trade	0.86%	Medium
Agriculture, Forestry, and Fishing	0.00%	Very Low
Total	100%	

Source: PwC's Geospatial Economic Model [19] .

Various attempts have been launched to limit the risks now posed to the human- and urban-scape, encapsulated as part of the City of Sydney's Recovery Plan [36] which was informed by inputs collected from a survey opened to public consultation. In an attempt to manage the complex interactions across social, economic, and political factors, and to understand the risk of the future urban-scape, more emphasis should be placed on understanding the human-scape and associated changes of user-values and user-needs, which will ultimately shape attractive future city centres [20]. Therefore, this research further investigated the human-scape, based on the perspectives of three different sectors, included as part of a narrative review methodology.

4. A Narrative Review: Reflections of Sydney's Urban Identity

This research employed a qualitative methodology, in the form of a narrative review, to understand the changing needs and values connected to the human-scape and associated urban-scape amid the COVID-19 global pandemic. The narrative review followed a phenomenological approach in an attempt to understand the social reality, grounded in people's experiences pertaining to the social reality [37]. The narrative review aimed to contextualise lived experiences and practices, capturing the human-scape through narratives, and drawing on the events and impacts brought forward by the COVID-scape.

To understand the changing human-scape needs and associated risks posed to the urban-scape, this research reflected on the impact of COVID-19 from three different perspectives: (1) the community sector, (2) the public sector, and (3) the private sector. The perspectives were captured by means of expert contributions of individual stakeholders sharing their reflections from each of the respective sectors. Expert contributions were selected as part of the methodology and the exploratory phase since it is proven to be a more efficient and concentrated method of gathering data than, for example, participatory observation or systematic quantitative surveys. Expert contributions as part of empirical research are underpinned by the theory of society and a democratic theory perspective, as well as from the sociology of knowledge, scientific, or technical research standpoints [38,39]. Expert knowledge also pertains to modernization theory, where changes in the modern world form the point of view of knowledge dynamics, and is therefore part of "institutional reflexivity" [40]. This research relied on expert contributions to provide insider knowledge [38] and access to a particular social field related to change management during the COVID-19 pandemic, from the perspective of the community, public sector, and private sector. Expert contributions included perspectives of (1) the Faculty of Design, Architecture, and Building, UTS; (2) Transport for NSW; and (3) Ontoit Global Pty Ltd., Sydney, NSW, Australia. The qualitative data include reflections since the start of the COVID-19 pandemic and first impacts, which were observed in Australia in March 2020, with the analysis including the period until mid-2021, when the pandemic was still ongoing and events unfolding. The perspectives informed a thematic analysis and identified challenges and opportunities for shaping future city centres (amid the trends brought about by the pandemic).

5. Analysis: Contextualising the Challenges and Opportunities of the City Centre

The shift to online spaces and removal of physical boundaries had differing impacts upon the competitive positioning of sectors which have previously engaged with central locations. An overview of the analysis of the reflections drawn from the empirical investigation are provided in Table 2 below, followed by an exploration of the challenges and opportunities by: (1) the community sector, (2) the public sector, and (3) the private sector.

Table 2. Challenges and opportunities identified from the narrative review.

Considering the Urban-Scape and Changing Human-Scape	
Challenges Identified	**Opportunities Identified**
Location no longer competitive advantage	Advanced communication technologies
Vibrant city identity no longer competitive	Greater flexibility of space
Inequality became more evident	High-value contact time
Increasing economic and social constraints	Meaningful engagements
Traditional workplace no longer deemed fit	Activity-based working possibilities
Traditional work ways no longer deemed fit	Active transportation modes
Health agenda dictated a new normal	Repurposed buildings
Limited agglomeration economics	Multipurpose spaces
Lack of attractiveness and sense of place	Creation of working hubs
Fast-changing societal needs	Evolving multiculturism

5.1. Challenges Observed in the Human- and Urban-Scape

The location of the urban-scape was no longer considered a competitive advantage as digital shifts depicted a reduction in competitiveness across multiple physical locations.

(1) "Being located in the city centre was UTS's competitive advantage with convenient transport modes and connections, as well as availability of adequate student accommodation. COVID-19 impacted the locational advantage and replaced the central teaching location with a virtual learning environment that had no geographical boundaries. The urban-scape, as experienced by this sector, was transformed by the digital economy."
(2) "The traditional workplace and ways of working were no longer deemed fit when COVID-19 response measures were put in place. It became evident that hybrid

working approaches would be the way forward and that more focus would need to be placed on enhanced connectivity and workplace experience."

(3) "Ontoit has progressively embraced cloud-based technologies to enable effective collaboration between staff located in its interstate offices and its remote clients. This enabled a rapid transition, enabling staff from remote locations, moving away from the economies of scale which the urban-scape previously offered."

The digital shift was accelerated and applied on a much larger scale than previously. This shift has had complex impacts on the competitiveness of cities, with expectations to pivot amid a changing landscape of public health information. Inequality also became more evident across boundaries.

(1) "The vast inequalities that previously existed between different countries, regions, and areas became more evident when international students now had to attend classes from their home locations, in some cases not being able to access the technological advances and infrastructure which was usually at their disposal through the UTS campus. These challenges, which were previously not considered in the higher education environment in Sydney, such as efficient and accessible internet connections, data availability, and digital communication, were now part of the reality."

(2) "The long-term planning and visions of Transport for NSW had to instantly adapt to cater for changing societal needs and an unknown future about the needs of the resident population, how movement and travel patterns would change over time and the role of public infrastructure in creating healthy, sustainable city centres."

(3) "Traditional workplace and working ways were no longer deemed fit as the COVID-19 pandemic changed the face-to-face culture of Ontoit, abruptly reverting to remote working arrangements, with access to the offices limited by its COVID-19 safe working policy informed by federal and respective state government rules. This meant a complete shutdown of offices or limited attendance capacity to meet safe physical distancing regulations. With large businesses reverting to a similar arrangement, there was a complete desertion of city centres by office workers, which had a further abrupt and cascading impact on service-related businesses in the urban-scape."

All three sectors revealed that while digital technologies can enable a more streamlined and consistent experience for communities across Sydney, the vibrancy of the physical city was very much valued as a competitive and social equity advantage for all communities. The city-wide shift to a digital space has brought a complex range of impacts for all three communities.

(1) "The vibrancy of the city centre, and the social and cultural benefits it provided as part of the community sector's support system, was now more evident than ever. The sector was challenged to respond to vast changing social needs underpinned by a health agenda."

(3) "A large part of Ontoit's business-to-business engagement relied on its city centre location, nearby transport hubs, dining, and entertainment precincts in close proximity, which was no longer a competitive advantage, as the resident population migrated out of offices in the city centre to work remotely. Limited agglomeration economics, along with a lack of attractiveness and sense of place was characterising the urban-scape."

5.2. Opportunities Observed in the Human- and Urban-Scape

Advanced communication technologies were rapidly introduced which offered greater flexibility of space within the urban-scape.

(1) "As UTS moved towards a blended learning mode to accommodate both online and on-campus students, greater flexibility was introduced, drawing on keeping the best of both the face-to-face and online teaching environments, with a focus on high-value contact time."

(2) "Changing transport patterns defined the 'new normal', shifting from the major flow of public to and from city centres in the peak hours (Monday to Friday), towards fewer, but more frequent journeys throughout the day to regional centres."
(3) "The understanding of the resident population of the city centre changed to be more flexible and seasonal than before. Some opportunities, such as sourcing co-working hubs within local neighbourhoods, were introduced as alternatives for commuting to city centres on a daily basis."

The opportunities to repurpose buildings and introduce multipurpose spaces were recognised across all communities.

(1) "An attractive city centre would entail one that offers great flexibility and options, inclusive of communal meeting spaces, and design elements [on campus] which prioritise public health."
(2) "Adequate public transport provision, flexibility, and options to support a safe environment will create an attractive city centre."
(3) "Active transport modes, efficient links between the city centre and regional hubs, fast connections, flexible movement patterns, and prioritization of the health agenda through planning and design elements will play an increasingly important role in terms of attractiveness of the urban-scape."

The opportunity to embrace "active transport" modes became more prominent, in response to the health agenda and congested passive transport routes.

(2) "The public sector is revisiting the notion of public goods from a health perspective. For Transport for NSW it implies reflecting on concepts of 'active working' and 'active transport' and how to align the public sector infrastructure provision with fast-changing social needs."
(3) "The use public transport was inhibited by the fear of COVID-19 infection and challenges in enforcing social distancing regulations. The use of private transportation modes, and active mobility such as walking or cycling to travel to and from the workplace, significantly increased since the start of the COVID-19 pandemic."

The creation of working hubs and activity-based working spaces and possibilities were also highlighted as opportunities for the future urban-scape.

(3) "While city centres will continue to be the hubs for business, the permanent nature of these will change and make room for more flexible working arrangements with temporary (rotating) staff, leaving many of the envisioned office spaces unoccupied. Some of these commercial spaces could be repurposed to become accommodation for workers or to accommodate multipurpose uses. It does imply a vast shift in thinking about inward investment and national and international capital for developments in city centres. A 'new normal' for city centres is expected where businesses will operate from remote locations (regional or suburban) to accommodate flexibility. This would imply (even if temporarily) some opportunity to convert offices and to repurpose these spaces for accommodation or other uses."

The COVID-scape redefined the broader understanding of 'business as usual' and has introduced various challenges and opportunities to be considered for planning liveable (future) city centres. The reflections highlighted the prominence of the human-scape as a critical factor guiding the urban-scape, and the changing trends and evolving multiculturism that were brought along by the recent pandemic, of which some might be part of the 'new normal' going forward.

6. Discussion: Transitioning from Urban-Scape to Human-Scape

The urban-scape will always be impacted by the knowledge production, service provision, productivity, innovation, and economic development [41] that contribute to the agglomeration forces which define the city centre, but human-scape considerations such as high-value connection spaces to embrace quality of life, deep connections, cultural recharge, and sanctuary will progressively take the lead in shaping future cities. Current trends at this time predict that social considerations will far outweigh the economic competitiveness of spaces and will increasingly be the core denominator in future city centres where the transition from an urban-scape to a fit-for-purpose human-scape will be evident. This would, however, imply a change to 'business as usual', where greater flexibility, choice, and social needs would lead the conversation on the attractiveness of city centres. Based on the reflections included in this research, the following themes were identified as the core issues that will support the transition from contemporary, post-COVID urban-scape to human-scape.

6.1. Changing Movement Patterns

The global uptake in remote working would possibly continue in the future even when, to a lesser extent, it will have severe impacts in terms of the broader movement patterns in (and around) cities. The decline in public transport patronage was evident as movement patterns changed according to the societal needs and 'active transport' options saw great interest, confirming previous research. A decline of the resident population of the city centre was evident, both in terms of local users of the space (the regulars) visiting the city centre daily or weekly, and also in terms of visitors (tourists) who used to shape the city centre. Flexible movement patterns and fast (selective) connections would define future cities in supporting the transition from the urban-scape to the human-scape.

6.2. Changing Social Infrastructure

There is a new understanding of "available versus accessible". As remote working and flexible working hours are becoming more prominent, the need for supporting social infrastructure will likewise also expand. The rapid deployment of collaborative tools and technologies will define our future cities to enable communities to work effectively and efficiently. City centres will become an integral part of the broader ecosystem as we progressively understand that economic prosperity depends upon healthy social structures. This research confirms that economic prosperity will depend upon healthy social structures. The significance of urban identity would need to be revisited in light of sense of place theories and quality of life objectives, pertaining to the dimensions set forward by Lynch (1981) [9] that contemplate how form will affect vitality and human sense, how people could better access the activities and services of the city centre, and how societal needs will shape these urban spaces. New advances in communication technologies and supporting urban metropolitan transport systems now allow citizens to stay selectively in touch, while disconnecting from the city at large, reframing the social infrastructural needs of traditional city planning approaches. Social infrastructure will play a critical part in future cities as the enabler of social connections, bringing societies together for more fractional, but high-value interactions.

6.3. Increasing Multifunctionality

During the first quarter of 2021, the estimated occupancy levels in the city centre of Sydney were between 25% and 40%. Occupancy levels were, however, drastically reduced after the June 2021 lockdown, with some experts questioning if this would entail a more 'permanent reminder of the new normal'. The evidence that urban space is changing calls for a renewed understanding of urban land value and multifunctionality, where specific spaces could be better used to accommodate a range of uses, users, and activities. As a result, the urban identity now has to incorporate the new dynamics of a COVID generation, and multifunctionality will be increasingly employed in future cities to accommodate changing needs, activities, and forms of interaction, ultimately accommodating the change from urban-scape to human-scape. Table 3 captures the trends identified from the urban-scape in accordance with the human-scape considerations that will ultimately shape attractive (future) city centres.

Table 3. Changing trends that will define future cities.

Issues	**Trends Identified from the Urban-Scape**	**Human-Scape Considerations to Shape Attractive (Future) City Centres**
Changing movement patterns	Greater flexibility brought about by the impact of remote working policies on the function and form of the urban-scape. A disconnection from the urban-scape was evident, while a deeper connection to the human-scape arose.	• Prioritise the planning of "active transport" modes • Plan for activity-based environments • Accommodate flexible uses, users, and activities as part of city planning approaches • Include transport systems that allow for fast, flexible connections to the urban-scape • Plan for temporary spaces
Changing social infrastructure	Hybrid working ways changed the infrastructural needs and interaction between 'availability' and 'accessibility'.	• High-value connection spaces should support accessibility and availability • Urban spaces should be planned for enhanced experience and meaningful encounters • Availability of staff should not be location-focused, rather supported by technologies to bridge geographical distances • Social considerations should lead the notion of attractiveness of city centres
Increasing multifunctionality	The change in urban land use was observed on a global scale. The need for multifunctional spaces to accommodate changing activities, users, and uses were continuously highlighted.	• Healthy environments should be prioritised as part of broader spatial planning approaches • Focus should be placed on the greater deployment of collaboration technologies • The end goal should be to enhance user experience within the city centre

7. Conclusions: Shaping Attractive Future City Centres

The human-scape, contextualised by social equity and social capital, will become more prominent in the future, addressing a universal fulfilment of the most fundamental human needs within the urban-scape [12,42,43]. The urban identity will accordingly be influenced by user-values and user-needs, driven by human capital, social issues, and liveability considerations. The future of the city centre is dependent on our ability to successfully manage the transition from an urban-scape to a human-scape. It implies the human-scape being articulated in broader spatial planning approaches to respond to the impacts of changing movement patterns, changing social infrastructure, and increasing multifunctionality as core themes. While these impacts challenged the contemporary urban-scape, they also provided a unique opportunity to shape future cities following the trends that were set in motion during the COVID-19 pandemic. Active transport modes, greater flexibility, temporary uses and spaces, improved accessibility, enhanced experiences, and healthy environmental and collaborative technologies will define the urban identity of future city centres. In a quest to reclaim attractive city centres, the urban-scape would need to transition to embrace and prioritise the human-scape.

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Article

Tactical Urbanism Interventions for the Urban Environment: Which Economic Impacts?

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Abstract: In the last decades, the emergence of new social, environmental, and economic demands, exacerbated by the COVID-19 pandemic, has led urban planning to innovate its themes, methods, and approaches. In this context, temporary urbanism has emerged as a mainstream approach. How-ever, the impacts of temporary approaches to urban planning are far from being fully understood. In this light, this study focuses on one of the mainstream approaches to temporary urbanism, tactical urbanism, and tries to understand its economic impacts on contemporary cities. Indeed, despite the growing interest in tactical urbanism interventions and their value as an urban regeneration tool, there are no specific reflections focused on investigating their economic effects. Based on these premises, this paper focuses on different tactical urbanism experiences in the Italian context and tries to assess the economic impacts of tactical urbanism interventions by adopting the lens of real estate values as a suitable proxy when dealing with urban environments. The first obtained results show that the experiences of tactical urbanism, partly because of their temporary nature and their tendency toward minimal intervention, fail to trigger regeneration processes or produce significant economic impacts on the territory. Instead, such experiences can play a role in accelerating or consolidating urban regeneration processes already underway, and, in this sense, they contribute to the generation of economic impact on the territory.

Keywords: temporary; urban regeneration; tactical urbanism; real estate market; impacts

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1. Introduction

In the last decades, the emergence of new social, environmental, and economic demands and the evident failure of traditional planning have led urban planning to deeply innovate its themes, methods, and intervention approaches [1,2]. Indeed, its primary focus has shifted from governing urban expansion and radical transformations to regenerating consolidated cities by giving prominence to the themes of reversibility and reuse [3,4].

As a consequence of this shift, the debate about vacancies in urban contexts has gained a central role in the urban planning discourse of many European cities [5], and the urgent need to find quick and tailor-made solutions to recover vacant and neglected urban areas has triggered the spreading of new tactics of urban spaces' temporary use [6].

Traditionally, the concept of temporariness in urban transformations is linked to self-organized and non-institutionalized experiences [7], dealing with vacant and neglected areas [8].

However, in recent years, temporary uses have been included in the urban planning domain [9], thus providing the concept of "temporary" with a new meaning: from its original meaning as a "limited in time" intervention, it has moved on to identify short-term and easily reversible actions, thus allowing for testing cities' and communities' reactions to them before their permanent inclusion in urban strategies. According to this perspective, indeed, they can represent a valuable urban planning tool "to react to a world where the future is more uncertain and less secure, and a response to rapid [. . .] changes that are shortening the present into smaller and smaller time frames" [10].

Based on this main difference between non-institutional and institutional approaches to temporariness, which Bragaglia and Rossignolo [11] identify as "temporariness as practice" and "temporariness as policy," the emerging paradigm of temporary urbanism can be realized through multiple forms of short-term actions [11]. In greater detail, short-term experiences belonging to the "temporariness as practice" category, resting on explicitly challenging dominant and institutional urban development strategies, find their most frequent realization in:

- *Autonomous geographies*, considered as "spaces where people desire to constitute non-capitalist, egalitarian and solidaristic forms of political, social, and economic organization through a combination of resistance and creation" [12]. In this sense, they can be seen as radical forms of urban interventions, openly challenging institutional planning and distancing from public administrations' agendas. In this sense, *autonomous geographies* cannot be merely intended as spatial strategies for urban transformation but rather find their distinctive features in their social relevance and in their stress on the interventions' participatory and ethical connotations [13];
- *Guerrilla urbanism* practice, intended as a planning approach "recognizing both the ability of citizens and opportunities in the existing urban conditions for radical and everyday changes against the dominant forces in the society" [7]. Also, this practice openly distances itself from the institutional planning domain in its attempt to rearrange the "official" public space's structure and release opportunities for new relationships and meanings creation.

Instead, short-term experiences related to the "temporariness as policy" domain find their best-known realizations in:

- *The Do-it-Yourself (DIY) Urbanism* movement, born in the United States, which consists of actions implemented by residents to address urban issues and results in spontaneous interventions to improve everyday experiences in public spaces [14]. From this perspective, such a kind of temporary urbanism's realization finds its specificity in a non-professional, rather than in a non-institutional, attitude.
- *Pop-up urbanism*, which takes up the widely used "pop-up" locution for places that occupy a site for a limited amount of time [15] and relates it to urban planning issues, thus identifying quick and low-cost actions to deal with vacant spaces [16].

Among these various forms of temporary urbanism, differing from each other in their interpretation of temporariness [17], however, tactical urbanism has emerged as a mainstream approach in the urban agenda. It is defined as "an approach to neighborhood building and activation using short-term, low-cost, and scalable interventions and policies" [18]. It can be considered a realization of the "temporariness as policy" approach because, in the last two decades, it has been implemented by a wide range of actors, from public administrators and private companies to non-profit organizations and citizens. Its main feature, common to other temporary urbanism approaches, lies in its grounding in an open and iterative process that, by leveraging the potential related to social engagement, brings intentional and flexible responses for public spaces [18]. Tactical urbanism approaches, indeed, find their legitimacy in the spreading of the consciousness that urban planning actions cannot control every process's variables and, in this sense, it allows for correction.

It is not easy to date the entrance of tactical urbanism into the urban discourse because it is possible to find several historical precedents of this impulse to create "temporary and low-cost impulses to the challenges of urban life" [18]. However, its rise and spread can be dated back to 2010 in North America under the pressure of four relevant phenomena: people coming back to cities, the Great Recession, the spreading of the internet, and the growing detachment between government and communities [19]. Since then, this

″innovative″ approach to urbanism has rapidly spread to Europe, leading to the birth of several relevant experiences of tactical urbanism, which adapt the plurality of American approaches to the European urban environment's specificities.

Based on the different reasons and actors behind their conception, tactical urbanism's most common applications can be categorized as [18]:

- Promoted by local communities to overcome the conventional project delivery process, thus directly demonstrating the possibility of change and exercising their "right to the city";
- As a tool for municipal planning, private developers, and non-profit organizations to engage local communities during the design and development process;
- As a "phase 0" tool used by cities or developers to test interventions before their permanent implementation.

If, in their application as a "right to the city" exercise, tactical urbanism interventions can be traced to the domain of "temporariness practice" approaches, the second and third applications' typologies mainly relate to the "temporariness policy" domain. However, these three tactical urbanism applications are not mutually exclusive. Indeed, often the first has been the basis for the second, which has led to the third, thus promoting tactical urbanism spreading as a municipal planning tool.

Nowadays, scholars are divided on the role and impacts of tactical urbanism approaches in re-shaping our cities. Indeed, on the one hand, these approaches are recommended as quick and tailor-made solutions to promptly meet the rapid changes required by contemporary cities and to address the renewed need for public spaces [20,21]. On the other hand, they are criticized for the risk of being mere marketing strategies, for the uncertainty of their effects in the long-term scenario [22], or for being a vehicle of gentrification, thus displacing vulnerable populations [23].

What is true is that the impacts of temporary approaches to planning on urban development dynamics and their possible role in cities' reshaping are far from being fully understood and assessed [24]. Based on these premises, in Section 2, this paper deals with the investigation of tactical urbanism's impacts by describing the adopted research method. It moves from providing an overview of the scientific debate to focusing on the values and impacts of tactical urbanism interventions as urban regeneration, which is described in Section 3. This overview, resulting from a literature review of scientific papers dealing with tactical urbanism, finds that there are no specific reflections on the possible economic impacts related to tactical urbanism interventions' implementation.

For this reason, this paper starts addressing this gap in the scientific debate on tactical urbanism and focuses on understanding if and to what extent tactical urbanism interventions, as small-scale and minimal urban regeneration processes, can trigger economic dynamics by adopting the lens of real estate values. To this end, Section 4 focuses on several tactical urbanism case studies in the Italian context belonging to different realities in scale and real estate dynamics, and, after describing them, provides an analysis of the real estate market values' trends in their influence areas with the same trend related to a larger reference territorial scale. Finally, in Section 5, the analysis's results are discussed, and some final reflections and future research perspectives are drawn [10].

2. Research Method

Regeneration projects can bring important effects to the nearby context and increase the value of nearby properties. In fact, it has been widely discussed how external characteristics can influence house prices both positively and negatively and how the impact can be different from country to country. D'Acci [25] explored different features that could influence the overall quality of the urban space and home values by analyzing the literature and several case studies. *Proximity to green spaces*, for example, can vary from +0.016% [26] to +117% [27], as in the case of the Centennial Olympic Park in Atlanta; the *view,* if unpleasant, can decrease by −25% the property value [28]; meanwhile, a generally attractive landscape could increase it by +5/12% [29] and up to +68% in the case of a full ocean view adjacent to the coast [30]. Also, *open space* can have a negative impact, −6% [28], in the case of degradation and low flow, and it can also have a positive impact, +17% [31], if in proximity to a cleaned-up vacant lot.

An Intervention of urban regeneration is aimed at improving the quality of the open space and ensuring, at the same time, affordability, access to services, and involving citizens in the decision process [32]. The effect provided directly impacts the Positional Value (PV) of a building, defined as "part of the real estate value given from the extrinsic characteristics" [25].

As discussed in the previous section, tactical urbanism interventions aim to propose practices for the regeneration of urban spaces with the involvement of social components in order to carry out low-cost, easily replicable, flexible interventions and to produce urban fabric reactivation effects that go beyond the specific area in which the works are concentrated, which is usually circumscribed. Moreover, the extreme adaptability of interventions to the context's physical, economic, and social conditions means that they can be replicated relatively easily in similar situations within the same urban body or grow incrementally over time. Because of these potentials, tactical urbanism, which has gone from being an alternative mode of intervention to encompassing established practices of the design and management of public space, is now recognized as one of the main levers for the implementation of urban regeneration strategies based on the cumulative effect of punctual actions coordinated with each other that, although temporary, can generate effects in the long term [33]. Beyond its possible realizations, the familiar principle underlying this approach is that each intervention triggers a process of multiplication of regenerative effects well beyond its punctual and temporary character, a characteristic that, despite its "informality," has leant it to disciplinary attention as one of the main paradigms of reference in the debate on the contemporary city [34].

From this perspective, it seems interesting to analyze the economic impact of tactical urban planning interventions in different contexts and territorial areas to highlight whether and under what conditions, effects are realized in reality, even in the long term, and what are the leading indicators of this change process.

Consistent with the new theories of urban regeneration [35], the effects of a tactical urban planning intervention do not only concern physical space but must also be examined concerning a broader vision that invokes the dimensions of sustainability, namely the social, environmental, and economic dimensions. In particular, this paper, starting from this assumption, aims to investigate whether and under what conditions tactical urbanism interventions have generated virtuous processes of public space redevelopment and whether this effect is also reflected in an increase in real estate prices.

Considering the holistic impacts generated by these interventions and their process of physical change, the framework proposed by Lang [36] has been taken as a main reference to structure the methodological approach, which has been further implemented and detailed. As it is possible to see from Figure 1, among the dimensions involved, the economic one has been investigated with a particular reference to the effect on the real estate market and the residential asset class. The flowchart presented is a preliminary proposal because, to understand the overall impact generated by tactical urbanism interventions, it is necessary to detail with additional criteria the economic dimension and to break down the other three.

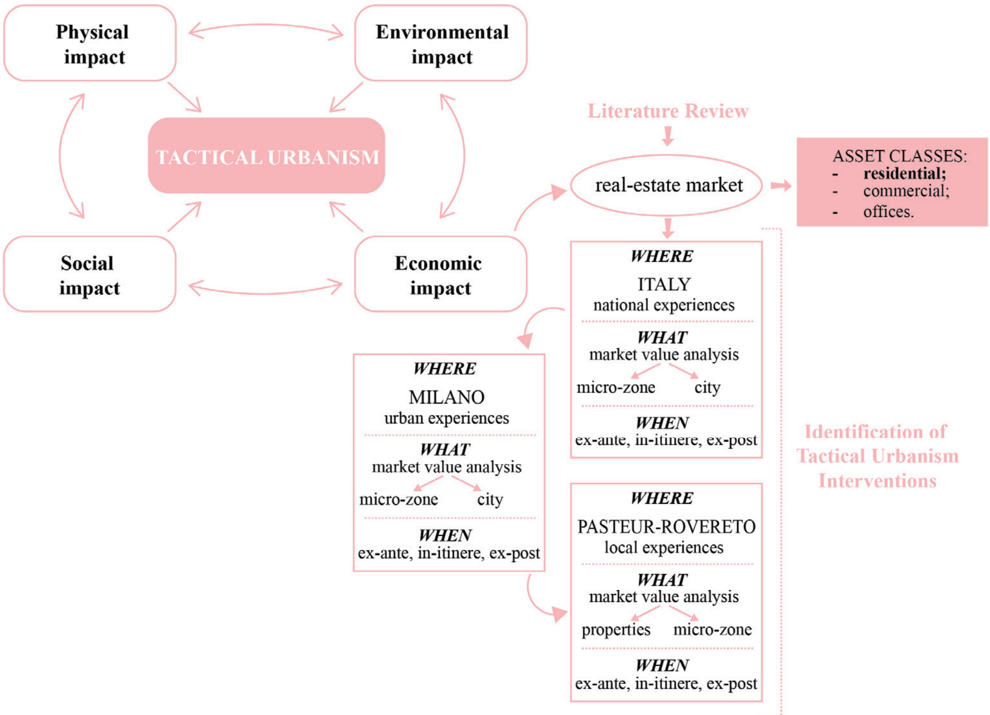

Figure 1. Methodological framework.

After a literature review aimed at analyzing how other scholars have faced this topic and if correlations between economic impact and tactical urbanism exist, the analysis to investigate existing case studies was developed in three phases and on three scales:

1. **National levels:** Experiences of tactical urbanism interventions located in the Italian context were selected and a market value analysis was performed considering both the city and its micro-zone and, as a time horizon, before (ex-ante), during (in-itinere), and after (ex-post) the realization of the projects;
2. **Urban level:** Experiences of tactical urbanism interventions located in the city of Milan were selected, and a market value analysis was performed considering both the city and its micro-zone and, as a time horizon, before (ex-ante), during (in-itinere), and after (ex-post) the realization of the projects;
3. **Local level:** Experiences of tactical urbanism interventions located in a specific Milanese neighborhood (micro-zone) were selected, and a market value analysis was performed considering both the micro-zone and the nearby properties and, as a time horizon, before (ex-ante), during (in-itinere), and after (ex-post) the realization of the projects.

The market value analysis was performed based on asking prices provided by the real estate platform Immobiliare.it, as the division in micro-zones is taken as a reference for the analysis. This choice stems from the low level of transparency of the Italian real estate market and the impossibility of freely accessing transaction prices.

The results of the analysis are presented in Section 4.

3. The Value of Tactical Urbanism Interventions as Urban Regeneration Projects

In this context, it results interesting and strategic to investigate the role of tactical urbanism projects for the physical and social regeneration of a neighborhood, and further understand in which contexts they have been mainly analyzed by other scholars, as well as their capacity for raising or decreasing property values by taking into consideration also the most influential factors in play.

Among the economic evaluation methodologies, and, in detail, the revealed preference ones, the Hedonic Price Methods (HPM) methodology is aimed at investigating the influence of specific characteristics on the formation of the value of an asset [37]. Therefore, within this context, the HPM can be considered the most coherent approach to assessing the impact of tactical urbanism interventions on the housing market value. Starting from this assumption, a literature review was developed by searching the Scopus database and using, firstly, the keywords "hedonic price" AND "tactical urbanism," and, secondly, "hedonic price" AND "market value," but no documents were found.

The search then moved to understanding how this topic has been investigated and in which fields; in fact, a new analysis using the same database was developed by narrowing to the keyword "tactical urbanism," and 160 papers resulted. As it is possible to see in Figure 2, the attention to this topic increased from 2020 simultaneously with the emergence of the COVID-19 pandemic; in fact, almost 60% of the contributions have been published in the last four years.

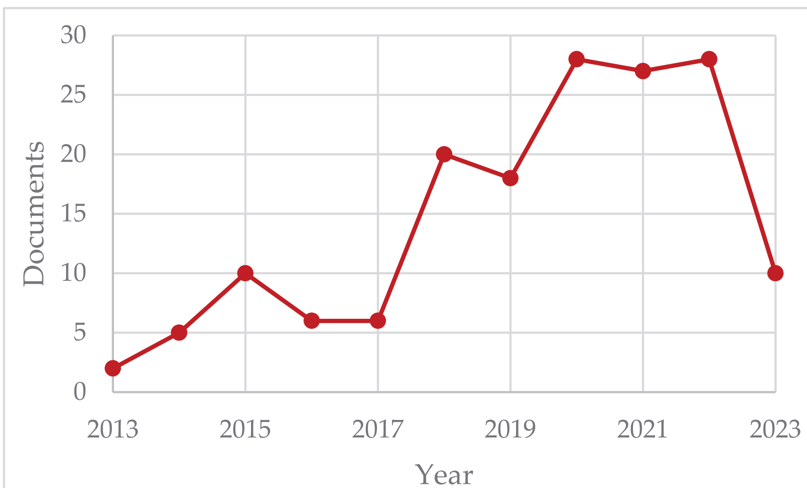

Figure 2. Documents by year developed using the Scopus database.

To understand the most frequent keywords and clusters of keywords combined together in the papers found, the VOSviewer software version 1.6.17 supported the analysis and the visualization of the co-occurrence network. Twenty-five keywords resulted from the investigation, and five clusters were developed, which specify the different domains of research (Figure 3). The main important concepts underlined by the network consist of developing strategic approaches to design sustainable neighborhoods [38]; the adoption of sustainable practices through transport policy in the COVID-19 era [39]; and the engagement of the community and the promotion of policies to improve the overall quality of open spaces [40,41].

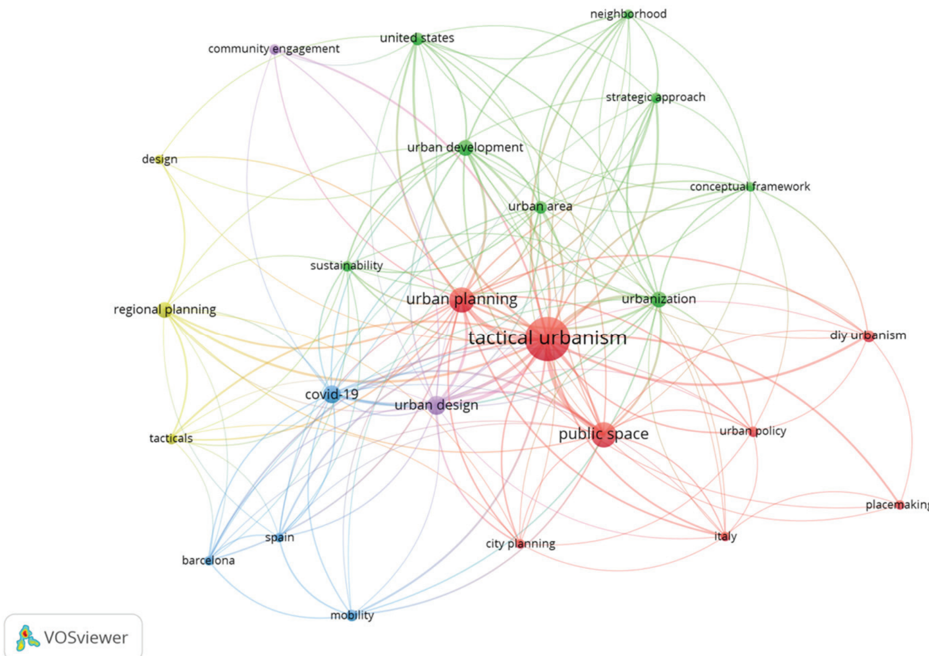

Figure 3. Keyword co-occurrence network developed with VOSviewer version 1.6.17.

Focusing on the Italian context, a total of 18 papers resulted from the analysis, which is in line with the trend previously highlighted; the majority (in fact, 75%) were published from 2020 onward, and they touch on several topics. For instance, [42,43] discuss the role of active travel in increasing the resilience of urban transport systems, describing the main policies implemented in various pandemic phases and stressing the importance of tactical urbanism interventions to support walking and cycling. Meanwhile, [44] illustrates two case studies, one in Paris and one in Rome, of the temporary (re)use of vacant spaces, underlining the importance of local communities, while [45] defines a qualitative matrix to evaluate the effectiveness of the project over time. Furthermore, [46] explores the role of temporary gardens in tactical urbanism. Additionally, [47,48] present the concept of the 15-minute city, connecting it to the potentials of tactical urbanism actions conceived as long-term strategies to regenerate open spaces. In this context, [49] describes, in addition to tactical urbanism, two other approaches to design the urban space, proposing an intervention located in the city of Milan where two types of software have been applied to estimate the environmental benefits generated. Also, [24,50] recognizes the strength of these kinds of strategies for fostering transformations belonging to a strategic vision, and [48,51] list tactical urbanism among the strategies to design "Healthy and Salutogenic cities." At the same time, [52–55] critically discuss their pros and cons and the possible negative effects, such as lines of tensions and social inequalities. Meanwhile, [56] combines digitalization with the concept of tactical urbanism actions to make more inclusive cities, while [57] experiments with Information and Communication Technologies (ICT). All these contributions highlight the importance of community engagement alongside the process of concept design to increase citizens' interest in planning choices [58] and in regeneration activities; experimenting, for example, with do-it-yourself (DIY) urban practices [59].

Despite the interest detected from the analysis of the literature in tactical urbanism and the wide span of topics described (including social engagement, environmental benefits, mobility issues, and urban resilience), there are no studies focused on investigating its economic effect. In order to fill this gap highlighted by the literature review on tactical urbanism, the next section is focused on understanding if and to what extent tactical urbanism interventions, as small-scale and minimal urban regeneration processes, can trigger economic dynamics by adopting the lens of real estate values. The methodology adopted is based on the analysis of different Italian case studies belonging to different realities in scale and real estate dynamics.

4. Case Studies Analysis

The willingness to understand if and to what extent tactical urbanism interventions, as small-scale and minimal urban regeneration processes, can trigger economic dynamics has led to delving into analyzing some Italian case studies.

The bottom-up and participatory nature of many tactical urbanism experiences brings along the high social potential of this innovative approach to urban planning [60]. However, there is no clear evidence related to the economic impacts of tactical urbanism interventions, which is also because these experiments arise as temporary and they are relatively recent [24]. Based on these reasons, this analysis tries to assess the economic impacts of tactical urbanism interventions by adopting the lens of real estate values as a suitable proxy when dealing with urban environments [61].

In greater detail, this analysis compares residential market and rent values trends in each selected case study's influence area with the same trend related to a larger territorial scale. This comparison allows an understanding of whether areas affected by tactical urbanism interventions show higher growth in the considered values in a specific period, thus providing preliminary insight into these temporary approaches' economic impacts and these impacts' relationships with different territorial contexts.

Indeed, the reference territorial context's conditions (i.e., the existing urban attractiveness or the tactical urbanism's integration within a broader urban regeneration strategic framework) can heavily and diversely affect its response to tactical experiments and these experiences' impacts on the real estate market.

Such relationships between the single intervention and its reference territorial context are crucial for outlining an assessment of tactical urbanism's economic impacts, even if preliminary and partial. For this reason, this analysis considers different tactical urbanism case studies in the Italian context belonging to different realities in scale and real estate dynamics. These case studies can be traced back to two main groups:

- *Tactical urbanism experiences in Italy.* This group involves tactical urbanism case studies in different Italian cities mainly characterized by negative or stagnant trends in real estate values [62];
- *Tactical urbanism experiences in Milan.* This group involves tactical urbanism experiences in Milan, whose real estate market stands as an outlier in the national context due to prices' order of magnitude and their dramatic growth in the last decades. Furthermore, these experiences belong to an institutional and strategic program launched by the Milan municipality in 2018: the *Piazze Aperte Program* [63].

4.1. Tactical Urbanism Experiences in Italy

In recent years, the Italian planning scenery has seen the birth of different tactical urbanism experiences, which stand as innovation and experimentation opportunities starting from different places. These experiences are often led by active citizens and advocacy planners and share some main intervention approaches, such as the self-construction of neglected and marginal public spaces or transforming streets or parking lots into public spaces [62]. Among them, this study deals with ten different tactical urbanism experiments, which stand as a representative case studies sample in terms of intervention approaches, geographical localization, the reference urban context's scale, real estate market dynamics, and the implementation year (Figure 4):

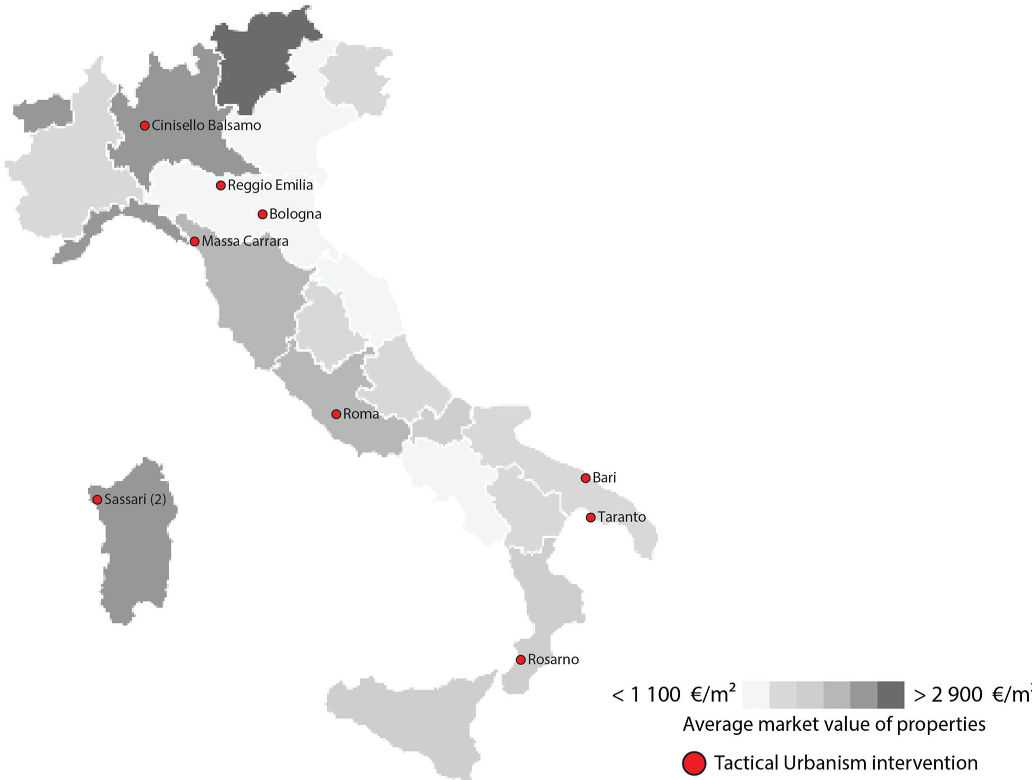

Figure 4. Tactical urbanism interventions in Italy.

1. *Park-Urka* in Taranto. This tactical urbanism experiment, dating back to 2009, aims at creating a new playground in one of the city's squares through a participatory design and a construction workshop [64].
2. *Open Bricolage* in Rome. This intervention, included in a broader urban regeneration initiative developed in Rome between 2011 and 2012, provides a residual and neglected public space in Via Fortebraccio with new equipment inspired by the domestic environment [65].
3. *Costruire Largo Milano* in Cinisello Balsamo. This experience resulted from a six-month project developed in 2013 that transformed a former parking lot into a multi-functional public space by resorting to participatory artistic and self-construction workshops [66].
4. *Parking day* in Massa Carrara. This tactical urbanism experience, dating back to 2013, works on transforming a parking lot into a square to be lived in by local communities [67].
5. *Relazioni-Cantiere Aperto* in Rosarno. This intervention, resulting from a collaborative process based on active citizens' involvement in 2013, aims at transforming a harsh and unsafe space into a public space for playing and open-air social events [62].
6. *FLPP—Contro-occupazione di un micro-spazio invaso dalle automobili* in Sassari. This 2015 tactical experiment provides the *San Donato* district with a new public space near a primary school by releasing it from cars [68].
7. *Dispersione zero* in Sassari. This experiment, developed in 2015 and funded by a program to tackle school dropout, works on transforming the pavement leading to the school through the use of colors and wood construction [69].

8. *Piazza del Popol Giost* in Reggio Emilia. This intervention, made in 2020 in Reggio Emilia's historical center, transforms the open space in front of a school from parking to a livable space with urban furniture [70].
9. *Piazza Santa Maria del Fonte* in Bari. This intervention is conceived within the *Open Space* program, launched by the Bari municipality in 2020, to promote sustainable mobility and public spaces, thus meeting the new needs raised by the COVID-19 pandemic. It involves square pedestrianization and its equipment includes pavement painting and urban furniture [71].
10. *Via Milano* in Bologna. This tactical urbanism experiment, developed in 2021, aims for a new spatial configuration and the pedestrianization of Via Milano, a street with no specific relevance in the urban mobility system [72].

These different experiences are taken as case studies toward a preliminary investigation of the economic impacts of tactical urbanism interventions through the real estate market lens. In this sense, each intervention's influence area's average residential market value trend is compared with the same for the whole municipality.

The tactical intervention's influence area in this analysis, referring to the whole Italian context, is placed as equal to the reference municipality micro-zone as defined by *Immobiliare.it*, one of the leading real estate platforms in Italy [73]. The choice of this platform for the municipalities' zoning and, as a consequence, for data mining, lies in its providing a more detailed division of municipal territories in micro-zones, according to a homogeneity criterion for real estate market conditions, than the official database (e.g., developed by Agenzia delle Entrate, a tax agency of the Italian public administration under the Ministry of Economy and Finance) of real estate prices (Osservatorio del Mercato Immobiliare—OMI) [74].

However, because *Immobiliare.it* provides data about real estate offer prices starting from 2014, this analysis focuses on case studies dated after 2014, thus allowing for making some comments on the possible impacts of tactical urbanism interventions on real estate price variation (Table 1, Figure 5).

Table 1. Comparison of residential assets' average market value trends in the tactical urbanism intervention's influence area and in the whole municipality between 2014 and 2022 (authors' elaboration on *Immobiliare.it* data).

