

Article

Land Transformations in Irpinia (Southern Italy): A Tale on the Socio-Economic Dynamics Acting in a Marginal Area of the Mediterranean Europe

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Abstract: Marginal areas in economically advanced countries are a critical issue that European and national policies have been addressing for some time. These areas are affected by depopulation, infrastructural gaps and labor systems that do not reach the corresponding national levels and where often agriculture still plays a critical role. In Italy, despite the fact that the National Strategy for Inner Areas (SNAI) has been active for about a decade with the aim of increasing the territorial cohesion of these fragile areas, rather limited results have been achieved in terms of halting economic marginalization and demographic decline. In this specific context, our work is aimed at analyzing land use changes, the loss of ecosystem services and demographic trends in a Mediterranean region (Irpinia—Southern Italy) on district and municipal scales in the last 30 years (1990–2018) to capture current, subtle socio-economic dynamics. The analysis carried out has indicated a substantial increase in urban areas due to the development of new industrial areas and discontinuous urban fabric (urban sprawl) at the expense of natural areas (mainly meadows and shrublands). The agricultural areas have remained substantially unchanged in terms of extension, with a slight increase in heterogeneous agricultural areas and an expansion of high-value crops (vineyards), that are the most suitable for multifunctional agriculture activities (experiential and rural tourism). The analysis of the demographic trend has highlighted a widespread phenomenon of depopulation, with the exception of those municipalities who economically orbit around the provincial capital of Avellino. The municipalities in depopulation are mostly located in the inner areas characterized by a more rugged morphology and infrastructural gaps. Unexpectedly, most of municipalities show a significant anticorrelation among the population and agricultural areas which is an indicator of social and economic phenomena as complex as they are underestimated. As a final step, this analysis highlights also a loss of carbon storage mainly attributable to the soil sealing of large areas. This study can help to comprehensively understand the conditions of marginal areas in Mediterranean Europe over recent decades in the light of the main socio-economic dynamics to better direct efforts towards the containment of the human capital hemorrhage, consisting of persistently negative natural and migratory rates, and the sustainable empowerment of these geo-economic peripheries.

Keywords: land use changes; marginal areas; Mediterranean Europe; depopulation; ecosystem services

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1. Introduction

Global land use/cover changes over the last six decades are proceeding at a high rate, involving around a third of the global lands with a divergent behavior in the two hemispheres: the expansion of agricultural areas coupled with deforestation in the Global South, while the Global North is affected by cropland abandonment accompanied by afforestation processes [1]. In Europe, these dynamics coexist with relentless urbanization [2,3], often exceeding population growth rates [4–6] and taking the striking form of littoralization in conurbated coastal areas, especially in Mediterranean regions [7,8]. On the one hand, these phenomena of land consumption are also linked to land abandonment, and on the other, to its reverse, i.e., agricultural intensification [9,10], as two interlinked aspects of a joint process of space reconfiguration [11] under the influence of several drivers: the European CAP (common agricultural policy), the globalization of markets and the changing geopolitical scenarios [12–15].

In this context, a delicate question arises for predominantly rural areas that represent in Europe almost 45% of the overall continental area, but are inhabited by only 21% of the total population (data updated to 2021, see Eurostat report at <https://ec.europa.eu/eurostat/en/web/products-eurostat-news/w/ddn-20230117-2>, accessed on 20 August 2020). These figures are destined to worsen because the population of predominantly rural areas has recorded an annual decrease of 0.1% over the period 2015–2020, while mostly urban areas have grown by 0.4% each year [16]. Typical challenges that rural communities face are demographic aging and decline, low income levels, a lack of job opportunities, a widening of the digital divide, inadequate infrastructure, and also impacts of climate change and land degradation phenomena [17–23]. All this exacerbates the hemorrhage of manpower contributing to the vicious cycle that culminates in the severe depopulation of these areas.

To counter this phenomenon, the EU's new CAP (2023–2027) has recently evolved to support a more comprehensive approach that combines rural development with agricultural productivity [24]. In line with these efforts, the European Commission published in 2021 a communication outlining the long-term vision for rural areas in the EU until 2040 (https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3162, accessed on 20 August 2024) aimed at addressing various challenges and harnessing the benefits of the green and digital transition. The plan is designed to make rural areas stronger, connected and resilient to potential exogenous shocks contributing to the necessary development to make them attractive once again.

In parallel to CAPs, the European Commission set in 2011 a goal of achieving ‘no net land take by 2050’ as a recommendation to protect the soil, safeguard biodiversity and improve overall quality of life. Land conversion to artificial surfaces, at the expense of natural and agricultural covers, mainly occurs in urban and peri-urban areas, disrupting ecological functions and weakening ecosystem resilience. To meet the EU's target of “no net land take by 2050,” significant efforts are needed to drastically reduce land conversion by 2030. In 2021, a decade later, this objective was reaffirmed within the European Union Soil Strategy, though it remains non-binding for member states. Despite the lack of a legal mandate, several member states and regions have chosen to follow the recommendation to curb the urban sprawl (<https://www.eea.europa.eu/en/analysis/indicators/net-land-take-in-cities>, accessed on 20 August 2024).

To this European trend, Italy is no exception. Here, the demographic fall in rural areas is even more pronounced compared to the European level. The Italian National Institute of Statistics (ISTAT), in its annual report on demographic projections for 2021, indicates that, in addition to a generalized decline of the Italian population in the coming years (until 2031), there will be a significant contraction of residents in rural areas (approximately 5.5%) with about 86% of the total municipalities experiencing a negative balance [25]. The stronger demographic decrease will affect particularly the southern regions of Italy (94% of municipalities with an overall population reduction of 8.8%). In this report, ISTAT also refers to the so-called “inner areas,” which are specific zones that can only

provide limited accessibility to essential services for residents, impacting the well-being levels of the people who live there. The main features of inner areas are:

- A significant distance from major service centers offering essential services, including education, health and mobility pillars;
- Considerable endowment in terms of natural capital (water, forests, natural areas and anthropic landscapes) and cultural resources (archeological and monumental assets, historical settlements, churches and museums);
- Extreme heterogeneity of the land systems, resulting from the interweaving of complex natural systems, millennial anthropization and climate dynamics.

Italy promoted in 2013 a specific strategy, the so-called National Strategy for “Inner Areas” (SNAI), representing a pioneering approach to the territorial cohesion to revitalize economically and demographically marginal areas while maintaining their valuable natural assets [26]. The SNAI is grounded in an ambitious place-based policy that embraces a new multilevel local governance model. This approach involves integrated local promotion and development strategies, tackling demographic challenges and meeting the specific needs of territories affected by important geographical and socio-economic issues [27]. Inner Areas, considered fragile territories because they are subjected to demographic decline [28], stretch over 60% of the national surface and host 52% of Italian municipalities and 22% of the total population (<https://www.agenziacoesione.gov.it/strategia-nazionale-aree-interne/>, accessed on 20 August 2024). Contrary to popular belief, the game of environmental sustainability is not played only on the large numbers of megacities or metropolitan areas, but both globally and in Italy (especially in central–southern and insular regions of the country), it is the medium-sized and small cities that emerge as concrete examples of unsustainable resource use. In the face of a growth in land consumption, often also disjointed and inefficient (urban sprawl), there is a progressive demographic fall linked to socio-economic issues.

Our work is aimed at analyzing land use changes using a loss of ecosystem services and demographic trends in a Mediterranean region (Irpinia—Southern Italy) at the district and municipal scale in the last 30 years (1990–2018) as a starting point, aimed at understanding the intricate links between environmental transformations, socio-economic dynamics and ecosystem service changes. The choice of the study area is supported by its peculiar features: predominantly inner, not very connected, compounded by a painful history of a district emerging from a striking calamitous event (the 1980 earthquake [29]), accompanied by more recent dynamics of sprawling urbanization, population decline, agricultural extensification and increasing investments in tourism activities [30–32]. This study can shed light on the dynamics of this area to understand how both national/local support policies (e.g., the strengthening of the infrastructure network, incentives supporting the birth and development of new businesses) and spontaneous actions generating compensatory circuits (e.g., agritourism, local traditions) could be promoted to revitalize the inner areas of the Mediterranean regions.

2. Materials and Methods

2.1. Study Area

Irpinia roughly corresponds to the mountainous area of the Campania region (NUTS2 level—Nomenclature of Territorial Units for Statistics) and can be considered to be overlapping with the province of Avellino (NUTS3 level), located in the central–eastern part of Campania (Figure 1).