ID	Year	Tactical Urbanism Intervention	Average Residential Market Value (€/sqm)				Average Residential Market Value Variation (%)		
			Aug 2014	**Jan 2017**	**Jan 2020**	**Oct 2022**	**14–22**	**17–22**	**20–22**
1	2015	*FLPP*	1201	1108	957	1031	−14.15%	−6.95%	7.73%
	2015	*Dispersione zero*	1362	1241	1141	1240	−8.96%	−0.08%	8.68%
	-	**SASSARI**	**1453**	**1291**	**1234**	**1239**	**−14.73%**	**−4.03%**	**0.41%**
2	2020	*Piazza del Popol Giost*	1573	1430	1504	1821	15.77%	27.34%	21.08%
	-	**REGGIO EMILIA**	**1633**	**1479**	**1531**	**1822**	**11.57%**	**23.19%**	**19.01%**
3	2020	*Piazza Santa Maria del Fonte*	2050	1690	1460	1441	−29.71%	−14.73%	−1.30%
	-	**BARI**	**2258**	**2025**	**1823**	**1880**	**−16.74%**	**−7.16%**	**3.13%**
4	2021	*Via Milano*	2575	2579	2854	2912	13.09%	12.91%	2.03%
	-	**BOLOGNA**	**2753**	**2620**	**3010**	**3239**	**17.65%**	**23.63%**	**7.61%**

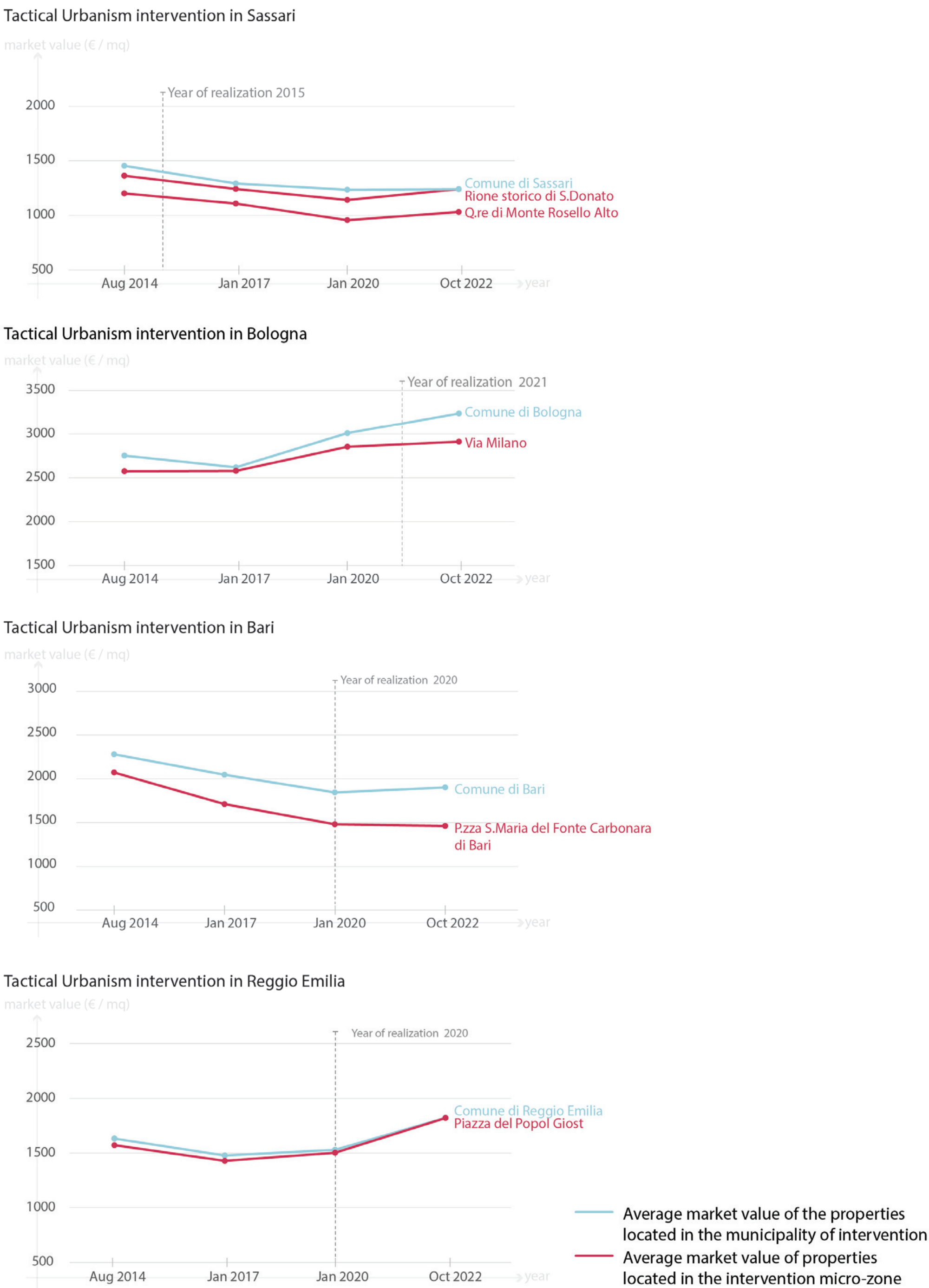

Figure 5. Average market value in the city and micro-zone where the tactical urbanism interventions have been developed.

This preliminary comparison reveals that it is impossible to make general comments on the impacts of tactical urbanism interventions on the real estate market dynamics; instead, a case-by-case approach to this investigation is required. Indeed, these small-scale urban regeneration experiments are related to the average market value variation in different ways.

For instance, in Sassari, where the real estate market is affected by a steady depression in values with some recovery signals in recent years, the comparison with the average market value trends at the municipality level shows a possible positive impact of tactical urbanism interventions. Indeed, in both areas affected by these urban regeneration experiments, the market dynamics are more positive than the average municipal ones. In this sense, these interventions can be considered responsible for re-aligning market values in the influence area to the municipality level. In the case studies of Bari and Bologna, the residential assets' market value variation in tactical urbanism experiences' influence areas follows the same trend observed at the municipality level, thus hinting at no specific influence of these interventions on real estate market dynamics. However, it is worth mentioning that, except for Sassari, the analyzed experiences refer to 2020 and 2021; thus, the limited observation period can affect the results of this investigation.

4.2. Tactical Urbanism Experiences in Milan: The Piazze Aperte Program

The investigation of the possible economic impacts related to tactical urbanism interventions through the real estate market lens can be better focused by analyzing the case of Milan, which hosts the most relevant and widespread experience of tactical urbanism in Italy. This experience is related to the *Piazze Aperte* (Open Squares) program, launched by the Milan municipality in 2018 to bring open spaces back to the center of neighborhood spatial systems and communities' lives. It is devoted to converting former streets and parking areas into equipped public spaces through tactical urbanism techniques [63]. The *Piazze Aperte* program stands as a valuable case study for attempting to understand tactical urbanism interventions from an economic point of view for two main reasons:

- The typology of the tactical interventions, which can be traced to the domain of "temporariness as policy" approach. In greater detail, its applications can be read as "phase 0" tools used by the Milan municipality to test interventions before their permanent implementation. Most of these interventions, after a preliminary "test" phase, have been made permanent, thus allowing for the presence of a long-term perspective, which is essential for investigating economic impacts.
- The high number of implemented interventions. This program has allowed for the development of 40 tactical urbanism interventions from 2018 to 2022, thus making more than 25,000 sqm of public spaces pedestrian and livable thanks to the installation of new furniture, benches, flower pots, and ping pong tables. This program has also been supported and extended by the public notice *Piazze Aperte in ogni quartiere* (squares open in every neighborhood), launched by the Milan municipality in 2019 to identify new spaces for transformation [75]. Thanks to this, citizens' involvement, considered a crucial factor for the program's success, has been widened to each step of the process: from the area proposal to the co-design and the realization of interventions [76].

Concerning the analysis of the possible economic impacts related to tactical urbanism in Milan, it moves to consider the 38 experiences implemented by the municipality between 2018 and 2021. They are widespread across the municipal territory, especially in its peripheral area, because they are conceived in a strategic framework toward promoting urban regeneration in all of the city's neighborhoods (Figure 6). Focusing on these 38 case studies, as already performed for the experiences in other Italian contexts, the analysis compares the residential assets' market value trends in the intervention's influence area between 2015 and 2022 with the same trend observed at the municipal scale (Table 2). The choice to include in the time horizon the period of 2015–2017, which is not affected by the considered interventions' implementation, rests on the willingness to reflect on tactical urbanism's possible impacts by relating them to a broader reference zone's real estate dynamic. Also, in this case, the reference for the influence zones' definition and data is identified in the *Immobiliare.it* database.

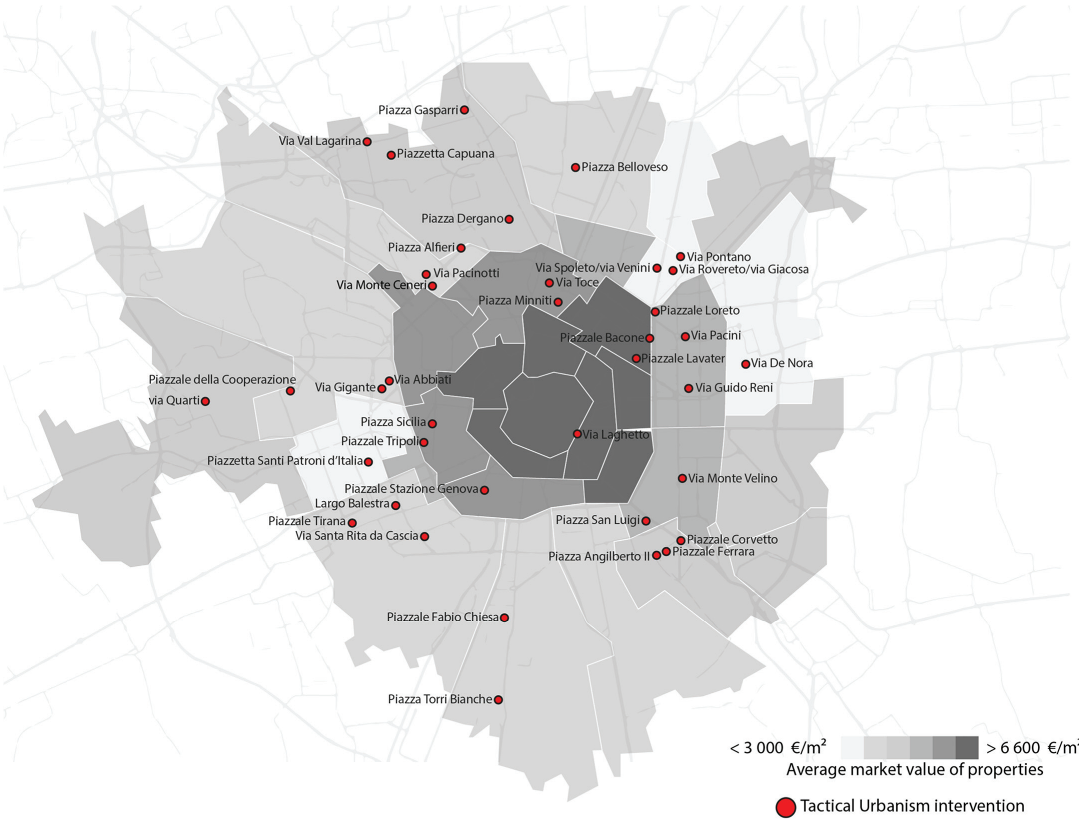

Figure 6. Tactical urbanism intervention in Milan.

This preliminary analysis of the Milan context shows that, as for the other experiences selected in the national territory, it is impossible to infer a univocal effect of tactical urbanism experiences on the real estate market trends. However, by considering the residential assets' market value variation between 2020 and 2022, it is possible to observe that, in more than 70% of the case studies' influence areas, the market value variation is higher than the average one referring to the whole municipal territory. This result suggests the existence of a limited positive economic impact of tactical urbanism interventions, but it must also be taken with caution, because it represents only a part of the broader projects portfolio implemented in the Milan municipality to trigger urban regeneration [77]. In this sense, it can be worth narrowing the analysis's observation scale by focusing on a limited number of case studies and by looking at them in a smaller territorial context. Such a narrowing allows, on the one hand, to adopt a more detailed and suitable perspective for these small-scale and minimal interventions. On the other hand, it enables the recognition of related urban regeneration projects to consider them in assessing tactical urbanism's impacts through the real estate market lens.

Table 2. Comparison of residential assets' average market value trends in the tactical urbanism intervention's influence area and in the Milan municipality between 2015 and 2022 (authors' elaboration on *Immobiliare.it* data).

ID	Year	Tactical Urbanism Intervention	Average Residential Market Value (€/sqm)				Average Residential Market Value Variation (%)		
			Jan 2015	Jan 2017	Jan 2020	Oct 2022	15–17	17–20	20–22
1	2018	*Piazza San Luigi*	3185	3268	3833	4801	2.61% *	17.29%	25.3% *
2	2018	*Piazza Angilberto II*	2518	2386	2962	3735	−5.24%	24.14% *	26.1% *
3	2018	*Piazza Dergano*	2414	2296	2603	3292	−4.89%	13.37%	26.5% *
4	2019	*Via Spoleto*/Via *Venini*	2736	2712	3434	4346	−0.88% *	26.62% *	26.6% *
5	2019	*Piazzale Stazione Genova*	5641	5802	7202	7347	2.85% *	24.13% *	2.0%
6	2019	*Piazza Gasparri*	2414	2296	2603	3292	−4.89%	13.37%	26.5% *
7	2019	*Porta Belloveso*	2481	2386	2857	3521	−3.83%	19.74%	23.2% *
8	2019	*Piazzale Lavater*	4278	4226	5486	6303	−1.22%	29.82% *	14.9%
9	2019	*P.le della Cooperazione*	2250	2113	2218	2658	−6.09%	4.97%	19.8% *
10	2019	*Piazzale Corvetto*	2518	2386	2962	3735	−5.24%	24.14% *	26.1% *
11	2019	*Piazza Alfieri*	2956	2845	3182	3558	−3.76%	11.85%	11.8%
12	2019	*Via Abbiati*	2956	2845	3182	3558	−3.76%	11.85%	11.8%
13	2019	*Via Guido Reni*	3637	3517	4605	5251	−3.30%	30.94% *	14.0%
14	2019	*Santa Rita da Cascia*	2830	2799	3227	3874	−1.10% *	15.29%	20.0% *
15	2019	*Via Gigante*	2956	2845	3182	3558	−3.76%	11.85%	11.8%
16	2019	*Via Rovereto*/via *Giacosa*	2736	2712	3434	4346	−0.88% *	26.62% *	26.6% *
17	2020	*Piazza Sicilia*	4793	4874	6080	6452	1.69% *	24.74% *	6.1%
18	2020	*Piazza Minniti*	3872	4098	5206	6108	5.84% *	27.04% *	17.3% *
19	2020	*Largo Balestra, Giambellino*	2830	2799	3227	3874	−1.10% *	15.29%	20.0% *
20	2020	*Via Pacini*	3637	3517	4605	5251	−3.30%	30.94% *	14.0%
21	2020	*Piazzale Tripoli,* Via *Zanzur*	3521	3450	4436	4862	−2.02%	28.58% *	9.6%
22	2020	*Via Monte Velino*	3185	3268	3833	4801	2.61% *	17.29%	25.3% *
23	2020	*Via Laghetto*	7794	7895	9259	9879	1.30% *	17.28%	6.7%
24	2020	*Via Toce*	3872	4098	5206	6108	5.84% *	27.04% *	17.3% *
25	2020	*Piazzale Fabio Chiesa*	2951	2838	3231	4083	−3.83%	13.85%	26.4% *
26	2020	*Via Val Lagarina*	2414	2296	2603	3292	−4.89%	13.37%	26.5% *
27	2020	*Via Pontano*	2736	2712	3434	4346	−0.88% *	26.62% *	26.6% *

Table 2. *Cont.*

ID	Year	Tactical Urbanism Intervention	Average Residential Market Value (€/sqm)				Average Residential Market Value Variation (%)		
			Jan 2015	**Jan 2017**	**Jan 2020**	**Oct 2022**	**15–17**	**17–20**	**20–22**
28	2020	*Piazza Tirana*	2830	2799	3227	3874	−1.10% *	15.29%	20.0% *
29	2020	*Piazzetta Capuana*	2414	2296	2603	3292	−4.89%	13.37%	26.5% *
30	2020	*Piazzale Ferrara*	2518	2386	2962	3735	−5.24%	24.14% *	26.1% *
31	2020	*Piazzale Loreto*	2736	2712	3434	4346	−0.88% *	26.62% *	26.6% *
32	2020	*Via Quarti*	2250	2113	2218	2658	−6.09%	4.97%	19.8% *
33	2020	*Via Monte Ceneri*	2641	2444	2858	3643	−7.46%	16.94%	27.5% *
34	2020	*Via Pacinotti*	2641	2444	2858	3643	−7.46%	16.94%	27.5% *
35	2021	*Piazzale Bacone*	4278	4226	5486	6303	−1.22%	29.82% *	14.9%
36	2021	*Piazzetta Santi Patroni d'Italia*	3107	3053	3641	4341	−1.74%	19.26%	19.2% *
37	2021	*Piazza Torri Bianche*	2951	2838	3231	4083	−3.83%	13.85%	26.4% *
38	2021	*Via De Nora*	2827	2870	3264	3956	1.52% *	13.73%	21.2% *
		MILAN	**3745**	**3702**	**4476**	**5150**	**−1.15%**	**20.91%**	**15.1%**

* Values highlighted in grey refer to a market value variation higher than the average one at the municipal level in the considered period.

4.3. Narrowing the Observation Scale: the Case of NoLo

The willingness to narrow the investigation scale has led to detailing the market value trends analysis to one of the Milan real estate market's micro-zones, as defined by *Immobiliare.it*: the *Pasteur–Rovereto* zone in the northeastern part of Milan. This zone includes four tactical urbanism interventions promoted by the Milan municipality within the *Piazze Aperte* program [75]:

- *Via Spoleto*/Via *Venini.* This pivotal intervention for tactical urbanism in Milan, implemented in 2019, works on transforming a crossroads into a square, thus creating a public space in close relationship with the school facing it and determining the existing roads' and traffic system's redesign;
- *Via Rovereto*/via *Giacosa.* This tactical urbanism experiment, dating back to 2019, focuses on creating a green buffer area between the neighborhood and *Trotter Park*, which is the main green space in the area;
- *Via Pontano*. This intervention, implemented in 2020, is conceived in a bigger regeneration process of the railway front and tunnels in the area, the *Tunnel Boulevard Plan,* based on social design and street art actions. In greater detail, the tactical urbanism intervention focuses on a crossroads transformation to connect the main public spaces in the area from a soft mobility perspective;
- *Piazzale Loreto*. This 2020 tactical urbanism experience releases a residual space of the road system from cars and returns it to the local community by endowing it with urban furniture.

In recent years, as mentioned when describing the Via *Pontano* intervention, the *Rovereto–Pasteur* area has been affected by several *bottom-up* urban regeneration initiatives triggered by a neighborhood rebranding operation around the name NoLo (which stands for North of Loreto). This regeneration process has dramatically changed this area's image and role within Milan's social and cultural life context.

The focus on tactical urbanism case studies in this area thus makes it possible to reflect on the impact of these interventions according to their different relationships with a broader urban regeneration process and with complementary specific actions.

Coming to the analysis, the comparison between the residential market value trends in the tactical urbanism experience's influence area and its broader territorial context can be further detailed than the previous analyses in the Italian context and the whole Milan municipality. In this sense, each intervention's influence zone can be identified in the area falling within an 800 m radius from the tactical urbanism experience's localization; since this distance, as mentioned in the *Piazze Aperte* program, corresponds to 15 min walking distance [78].

The reference data are still retrieved from *Immobiliare.it.* In greater detail, the average market value trends for the 800 m radius influence areas are built by considering the offer market values for residential assets (Figure 7) in the area in reference to three different times: January 2017, January 2020, and October 2022 (Table 3). Instead, the trends for the broader territorial context for comparison are built by considering the average market values for residential assets in the micro-zone *Pasteur–Rovereto*.

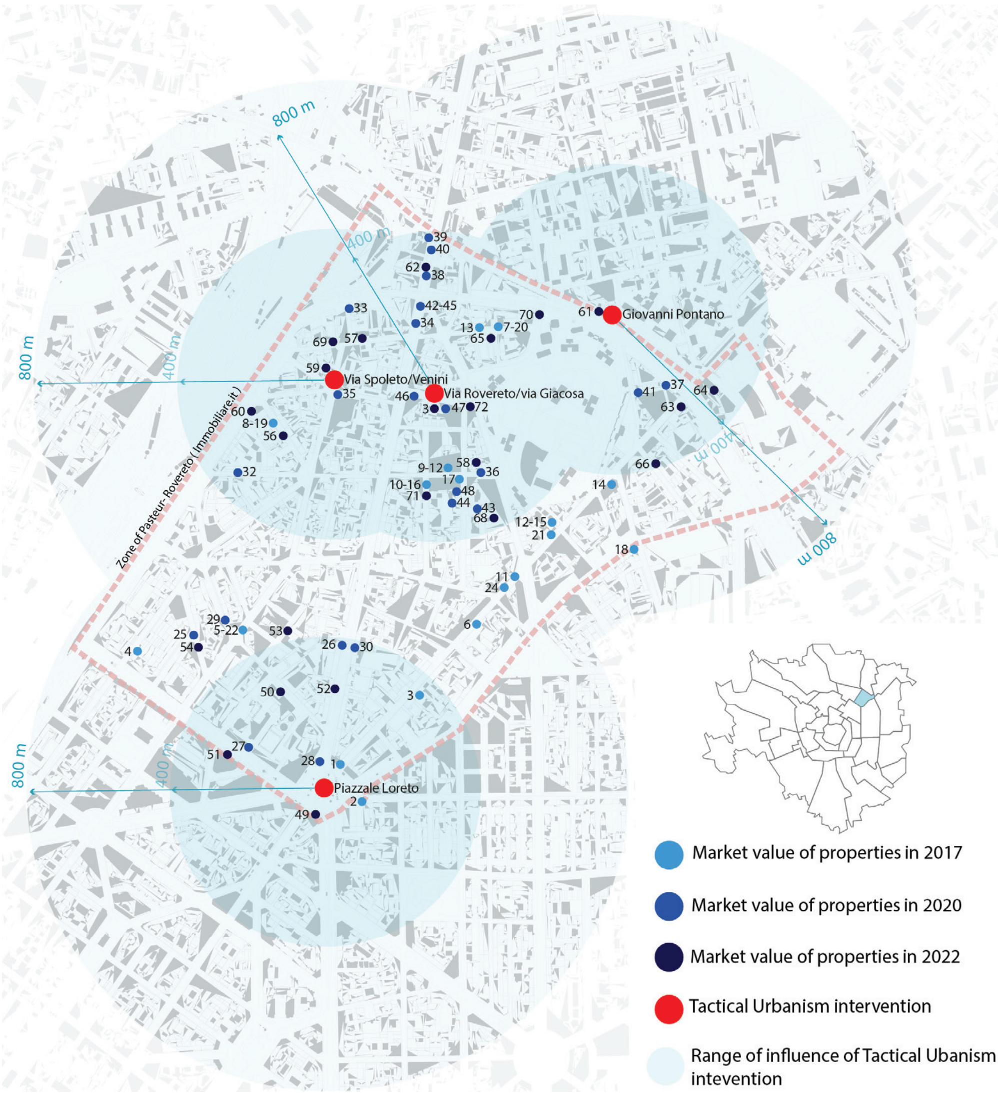

Figure 7. Variation in the market value of properties in the NoLo neighborhood.

Table 3. Average market value calculation for residential assets in each intervention's 800 m radius influence area in reference to 2017, 2020, and 2022 (authors' elaboration on *Immobiliare.it* data).

Tactical Urbanism Intervention: Via *Spoleto*/Via *Venini*								
2017			**2020**			**2022**		
ID	**Asset's Address**	**Value [€/sqm]**	**ID**	**Asset's Address**	**Value [€/sqm]**	**ID**	**Asset's Address**	**Value [€/sqm]**
1	Via Bolzano 22	2800.00 €	6	Via S. Alessandro Sauli 18	4214.28 €	11	Via Nicola d'Apulia 13	4438.46 €
2	Via Nicola d'Apulia 13	2882.35 €	7	Via Luigi Varanini 29	3980.00 €	12	Via Popoli Uniti	4700.00 €
3	Via Pietro Crespi 12	2360.00 €	8	Viale Monza 79	4428.57 €	13	Via Varanini 26	4838.24 €
4	Via Termopili 27	2750.00 €	9	Martiri Oscuri 8	3100.00 €	14	Via Spoleto 2	3813.01 €
5	Via Padova 31	2653.33 €	10	Via Luigi Varanini 1	4285.71 €	15	Via Ferrante Aporti 54	4600.00 €
Average market value in the influence area (*Spoleto*)		**2689.14 €**	**Average market value in the influence area (*Spoleto*)**		**4001.71 €**	**Average market value in the influence area (*Spoleto*)**		**4477.94 €**
Tactical urbanism intervention: Via *Rovereto*/Via *Giacosa*								
2017			**2020**			**2022**		
ID	**Asset's address**	**Value [€/sqm]**	**ID**	**Asset's address**	**Value [€/sqm]**	**ID**	**Asset's address**	**Value [€/sqm]**
16	Via Nicola d'Apulia 13	2882.35 €	21	Via Marco Aurelio 32	4960.00 €	26	Via Rovereto 3	4636.36 €
17	Via Bolzano 22	2800.00 €	22	Via dei Transiti 26	5000.00 €	27	Via Marco Aurelio 44	5208.33 €
18	Via Oldrado da Tresseno 1	3660.38 €	23	Via Rovereto 6	3691.30 €	28	Via Popoli Uniti 23	4985.71 €
19	Via Pietro Crespi 12	2360.00 €	24	Via Rovereto 5	4469.38 €	29	Via Felicita Morandi 11	4384.62 €
20	Via Padova 30	2653.33 €	25	Via Pietro Crespi 10	2761.00 €	30	Via Giuseppe Giacosa 55	5044.78 €
Average market value in the influence area (*Rovereto*)		**2871.21 €**	**Average market value in the influence area (*Rovereto*)**		**4176.34 €**	**Average market value in the influence area (*Rovereto*)**		**4851.96 €**
Tactical urbanism intervention: Via *Pontano*								
2017			**2020**			**2022**		
ID	**Asset's address**	**Value [€/sqm]**	**ID**	**Asset's address**	**Value [€/sqm]**	**ID**	**Asset's address**	**Value [€/sqm]**
31	Via Bolzano 23	2225.81 €	36	Via Bassano del Grappa 17	3930.23 €	41	Viale Monza 92	3777.78 €
32	Via Padova 90	2461.54 €	37	Viale Monza 90	2250.00 €	42	Viale Padova 100	3750.00 €
33	Via Padova 55	4326.92 €	38	Viale Monza 101	3055.55 €	43	Via Carlo Esterle 25	4000.00 €
34	Via Termopili 27	2750.00 €	39	Via Bassano del Grappa 1	3333.33 €	44	Via Bolzano 21	4071.43 €

Table 3. *Cont.*

Tactical Urbanism Intervention: Via *Spoleto*/Via *Venini*								
2017			**2020**			**2022**		
ID	**Asset's Address**	**Value [€/sqm]**	**ID**	**Asset's Address**	**Value [€/sqm]**	**ID**	**Asset's Address**	**Value [€/sqm]**
35	Via Pietro Crespi 13	3380.00 €	40	Viale Monza 81	5142.00 €	45	Via Arquà 14	4166.67 €
Average market value in the influence area (*Pontano*)		**3028.85 €**	**Average market value in the influence area (*Pontano*)**		**3542.22 €**	**Average market value in the influence area (*Pontano*)**		**4302.06 €**
Tactical urbanism intervention: *Piazzale Loreto*								
2017			**2020**			**2022**		
ID	**Asset's address**	**Value [€/sqm]**	**ID**	**Asset's address**	**Value [€/sqm]**	**ID**	**Asset's address**	**Value [€/sqm]**
46	Piazzale Loreto	3940.59 €	51	Via Pietro Marocco 12	3620.68 €	56	Piazzale Loreto	5284.55 €
47	Via Ricordi	3613.45 €	52	Viale Monza 23	4090.90 €	57	Via Natale Battaglia	5686.27 €
48	Via Soperga 36	4133.33 €	53	Viale Brianza 12	4318.18 €	58	Viale Brianza 9, Centrale	4491.02 €
49	Via Oldrado da Tresseno 1	3660.38 €	54	Via Natale Battaglia 29	4102.50 €	59	Viale Privata Pomezia	5288.24 €
50	Via Padova 31	2653.33 €	55	Viale Monza 18	4781.91 €	60	Via Pietro Marocco 7	6390.00 €
Average market value in the influence area (*Loreto*)		**3600.22 €**	**Average market value in the influence area (*Loreto*)**		**4176.34 €**	**Average market value in the influence area (*Loreto*)**		**4851.96 €**

The market value trends comparison (Table 4) clearly shows how the *Pasteur–Rovereto* area has been affected by a dramatic increase in market values in recent years. Concerning the economic impacts of tactical urbanism interventions, even this smaller-scale observation reveals the impossibility of outlining a homogeneous pattern.

Table 4. Comparison of residential assets' average market value trends in the tactical urbanism intervention's influence area and in the Pasteur–Rovereto zone between 2017 and 2022 (authors' elaboration on *Immobiliare.it* data).

ID	**Year**	**Tactical Urbanism Intervention**	**Average Residential Market Value (€/sqm)**			**Average Residential Market Value Variation (%)**		
			2017	**2020**	**2022**	**17–20**	**20–22**	**17–22**
4	2019	*Via Spoleto*/Via *Venini*	2689	4002	4478	48.81% *	11.90%	66.52% *
16	2019	*Via Rovereto*/via *Giacosa*	2871	4176	4852	45.46% *	16.18%	68.99% *
27	2020	*Via Pontano*	3029	3542	4302	16.95%	21.45%	42.04%
31	2020	*Piazzale Loreto*	3600	4183	5428	16.18%	29.77% *	50.77%
	PASTEUR—ROVERETO		**2712**	**3434**	**4346**	**26.62%**	**26.56%**	**60.25%**

* Values highlighted in grey refer to a market value variation higher than the average one at the municipal level in the considered period.

Indeed, in *Piazzale Loreto*'s, Via *Pontano's,* and Via *Rovereto/Via Giacosa's* influence areas, the market value variation follows the same increasing trend observed for the whole *Pasteur–Rovereto* microzone (Figure 8). However, in the Via *Pontano* intervention's influence area, which is affected by a broader regeneration plan, the tactical urbanism experience's economic impact does not emerge. Instead, in *Piazzale Loreto* and Via *Rovereto,* the comparison returns a possible positive impact of the analyzed interventions in the influence area's residential market values' growth. Finally, a different pattern can be observed in Via *Spoleto*/Via *Venini's* influence area (Figure 9). Here, looking at the values' variation between 2017 and 2022, the tactical urbanism intervention seems to have a positive economic impact in the short run and then, in the following years, it is absorbed by the overall market values' increase related to the whole area's regeneration.

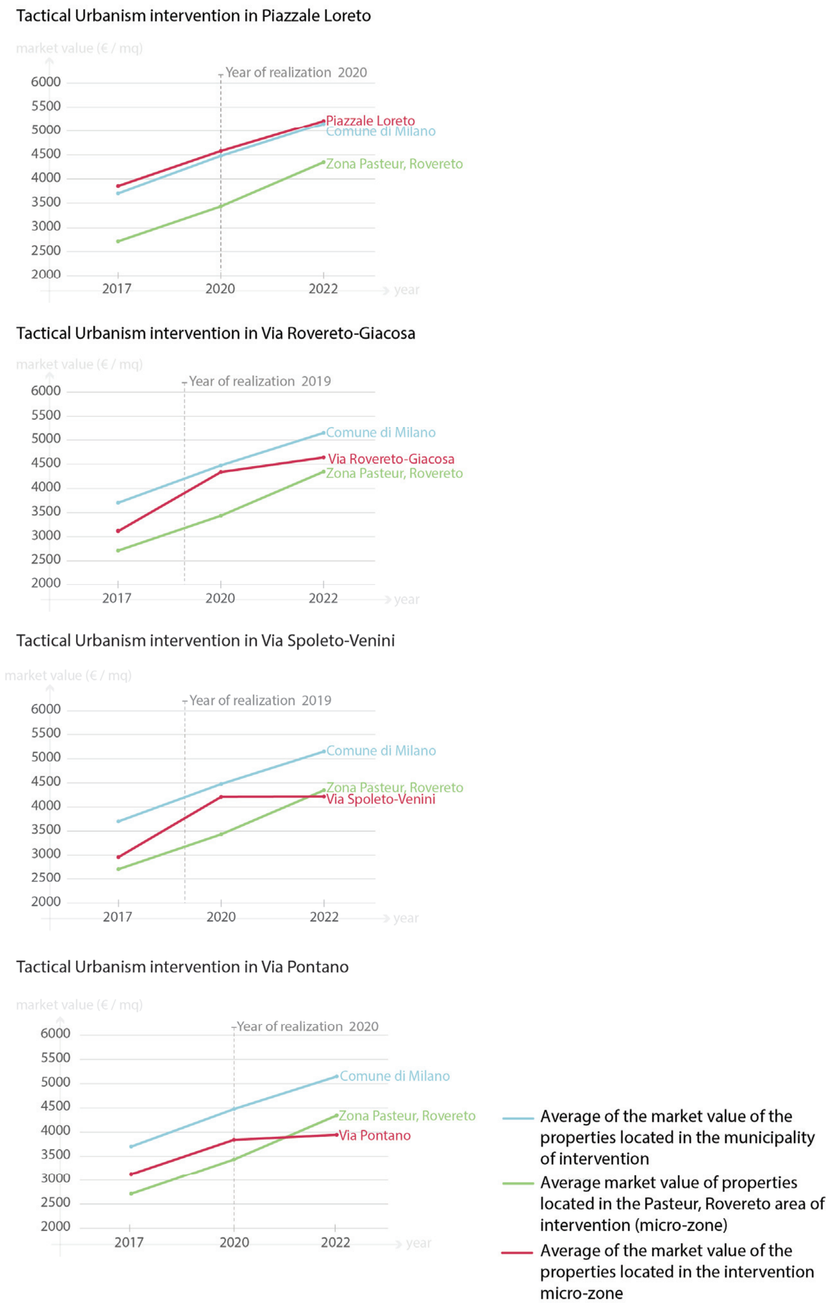

Figure 8. Variation in the market value of properties in different years.

Figure 9. Via Spoleto/Venini tactical urbanism interventions.

5. Discussion and Conclusions

The analysis carried out aimed to assess the economic impacts related to tactical urban planning interventions by looking at them through the lens of the residential real estate market. The focus on the various case studies selected within the national context, and, in more detail, in the municipality of Milan, returns a fairly diversified picture concerning the assessment of the possible economic impacts of similar experiences. In fact, in the cases of Sassari and Reggio Emilia, the tactical urban planning interventions implemented seem to play a role in triggering a positive trend in market values in the respective areas of influence. In contrast, real estate dynamics in the areas subject to tactical urbanism experiences in Bari and Bologna do not seem to be affected by the presence of such interventions. Even in Milan, where the multiple experiences of tactical urbanism are part of a broader strategic design of regeneration, traceable to the application domain of "temporariness as policy," the evaluation conducted returns diversified results: in the cases of *Piazzale Loreto,* Via *Rovereto*, and Via *Spoleto*/Via *Venini*, it is possible to identify an (albeit limited) influence of such interventions on the growth of real estate values in the respective areas of influence; in other cases, such as that of Via *Pontano*, instead, real estate dynamics seem indifferent to the presence of the tactical experience.

The synthesis of the analyses of the various case studies, with their differences in terms of spatial context and reference real estate market, as well as the modalities and outcomes of the tactical urban planning experience, therefore, does not allow for an unambiguous answer to the research question about the economic impacts of such interventions. It is also complicated, on the one hand, by the fact that most interventions, especially those in Milan, are recent, and, therefore, there is no medium- to long-term time horizon, which is more appropriate to the analysis and evaluation of interventions at the urban scale. On the other hand, most of the experiences of tactical urbanism have been carried out on the back of, or, in conjunction with, the COVID-19 pandemic, which, having profoundly altered the dynamics of the real estate market at the national level, constitutes an element of further complication with respect to the reading of such experiences in terms of economic impacts.

What emerges from the analysis in its current stage is that the experiences of tactical urbanism, partly because of their temporary nature and their tendency toward minimal intervention, fail to trigger regeneration processes or to produce significant economic impacts on the territory. Evidence, in this sense, can be retrieved by comparing the market value trends in the influence areas of the Via *Spoleto/Venini* and Via *Rovereto/via Giacosa* interventions. Indeed, despite the two interventions' proximity, it is not possible to observe a synergistic effect on property prices, thus returning the tactical urbanism interventions' presence as a "weak" influence factor in determining property prices. Instead, as seems to have happened and is happening in Milan in recent years, such experiences can play a role in accelerating or consolidating urban regeneration processes already underway, and, in this sense, contributing to the generation of economic impact on the territory. This analysis, therefore, prompts one to look at such interventions through the social impacts they can produce on local areas and their communities, rather than in terms of economic impacts.

Based on this awareness, a future development of this research could be the integration of the proposed methodological approach with the Hedonic Price Method (HPM). This implementation could allow for quantifying the economic impact of tactical urbanism interventions on properties' values. Moreover, it would be interesting to broaden the scope of the investigation to other market sectors, such as offices and commercial services, as well as enlarge the analysis of the evaluation of the social and environmental impacts of such interventions. Actually, tactical urbanism projects also have the potential to support economic revitalization by bringing more people in front of local businesses. The new use of space to promote economic activities may serve as an opportunity to recover and adapt to the new economic reality after the pandemic period. In fact, it is interesting to underline how the number of restaurants in the neighborhood taken as the reference for the last level of analysis increased by about 200%. This evidence cannot only be associated with the presence of tactical urbanism interventions, but, of course, there is a strong correlation with the overall attractiveness of the area and its local identity. Given the high number of variables that deserve to be analyzed to understand the impact of these projects under an economic perspective, the next phase of the research is grounded in the application of a multidimensional methodology, as shown in the initial framework. The limitations that emerged from this first exploratory part reinforce the need to look at these interventions with a lens not only related to the real estate market.

Tactical urbanism is a method of rapid, low-cost project implementation using a set of techniques designed to enhance the built environment with the intent of bringing about long-term positive outcomes for the community. In this sense, it will be necessary to verify whether there will be the desired connection between the short time of temporary use projects and the reversibility of tactical interventions with the long time of long-term territorial regeneration projects.

At the methodological level, it is evident that an approach based only on the analysis of case studies with reference to residential real estate market values presents limits in capturing the added value in economic and social terms produced by such interventions.

Innovative approaches based on multidimensional values, such as the Discrete Choice Experiment (DCE) or Impact Analysis, could be tested in order to measure the social and environmental values produced compared to the investment costs.

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Article

Towards European Transitions: Indicators for the Development of Marginal Urban Regions

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Abstract: Urban transitions and urban-scape have been heavily impacted by the COVID-19 pandemic and will likely be affected by the current Ukrainian-Russian conflict. These two major events have affected European urban regions and especially marginal regions. Indeed, these regions are mostly struggling with inequality, lack of optionality, interoperability, and resilience due to their energy dependency and digital asymmetries. The continuous demand for a green and digital transition to strengthen social and economic resilience sought and targeted by the European Community has driven the policy of recent years to new European Guidelines. Nevertheless, the digital transition will require sustainability targets in the urban context, changing economic, social, and ecological relationships and balances. In this context, faced with these new transitions, marginal urban regions must plan, design, build, and manage future urban planning choices in a new digital-hybrid space. Therefore, it is crucial to support these transitions with a multi-dimensional sustainability concept through economic, environmental, social, and digital measurements. Urban sustainability indicators (USIs) play an essential role in supporting urban choices and planning. The current study analyzes recent literature and European standards to verify if and how they have changed in embracing the European Policy Pillar under a new and different sustainability profile, which needs to include digital sustainability. As a matter of fact, even if the concept of digitization has been recognized as a pillar of ongoing transitions, the literature and even European indicators struggle to recognize it as a tangible and measurable indicator of sustainability. Seeking to bridge the gap between European requirements and urban practice, the aim of this study is to identify and suggest new key indicators of digitalization to enable the digital sustainability of urban planning to be measured. These indicators can be used to implement a new valuation tool capable of supporting marginal regions by promoting sustainable urban investments in this new hybrid space.

Keywords: marginal areas; sustainable planning; urban sustainability; digital and green transitions; urban sustainability indicators

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1. Introduction

In recent years, the COVID-19 pandemic has been one of the engines of European dual transition policies, despite its social and economic impacts. In addition to the pandemic situation, the current Ukrainian-Russian conflict heavily impacted and currently is affecting the urban scape and, in particular, marginal urban regions development. These two events have stressed out the existing disparities between urban regions and marginal regions. On the one hand, the pandemic has highlighted the digital discrepancies and delay of these areas in health, work, and administrative responses to digital demands dictated by these events. On the other hand, the Ukrainian conflict has highlighted the high European energy dependence, aggravated by unsustainable and highly under-digitized energy choices. As mentioned, the social–economic life has had to struggle, mostly addressing digital urban deficiencies in different sectors.

These challenges have been the opportunity and the boost to implement new policies seeking for a more environmentally sustainable, social, digital, and resilient Europe [1–3].

This ongoing request for green and digital transitions to strengthen social and economic resilience requested and targeted by the European Community has driven the policies of recent years, leading to new European Policy Guidelines. This Program focuses on six headline ambitions for Europe in the coming years: (1) A European Green Deal (EGD); (2) An economy that works for people; (3) A Europe fit for the digital age; (4) Protection for our European way of life; (5) A stronger Europe in the world; (6), and a new push for European democracy [4]. These are the six pillars and challenges that European Urban Regions will face and handle in the near future to strengthen European cohesion. Indeed, European countries are undergoing unprecedented transformations and transitions in the context of major uncertainties linked to the global and security outlook.

The first pillar (1) set by the European Green Deal, approved in 2019, leads to green and ecological transitions that may make it possible to achieve climate neutrality by 2050 through an intermediate transition step to 55% by 2030. This ambitious plan demands a drastic drop in greenhouse gas emissions to be implemented immediately by all European countries, leading to tangible improvements of urban and environmental living conditions [5]. Cities, urban developments, and regions have already started to confront ecological challenges and changes to achieve this goal through projects and plans that seek a circular economy and clean technologies.

The second (2), fourth (4), and sixth pillar (6) are tightly related to social transitions that Europe must handle. Social fairness, equity, resilience, and welfare are the targets under these pillars. To consolidate its social, economic, and regional cohesion, according to the Treaty on the Functioning of the European Union, the EU aims to reduce development disparities between European regions, the underdevelopment of peripheral regions and the rural areas suffering from production, demographic, and natural deficiencies. By including these three pillars, the EU introduced a new dimension that was previously barely considered the social aspect of sustainability and equality [6]. As pointed out by Newell and Simms, many transitions seeking green and ecological benefits have historically led to social regression, such as the shift from coal to gas in the 1980s in the UK. [7].

Literature and practice have already introduced and consolidated an environmental and social sustainability assessment of urban settlements through more or less traditional indicators and indexes [8–14]. There is a consistent and substantial background that fills the need for urban sustainability assessment of these two European macro-pillars as social and environmental transitions have been a part of European aims even before the European Green Deal approval. On the contrary, the third pillar, "Europe fit for the digital age" (3), is a more recent pillar that has been introduced and announced in 2020. This headline deals with digitalization through digital technologies, artificial intelligence, data, and metadata that are changing and interfering with social, ecological, and economic dimensions of our life [4,15]. On 9 March 2021, the European Commission (EC) presented a vision for European digital transformation to be achieved by 2030. This proposal seeks a Digital Compass involving four major cardinal goals: digital skills, digital transformation of businesses, secure and sustainable digital infrastructures, and digitalization of public services. Furthermore, the European Commission (EC) is currently working on a digital transformation that pursues three macro-pillars: technology that works for the people; a fair and competitive digital economy; an open, democratic, and sustainable society. However, even though the concept of digitization has been recognized as a pillar of ongoing transitions, the literature and even European indicators struggle to recognize it as a tangible and measurable indicator of sustainability. This lack is evident in the assessment of the urban sustainability sector, which hardly tends to value digitalization as a value-added tool able to account for sustainability achievements in the planning processes.

Assessing sustainable developments and measuring the achievements of required targets is a real challenge for urban regions pursuing European Goals [16]. This difficulty is primarily due to the combination of Urban Scale complexity with the challenge of sustainability measurement through indices and indicators. This complexity can be exponential if we need to introduce additional variables and indicators that are no more linked to the traditional physical urban scale and space but to a third hybrid dimension, which has been introduced by the digital space.

To systematically assess urban processes through all the different dimensions of sustainability, we first need to describe how sustainability has been addressed at an urban scale and then identify how the literature, practice, and policies assessed it through indexes and indicators.

Given the context described above, critical reviews and comparative analyses on existing indicators and indexes have been performed to analyze the current practices to value urban sustainability levels and to suggest possible future drivers in this field. Our analysis investigates the recent literature, following the new European Policy Guidelines publication in 2019. This short timeframe has been selected to capture whether the literature and practice started to implement urban assessment tools and indicators after Europe recognized digitalization as a fundamental pillar. Consequently, we inscribed our work in this incipient line of research by addressing the following research questions:

- Which sustainability dimensions do current indicators cover in urban assessment?
- Has the digital transition been taken into consideration in the assessment of urban sustainability?
- What lessons can be drawn from current practices to support the development of future indicator sets for urban sustainability assessment?

The findings of the current study lay the foundations for future research on defining new evaluation matrices for urban sustainability assessment. The results can assist policymakers in implementing valuation tools to support and justify sustainable urban programmatic choices. Further studies in this field need to focus on implementing indexes and indicator matrices to assess digital sustainability. This study may represent a starting point for completing the missing knowledge on digital sustainability in the urban sector.

There are five sections in this study. Following the introduction, Section 2 details the related literature review, and Section 3 details materials and methodology including the research design and search strategy. Section 4 elucidates the results of the study and presents the discussion focusing on the absence of digital indicators in the urban field. Finally, Section 5 discusses the conclusion, limitations, and future research directions.

2. Literature Review

Sustainability, and specifically sustainable urban planning is considered a mandatory strategy to improve livability, ensure self-sustaining communities, and reduce environmental impacts over the long-term [17]. Over the last decade, urban sustainability has become increasingly eminent both on political agendas and on scientific studies due to the recent European sustainability policies emission [18].