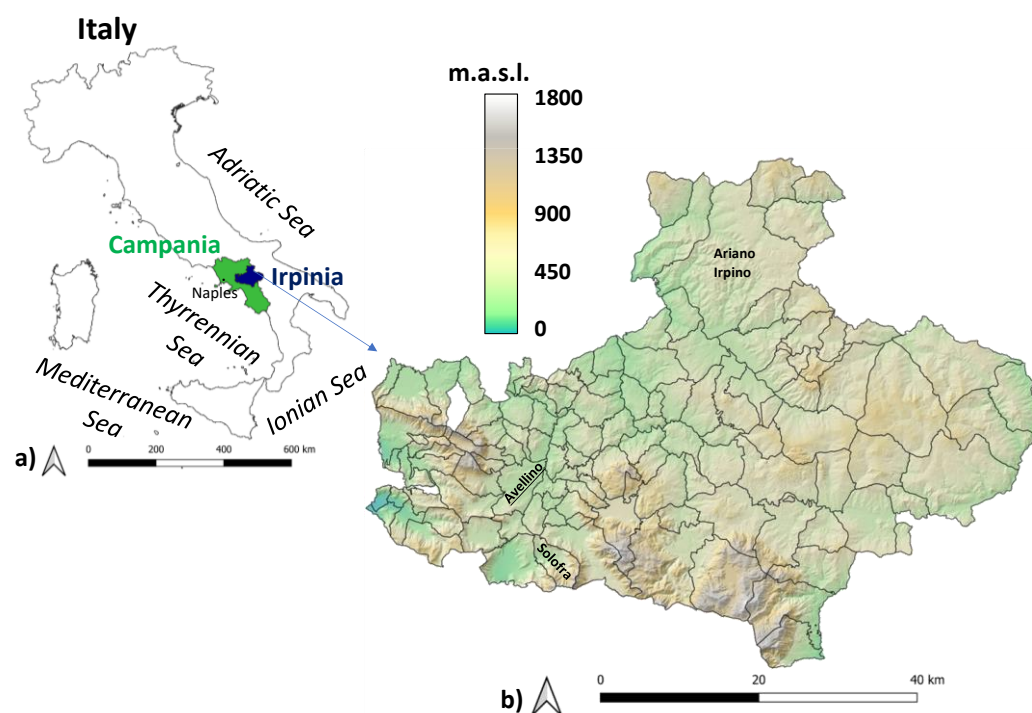


Figure 1. Study area: (a) Irpinia (Avellino province) embedded within the Campania region (Southern Italy), (b) DEM (Digital Elevation Model) overlapped to the municipal boundaries of the study area.

It is a predominantly mountainous territory, carved by valleys and traversed by several rivers and streams. The abundance of water resources represents one of the main assets of Irpinia, which supplies water to the surrounding regions through ancient and modern canalization works, such as those involving the sources of the Sele and the Conza della Campania reservoirs.

The mountainous nature is one of the most typical features of the Irpinia landscapes, with elevations exceeding 1800 m in the southwestern area of the province, while in the eastern area, the orography is characterized by clayey lithologies originating less elevated peaks. In this geographic setting, numerous significant geological and geomorphological sites exist, showcasing a broad geodiversity stemming from intricate geological processes [33]. Although only partially mountainous, the morphology of the Irpinian territory somehow influences the geo-cultural perception of the settled communities, both in the actual mountainous areas and in the urban systems [34].

The climate is generally Mediterranean, where the driest periods correspond to the hottest ones during the year even though mid-hills and mountains enjoy a pleasant summer climate and cold/humid winters [35].

Natural aspects linked to the mountainous landscapes are not the only peculiar traits shaping the identity of Irpinia: this area is one of the 175 seismic districts in Italy, within which 58 municipalities are classified by the Department of Civil Protection as having a high seismic risk out of the total 118 municipalities of the district territory [36]. It is precisely the seismic activity, the most dramatic manifestation of which was undoubtedly the earthquake taking place on 23 November 1980, that represents one of the focal points around which much of the territory's culture revolves. Struck by that devastating event, the district reconstructed its identity around the perception of risk and restarted its historical memory precisely from that collective trauma [37]. The earthquake of 1980, along with all the complexity and challenges of the reconstruction processes, has left local communities with a significant legacy in terms of the culture and perception of its natural environment. Embedded in the traditional definition of the Irpinia as the inner area, this has contributed to producing, over the decades, entrenched forms of political-cultural

marginalization, which are most evident in the more inner territories where, due to specific social and infrastructural conditions, the concept of the inner area has often been perceived as marginalization [38].

Viewed as a whole, Irpinia enjoys a favorable position with respect to the main arterial roads of Southern Italy due to its location between the Tyrrhenian and Adriatic sides. However, if we take into account the level of infrastructure provision and the opportunities offered for mobility by transportation services, the emerging point is the absolute dominance of road transport over rail and, on the other hand, a densification of the network in the areas closest to Naples, with a more sparse network as one moves towards the more inner municipalities of the study area [39].

Demographic trends represent one of the elements often interpreted as the most illustrative of the marginalized conditions of Irpinia. ISTAT data (<https://ottomilacensus.istat.it/sottotema/064/064008/1/>, accessed on 20 August 2024) indicate a significant depopulation trend in Irpinia over the period (1990–2018), recognized as one of the highest in the inner areas of Campania ([30], see Table 1). As shown in Table 1, the population was 437,131 inhabitants in 1990, while it reached 414,109 inhabitants in 2018 with a decrease that brings us to a population balance of −23,022 inhabitants (−5.27%), a trend that is destined to be accentuated in the last five years, pushing the population below the threshold of 400,000 inhabitants (<http://dati.istat.it/Index.aspx?lang=en&SubSessionId=44345b45-4dd5-465a-b072-1a8d4e02f8f6>, accessed on 20 August 2024).

Table 1. ISTAT data of resident population in the province of Avellino.

Year	Inhabitants	Foreign Population *
1990	437,131	
2001	430,344	
2011	428,855	11,257
2018	414,109	14,590

* The resident population includes all citizens (Italians and foreigners) registered in municipal databases. Immigration is a recent phenomenon in Irpinia, so census data available before 2011 are not significant (and not immediately available). Actually, immigration in the inner areas of Southern Italy began after the EU enlargements cycles of 2004 and 2007.

Focusing on the socio-economic aspects of Irpinia, a strong tradition emerges in the primary sector that encompasses activities related to agriculture, animal husbandry and natural resource extraction. Despite the considerable transformations of this sector over time, currently, agriculture still retains a significant role in the local economy with a diversified production, including wheat, olives, grapes, vegetables and fruits [40]. Viticulture and oenology hold a prominent place, with the production of high-quality wines, such as the Taurasi DOCG and native grape varieties like Aglianico [41]. Livestock farming, especially sheep and goats, is a well-established agricultural pillar contributing to the production of dairy products, which are an important part of the local culture, while chestnut cultivation represents an ancient tradition in some Irpinian areas [42].

Industrial areas have mainly developed around the large municipality of Ariano Irpino and along the North–South axis between Avellino and the Tyrrhenian coast.

2.2. Data

The data used in this work are:

- CORINE Land Cover maps—CLC relative to land use/land cover in the years 1990 and 2018 (<https://land.copernicus.eu/en/products/corine-land-cover>, accessed on 20 August 2024);
- Demographic data of Irpinia (source ISTAT: years 1990 and 2018, see <https://demo.istat.it/?l=en>, accessed on 20 August 2024);

- Shapefile of the administrative boundaries of the province of Avellino (<https://www.istat.it/notizia/confini-delle-unita-amministrative-a-fini-statistici-al-1-gennaio-2018-2/>, accessed on 20 August 2024).

CLC is a program promoted by the European Environment Agency (EEA) since the 1980s [43]. It constitutes a comprehensive system for classifying land cover and land use, monitoring landscape changes, and assessing the impact of human activities on the environment. The program adopts a standardized classification system to categorize different types of land cover into distinct classes. The areas included in the CLC project encompass a significant portion of the European territory, progressively expanding with each new edition of the database developed over time: CLC1990, CLC2000, CLC2006, CLC2012 and CLC2018. The use and analysis of high-resolution satellite imagery have enabled the creation of mapping with the following technical characteristics:

- Nomenclature with three hierarchical levels and 44 classes;
- A minimum mappable unit of 25 hectares;
- Geometric accuracy of 100 m.

This study specifically utilized CLC 1990 and 2018 at the third level of detail. The choice of CLC datasets is justified by their availability over a 30-year time span and their labeling facilitating empirical analysis in different fields [44–46]. Actually, some analyses focusing on human–environment interactions would probably benefit from a more detailed classification of artificial and agricultural covers and a finer spatial detail. However, for the purposes of this work, which focuses on the district scale, the technical features of this dataset in terms of labeling and spatial resolution are sufficient to provide a plausible overview of the changes occurring in the time window examined.

The demographic information was derived from census data, available at a municipal scale so as to obtain population trends in the examined period (<https://demo.istat.it/?l=en>, accessed on 20 August 2024).

2.3. Methodology

The analysis of the CLC datasets and the demographic data for the years 1990 and 2018 was carried out through geospatial tools populating GIS environments (in our case, QGIS 3.16.11 and GRASS GIS 7.8.5, see <https://qgis.org/en/site/> and <https://grass.osgeo.org/>, accessed on 20 August 2024). We preliminarily rasterized the CLC vectors at a pixel size of 5 m, then we reclassified the CLC categories into macro-classes to better identify land transformations which occurred in the time frame examined (1990–2018). This was made according to the legend simplification adopted by [47]. They propose a reduced number of CLC classes for Mediterranean environments passing from the original 44 categories to only 9 macro-classes (Table 2).

Table 2. Land use/cover groups obtained from the reclassification of the original CLC nomenclature at third level of detail (the table includes only the classes actually present in the study area).