It is clear how difficult it is to measure such a volatile and aleatory concept as that of sustainability. However, the need to go through its measurement has become mandatory to ensure responsible and interoperable planning for policymakers. To help policymakers, municipalities, and public institutions to pragmatically measure, assess, and infer in the urban sustainable development field, the use of indicators and indexes can be a supportive and easily readable tool, if properly implemented [9,19–21]. Nowadays, the gap between theory and practice is evident. The literature and theory have developed various tools to measure urban sustainability that often discount the problem of an adequate interpretation of the concept of sustainability, which is vague and not unique [16].

The use of indicators has become increasingly important in recent years for two strictly related aspects:

1. Their nature and purposes.
2. Their outcomes.

Regarding the the first aspect, indicators can be seen not only as neutral and numerical instruments such as "data carriers" for measuring sustainability, but also considered as "messages carriers" [19,22–25]. As for this second aspect, indices and indicators are not only measurement tools that researchers and specialists use in their analysis, but are also political and normative tools used by policy makers and the public sector to set targets and funds [18,26].

To facilitate their application, Urban Sustainability Indicators (USIs) are used and classified according to different sustainable dimensions. The literature, studies, and practice have so far embraced the division of sustainability into three dimensions or pillars: economic, environmental or ecological, and social or governmental/ethical factors [9–11,17,27–31]. These three pillars are so widely accepted that this taxonomy is also known as the "Triple Bottom Line". Each pillar includes several indicators that can best represent and measure the state of the specific dimension. The sustainability concepts linked to these three dimensions focus primarily on improving long-term human well-being by balancing these three pillars. They provide for the reduction of resource consumption and environmental damage, maximizing efficiency in the use of resources and ensuring social equity and democracy [18,32–39].

In Table 1, we identified these three main urban sustainability dimensions including a brief description for each dimension, which summarizes the frameworks that the literature and practice link to each dimension. The descriptions are extracted from the related literature, attempting to describe urban sustainability divided into dimensions [9,40–44].

Table 1. Urban Sustainability Dimensions: definitions and covered SDGs.

Urban Sustainability Dimensions	Key Words (Literature Review)	Key Words (European Commission)	SDGs 2030 Agenda
Social & Governance/Institutional	Social values, Gender equality, Identities, Relationships and institutions, Health, education, Food, Water, Housing affordability, Social Cohesion, Inequalities and Justice, Welfare and Equity	Social: health life, work and inclusion, empowerment, free or non-remunerated time, equality, Governance: fundamental rights, security, transparency, sound public finances, education, wealth	1 NO POVERTY; 3 GOOD HEALTH AND WELL-BEING; 4 QUALITY EDUCATION; 10 REDUCED INEQUALITIES; 11 SUSTAINABLE CITIES AND COMMUNITIES; 16 PEACE AND JUSTICE STRONG INSTITUTIONS; 5 GENDER EQUALITY
Economic	Human and social capital, Intergenerational equity for resources, Distributional equity, Optimal growth, Economic activity	Labour productivity and research and development intensity, industrial base, economic growth, Trickle down	2 ZERO HUNGER; 8 DECENT WORK AND ECONOMIC GROWTH; 17 PARTNERSHIPS FOR THE GOALS; 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
Environmental	Climate change, Natural resource management and thresholds, Resource and renewable energy consumption, Infrastructure and cities, Biodiversity and Ecosystem	Eco-system integrity, Carrying capacity, Greenhouse gas emissions reduction, biodiversity, material use, energy productivity	6 CLEAN WATER AND SANITATION; 7 AFFORDABLE AND CLEAN ENERGY; 12 RESPONSIBLE CONSUMPTION AND PRODUCTION; 13 CLIMATE ACTION; 14 LIFE BELOW WATER; 15 LIFE ON LAND

According to the literature, Social Sustainability is achieved by fostering the capability of present and future generations to create fair, rightful, and sustainable communities. The mandatory key words of the pillar related to this are: identities, relationships, institutions, participation, health, education, food, water, housing affordability, social cohesion, inequalities, justice, welfare, and equity [17,45]. Economic Sustainability refers to utilizing, preserving, and maintaining resources in urban development and management, generating long-term value, which must be achieved through optimal use, recycling, and protection of scarce natural resources [17,46–48]. The literature associated with this pillar uses keywords such as human and social capital, intergenerational equity for resources, distributional equity, optimal growth, and economic activity. Finally, Ecological Sustainability on an urban scale is directly linked to vulnerability and increasing resilience of citizens at the environmental level [28]. Both sustainable urban policies and urban environmental planning are crucial tools, capable of monitoring and managing ecological resources and services, biodiversity and natural ecosystems [17].

The literature and best practices associated with this pillar are concepts such as climate change, natural resource management and thresholds, resource and renewable energy consumption, infrastructure and cities, biodiversity and ecosystem.

In the same table, we have included the Sustainable Development Goals of the 2030 Agenda for Sustainable Development (SDGs) to be associated with each urban dimension that better fits the goal targets. Seven goals are associated with the Social Dimension, while six goals are included in the environmental dimension, and four goals with the economic dimension.

Despite the three-macro dimensions recognized above, some authors usually divide the Social Dimension into two categories: the Social and the Governance/Institutional dimensions. A recent literature review study conducted in 2021 was performed to identify how the authors classify USIs by pillars [49]. This study showed that about 60% of the analyzed papers did not organize the frameworks in pillars, only 18% of the studies were organized within four pillars (Economic, Environmental, Social, and Institutional/Governance), and 22% of the papers were organized into three sustainability dimensions (Economic, Environmental, and Social). [50].

Also, according to the EU's 2022 Annual Sustainable Growth Strategy, sustainable transitions can be reach and need to be measured through four dimensions (Economic, Environmental, Social, and Governance) [50,51]. Composing a Transitions Performance Index (TPI), the EC monitors and ranks countries based on their progress towards fair and prosperous sustainability across the four mentioned transitions, focusing on resilience, inclusiveness, and sustainability. Each dimension is described as detailed in Table 1:

- Social: health life, work and inclusion, free or non-remunerated time, equality;
- Governance: fundamental rights, security, transparency, sound public finances;
- Economic: education, wealth, labor productivity and research and development intensity, industrial base;
- Environmental: reduction of greenhouse gas emissions, biodiversity, material use, energy productivity.

However, considering the recent update of the European Policy Guidelines, which includes digitalization as one of the main ambitions, we believe that it is mandatory to include this pillar as one of the sustainability dimensions mentioned above. This inclusion will lead to adequate recognition and assessment of the Digitalization Sustainability dimension as an independent pillar to be persecuted.

Digitalization has been defined in several ways in these recent years by the literature and sector studies [27,52–54]. However, the common thread of the definitions could be summarized as "the way many domains of social life are restructured around digital communication and media infrastructures" [55]. Digitalization is an effective and recognized tool that can improve effectiveness, interoperability, and transparency, reducing costs and wastefulness through automatization in many different fields and sectors. Many studies have been conducted to define whether and how digital technologies are really supporting sustainable developments by helping to address the major challenges of tackling climate change [56].

It can be said that little has been studied about the effects of digitization on the urban system compared to other areas. However, today it is accepted worldwide that intangible investments, such as digitalization and R&D, information technology, artificial intelligence and 'big data' development and exploitation changed the accounting, financial, and enterprises world. In addition to this, a change in the accounting method is required [57,58]. Digitalization and intangible investments are recognized as non-assessed value capturing in the accounting field. Due to this lack, in 2019 Lev [58] proposed a reform in accounting approaches. This change, required by Lev for non-tangible assessment, is necessary not only in the accounting field, but in general in all sectors that include intangible investments, such as the urban field.

As mentioned, several fields could take advantages from digital sustainability, creating new opportunities for sustainable developments [15]. However, on the other hand, digitization also implies new challenges in balancing technological drive, energy consumption, and social imbalances. It is mandatory to balance the use of digital technology fairly and wisely in order to not penalize yield distribution nor increase inequalities [59–61].

Few studies have been performed on how digitalization can negatively affect both environmental and social sustainability [62]. However, despite the possible dual effects that digitization may have on the sustainability pillars, it can still be said that digitalization could be an effective tool in urban planning and building design if properly applied, through technology that improves efficiency, smartness, and reduction of emissions, waste of resources, and time [63].

In this perspective, we want to explore how digitalization can pave the way for sustainable development, even in the urban field. We propose Digitalization as a Sustainable Dimension in the urban field to be included in the existing three sustainable pillars, implementing a new Dimensions Classification that we are going to call from here onward the ESED Classification (Economic-Social-Environmental-Digital).

On the basis of this, in the next Section we will demonstrate that urban sustainable indicators and indexes are lacking in assessing the digital sphere both at the literature and the European Commission levels, underestimating the digital dimension.

3. Materials and Methods—Indicators for Urban Sustainability

In the urban context, the use of indexes and indicators to assess urban sustainability levels has become increasingly important in supporting urban regions' transitions [64,65]. This is due to the key role of urban assessment, which started to distinguish between sustainable and unsustainable investments. The impact of urban indicators is crucial in assessing urban development process. Indicators help policymakers, decision-makers, and more in general the public to better understand and map the status of a regional area, measuring and assessing its current strengths and weaknesses. By defining needs and opportunities policymakers can easier identify urban development priorities and strategies according to sustainable targets [17,66]. Indicators are used to improve urban assessment robustness of urban assessment and to secure the analysis. To assess different levels of sustainability often indicators are compounded together to create ad hoc indexes. Simple indicators, which assess individual phenomena, can be weighted together to compose indexes capable of describing complex scenarios [67]. Indicators and indexes are often used mainly for two reasons. First, they are quantitative measures easily readable by the involved stakeholders in the decision-making processes, who are often not technicians. Indeed, indicators can help them to implement informed decisions without ambiguity, which can be clearly reported to the community [68,69]. Furthermore, indicators can be used through all the stages of the urban process comparing expectations, results and impacts in sustainability targets [70]. Due to their impact on public decision policy, since the early 90′s many studies focused on the classification and selection of Urban Sustainability indicators. However, since then many aspects of urban developments have been changed and even European Policy has been update trying to integrate these changes and new features in Sustainability concepts.

The approach applied in this study followed the three phases showed below and presented in Figure 1. A fourth phases will be conducted in future research as an application of the current results.

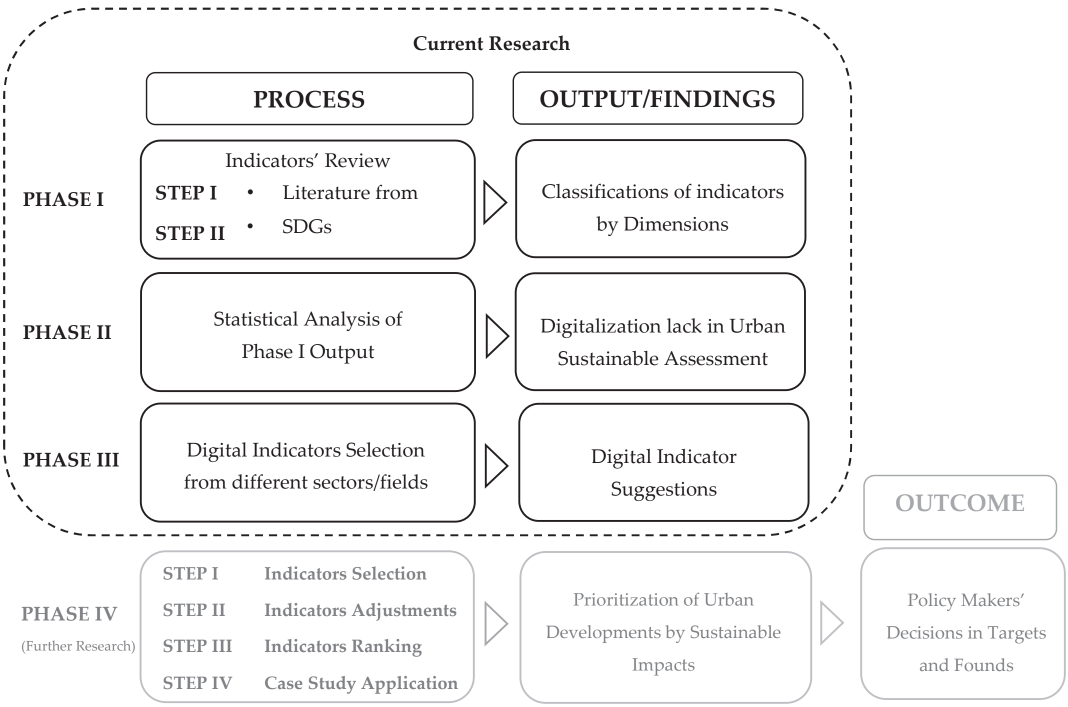

Figure 1. Detailed steps of the Research Process. Source: Authors.

Phase I provides for an extensive review of USIs both in Literature (Step I) and through the European SDGs (Step II). The 2019 Political Guidelines focused on six headline ambitions for Europe are considered as leverage steps toward sustainable programmatic choices in different fields. However, we investigated whether academic studies have internalized Digitalization Goals and Targets set off by the EC to respond to urgent sustainable needs in the urban field as well. To achieve this, we analyzed studies on the Urban Sustainable Assessment that occurred after Political Guidelines publications in Step1, from 2020 onwards. We want to respond to the following question: "has the digital transition been taken into account and internalized in the assessment of urban sustainability?"

There is an extensive literature review on USIs and an accurate classification of indicators that has been run by Verma and Raghubanshi in 2018 [9]. However, what happened next? We conducted a systematic ESED Classification of urban sustainability indicators by comparing existing studies in Urban Sector. In Step II, we organized Sustainable development goals Indicators (SDGIs) according to our ESED Classification.

Phase II provides a statistical analysis of the data collected in Phase I and presents these results. In Phase III, to recognize the importance and the impact that Digital Transition will have on Urban Filed, we proposed to implement the Digital Sustainable Dimension, introducing new digital indicators to be drawn from different fields.

3.1. Phase I—Indicators for Urban Sustainability

3.1.1. Academic Studies

In collecting the sets of indicators, the retrieval of measurement initiatives from academia was deemed necessary to verify whether and how literature has internalized digital transition in its approaches as one of the European new Pillar. Only documents published from 2020 onwards have been analyzed.

Academic measurement initiatives were identified through a systematic literature review, for which the Scopus search engine was selected due to its wide coverage of sustainability journals. This was then crossed with a Google Scholar search. The search was conducted using 'urban' AND 'sustain*' (to include both the terms "Sustainability" and "Sustainable") as keywords from 2020 onwards, with the following query: TITLE (urban AND sustainab*) AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020)) AND (LIMIT-TO (LANGUAGE, "English")) AND (EXCLUDE (SUBJAREA, "ARTS") OR EXCLUDE (SUBJAREA, "MATH") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "CENG") OR EXCLUDE (SUBJAREA, "PHYS") OR EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "PSYC") OR EXCLUDE (SUBJAREA, "CHEM") OR EXCLUDE (SUBJAREA, "NURS") OR EXCLUDE (SUBJAREA, "VETE") OR EXCLUDE (SUBJAREA, "HEAL") OR EXCLUDE (SUBJAREA, "IMMU") OR EXCLUDE (SUBJAREA, "NEUR")). In the first selection, all studies not strictly correlated and relevant to the current research topic were excluded. The remaining selection yielded 962 results as of July 20, 2022, which have been reduced to 150 including the 'inde*' query. We then crossed this search output with the search that was run in Google Scholar. The remaining studies were then filtered and included in the final sample according to the following criteria: (i) large-scale application, at least 30 indexes included in each study; (ii) clear and comprehensive focus on sustainability; (iii) urban scale field recognition; and (iv) list of indicators or indexes that can be clearly identified and accessible. The application of the filters mentioned above yielded a final sample of 1.112 indexes through 10 selected studies.

To determine how urban sustainability translates into metrics, a systematic analysis of the 1.112 collected indexes was carried out, assigning a Sustainability Dimension and a Sustainability Sub-Areas to each indicator. The Sustainability Dimensions selected as described in Section 2 can be classified as ESED, including Economic, Social/governance/institutional, Environmental, and Digital Dimensions.

We presented our results in Table 2, which classifies indexes and indicators of the different Authors by Dimensions and Sub-Areas.

3.1.2. Sustainable Development Goals Indicators

In Step 2 of Phase I, we analyzed the SDGIs as presented by EC. Established by the United Nations' 2030 Agenda for Sustainable Development, the Sustainable development goals Indicators (SDGIs) set up major principles and priorities, representing a combined goal- and issue-oriented framework [71]. The 17 SDGs covers a thematic area (Goal) and is further sub-devided in169 Targets and 231 unique indicators, However, we need to emphasize that the total actual number of SDGIs is 248, 13 of them have been used multiple times under different targets. The proposed SDGIs have been linked to the most applicable and pertinent categories within each. According to this classification, each indicator has been identified with a cross-typological characterization to standardize comparisons and statistical analysis. As said, each indicator is identified by a unique code that identifies the Goal and the Target, to whom the indicator belongs. For example, the Indicator "Ratio of land consumption rate to population growth rate" is identified by the code number 11.3.1, which means that this indicator is the first one (0.1) belonging to Goal 11 ("Make cities and human settlements inclusive, safe, resilient and sustainable") and to Target 3 ("By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries).

Table 2. The most popular USIs used in Literature after 2019, categorized by ESED Classification.

Sustainability Dimensions	Sustainability Sub-Areas	Indicators	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezael, 2021	Zeng et al., 2022	Amoushahi et al., 2022
Economic												
	Economic Employment											
		Unemployment rate/duration	1	1	1	1	1	2	28	2		3
		Qualified workers			1							
	Business Wellbeing											
		Active business/competitiveness				1			37			2
		Green business									2	
		Local Activities/Businesses				1						1
		Foreign direct investments	1									
	Poverty											
		Per capita annual expenditures					2		3			
		Poverty rate	1			1		1	12			1
		Engel coefficient									1	1
		Child labor rate										1
	Economic Wellbeing											
		Retirement security						1	13			1
		Average income	1		1		1	1	6	1		1
		Cost of Living								1		
		GDPs	3					1	10			1
		Inflation rate							13			1
		Households									1	
		Government debt				1	2		17	1		
		GINI coefficient		1				1				
	R&D											
		R&D costs							14			1
		High-tech industries/employability	1									
	Political Situation											
		War										1
		Economic downturn										1
		Health expenditure by government					1		3			
Social												
	Population											
		Demographic								3		1
		Family Size								2		
		Population growth rate								1		1
		Immigration Rate								1		
		Population density	1				1	1	13	1		1
	Education											
		The number of schools										1
		People Education Level/Years	1			1	4	1	33	2		2
	Medical care											
		Mortality rate				1						1
		Number of doctors/Health institutions					5	1	27	1		2
		Access to hospitals								4		
		Percentage of adults who exercise			1							1
		Addictions				1						2

Table 2. *Cont.*

Sustainability Dimensions	Sustainability Sub-Areas	Indicators	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezael, 2021	Zeng et al., 2022	Amoushahi et al., 2022
	Life expectancy											
		Medical coverage				1		1			1	
		Life expectancy	1					1				1
	Social security											
		Total crime rate	1				1	1		2		1
		The number of deaths due to suicide										1
		Police/Fire D. interventions				1	2			5	1	1
	Equality											
		Education equal rights				1			25			1
		Employment equal rights				2			11		1	1
	Culture											
		Number of recreational facilities			1	2		1	21	5	1	1
		Community garden									1	
		Number of NGOs										1
	Social capital											
		Social engagement (Voters/Volunteers)	1			1		2	21		1	2
		Number of homeless									1	1
		House price								1		1
		Social Housing	1		1				26			1
		Sustainability Policies		9	3				17	1	1	
		Number of traffic injuries						1				
Environmental												
	Water quality											
		Water consumption (per capita)	1	3	1	1	1	1	39	1	1	1
		Wastewater collected		1	1							
		Recycled water/Treatment systems		2	2							1
		Households with safe water		1	1			1				1
		Water quality								1		1
	Waste management											
		Waste production rate		5		1	3	1	34	2		1
		Waste recycling rate	1	4	1	1	1	1		1	1	1
		Hazardous waste management			1			1				1
		Sewage treatment capacity/rate					2					
	Air quality											
		Number of air pollution monitoring			1							1
		Number of polluted days			1				33			1
		Greenhouse gas emissions	5	8	2	1		4	21	1	1	1
	Energy resources											
		Non-RES consumption	1	13	1	1	3	1	31	2		1
		RES consumption	1	1	1						1	1
		RECs/Smart Grids		2								
	Urban noise											
		Noise pollution	1	1				1	16	1		2
	Transportation											
		Motor/non-motor vehicles	1	3	2	1		1				2
		Public transport rate/Proximity	1	1	3		1	2	39	2		1
		Travel time/ Traffic congestion		2	1	2						
		Modal split/Public Transport Use	1	1	1	1		1				1
		Road network density per person			2		2			1		2

Table 2. *Cont.*

Sustainability Dimensions	Sustainability Sub-Areas	Indicators	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezael, 2021	Zeng et al., 2022	Amoushahi et al., 2022
	Buildings											
		Use of local materials/resources		1	1						1	1
		Buildings age		1	1							1
		Conservation Projects			1					1		
		Buildings Energy Certificates			2							2
	Planning											
		Urbanization rate					1		19			2
		Housing density/Surface coverage	1	1	2	1			29		1	2
		Sidewalk route length	1		1							1
		Use of existing sites			1							
		Public spaces vs. Private spaces			1							
		Distance to basic services	1		3	5			25			1
		Green coverage rate of built-up areas	2		3	1		2	15	1	2	2
		Land use management Plan								1	1	1
	Biodiversity											
		Tree density	1						7	1	1	1
		Shannon-Wiener index	1						23	1		
	Hazards/Climate Change											
		Soil erodibility							3	1		2
		Natural disasters							6			4
		Vulnerability to climate change	1				1		21			2
Digital												
	Connections											
		Internet access/Digital services		2	1	1						1
		Mobile phone traffic		1								
		Energy used for web servers		2								
	Buildings											
		Domotic		1								

As we performed with academic studies, we then classified the 231 indicators, set by the UN, into the four Sustainable Dimensions (ESED) identified by the authors. After analyzing SDGs Indicators, we acknowledged that some of them were the combination of multi-index. Some indicators proposed by the SDGs are characterized by complex formulations and are a combination of several and different factors. For this reason, we had to classify them under multiple and non-univocal Sustainable Dimensions. As shown in the Venn Diagram (Figure 2), many indicators have been placed under two or more different dimensions.

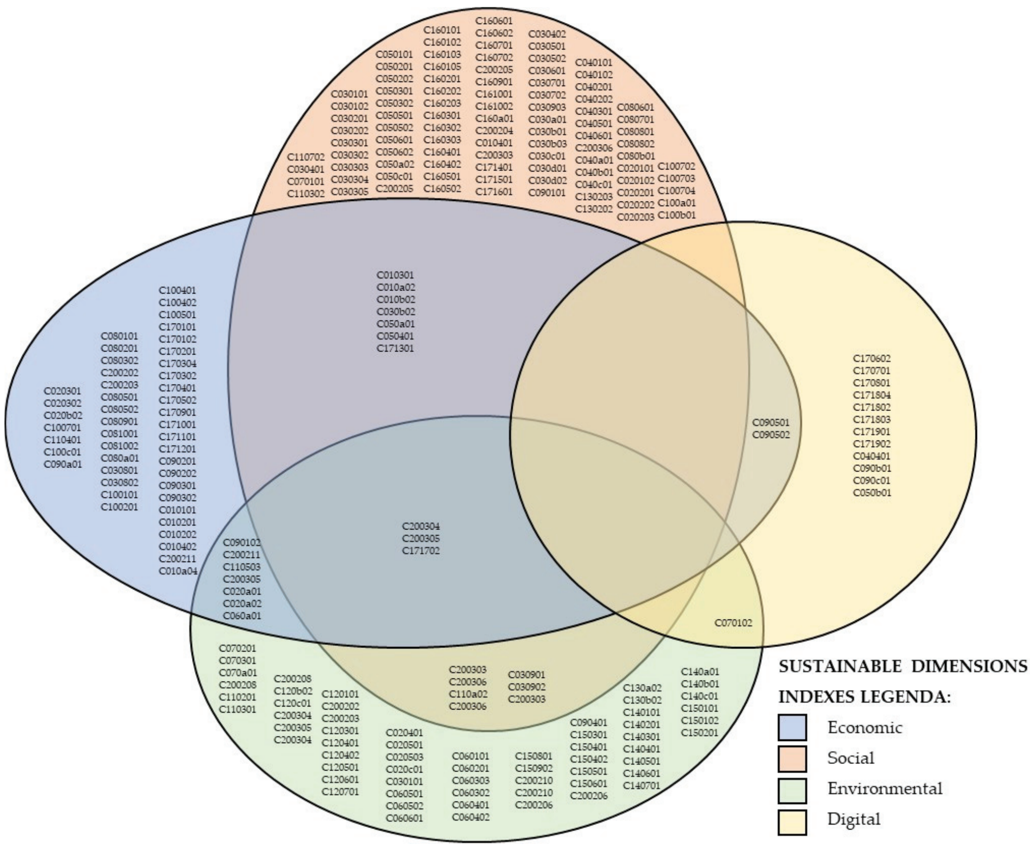

Figure 2. Venn diagram of SDGIs classified by ESED. Source: Authors.

4. Results and Discussion—Phase II and III

It is crucial to analyze the results of our classifications. This study identified and classified under each dimension over 1.390 indicators.

According to the summary of the descriptive analysis (Table 3), which combined the classification of both Academic Studies and SDGs Indicators, 20% of the Indexes (i.e., 277) have been classified in the Economic Dimension, 30% of the Indexes (i.e., 423) have been classified in the Social Dimension, 48% of the Indexes (i.e., 672) have been classified in the Environmental Dimension and only 2% of the Indexes (i.e., 22) have been classified in the Digital Dimension. According to our classification, the United Nations are the ones that mostly considered Digitalization Dimension in their indicators. The results of the SDGs Indicators show that 24% of the indexes were included in the Economic Dimension, 41% in the Social Dimension, 31% in the Environmental Dimension, and 5% in the Digital Dimension.

Table 3. Sustainability Indicators categorized by ESED Classification-Results.

Sustainable Dimension	Feleki et al., 2020	Maranghi, 2020	Chao 2020	Steiniger et al., 2020	Mangi, 2020	Merino-Saum, 2020	Michalina 2021	Robati & Rezael, 2021	Zeng et al., 2022	Amoushahi et al., 2022	SDGIs	AVERAGE	TOTAL
Economic	8	2	3	5	7	7	156	5	4	16	64	25	277
Social	6	9	6	11	13	10	194	29	8	25	112	38	423
Environmental	21	51	38	16	15	17	361	18	10	42	83	61	672
Digital	0	6	1	1	0	0	0	0	0	1	13	2	22
TOTAL	**35**	**68**	**48**	**33**	**35**	**34**	**711**	**52**	**22**	**84**	**272**	**127**	**1394**
Economic	23%	3%	6%	15%	20%	21%	22%	10%	18%	19%	24%	20%	
Social	17%	13%	13%	33%	37%	29%	27%	56%	36%	30%	41%	30%	
Environmental	60%	75%	79%	48%	43%	50%	51%	35%	45%	50%	31%	48%	
Digital	0%	9%	2%	3%	0%	0%	0%	0%	0%	1%	5%	2%	

If we exclude the source of SDGs and analyze only the Academic Studies (Figures 3 and 4), only four authors included at least one Digital indicator to account for Urban Digital Sustainability, with an average of only one digital indicator per study. According to Figure 4, 19% of the Indexes (i.e., 213) have been classified in the Economic Dimension, 31% of the Indexes (i.e., 311) have been classified in the Social Dimension, 59% of the Indexes (i.e., 589) have been classified in the Environmental Dimension and only 1% of the Indexes (i.e., 9) have been classified in the Digital Dimension.

Comparing Academic Studies with the classification of the European Goals (Table 4), it is clear that Academic Studies are decidedly more concerning and tend to pay more attention on the Environmental Dimension of Sustainability (52% vs. 31%), and they tend to underestimate the social (28% vs. 41%) and the digital dimension (1% vs. 5%) with respect to the UE Targets.

Table 4. SDGs vs. Academic Studies Indicator Classification.

	SDGIs		Academic Studies	
Sustainable Dimension	**N. of Indexes**	**%**	**N. of Indexes ***	**%**
Economic	64	24%	21	19%
Social	112	41%	31	28%
Environmental	83	31%	59	52%
Digital	13	5%	1	1%
TOTAL	**272**	**100%**	**112**	**100%**

* Average number per Study.

Analyzing the results of our ESED classification, as presented in Table 4, we can observe how the digital dimension at both UE and Academic Level is not adequately taken into account, with an overall average of only two digital indicators per study (Table 3), more precisely academic studies show an average of one digital indicator per study, with an average of 1% of the overall indicators, as shown in Table 4. At European level the number of digital indicators rises up to 13, with a 5% distribution, which is above the academic studies indications. These results stress out how academic research is still far behind the European requirements in terms of digital transition. The Digital Dimension, which is represented by the studies analyzed above, accounts for urban Sustainability by including the following indexes: Internet and digital access, services or skills, Mobile phone traffic or possession, Energy used for web servers, Domotica Percentage. Considering the strong emphasis that the EC is giving to the twin transition, these few indicators seem not to be exhaustive and seem to underestimate the sustainability measure of the digital dimension in the urban field, focusing mainly only on measuring digital sprawl rather than its sustainability.

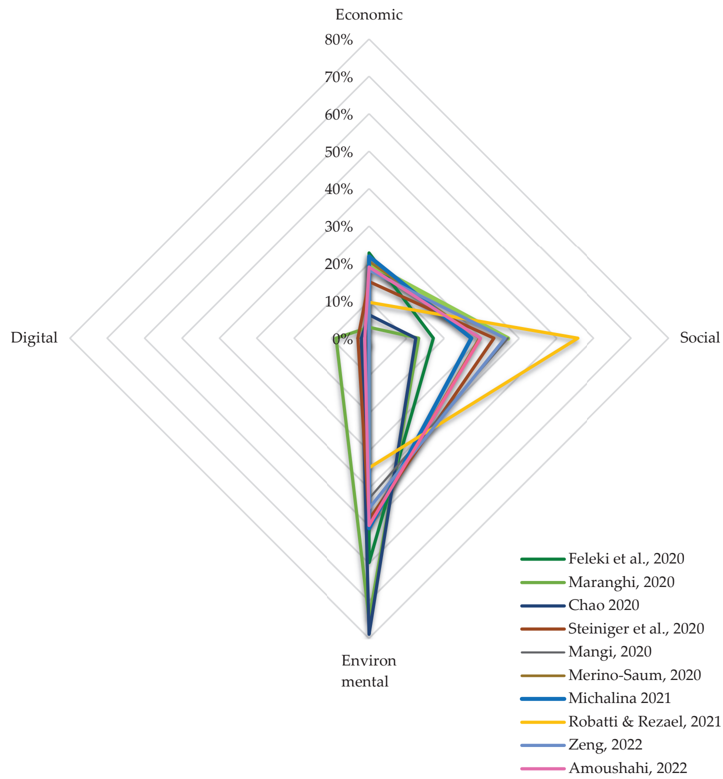

Figure 3. Academic Studies: radar chart of Sustainability Indicators Dimensions by Authors.

An extensive literature review on the digital sustainability definition was provided by Wut et al., which exanimated this concept in several research fields. They summarized their findings describing digital sustainability as digital preservation along its overall life cycle in the socio-cultural and organizational context [72]. However, the introduction of new additional digital indicators will have to address the awareness that digitalization also leads to various sustainability challenges. The increase in digitization processes could generate spillover effects both at an environmental and social level. As regards environmental externalities, the increase in energy consumption could be a concern. In terms of social effects, the main problems could be related to increasing social vulnerability, due to the disparity and inequality in the distribution of value capture, and due to the increasing gap in information and technology access. This effect is well known as the digital divide effect [73].

Despite many studies focusing on digital sustainability definition, the literature shows a profound lack of contextualization and presence in the urban sector. As a consequence, today the absence of an appropriate selection of indices and indicators capable of defining the Sustainable Dimension is relevant. An attempt to introduce digitalization indicators in urban contests was made by Dmitrieva and Guseva [74]. The authors proposed to take into account the digitalization factor as one of the keys to assessing territorial competitiveness. However, this study takes into account only the traditional concept of urban competitiveness from an economic point of view and does not seek global sustainability. Feroz et al. mentioned the impact that digitalization is having on urban sustainability, focusing on a literature review of studies on smart cities and sustainable cities [75]. Yet, they do not account for sustainable assessment and measure through indexes and indicators. In fact, they limit their study to verifying whether it is well accepted, by current literature, that digitization contributes to resilience and sustainability of the urban sector.

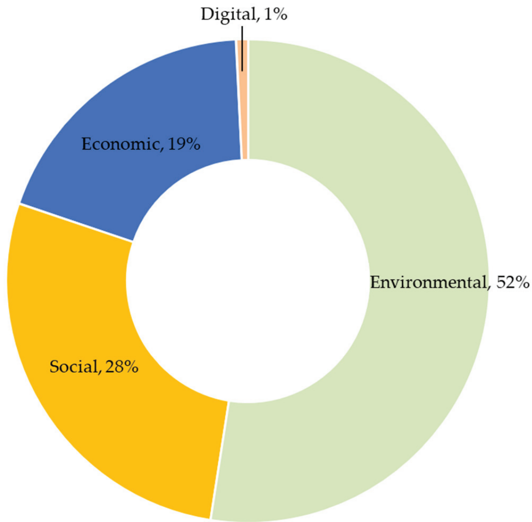

Figure 4. Academic Studies: pPie chart of Sustainability Indicators Dimensions.

Considering that urban studies lack consideration and therefore measurement of digital sustainability, our suggestion is to look for digital indexes and indicators in other fields, such as entrepreneurial, business financial, and industrial fields. These areas have a more consolidated and sensitive awareness of the impact and the effects that digitalization could have on the dimension of sustainability, given the longer contacts that they had with digital transformations. These fields already recognized digitalization impacts on costs, spaces, optionality, resilience, and information asymmetries in their systems. To verify which sectors are highly involved in the digital sustainability assessment, we first run a literature review on Scopus and exported in VOSviewer. The VOSviewer software was used to analyze the keywords "digital index" and "digital indicators" [76]. This software allows users to visualize data maps of bibliometric networks based on Visualization of Similarities (VOS) and it is ussually used to perform preliminary research litterature review [77–79]. The distance between the nodes (in our cases the names of the Journals) is proportional to the divergence that occurs between the topics of the journals [80].

Through this logic, our two-dimensional map (Figure 5) represents the existing network between journals that published papers and sudies between 2020 and 2022 that include the keywords mentioned above. In addition, the size of the nodes is weighted by the number of articles published in the quoted journal based on the selected query.

The analysis produced a total of five clusters which represent five different journal topics. According to the names of the journals, these are the main topics for each cluster:

- Cluster 1: social, communication, economic and business science.
- Cluster 2: natural and environmental science.
- Cluster 3: computer and technology science.
- Cluster 4: energy and engineering.
- Cluster 5: material and mechanical science.

This clustering can help identify the most relevant fields that study and suggest digital indicators to measure sustainable systems.

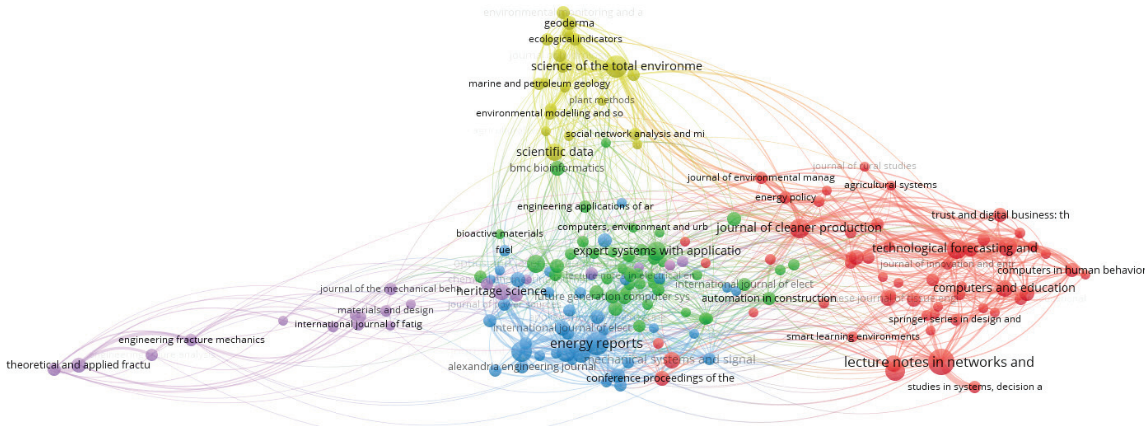

Figure 5. Source visualization 2-D map including "Digital" and "Index" and "Indicator" keywords. Source: authors' elaboration using VOSviewer.

We further analyzed, in depth, some of the papers mentioned above to search for digital indicators and indices that could encourage and be a sort of guideline to the urban sector in measuring digital sustainability. In Figure 6, we reported the results of this preliminary research, identifying the most recurrent digital indexes classified by the field of belonging. Most of the indexes detected belong to the social and economic and to information and technology fields. [27,81–84].

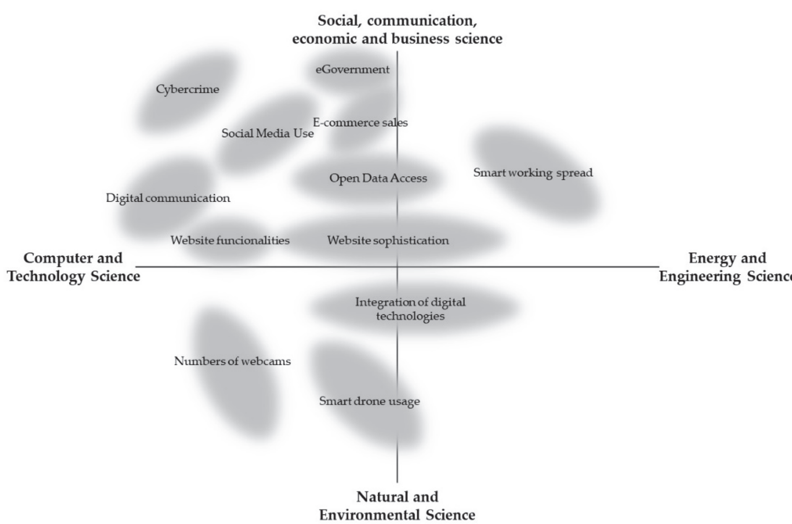

Figure 6. Digital Sustainability Indexes and Indicators suggested by different academic fields.

The indices and indicators examined are a possible driver for further research as a link between the urban field and the digital sustainability assesment. However, these indices need to be deeper analyzed to better interpret the urban dimension and its peculiarites. We believe that a systematic review of these indicators and indices could help urban studies to implement the assessment of the Digital Sustainable Dimension, which can be an engine for the development of marginal urban regions.

5. Conclusions

In the near future, new digital technologies will increasingly lead us to convert traditional activities and processes towards new forms of virtual actions. Digitization will therefore bring new challenges to be faced in a "hybrid" virtual space with countless benefits. However, we are still unprepared to properly and wisely assess the economic, environmental, and social risks and implications. In this uncertain and unexplored near future, marginal urban regions need to ensure programmatic choices for sustainable development. To support them in their decisions, we believe that it will be extremely important to correctly assess and measure the sustainability of their choices. In this global contest, sustainability includes four pillars: Economic, Social, Environmental, and Digital (ESED Classification).

By analyzing the scientific literature of the last three years in the urban sector, the lack of sensitivity and digital evaluation was highlighted. Furthermore, our study proposes new indicators to be transferred to the urban environment to measure digital sustainability. This report is the starting point for follow-up studies that have the potential to introduce the digital dimension into the urban sector. In particular, further studies will have to focus on the possible correlations between these four pillars (ESED). Indeed, the identification of new indicators and evaluation matrices capable of measuring the sustainability of urban development will be crucial to promote sustainable marginal regional investments.

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Article

"Location, Location, Location": Fluctuations in Real Estate Market Values after COVID-19 and the War in Ukraine Based on Econometric and Spatial Analysis, Random Forest, and Multivariate Regression

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Abstract: In this research, the authors aim to detect the marginal appreciation of construction and neighbourhood characteristics of property prices at three different time points: before the COVID-19 pandemic, two years after the first COVID-19 alert but before the War in Ukraine, and one year after the outbreak of the War. The marginal appreciations of the building's features are analysed for a pilot case study in Northern Italy using a Random Forest feature importance analysis and a Multivariate Regression. Several techniques are integrated into this study, such as computer programming in Python language, multi-parametric value assessment techniques, feature selection procedures, and spatial analysis. The results may represent an interesting ongoing monitoring of how these anomalous events affect the buyer's willingness to pay for specific characteristics of the buildings, with particular attention to the location features of the neighbourhood and accessibility.

Keywords: market value; value assessment; multiple regression; location; fixed effects; computer programming; random forest; diachronic analysis

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1. Introduction

1.1. Fixed Effects and Market Value

"There are three things that matter in property: location, location, location", states Lord Harold Samuel in his iconic sentence [1]. Even though the location is not the only characteristic of a property on which its market value depends, it is undoubtedly one of the most significant features, if not the most important one. As such, this research will discuss how fixed effects influence the best estimate of a property's market value through multi-parametric estimation techniques [2,3]. Concomitantly, the authors wish to investigate whether the recent events of the COVID-19 pandemic and the War in Ukraine have changed the influence of a property's location on its market value.

Has a demand shift occurred due to these impactful and significant events? Does the axiom "location, location, location" still remains unchanged?

This investigation is carried out from a market value perspective. The aim is to analyse whether the factors contributing to price formation have changed, questioning whether the demand has altered the appreciation of certain building features over time or if some of the usually most significant factors have become less influential in assessing the market values. The approach proposed is strongly interdisciplinary, integrating statistical techniques with economic analyses and geographic-spatial information. The intersection between statistics, economics, regional science, and econometrics can be identified as spatial econometrics or spatial analysis, which is sometimes (improperly) used as synonyms [4]. This research field helps to understand the spatial aspect of economic events, analyse spatial relationships, and leads to the production of a geographically centred interpretation of observations.

Specifically, this paper will apply a multivariate regression (MR) with spatial regressors to an illustrative case study to assess a property's market value as a function of its descriptive features, such as location, distance from specific points of interest, construction features, and size. The MR will be developed based on three databases collected at different time points but pertaining to the same city (i.e., Padova, Northern Italy). The first database represents a pre-COVID-19 scenario. The second database was collected two years after the first COVID-19 alert, therefore illustrating the first effects that the pandemic has brought to the real estate market in North Italy. In contrast, the third database was collected one year after the outbreak of the War in Ukraine.

The MR belongs to multi-parametric market value assessment techniques. Such methodologies are extremely useful for the present work since they assess a property market value depending on a bundle of its descriptive characteristics. While in mono-parametric approaches, the estimate of the market value is only described as a function of one single characteristic of the building, most commonly the floor area (sqm); multi-parametric methods are able to include and balance a plethora of descriptive information of a property, comprising both construction and neighbourhood features [5].

Among the neighbourhood characteristics, the authors' intent is to analyse the location of the building in central, semi-central, or suburban areas, its proximity to the city centre and public services, the accessibility to public transport or employment centres, but also the urban quality of the district, including pollution, healthy environment, parks and gardens, social context and security, leisure services, absence of high noises, or low building density.

As far as construction characteristics are concerned, it is the author's will to consider simultaneously several features that define the quality of the building, such as its size, the number of rooms and bathrooms, the floor level, the maintenance status, the quality of materials, the energy performance, the presence of technologies such as domotics, photovoltaic systems or solar panels, the presence of additional areas such as a balcony, a private garden, or a garage, and the orientation of the building or its panorama and view.

1.2. Choosing the Econometric Model among the Multi-Parametric Value Assessment Methods

In the field of property valuation in Italy, multi-parametric methods include the simplified scoring techniques called "punti di merito" (in its two variants, i.e., the "additive approach" or the "multiplicative approach"), the "market comparison approach", a method originated in the United States and reinterpreted in our country [6–8], and the "econometric models" or the more sophisticated "machine learning" models [9].

Econometric and machine learning models can be used as a mass appraisal technique in real estate valuation. A mass appraisal technique can be defined as the process of valuing a building stock or a property asset based on common parameters and statistical techniques [10].

The latter two methodologies, in general, aim to find the statistical relationship/algorithm that relates some economic quantities describing the property (independent variables) and the market value (dependent variable) [11].

The econometric model of hedonic prices quantifies how much each independent variable contributes to the variation of the market price. Each variable is assigned a numerical coefficient, and a mathematical assessment formula is consequently built [12]. Machine learning assessment procedures, such as Regression Trees and Random Forest, Artificial Neural Networks, Nearest Neighbours, Support Vector Machines, and Genetic Algorithms, ensure great accuracy in the value assessment. They enable the inclusion of numerous independent variables in the predictive model and can produce complex forecasting algorithms [13,14].

Econometric approaches generally have a high inferential capacity at the expense of a lower predictive capacity [15,16], while machine learning procedures show a higher predictive capacity but a lower inferential capacity [17,18]. Since inferential capacity refers to the effectiveness of the model in identifying cause–effect relationships among dependent and independent variables, whereas the predictive capacity represents the ability of the model to produce forecasts really close to the expected values, the authors believe that for the purposes of this article, the hedonic price estimation method could be the best choice to investigate the fixed effects in the real estate market.

The hedonic price method is founded on the assumption that a property is characterised by a set of elements (the building characteristics) and that the value of the property can be calculated as a sum of the estimated values of its elements [19]. This way, a marginal price is given to every building attribute, implicitly understanding how much that characteristic influences the market value [20]. In any real estate market, the demand compares the buildings for sale based on their characteristics, and the buyer will purchase the property that seems the most convenient. However, different characteristics are valued differently by the operators on the demand side. Some characteristics may be considered almost "objectively" valued by the demand, while others remain highly subjective. The marginal prices of the building characteristics depend on several factors, such as the housing market segment, politics and laws, fashions and trends, market cycles, social status, and the spending capacity of the demand, and they are subject to variation over time.