CLC Categories—III Level of Detail	CLC Reclassification
Continuous urban fabric (111)	Artificial surfaces (1)
Discontinuous urban fabric (112)	
Industrial or commercial units (121)	
Road and rail networks and associated land (122)	
Mineral extraction sites (131)	
Dump sites (132)	
Construction sites (133)	
Non-irrigated arable land (211)	Agricultural areas (2)
Vineyards (221)	
Fruit trees and berry plantations (222)	
Olive groves (223)	

Pastures (231)	
Annual crops associated with permanent crops (241)	
Complex cultivation patterns (242)	Land principally occupied by
Land principally occupied by agriculture, with significant heterogeneous agricultural areas of natural vegetation (243)	areas (3)
Agro-forestry areas (244)	
Broad-leaved forest (311)	
Coniferous forest (312)	Forests (4)
Mixed forest (313)	
Natural grassland (321)	Natural grasslands (5)
Sclerophyllous vegetation (323)	
Transitional woodland/shrub (324)	Shrublands (6)
Beaches, dunes, sands (331)	Open spaces with little or
Sparsely vegetated areas (333)	no vegetation (7)
Burnt areas (334)	Burnt areas (8)
Inland marshes (411)	
Water Bodies (512)	Water bodies (9)

Subsequently, we calculated gains and losses for each category of the simplified nomenclature. The final step was the cross-tabulation of the identified classes to detect the major trajectories characterizing Mediterranean landscapes: artificialization, agricultural expansion, agricultural intensification, agricultural extensification, forest expansion, shrubland expansion and forest degradation (see e.g., [48–53]). According to [47], these trajectories were obtained by aggregating the crosses of the 9 macro-classes reported in Table 2. Specifically, by the word Artificialization, we mean the basic land take processes consisting of changes from agricultural/natural classes to urban/commercial/industrial uses. Agricultural intensification is a transformation occurring within agricultural uses from the heterogeneous agricultural classes to monoculture (from 3 to 2), while agricultural extensification is its reverse (from monoculture to heterogeneous land classes, from 2 to 3). Agricultural expansion encompasses those changes involving all the natural classes (forests, shrubs, grasslands and areas with little or no vegetation, i.e., the macro-classes 4, 5, 6 and 7) that become agricultural categories (macro-classes 2 and 3). Forest expansion represents the enlargement of forests at the expense of agricultural classes, grasslands, shrublands, areas with little or no vegetation and burnt areas (from 2, 3, 5, 6, 7 and 8 to 4). Shrubland expansion indicates changes from agricultural land uses and grasslands to shrublands (from 2, 3 and 5 to 6), whereas forest degradation refers to those classes which were previously forests and have now become shrublands, natural grasslands, areas with little or no vegetation or burnt areas (from 4 to 5, 6, 7 and 8).

The original 1990 and 2018 CLC land use maps at the III level of detail (appropriately converted in raster with 5 m of spatial resolution) were used to feed the free software InVEST (Integrated Valuation of Ecosystem Services and Trade-offs), developed by Stanford University within the Natural Capital Project and able to quantify ecosystem goods and services over time [54]. Among the different modules populating the software and dedicated to specific ecosystem services, we choose “Carbon Storage and Sequestration”, estimating the amount of carbon stored and sequestered over time. This is due to the paramount importance of this ecosystem service within the context of sustainable land planning. This module estimates the net amount of carbon stored over time, requiring four varieties of the carbon pool: aboveground biomass, belowground biomass, soil and dead organic matter. The values of these coefficients for the different CLC classes were obtained by consulting multiple bibliographic sources related to biogeographic areas similar to those under study [55–58] and finally following the indications of [59] (see this paper for a complete picture of the used coefficients). The most important fact is that sealed areas do not contribute to carbon storage, making artificialization the most dangerous land use trajectory.

Lastly, in the present work, possible correlations at the municipal level between the different variables describing landscape transformations (a gain/loss of artificial, agricultural and natural areas) and demographic trends from 1990 to 2018 were calculated. In particular, for these statistical analyses, land uses were again re-aggregated into four main macro-classes by merging the categories reported in Table 2: ART—Artificial surface (1); AGR—Agricultural area (2) + Land principally occupied by agriculture (3); FOR—Forests (4) + Natural grasslands (5) + Shrublands (6) + Open space with little or no vegetation (7) + Burnt areas (8); WAT—water bodies (9). All balances related to the main land uses (ART, AGR, FOR and WAT) were normalized to the municipal area, while the demographic balance was normalized to the 1990 population.

3. Results

Maps depicted in Figure 2a represent the land cover patterns of Irpinia in 1990 and 2018, as aggregated in nine macro-classes. We observe at a glance the still predominantly agricultural matrix of the region with an important presence of forests and a moderate occurrence of natural non-tree vegetation (shrublands, pastures and sparsely vegetated areas). The other macro-classes occupy a marginal space. Even though artificial areas accounted for only 4.46% of the overall surface in 2018, their relevance is increased over time (in 1990, they represented only 3.06%) with an additional 40 km² of sealed soil (Figure 2b). For the agricultural areas, a slight shrinking is recorded (about −5%, corresponding to approximately 60 km²) to the advantage of heterogeneous agricultural areas mixed with natural spaces (the macro-class named “Land principally occupied by agriculture” that expands by nearly 10%). Within natural covers, forests slightly expand (less than 1% corresponding to a little more than 11 km²), whereas significant losses characterize both shrublands and grasslands (about −24% and −56%, respectively, meaning a decline of nearly 34 km² and 26 km²). There was a considerable growth of scarcely vegetated areas and bare soils (+241%, although the areal increase is just 9 km²). Burnt areas, that were not present in 1990, amounted to 3.23 km² in 2018. Wetlands and Water bodies increased by about 40% (+1.33 km²).

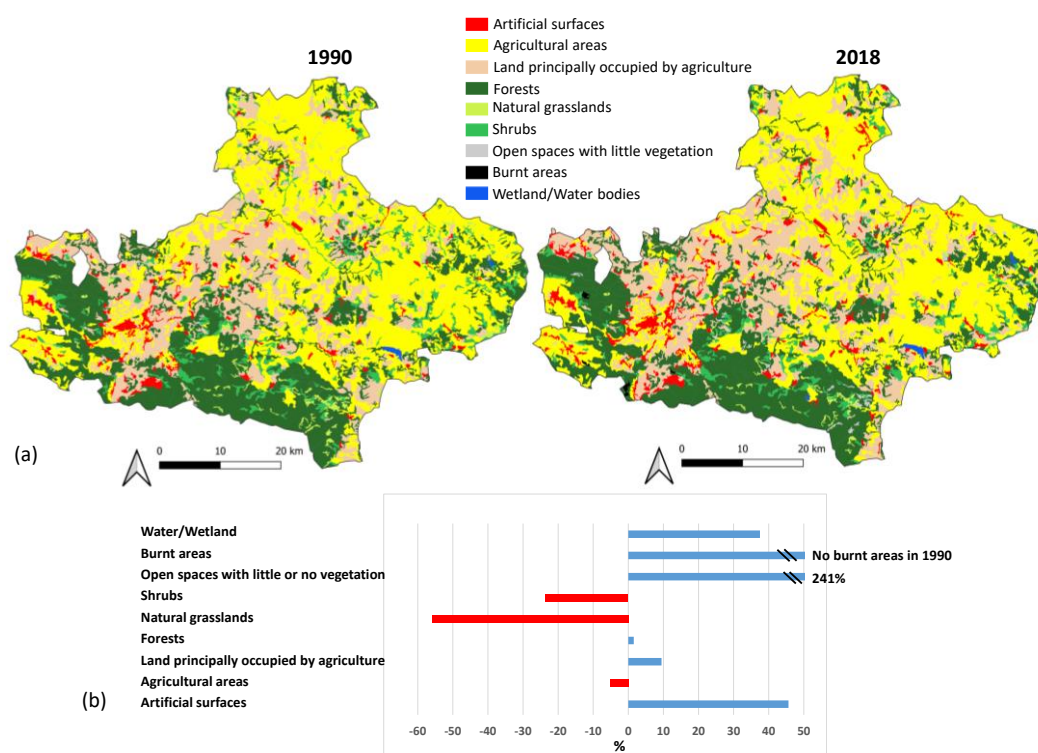


Figure 2. Reclassification of 1990 and 2018 CLC in 9 macro-classes (a) and respective losses and gains recorded in Irpinia in the time-frame analyzed (b).

More specifically, speaking in terms of processes, Figure 3 shows a strong presence of pink patches corresponding to agricultural extensification phenomena, which are clustered in some areas of Irpinia. Less extensive and highly fragmented areas have taken the opposite trajectory of agricultural intensification (orange-colored patches). The expansion of agriculture (in the form of monoculture or heterogeneous agricultural areas) has a rather evident spread in the eastern quadrants of the region. Artificial processes, intrinsically characterized by a moderate extent, are in practice presently throughout the study area except in the eastern zone where they are quite scattered. Conversely, they are very pervasive in the western sector around the provincial county seat of Avellino (see also Figure 1) and in the municipality of Ariano Irpino (the north-eastern part of the study area). Apart from a sizable patch in the center of the area, forest expansions are sparse and of a limited extent. Areas where shrub encroachment and forest degradation occur are even more narrow.