As such, the paper is structured as follows. Section 2 will introduce the methodological approach adopted for this research, while Section 3 describes the practical case study. A discussion about the regressors is illustrated in Section 4, whereas Section 5 outlines the complex procedure involved in downloading information, and Section 6 presents the Random Forest feature importance process. In Section 7, the Multivariate Regressions and the spatial analyses are developed and discussed. Finally, Section 8 draws the conclusions of this research, highlighting further possible developments.

2. Purpose and Materials and Methods

2.1. A Diachronic Analysis Related to Major Anomalous Events

As the authors are leading this research, it is early 2023. The present study is a specific development of a more comprehensive research stream that monitors and investigates multi-parametric value assessment techniques and hedonic prices in several Italian markets over time [21,22]. As a result of the globally impactful events that have occurred in recent years, this monitoring process of real estate values and marginal prices allows us to describe the shifts in demand preferences after the COVID-19 diffusion and the outbreak of War in Ukraine.

As of now, more than three years have elapsed since the first signs of the pandemic emerged in December 2019, originating from China [23], leading to various effects on the economy, labour, or trade, other than its clear impact on the health sector [24]. On the other hand, more than a year has passed since the outbreak of the War in Ukraine, when in the early morning of 24 February 2022, Russia launched numerous attacks on Ukraine's major cities [25]. The domino effect of this unfortunate event changes the dynamics of so many sectors, directly and indirectly, bringing obvious consequences, such as political, financial [26–28], environmental, and energy-related impacts [29–31]. Further, it has also affected psychological health and social dynamics [32–34]. Moreover, these significant events also impact the real estate sector in terms of demand preferences, cost of construction, willingness to pay, property prices, and market dynamics.

Regarding our field of interest, real estate Researchers and Professionals are now wondering how and to what extent both the COVID-19 pandemic [35–38] and the War in Ukraine [39,40] might affect price formation mechanisms and thus their profession.

The scope of this research is twofold. On the one hand, the aim is to understand the marginal contribution of building features to the price, distinguishing between the fixed effects (location, neighbourhood, and accessibility) and the building's construction characteristics. On the other hand, the analysis is diachronic, aiming to point out if any difference in the marginal appreciation of the features has occurred due to COVID-19 and the War in Ukraine.

Political, geographical, social, and economic factors strongly influence real estate market dynamics. In this case, those factors can undoubtedly be classified as anomalous events.

Well defined in [41], an anomalous event is an unexpected and unpredicted shock whose causes are exogenous to the market in question, but the effects change and influence the market. The methods applied and the intended purposes in the research that have analysed the effect of anomalous events on the housing market appear to be very heterogeneous, primarily differing on the basis of the extent of the impact, i.e., distinguishing events with microeconomic consequences from events with macroeconomic consequences, as is the case in this study. Another distinction that should be considered is temporary versus permanent effects on the market dynamics.

The methodologies employed on an international panorama to analyse such anomalous phenomena are varied and multifaceted, showing different approaches and scopes. For instance, in [42], the authors conducted an economic analysis of the historical series in the United States over a 90-year time span and related natural disasters to economic responses. The hedonic price approach is widely employed in the literature to relate anomalous events and price changes. Several techniques have also been employed in the literature to understand the marginal contribution that building features (construction and neighbourhood) bring to the formation of the market price, such as spatial analysis, GIS (geographic information system), and, again, hedonic price regressions and neural networks [43,44].

2.2. Methodological Approach and Workflow

For this research, as introduced in Section 1, the hedonic price approach is adopted through an optimized and multivariate polynomial regression. The methodological strategy leading to understanding the price formation mechanisms after the COVID-19 pandemic and the War in Ukraine, illustrated in Figure 1, is as follows:

- In STEP 1, the exemplary case study is defined, i.e., the real estate market in Padova. The case study is described based on three databases (DBs) collected at different times. The first database is dated 2019, II semester, representing the pre-COVID-19 situation. It is named DB_{2019} for the sake of simplicity. The second database is dated 2021, II semester, portraying the market two years after the first COVID-19 alert but before the outbreak of the War. It is called DB_{2021}. The third database is dated 2023, I semester, depicting the market changes one year after the outbreak of the War in Ukraine. This last database is named DB_{2023}.
- As far as STEP 2 is concerned, a set of construction and neighbourhood descriptive features of the buildings are selected and discussed as the independent regressors in the econometric models. In contrast, the market value of the property is the dependent variable.
- In STEP 3, the authors develop an automated procedure to download data and information about the buildings for sale in Padova. This step is carried out in Python® computer language, producing a web-crawling software to browse and extract information from web pages according to a predefined path. The web crawler has been used three times (2019, II semester; 2021, II semester; 2023, I semester) to read and download information from specific Italian selling websites regarding properties for sale, monitoring market changes in asking prices over time.
- Before producing the regression models, in STEP 4, a feature selection process is conducted to understand how each predictor variable influences the response variable and eliminate the less significant regressors. The feature selection procedure helps to simplify the model outcome, reduces computational time, and overcomes the overfitting problem. The Random Forest (RF) regressor is used to test the variable importance, leading to exclude some predictors from the regression models. The RF procedure is again conducted in Python code.
- STEP 5 produces the spatial-econometric models as Multivariate Regressions (MRs). The econometric model MR_{2019} is developed based on the dataset DB_{2019}, the MR_{2021} refers to the dataset DB_{2019}, and the MR_{2023} corresponds to DB_{2023}. The spatial analyses are conducted using the GeoDa® software, while the stepwise analysis produced to define the MRs is developed with the help of the IBM SPSS 29® software.

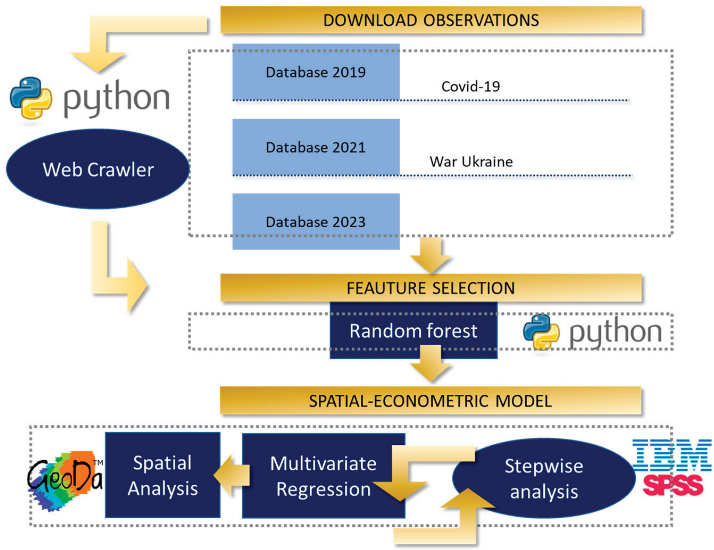

Figure 1. Workflow and the methodological approach.

3. The Case Study

Since the authors have been monitoring and recording data about the city of Padova during the last years to carry out several research projects, this may represent a good case study to understand market variations over time after the latest events because of the enormous data availability about this city. Nevertheless, this case study can also be a good representative of market changes because, besides the access to high-quality and numerous information, Italy is one of the countries majorly hit by COVID-19 and its economic consequences.

Indirect sources (aggregated market quotations) show that after a steep decrease, medium asking prices increased slightly again after the pandemic's beginning. Moreover, this increment keeps constant in 2019–2023, as represented in Figure 2 [45]. Those data have been collected from historical web archives regarding residential properties on sale (asking prices) considering, at an aggregate level, excellent, good, and poor conditions.

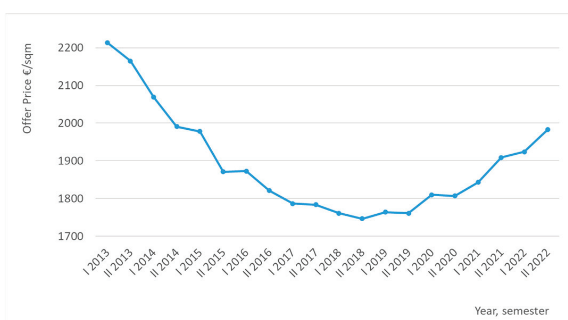

Figure 2. Historical series of the asking prices in Padova for residential properties in optimal/good/poor conditions (immobiliare.it, data collected at City level).

Other sources of indirect information, namely, the Nomisma publications [46] and also the real estate Observatory "OMI" (Osservatorio Mercato Immobiliare) [47], provide the historical series of the actual transaction prices. The difference between the asking prices and the market values (real transactions) gives an idea of the medium negotiation margin. Figure 3 displays the selling prices recorded in Padova from the Nomisma Market Observatory from 2010 to 2022 (the latest information available), while Table 1 resumes data from 2019 to 2022. In this case, the transaction prices have kept relatively constant since 2019, with a slight increase beginning in 2022. In fact, there is always a time lag in the response of transaction prices if compared to the concomitant increase/decrease in the asking prices. Regarding the margin of negotiation, it is now around 4.5% for new constructions and 8.5% for residential properties to be refurbished. The time required to sell a property is around 4.8 months for properties in excellent maintenance and 5 months for good and poor conditions [46].

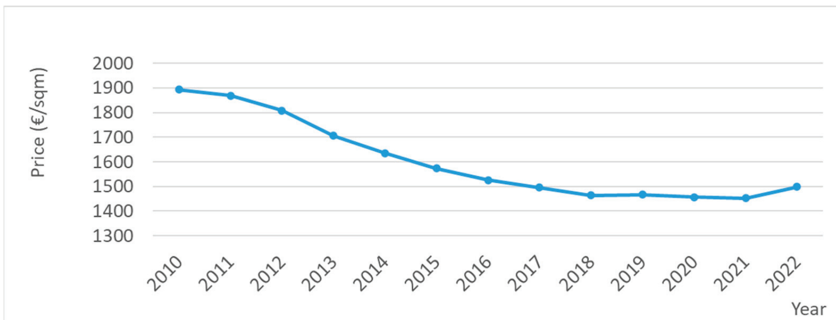

Figure 3. Historical series of the transaction prices in Padova for residential properties in optimal/good/poor conditions (Nomisma, data collected at City level).

Table 1. Average transaction prices in Padova: evolution over time (Nomisma).

Transaction Prices in PADOVA (€/sqm)										
Semester, Year	**Maintenance Conditions**	**Prestigious Areas**		**Centre**		**Semi-Centre**		**Suburbs**		
		Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	
I 2022	New constructions	3532	4290	2964	3659	1910	2254	1214	1547	
	Good maintenance conditions	2655	3221	2119	2579	1322	1739	945	1212	
	Poor maintenance conditions	1632	2160	1462	1790	858	1180	623	851	
I 2021	New constructions	3482	4209	2793	3518	1846	2159	1192	1496	
	Good maintenance conditions	2583	3038	2041	2496	1273	1685	925	1197	
	Poor maintenance conditions	1573	2062	1442	1707	835	1140	608	824	
I 2020	New constructions	3520	4323	2761	3440	1857	2168	1201	1507	
	Good maintenance conditions	2612	3170	2075	2524	1285	1664	901	1183	
	Poor maintenance conditions	1571	2155	1440	1718	847	1154	603	835	
I 2019	New constructions	3451	4226	2745	3485	1848	2175	1212	1542	
	Good maintenance conditions	2571	3108	2042	2583	1307	1672	919	1194	
	Poor maintenance conditions	1577	2142	1483	1788	855	1147	618	841	

From 2019 to 2023, the negotiation margin decreased by 3.5% for old buildings and 2% for new constructions. Moreover, the time required to sell a property has decreased from 2019 to 2023, diminishing by 1.7 months for old constructions and 1.3 months for new buildings [46].

4. A Discussion of Construction and Neighbourhood Variables

This chapter aims to define and discuss the descriptive independent variables of each building collected over time to define DB_{2019}, DB_{2021}, and DB_{2023}. The independent variables will be the regressors, expressing their contribution to the price formation in the MR, and the dependent variable will therefore be the property's market value. As introduced in Section 1, the hedonic price method explicitly refers to the principle that the market value of a building depends on a bundle of its characteristics [19]. For this research, the characteristics of the building that determine its price are generally classified into construction and neighbourhood. This distinction allows us to check whether the neighbourhood features vary in their contribution to the price formation over time.

4.1. Construction Parameters

Regarding construction features, they represent a property's physical features and are directly related to the building typology [48]. Construction features are otherwise indicated as dwelling or building characteristics.

According to [49], construction characteristics may be logically clustered into two complementary sub-groups, i.e., the single dwelling and building characteristics. On the one hand, the first bundle of features strictly refers to the single dwelling and describes the peculiarities of each unit located in a building, including physical features (such as the floor area, the number of rooms, the number of bathrooms, and the maintenance conditions) and technological features (including heating/cooling systems, solar or photovoltaics panels, domotics, alarm systems, or others).

On the other hand, the building characteristics describe the features of the entire building shared by all the single units, such as the presence of a shared garden, parking spaces, lifts, or shared terraces. Clearly, for single-building typologies and independent constructions, the two sub-groups coincide.

In this research, the construction features of the premises are resumed by a total of 40 indicators that are displayed in Table 2.

Table 2. Regressors: the construction features.

INTRINSIC FEATURES: Construction Characteristics		
Building construction characteristics	Terrace Area	Energy Class
Floor area	Top Floor	Construction year
no. of bathrooms	Fireplace	**Typology of the building**
no. of rooms	Maintenance level	Apartment
Floor	**Building installations**	Apartment in a Villa
no. of internal floors	Building Automation	Penthouse
Common garden	Central Heating	Farmhouse
Private Garden	Photovoltaic System	Loft
Private Garden Area	Mechanical Ventilation	Attic
Private Garage	Air Conditioning	Multi-storey single-family home
Private Garage Area	Optical Fiber	Single-family home
Common Parking Space	Lift	Terraced house
Basement	Solar Panels	Two-family villa
Basement area	Heat Pump	Multi-family villa
Terrace		

4.2. Neighbourhood Parameters

For what concerns the neighbourhood characteristics, instead, they represent the location of the building, and they describe its external environment and position. Therefore, the neighbourhood characteristics are chosen to conduct a spatial-econometric analysis, where the economic value of the building is assessed as a function of its location attributes. As defined in [50], spatial analysis generates helpful knowledge to answer questions about order, pattern, and structure inherent in spatial problems. Therefore, the MR's quantitative methodology is intended to answer a spatial question to understand market value fluctuations along a diachronic analysis in relation to position and neighbourhood.

Neighbourhood features may be classified into two groups: urban attributes and accessibility attributes.

On the one hand, urban attributes are related to the level of urban quality. As it goes without saying, a buyer would be willing to pay a higher price for a property located in a position with higher urban quality. Even though no specific literature provides an exhaustive list of the urban attributes (otherwise called urban amenities) that fully describe what drives the buyer's choice, the classification proposed in [51] is often adopted in these kinds of research. The authors [51] classify urban amenities into *natural amenities*, such as air quality, water presence, and open spaces; *historical amenities*, such as monuments, historical sites, or cultural infrastructures; and *modern amenities*, for example, hospitals and health services, shopping malls, educational buildings, leisure, banks, or others. Another classification for the urban characteristics may divide *supply services* from *open-air amenities*. Among the supply services, there are all medical and health facilities (hospital and medical care centres, pharmacies, and herbalists), financial facilities (banks and postal services), educational facilities (nurseries, kindergartens, elementary schools, middle schools, high schools, and universities), cultural facilities (theatres, cinemas, libraries, galleries, museums, and opera houses), commercial facilities (shopping centres, malls, supermarkets, groceries, and tobacconists), and sports facilities (fitness, pools, and sports centres). The open-air amenities are public parks and gardens, playgrounds, walking areas, natural paths, cycle lanes, skating areas, rugby/football/volleyball/basketball/tennis courts, or open-air swimming pools.

On the other hand, accessibility attributes are related to the distance of the house from specific points of interest (POI), such as the city centre, and the link to transportation systems, such as train stations, subway stations, accesses to motorways and ring roads, but also to bus stops and trams.

In this research, urban attributes and accessibility are characterised by analysing the following POI: city centre, train station, bus stop and tram stop, education facilities, big shopping malls, big commercial facilities, small supermarkets, urban parks/public gardens, sports facilities, hospitals, and pharmacies. The list of localisation indicators is presented in Table 3.

Table 3. Regressors: the neighbourhood features.

EXTRINSIC FEATURES: Neighbourhood and Accessibility			
	Point of Interest (POI)		**Point of Interest (POI)**
market segment	City Centre	commercial facilities	Shopping malls
	central train station		Big commercial areas
accessibility to trsnsports	minor train stops		Small-supermarkets
	Bus stop Tram stop	natural amenities	Urban Parks Public gardens
education facilities	nursery kindergarten primary school	modern amenities	Sport facilities Hospitals Pharmacies

5. A Web Crawler to Download Data

5.1. Developing the Web Crawler

This session discusses the methodology for collecting the data and information required to develop the MPRs. In order to make this operation feasible, automated crawling software is designed in Python computer language. The web crawler is able to parse specific selling websites of real estate properties for sale in Padova and automatically download a set of predefined attributes per each parsed property. Specifically, the web crawler identifies and downloads the asking prices of the premises and the corresponding construction and localisation characteristics.

Before the downloading phase, the online search for the web crawler needs to be targeted through the definition of a web-searching domain. In particular, this research is limited to residential properties for sale in Padova, including new constructions and existing buildings (apartments, multi/two/single-family villas, attics, and terraced houses).

Non-residential properties (commercials and directional) are excluded from the searching domain as well as all properties on rent. Regarding the location, all the municipal areas provided by OMI (Osservatorio del Mercato Immobiliare/Real Estate Market Observatory) of the Italian Revenue Agency are included in the domain, such as central, semi-central, peripheral, and suburban areas. A municipal area may represent a portion of the territory that reflects a market segment, i.e., a part of the market in which there is a homogeneous appreciation of economic, social, and environmental conditions.

The Python library "*Beautiful Soup*", a package developed by Leonard Richardson to analyse HTML documents, is integrated into the web crawler. This operation allows the authors to extract and isolate data from the HTML pages by producing a parse tree in every parsed web page. According to the construction and localisation features defined in Section 4, the class of objects and functions is built inside the Python environment to structure the parse trees according to the dataset extracted from every selling advertisement.

After that, another Python library is integrated into the coding. The library "*Pandas*", developed by Wes McKinney, can extract a file in the ".xls" format from any web-crawling process. This library allows to collect and order data and organise them in the form of a table, where the rows of the table represent each observation, while every column is one of the building features. After the crawling-downloading procedure from specific real estate selling websites, DB_{2019} shows 2595 observations, DB_{2021} contains 2729 observations, and DB_{2023} has 2352 observations.

In Figure 4, all the observations from 2019, 2021, and 2023 are represented based on their position in space (latitude and longitude on the map).

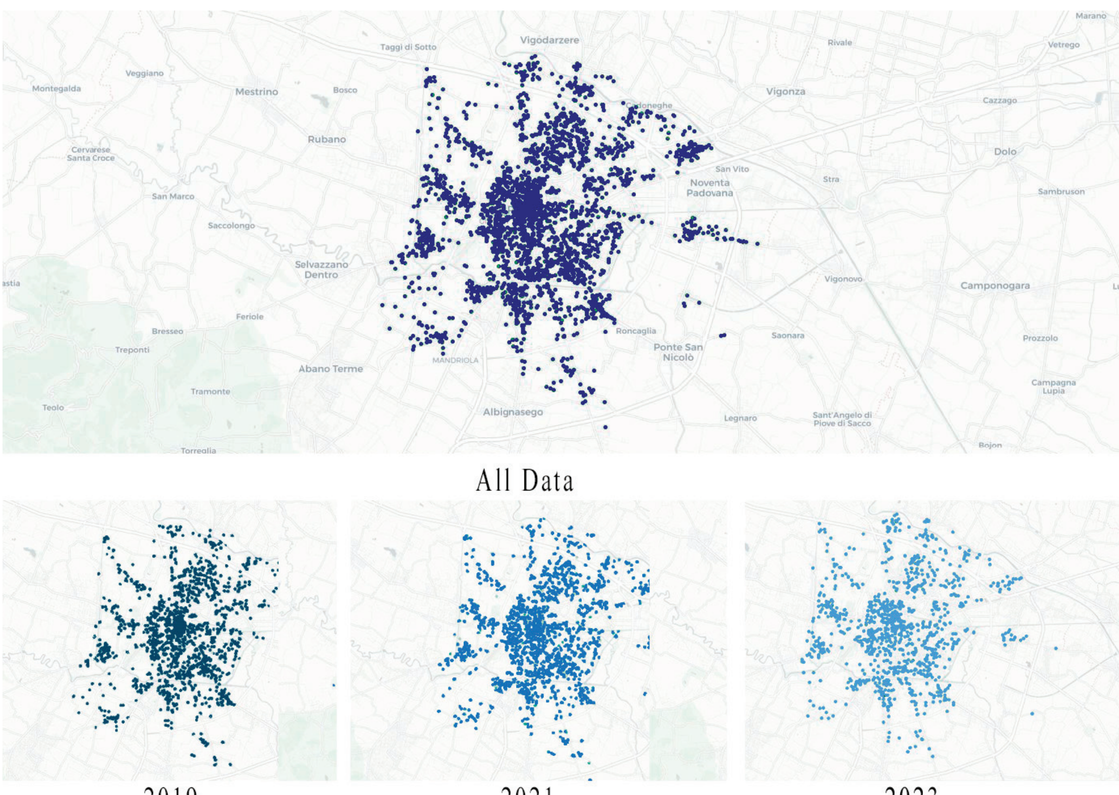

Figure 4. Collected and geo-localised observations in Padova.

5.2. Measuring the Observations

In conjunction with the process of observation downloading, the authors had to decide how to measure the independent variables. Indeed, the regressors express very heterogeneous quantities, both quantitative and qualitative. Since this research aims to relate and quantify the effect of construction and localisation features of a building on its price, it is crucial to understand how to consistently measure each feature and make the impact of different quantities homogeneous in the regression models.

Continuous variables express a measurable quantity that can assume any value. An ordinal variable is a type of qualitative statistical variable that expresses a quality of an ordinal nature. A dummy variable is a "substitute" for a qualitative variable, aiming to make it possible to work with numerical values even when the measure is qualitative. Specifically, using a dummy variable means encoding data within a variable so that it can only assume the value of 0 or 1. The dummy variable is, therefore, a binary numeric variable, a dichotomous nominal qualitative measure.

Regarding construction characteristics, some variables are measured through continuous scales, such as the floor area (sqm) and the market price (€). Most of the features are represented by the binary code 0/1, i.e., absence/presence of the feature, such as lifts, solar panels, building automation, building typology, or others. Qualitative variables are transformed into an ordinal scale. The maintenance level is expressed as a number (1,2,3,4), where 1 represents obsolete buildings, 2 is for poor maintenance conditions, 3 for good maintenance, and 4 stands for optimal maintenance or new constructions. The energy class is, again, represented as an ordinal scale from 1 to 10, where 10 is the highest energy class (A4) and 1 is the lowest class G. Construction characteristics are downloaded, as explained above, through the web crawler with the support of the Python Libraries Beautiful Soup and Pandas. The selected units of measure (U.o.M.) per regressor are resumed in Table 4.

Table 4. Construction features, U.o.M.

INTRINSIC FEATURES: Construction Characteristics					
Variable	**Unit**	**Variable**	**Unit**	**Variable**	**Unit**
Floor area	sqm	Terrace Area	sqm	Energy Class	10 ->1 (A4 -> G)
no. of bathrooms	number	Top Floor	0/1	Construction year	Year (number)
no. of rooms	number	Building Automation	0/1	Apartment	0/1
Floor	number	Central Heating	0/1	Apartment in a Villa	0/1
no. of internal floors	number	Photovoltaic System	0/1	Penthouse	0/1
Common garden	0/1	Mechanical Ventilation	0/1	Farmhouse	0/1
Private Garden	0/1	Air Conditioning	0/1	Loft	0/1
Private Garden Area	sqm	Optical Fiber	0/1	Attic	0/1
Private Garage	0/1	Lift	0/1	Multi-storey single-family home	0/1
Private Garage Area	sqm	Solar Panels	0/1	Single-family home	0/1
Common Parking Space	0/1	Heat Pump	0/1	Terraced house	0/1
Basement	0/1	Fireplace	0/1	Two-family villa	0/1
Basement area	sqm	Maintenance level	1/2/3/4	Multi-family villa	0/2
Terrace	0/1				

On the other hand, neighbourhood characteristics are relatively more challenging to be measured. In fact, "measuring" neighbourhood and accessibility is one of real estate forecasts' most problematic methodological issues. Therefore, several strategies have been adopted and compared in the specific literature. Two major approaches can be distinguished: continuous and dummy measures [52].

Continuous measures may represent the *straight-line distance* between the premise and any POI, which is the Euclidian distance expressed in metres or kilometres (as in [53–55]) or expressed in logs (as in [56]). A more sophisticated approach may instead consider the actual *travel distance*, again expressed in metres or kilometres, from the building to the POI, which is the realistic distance covered by the existing road networks. Another option may be represented by the *travel time* it takes from the premise to the POI, as suggested in [57–62].

Dummy measures, instead, are qualitative variables, and they are only able to define *proximity*, namely, if the building is located within a predetermined distance from the point of interest, as in [63–68]. The predetermined distance may be the "*Ped shed*" (Pedestrian shed), which is usually a 400-metre distance considered to be equivalent to a 5 min walk or any ring buffer around the building [69].

Otherwise, a few other studies measure localisation or accessibility through less common and more specific variables, such as transportation costs/savings as a proxy of accessibility [70]. Again, the number of services or facilities may be counted inside a predetermined ring buffer, producing ordinal variables, as in [71–74]. Another approach may measure density levels, representing the ratio of services over the district's population [75].

In this research, the units of measure employed to give a qualification/quantification of accessibility and neighbourhood are the straight line distance, the actual travel distance by car, the travel time by car, on foot and with public transports, the number of POI (point of interest) in the Ped Shed, and a 1 km ring bugger.

In addition, the observation position is recorded as a coordinate (latitude, longitude). The U.o.M are resumed in Table 5. Calculating the distances and times from the observation to the POIs is quite tricky to accomplish. Integrating the Python web-crawling program with google maps consultations and GIS software is necessary.

Table 5. Neighbourhood features, U.o.M.

EXTRINSIC FEATURES: Localization and Accessibility		
	Variable	**Unit**
position	Latitude of the building (observation)	coordinate
	Longitude of the building (observation)	coordinate
distance	Straight line distance from POI	Km
	Actual travel distance from POI by car	Km
time	Travel time from POI by car	min
	Travel time from POI on foot	min
	Travel time from POI by public transports	min
proximity	N. of POI in the Ped shed (400 m)	n.
	N. of POI in a 1 Km ring buffer	n.

6. The Random Forest as Feature Importance

6.1. Analysis of the Databases

After downloading via the web crawler, raw data are available and displayed as a table. As the first action, missing or misleading observations must be removed from the database to work on "clean" information.

The "cleaning" procedure consists of an elimination, first, of the missing/misleading columns of the tables (features), then an elimination of the rows of the tables (observations).

Regarding the columns, it was almost immediately understood which features should be excluded from the analysis because approximately 90% of the observations did not report that information. As a result, only the construction features represented in Table 6 remain for the optimised feature selection analysis. The neighbourhood features all remain for the MR analysis since every data can be extracted.

Table 6. Definitive construction features.

INTRINSIC FEATURES: Construction Characteristics					
Variable	**Unit**	**Variable**	**Unit**	**Variable**	**Unit**
Building construction characteristics		Maintenance level	1/2/3/4	**Typology of the building**	
Floor area	sqm	Energy Class	10 ->1 (A4 -> G)	Apartment	0/1
no. of bathrooms	number	Construction year	Year (number)	Apartment in a Villa	0/1
no. of rooms	number	**Building Installations**		Penthouse	0/1
Floor	number	Building Automation	0/1	Farmhouse	0/1
no. of internal floors	number	Central Heating	0/1	Loft	0/1
Common garden	0/1	Photovoltaic System	0/1	Attic	0/1
Private Garden	0/1	Mechanical Ventilation	0/1	Multi-storey single-family home	0/1
Private Garage	0/1	Air Conditioning	0/1	Single-family home	0/1
Common Parking Space	0/1	Optical Fiber	0/1	Terraced house	0/1
Basement	0/1	Lift	0/1	Two-family villa	0/1
Terrace	0/1	Solar Panels	0/1	Multi-family villa	0/1
Top Floor	0/1	Heat Pump	0/1		

Moreover, the table's rows (observations) reporting incomplete classes are also excluded because they cannot be used in the regression procedure. Finally, even outliers and observations containing obvious errors are removed. Outliers are those data with anomalous and aberrant values, namely, a value distant from the other available observations. Observations containing obvious errors are referred to as selling ads containing, for example, null selling price or null floor area. As such, the three databases had to be decreased in the number of observations so that DB_{2019} shows 1457 observations, DB_{2021} contains 1687 observations, and DB_{2023} has 1501 observations.

6.2. Feature Importance Analysis

The neighbourhood and construction regressors on which the market value depends are manifold. This vast amount of information may be hard to synthesise in a regression analysis. Only some regressors have the same impact on price prediction, and the less impactful variables could be excluded from the inferential statistics. A feature importance analysis allows us to understand each independent variable's impact on the forecast. When the less significant variables are excluded (feature selection), it helps reduce the problem's dimensions.

Generally, there are three main categories of feature importance methods: the Filter-based, the Wrapper, and the Embedded approaches [76]. The first category includes the approaches based on univariate statistics, such as the Fisher's Score, the chi-square test, the Mean Absolute Difference, the Dispersion ratio, the Variance Threshold, and the well-known Pearson's correlation coefficient. The second category includes Exhaustive Feature Selection, Recursive Feature Elimination, Forward Feature Selection, or Backward Feature Elimination. Wrapper methods treat the problem of feature selection as a search problem [77–79]. Embedded approaches, such as the Random Forest or the LASSO Regularization, can combine the qualities of filter and wrapper methods [80].

In this research, the authors prefer to use the Random Forest (RF) feature importance methodology since this procedure is extremely accurate and reliable, producing good generalisation properties. Furthermore, the RF regressor is implementable in the Python coding created ad hoc for this study.

In machine learning techniques, RF models are non-parametric models that can be used for regressions and classifications. RF models are a popular bagging method, where bagging methods are a machine learning technique in the ensemble learning category. In bagging methods, multiple models are trained on different sub-datasets, each obtained from the initial dataset by bootstrapping, and then the multiple models are aggregated together (ensemble methods).

In fact, the term "bagging" represents the combination of the words *bootstrap* and *aggregation*. Ensemble learning involves the use of various ensemble models in order to improve the performance of each simple classifier taken individually.

Specifically, a RF is an ensemble classifier formed by a set of decision trees, i.e., the simple classifiers [81], so that RF models combine the simplicity of decision trees with the flexibility and reliability of an ensemble model. In computer science, a decision tree is a structure of information made from nodes and arcs, which has to be read from the top to the bottom. The information is contained inside the nodes of the tree. The connections between the nodes are the arcs.

The decision trees are trained based on a randomly selected database subset. In this research, the three training databases are DB_{2019}, DB_{2021}, and DB_{2023}.

The RF process is performed on the three DBs implementing the "Numpy" library inside Python. During the training, the RF regressor measures how much the impurity of each variable decreases, which gives an order of importance of the regressors over the dependent variable. A variable has higher importance when it diminishes its impurity the most. The impurity for discrete variables is given by the Gini impurity or by the information gain/reduction in entropy, while in continuous variables, it is given by the variance.

To perform the RF selection, 80% of the data per each DB constitutes the training sets, and it is chosen to use the leftover 20% of observations as testing sets. In training the classifiers, the authors decided to build 5000 trees and to set the threshold at 0.75 of the mean value of the importance coefficients.

The RF regressor is able to assess the independent variables' "coefficients of importance" by calculating their decrease in impurity. The impurity of a variable is the mean of the decreased values produced by each tree. As a result of the feature importance approach, the RF-aggregated coefficients are presented in Table 7.

Table 7. Random-forest-aggregated coefficients.

Class Element or Function	RF Coefficients		
Intrinsic	**2019**	**2021**	**2022**
Typology of the building	1.24%	0.94%	0.80%
Building construction characteristics	31.49%	38.23%	74.67%
Building installations	2.13%	1.53%	0.42%
Extrinsic	**2019**	**2021**	**2022**
City centre proximity	35.70%	12.88%	4.81%
Transports accessibility	3.36%	3.60%	1.80%
Health services proximity	4.72%	4.40%	2.98%
Urban amenities and leisure	11.95%	28.19%	8.73%
Commercial areas	3.46%	4.61%	2.71%
Education facilities proximity	5.95%	5.61%	3.07%
	100.00%	100.00%	100.00%

7. A Spatial and Econometric Analysis

7.1. The Multivariate Regressions

Before performing the MR, it is necessary to verify whether the feature selection process has ensured the minimum balance between the number of observations in every DBs and the number of used independent variables. Several "rules-of-thumb" have been suggested in the literature over time in order to determine the minimum number of observations necessary to elaborate a multiple regression analysis. In [82], the authors suggest that $N \geq 50 + 8R$ in multiple correlations and $N \geq 104 + R$ in partial correlations, where N is the number of minimum observations, and R is the number of predictors. However, the authors in [82] also state that for multiple correlations, the rule $N \geq 50 + 8R$ produces values excessively large for N when $R \geq 7$. Therefore, the so-called "effect size" should also be considered in questioning the minimum sample size.

In this case, the number of observations fully justifies the number of the selected regressors later illustrated in this paragraph.

The MR helps to understand the relationships with multiple independent variables, as it is in this research. The dependent variable (Y), i.e., the market value of the property, depends on several independent variables (X_r), namely, the descriptive building features, and R is the total number of the regressors, as in Equation (1):

$$Y = a_0 + \beta_1 X_1 + \cdots + \beta_r X_r + \cdots + \beta_R X_R \pm \varphi \quad (1)$$

In the equation:

- Y is the dependent variable (i.e., the market value measured in €/sqm);
- a_0 is the constant;
- β_r are the coefficients of the regressors X_r, $1 \leq r \leq R$;
- X_r are the dependent variables $1 \leq r \leq R$ (i.e., the characteristics of the buildings);
- R is the total number of dependent variables (X_r);
- φ is the error.

The regressors are normalized in the interval 0–1 to be homogeneous and coherent. The normalization allows all the terms to be compared through the same seize order and to be consistent in the results.

With the help of the SPSS 29 software, the authors conduct a stepwise analysis, both forward and backwards, to identify the optimal function that explains the dependent variable. The stepwise analysis includes and excludes iteratively the regressors intending to minimize the error on the forecast. The final regressors are defined as follows:

- X_1 = Building internal services (Σ 0/1 of lift, private garden, private garage, shared parking space, cellar, terrace, building automation, central heating, photovoltaic system, MCV, air conditioning, optical fibre, and fireplace);
- X_2 = Floor area (sqm);
- X_3 = Energy class (from 10 to 1, where 10 represents the highest class A4, and 1 the lowest, i.e., class G);
- X_4 = City centre straight line distance (km);
- X_5 = Urban amenities and leisure (total n. of services in 1 km ring buffer of cultural facilities, museums, art galleries, theatres, cinemas, and libraries);
- X_6 = Commercial services (total n. of services in 1 km ring buffer of big shopping malls, big commercial facilities, and small supermarkets);
- X_7 = Bus and tram stop (total n. of services in the Ped shed of bus stop and tram stop).

The MR developed on DB_{2019} produces the function Y_{2019}, on DB_{2021} the function is called Y_{2021}, whereas on DB_{2023} the regression formula is named Y_{2023}. The results of the MR analysis are reported below in Equations (2)–(4). All the regressors show a T-student value > 2 and a p-value < 0.05. The Gaussian distribution of the values representing the difference between the expected value and the forecast can be appreciated by the analysis of residuals. As far as R-sq is concerned, $Rsq_{2019} = 0.71$, $Rsq_{2021} = 0.79$, and $Rsq_{2023} = 0.74$.

$$Y_{2019} = 1766.16 - 33.29X_1 - 0.57X_2 + 68.88X_3 - 25.98X_4 + 2.65X_5 - 17.75X_6 + 5.14X_7 \quad (2)$$

$$Y_{2021} = 1801.46 + 52.31X_1 - 6.26X_2 + 74.59X_3 - 92.83X_4 + 8.92X_5 - 9.89X_6 - 27.49X_7 \quad (3)$$

$$Y_{2023} = 1673.95 + 10.62X_1 - 2.08X_2 + 144.07X_3 - 57.79X_4 + 12.94X_5 - 29.38X_6 - 27.11X_7 \quad (4)$$

In these equations, X_1, X_2, and X_3 represent the construction properties of the buildings, while X_4, X_5, X_6, and X_7 embody location attributes. Since such neighbourhood features add spatial information to the regression analysis, the authors believe that further clarification and exploration of this issue may be required here.

There are fundamental differences between spatial and a-spatial data: unlike the former, the latter usually fulfils certain critical assumptions in statistical analyses [4]. The first assumption is independence within the sample. The assumption of independence underlies not only various techniques, including regression, but, more generally, inference and inferential statistics. However, spatial data tend to violate it because they are characterised by spatial dependence naturally.

The second assumption is spatial homogeneity, which is similar to the first assumption because both properties are related to the covariance of spatial processes, producing similar effects on statistical and inferential analyses.

A regression analysis, as in this research paper, rests on a number of statistical assumptions that, when fulfilled, guarantee the *optimal* properties of the forecasts. However, it is rare for spatial data to satisfy those assumptions, which implies that, generally, the calculation of model parameters from spatial data samples is carried out in violation of those assumptions, so that regression, including spatial data, tends to be affected by more significant variability than those obtained from a-spatial data. The R-sq calculated in the three models is, in fact, representative of about 70% of the sample, which is good reliability on the forecasts but not optimal, remembering that spatial econometrics naturally deals with spatial dependence and spatial heterogeneity [83].

The crucial point is related to spatial autocorrelation, which measures, regarding a single variable, the correlation (positive or negative) between specific spatial units and other spatial units and the dependence between them [84]. There are several indices of spatial autocorrelation, the best known of which are Moran's and Geary's [4].

According to Moran's index, autocorrelation is positive when neighbouring attributes are more similar (attraction), negative when they are more dissimilar (repulsion), or close to zero when there is no relationship between similarity and distance, in which case the spatial process is a random process (complete spatial randomness) [85]. The Univariate Moran (I) index has been assessed on DB_{2019}, DB_{2021}, and DB_{2023}. According to the following Formula (5):

$$I = \left(\frac{N}{\sum_i \sum_j W_{ij}} \right) \left(\frac{\sum_i \sum_j W_{ij} (X_i - X_{med})(X_j - X_{med})}{\sum_i \sum_j W_{ij} \sum_i (X_i - X_{med})^2} \right) \tag{5}$$

$1 \leq i \leq N$
$1 \leq j \leq N$
$-1 \leq I \leq 1$

where N is the number of observations (points in the space), X_i is the variable that describes the phenomena, X_{med} is the sample mean, and W_{ij} is the weights matrix. The spatial weights matrix consists of as many elements as spatial units sampled (N), and each of its elements defines the contiguity between two spatial units. Typically, the matrix comprises a binary structure multiplied by a distance friction function. The task of the binary structure is to determine which units are considered contiguous. The matrix obtained by multiplying the binary structure by the distance friction function weighs the observed interaction for the distance between two spatial units in all cases where they are defined as contiguous.

For this reason, the contiguity matrix is often also called the spatial weights matrix. In this case, the spatial observations are points (latitude and longitude). Therefore, the weights matrix is built using the k-nearest neighbour methodology. As such, $I_{2019} = 0.53$, $I_{2021} = 0.32$, and $I_{2023} = 0.29$, also represented in Figure 5.

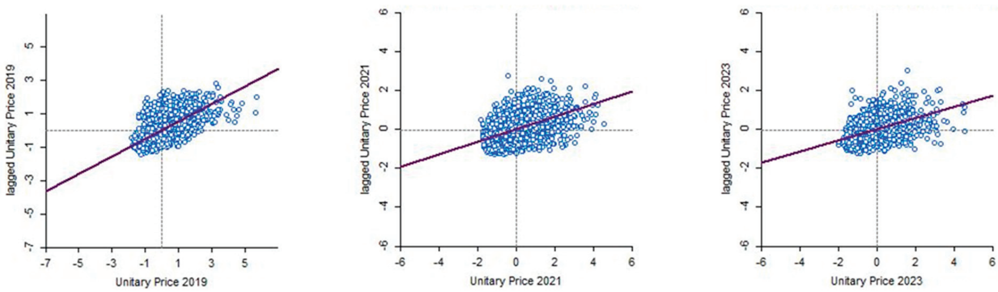

Figure 5. Univariate Moran I.

7.2. Discussing Fluctuations in Market Preferences

By comparing the functions above, i.e., Y_{2019}, Y_{2021}, and Y_{2023}, it is clear that some changes have occurred in the marginal appreciation that buyers attribute to the characteristics of the buildings. Moreover, the RF feature importance process helps to understand the different willingness to pay for specific attributes over time (please refer to Table 7 in Section 6), and the Moran I indexes lead to understanding the evolution of spatial autocorrelation.

Regarding the construction features of the buildings, expressed by the regressors X_1, X_2, and X_3, a higher appreciation of certain features, such as a wider surface area or the energy class, is clearly recorded after the COVID-19 pandemic. The energy class coefficient in the MR is positively correlated to the forecast, and the coefficients increase from 2019 to 2023. In addition, the RF results show the increasing importance of the buildings' construction characteristics over time.

These results can be considered consistent with similar research performed in other Italian cities, such as in [86], and they can be interpreted as a response to the COVID-19 pandemic: The lockdown periods have changed the way people experience their home and have (obviously) increased the amount of time spent there. Although lockdown periods have now ended, people's daily routines still remain affected by that experience, as it is, for instance, for smart working new schedules. This made certain features of the houses more significant, like bigger spaces, while technologies and installations are now more appealing to buyers, especially from an energy efficiency point of view. It is significant to mention in this context that the attention to the reduction in energy consumption has also increased with the "110%-Superbonus" and "Sismabonsus" Italian Government initiatives and concomitantly, due to the exponential growth of energy prices and construction costs due to the War in Ukraine [87]. These government initiatives have undoubtedly played an important role in the market value variations according to maintenance characteristics and energy classes. The effects on the real estate market of such initiatives have had additional and simultaneous effects on COVID-19. On the one hand, the demand for properties in poor maintenance conditions was increased, considering that the owner could have benefited from retrofit/renovation bonuses. Furthermore, the demand for energy-efficient performances and good conservation conditions may have been losing some appeal due to the possibility of asking for financial incentives.

Due to the War in Ukraine, however, there has been a significant increase in energy prices, and the request for properties with high energy performances, with new technologies and renewable energy installations, has also increased. Meanwhile, a sharp increase in construction costs has been holding back the construction of new buildings, making the supply of such goods scarce.

Regarding localisation features, the feature importance analysis helps to quantify the impact of the localisation variables on the market price.

First, the proximity to the city centre generally produces a non-linear increase in market values. In this case, the proximity to the city centre clearly shows decreasing RF coefficients from 2019 to 2023. This positional characteristic is prone to influence the market value less after the COVID-19 and Ukraine War events. However, the regression equations still show that the nearer to the centre, the higher the value. Clearly, the city centre's concentration of services and facilities is the highest, therefore playing a significant role in enhancing people's quality of life. The main cultural amenities are located in the city centre, and various studies showed that the proximity to an important museum [88], an archaeological site, a historical building [89], or cultural heritage [90] might increase the market values of the properties because of the positive impact on the district's image [91]. The Moran I index still confirms that as much as the position of the building with respect to the city centre remains determining, the market segmentation (spatial autocorrelation of market prices) has decreased from 2019 to 2023.

The market value is also influenced by accessibility to public transport, and coherently with the analysis developed here, the authors in [92] identified a significant impact of accessibility on market segmentation. However, in this case, the RF analysis also allows us to understand that access to transport has seen a decrease in its impact on the market value from 2021 to 2023.

The proximity of hospitals and medical centres seems to slightly influence the market value in Padova, and such regressors have been excluded from the MRs as they did not show sufficient statistically significance in the regression stepwise analysis. Several researchers have extensively explored this issue in the literature, but their findings produced controversial results. Some authors have found that the proximity to hospitals has a slightly negative impact on the prices, as in [93] and [94], especially if the premise is very close to the hospital [95], probably due to ambulances' high noise and traffic congestion. However, the same authors [95] have highlighted that medical facilities can increase the market value within a certain distance from the premises (a ring buffer of 1 to 2 miles). Other publications have found no significant impact of hospitals' proximity on the prices [96].

Educational facilities are slightly correlated to the market value of a property in Padova, and these regressors have been excluded from the MRs since they are not statistically significant enough according to the regression stepwise analysis. The results in the literature are divergent. For instance, in [97,98], the authors have identified a positive impact of educational facilities' proximity on house prices and the increase in price is often associated with the school rating/performance index. Higher school quality increases housing prices [99], and public high-performing schools seem to have the highest impact [100]. Educational facilities also increase the number of operators in the market demand [101].

Regarding sports facilities and urban parks, the influence on the market value over time in Padova seems negligible in the MRs. The RF coefficients show an increase in impact on the forecast in 2021 and a decrease in importance in 2023. As also mentioned in the literature, as in [102–105], only large stadiums and arenas produce a sensible variation in market prices, and the results are quite controversial. The effects of proximity to large sports infrastructures lead to a general increase in the prices of the district, but, at the same time, they lead to a decrease in market values of the nearest buildings due to the negative externalities. The literature is relatively consistent in relating an increase in housing prices when a park or a greenway is in the proximity of the building [106] since the quality of the neighbourhood is positively enhanced, especially if inside the "Ped shed" [107].

Commercial facilities show a negative impact in the regression equations produced, even though the RF shows that this is certainly not the primary influence on the prices. These results are quite controversial in the research: In [108], the author detected a rise in housing prices within a proximity range of 1–5 miles. A price increase in the district was also identified by [109] due to the presence of groceries. Big supermarket chains also contribute to a rise in prices, as in [110,111], especially when they are in the Pedestrian Shed [112]. Other studies have found a counter-trend, where the closest houses to commercial facilities may experience a slight decrease in market values due to noise and traffic [113].

8. Discussion and Conclusions

The scope of this study was to highlight the different marginal appreciation of construction and localisation features of properties in determining their market value. The analysis was diachronic and regarded as one exemplary case study in North Italy. The case study has been analysed at three different time points:

1. Before the first COVID-19 pandemic alert;
2. Two years after the first COVID-19 alert but before the outbreak of the War in Ukraine;
3. One year after the outbreak of the War in Ukraine.

Several techniques have been integrated into this research: computer programming in Python language, spatial analysis, Multivariate Regression, and Random Forest feature importance analysis.

First, an automated procedure was developed in Python® computer language to download descriptive data about the buildings. Then, a web-crawling software was produced to extract information from specific real-estate-selling websites. Finally, the set of construction and localisation descriptive features of the buildings to be downloaded was defined.

Specifically, the web crawler was applied at three different time points. The first download dates back to the beginning of the II semester of 2019, to capture a pre-COVID-19 scenario. The second download is dated 2021, the beginning of the II semester, to portray the situation two years after the first COVID-19 alert but before the outbreak of the War. Finally, the third download goes back to the beginning of the I semester in 2023 so as to depict market variations one year after the outbreak of the War in Ukraine.

Before producing the regression models, feature importance and feature selection analyses were applied to the three databases.

The feature selection procedure was chosen to understand the variables' importance in the Random Forest regressor. This analysis helps to exclude the less significant predictors from the regression models, reducing the complexity and computational time of the regressions.

Then, three forecasting econometric models are produced as Multivariate Regressions to forecast the market value of a property as a function of a bundle of its descriptive characteristics.

The three models are diachronic and are dated 2019, 2121, and 2023. By comparing the three equations, it is possible to understand how the marginal contributions have changed per building feature after those two anomalous events. Particular attention has been dedicated to the comparison of neighbourhood versus construction characteristics.

The significant result of this research is a deep monitoring of the fluctuation in demand preferences in response to the last year's anomalous events. Location is the primary factor in determining market prices, but other building attributes affect the buyer's choices more and more. Among the significant limitations of this study, it can be stated that the case study is very specific. The case study of the city of Padova was selected due to the availability of extensive and detailed amount of data from several previous works. However, in further developments of this research, the authors intend to expand this market value analysis methodology to other Italian cities. Another limitation of the present study is the short time span during which the analysis was carried out. For this reason, the authors continue to monitor market variations over time in order to observe diachronic changes and understand future developments.

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Nomenclature

a_o	constant (intercept of the regression)
DB	database
DB_{2019}	database dated 2019, II semester
DB_{2021}	database dated 2021, II semester
DB_{2023}	database dated 2023, I semester
DBs	databases
GIS	geographic information system
I	Univariate Moran I index
I_{2019}	Moran I index developed on DB_{2019}
I_{2021}	Moran I index developed on DB_{2021}
I_{2023}	Moran I index developed on DB_{2023}
MR	Multivariate Regression
MR_{2019}	Multivariate Regression developed on DB_{2019}
MR_{2021}	Multivariate Regression developed on DB_{2021}
MR_{2023}	Multivariate Regression developed on DB_{2023}
MRs	Multivariate Regressions
N	number of observations
POI	Point of Interest
POIs	Points of Interest
R	total number of predictors
RF	Random Forest
U.o.M.	unit of measure
Wij	the weights matrix
X_i	the variable that describe the phenomena
X_{med}	the sample mean
X_r	dependent variables $1 \leq r \leq R$ (i.e., the characteristics of the buildings)
Y	dependent variable (i.e., the market value)
Y_{2019}	dependent variable (i.e., the market value $_{2019}$)
Y_{2021}	dependent variable (i.e., the market value $_{2021}$)
Y_{2023}	dependent variable (i.e., the market value $_{2023}$)
β_r	coefficients of the regressors X_r, $1 \leq r \leq R$
φ	error

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Landscape Value in the Spanish Costa del Sol's Real Estate Market: The Case of Marbella

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Abstract: Housing prices are influenced by extrinsic and intrinsic factors. This study aims to highlight the economic impact of the perceived landscape on single-family houses prices in a Spanish Mediterranean urban area (Marbella). Considering the landscape an important added value in real estate markets, this study also explores the landscape elements that contribute the most to the value of housing. A particularly positive influence of mixed views (urban elements and Mediterranean scrub) and sea views is detected in the analysis. Sea views are highly requested in the local housing market, but due to the graded topographical layout of Marbella, it is not very difficult to have sea views for houses. The low importance of views on natural land areas is worth noting when one of the attractions of this municipality is that of a highly valued Mediterranean natural environment. Views on the old town centre are somewhere in between: although the old town centre is highly regarded, with a generally good state of preservation, the sampled properties have poorer quality perspectives, with reduced visual basins and views centred on the foreground, usually the houses opposite.

Keywords: landscape value; real estate market; Costa del Sol; geoadditive models; GIS

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1. Introduction

Housing is one of the goods considered a right in the United Nations' Universal Declaration of Human Rights [1]. However, this good not only fulfils the function of covering a basic human need, because it is usually commodified through trades and sale prices. Housing value in terms of use and exchange values implies several phenomena on its economic valuation, with real estate prices that increase in misalignment with its characteristics.

Property prices are influenced by extrinsic and intrinsic factors, such as, e.g., maintenance state and quality of materials [2], comfort [3], safety [4–6], energy efficiency [7–12], social status of its owner [13] and the surroundings [14–17], environmental, historical or architectural amenities [18]. In the same way, real estate market is also conditioned by contextual socioeconomic factors [19,20] and the variation in the mode of real estate goods appreciation [21,22]. These aspects favour the use of advanced hedonic pricing models based on the survey and statistical analysis of real estate market data.

The econometric analysis of real estate prices can be used for the landscape's monetary valuation, considering that real estate prices are receptors of environmental externalities. In the same way as the position income is integrated into real estate prices, so the value of environmental externalities and landscape can be estimated measuring real estate price changes resulting from the environmental variation detected. This analysis type requests pluriparametric statistical models (e.g., multiple regression or semiparametric models) to express property prices through a complex function linked to real estate characteristics, including those relating to the environmental qualification or landscape.

Starting with these considerations, a geoadditive model was applied to measure the economic impact of the possible perceived landscapes on single-family houses prices in a Spanish Mediterranean urban area (Marbella). Geoadditive models (GM) are a variant of generalized additive models (GAM), the most common nonparametric multivariate regression technique used for these purposes because they have many advantages, mostly in small local real estate markets. They help to analyse price variations in the area of interest, predicting and quantifying in real time where and how prices vary in the urban context considered, with a possibility to correlate these variations with any phenomenon or economic effect. Moreover, if penalized splines are combined with techniques of spatial statistics (kriging), these models allow obtaining spatial maps with high reliability to support any decisions related to urban investments [23,24].

2. Literature Review

In international literature, many studies applied spatial nonparametric or semiparametric additive regressions to the formulation of housing market's hedonic price models. Often, these models proved to be the best tools for property price forecasting because nonlinear models better fit the spatial heterogeneity of and nonlinear relationships between real estate characteristics and selling prices [23,24].

Mainly, these studies focused on generalized additive models and the so-called "backfitting algorithm" [25] as the main resolution tool of additive models based on the available statistical data [26].

With the objective to limit computational difficulties in estimating the individual functions of additive models, specific smoothing spline functions are placed and matched. Currently, smoothing spline functions are of particular interest when working with fuzzy databases, but also when applied in many scientific fields, e.g., chemistry, natural and physical sciences, medicine, economy [27]. Semiparametric models applied to real estate appraisals are currently a subject of specialized literature and, particularly, they focus on analysing real estate markets and marginal pricing of relevant real estate characteristics [28].

Specifically, in this study, a semiparametric model with geostatistical extension as used to discern the value of landscape qualities in a local real estate market.

As van der Heide and Heijman pointed out, until the 1970s, landscape was not considered a relevant economic variable in Western Europe and because of that, it was not studied in depth by economists [29].

In recent decades, there has been a growing interest in the extrinsic factors influencing real estate prices or the effects of environmental variables on surrounding areas, albeit in a disaggregated way: the studies have aimed to isolate specific elements of the environment, such as the presence of green spaces [30,31], water bodies [32–35] or air quality [36–38]. These variables may reflect the landscape value, but the mentioned studies focus their analysis considering other aspects such as accessibility or the simple positive or negative connotation of their proximity. However, the consideration of landscape in an integral way, especially in the dimension with the greatest impact on the human being, the visual, is still in the incipient phase due to the complexity of measuring and separating it from other housing features.

Most relevant studies with this scope have begun to be carried out both on the regional scale in 2021, such as in the Tuscany region in Italy [39], as well as on the intraurban scale, in cities like Hong Kong in 2009 and 2011 [40,41], New York in 2021 [42] or Geneva in 2011 [43]. Although quantitative studies are more frequent, because they are more easily replicable in other territorial units and allow larger statistical samples, there are also studies that apply qualitative methods such as those by Damigos and Anyfantis conducted in 2011 [44], by Castro, Vías and Mérida in 2022 [45] or by Vizzari in 2011 [46].

More precisely, qualities of neighbourhoods and their surroundings were studied by Kiel and Zabel in 2008 [47], but the location qualities value is very difficult to express, as D'Acci affirmed in 2014 [48]. The issue of location quality valuation in monetary terms usually concerns the relationship between real estate prices and the distance to characteristic places with the necessary support services and structures: see the studies of Chiang et al. conducted in 2015 [49] or of Jang and Kang in 2015 [50]. Since hedonic models are the preferred tools for expressing the relationship between housing prices and location qualities, it is worth noting that they often include structural factors that may introduce noise effects (such as building age, area, etc.): e.g., see the studies of Hui et al. conducted in 2007 [51], Jim and Chen in 2010 [52], Xiao et al. in 2017 [53]. A wide literature review about hedonic models is reported in the work of Malpezzi et al. published in 2002 [54]; however, the analysed studies showed that the real estate characteristics weight varies in significance and dimension, confirming that every study is specific and valid only for the real estate market to which it refers. Sirmans et al. also arrived to this conclusion in 2005 [55].

Other recent studies have focused on more specific social aspects of landscape value. Cellmer in 2023 dealt with the issue of urban landscape value considering it as one among many "points of interest" (POI), taking into account the number and density of POIs in the surrounding territory (in Poland), thus reflecting, among other things, the effect of the degree of urbanization and the city's spatial structure [56]. Grundel et al. explored in 2022 a collaborative process for Sweden, namely landscape resource analysis, as a tool to identify a variety of values and sometimes conflicting interests and to improve communication about these among different stakeholders by using maps and GIS [57]. In 2022, Martin and Yepes applied an analytic multicriteria valuation method to estimate the landscape's economic contribution [58]. In 2013, Tagliafierro et al. proposed a multidisciplinary approach integrating landscape ecology, landscape preference studies and environmental economics to assess the economic value that people attach to different landscape attributes [59].

3. Materials and Methods

3.1. Study Area

The real estate data sample consisted of 403 single-family houses offered for sale in 2022 and located in the municipality of Marbella (a Spanish Mediterranean town of western Costa del Sol, see Figure 1).

Figure 1. Properties sampled in Marbella and highlighted with orange dots (source: authors' elaboration based on the cartography provided by Andalusian Institute of Statistics and Cartography [60]).

Marbella features a particular topographical connotation. The town is located between the coastline and a mountain range, which favours the possibility of having wide panoramic views from numerous urban spaces. If a mild Mediterranean climate and urban development without traces of industrial use are added to these aspects, the result is a residential tourism destination in which the views from houses are a particularly appreciated characteristic.

3.2. Variables

The variables listed in Table 1 were selected to analyse the Marbella real estate market and highlight the economic impact of landscape on real estate values.

Table 1. Variables description.

Variable	Description
Housing sales price (PRICE)	Expressed in euros
Commercial area, the sum of the internal area and other virtualized secondary surfaces (AREA)	Expressed in square meters
Housing unit sales price (UPRICE)	Expressed in euros per square meter (UPRICE = PRICE/AREA)
Landscape views (VIEW)	Expressed in square meters for each view (natural environment, sea, old town, other)
Qualitative segment of the real estate market (TYPE)	Three levels: lower-middle, upper-middle, luxury
Euclidian distance to the sea (DIST)	Expressed in meters

Source: authors' elaboration.

The values of the AREA and TYPE variables were normalised in order to improve the performance of the mathematical model. These variables were grouped into three categories considering the specific characteristics of the Costa del Sol real estate market.

3.2.1. Housing Sales Price (PRICE, UPRICE)

Due to the geographical and topographical connotations of Marbella, the average price per square meter is considerably higher than the average unit price in the rest of the western Costa del Sol region: the average unit price per square meter in Costa del Sol is about 2600 euros; in Marbella, it reaches a value higher by 30–35% (about 3400 euros).

The housing prices in the municipality went from about 2300 euros in 2007 to about 4000 euros per square meter in January 2023, recording an increase of about 77% (see Figure 2). Some intermediate periods after the real estate bubble in 2006 and the world financial crisis of 2008 must be highlighted in this real estate dynamic, where the prices dropped to a minimum of about 2050 euros per square meter (November 2013). Thus, from January 2013 to 2023 the housing prices increased by up to 96% in about ten years, with an average increase of ca. 0.8% per month [61].

Considering each real estate market segment since July 2011, we can detect uneven variations for the houses sampled in this study. For the luxury segment, the price increase rate was ca. 57%, for the upper-middle segment, it was ca. 90%, and for the more affordable segment, it was ca. 70%. The data sample considered, consisting of 403 single-family houses extracted from the Idealista Maps website, is distributed across different town areas (urban centre to periphery). The sample was composed of the real estate listings available for 2022. Some scientific studies have considered heterogeneous residential spaces, while others have tried to select units of specific types [62]; in our case, only single-family houses were sampled to avoid possible biases in the statistical analysis.

The UNI 11612:2015 standard (Italy) introduces the possibility to use asking prices for real estate appraisal purposes. In particular, when insufficient, undetectable and/or unreliable real estate trades have occurred in the reference market segment in a recent period, price requests for similar properties offered for sale can be considered (asking price).

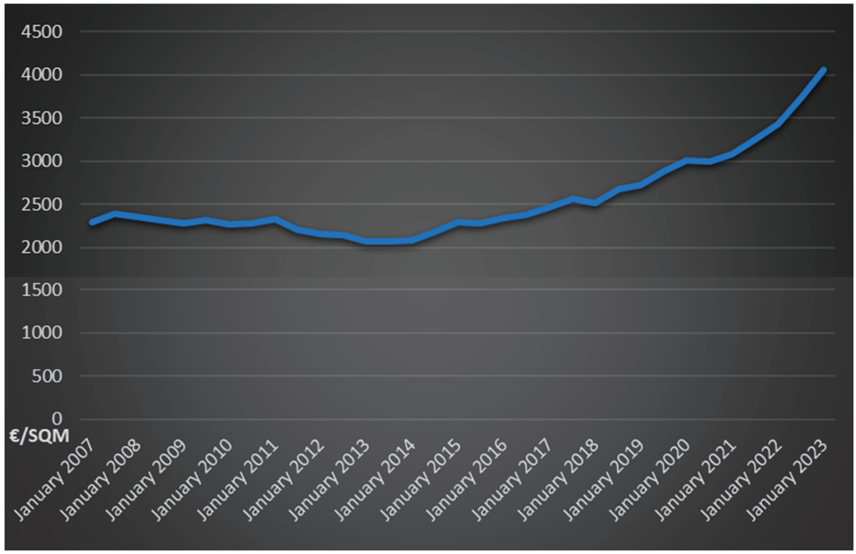

Figure 2. Evolution of the average housing unit prices in Marbella [61].

3.2.2. Commercial Area (AREA)

The property's commercial area is one of the variables that influences the selling price the most, and it has been included into the analysis. The different weighting between the internal surface and other secondary surfaces (gardens, garage, cellars, etc.) has been considered on the basis of the guidelines provided by the European Valuation Standards [63].

3.2.3. Landscape View of the House (VIEW)

According to the European Landscape Convention of the Council of Europe [64], landscape valorisation has been subject to a growing sensitivity towards less tangible aspects of landscape experience [65–68]. Due to the combination of its physical characteristics and cultural relevance, landscape is considered to have a direct impact on the quality of life of those who experience it. However, this concept involves consideration of a qualitative distinction from similar places, because they may generate more biases rather than a clarification of the processes behind real estate prices. The views of houses can have a varied composition, combining more or less desirable landscape elements arranged on different levels, so each view can have a different appreciation. For this reason, a disaggregation of views into four landscape types was chosen in this study. The views were limited to three areas with a theoretical positive connotation: natural elements of the sea or mountains, urban elements of the historic centre, all remaining views with attribution of the same landscape classification.

3.2.4. Qualitative Segment of the Real Estate Market (TYPE)

A classification into three categories (luxury, upper-middle and lower-middle segments) was made for the single-family houses sampled. The differentiation criterion was based on the architectural features of the house, and fieldwork was carried out to evaluate them. The architectural style, the height–width ratio, the window–wall ratio, as well as the surrounding buildings are the aspects that were evaluated as priorities in previous studies and were taken into account [69].

3.2.5. Euclidean Distance to the Sea (DIST)

In tourist locations, the proximity of a house to the sea can be as decisive element for its price due to its visual perception [70]. Among other reasons, this is due to the perception of the sea as a natural recreational resource where such activities as swimming, nautical sports, sunbathing, etc. can be carried out [71] or the climate-regulating function it exerts on the nearby environmental and human resources. For all this, the straight-line distance (Euclidean distance) from the sampled houses to the sea was measured and considered in this work.

3.3. Dataset Preparation

With the exception of the georeferenced real estate values, all the other data analysed in this study were generated using a geographic information system through the QGIS 3.28.5 'Firenze' software [71].

The first step consisted in the definition of the landscape information layer characterized by four general landscape levels: three levels with an added value for observers (mountain, sea, old town) and another level for all the remaining views. This layer had a five-kilometre extension over the limits of the Marbella municipality for two reasons: on the one hand, to include the perception of the nearby landscape background; on the other hand, the houses located in areas near the municipal limits have similar views to the more central areas.

The second step regarded the definition of the variables related to coastal landscape, such as proximity and distance to the sea. This was calculated in two different ways: by measuring the Euclidean distance from the nearest point of the coast to each house using the ArcMap tool [72] or by analysing the road network by means of a layer obtained from Open StreetMap [73]. After a preliminary process of shapefile conditioning, an isochronous map was created based on the traffic speed in each section.

After discovering that the architectural type variable generated noise in the spatial logic of equation results, a coefficient was applied to the prices according to the architectural type and finally omitting this variable. A different coefficient was applied to the houses sampled based on their type.

The last step elaborated the visual basin of each house using a digital surface model (DSM) with a pixel resolution of five meters provided by the National Geographic Institute of Spain [74]; the four stages of this process were as follows:

- A viewpoints layer was created for each house sampled in the study area. To do this, the polygons layer representing the plots of different urban buildings was transformed into a points layer by calculating the centroid of each polygon (in this case, the layer had 403 observation points). To this points layer, an attribute referring to the observer's standard height (1.65 m) and visibility radius (five kilometres) was applied.
- After configuring the observation points, the visual basins were calculated with the viewshed algorithm based on the DSM, assuming the default values provided by the tool in terms of Earth sphericity and the atmospheric refractive index. This calculation process was performed 403 times, once for each observation point, obtaining a raster layer with binary values: 0 (not visible) and 1 (visible areas).
- Finally, the visible area value in square meters was calculated for each of the 403 visual basins. The visible surface was the result of multiplying the number of pixels with value 1 by the surface of each pixel (25 square meters in this case study).
- The perceived surface characteristics were classified by cross-referencing the information of the landscape units that cover the entire study area.

3.4. Model Specification: Penalized Spline Additive Models and Geostatistical Extension

The complexity of the relationship between real estate prices and explanatory variables was applied to the implementation of a geoadditive model.

Typically, geoadditive models are composed using a semiparametric additive component, which serves to express the relationship between the model's nonlinear response and explanatory variables and a model with linear mixed effects that expresses the spatial correlation of the observed values [75].

The first component involves a low-rank mixed model representation of additive models. To summarize the process, the case of two additive components is presented. Suppose that (s_i, t_i, y_i), $1 \leq i \leq n$, represent measurements using two predictors s and t for the response variable y; in this case, the additive model is as follows:

$$y_i = \beta_0 + f(s_i) + g(t_i) + \varepsilon_i \tag{1}$$

where f and g are unspecified smooth functions of s and t, respectively. Therefore, if u_+ is defined to be equal to u for $u > 0$ and 0 otherwise, a penalized spline version of model (1) involves the following functional form [26]:

$$y_i = \beta_0 + \beta_s \cdot s_i + \sum_{k=1}^{Ks} u_k{}^s (s_i - \kappa_k{}^s)_+ + \beta_t \cdot t_i + \sum_{k=1}^{Kt} u_k{}^t (t_i - \kappa_k{}^t)_+ + \varepsilon_i \tag{2}$$

In Equation (2), there is penalization of the knot coefficients $u_k{}^s$ and $u_k{}^t$, where $\kappa_1{}^s$, ..., $\kappa_{ks}{}^s$ and $\kappa_1{}^t$, ..., $\kappa_{kt}{}^t$ are knots in the s and t directions, respectively. The penalization of $u_k{}^s$ and $u_k{}^t$ is equivalent to treating them as random effects in a mixed model [75].

Setting $\beta = (\beta_0, \beta_s, \beta_t)^T$, $u = (u_1{}^s, ..., u_{ks}{}^s, u_1{}^t, ..., u_{kt}{}^t)^T$, $X = (1\ s_i\ t_i)$ with $1 \leq i \leq n$, $Z = (Z_s \,|\, Z_t)$ using the following equations:

$$Z_s = [(s_i - \kappa_k{}^s)_+]_{1 \leq i \leq n,\, 1 \leq k \leq Ks}\ ,\ Z_t = [(t_i - \kappa_k{}^t)_+]_{1 \leq i \leq n,\, 1 \leq k \leq Kt} \tag{3}$$

the penalized least squares value is equivalent to the best linear unbiased prediction in a mixed model:

$$y = X\beta + Zu + \varepsilon\ ;\ E\begin{pmatrix} u \\ \varepsilon \end{pmatrix} = 0\ ;\ cov\begin{pmatrix} u \\ \varepsilon \end{pmatrix} = \begin{bmatrix} \sigma^2{}_s \cdot I & 0 & 0 \\ 0 & \sigma^2{}_x \cdot I & 0 \\ 0 & 0 & \sigma^2{}_\varepsilon \cdot I \end{bmatrix} \tag{4}$$

Model (4) is a variance components model since the covariance matrix of $(u^T \varepsilon^T)^T$ is diagonal. The variance ratio $\sigma_\varepsilon{}^2/\sigma_s{}^2$ acts as a smoothing parameter in the s direction. Penalized spline additive models are based on low-rank smoothers as defined by Hastie [76], considering that linear terms are easily incorporated into the model through the $X\beta$ component.

At this point, a geographical component can be incorporated by expressing kriging as a linear mixed model and merging it with an additive model such as model (4) to obtain a single mixed model (defined as a geoadditive model).

The universal kriging model for (x_i, y_i), $1 \leq i \leq n$ (y_i is scalar and x_i represents the geographical location included in the R^2 domain) is as follows [75]:

$$y_i = \beta_0 + \beta_1{}^T x_i + S(x_i) + \varepsilon_i \tag{5}$$

where $S(x)$ is a stationary zero-mean stochastic process and ε_i is assumed to be an independent zero-mean random variable with common variance $\sigma_\varepsilon{}^2$ and distributed independently of S. Prediction at an arbitrary location x_0 is performed using the following expression:

$$y(x_0) = \beta_0 + \beta_1{}^T x_0 + S(x_0)$$

Then, for a known covariance structure of S, the resulting equation is as follows:

$$y(x_0) = \beta_0 + \beta_1{}^T x_0 + c_0{}^T \left(C + \sigma_\varepsilon{}^2 I\right)^{-1} \left(y - \beta_0 - \beta_1{}^T x\right) \tag{6}$$

where:

$$C = \left(cov\{S(x_i), S(x_j)\}\right)_{1 \le i,j \le n}$$
$$c_0{}^T = (cov\{S(x_0), S(x_i)\})_{1 \le i \le n}$$

For the implementation of Equation (6), we can use the following equation:

$$cov = \{s(x), S(x')\} = C_\theta(\|x - x'\|) \tag{7}$$

where $\|v\| = \sqrt{(v^T v)}$ and C_θ is a term of the Matérn covariance function. The complete formulation of the C_θ term corresponds to the following:

$$C_\theta(r) = \sigma^2{}_x(1 + |r|/\rho)\exp(-(r)/\rho) \tag{8}$$

Equation (8) is the simplest member of the Matérn family and the ρ term can be chosen with the following rule to ensure scale invariance and numerical stability [76]:

$$\rho = \max_{1 \le i,j \le n}\|x_i - x_j\| \tag{9}$$

For all the aspects and issues previously reported, a geoadditive model can be described, essentially, as a single linear mixed model as follows:

$$y_i = \beta_0 + f(s_i) + g(t_i) + \beta^T{}_1 \cdot x_i + S(x_i) + \varepsilon_i \tag{10}$$

It we take $X = (1\ s_i\ t_i\ x_i^T)$ with $1 \le i \le n$ and $Z = (Z_s\,|Z_t\,|Z_x)$, where Z_s and Z_t are defined by Equation (3) and $Z_x = Z\Omega^{-1/2}$ with the following equations:

$$X = (1\ x_i^T)_{1 \le i \le n}$$

$$Z = \left[C_0\left(\underset{1 \le k \le K}{\|x_i - \kappa_k\|/\rho}\right)\right]_{1 \le i \le n}$$
$$\Omega = \left[C_0\left(\underset{1 \le k,k' \le K}{\|\kappa_k - \kappa_{k'}\|/\rho}\right)\right]$$
$$C_0(r) = (1 + |r|)\exp(-|r|)$$

The model has the following representation:

$$y = X\beta + Zu + \varepsilon \tag{11}$$

where

$$E\begin{pmatrix} u^s \\ u^t \\ \tilde{u} \end{pmatrix} = 0;\ cov\begin{pmatrix} u \\ \varepsilon \end{pmatrix} = \begin{bmatrix} \sigma_s^2 I & 0 & 0 & 0 \\ 0 & \sigma_t^2 I & 0 & 0 \\ 0 & 0 & \sigma_x^2 I & 0 \\ 0 & 0 & 0 & \sigma_\varepsilon^2 I \end{bmatrix} \tag{12}$$

Model (10) can be extended to incorporate linear covariates through the $X\beta$ term. The extension to more than two additive components is straightforward.

4. Results

4.1. Results of View Estimation Calculations

The GIS elaboration of the views perceived by the single-family houses sampled allows estimating their presence and how they may affect sale prices.

Figure 3 shows that a large proportion of the properties analysed have views on natural landscape elements with a recognised positive effect on prices, being 94.3% for the "views on natural land areas" (NTVIEW) and 76.4% for the "views on the sea" (SVIEW). The value is considerably reduced for the "views on the historic centre" (HVIEW) since the old town of Marbella has undergone an intense process of urban expansion in the recent decades; besides many of the buildings surrounding the old town block it from the outside due to their larger dimensions. The "other views" variable (OVIEW) includes mixed views on built urban elements, open spaces and undeveloped areas without a special natural attraction; a catch-all that covers an important part of this case study, because some of these views can always be perceived from all the houses sampled.

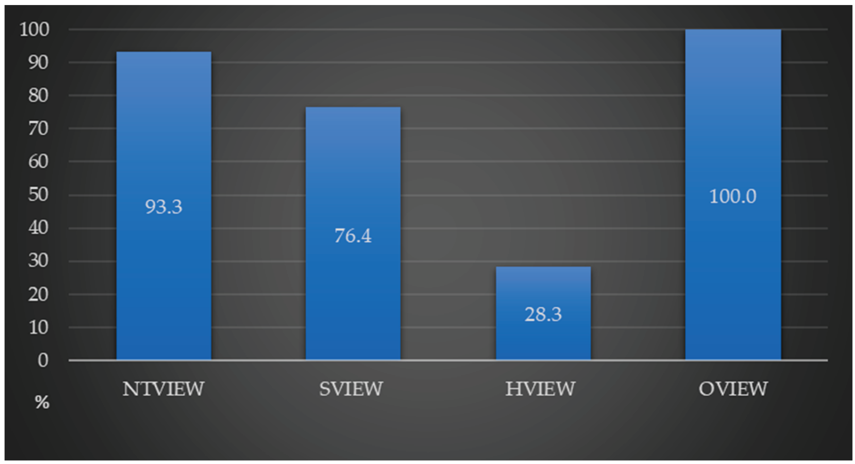

Figure 3. Percentage of the houses with a landscape view, with an indication of landscape components (source: authors' elaboration).

Filtering the importance of the different view types, the situation changes considerably. As can be seen in Figure 4, while almost 83% of the houses with sea views have this element as the predominant one in their views, for houses with views on natural land areas, only 34.8% enjoy views in which it is the most representative element. For views on the old town, this situation is generated in very few cases since there are no houses within this area while the other visible elements, although present in all the houses analysed, only predominate in 3.5% of cases.

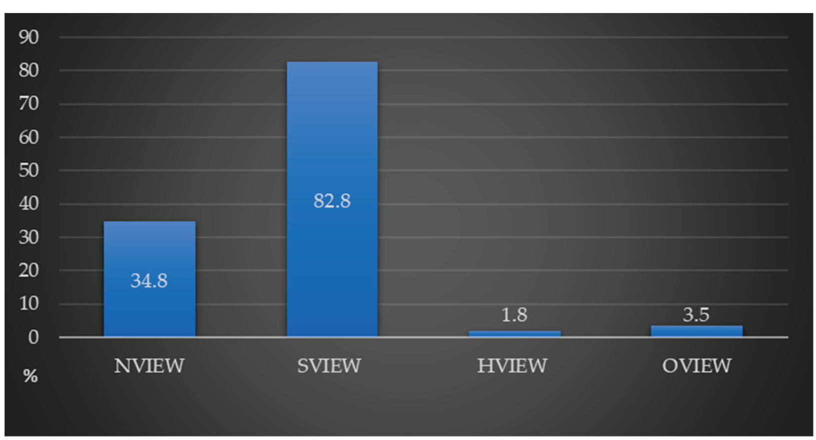

Figure 4. Percentage of the houses with views exceeding 50% of each view type (source: authors' elaboration).

4.2. Results of the Geoadditive Model

In this section, the results of the semiparametric model described in the previous section as applied to the real estate sample considered are presented.

For each property of the sample, the asking price and the amounts of some relevant property characteristics are known, as shown in Table 2. The statistical description of the variables is reported in Table 3.

Table 2. Statistical description of the variables.

Index	UPRICE	XCOORD	YCOORD	DIST	NTVIEW	SVIEW	HVIEW	OVIEW
Mean	3639.8183	32.954502	4.0420688	1137.067	3,008,938.2	35,686,576	1755.7692	608,186.41
Std. error	52.901956	0.0242687	7.549×10^{-5}	43.180856	123,399.03	2,347,550.5	213.06258	60,654.215
Median	3676.7893	32.976917	4.042123	789	2,640,525	12,581,450	0	169 075
Std. deviation	1061.9994	0.4871915	0.0015155	866.84964	2,477,218.3	47,126,747	4277.2014	1,217,624.9
Kurtosis	0.75846	1.0935251	0.082315	−1.4045671	0.1256148	0.617069	5.7486999	16.900864
Asymmetry	−0.3699597	0.6049463	−0.7866755	0.3475425	0.7122325	1.3360771	2.6072192	3.8223405
Range	6954.3428	2.352083	0.005938	2764	12,782,600	165,089,800	22,650	8,091,100
Minimum	178.41158	32.047947	4.038591	36	0	0	0	175
Maximum	7132.7544	34.40003	4.044529	2800	12,782,600	165,089,800	22,650	8,091,275
Confidence interval (95.0%)	103.99904	0.0477095	0.0001484	84.888496	242,588.02	4,615,008.8	418.85603	119,239.07

Table 3. The model's main results with the estimation of fixed effects for the linear and nonlinear model components.

Variable	Coefficient	SE	Ratio	*p*-Value
Intercept	5.375×10^{5}	5.402×10^{6}	0.09951	0.9207
NTVIEW	-7.583×10^{-5}	2.270×10^{-5}	−3.34100	0.0009
SVIEW	2.470×10^{-6}	1.846×10^{-6}	1.33800	0.1811
HVIEW	-1.136×10^{-2}	1.617×10^{-2}	−0.70240	0.4826
OVIEW	8.084×10^{-5}	8.555×10^{-5}	0.94500	0.3448
Variable	df	spar	Knots	
f (XCOORD, YCOORD)	12.68	264.8000	34	
f (DIST)	18.12	0.1086	100	

Based on the real estate data, the following semiparametric model was implemented:

$$\text{UPRICE} = \text{f(XCOORD, YCOORD)} + \text{f(DIST)} + \text{NTVIEW} + \text{SVIEW} + \text{HVIEW} + \text{OVIEW}$$

where XCOORD and YCOORD are the geographical coordinates; DIST is the distance from the property to the coastline; NTVIEW is the area of mountain views; SVIEW is the area of sea views; HVIEW is the area of views on the old town; OVIEW is the extent of views on other landscape elements.

In the absence of multicollinearity phenomena, given the low correlation between the explanatory variables, the main verification indices of the model are shown in Table 3.

Determination of the knots for the model's spatial component and its geographical coordinates were performed using the space-filling algorithm implemented in the default.knots.2D function library of the R software [77]. The model was therefore estimated by the Re.M.L. method using the spm library of the R software.

The nonlinear effects of the model are significant based on the values obtained for the freedom degrees (df) and smoothing parameters (spar). The values of the obtained predictions are consistent with the observed data; analysis of the residuals did not show any abnormality in their structure as well. In the examined area, the spatial distribution of the real estate unit prices clearly shows how the geographical component affected the prices of the sampled properties.

The main result of the model is a graphic interpolation or a thematic map depicting the real estate unit values in the urban context considered, in which blue and red colours represent the lowest and highest unit values, respectively (see Figures 5 and 6).

Figure 5. Spatial distribution of the knots placement and locations of the sampled houses (source: authors' elaboration).

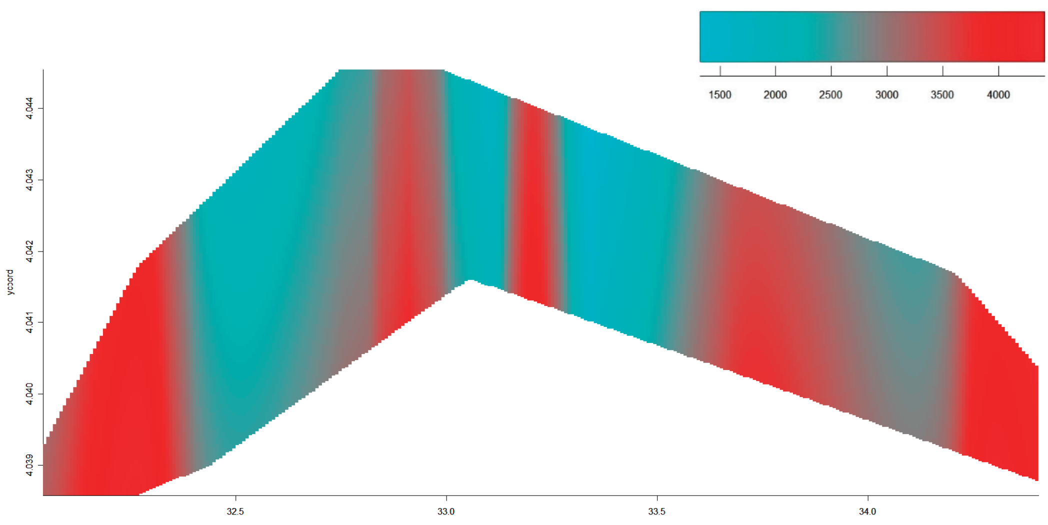

Figure 6. Map of the real estate isovalues (source: authors' elaboration).

4.3. Discussion of the Results

The results obtained demonstrate that landscape is an important added value in the local real estate market of Marbella, especially in the higher-priced housing segments. In this way, the study explored the landscape elements that contributed most to the housing values.

A particularly positive influence of "other views" was detected in the analysis, followed by "sea views". The importance of "other views" is striking since this element is characterized by mixed urban elements and natural ground with no notable wooded areas. A possible explanation for this positive contribution is exactly a more varied and complex composition of views, which is more attractive than simpler perspectives (with the exception of fully sea views, a very rare condition, especially for single-family houses).

Sea views are highly sought, but due to the graduated topographical and geomorphological layouts of Marbella, it is not very difficult to have sea views for houses (about 83% of the sample have about 50% of the views towards the sea).

On the other hand, it is worth noting the low importance of views on natural land areas when one of the most relevant attractions of Marbella's territory is a highly valued Mediterranean natural environment.

The views on the old town centre are less appreciated than all the other types of views. Although the old town centre is highly regarded, with a generally good state of preservation, the model results can be partially explained by the fact that the houses sampled are located in its immediate surroundings, albeit outside this specific area. In addition, due to the circumstances of this case study, the old town views have poorer quality perspectives, with reduced visual basins and views centred on the foreground, usually on the buildings opposite.

Conclusively, a summary of qualitative and quantitative rankings relating to the different types of landscape views for Marbella can be expressed.

From a merely qualitative point of view, the most valuable landscape view is the mixed type, followed by the sea view, the views on natural land areas and lastly the views on the old town.

The interpretation of the results from a quantitative point of view appears to be more complex. Indeed, the relevance of each landscape element with respect to the others varies in relation to the specific element considered. This is why, in Table 4, the quantitative relevance attributable to each landscape element with respect to the others is reported to have a general indication of the phenomenon.

Table 4. Quantitative relevance attributable to each landscape element with respect to the others.

	Other Views	Sea Views	Natural Land Views	Old Town Views
Other views	1.00	32.73	−1.07	−0.01
Sea views	0.03	1.00	−0.03	0.00
Natural land views	−0.94	−30.70	1.00	0.01
Old town views	−140.52	−4599.19	149.81	1.00

In absolute terms, the greatest economic impact occurs for old town views (1.136×10^{-2}), followed by other views (8.084×10^{-5}), natural land views (7.583×10^{-5}) and sea views (2.470×10^{-6}). The impact of each element must be read in reciprocal terms between the different types of views, with respect to the amounts and signs that distinguish them (see Table 4).

5. Conclusions

In this study, the economic impact of the perceived landscape on single-family house prices in a Spanish Mediterranean urban area (Marbella) was analysed. Considering the landscape an important added value in real estate markets, this study also explored the landscape elements that contribute the most to the value of housing.

From a methodological point of view, the versatility of semiparametric models applied to real estate valuations and the possibilities to measure the influence on real estate prices of property characteristics were verified, proving their usefulness with an environmental variable of intangible nature such as landscape. Moreover, the real estate isovalues map obtained makes possible to have immediate evidence and identify exactly where the houses have the greatest commercial attractiveness, adequately weighing all the real estate characteristics. Due to the diffuse opacity of real estate markets, geoadditive models can help to better interpret the different segments of local real estate markets or even in the prediction and interpretation of the phenomena related to the genesis of rewards of position with reference to the problems of transformation and investments in urban areas affected by projects or plans and to optimize the choices of the use of goods and resources.

With regard to the social and economic impacts, the current concepts of landscape value and its protection need to know the economic impacts that this environmental and cultural resource confers on private economic assets as well as on the community. The importance of landscape value assessment results does not lie so much in their specific entity but rather in their potential to provide a reference point for economic operators and decision-makers called to make choices [78–80]. In the complex issue of landscape protection and management, the economic dimension is gaining much more relevance. Landscape is increasingly considered a social element, and therefore an expression of widespread, common, individual perceptions and value judgments of various kinds, including those of economic nature whose measurement requires operating principles and schemes not yet consolidated.

The landscape is a public territorial resource, the value of which is not directly detectable by real estate markets. Knowing the economic impacts of landscape is useful not only for investment choices, but also because it would allow economic justification for building interventions, for which sometimes only the indirect and direct costs associated with the constraints and prohibitions imposed by traditional regulatory tools based on the protective actions imposed are known.

In perspective, the conclusions drawn from this type of research can have a wide range of applications: from an increase in the consideration of landscape in territorial planning for areas with attractive landscapes, hierarchizing the protection of specific territorial units with landscape value, to more accurate real estate valuation models.

Author Contributions: H.C.N. designed the conceptual approach, analysed the data with GIS tools, interpreted the results and was involved in writing the manuscript. P.D.P. and H.C.N. were involved in the methodology design. P.D.P. was involved in developing the methodology, writing the manuscript, supervising, reviewing and approving the final version of the manuscript. P.D.P. analysed the data in the geoadditive model. J.V.M. was involved in the development of the methodological procedure, preparation of the database and revised and approved the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Article

Switching from Risks to Opportunities: The Application of a Superbonus Tax Incentive to Heritage Buildings from the 1960s in Fragile Mountain Contexts

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Abstract: This paper introduces actual considerations for the progressive disuse of residential space in the Alpine territory, considering possible actions. Nowadays, the building complexes built around the 1960s and 1970s (a symbol of mass tourism) are suffering and searching for a new identity. The generation of owners who bought them has aged and the propensities of the new generations for holiday in those places has changed, which means fewer opportunities for leisure, particularly in the winter. Due to the great attention (and seeming opportunities) of current incentive policies toward improving the energy use of the existing stock, the authors investigate the private conveniences of transformations through the refurbishment of these buildings. Starting from a study of the territory and the dynamics of the local population, this research analyzes a possible set of energy works, based on a new (2020) incentive measure, the 110% Superbonus, which consists of a series of facilitation mechanisms, deductions, and reimbursements for building interventions. A large part of the insight is focused on a technical and economic feasibility study of the possible actions, following a process based on the evolution of the legislation. This work is based on a specific case study, located in a small municipality in the Piedmont mountain area, consisting of three apartment blocks of mostly second homes. The methodology adopted lends itself on the one hand, as a guide for preliminary economic energy assessments and, on the other hand, as a policy evaluation tool from the public and private perspectives.

Keywords: energy efficiency; existing buildings; maintenance; envelope retrofitting; Superbonus 110%; economic sustainability

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1. Introduction

Studies of the earth's climatic history show how, over the centuries, there have always been more or less rapid and more or less cyclical phases of climate change. However, the last 150 years, from industrial development onward, have witnessed a progressive and anomalous increase in temperatures, as well as the intensification of extreme climatic events, such as heat waves, droughts, or very intense and protracted rainfall. Undoubtedly, one of the main causes of these sudden variations is mankind with its activities and related greenhouse gas (GHG) emissions [1,2]. In fact, according to the "Global Warming of 1.5 °C" report by the Intergovernmental Panel on Climate Change (IPCC), these have already caused global warming of about 1 °C compared to pre-industrial levels, and it is likely that this value will increase further, reaching 1.5 °C between 2030 and 2052 [3]. The future of natural and anthropogenic systems depends on the temperature increase, its magnitude, and the speed with which it occurs [3,4]. In December 2019, the European Commission adopted the "Green Deal", a new growth strategy that aims to achieve climate neutrality in 2050 with zero CO_2 emissions [5]. By 2030, GHG emissions will have to be reduced by 55 percent compared to 1990 values, so many transformative policies will have to be developed and financed in various sectors, from energy to industry or even, for example, transport. A key role will certainly be played by buildings [6–8], regardless of their intended use. These, in fact, in addition to being highly energy-consuming (responsible for 40% of final energy consumption), are also responsible for 36% of GHG emissions [9]. It is believed that in order to reach the 2030 targets, actions taken on buildings should be able to reduce GHG emissions by 60% [10]. However, the average annual rate of energy refurbishment of the EU building stock is currently too low (around 1% per year [10]). Therefore, in order to stimulate energy efficiency measures, tax incentives have been developed and adopted in some EU countries in the residential, commercial, and public administration sectors [11] (Figure 1). In particular, as far as the residential sector is concerned, the country that has introduced the most incentive measures is Belgium, followed by France and Portugal.

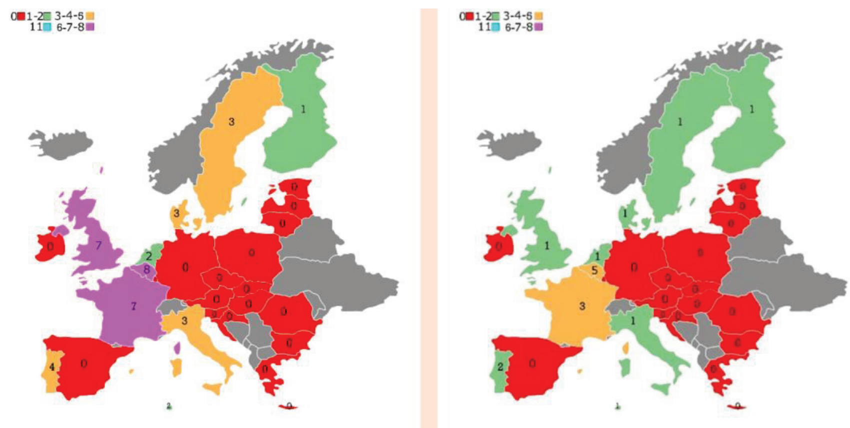

Figure 1. The total number of tax–level incentive measures adopted in each state encompassing the residential and/or commercial and/or government sectors (**left**) and the total number of tax–level incentive measures adopted in each state pertaining to residential only (**right**) (source: ENEA [11]).