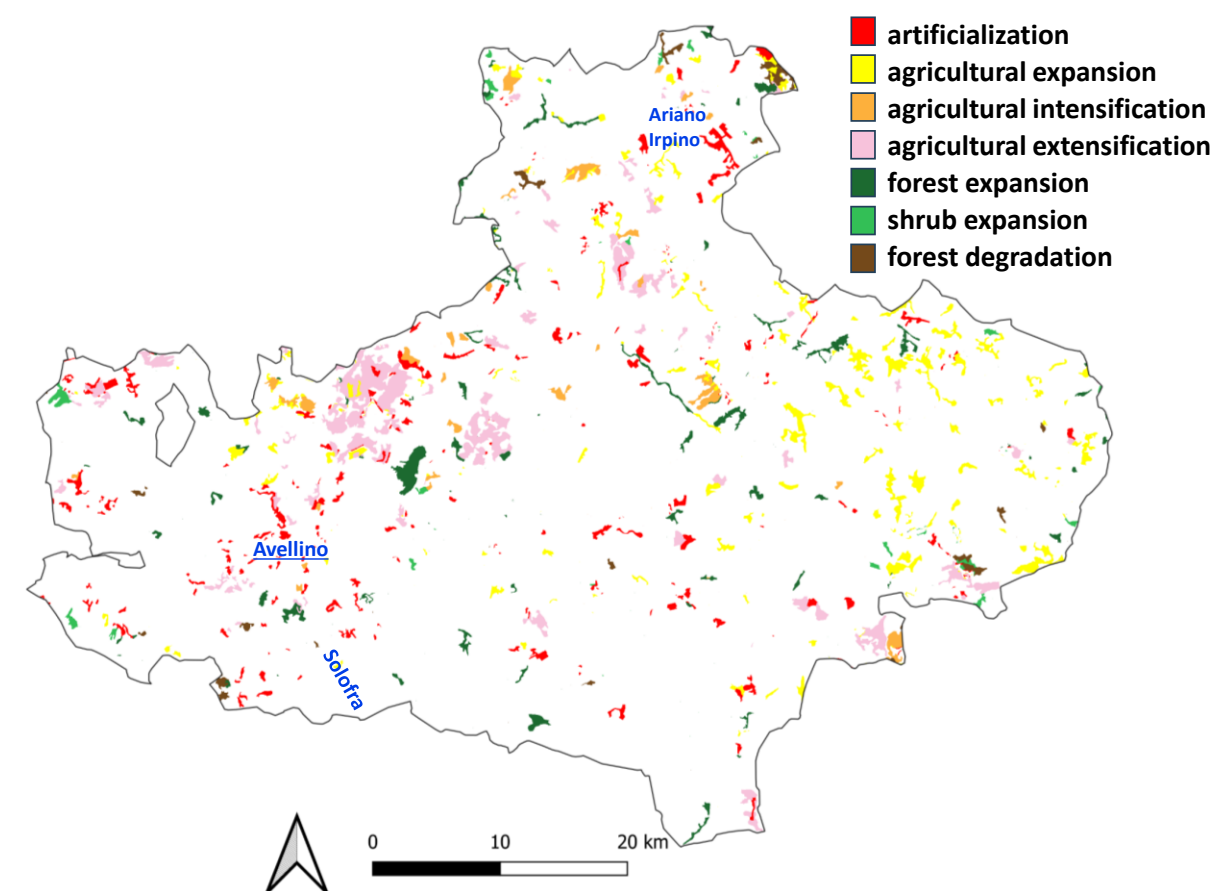


Figure 3. Main land use trajectories which occurred in Irpinia in the period 1990–2018.

The transition matrix of changes which occurred in the period 1990–2018 offers the possibility to obtain a complete picture of each transformation that has taken place in Irpinia (Table 3). Specifically, urban expansion mainly occurs to the detriment of agricultural areas (both monoculture and heterogeneous agricultural areas). While there is a continuous remixing between monoculture and heterogeneous agricultural areas, we observe that extensification processes prevail because the dominant transition is from the monoculture to the heterogeneous agricultural area (69.51 km² vs. 16.96 km²). Grasslands have been replaced mainly by bare or sparsely vegetated areas or by agricultural patches, while shrublands have undergone processes of forest colonization (15.2 km²) or anthropic predation for agricultural uses (mainly heterogeneous agricultural areas, about 21 km²). Forests expand at the expense of small surfaces of agricultural and natural covers. The increase in wetlands and water bodies can only be attributed to land transformations due to

the experimental commissioning of the Conza Dam in 1992, involving nearby agricultural and natural areas.

Table 3. Land use/land cover transition matrix for the Irpinia (Southern Italy) representing the period 1990–2018 (data from CLC datasets are expressed in hectares).