As far as the Italian case is concerned, until the end of 2019, there was only one incentive measure (Ecobonus [12]), but since July 2020, a new one has been introduced (Superbonus [12]), which, due to the rates introduced, is expected to be very impactful not only in terms of energy efficiency and seismic upgrading of buildings but also for the creation of new jobs and, more generally, for the fact that it is expected to stimulate the recovery of a sector that has been struggling to recover since the crisis that started in the US in 2007 with the deflation of the real estate bubble [13]. Analyzing the trends over the last twenty years of investments in redevelopment and new construction (Figure 2), it is easy to see that these have had completely different trends. In fact, while the latter recorded strong growth between 1998 and 2006 and then collapsed from 2007 onward, investments in redevelopment activities have almost always recorded a slightly increasing trend, except for the period between 2000 and 2013, in which they basically remained constant.

Undoubtedly, the positive trend in the last years is due to the introduction of tax incentive measures and the increase in the respective rates. In fact, between 1998 and 2019, there was a significant increase in private building renovation interventions and, of these, the percentage of investments channelled by tax incentives rose from 12.9% to 55.3% [14]. Thus, in practice, at least one out of every two interventions are nowadays conveyed by the use of tax incentives that differ both according to the type of work to be carried out and the type of property being worked on. Specifically, there are some different facilitations that can be grouped into three different categories: (1) those applicable to interventions aimed at the energy efficiency of buildings ("Ecobonus" from Art. 14 of Decree Law No. 63/2016 [15] and "Superbonus" from Art. 119 of Decree Law No. 34/2020 [16]); (2) those aimed at improving the structures of buildings from a seismic point of view ("Sismabonus" from Art. 16 of Decree Law No. 63/2016 [15]); and (3) those for building renovation works and the elimination of architectural barriers ("Bonus Casa" from Art. 16 of Decree Law No. 63/2016 [15] and "Bonus 75% barriere architettoniche" from Art. 119-ter of Decree Law No. 34/2020 [16]).

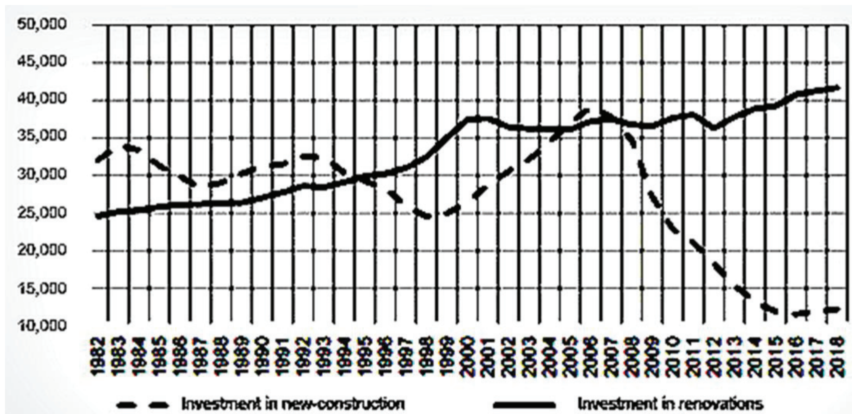

Figure 2. Investment in residential construction, 1982–2018 (in millions of Euros at 2005 prices) (image reprocessed by the author, source: CRESME, Ministry of Economy and Finance).

Certainly, the existence of these incentives will facilitate the upgrading of Italy's building stock, which certainly needs improvement. In fact, if we analyze the characteristics of the existing residential stock, we see that on the national territory, about 7.2 million buildings, or about 60 percent, were built before 1980 and are more than 40 years old, while 5.2 million buildings, or 42.5 percent, are more than 50 years old [14]. In addition, perhaps the most significant finding is that 51 percent of all housing was built before 1970, i.e., before the first energy conservation law (Law 373/76) and is, therefore, definitely energy intensive [17]. In order to cope with the long paying back times of building renovations, to stimulate the building sector, which is in a deep crisis, and to achieve the challenging goals of energy saving and emission reduction by 2030, as mentioned above, a new incentive measure was introduced in 2020 in Italy: the Superbonus tax incentive. With the research work reported here, the authors decided to analyze this measure (as it arose) in order to understand its potential and its critical issues from the perspective of building owners.

Therefore, in what follows, we will briefly describe the Superbonus measure by identifying the resources required for its activation and the possible short-, medium-, and long-term effects. Starting from this schematisation, we will then proceed to verify, with the support of a theoretical case study, one of the short-term objectives identified. In particular, the increase in the attractiveness of energy efficiency interventions in existing buildings by the owners of the building units that comprise them will be verified, since it is believed that this element is the catalyst for an extensive and consistent requalification of the private building stock.

2. The New Italian Incentive Measure: The Superbonus

The spread of the COVID-19 epidemiological emergency forced the Italian government to swiftly activate a series of measures on health, work, and economic support, as well as social policies to cope (Relaunch Decree: DR [16]). Among them, as far as the construction sector is concerned, the "Superbonus" (SB) certainly stands out, which aims to make Italian homes more efficient and safer by facilitating energy efficiency works (with the "Super Ecobonus") and structural earthquake-proof improvements (with the "Super Sismabonus") [18].

However, this measure does not apply indiscriminately to all types of buildings. These, in fact, in addition to having to be intended for residential use, must also prove that they comply with urban planning and building regulations, ensuring the correspondence between the state of affairs and the building title with which the municipality authorized their construction and/or subsequent renovations and extensions.

Eligible interventions under this new measure are those carried out on the common parts of condominium buildings on functionally independent real estate units (i.e., units with exclusive ownership of at least three of the following installations: water supply systems, gas systems, electricity systems, and winter air-conditioning systems [18]) and with one or more independent accesses from the outside, which can be carried out on units inside multi-family buildings or applied to individual real estate units (up to a maximum of two).

Respecting the basic conditions listed above, the expenses incurred for the efficiency and safety of existing buildings can be deducted at 110%. In particular, limiting the study to the Super Ecobonus, the eligible works are divided into "Driving Intervention" (DI) and "Towed Intervention" (TI). In particular, the former include:

- Interventions for the thermal insulation of vertical, horizontal, and inclined opaque surfaces affecting the building envelope, including single-family buildings, with an incidence of more than 25% of the building's gross dispersion surface;
- Interventions for the replacement of existing winter air-conditioning systems with systems for heating and/or cooling and/or the supply of domestic hot water.

In addition to these, which are the predominant ones, "Towed Interventions" (TI), consist of:

- Further energy efficiency measures such as, for example, the replacement of windows and doors, the installation of biomass heat generators and thermal solar panels, etc.;
- Interventions for the installation of grid-connected solar photovoltaic systems on buildings;
- Interventions for the installation of storage systems integrated with subsidized solar photovoltaic systems;
- Interventions for the installation of infrastructure for recharging electric vehicles in buildings.

Starting from these two categories of interventions, for each energy efficiency project —for which one intends to access the SB— it must be demonstrated that the mix of interventions chosen leads to an effective improvement in the energy conditions of the building. To achieve this, the DR requires two energy analyses to be carried out on the building, one "ante" intervention and one "post", and that there must have been an improvement of at least two energy classes between the two.

Regarding the tax modalities by which the Superbonus can be enjoyed, Article 121 of the DR identifies three alternatives: the Direct IRPEF Deduction (DD) [19], the Invoice Discount (ID), and the Credit Transfer (CT), nowadays heavily revised in their general application (as will be mentioned below).

The DD, recognized to the extent of 110%, is to be divided among those entitled to five annual instalments of equal amount and for expenses incurred in 2022 in four annual instalments of equal amount, within the limits of the annual tax liability resulting from the tax return [20]. This arrangement also allows the full amount of the deductions to be used without it being reduced by expenses caused by transactions by third parties.

The ID, on the other hand, provides that suppliers may obtain a discount, in part or in full, for the amount due for their services. The discounted amount may then be recovered by the suppliers themselves in the form of a tax credit equal to 110% of the amount; alternatively, they may, in turn, assign the credit accrued to credit institutions or other financial intermediaries [20].

Finally, the CT mechanism allows the creditor to transfer the accrued credit to suppliers, credit institutions, and financial intermediaries, or other parties such as natural persons, self-employed or businesspersons, or companies and entities [20]. It is clear that the latter alternative, for the owner of the property, will entail an economic "sacrifice" equal to the discount of the tax; thus, the deduction enjoyed will be lower (approximately 100–104%) but the amount will be payable immediately by the taxpayer [20].

Lastly, a workflow summarizing the actions to be carried out in the case of implementing an energy efficiency intervention benefiting from the SB measure is outlined in Figure 3.

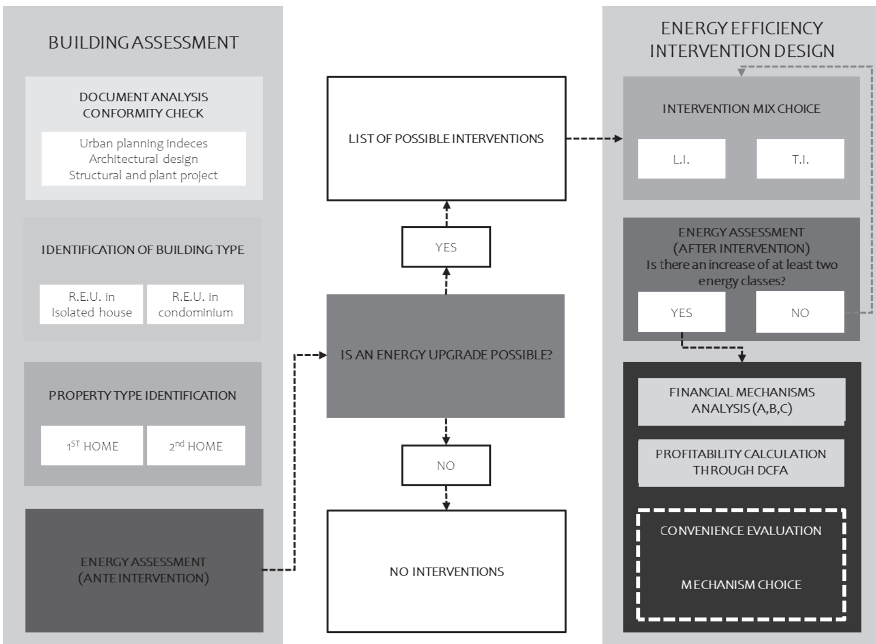

Figure 3. A schematic breakdown of the actions to be carried out in order to access incentives under the SB measure in case one intends to carry out energy efficiency work on a building (source: authors' elaboration).

2.1. Analyses and Objectives

In this study, an attempt was made to trace the mechanism that led to the formulation of the SB measure, identifying the reasons and objectives for which it was devised.

The technique used to coherently reconstruct the complexity associated with the introduction of SB is the logic model [21], which consists of a layered approach. Specifically, the method consists of applying a conditional logic (if-then) that starts from the identification of the resources invested in the programme (inputs) and the practical actions necessary to achieve the objectives (activities), and then it goes on to highlight the results (outputs) and the short-, medium- and long-term changes (outcomes and impacts) resulting from the actions introduced [22].

Starting from this framework (summarized in Figure 4), we then focused on verifying the attractiveness of this new measure for an owner who intends to carry out an energy efficiency intervention on his or her property, focusing, in particular, on verifying the different economic benefits that can be achieved according to the different ways in which the deduction envisaged by the SB can be used.

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
Implementation of European directives (Relaunch Decree)	Enactment of legislative and administrative measures	Introduction of new tax deduction at the rate of 110%	Increased attractiveness of energy efficiency interventions and/or interventions for seismic improvement of existing buildings	Against Economic Emergency: 1. Re-activation of the construction market (private sector) 2. Increase in GDP 3. Increase in employment in the short to medium term
Design of new tools to stimulate upgrading (energy and structural) of the built heritage	Training (PA)	Introduction of new ways to take advantage of the tax deduction (invoice discount, credit assignment)	Increased attractiveness of financial transactions related to the introduction of the SB measure	Against climate emergency: 1. Reduction in energy consumption related to existing construction 2. Reduction in CO_2 emissions 3. Increased production of green energy
Money	Identification of responsibilities of public entities	Improvement of existing digital platforms	Simplification of financing procedures by lending institutions	
Personnel	Organization of digital platforms	Improving interoperability among existing digital platforms	Increased demand for professionals specialized in the construction sector	
PA digital infrastructure			Increased demand for professionals with high digital and technological skills	
Regulatory bodies			Increased demand for raw/secondary materials	

Figure 4. SB measure analysis by the application of the logic model (source: authors' elaboration).

2.2. The Application to the Case Study

In the 19th century, Italian tourism was only possible for a few wealthy families (aristocrats or upper middle class) [23]. However, between 1950 and 1960, thanks to the sudden improvement of general economic conditions and the development of transport routes, it also became accessible to the less well-off. This change led to speculative phenomena and the proliferation of a "second homes"—i.e., dwellings lived in only at certain times of the year—that had to be sufficiently flexible, "easy to maintain and abandon", and be able to accommodate large families [24].

The chosen case study is located in Sampeyre, a small mountain municipality in Val Varaita, in the Northwest of Italy (Piedmont), and belongs to one of those complexes that arose to satisfy the demand for second homes. In Figure 5, it is easy to see that these architectures are easily identifiable both because they do not respect the typical construction canons of the place and because of their dimensions, which are completely out of scale.

Due to the changing tourist habits of Italians, who increasingly prefer to explore new places rather than spend their holidays always in the same places, and due to the old age and functional obsolescence of these buildings erected between the 1960s and 1970s, there has been a progressive abandonment of them in recent years.

However, precisely because of the current health epidemic (COVID-19), it would seem that the use of second homes is making a comeback [25].

From this perspective, the SB measure is, therefore, of great interest to a wide segment of the population, from those who decide to upgrade their homes for habitual residence to those who intend to re-use them for summer or winter holidays, or those who intend to rent them out to those who intend to sell them for a profit.

In order to better understand the different economic benefits that can be derived from the application of SB, the case of the "Monte Nebin" complex in Sampeyre was chosen [26]. The accommodations that are part of the complex's three buildings are mostly second homes (Figure 6) and, to date, many of them are empty, having not been used for many years.

Figure 5. Mount Nebin complex in the foreground (Sampeyre, Cuneo) (source: Google Street View).

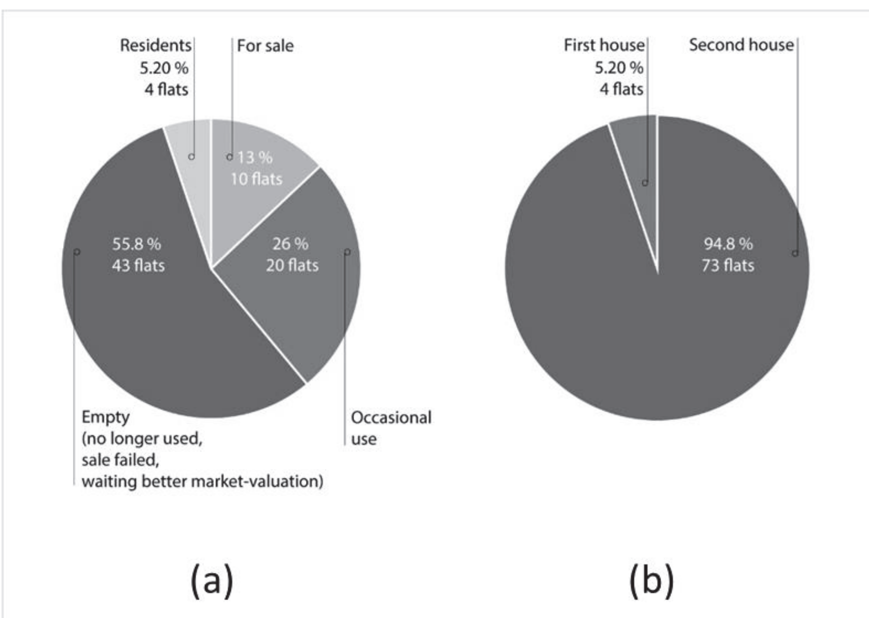

Figure 6. (**a**) Housing utilization of the entire complex and (**b**) ownership of the complex's units (source: authors' elaboration starting from [26]).

Most of the owners of the flats in the complex are pensioners who bought the flats in the late 1960s with the intention of investing their savings (remember that in that historical period the investment was considered "safe"). In particular, the most common types of flats are two-room flats, but there are also some three-room flats with a different average size (Figure 7).

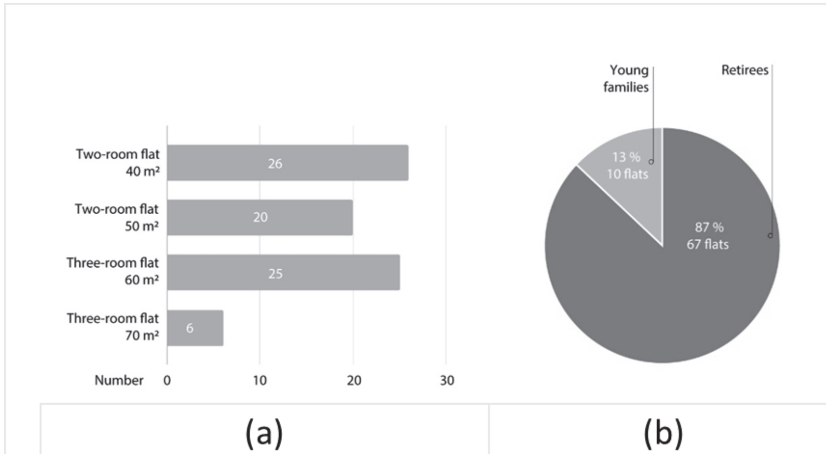

Figure 7. (**a**) Types of accommodation in the complex and (**b**) owners of units in the complex (source: authors' elaboration starting from [26]).

Regarding the maintenance condition, the exterior of the building is in good condition overall, as a façade painting job was carried out in 2018, and inside there are numerous architectural barriers as well as some issues related to thermal comfort.

2.3. Design and Scenarios

One of the prerequisites for access to the Superbonus measure is the requirement to improve the energy conditions of the building so that it makes a jump of at least two energy classes. In the specific case study, insulation of the opaque envelope was chosen as the leading intervention for all scenarios (by law, insulation must cover more than 25% of the dispersing surface), and the following were chosen as leading interventions: replacement of the windows and doors with new, low-emission ones, installation of solar screens and insulation of shutter boxes; replacement of old boilers with heat pump water heaters (PDC); and installation of solar collectors, puffers, photovoltaic panels, and storage batteries. All the scenarios analyzed qualify as major second-level renovations, as an opaque dispersing surface greater than 25% is always insulated.

Below is a diagram (Figure 8) of the scenarios assumed, resulting from the aggregation of the various interventions. As can be seen, scenario A considers only the insulation of the opaque envelope, while the scenarios that follow add the various towed interventions. Scenario B includes the replacement of window frames and the insulation of shutter boxes, as well as the addition of shading systems. Scenarios C and D contain not only the actions on the dispersing envelope but also the choices made for the building plant system. Specifically, photovoltaic panels have been sized for both, which will be connected to the grid in such a way as to be able to cover the auxiliary electricity consumption of the PDC water heaters throughout the year, thanks to the storage batteries. In scenario C, the water heaters were sized according to the domestic hot water (DHW) needs of each property unit, choosing between models with 80/100/200 litres of storage based on the estimated number of users. In scenario D, on the other hand, it was decided to maximize the production of DHW, choosing a hybrid installation. Eighty litre storage water heaters for each dwelling were chosen as the "minimum resource" (to avoid the installation of the largest and noisiest models), while to cover the needs of the largest dwellings, each unit was connected to the centralized 750-litre puffer, inside which the water was pre-heated by solar collectors.

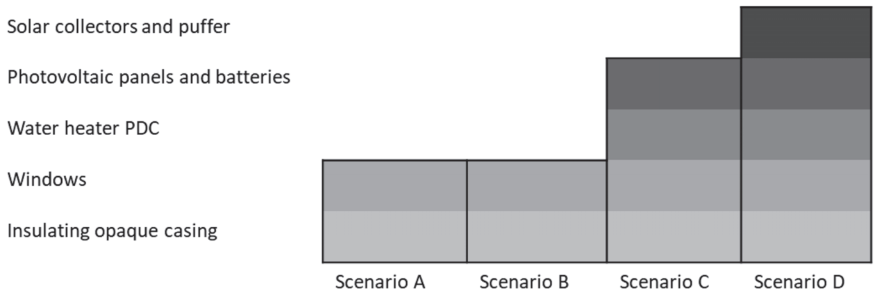

Figure 8. Summary of the interventions included in each scenario (source: authors' elaboration starting from [26]).

Since scenario A, as designed, would not allow access to SB, it was decided to not consider it in the subsequent analysis. Scenario B is, therefore, the one that contains the minimum mix of interventions to guarantee a jump of two energy classes for the building and, therefore, access to SB.

Based on this consideration, the economic tests only covered scenarios B-C-D and were organized into different sub-scenarios according to the different assumptions made (Figure 9), but in any case, the point of view remains for the owner of the typical real estate unit (with an average cut-off of 85 m^2).

Sub-scenario	HP.1	HP.2	HP.3	HP.4
Ss.1	100% Equity	No	No	No
Ss.2	100% Debt	No	No	No
Ss.3	100% Debt	Yes: TARI IMU	Yes	No
Ss.4	100% Debt	Yes: TARI IMU	Yes	Yes
Ss.5	100% Debt	Yes: IMU	No	No
Ss.6	100% Debt	Yes (50%): TARI IMU	Yes (50%)	No

Figure 9. Summary of the assumptions underlying each scenario (source: authors' elaboration).

For sub-scenarios 1-2-3-4, it was assumed that the typical dwelling was used exclusively by the owners as a second home, while for sub-scenario 5, the opposite hypothesis was made, i.e., that the dwelling was rented out year round, and finally with sub-scenario 6, a "compromise" hypothesis was analyzed, in which the dwelling was used for half the year by the owners and was rented out as a "holiday home" for the other half.

The economic analyses reported in the "results" section, as mentioned, vary according to the different assumptions, specifically:

- HP.1 determines whether the capital used to carry out the interventions is all from the owner (equity) or the loan (debt); in the latter case, the interest on the debt incurred with a possible credit institution must be taken into account;
- With Hp.2, taxes were taken into account (or not); in particular, the waste tax (in Italy "TAssa sui RIfiuti: TARI") relating to waste management and intended to finance the costs of waste collection and disposal services, borne by the tenant, and a direct tax

of a patrimonial nature, borne by the owner, which in Italy is known as the "Imposta MUnicipale propria" (IMU);

- With Hp.3, the condominium management costs have been considered, i.e., only those dependent on the common parts and thus not related to the consumption of the individual users of the various building units; these costs have been considered to be zero if the building unit is fully rented, if it is used as a second home continuously, or 50% rented for half a year;
- Hp.4 considered the increase in market value resulting from the energy efficiency operation, which is assimilated to an extraordinary maintenance operation; the percentage of increase was considered to be 25% [13] compared to the market value prior to the operation.

Finally, it should be noted that for each sub-scenario of each scenario analyzed, different conveniences were calculated depending on whether the owner decided to take advantage of DD, CT, or ID. Thus, specifically, 36 analyses were conducted (Figure 10).

Scenario	Sub-scenary	Alternatives
A	[-]	[-]
B	Ss1;	Ss1-DI; Ss1-SF; Ss1-CC;
	Ss2;	Ss2-DI; Ss2-SF; Ss2-CC;
	Ss3;	Ss3-DI; Ss3-SF; Ss3-CC;
	Ss4;	Ss4-DI; Ss4-SF; Ss4-CC;
	Ss5;	Ss5-DI; Ss5-SF; Ss5-CC;
	Ss6	Ss6-DI; Ss6-SF; Ss6-CC;
C	Ss3;	Ss3-DI; Ss3-SF; Ss3-CC;
	Ss5;	Ss5-DI; Ss5-SF; Ss5-CC;
	Ss6	Ss6-DI; Ss6-SF; Ss6-CC;
D	Ss3;	Ss3-DI; Ss3-SF; Ss3-CC;
	Ss5;	Ss5-DI; Ss5-SF; Ss5-CC;
	Ss6	Ss6-DI; Ss6-SF; Ss6-CC;

Figure 10. Framework of the alternatives analyzed for each sub-scenario (source: authors' elaboration).

The following section shows the results obtained, in terms of the internal rate of return (IRR) for the various sub-scenarios.

3. Results and Discussion

Below are the results obtained from the various processes (Figure 11).

As can be seen in Figure 11, the best investment hypothesis is definitely that of using only the owner's capital (Ss1), thus avoiding the payment of interest expenses required by a loan. In this hypothesis, there are all positive returns, demonstrating that the SB instrument is efficient and, above all, that one achieves returns on the investment in only 5 years or less. The best mechanism for taking advantage of SB is the assignment of credit, which shows the highest profitability because it allows the investment to be returned in the first year even though the final refund is less than 110% (in the calculations, the assignment to a local bank was hypothesized, which disburses 92.7% of the accrued credit to the assignee).

Comparing hypotheses Ss2 and Ss3, it can be seen that with the same initial conditions (100% financed), introducing the fixed costs (IMU, TARI, and the running costs of the condominium) in the hands of the owner leads to negative results in Ss3. This behavior is due to the non-influence of the proposed interventions on fixed costs such as IMU TARI, and condominium management. This analysis, however, is a short-term (5 years) view of the SB benefit, because if counted over the long term, the results would be much better.

SCENARIO	MODALITIES	Ss1	Ss2	Ss3
		IRR	IRR	IRR
B:	(DD)	15.29%	7.25%	*
	(ID)	23.85%	15.37%	*
	(CT)	85.91%	73.81%	*
C:	(DD)			*
	(ID)			*
	(CT)			*
D:	(DD)			*
	(ID)			*
	(CT)			*

SCENARIO	MODALITIES	Ss4	Ss5	Ss6
		IRR	IRR	IRR
B:	(DD)	26.87%	41.58%	9.94%
	(ID)	33.96%	70.15%	18.02%
	(CT)	45.50%	228.30%	42.82%
C:	(DD)		33.82%	3.40%
	(ID)		53.39%	6.95%
	(CT)		117.22%	9.10%
D:	(DD)		24.96%	2.08%
	(ID)		40.54%	4.82%
	(CT)		92.24%	3.76%

Legend: * Invalid/negative values

Figure 11. Summary of the results obtained from the analysis carried out (source: authors' elaboration).

The results of the more realistic approach (Ss4), taking into account the increase in market value, were also reported, and the results were significantly better than the previous ones (Ss2–Ss3). However, a comparison with Ss1 shows that the profitability for DD and ID increases, while for CT it decreases. This trend shows that CT has a positive effect in the short term, given the repayment in the first year, but in the long term (also taking into account the increase in the real estate value of the asset) it is an instrument that penalizes the profitability of the transaction (as there is a final repayment of less than 110%).

Maximum profitability was assessed between scenarios B-C-D in the following three modes: counting the fixed costs of ownership (Ss3), partially leased (Ss6), and fully leased (Ss5). As was to be expected, hypothesis (Ss3) reports all negative results for all scenarios, while switching to modes (Ss5) and (Ss6) shows a gradual improvement in affordability. Hypothesis (Ss5) achieves IRR values above 100 percent, confirming that maximizing the benefit created by SB by leasing is a winning action, both because tenants are left with the management and TARI costs and because they enjoy the increase in value, which implicitly increases the rent.

An important aspect to keep in mind is that all calculations were made over a very short time span (5 years: the duration of the Superbonus incentive disbursement) but the benefits, such as savings on heating and domestic hot water production, last over time. If the investment were analyzed over several years, there would certainly be a positive return in all modes of access to the 110% Superbonus.

The tax incentive put in place by the Superbonus offers unprecedented possibilities because it allows a tax deduction of 110% on the basis of the expenditure incurred in a very short time and also allows all people with little tax capacity or even incapacity to benefit. This bonus is definitely worth considering, especially in cases such as the one analyzed, where one has a property that is not attractive on the real estate market and needs renovation.

4. Conclusions

The high convenience of the measure, in all its forms, suggests the following considerations. As expected, credit assignment is—of the three measures—the one that has the most obvious impact on the convenience of owners. At the moment, due precisely to this extreme attractiveness, the large number of requests for credit assignments has frozen the market, slowing down procedures and creating uncertainty for owners and traders. Consequently, the regulatory situation has changed.

As a result, the regulatory situation was changed. With the Budget Law of 2023 [27], the incentive rate (initially 110%) was redefined and modulated differently depending on a number of factors including the type of buildings on which the interventions were applied, compliance with the time limits imposed for the submission of building permits and, in some cases, the income of the property owners. The same law also partially ended the mechanism of credit assignment and invoice discounting. In fact, as of 17 February 2023, for interventions of building heritage rehabilitation, energy efficiency, seismic improvement, facade rehabilitation or restoration, installation of photovoltaic systems, and installation of charging stations, it will only be possible to access the mechanism of direct deduction. However, the other mechanisms, i.e., invoice rebate and credit assignment, remain possible for certain types of buildings provided that, for them, the application for the acquisition of the authorization title has been submitted by 17 February 2023 and, in the case of blocks, the resolution of the condominium assembly also exists.

Recognizing the effectiveness of the legislative instrument (verified in terms of the number of interventions [28]), we believe it is meaningful to reduce the incentive rate under the measure; in fact, going from the 110% rate to 90% (and in some cases even lower) will, in our opinion, have multiple benefits. First, the beneficiary (owner) will be "empowered" and will be more judicious in choosing which interventions to carry out, reducing them to a minimum and thus identifying only those that are really necessary. In fact, for example, there will no longer be any replacement of already high-performing shutters (e.g., with double glazing) with others that are a little better (e.g., triple glazing) because this would correspond to a waste of money in the face of a very low return from an energy point of view. Secondly, precisely because the beneficiary will have to contribute using their own capital, it will be enticing to carry out more market research, thus identifying economic operators who, under the same conditions required, offer the best price for the performance of their services. These two factors will cascade a series of improvements at the macro level. The market should return to a situation of normality, in which, thanks to healthy competition, the value of interventions will once again become fair, waste (the example of windows and doors made earlier) will decrease, and the demand for building materials will decrease and thus, with the same materials produced, their price will be lowered until it returns to a sustainable situation.

It is also believed that by directly involving the capital of those wishing to access the incentive, the risk of related fraud will also decrease, and it will then be possible to reopen the channel of credit assignment (and invoice discounting), perhaps opening up the possibility of credit securitization which, in the face of a "healthy" mechanism, will be sustainable.

However, special attention will have to continue to be paid to private convenience, which should never fall below acceptable levels; this would allow, with more simplified rules, extending the number of applications and aiming for the 2035 target that does not seem so easily attainable now.

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Article

Energy Communities in Urban Areas: Comparison of Energy Strategy and Economic Feasibility in Italy and Spain

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Abstract: Energy communities using renewable energy sources directly contributes to reduction of climate change gas emissions and energy consumption in the European Union. In addition, energy communities enable citizens to transform from (passive) consumers to prosumers (active consumers and producers) and to play a proactive role in the deployment of energy transition in urban areas. As the transposition of European rules about energy communities into the national laws of EU Member States is very articulated and differentiated, this study proposes a framework to analyze and compare regulatory and financial instruments. This framework is applied to the analysis of the cases of Italy and Spain as representative of European states in which collective actions in the energy sector are not very common, with the aim of highlighting the main critical issues affecting the effectiveness of energy transition strategies and assessing the economic feasibility of energy communities. Based on analysis of regulations and procedures, including at the local level, it appears that municipalities play an important role as promoters of initiatives among citizen communities, while complex bureaucratic procedure is the most critical issue in both countries and can significantly hinder the spread of energy communities. With respect to the different financial incentives available for the formation of energy communities in Italy and Spain, a few cases studies are hypothesized, calculating the most relevant cost-effectiveness indicators, e.g., Net Present Value. It turns out that a project with the same characteristics achieves greater economic feasibility in Italy than in Spain, depending on the type and size of incentives set by national laws and, above all, that financial incentives are necessary to make the formation of energy communities cost-effective and thus to achieve direct citizen involvement in energy transition actions.

Keywords: energy communities; financial incentives; economic feasibility

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1. Introduction

Environmental and energy policies of European Union (EU) actively promote the transition to a low-carbon society and sustainable energy systems and to reach these goals the EU signed the Paris Agreement on climate change [1] and adopted the 17 Sustainable Development Goals (SDGs) in the 2030 Agenda for Sustainable Development [2] (Figure 1).

The SDGs promoted by the United Nations (UN) in 2015 can only be achieved if there is a radical change in the management of natural resources, which includes drastically lowering greenhouse gases emissions as well as reorganizing economic systems according to the principles of circular economy. For this reason, the European Commission (EC) has progressively committed itself to issuing policies and directives and implementing instruments to support environmental protection and sustainable development in the European Union. Several official acts, such as “A policy framework for climate and energy in the period from 2020 to 2030” or “The European Green Deal” [3–5], involve energy efficiency and retrofitting actions on the urban and building scales. In fact, transforming urban energy systems is one of the key factors in ensuring accessible, green and secure energy services for all and in making cities and communities inclusive, sustainable and resilient, as required by "Goal 7: Clean and Affordable Energy" and "Goal 11: Sustainable Cities and Communities" of the SDGs, respectively.

Figure 1. The 17 Sustainable Development Goals (SDGs) (source: United Nations).

SDGs 7 and 11 therefore recognize the close interrelationships between the city and the energy sector to ensure the welfare of citizens, reduce social inequalities and preserve the natural environment while also reducing the effects of climate change [6]. Cities are required to take an active part in this renewal process and have to adopt new patterns of urban space and public and private mobility, waste management and supply of natural resources, especially by imposing high standards of energy efficiency on urban building stock [7]. In addition, on the urban and building scales, both a drastic reduction in energy demand for the air conditioning of buildings through the implementation of energy efficiency measures and the territorial spread of renewable energy sources are required to accelerate energy transition.

The foresting of strategies and actions to make urban environments and buildings more sustainable, both in the private and public sectors, is a cornerstone of the European Union's long-term vision for a climate-neutral economy. Economic and financial feasibility analysis of energy efficiency measures on the building, district and city scale have been widely applied to the evaluation of energy retrofit projects for near-zero energy buildings (NZEB) and various types of existing buildings [8–11], as well as for the definition of best urban energy scenarios [12,13], also in the presence of public incentives and supporting public decisions with multi-criteria models [14,15].

In 2010, the achievement of energy neutrality at the building scale had already been tested in Net Zero Energy Buildings (NZEB) and, similarly, energy neutrality on the district scale had been applied in Net Zero Energy Districts (NZED), where, in addition to energy efficiency measures in buildings, renewable energy production systems capable of achieving high levels of efficiency due to the economies of scale associated with the size of the district as opposed to the size of the individual building have been explored [16]. To this end, the European Union launched the Renovation Wave Strategy in October 2020 as part of the European Green Deal [17], which aims to double renovation rates over the next ten years to reduce energy consumption in buildings as well as to increase financing opportunities to support the implementation of energy retrofitting projects.

The results of these experiments have shown, however, that the economic feasibility of retrofit measures is often not attained without public subsidies [18,19]. On the other hand, public incentives have an enormous influence on the selection and implementation of energy retrofit measures both in terms of ranking alternatives and validating environmental policies [20,21].

Energy efficiency measures in buildings aim to decrease final energy consumption but, obviously, do not reduce it to zero; therefore, to further lower greenhouse gas emissions, it is necessary to accelerate energy transition locally and globally through the use of renewable energy sources (RESs). According to Eurostat data [22], the share of energy from renewable sources in EU countries has been gradually growing from an average of 9.6% in 2004 to 21.8% in 2021 (Figure 2), but it must increase significantly in the years ahead to meet the new mandatory RES target of 42.5% by 2030 set in the 2023 revision of Directive 2018/2001/EU [23,24].

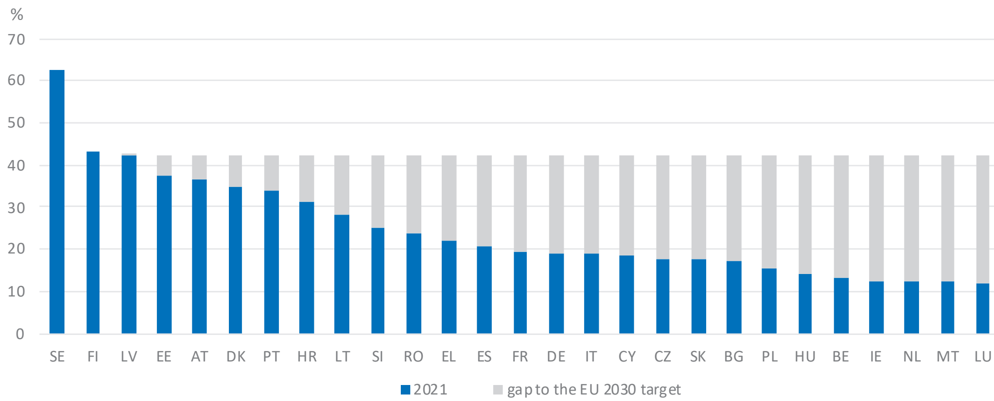

Figure 2. Share of renewable energy source in gross final energy consumption per EU member states in 2021 in relation to the EU 2030 target (source: our elaboration on Eurostat data).

In this energy transition process, the EU has promoted the formation of the "energy community" as a new entity that enables citizens (passive consumers) to become prosumers (active consumers and producers) and to play a proactive role in the deployment of renewable energy sources. Energy communities enable consumers to jointly pursue their individual and collective economic, environmental and social goals while contributing to the decarbonization of the EU energy system. Furthermore, energy communities, acting locally, can promote sustainable development in European cities and act as a driving force for the achievement of the Sustainable Development Goals (SDGs) 7 and 11 [2] and the EU climate and energy targets [25]. The gradual fragmentation of local energy production systems into a multiplicity of small, diffuse installations modifies the peculiar characteristics of heritage buildings and produces significant impacts on the urban and social system, which deserve to be investigated [26]. Indeed, local energy transition and climate adaptation actions have posed significant urban, social, economic and valuation challenges to cities that have required the development of adequate tools to guide and plan such transition within cities and their historical centres [27].

Although the energy sector is mainly controlled by state-granted or commercial companies, a recent study collected data in many European countries and provided the first quantification of the aggregate contribution to the European energy transition by citizen-led initiatives and projects in the energy sector [28,29]. Citizen-led initiatives are classified as formal or informal groups—e.g., energy cooperatives, eco-villages and also sustainable energy communities—which meet the following three criteria: citizen leadership; non-economic benefits, i.e., initiatives which do not pursue a profit; and activity in energy services provision, such as production and distribution of renewable energy as well as education activities for energy behavior change. Citizen-led initiatives are able to promote several types of projects, (e.g., to operate solar photovoltaic projects, to develop wind parks, to draft plans for developing smart villages, etc.) and involve a large number of people.

The highest concentrations of citizen-led energy initiatives, founded from 2000 to 2021, are in Germany and other northern European countries, e.g., the Netherlands, Denmark and Ireland (Figure 3). However, the corresponding number of people involved is widely variable depending on the type of promoted projects, so it can be large even for a small number of citizen-led energy initiatives, as in the case of Denmark, the Netherlands, Spain and Belgium [29]. Nevertheless, when the aggregate citizen-led energy initiatives were related to the population in 2021, the resulting indicator quantified citizens' commitment to directly participating in and promoting energy transition in each EU country (Figure 4). We can observe that this indicator has very low values in all EU member states—with the exception of Denmark, where it is equal to 525 people involved per 10,000 population—being below 50 for most states, e.g., 39 for Spain and 13 for Italy. This prevailing unwillingness of citizens to become involved could be a social factor that makes the spreading of energy communities slower and more difficult.

Figure 3. Citizen-led energy initiatives (left axis) and corresponding people involved (right axis) per EU countries (year 2000–2021) (source: our elaboration on Schwanitz et al., 2023 [29]).

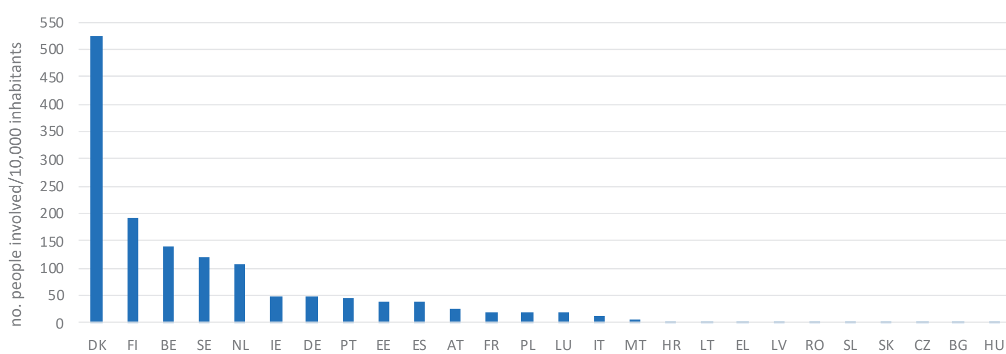

Figure 4. People involved in citizen-led energy initiatives per 10,000 inhabitants in EU countries (year 200–2021) (source: our elaboration on Eurostat and Schwanitz et al., 2023 [29]).

From a social perspective, however, energy communities can provide fair, direct and democratic access to energy resources, promote social cohesion and reduce energy poverty. Unfortunately, there is also the risk of accentuating social inequalities between states, regions and cities, as the degree of spread of energy communities is not equal among EU member states due to peculiar economic and cultural factors, as well as significant differences in the transposition of European directives, such as the types of energy communities or the financial incentive instruments to support their formation.

Several studies have been conducted to investigate the role of citizens as actors in energy communities. Berrou and Soulier [30] developed a methodology based on the *Actor-Network Theory* model that helps to clarify the social dynamics of energy community formation; De Vidovich et al. investigated the organizational models of energy communities [31], while Musolino et al. [32] analyzed the influence of the local context on the composition and characteristics of actor-networks connected to energy communities (in particular, the differences between areas in northern and southern Italy). Other studies have investigated the social impact of energy communities in Europe [33] or the variation of social, economic and technical aspects of energy communities concerning the evolution of European directives on energy sharing [34].

Other fields of study have focused on the economic feasibility of forming energy communities, given the large number of actors involved and the need to allocate costs among community members to ensure investment recovery. Various business models (Energy Community Business Models—ECBMs) have been proposed to support the development of energy communities [35] or to guide decision-makers towards the types of energy communities that best meet specific policy objectives [36]. In parallel, models have been developed to maximize the economic feasibility of building energy communities through self-investment or third-party financing [37] and supporting the decision-making process of stakeholders involved in energy communities.

Several other studies have been carried out to compare policies to support self-consumption of energy in some EU countries [38]. Concerning Italian legislation, optimization models have been developed to guide the dimensioning and management of energy flows in energy communities [39] or to minimize operating costs and identify general guidelines for the optimal economic operation of energy communities [40]. Furthermore, studies have been conducted on particular cases of energy community formation, such as positive energy districts [41] or university campuses [42]. With regard to Spanish legislation, the size of optimal self-consumption installations [43] and the impact of incentive measures on the profitability of residential, commercial and industrial prosumers, as well as the variation of certain system conditions, were analyzed [44], including the sharing of domestic hot water production in energy communities [45]. The impacts of the implementation of the energy community of single-family building stock on a large scale have also been estimated in land and urban areas with certain peculiarities, such as rural areas [46].

Considering that the topic of energy communities is constantly and dynamically evolving, this study proposes a framework for analyzing and monitoring the effectiveness of regulatory and financial instruments that support the formation of energy communities. This framework refers to the four phases necessary to achieve the operation of an energy community and consists of three level of analysis, which are technical, financial and social. Energy communities are obviously promoted to achieve environmental goals (use of renewable energy sources and CO_2 reduction) but have the peculiarity of requiring the prerequisite of constituting a community of citizens. This makes it clear that energy communities also have important social goals to achieve in terms of social inclusion and combating energy poverty.

The proposed framework of analysis can be used for benchmarking, such as among EU states, and supports highlighting similarities and differences, bringing out best practices or any critical issues, as well as inefficiencies and inconsistencies to be corrected, in order to avoid creating or exacerbating territorial inequities at the local, national or European scale. The analysis of financial instruments is also related to four implementation phases of the energy community, whereas the economic feasibility of energy communities is assessed via economic indicators per type of financial instruments proposed by different nations.

The proposed framework is applied to two EU state members, Italy and Spain. These two states were chosen because they both have a near-average share of renewable energy sources in gross final energy consumption and, in addition, due to their climatic conditions and geographical location in southern Europe, have great potential for development, especially in photovoltaic and wind power generation. In contrast, the social habits of Italian and Spanish citizens to be directly involved in collective action in the energy sector has been very low so far, but it needs to be strengthened because it is the main factor on which energy communities are founded. The applied framework is a tool to point out the main critical issues affecting the effectiveness of energy transition strategies in Italy and Spain and assess the degree of economic feasibility for citizens involved in energy communities, based on the most recent legislative updates.

This paper is structured as follows: in the next section, the regulatory instruments on typologies of energy communities in the EU, Italy and Spain are presented. Section 3 illustrates the financial instruments to incentivize the formation of energy communities in Italy and Spain. The methods for testing the effectiveness of Italian and Spanish legislation on energy communities are described in Section 4. Section 5 discusses the qualitative and quantitative results of the comparison between Italian and Spanish energy communities. Finally, Section 6 presents conclusions and future research lines.

2. From Consumer to Prosumer: Typologies of Energy Communities

Energy communities have recently assumed a prominent role in energy transition policies, but significant differences between EU countries can be seen at the national, regional and local levels. Italy and Spain were chosen as southern European countries to evaluate the effectiveness of their strategies and the degree of cost efficiency for citizens. Indeed, Italy and Spain have a very low number of citizen-led energy actions compared to their population and only in the last two years has there been an upward trend in the spread of energy communities due to new regulations and incentives.

The study is organized in the following phases:

- Comparative analysis of the types of energy communities in the European Union, Italy and Spain through the review of current legislation;
- Comparative analysis of the financial instruments available for promoting the constitution of energy communities in Italy and Spain;
- Evaluation of the procedural, technical, economic and social critical issues related to energy communities.

2.1. European Union Guidelines on Energy Communities

According to the European Commission, energy communities are structured groups that can participate in any stage of the energy supply chain. Specifically, an energy community is a legal entity formed openly and voluntarily by members or shareholders—such as natural persons, companies, local authorities or public administrations—who choose to provide themselves with infrastructure for the production of energy from renewable sources through a model based on sharing, in accordance with the Renewable Energy Directive II (RED II Directive) [29] and Internal Markets Electricity Directive (IME Directive) [47].

Energy community members play an active role in the market by generating, consuming, sharing, storing or selling energy. As a result, consumers become prosumers unhinging the traditional supplier–consumer relationship and generating a profound transformation of the energy production model. The traditional centralized and hierarchical system, powered mainly by fossil fuels, is being replaced by a distributed and collaborative system, powered by renewable sources, which enables democratic access to autonomously managed energy. Indeed, energy communities are considered an essential tool to make energy transition fair and inclusive, allowing citizens to play a proactive role in their local energy system.

First, it is relevant to clarify the distinction between individual and collective self-consumption. Individual self-consumption relates to the single end-user, who produces renewable energy for his own energy needs and can store or sell the surplus of energy produced to the market. Collective self-consumption, on the other hand, is based on a virtual model in which a group of users produces, stores and sells energy to other end-users who are either in the same building (pure collective self-consumption) or are geographically distant (community self-consumption).

According to EU directives, there can be different energy community models: the collective self-consumption and Renewable Energy Community (REC) (RED II Directive); or the Citizens Energy Community (CEC) (IME Directive).

The REC is an autonomous legal entity that invests in producing, selling and distributing energy (obtained from renewable sources) to those who are located in the vicinity of the production facilities. The main objective of a REC must be the provision of environmental, economic or social benefits to the community, its shareholders or members or the local areas in which it works, rather than making profits.

The CEC is a legal entity with no proximate link between community members and energy production facilities. In CECs, the rights of final customers are increased in terms of transparency of offers, contracts and bills; the possibility of setting up closed distribution systems has been regularized; and the liberalization of retail markets has been initiated, safeguarding the most vulnerable customers.

In summary, the main differences between Renewable Energy Community (REC) and Citizens Energy Community (CEC) are as follows:

- RECs are based on the principle of autonomy among the members, the constraint of proximity to power generation facilities and the management of different forms of energy (such as electricity, heat or gas) as long as they are generated from renewable sources;
- CECs have no proximity constraints and can manage electricity generated from both renewable and fossil sources.

These new forms of energy production and sharing support sustainable development at local level, as they offer numerous benefits to society:

- Environmental benefits, resulting from reduced emissions of CO_2 or other climate-changing gases through increased local and diffuse renewable energy sources;
- Social benefits, related to greater social cohesion resulting from citizen participation and cooperation and the mitigation of energy poverty;
- Economic benefits, related to a higher assurance of energy supply, less energy dispersion, shorter energy transport distances, bill savings from self-produced energy consumption, revenues from the sale of excess energy to other users and dissemination of both sharing economy and circular economy models.

While respecting the EU Directives, each EU member state has its own legislation (Table 1), characterized by different evolution in both content and timing of implementation, in which standards, constraints and characteristics of energy communities are specifically defined. The EU Directives regarding RECs and CECs, however, have provided a common and basic legal ground for all EU state members, while all national legislations enable citizens to shift towards renewable energy sources, adapting them to local economic and social conditions.

2.2. Tylogogies of Energy Communities in Italy

In 2019, Italy established two types of energy communities, which, in line with European directives, can be:

- Renewable Energy Self-Consumers;
- Renewable Energy Communities (RECs).

Renewable Energy Self-Consumers are end-users who, operating within the constraint of proximity, act collectively by producing renewable electricity for instantaneous and deferred collective self-consumption (through the use of storage batteries); therefore, they may also store or sell self-produced renewable electricity, provided that these activities are not their main commercial or professional activity.

Table 1. Main legislation on energy communities in the European Union, Italy and Spain.

EU	Italy	Spain
Directive 2018/2001/EU Renewable Energy Directive II (RED II) Formal and legal definition of collective self-consumption and Renewable Energy Community (REC)	**Decree-Law No. 162/2019** Definition of self-consumers and Renewable Energy Communities	**Royal Decree-Law 15/2018** Transposition of the RED II Directive
Directive 2019/944/EU Internal Markets Electricity Directive (IME)Formal and legal definition of Citizens Energy Community (CEC)	**ARERA Resolution 318/2020/R/eel** Rules for energy sharing	**Royal Decree 244/2019** Definition of energy communities with direct sales or a simplified net billing system
	Ministerial Decree of 16/09/2020 Rules on the remuneration of self-production installations and collective energy consumption for energy communities	**Royal Decree 477/2021** Incentive programmes for self-producing energy installations
	Legislative Decree 199/2021 Transposition of RED II and IME Directives	**Royal Decree 377/2022** Amendment to previous legislation
	Draft Decree of the Minister of the Environment and Energy Security of February 2023 (not yet approved) Incentives for self-production installations and collective energy consumption for energy communities	

RECs, on the other hand, are legal entities composed of sets of members (e.g., natural persons, local authorities, companies) located in proximity to renewable energy production facilities, who come together to produce and consume clean electricity voluntarily, in accordance with the principles of self-consumption and self-sufficiency. RECs must comply with the following constraints [48,49]:

- physical proximity for aggregations between members;
- maximum power limit for installations of 1 MW;
- use of the existing electricity grid for energy sharing (paying system charges).

Furthermore, the process of forming a REC requires several steps and requirements that include:

- the establishment of a legal and autonomous entity relating to its members (natural persons, companies or local public administrations);
- the adoption of a statute;
- the compliance with the rules of private law contracts.

From a technical point of view, there are no constraints either on the type of renewable source or on the area where the renewable energy facility is to be installed, although the facility, as well as having to be located close to consumers, must comply with the obligation to be connected to the low-voltage electricity grid through the same MV/LV transformer substation. The installation of a *smart meter*, to collect real-time data on production, self-consumption, energy transfer or withdrawal from the grid is also required. The facility, however, does not have to be owned by the community but can be made available by one of the members or an external party.

When production exceeds consumption, the energy surplus can be placed in storage systems for use when renewable sources are unavailable (e.g., during the night) or when peak demand exceeds the amount of energy available at that moment. Alternatively, excess energy can be sold to the grid.

2.3. Typologies of Energy Communities in Spain

Spain was the first European state to introduce the possibility of collective self-consumption [50] based on the European RED II Directive in 2018 and defined the rules for the setting up of energy communities [51]. The result was a radical change to the country's energy management, as previous legislation hindered energy self-consumption, and the possibility of sharing energy without the requirement of a private distribution network opened up.

Two types of installations are allowed for collective self-consumption of energy:

- installations with a simplified net billing system;
- installations with direct sales.

The first category includes small domestic installations or larger systems, with a maximum output of 100 kW, that supply electricity to services or industrial buildings. The second category includes installations with a power output of more than 100 kW that sell electricity to the market.

The legislation allows nearby consumers to share a single installation, as long as one of the following conditions is satisfied:

- the distance between the consumers' properties must be less than 500 m (or their register numbers must share their initial 14 digits);
- the consumers must be connected to the same low-voltage (LV) network.

In addition, the consumers of a shared system must determine how to distribute the self-produced energy among all members through fixed sharing ratios.

3. Financial Instruments Supporting Energy Communities

Each country may adopt a set of financial instruments to support the deployment of energy communities according to its energy policies and to implement national and local environmental sustainability and economic development objectives.

The establishment of energy communities creates social benefits related to participative forms of cooperation involving the local community and environmental benefits resulting from the production of energy using renewable sources that contribute to global sustainability. The energy community members may also receive economic benefits, although these may not be the principal purpose of forming such a community.

The main economic benefit is, of course, the reduction in energy bills due to the self-production of energy, which compensates for the initial investment (costs of the establishment of the energy community, the construction of the renewable energy installation, etc.).

3.1. Financial Instruments to Support Energy Communities in Italy

To improve the economic feasibility of investments in energy communities, in Italy there are the following set of financial instruments:

- Feed in premium—credit on self-consumption of energy;
- Tax incentive—tax deduction;
- Investment grant—direct subsidy.

To promote the use of storage systems and the convergence of energy production and consumption, the Energy Services Manager (Gestore dei Servizi Energetici—GSE) has set an incentive (feed-in-premium), differentiated by the typology of energy community, which rewards the self-production and consumption of energy from renewable energy installations over 20 years. In addition, energy communities receive tax deductions for some items in their energy bills, corresponding to the avoided transfer of self-consumed energy into the grid (Table 2) [52].

Table 2. Typologies of incentives for energy communities in Italy.

Typology of Collective Consumption	Feed-In Premium EUR/MWh	Tax Incentives EUR/MWh
Renewable Energy Self-Consumer	100	10
Renewable Energy Community (REC)	110	8

Investment grants and tax deductions for the implementation of renewable energy installations could be obtained through other regulations, such as the *Ecobonus* [53], but, in these cases, it is mandatory that the installation be part of an overall system of energy efficiency measures for the building.

Investment grants are provided specifically for energy communities in a draft Decree by the Ministry of Environment and Energy Security of February 2023, which, however, is awaiting verification by the European Commission. These incentives are financed by the Italian National Recovery and Resilience Plan (Piano Nazionale di Ripresa e Resilienza—PNRR) [54] and may be granted to municipalities with a population of fewer than 5000 to implement collective self-consumption systems and RECs from renewable energy sources, with a contribution of up to 40% of the investment cost. Depending on the power capacity of the installation, maximum allowable costs are established, ranging from 1500 EUR/kW to 1050 EUR/kW, respectively, for installations up to 20kW and for installations greater than 200 kW and up to 1000 kW. In addition, this proposed decree establishes new values for shared energy premium tariffs, which range from 100 EUR to 200 EUR/kW, depending on the power of the installation and, for photovoltaic installations, are increased to consider the different levels of insolation in the national territory—e.g., the premium tariff to installations located in northern Italian regions is increased by 10 EUR/kW to compensate for the penalty resulting from low insulation. Should this draft decree be approved, the incentives could support both territorial rebalancing policies and local energy transition.

Finally, according to the current law (Ministerial Decree of 16 September 2020) [55], each member of an energy community can periodically receive an amount corresponding to the division of economic benefits according to rules that each community freely establishes in a contract.

These economic benefits result from:

- sale of surplus self-generated energy;
- incentives on self-consumed energy;
- savings from physical self-consumption.

To supplement this national legislation, Italian regions have promulgated their own regulations and incentives to promote energy communities at the local level and to integrate them into territorial policies.

The framework of regulatory and financial instruments is highly differentiated between the Italian regions in terms of, for example, the definition of eligible expenses that constitute the base value for the calculation of the incentive or the role of local government agencies, which are sometimes the exclusive recipients of grants and, in other cases, receive an additional premium for their membership in an REC.

The cases of the regions of Sicilia and Campania (in southern Italy), Emilia–Romagna and Friuli–Venezia Giulia (in northern Italy) are offered as examples of the variety of local incentives.

The Sicilian Region published a call in 2022 to "promote self-consumption, maximize local energy consumption, and lower energy costs for citizens and businesses, also in anticipation of the centrality that such aggregated forms of self-consumption will assume in the concrete implementation of the ecological transition promoted and supported by the PNRR" [56].

This call grants incentives to the Sicilian municipalities that commit to establishing at least one Renewable Energy Community by assuming the role of promoter and being responsible for:

- identifying a minimum initial core of REC members (at least 10% of whom live in energy poverty, according to the parameters of the Italian Energy Poverty Observatory—OIPE) [57];
- dealing with the legal establishment of the REC;
- facilitating the formation of at least one facility by making a municipally owned area available to the energy community.

The municipal government therefore has three options: build a renewable energy system; fund a third party to build at least one renewable energy system; or aggregate those willing to make their energy system available to community.

These incentives are investment grants which are formed by a fixed and a variable portion based on the number of inhabitants of the municipality (Table 3). Eligible expenses to be refunded are exclusively the costs of the REC's technical–economic feasibility study, the administrative and legal costs for the constitution of the Legal Entity and the application for registration of the Energy Community with the GSE. Thus, there are no incentives for the costs of implementation of renewable energy installations.

Table 3. Distribution of investment grants to Sicilian municipalities (our elaboration on data from Sicilian Region, 2022).

Inhabitants No.	Fixed Grant EUR	Variable Grant		
		EUR/Residents	Minimum EUR	Maximum EUR
No. ≤ 5000	9500	0.80	—	4000
5000 < No. ≤ 10,000	9500	0.40	2000.40	4000
10,000 < No. ≤ 50,000	9500	0.20	2000.20	10,000
50,000 < No. ≤ 100,000	9500	0.18	9000.18	18,000
100,000 < No. ≤ 200,000	9500	0.15	15,000.15	30,000
200,000 < No. ≤ 500,000	9500	0.10	20,000.10	50,000
50,000 < No.	9500	0.08	40,000.08	63,398

The Campania Region provides investment grants exclusively to municipalities with fewer than 5000 inhabitants and that will take on the role of REC promoters. This grant has a maximum limit of 8000 EUR and can cover only expenses for the technical–economic feasibility study of the ERC, the administrative and legal costs for the constitution of the legal entity [58].

The Emilia–Romagna Region has provided also an investment grant for the costs of the REC's technical–economic feasibility study, administrative and legal expenses for the REC's establishment and the management of the project [59]. Grants are 80% of eligible expenses with a maximum limit of 50,000 EUR per REC. This grant can increase by 10% in particular cases of RECs, which include: RECs located in mountainous or inland areas as an incentive to counter depopulation; RECs that have among their members households living in energy poverty, social or public housing management or ownership entities; or local authorities that participate in the REC by providing areas or roofs of public buildings for the installations. Thus, unlike the Sicilian regulations, in this Italian region, grants can be offered to all entities that want to form an energy community, whereas the municipality's membership in the REC allows for an additional bonus.

The Friuli–Venezia Giulia Region provides grants exclusively to public entities; however, it extends the list of eligible expenses to include the costs of planning and implementation of photovoltaic systems, connection, storage systems, smart grids, REC technical–economic feasibility studies, administrative and legal expenses for the REC establishment and project management expenses [60]. The grant is 80% of the total eligible expenses with a maximum limit of 500,000 EUR per production facility.

Specifically, the subsidy for installation projects and construction costs is 30% of the investment cost of installations with a capacity of up to 500 kW and 45% of the additional cost for photovoltaic systems with a capacity of more than 500 kW—the additional cost is calculated compared with the average cost of a conventional energy installation (Table 4).

Table 4. Grants for the establishment of renewable energy communities in the Italian regions of Sicily, Campania, Emilia–Romagna, and Friuli–Venezia Giulia (our elaboration on data from Italian regions).

Italian Region	Parties	Eligible Expenditures	Grants		
			Amount	Min. EUR	Max. EUR
Sicily	Municipality with other parties	Technical and economic feasibility study, legal and administrative fees	Fixed + variable (depending on the No. of inhabitants)	9500	63,398
Campania	Municipality (if population <5000)	Technical and economic feasibility study, legal and administrative fees	Fixed		8000
Emilia-Romagna	Public and/or private parties:	Technical and economic feasibility study, legal and administrative fees	80%		50,000
	• in mountain or inland areas • with members in energy poverty • owners/managers of public or social housing • public entities that dispose of areas or roofs for installations	Technical and economic feasibility study, legal and administrative fees	90%		50,000
Friuli-Venezia Giulia	Public bodies	All types of works (from preliminary studies to construction and grid connection)	80%		500,000

3.2. Financial Instruments to Support Energy Communities in Spain

In Spain, financial instruments to support energy communities aim to increase the economic viability of establishing energy communities through measures that promote both revenue generation, by regulating the conditions of sale of surplus energy, and cost reduction, by cancelling taxation on self-consumed energy. Thus, the financial instruments chosen are energy expenditure credits and tax exemptions. Non-repayable contributions are reserved for pilot projects or are provided by programs that incentivize self-consumption of renewable energy which many private and public entities, including RECs, can access.

Regarding power purchasing, during phases when the self-generation of energy is less than demand, prosumers buy imported electricity from the grid at market price (determined by a contract with a private electricity retailer or with a contracted company that charges a fixed tariff). However, during phases when PV energy production exceeds community demand, electricity exported to the grid is sold at an agreed price or at a price linked to the wholesale market price, depending on the type of collective self-consumption:

- In the simplified monthly net billing system, if the prosumer has a contract with a partnered retailer, the wholesale price of energy is charged, whereas in the case of a free-market electricity retailer, a price agreed between the parties is charged.
- In the direct-sale system, prosumers sell excess electricity to the grid like any other producer, i.e., at the wholesale price.

In both collective self-consumption systems, there is an exemption from both the grid access tariff (0.5 EUR/MWh) and the generation tariff (7%).

Some differences between the two systems concern the administrative procedure and revenue characteristics. The monthly net billing system has the advantage of simple administrative and technical requirements. Revenues from surplus electricity transferred to the grid are discounted directly from the electricity bill with a monthly credit and are not subject to taxation since they are obtained in the form of savings, although they cannot be high due to the capacity limit of the installations.

The direct-sale system requires more complex administrative and technical procedures, but there are no limits to potential profits since there is no constraint on maximum installation capacity or monthly billing.

In 2021, six incentive programs were launched for the implementation of self-consumption installations with renewable energy sources, with or without storage systems in many sectors—the service sector, production sectors, residential sector, public administration and third sector (Programs 1, 2 and 4)—but also for the inclusion of storage systems in existing self-consumption installations (Programs 3 and 5) and finally for the implementation of renewable thermal energy installations in the residential sector (Program 6) (Real Decreto 477/2021) [61].

Different types of entities, including RECs and city energy communities, can benefit from these programs. Eligible expenses cover all works and facilities required for renewable energy production, e.g., cost of construction of structures, installations, monitoring systems, low-voltage and high-voltage electrical systems, edifications, demolition, the cost of project design and management, operating expenses, etc. Instead, the fees of formation of RECs are excluded.

The Spanish incentive system is very complex because it depends not only on the type of program, but also on many other factors, including the basic costs of installation and generation of the systems, which are differentiated by type of renewable source, and size of company, with cost percentages ranging from 15% to 65%. Alternatively, the subsidy is established based on the type and power of the system, e.g., from 250 to 2250 EUR/kW, but differs according to the typology of the ultimate beneficiaries (e.g., natural persons, businesses or public housing ownership). Finally, there are the additional subsidies; for example, the incentive increases by 5% for municipalities with a population of up to 5000 or for non-urban municipalities with a population of up to 20,000, whose villages have a population of less than 5000.

Other subsidies for the formation of energy communities have been granted to pilot projects under the Recovery, Transformation and Resilience Plan (Plan de Recuperación, Transformación y Resiliencia—PRTR) via the CE-IMPLEMENTA program (December 2021) [62]. The program's goal is to promote social innovation and citizen participation in energy efficiency, renewable energy availability and electric mobility and identifies energy communities as a key player in the energy transition.

Pilot project subsidies cover 30% to 60% of eligible project costs through calls for proposals (4 calls have been made from December 2021 to February 2023). For renewable thermal energy and renewable electricity plants, the share is 60%, and eligible costs include design, administrative and legal expenses and, most importantly, installation costs. In the evaluation of the project proposal, particular importance is given to the proximity of REC members to the project location, innovative features and the social impact of the projects, especially regarding the presence of REC members with low incomes or social vulnerabilities and the location of projects in municipalities at risk of depopulation in order to achieve territorial and social cohesion objectives [63].

4. Verification of the Effectiveness of Legislation on Energy Communities in Italy and Spain

In order to verify the effectiveness of energy transition strategies and the economic feasibility of investment in energy communities, a framework of analysis is applied to the Italian and Spanish regulations, administrative procedures and financial incentives. This framework consists of:

- a qualitative and comparative analysis of laws and rules regarding energy community from a technical, social and financial point of view;

- an evaluation of economic feasibility of energy communities through the calculation of economic performance indicators.

The comparative analysis first focuses on the characteristics of the various types of energy communities established by law, and second on four main phases of the entire procedure for making an energy community operational. The phases considered are the "Feasibility Study" and "Development and Implementation" initial phases and "Activation" and "Operation" advanced phases.

The economic indicators are calculated with respect to some hypothetical case studies of energy communities composed of a variable number of households and with different incentives. In particular, it was assumed that three case studies focus on energy communities in which the number of households and, consequently, the size of the buildings varies. In case studies 1, 2 and 3, the energy community consists of 48, 72 and 214 households, respectively, with three members per household, living in 8- or 12-floor buildings. The photovoltaic energy installation is 100 kW_p in cases 1 and 2 and 200 kW_p in case 3. The characteristics of the case studies are presented in Figure 5.

Data	Units	Case 1 (48 households)	Case 2 (72 households)	Case 3 (216 households)
Buildings	no.	1	1	3
Building floors	no.	8	12	12
Dwellings per floor	no.	6	6	6
Dwelling area	m^2	80	80	80
Total dwellings	no.	48	72	216
Household members	no.	3	3	3
Installation power	kWh	100	100	200
Photovoltaic panel surface area	m^2	670	670	1340

Figure 5. Characteristics of the case studies 1, 2 and 3.

All case studies are analyzed against four different scenarios:

- Scenario REC_IT. In this scenario, the incentives available in Italy for Renewable Energy Community are considered;
- Scenario RESC_IT. In this scenario, the incentives available in Italy for Renewable Energy Self-Consumers are included;
- Scenario ISC_IT. This scenario consists of individual self-consumption in Italy, and no incentives are available;
- Scenario PR6_ES. In this scenario, the incentives of Program 6 available in Spain for renewable energy installations in the residential sector are considered.

However, it is important to clarify that the main goal of this study is not to optimize the size of a PV system, but rather to evaluate, for the same PV system, the impact of different or absent incentives on the cost-effectiveness of investment in community energy.

The economic performance indicators applied to the case studies are those most commonly used in the energy field, e.g., Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PBP).

The Net Present Value is the discounted present value of cash flows resulting from the difference between inflows and outflows over a period of time. An investment (or project) is profitable when the NPV is positive; therefore, an investment with negative NPV values does not achieve economic feasibility for investors. The NPV formula is as follows:

$$NPV = \sum_{t=1}^{n} \frac{(R_t - C_t)}{(1+r)^t} - C_0 \quad (1)$$

where: R_t is revenues for year t; C_t is costs for year t; r is the discount rate; n is the period of analysis; C_0 is the initial investment.

The Internal Rate of Return is the rate that makes the NPV of a project equal to zero; consequently, an investment or project with an IRR greater than its cost of capital is profitable. The IRR formula is as follows:

$$\sum_{t=1}^{n} \frac{(R_t - C_t)}{(1 + IRR)^t} - C_0 = 0 \tag{2}$$

Both indicators, NPV and IRR, express the economic feasibility of a project from the investor's point of view.

Finally, the Payback Period represents the point in time when the flows generated by the investment cover the initial costs (Ci) that triggered it. The PBP formula is as follows:

$$PBP = \frac{C_i}{\sum_{t=0}^{n} (R_t - C_t)_0} \tag{3}$$

5. Discussing the Italy–Spain Comparison of Energy Communities

EU member states have contributed to creating the required political, legislative and economic conditions to achieve environmental sustainability goals. With specific reference to energy efficiency measures and energy production from renewable sources, Italy and Spain have promoted the dissemination of energy communities, recognizing their potential role in reducing the use of fossil energy sources and, consequently, greenhouse gas emissions.

Both countries allow individual self-consumption, so each consumer can potentially become a prosumer and provide the energy required for his own needs and, eventually, sell the surplus energy to the grid. Individual self-consumption is feasible mostly in low-density urban areas or rural areas where it is not viable to establish the energy communities due to technical and/or legal constraints (e.g., proximity or sharing the same transformer substation).

Collective self-consumption and energy communities are regulated differently in the two countries: Italy has made provision for both, while Spain has two different regulations for the sale of excess energy. Both self-consumption types and energy communities can provide environmental benefits from reduction of CO_2 emissions and use of renewable energy sources; social benefits related to active participation and cooperation of citizens and potential reduction of energy poverty; economic benefits in terms of savings on utility bills (from self-produced energy consumption) and from profits on the sale of surplus self-produced energy.

Table 5 shows that the profiles of energy communities differ mainly in terms of social benefits. In particular, even though energy poverty is mentioned as a social problem in many policy acts, current legislation does not provide for financial measures to support the expenses borne by those living in this condition, with the consequence of effectively excluding them from participation in the energy transition.

Table 5. Environmental and social benefits by typologies of energy communities in Italy and Spain.

Country	Typology of Energy Community	Environmental Benefits		Social Benefits	
		Reduced CO_2 Emissions	Increased Use of Renewable Energy	Social Cohesion	Reduced Energy Poverty
Italy and Spain	Individual self-consumption	Low	Low	None	None
Italy	Collective self-consumption	Medium	Medium	High	Low
	Renewable Energy Communities	High	High	Medium	Medium
Spain	Collective self-consumption with direct sales	Medium	Medium	Medium	Low
	Collective self-consumption with simplified net billing	High	High	Medium	Low

5.1. Critical Technical, Social and Financial Issues

To highlight some critical issues that need to be addressed by the respective countries in order to improve the promotion and deployment of energy communities at the local level, a framework analysis was applied to Italian and Spanish regulations on energy communities and energy sharing arrangements. This framework consists of three levels, which are technical, social and financial, and was detailed according to four main phases of formation of energy community:

- the preliminary feasibility and cost-effectiveness studies of the energy community project;
- the development and implementation phase of the energy community;
- the construction of the installations and the formal establishment of the energy community;
- the activation phase of the energy community, which includes the launching of the production and consumption of renewable energy and the granting of the incentives or tax benefits.

In some respects, mainly technical and social ones, the representation of critical issues that emerged in the two countries is quite similar (Table 6). From a technical point of view, many factors have a negative impact in both Italy and Spain, such as lack of specific expertise; unclear procedural processes; very lengthy administrative requirements; inadequate regulations; and slow procedures. In addition, these factors also make it slow and difficult to activate individual PV systems for self-consumption [38,64].

Table 6. Critical issues on energy communities by phase of procedure in Italy and Spain (source: own processing).

Critical Issues	Initial Phase				Advanced Phase			
	Feasibility Study		Development and Implementation		Activation		Operation	
	Italy	Spain	Italy	Spain	Italy	Spain	Italy	Spain
Technical	Technical and specialized skills deficit		Unclear and complex administrative procedures		Long and complex administrative procedures		Slow administrative procedures	
Social	Low knowledge and citizen involvement		Difficulties in accessing technical and specialized knowledge		Lack of motivation among community members		Difficulties in shared energy management	
Financial	Difficulty in having investment capital		High risk aversion of traditional lenders Difficulty in accessing financing		High financial exposure	Average financial exposure	Slow provision of incentives	High incidence of fixed costs of energy bill

From the social point of view, the problems common to Italy and Spain concern, first of all, the detection of a low level of knowledge about energy communities and their benefits [65], which affects the involvement of citizens and would require the launch of more efficient information and dissemination campaigns. Significant difficulties also relate to access to expert knowledge on procedures, timeframes and the amount of economic investment required to establish an energy community. Finally, difficulties have been encountered in shared energy management due to a regulatory framework that is still not fully adequate to address all the cases related to local energy networks.

Additionally, from a financial point of view, there are also similar critical issues in the two countries in both the low disposability of investment capital and access to financing, partly due to the absence of financial products specifically targeting small renewable energy investments. This leads to high initial producer exposure—mitigated in Spain by some incentives for installation construction costs—which is compounded by long waiting times for incentives or high fixed charges, which keep the perceived risk level of the investment high.

Italy and Spain, on the other hand, followed an opposite approach concerning the choice of the type of grants and incentives. Italy focused on the typology of feed-in-premium and tax incentives, while Spain provided investment grants. Table 7 shows how these two approaches correspond to the provision of measures and financial incentives in the different stages of the realization of energy communities.

Table 7. Measures and incentives for energy communities by phase in Italy and Spain (source: own processing).

Measures and incentives–Initial Phase				Measures and incentives–Advanced Phase			
Feasibility Study		**Development and Implementation**		**Activation**		**Operation**	
Italy	**Spain**	**Italy**	**Spain**	**Italy**	**Spain**	**Italy**	**Spain**
Local grants for feasibility study costs (in some regions)	—	Local grants for administrative and legal expenses	Co-funding for project design costs	(Only in case of building renovations: investment grants and tax incentives from other financial instruments, e.g., Ecobonus),	Investment grants for construction of self-consumption installations with renewable energy sources or storage systems	Bill savings achieved from self-generation of energy	
						Gain from the sale of self-produced energy to the grid	
						GSE feed-in-premium on self-produced and consumed energy	—
						Tax deduction on energy bill (corresponding to the avoided transfer of energy into the grid)	Tax deduction from payment of grid access tariff and generation tariff

In Italy, incentives are mainly related to self-produced and self-consumed energy, with the aim of supporting the return on capital invested in the operation phase of the installations. Additional regional grants are available to supplement the costs of the initial stages—costs of feasibility studies and other costs preparatory to the development and implementation of the energy community. However, in most cases, these incentives can only be accessed by municipalities and public entities that assume the role of promoters of energy communities. In this regard, it is important not to underestimate the potential benefits obtainable from the presence of grants for the feasibility study stage. Previous studies suggest that financial incentives should be considered in both the early and later stages of a project's life cycle [66]. In fact, having incentives in the early stages to investigate the economic feasibility and technical viability of an energy community allows for the mitigation of higher risks in the later stages and, in general, is a crucial element in all projects that require the involvement of multiple stakeholders and citizens, especially if there are citizens in socially and economically vulnerable conditions among them.

In Spain, according to the results of some studies [38,44], the legislation before 2021 did not yet guarantee adequate economic–financial instruments to facilitate the dissemination of energy communities throughout the country, and the profitability of investments in self-consumption energy installations was lower than in other countries. Instead, the programs provided by Royal Decree 477/2021 have focused on investment grants, i.e., a partial funding of the costs of building energy communities, and have made it possible to address the multiple financing needs of energy production and self-consumption facilities in different, including residential (Program 6), sectors, thereby decreasing the financial exposure of energy community construction by citizens and attracting more private investors.

Table 8 summarizes the main advantages and disadvantages corresponding to the two energy self-consumption typologies in Italy and Spain.

Despite a low-complexity administrative procedure, there are more constraints for collective self-consumption in Italy and self-consumption with simplified net billing in Spain than for the other two typologies of energy communities. These constraints mainly concern the proximity to power generation facilities in the first case, and the maximum power output of the installation in the second case, which consequently limits the production of photovoltaic energy and the potential profits from the sale of excess energy to the grid. In contrast, RECs in Italy and self-consumption communities with direct sales in Spain, allowing the participation of many members and large installations, ensure a wider coverage of energy consumption.

Table 8. Advantages and disadvantages by type of energy community in Italy and Spain (source: own processing).

Country	Type of Energy Community	Advantages	Disadvantages
Italy	Collective self-consumption	Higher tax incentives than those for REC	Mandatory connection to the same LV/MV transformation cabin (secondary cabin)
		The constitution of a legal entity is not required	The energy produced must be shared in the same place where it is generated
		Administrative procedure shorter than that for REC	
	REC	Higher feed-in premium than that for collective self-consumption	Mandatory constitution of a legal entity
		Potential membership by numerous public and private parties (citizen, entrepreneurs, municipalities, etc.)	Longer and more complex administrative procedure
		Possibility of connection to the same primary (HV transformation) cabin instead of secondary cabin	
Spain	Simplified net invoicing	Simplified administrative procedure	Constraints on installation capacity
		Exemption from grid access charges for excess energy	Limited revenues
		Revenues exempt from taxation	Monthly revenue billing
	Direct sales	No constraints on installation capacity	Complex administrative procedure
		No constraints on profit level	Payment of grid access tariff for excess electricity
		No monthly revenue limit	Payment of energy generation tax
		Exemption from grid access cost for excess energy	

From an environmental sustainability point of view, all four types of energy communities help to address local energy supply problems but can cause visual impacts that alter the urban landscape if PV systems are not well integrated into buildings. However, the first two systems have a low visual impact as the energy installations should be mainly domestic and located on the roof of buildings, while the other two types of energy communities (CERs in Italy and direct sale in Spain), due to their large size, could generate a positive and significant impact on the reinforcement of renewable energy networks, but also a potential and strongly negative impact on the urban landscape, so their location in the urban landscape and their design must take into account the protection of architectural and identity values.

5.2. Variability in Economic Feasibility

The economic feasibility of the formation of energy communities in all four scenarios of the case studies 1, 2 and 3 (see Section 4) were evaluated on the basis of technical (e.g., energy produced, energy shared, etc.) and economic (e.g., capital invested, incentive on shared energy, etc.) data (Figure 6).

Data	Unit	Case 1 - Scenarios				Case 2 - Scenarios				Case 3 - Scenarios			
		REC_IT	RESC_IT	ISC_IT	PR6_ES	REC_IT	RESC_IT	ISC_IT	PR6_ES	REC_IT	RESC_IT	ISC_IT	PR6_ES
Photovoltaic system cost	€/kW$_p$	1500	1500	1500	1068	1500	1500	1500	852	1500	1500	1500	900
Discount rate	%	4	4	4	4	4	4	4	4	4	4	4	4
Total energy consumption	kWh/year	132,300	132,300	132,300	132,300	197,100	197,100	197,100	197,100	585,900	585,900	585,900	585,900
Energy produced	kWh/year	137,773	137,773	137,773	137,773	137,773	137,773	137,773	137,773	275,546	275,546	275,546	275,546
Shared energy	kWh/year	49,571	49,571	49,571	49,571	66,043	66,043	66,043	66,043	166,291	166,291	166,291	166,291
Surplus energy	kWh/year	86,806	86,806	86,806	86,806	70,335	70,335	70,335	70,335	107,859	107,859	107,859	107,859
Energy self-sufficiency index	%	38.52	38.52	38.52	38.52	34.22	34.22	34.22	34.22	28.62	28.62	28.62	28.62
Capital invested	€	150,000	150,000	150,000	106,800	150,000	150,000	150,000	85,200	300,000	300,000	300,000	180,000
Installation cost per household	€/household	3125	3125	3125	2225	2083	2083	2083	1183	1389	1389	1389	833
Energy purchase price	€/kWh	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Energy sale price	€/kWh	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Revenues from energy fed into the grid	€/year	6819	6819	6819	6819	6819	6819	6819	6819	13,708	13,708	13,708	13,708
Savings from physical self-consumption	€/year	726	726	726	726	726	726	726	726	726	726	726	726
Operating costs	€/year	400	400	400	400	400	400	400	400	600	600	600	600
MISE incentive on shared energy	€/kWh/year	0.11	0.10	0	0	0.11	0.10	0	0	0.11	0.10	0	0
Refunds of tariff component	€/kWh/year	0.008	0.01	0	0	0.008	0.01	0	0	0.008	0.01	0	0
MISE incentive on shared energy	€/year	5453	4957	0	0	7265	6604	0	0	18,292	16,629	0	0
Refunds of tariff component	€/year	407	407	0	0	543	543	0	0	1367	1367	0	0
Avoided grid losses	€/year	0	72	0	0	0	94	0	0	0	237	0	0

Figure 6. Technical and economic data of the case studies (source: own processing).

The resulting economic indicators NPV, IRR and PBP in Figure 7 were calculated by applying the formulas (1), (2) and (3) and using the RECON software (by ENEA) [67].

Economic indicators	Unit	Case 1 - Scenarios				Case 2 - Scenarios				Case 3 - Scenarios			
		REC_IT	RESC_IT	ISC_IT	PR6_ES	REC_IT	RESC_IT	ISC_IT	PR6_ES	REC_IT	RESC_IT	ISC_IT	PR6_ES
Net Present Value (NPV) at 20 years	€	73,299	67,896	-8721	34,479	99,934	92,772	-8721	56,079	247,752	229,819	-24,143	95,857
Pay Back Period (PBP)	years	13.2	13.6	>20	15.6	11.6	12.0	>20	12.7	9.8	10.34	>20	13.6
Internal Rate of Return (IRR)	%	8.02	7.71	3.05	6.48	9.52	9.11	3.05	9.07	10.84	10.5	2.82	8.13

Figure 7. Economic indicators of the case studies (source: own processing).

The comparison of the economic indicators of the case studies (Figures 8 and 9) shows that the scenarios REC_IT and RESC_IT, corresponding to the two types of Italian energy communities, have the best economic performance in all the case studies. Given the same scenario, the change in NPV in the three case studies —for example from 73,999 to 247,752 EUR in case studies 1 and 3 respectively— depends on the higher cost efficiency and size of the PV system relative to the number of households involved and energy consumption. In contrast, given the same case study, the higher NPV value of the REC_IT scenarios depends on the feed-in tariff and tax deduction, which are higher than those of the other scenarios. Similar results are found for the indicators IRRs and PBPs. On the other hand, the NPVs of the scenario PR6_ES are also positive, although they are much lower than those of the scenario REC_IT, depending on the different type and size of financial instruments available in Spain.

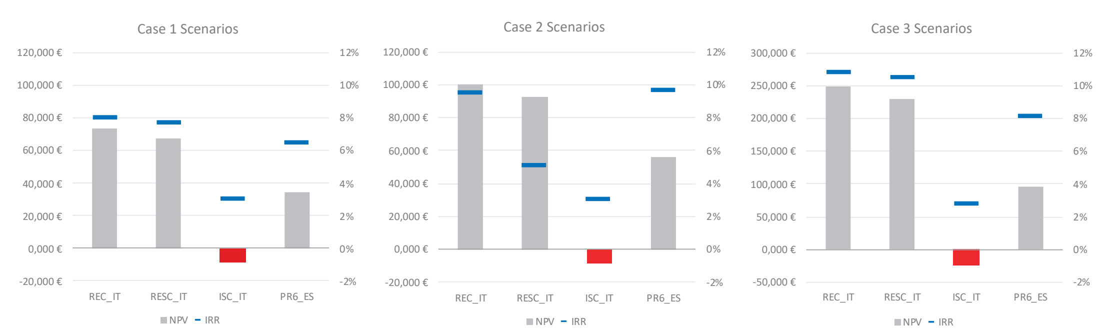

Figure 8. NPVs (left axis) and IRRs (right axis) of case studies 1, 2 and 3 (source: own processing).

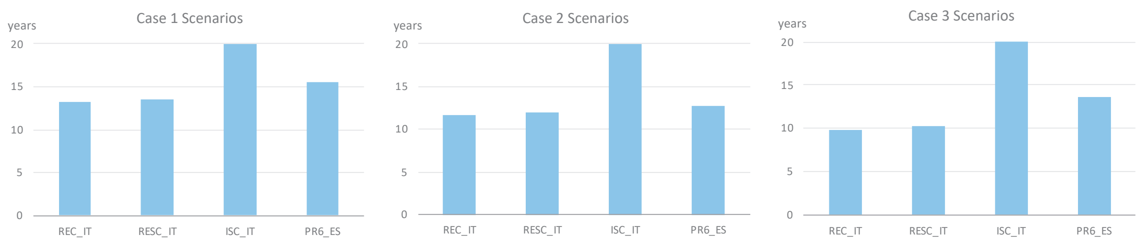

Figure 9. PBP of case studies 1, 2 and 3 (source: own processing).

It is worth noting that the three case studies always fail to meet economic feasibility without incentives; in fact, the NPVs of scenario ISC_IT are always negative and equal to -8721 EUR (case studies 1 and 2) or -24.143 EUR (case study 3), while the PBPs are always greater than 20 years. These results are indicative of the fact that such financial instruments are necessary to implement the energy transition in the current technical and economic conditions and to obtain the active involvement of citizens, as well as to increase the energy autonomy of cities.

5.3. Policy Recommendations

Energy communities are an instrument of environmental and energy policy and are based on the general principles of equity, energy autonomy and accessibility to energy sources. Their legal establishment is recent, so the transposition of general principles into norms and instruments is still being tested.

Assuming that there is no regulatory and financial system related to energy communities that can be adapted to every spatial, economic and social context; however, some policy recommendations can be pointed out based on the research and case study analysis presented in the previous sections.

Regulatory flexibility/complexity. While following EU directives, states and even regions can establish highly articulated regulations; of interest in this regard are the Programs for the implementation of self-consumption plants with renewable sources, which are differentiated by economic sector and type of energy (see Section 3.2). Obviously, more flexible regulations allow for better adaptation to the characteristics and needs of different sectors, but they also generate more bureaucratic complexity that can lengthen the time of bureaucratic processes.

Systematic national/transnational monitoring. In the absence of established procedures or practices, each country should conduct a periodic review of the consistency of regulation outcomes with overall energy transition goals; it would also be useful to document what is happening in other nations or regions. Monitoring data from the energy community should feed into an open-access database to facilitate the dissemination of best practices.

Type and size of monetary incentives. The choice of type and size of monetary incentives, while based on macroeconomic and microeconomic studies, must be subject to periodic revisions because changing initial technical, economic and social conditions may make them inefficient or ineffective. Of course, the combinations of incentive type/size are virtually infinite, but the cases already tested can provide some guidelines. For example, in the case studies presented, the scenario in which the energy community with the feed-in premium and tax incentives set by Italian law (REC_IT) is more convenient than that with the investment subsidy (PR6_ES) sets by Spanish law. From these results, it is necessary to explore the technical, financial and economic frontiers within which this convenience remains valid.

Citizen involvement. Energy communities are composed of citizens who need to be involved through local information and communication actions on energy transition and energy community issues. Implementing pilot projects, as has already been done for

NZEB buildings, provides tangible examples that can be shown to citizens in campaigns promoting energy communities and can facilitate their involvement.

Fair and direct access to renewable energy resources. Public authorities should pay more attention to social inclusion and energy poverty. Some social groups may have difficulty understanding the technical, procedural and economic aspects of energy community formation and affordability issues. These problems can be addressed by offering local counseling services, particularly in suburban neighborhoods, and by setting incentives specifically designed for them (possibly investment grants). In Italy, current legislation provides some incentives that offset the upfront costs (of design, legal fees, etc.) of energy communities, but this is not a sufficient measure to allow households in energy poverty to contribute to the overall expenses of the energy community and to prevent them from being excluded from the energy transition.

6. Conclusions

To strengthen ecological transition and reduce CO_2 emissions and energy consumption, the European Union has provided a legal groundwork for the formation of energy communities that transform citizens from passive consumers to prosumers and also enable citizens to play a proactive role in the diffusion of renewable energy sources in urban areas while gaining economic benefits. Furthermore, energy communities are also seen as a means of achieving a fair and inclusive energy transition.

As the field of energy communities is constantly and rapidly evolving and EU member states are providing very different actions to involve their citizens, this study proposed a framework of analysis of regulatory and financial instruments which consists of three levels and are related to each phase of the operating an energy community. In this framework, the effectiveness of the diffusion of energy communities in two European countries, Italy and Spain was analyzed, where the citizens' propensity for involvement in energy projects has been very weak but there is a great potential to be developed in photovoltaic and wind power generation. In particular, the regulatory and financial instruments adopted by the two countries were evaluated to determine whether they are adequate to promote the widespread formation of energy communities in urban areas and to meet economic feasibility of citizens involved in energy communities.

An analysis of the types of energy communities established in the EU, Italy and Spain has shown that they all produce environmental and social benefits, even if the issue of energy poverty is not yet effectively addressed. The comparative analysis of the financial instruments available to promote the establishment of energy communities, according to the most recent legislative updates, was the basis for the assessment of the economic feasibility of energy communities through the calculation of the most relevant economic performance indicators (Net Present Value, Internal Rate of Return and Payback Period) with respect to the different incentives currently available in Italy and Spain. According to the results reported in the previous section, a project with the same characteristics can reach different levels of economic feasibility depending on the type and size of incentives in place in the two countries, but above all, it is evident that the incentives are needed to make the formation of energy communities economically viable and, therefore, to succeed in involving citizens in the transition towards renewable energy sources.

The proposed framework of analysis made it possible to highlight the main procedural, technical, economic and social issues related to energy communities and which should be addressed by the two countries to implement energy communities more attractive. After all, the motivation for further efforts and investments to promote energy communities does not only concern the energy dimension but also the social and spatial dimension, since energy transition practices related to renewable energy sources can also become a tool for territorial policies to support social cohesion and inclusion and to increase the energy autonomy of cities.

Energy communities have only been legally established for a few years, so it may be useful to systematically monitor future changes in regulatory and financial instruments, as well as technical and economic studies, so as to highlight critical issues to be corrected and best practices to be emulated. Further research could also extend the comparative study to other European states or different regions of the same nation to make the process of achieving environmental goals more efficient and avoid exacerbating territorial and social inequalities.

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Evidence of Global Convergence: Perspectives for Economic and Territory Planning in Times of the COVID-19 Pandemic

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Abstract: Governments and international organizations have implemented efforts to promote the convergence of socioeconomic indicators between countries. The structural funds adopted by the European Union institutions are examples of policy instruments implemented to promote convergence in the GDP (gross domestic product) among the member states. Nonetheless, these policy measures are dependent on several internal and external factors, making these efforts vulnerable to exogenous shocks such as those associated with the global financial crisis and the COVID-19 pandemic. From this perspective, this research aims to analyze the convergence trends over the last few years and assess the respective implications of the pandemic on this framework. For that, statistical information from the World Bank for the GDP per capita was considered for the period 2006–2021 for all countries and organized for each group of levels of income and each world region. These data were analyzed through panel data approaches, considering the developments in convergence theory. The results show that the signs of convergence are different for each level of income and each region, highlighting the idea of clubs of convergence. On the other hand, the pandemic disturbed the trends of convergence verified worldwide, but nonetheless, it seems to be on a smaller scale than the global financial crisis. In any case, these findings should be confirmed in future research with more recent data.

Keywords: GDP per capita; panel data; sigma convergence; beta convergence

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1. Introduction

The convergence approaches may be divided into two groups, one related to absolute convergence and the other associated with conditional convergence. The principle of absolute convergence defends that countries and regions converge to the same "steady-state", in processes where the poorer areas have lower capital/labor ratios and, in this way, may attract more investment because they have higher marginal productivity for the capital. In the long term, the differences between the growth rates disappear due to free trade and the mobility of the factors. In these frameworks, the technical progress and the input supply are exogenous and easily available [1]. These developments of absolute convergence are associated with the neoclassical theory and are consistent with the exogenous growth theory of Solow [2] of constant or decreasing returns to scale.

The neoclassical approach to absolute convergence analyzes sigma and beta convergence. The sigma concept assesses, through the coefficient of variation (ratio among the standard deviation and the mean), the dispersion of the variable considered (level of income per capita, for example) between the economies taken into account. The beta concept investigates the relationships between the growth rate of the variable analyzed and its initial level. There is convergence if this relation is negative [1]. The concept of beta convergence is associated, for example, with Barro and Sala-i-Martin [3], and it is a necessary condition but not sufficient to have sigma convergence [4].

More recently, the endogenous growth theory with the conditional convergence approach appeared, where regions and countries converge to different "steady-states" depending on the levels of human capital stock, innovation, and technological advance [5].

In these contexts, the economies with similar characteristics present similar convergence processes that are different from those verified for other regions and countries with distinct particularities, in frameworks called clubs of convergence by the theory [6,7].

These are scenarios completely different from those predicted by Keynesian theory [8–11] or the new economic geography [12]. For these theories, polarization and agglomeration phenomena are expected, respectively, through circular and cumulative processes and increasing returns to scale. In these cases, the richer countries and regions become richer, and the poorer ones become even poorer.

The current reality worldwide and the economic growth dynamics over the last decades show that there is a place for different approaches to providing explanations about the empirical evidence. The adequacy of each theoretical argument depends on the specific scenario taken into account.

Considering the framework described before and the need for more contributions about the influence of the level of income and the location of the countries on the interaction worldwide in times of external shocks (namely to support more adjusted international programs with financial support and policies of cohesion), this research intends to analyze the trends of convergence worldwide since 2006 and assess the impacts of the COVID-19 pandemic on respective tendencies. To achieve these objectives, data from the World Bank [13] for the GDP per capita were considered (this data set is available at the World Bank for those who wish to replicate the results of this research) and explored through panel data approaches and the procedures proposed by Islam [14] and Stata software [15–17].

The following relevant published articles, among others, are suggested for further standardization and scholarship:

- Solow (1956) [2]: the base of the absolute convergence model;
- Barro and Sala-i-Martin (1991) [3]: associated with the concept of beta convergence;
- Sala-i-Martin (1996) [4]: relationship among sigma and beta convergence;
- Barro (1991) [5]: importance of the human capita for conditional convergence;
- Baumol (1986) [6] and Chatterji (1992) [7]: convergence clubs;
- Islam (1995) [14]: panel data models.

2. Literature Review

The COVID-19 pandemic impacted the trends of convergence in the European Union countries [18], as well as the global financial crisis. Over the period 2000–2019, the European Union's average convergence speed was 2.5% and the Eurozone's was 2.3% [19]. These signs of convergence were visible in the Bulgarian regions, for instance [20]. In general, the GDP per capita is the variable considered in the convergence analyses.

Nonetheless, the concepts associated with the convergence developments (beta convergence, for example) have also been taken into account by the researchers to assess the evolution of the following variables: homicide rates [21]; child stunting [22]; energy consumption per capita [23]; eco-innovation [24]; social conditions [25]; research and development expenditure [26]; population [27]; human well-being [28]; resource productivity [29]; rural sustainable development efficiency [30]; digital economy and society index [31]; religious diversity index [32]; per capita CO_2 emissions [33]; and carbon emission intensity [34].

Convergence is a complex process with, in some circumstances, bidirectional characteristics [35]. These processes are challenging worldwide [36], but they pose particular difficulties in African countries [37]. Often, the different countries converge at distinct speeds and follow diverse patterns, creating clubs of convergence [38], dependent on several factors [39]. This is also true for the regional convergence inside the countries [40], such as Poland [41] and the Russian Federation [42]. Regularly, there is convergence inside the clubs and divergence among clubs [43]. Fossil fuel endowments [44] and migration [45] are among the factors that may influence the convergence conditions.

The traditional concepts of convergence developments are sigma and beta convergence; however, recent contributions have brought new approaches [46], where spatial effects [47] and spatial autocorrelation [48] are included. In the convergence processes, the lower and middle-income regions catch up with the high-income ones [49], because they grow faster [50]. These frameworks associated with the convergence have attracted the attention of the scientific community, including for assessments with information from the eighteenth century [51] and before [52].

The idea behind the convergence approaches is that there is a trend for countries and regions to converge at the same level of the variable considered. This is the opposite perspective of the theories associated with the divergence, where polarization [53–55] and agglomeration [56] of economic activity and population are expected through circular and cumulative phenomena and trends.

3. Material and Methods

Considering the objectives proposed, statistical information from the World Bank [13] was considered for the period 2006–2021. Some countries were removed because of a lack of data for the whole period or for some years. These data were analyzed through panel data methodologies, considering the concepts of sigma and beta convergence. The sigma concept was analyzed through the coefficient of variation, and the speed of convergence beta was found from the coefficient of convergence, considering the developments of Tondl [57], for example, where beta is calculated through the following equation:

$$\text{beta} = -\ln(1 - \text{b})/\text{T} \tag{1}$$

In this equation, b is the coefficient of convergence, and T is the period.

The concepts of sigma and beta convergence have been considered in the scientific literature related to convergence theory. These approaches have also been taken into account in contributions related to divergence theory [58]. In this perspective, these concepts have been validated by the scientific community and have relevance for convergence assessments. Nonetheless, as mentioned before, there are other perspectives on the processes of economic growth [59,60], some of them related to polarization and agglomeration dynamics.

To better understand the processes of convergence and their respective catching-up tendencies worldwide, the statistical information was also organized for several groups by level of income and world regions. These groups were defined by the World Bank, considering the gross national income (GNI) per capita (U.S. dollars) to identify the income groups and regions taken into account for administrative purposes to form the groups of regions [13]. The list of countries considered by income is presented in Table A1. Summary statistics for these groups of countries by income are presented in Table A2. This approach allows for the investigation of the existence of clubs of convergence.

Following the contributions of Islam [14] and Tondl [57], the model taken into account in this study for panel data was the following:

$$\text{GDP per capita growth rate}_{it} = a - b^{*}\ln(\text{GDP per capita}_{it\text{-}1}) + u_{it} \tag{2}$$

In this equation, a is the constant, b is the coefficient of convergence, i represents the countries, and t is the number of years.

This approach to Islam was influenced by the model of Solow, where economic growth is influenced by the exogenous supply of inputs with constant or decreasing returns to scale. In fact, the existence of constant or decreasing returns to scale is relevant to explaining the processes of convergence between regions or countries.

To investigate potential statistical problems of cross-sectional independence, heteroscedasticity, and autocorrelation, the following tests were carried out: Pesaran's test of cross-sectional independence; the modified Wald test for groupwise heteroscedasticity; and the Wooldridge test for autocorrelation. To deal with these statistical problems, the correlated panel corrected standard errors (PCSEs) approach was used. This is an adjusted approach to carrying out regressions with panel data when the disturbances are heteroskedastic and contemporaneously correlated across panels [61]. This methodology is supported by the scientific literature [62–66], based on the study of Beck and Katz [67], because with heteroscedasticity, cross-sectional dependence, and autocorrelation, the OLS (ordinary least squares) regressions are not efficient.

4. Sigma Convergence

The global financial crisis of 2007–2008 had an impact on sigma convergence worldwide (Figure 1). The signs of convergence reappeared consistently after 2013 and were only disturbed by the pandemic in 2021. This evidence of divergence caused by COVID-19 seems weaker compared to that promoted by the global financial crisis.

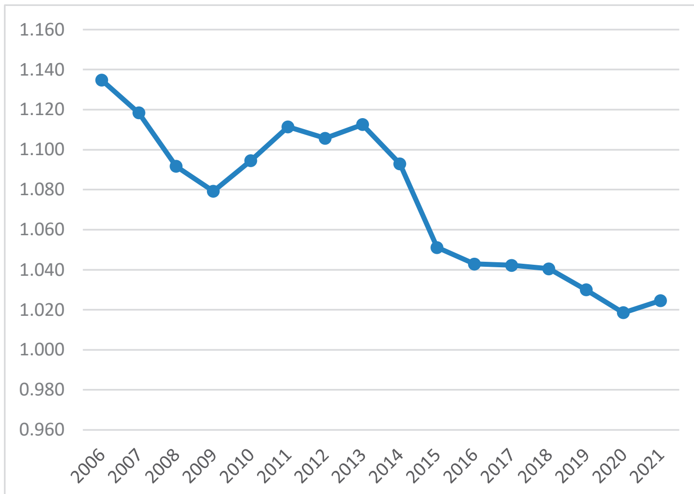

Figure 1. Sigma convergence (coefficient of variation), for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering all countries.

These findings reveal that the global financial crisis was more asymmetric than the COVID-19 pandemic, increasing the disparities between the countries. On the other hand, it seems that governments and international organizations learned from the impacts on the economy of the financial crisis and were better prepared to respond to pandemic shocks.

In any case, a true comparison of the Great Recession and COVID is not possible with the tools in this manuscript. This research should be updated in future studies to reflect this reality, either by adding more recent data or by adding.

The COVID-19 pandemic had similarly implications on the sigma convergence (Table 1) between the low and lower middle income countries (nonetheless here there are also signs of divergence in 2007, 2008, 2010, 2016 and 2017), the low and upper middle countries (in this case the evidence of divergence began in 2020 and there are also signs of divergence in 2007, 2008, 2012, 2017 and 2018), and among the low and high income nations (there is also evidence of divergence in 2010, 2011, 2012, and 2013). The impacts of the pandemic need to be confirmed in future research with more data, namely more recent statistical information. The lower middle-income nations presented signs of divergence in 2007, 2008, 2010, 2016, 2017, and 2021. There is also evidence of divergence among the lower- and upper-middle income countries in 2007, 2008, 2012, 2017, 2018, and 2021 and between the lower middle- and high-income nations in 2010, 2011, 2012, 2013, and 2021. In the upper middle-income countries, the signs of divergence are visible in 2007, 2008, 2012, 2017, 2018, 2020, and 2021. In the high-income nations, this evidence of divergence is present in 2009, 2010, 2011, 2012, 2013, and 2021 (with some signs in 2017). Among the upper middle- and high-income countries, the divergence appears in 2010, 2011, 2013, and 2021. These findings highlight that the different income groups have distinct dynamics with consequences for convergence patterns. These results call for adjusted policies and may be considered support for policymakers and decision-makers. One of the greater challenges will be promoting convergence between low- and high-income countries (this is also visible in Figure 2).

Table 1. Sigma convergence (coefficient of variation), for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each group of levels of income.

Level of Income	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Low	0.553	0.549	0.537	0.503	0.493	0.509	0.467	0.469	0.467	0.462	0.460	0.448	0.426	0.407	0.399	0.398	0.472
Low and lower middle	0.759	0.777	0.780	0.774	0.782	0.776	0.764	0.745	0.728	0.716	0.725	0.729	0.728	0.718	0.700	0.706	0.744
Low and upper middle	0.753	0.758	0.761	0.746	0.731	0.708	0.733	0.709	0.695	0.688	0.679	0.688	0.690	0.686	0.688	0.702	0.713
Low and high	0.830	0.822	0.806	0.806	0.828	0.847	0.851	0.862	0.843	0.799	0.792	0.792	0.791	0.782	0.772	0.776	0.812
Lower middle	0.613	0.631	0.634	0.629	0.638	0.629	0.615	0.592	0.572	0.556	0.563	0.566	0.563	0.551	0.535	0.537	0.589
Lower and upper middle	0.688	0.696	0.700	0.677	0.664	0.638	0.660	0.633	0.614	0.603	0.592	0.599	0.601	0.594	0.588	0.608	0.635
Lower middle and high	0.999	0.988	0.969	0.960	0.979	0.996	0.997	1.006	0.985	0.941	0.931	0.931	0.930	0.920	0.906	0.915	0.960
Upper middle	0.445	0.449	0.453	0.438	0.418	0.387	0.419	0.386	0.367	0.356	0.343	0.354	0.356	0.349	0.359	0.370	0.391
Upper middle and high	0.776	0.760	0.736	0.731	0.749	0.769	0.765	0.773	0.755	0.712	0.705	0.704	0.702	0.692	0.685	0.685	0.731
High	0.521	0.511	0.493	0.495	0.522	0.544	0.550	0.562	0.541	0.487	0.478	0.478	0.477	0.464	0.454	0.457	0.502

Note: The coefficient of variation is ratio among the standard deviation and the mean.

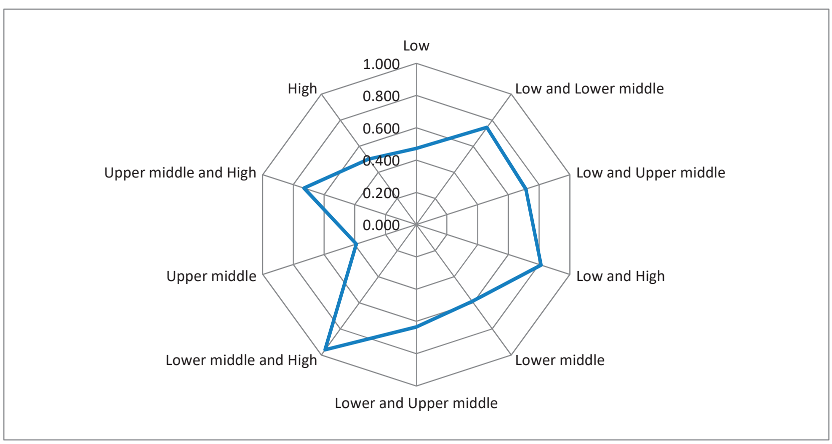

Figure 2. The average coefficient of variation, for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each group of levels of income.

The average coefficient of variation is higher between the low- and high-income countries and among the lower middle- and high-income nations (Figure 2), showing greater dispersion in these cases. The lower average values for the coefficient of variation appear in low, upper middle, and high-income nations.

There is evidence of divergence in 2021 for the following world regions (Table 2): East Asia and the Pacific; East Asia and the Pacific and Europe and Central Asia; East Asia and the Pacific and Latin America and the Caribbean; East Asia and the Pacific and the Middle East and North Africa; East Asia and the Pacific and North America; East Asia and the Pacific and South Asia; and East Asia and the Pacific and Sub-Saharan Africa. In Europe and Central Asia, and between this region and the other world regions, signs of divergence appeared in 2020 (which extended to 2021 only in Europe, Central Asia, and Sub-Saharan Africa). The divergence appeared already in 2019 for Latin America and the Caribbean countries, for the Middle East and North Africa nations, and among these regions and other world regions. This divergence disappeared in 2021, except in the following cases that presented signs of convergence in 2020: Latin America and the Caribbean; Latin America and the Caribbean and South Asia; and Latin America and the Caribbean and Sub-Saharan Africa. There is not any evidence of convergence in the Middle East, North Africa, or sub-Saharan Africa. There are similarly signs of divergence in 2021 for the following regions: North America; North America and Sub-Saharan Africa; South Asia; South Asia and Sub-Saharan Africa; and Sub-Saharan Africa.

Table 2. Sigma convergence (coefficient of variation), for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each world region.

World Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
East Asia & Pacific	1.301	1.320	1.302	1.292	1.356	1.419	1.438	1.468	1.421	1.276	1.253	1.277	1.284	1.249	1.112	1.164	1.308
East Asia & Pacific and Europe & Central Asia	0.903	0.902	0.881	0.881	0.902	0.920	0.928	0.942	0.919	0.858	0.849	0.850	0.845	0.826	0.792	0.803	0.875
East Asia & Pacific and Latin America & Caribbean	1.087	1.091	1.064	1.050	1.100	1.152	1.169	1.196	1.158	1.042	1.026	1.051	1.060	1.037	0.940	0.964	1.074
East Asia & Pacific and Middle East & North Africa	1.160	1.137	1.112	1.099	1.151	1.219	1.213	1.238	1.212	1.117	1.095	1.097	1.100	1.082	1.010	1.038	1.130
East Asia & Pacific and North America	1.217	1.227	1.211	1.196	1.229	1.267	1.277	1.299	1.261	1.151	1.133	1.153	1.156	1.130	1.035	1.074	1.189
East Asia & Pacific and South Asia	1.396	1.412	1.389	1.377	1.443	1.508	1.527	1.557	1.505	1.352	1.325	1.348	1.353	1.315	1.180	1.225	1.388
East Asia & Pacific and Sub-Saharan Africa	1.667	1.687	1.663	1.651	1.735	1.813	1.837	1.876	1.823	1.662	1.643	1.680	1.696	1.660	1.494	1.554	1.696
Europe & Central Asia	0.709	0.700	0.677	0.678	0.674	0.658	0.652	0.646	0.641	0.641	0.640	0.626	0.615	0.605	0.622	0.617	0.650
Europe & Central Asia and Latin America & Caribbean	0.803	0.794	0.769	0.759	0.750	0.734	0.724	0.715	0.710	0.713	0.714	0.708	0.703	0.699	0.727	0.720	0.734
Europe & Central Asia and Middle East & North Africa	0.773	0.746	0.719	0.716	0.723	0.731	0.717	0.714	0.708	0.703	0.696	0.676	0.666	0.660	0.680	0.675	0.706
Europe & Central Asia and North America	0.713	0.703	0.681	0.680	0.673	0.655	0.645	0.639	0.630	0.629	0.627	0.616	0.605	0.595	0.608	0.603	0.644
Europe & Central Asia and South Asia	0.816	0.807	0.783	0.782	0.775	0.759	0.751	0.744	0.737	0.737	0.735	0.722	0.711	0.701	0.722	0.715	0.750
Europe & Central Asia and Sub-Saharan Africa	1.149	1.143	1.121	1.114	1.108	1.092	1.082	1.075	1.070	1.075	1.078	1.072	1.066	1.061	1.078	1.080	1.092
Latin America & Caribbean	0.857	0.832	0.797	0.753	0.715	0.696	0.683	0.671	0.662	0.660	0.657	0.658	0.662	0.668	0.664	0.648	0.705

Table 2. *Cont.*

World Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Latin America & Caribbean and Middle East & North Africa	0.972	0.913	0.873	0.848	0.862	0.890	0.869	0.861	0.849	0.838	0.824	0.800	0.796	0.797	0.830	0.816	0.852
Latin America & Caribbean and North America	0.963	0.948	0.914	0.885	0.858	0.832	0.804	0.791	0.773	0.771	0.769	0.779	0.777	0.780	0.800	0.788	0.827
Latin America & Caribbean and South Asia	0.946	0.918	0.883	0.835	0.794	0.774	0.760	0.746	0.736	0.731	0.725	0.723	0.724	0.727	0.723	0.707	0.778
Latin America & Caribbean and Sub-Saharan Africa	1.217	1.197	1.170	1.122	1.079	1.062	1.051	1.037	1.028	1.027	1.026	1.028	1.034	1.039	1.019	1.018	1.072
Middle East & North Africa	0.965	0.901	0.865	0.846	0.883	0.954	0.908	0.916	0.917	0.903	0.881	0.842	0.836	0.842	0.873	0.867	0.887
Middle East & North Africa and North America	0.877	0.843	0.817	0.798	0.813	0.855	0.812	0.817	0.814	0.805	0.790	0.768	0.763	0.768	0.789	0.786	0.807
Middle East & North Africa and South Asia	1.192	1.119	1.077	1.054	1.087	1.147	1.104	1.106	1.097	1.080	1.054	1.011	0.999	0.999	1.041	1.027	1.075
Middle East & North Africa and Sub-Saharan Africa	1.652	1.566	1.522	1.495	1.531	1.584	1.550	1.545	1.530	1.521	1.504	1.469	1.464	1.465	1.491	1.499	1.524
North America	0.406	0.417	0.404	0.388	0.365	0.337	0.295	0.284	0.250	0.251	0.252	0.269	0.256	0.254	0.247	0.253	0.308
North America and South Asia	1.410	1.400	1.374	1.349	1.318	1.285	1.246	1.231	1.200	1.193	1.179	1.179	1.164	1.154	1.185	1.169	1.252
North America and Sub-Saharan Africa	1.997	1.987	1.952	1.909	1.875	1.832	1.780	1.763	1.729	1.739	1.744	1.771	1.771	1.774	1.771	1.799	1.825
South Asia	0.882	0.864	0.880	0.785	0.774	0.785	0.760	0.761	0.758	0.732	0.724	0.719	0.717	0.716	0.584	0.688	0.758
South Asia and Sub-Saharan Africa	1.173	1.208	1.243	1.209	1.134	1.147	1.142	1.115	1.101	1.074	1.064	1.060	1.058	1.059	1.002	1.037	1.114
Sub-Saharan Africa	1.240	1.286	1.326	1.301	1.217	1.232	1.232	1.200	1.185	1.159	1.149	1.146	1.144	1.145	1.101	1.124	1.199

Note: The coefficient of variation is ratio among the standard deviation and the mean.

In these contexts for the world regions, the big challenge is to deal with the convergence process of Sub-Saharan Africa with the remaining world regions (this can be confirmed in Figure 3).

The world regions with the highest averages for the coefficient of variation are the following (Figure 3): North America and Sub-Saharan Africa; East Asia and the Pacific and Sub-Saharan Africa; and the Middle East and North Africa and Sub-Saharan Africa. The lowest averages appear in Latin America and the Caribbean, Europe and Central Asia, and North America.

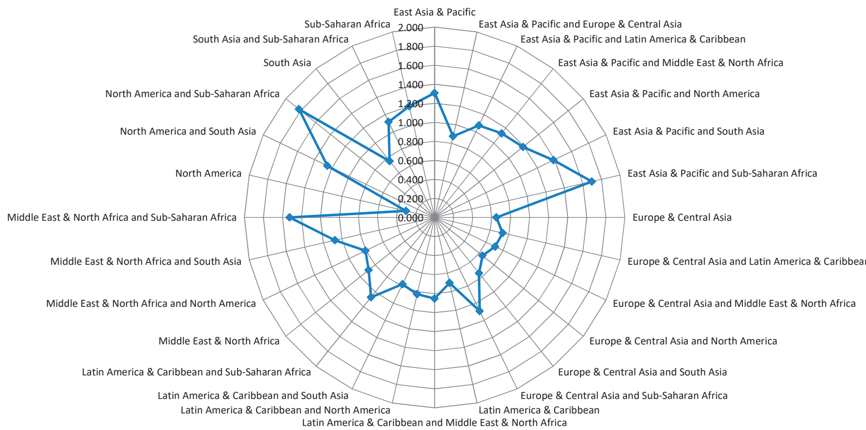

Figure 3. The average coefficient of variation, for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each world region.

5. Beta Convergence

The results presented in Table 3 (all results of this regression are presented in Table A3) reveal signs of beta convergence between the world's countries. This speed of convergence is higher for upper middle-income, high-income, and low-income countries (Tables 4 and A4). The coefficient of convergence is not statistically significant for the following groups of income levels: low and lower middle; low and upper middle; low and high; and lower and upper middle. The lowest speed of convergence was found for lower middle-income countries and for high- and upper-middle-income countries.

Table 3. Beta convergence, for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering all countries.

Independent Variable	Coefficient	Beta Convergence (%)
Logarithm of GDPpc lagged	−0.005 *	0.501

Note: *, Statistically significant at 1%.

Table 4. Beta convergence, for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each group of levels of income.

Level of Income	Independent Variable	Coefficient	Beta Convergence (%)
Low	Logarithm of GDPpc lagged	−0.020 **	2.02
Low and lower middle	Logarithm of GDPpc lagged	−0.002	
Low and upper middle	Logarithm of GDPpc lagged	−0.001	
Low and high	Logarithm of GDPpc lagged	−0.003	
Lower middle	Logarithm of GDPpc lagged	−0.011 ***	1.106
Lower and upper middle	Logarithm of GDPpc lagged	−0.009	
Lower middle and high	Logarithm of GDPpc lagged	−0.007 *	0.702
Upper middle	Logarithm of GDPpc lagged	−0.023 ***	2.327
Upper middle and high	Logarithm of GDPpc lagged	−0.014 *	1.41
High	Logarithm of GDPpc lagged	−0.022 *	2.225

Note: *, Statistically significant at 1%; **, Statistically significant at 5%; ***, Statistically significant at 10%.

These findings for beta convergence reveal that there are signs of convergence inside each income group; however, this evidence is weaker or inexistent between income groups, showing some signs of convergence clubs.

Table 5 (all results of these regressions are presented in Table A5) highlights that the speed of convergence is higher for the following world regions: North America; Europe and Central Asia and North America; Europe and Central Asia; Latin America and the Caribbean and South Asia; Europe and Central Asia and the Middle East and North Africa; and Europe and Central Asia and South Asia. The lowest values for the speed of convergence are found for Latin America and the Caribbean and North America; East Asia and the Pacific and Latin America and the Caribbean; East Asia and the Pacific and the Middle East and North Africa; and East Asia and the Pacific and North America. For the following regions, the coefficient of convergence is not statistically significant: East Asia and Pacific; East Asia and Pacific and South Asia; East Asia and Pacific and Sub-Saharan Africa; Europe and Central Asia and Sub-Saharan Africa; Latin America and the Caribbean and Sub-Saharan Africa; Middle East and North Africa and Sub-Saharan Africa; North America and Sub-Saharan Africa; South Asia; South Asia and Sub-Saharan Africa; and South Asia and Sub-Saharan Africa.

Table 5. Beta convergence, for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each world region.

Level of Income	Independent Variable	Coefficient	Beta Convergence (%)
East Asia & Pacific	Logarithm of GDPpc lagged	−0.007	
East Asia & Pacific and Europe & Central Asia	Logarithm of GDPpc lagged	−0.011 *	1.106
East Asia & Pacific and Latin America & Caribbean	Logarithm of GDPpc lagged	−0.009 **	0.904
East Asia & Pacific and Middle East & North Africa	Logarithm of GDPpc lagged	−0.009 ***	0.904
East Asia & Pacific and North America	Logarithm of GDPpc lagged	−0.008 ***	0.803
East Asia & Pacific and South Asia	Logarithm of GDPpc lagged	−0.008	
East Asia & Pacific and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.001	
Europe & Central Asia	Logarithm of GDPpc lagged	−0.017 *	1.715
Europe & Central Asia and Latin America & Caribbean	Logarithm of GDPpc lagged	−0.011 *	1.106
Europe & Central Asia and Middle East & North Africa	Logarithm of GDPpc lagged	−0.015 *	1.511
Europe & Central Asia and North America	Logarithm of GDPpc lagged	−0.018 *	1.816
Europe & Central Asia and South Asia	Logarithm of GDPpc lagged	−0.015 *	1.511
Europe & Central Asia and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.002	
Latin America & Caribbean	Logarithm of GDPpc lagged	−0.013 *	1.309
Latin America & Caribbean and Middle East & North Africa	Logarithm of GDPpc lagged	−0.013 *	1.309
Latin America & Caribbean and North America	Logarithm of GDPpc lagged	−0.011 *	1.106
Latin America & Caribbean and South Asia	Logarithm of GDPpc lagged	−0.016 *	1.613
Latin America & Caribbean and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.005	
Middle East & North Africa	Logarithm of GDPpc lagged	−0.013 **	1.309
Middle East & North Africa and North America	Logarithm of GDPpc lagged	−0.013 *	1.309
Middle East & North Africa and South Asia	Logarithm of GDPpc lagged	−0.015 **	1.511
Middle East & North Africa and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.003	
North America	Logarithm of GDPpc lagged	−0.032 *	3.252
North America and South Asia	Logarithm of GDPpc lagged	−0.012 *	1.207
North America and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.003	
South Asia	Logarithm of GDPpc lagged	−0.005	
South Asia and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.002	
Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.002	

Note: *, Statistically significant at 1%; **, Statistically significant at 5%; ***, Statistically significant at 10%.

These findings confirm the problems of convergence between the Sub-Saharan Africa countries and the remaining world regions.

6. Discussion

This research aimed to analyze the convergence of GDP per capita worldwide over the last few years (2006–2021) and assess the consequences of the recent exogenous shocks on this evolution. For that, data from the World Bank were considered for all countries and organized by groups, taking into account the level of income and the region to which each country belongs. This statistical information was analyzed through panel data methodologies, finding the results for sigma and beta convergence.

The literature review highlighted the trends of convergence verified in some parts of the world over the last decades, which were disturbed by the COVID-19 pandemic. This was shown, specifically, for the European Union countries [18]. The difficulties that the African countries have to converge between them and with the other continents are also revealed by the scientific community [37].

The results from the sigma convergence confirm the disruptions caused by the COVID-19 pandemic on the convergence process worldwide; however, its impact seemed weaker when compared to that caused by the global financial crisis. When the analysis was made by groups based on their level of income, these disturbances in 2021 were also verified. More recent statistical information is needed to confirm, in future approaches, these pandemic tendencies. On the other hand, lower average dispersion for the GDP per capita was found inside groups related to low, upper middle, and high income. This average dispersion was great when countries from different groups of levels of income were put together, such as low- and high-income nations and lower middle- and high-income countries. There are some signs of convergence clubs here. In general, the world region groups also presented signs of divergence in 2021. In some cases, these signs appeared in 2020, namely for the groups where European and Central Asian nations were considered. In other cases, the divergence began in 2019 (particularly when Latin America and the Caribbean and the Middle East and North Africa countries were taken into account). These findings highlight that the implications of the pandemic were asymmetric (to be confirmed in future research). This opens up new possibilities for future research in these fields. The average dispersion for the world region groups was lower in North America, Europe and Central Asia and North America, Europe and Central Asia and Latin America and the Caribbean, Europe and Central Asia and the Middle East and North Africa, Europe and Central Asia and Latin America and the Caribbean, Europe and Central Asia and South Asia, South Asia and Latin America and the Caribbean, and South Asia. These findings reveal evidence of clubs of convergence and some signs of catching-up phenomena between countries belonging to different world regions. The sub-Saharan African nations have higher average coefficients of variation.

The beta convergence analysis shows that there are signs of convergence worldwide; nonetheless, the speed of convergence is greater between the nations inside the following groups of income levels: low income; upper middle income; and high income. These findings confirm the idea of clubs of convergence for these groups. There is also evidence of beta convergence (with lower speeds) for the lower middle income, lower middle and high income, and upper middle- and high-income countries, showing signs of catching up processes. The world region groups with the highest speed of convergence have, generally, countries from North America, Europe, and Central Asia, revealing again signs of clubs of convergence and catching up trends.

7. Conclusions

The convergence process verified worldwide over the last few years (since 2006) was disturbed by exogenous shocks, including the global financial crisis and the COVID-19 pandemic. Nonetheless, these disruptions were not symmetric, and the consequences of the pandemic on the convergence process seem weaker globally than those from the financial crisis (to be confirmed in future studies with more recent data). In any case, the process of convergence has continued worldwide, with evidence of clubs of convergence and catching-up phenomena. In fact, there are signs of convergence inside some groups and between countries with different levels of income, revealing the role of the high-income countries in promoting income in the lower-income nations. On the other hand, special attention is needed for the African countries, specifically the sub-Saharan ones.

In terms of practical implications and insights for economic and territory management, it is important to reinforce cooperation worldwide to better promote the convergence in the level of income per capita between the countries, where the richer countries play a fundamental role in creating conditions for catching-up processes. In terms of policy recommendations, it could be important to design programs of financial support for the sub-Saharan countries, where the problems of convergence in GDP per capita seem to be more serious. Balanced economic growth is crucial for sustainable development. For future research, it is suggested to explore the contexts inside each group of countries. It could be interesting, for example, to better understand the frameworks of the sub-Saharan African countries, where the weaknesses are greater and the challenges to improving economic growth are enormous. This is particularly important for territory planning in these nations, where economic growth theories may provide relevant insights. Territory-related dimensions of convergence assessments have been highlighted in the literature [58]. It was also suggested to test other variables that may influence these trends of convergence, considering the approaches to conditional convergence. This research aimed to analyze the influence of the level of income and the location of countries on convergence trends worldwide. For future research, it is suggested to test the size of the pandemic in each group of levels of income and world regions. It could also be interesting to test the socioeconomic differences inside each region, the public policy responses to COVID-19, the European Union policies, cohesion, and differences in the industry structure.

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Appendix A

Table A1. List of countries by income.

Level of Income	Countries
Low income	Afghanistan Burkina Faso Burundi Central African Republic Chad Congo, Dem. Rep. Ethiopia Gambia, The Guinea Guinea-Bissau Liberia Madagascar Malawi Mali Mozambique Niger Rwanda Sierra Leone Sudan Togo

Table A1. *Cont.*

Level of Income	Countries
Low income	Uganda Zambia
Lower middle income	Algeria Angola Bangladesh Benin Bhutan Bolivia Cabo Verde Cambodia Cameroon Comoros Congo, Rep. Cote d'Ivoire Egypt, Arab Rep. El Salvador Eswatini Ghana Haiti Honduras India Indonesia Iran, Islamic Rep. Kenya Kiribati Kyrgyz Republic Lao PDR Lebanon Lesotho Mauritania Micronesia, Fed. Sts. Mongolia Morocco Myanmar Nepal Nicaragua Nigeria Pakistan Papua New Guinea Philippines Samoa Sao Tome and Principe Senegal Solomon Islands Sri Lanka Tajikistan Tanzania Timor-Leste Tunisia Ukraine Uzbekistan Vanuatu Vietnam West Bank and Gaza Zimbabwe
Upper middle income	Albania Argentina Armenia

Table A1. *Cont.*

Level of Income	Countries
Upper middle income	Azerbaijan Belarus Belize Bosnia and Herzegovina Botswana Brazil Bulgaria China Colombia Costa Rica Dominica Dominican Republic Ecuador Equatorial Guinea Fiji Gabon Georgia Grenada Guatemala Guyana Iraq Jamaica Jordan Kazakhstan Libya Malaysia Maldives Marshall Islands Mauritius Mexico Moldova Montenegro Namibia North Macedonia Palau Paraguay Peru Russian Federation Serbia South Africa St. Lucia St. Vincent and the Grenadines Suriname Thailand Tonga Turkiye Tuvalu
High income	Antigua and Barbuda Aruba Australia Austria Bahamas, The Bahrain Barbados Belgium Bermuda Brunei Darussalam Canada

Table A1. *Cont.*

Level of Income	Countries
High income	Cayman Islands Chile Croatia Curacao Cyprus Czechia Denmark Estonia Finland France Germany Greece Hong Kong SAR, China Hungary Iceland Ireland Israel Italy Japan Korea, Rep. Latvia Lithuania Luxembourg Macao SAR, China Malta Nauru Netherlands New Zealand Norway Oman Panama Poland Portugal Puerto Rico Qatar Romania Saudi Arabia Seychelles Singapore Slovak Republic Slovenia Spain St. Kitts and Nevis Sweden Switzerland Trinidad and Tobago United Arab Emirates United Kingdom United States Uruguay

Table A2. Summary statistics of the GDP per capita for the groups of countries by income.

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Low income	352	1773	822	705	5047
Lower middle income	848	5813	3424	1353	19,240

Table A2. *Cont.*

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum
Upper middle income	800	14,476	5656	3335	35,689
High income	976	44,507	22,245	4401	157,603

Table A3. Regression results for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering all countries.

Independent Variable	Coefficient	Standard Error	Z	P > |z|	Beta Convergence (%)	Hausman Test	Pesaran's Test of Cross Sectional Independence	Modified Wald Test for Groupwise Heteroskedasticity	Wooldridge Test for Autocorrelation
Logarithm of GDPpc lagged	−0.005 *	0.002	−2.660	0.008	0.501	194.740 *	163.010 *	32,962.530 *	17.909 *
Constant	0.063 *	0.014	4.630	0.000					

Note: *, Statistically significant at 1%.

Table A4. Regression results for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each group of level of income.

Level of Income	Independent Variable	Coefficient	Standard Error	Z	P > |z|	Beta Convergence (%)	Hausman Test	Pesaran's Test of Cross Sectional Independence	Modified Wald Test for Groupwise Heteroskedasticity	Wooldridge Test for Autocorrelation
Low	Logarithm of GDPpc lagged	−0.020 **	0.010	−2.020	0.044	2.020	24.410 *	5.670 *	1400.930 *	41.824 *
	Constant	0.157 **	0.073	2.150	0.032					
Low and lower middle	Logarithm of GDPpc lagged	−0.002	0.004	−0.410	0.682		96.070 *	38.331 *	7196.360 *	87.798 *
	Constant	0.029	0.028	1.060	0.287					
Low and upper middle	Logarithm of GDPpc lagged	−0.001	0.004	−0.320	0.748		83.490 *	52.078 *	10,764.370 *	10.074 *
	Constant	0.028	0.028	1.010	0.311					
Low and high	Logarithm of GDPpc lagged	−0.003	0.002	−1.400	0.163		95.400 *	83.078 *	10,614.300 *	126.831 *
	Constant	0.036 **	0.014	2.530	0.011					
Lower middle	Logarithm of GDPpc lagged	−0.011 ***	0.006	−1.920	0.055	1.106	55.830 *	32.528 *	5516.920 *	54.034 *
	Constant	0.113 **	0.046	2.460	0.014					
Lower and upper middle	Logarithm of GDPpc lagged	−0.009	0.006	−1.590	0.112		100.110 *	79.747 *	23,446.710 *	9.709 *
	Constant	0.102 **	0.047	2.180	0.029					
Lower middle and high	Logarithm of GDPpc lagged	−0.007 *	0.002	−3.970	0.000	0.702	113.560 *	111.357 *	16,621.350 *	146.453 *
	Constant	0.083 *	0.015	5.630	0.000					
Upper middle	Logarithm of GDPpc lagged	−0.023 ***	0.012	−1.880	0.060	2.327	45.000 *	51.063 *	2962.010 *	10.025 *
	Constant	0.241 **	0.113	2.130	0.034					
Upper middle and high	Logarithm of GDPpc lagged	−0.014 *	0.002	−5.880	0.000	1.410	106.600 *	139.267 *	19,356.890 *	14.468 *
	Constant	0.154 *	0.025	6.190	0.000					
High	Logarithm of GDPpc lagged	−0.022 *	0.007	−3.320	0.001	2.225	53.710 *	88.232 *	9086.180 *	77.035 *
	Constant	0.240 *	0.070	3.440	0.001					

Note: *, Statistically significant at 1%; **, Statistically significant at 5%; ***, Statistically significant at 10%.

Table A5. Regression results for the GDP per capita (PPP, constant 2017 international $), over the period 2006–2021, considering each world region.

Level of Income	Independent Variable	Coefficient	Standard Error	Z	P > |z|	Beta Convergence (%)	Hausman Test	Pesaran's Test of Cross Sectional Independence	Modified Wald Test for Groupwise Heteroskedasticity	Wooldridge Test for Autocorrelation
East Asia & Pacific	Logarithm of GDPpc lagged	−0.007	0.006	−1.190	0.235		32.610 *	21.984 *	15,627.300 *	58.236 *
	Constant	0.084 ***	0.048	1.740	0.082					
East Asia & Pacific and Europe & Central Asia	Logarithm of GDPpc lagged	−0.011 *	0.003	−4.370	0.000	1.106	60.550 *	87.639 *	10,192.110 *	116.156 *
	Constant	0.133 *	0.023	5.680	0.000					

Table A5. *Cont.*

Level of Income	Independent Variable	Coefficient	Standard Error	Z	P > |z|	Beta Convergence (%)	Hausman Test	Pesaran's Test of Cross Sectional Independence	Modified Wald Test for Groupwise Heteroskedasticity	Wooldridge Test for Autocorrelation
East Asia & Pacific and Latin America & Caribbean	Logarithm of GDPpc lagged	−0.009 **	0.005	−1.970	0.049	0.904	63.880 *	63.222 *	12,496.310 *	82.474 *
	Constant	0.101 *	0.038	2.660	0.008					
East Asia & Pacific and Middle East & North Africa	Logarithm of GDPpc lagged	−0.009 ***	0.005	−1.840	0.066	0.904	65.400 *	27.202 *	33,333.320 *	5.513 **
	Constant	0.103 **	0.041	2.490	0.013					
East Asia & Pacific and North America	Logarithm of GDPpc lagged	−0.008 ***	0.004	−1.850	0.065	0.803	34.840 *	26.059 *	13,660.390 *	63.502 *
	Constant	0.097 **	0.039	2.470	0.013					
East Asia & Pacific and South Asia	Logarithm of GDPpc lagged	−0.008	0.005	−1.480	0.138		47.660 *	28.625 *	18,287.450 *	18.211 *
	Constant	0.097 **	0.044	2.200	0.028					
East Asia & Pacific and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.001	0.003	−0.480	0.633		68.240 *	43.893 *	20,426.910 *	125.068 *
	Constant	0.028	0.021	1.350	0.177					
Europe & Central Asia	Logarithm of GDPpc lagged	−0.017 *	0.003	−6.900	0.000	1.715	20.600 *	79.307 *	1076.020 *	48.933 *
	Constant	0.196 *	0.030	6.540	0.000					
Europe & Central Asia and Latin America & Caribbean	Logarithm of GDPpc lagged	−0.011 *	0.002	−4.910	0.000	1.106	57.530 *	121.547 *	1632.080 *	75.389 *
	Constant	0.124 *	0.026	4.740	0.000					
Europe & Central Asia and Middle East & North Africa	Logarithm of GDPpc lagged	−0.015 *	0.002	−6.320	0.000	1.511	73.100 *	78.588 *	4927.760 *	7.852 *
	Constant	0.171 *	0.028	6.180	0.000					
Europe & Central Asia and North America	Logarithm of GDPpc lagged	−0.018 *	0.003	−7.150	0.000	1.816	22.050 *	85.559 *	1023.720 *	51.996 *
	Constant	0.202 *	0.030	6.670	0.000					
Europe & Central Asia and South Asia	Logarithm of GDPpc lagged	−0.015 *	0.002	−7.290	0.000	1.511	42.490 *	81.794 *	1789.310 *	13.340 *
	Constant	0.170 *	0.022	7.690	0.000					
Europe & Central Asia and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.002	0.002	−1.090	0.275		58.000 *	83.731 *	7168.120 *	102.275 *
	Constant	0.036 **	0.015	2.370	0.018					
Latin America & Caribbean	Logarithm of GDPpc lagged	−0.013 *	0.003	−3.800	0.000	1.309	35.990 *	50.349 *	381.770 *	34.654 *
	Constant	0.135 *	0.027	4.940	0.000					
Latin America & Caribbean and Middle East & North Africa	Logarithm of GDPpc lagged	−0.013 *	0.004	−3.140	0.002	1.309	96.830 *	53.538 *	3598.500 *	10.780 *
	Constant	0.132 *	0.035	3.770	0.000					
Latin America & Caribbean and North America	Logarithm of GDPpc lagged	−0.011 *	0.002	−4.970	0.000	1.106	39.840 *	55.668 *	419.710 *	36.585 *
	Constant	0.115 *	0.019	6.180	0.000					
Latin America & Caribbean and South Asia	Logarithm of GDPpc lagged	−0.016 *	0.004	−4.080	0.000	1.613	50.690 *	54.586 *	833.540 *	20.303 *
	Constant	0.163 *	0.030	5.380	0.000					
Latin America & Caribbean and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.005	0.003	−1.540	0.124		61.150 *	68.584 *	10,344.340 *	78.128 *
	Constant	0.052 **	0.021	2.470	0.014					
Middle East & North Africa	Logarithm of GDPpc lagged	−0.013 **	0.007	−1.970	0.049	1.309	55.980 *	6.941 *	4645.070 *	7.500 **
	Constant	0.143 **	0.062	2.290	0.022					
Middle East & North Africa and North America	Logarithm of GDPpc lagged	−0.013 *	0.004	−2.870	0.004	1.309	63.710 *	10.038 *	4268.200 *	7.697 **
	Constant	0.137 *	0.046	2.970	0.003					

Table A5. *Cont.*

Level of Income	Independent Variable	Coefficient	Standard Error	Z	P > |z|	Beta Convergence (%)	Hausman Test	Pesaran's Test of Cross Sectional Independence	Modified Wald Test for Groupwise Heteroskedasticity	Wooldridge Test for Autocorrelation
Middle East & North Africa and South Asia	Logarithm of GDPpc lagged	−0.015 **	0.006	−2.530	0.011	1.511	55.780 *	13.632 *	6287.900 *	7.578 **
	Constant	0.157 *	0.050	3.130	0.002					
Middle East & North Africa and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.003	0.003	−0.940	0.346		74.580 *	30.700 *	24,251.450 *	6.374 **
	Constant	0.038 ***	0.022	1.730	0.083					
North America	Logarithm of GDPpc lagged	−0.032 *	0.012	−2.700	0.007	3.252	2.400	4.619 *	2.110	15.184 ***
	Constant	0.356 *	0.129	2.760	0.006					
North America and South Asia	Logarithm of GDPpc lagged	−0.012 *	0.004	−2.760	0.006	1.207	18.600 *	11.165 *	708.600 *	2.065
	Constant	0.134 *	0.038	3.520	0.000					
North America and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.003	0.002	−1.460	0.143		28.150 *	27.741 *	5812.410 *	59.029 *
	Constant	0.038 **	0.016	2.330	0.020					
South Asia	Logarithm of GDPpc lagged	−0.005	0.015	−0.340	0.732		16.250 *	6.219 *	960.000 *	1.675
	Constant	0.078	0.125	0.620	0.535					
South Asia and Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.002	0.005	−0.350	0.730		47.970 *	29.184 *	10,551.060 *	13.570 *
	Constant	0.028	0.033	0.850	0.393					
Sub-Saharan Africa	Logarithm of GDPpc lagged	−0.002	0.004	−0.630	0.531		25.330 *	24.028 *	6236.360 *	56.352 *
	Constant	0.031	0.026	1.180	0.239					

Note: *, Statistically significant at 1%; **, Statistically significant at 5%; ***, Statistically significant at 10%.

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