	Artificial Surfaces	Agricultural Areas	Land Principally Occupied by Agriculture	Forests	Natural Grasslands	Shrubs	Open Spaces with Little Vegetation	Burnt Areas	Water/Wetland	Total 2018
Artificial surfaces	84.07	19.98	18.37	0.88	0	0.48	0.46	0	0	124.24
Agricultural areas	0.18	1069.55	16.96	3.71	9.36	6.85	0.28	0	0	1106.89
Land principally occupied by agriculture	0.75	69.51	543.09	4.88	5.28	20.94	0.28	0	0	644.73
Forests	0.17	3.36	8.56	729.85	2.55	15.2	0.18	0	0	759.87
Natural grasslands	0	0.09	0	0.02	19.1	0.96	0.14	0	0	20.31
Shrubs	0.15	3.48	1.54	5.91	1.79	95.75	0.43	0	0	109.05
Open spaces with little vegetation	0	0	0.46	1.42	7.99	0.96	1.64	0	0	12.47
Burnt areas	0	0	0	1.53	0	1.7	0	0	0	3.23
Water/Wetland	0	0.85	0	0.23	0	0	0.25	0	3.55	4.88
Total 1990	85.32	1166.82	588.98	748.43	46.07	142.84	3.66	0	3.55	2785.67

Regarding the demographic sphere, Figure 4 highlights effectively the demographic profile of Irpinia. It turned out that from 1990 to 2018, in almost all the study areas, there was a sharp population decrease. Only 33 municipalities out of the total 118 registered a population increase (on average +17%). The municipalities with the largest population growths are those around the large industrial areas surrounding the county seat of Avellino. In the remaining 85 municipalities, there was a strong demographic decrease (an average negative trend of -20%). The municipalities most affected by this phenomenon fall within the inner areas of Irpinia, far from the major trade routes and often settled on hilly or mountainous terrains where the infrastructure is less widespread and the main activity remains agriculture. These municipalities, which in the late eighties, after the deluge of grants obtained in the aftermath of the catastrophic earthquake of 23 November 1980, still counted at an appreciable demographic size, saw a consistent population decrease about thirty years later. This is mainly due to the increasingly low competitiveness of the agricultural sector and the end of the housing development characterizing the nineties with evident benefits on the whole economic system of these areas [60]. Unremarkably, the most densely populated areas coincide with those reporting the highest levels of demographic growth, further exacerbating a sort of demographic divide between the city of Avellino with its hinterland and the rest of Irpinia. This picture is only slightly tainted by sparse exceptions of municipalities with a high population density and negative demographic trend.

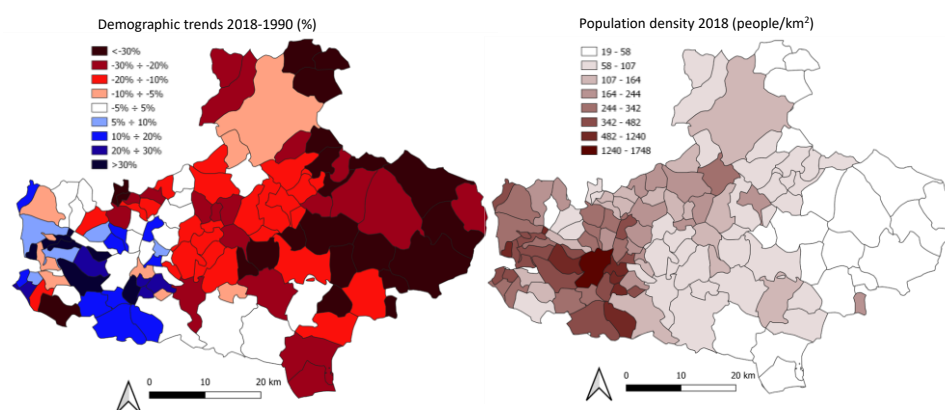


Figure 4. The demographic dimension of Irpinia: on the left, the population trends (1990–2018); on the right, the 2018 population density.

Regarding the estimation of ecosystem goods and services, the crucial parameter analyzed was the Carbon Storage and Sequestration to account for the significant land transformations which occurred in the analyzed period. The loss or gain of ecosystem goods and services in the study area are depicted in Figure 5. The comparison of the CLC1990 and CLC2018 maps outlines a picture where even though the pattern remains substantially the same, there is an appreciable loss of carbon storage in 2018 compared to 1990, as a result of the significant increase in sealed soils. Each land cover class has a different carbon storage capacity, which is obviously zero in the case of urban/commercial/industrial land uses. The increase in these land uses, at the expense of agricultural and semi-natural areas, has resulted in a widespread loss in the carbon storage capacity involving the vast majority of the municipalities of Irpinia. The orange/red patches (loss of carbon) are actually scattered in the whole study area with a higher density and magnitude with respect to the cyan/blue patches (gain of carbon). A remarkable fact is that carbon loss not only preserves the areas with greater urban/industrial development and a high population density, but also affects inner areas, albeit to a lesser degree, where agriculture still dominates. The overall balance is a loss of more than 128,000 M of carbon.

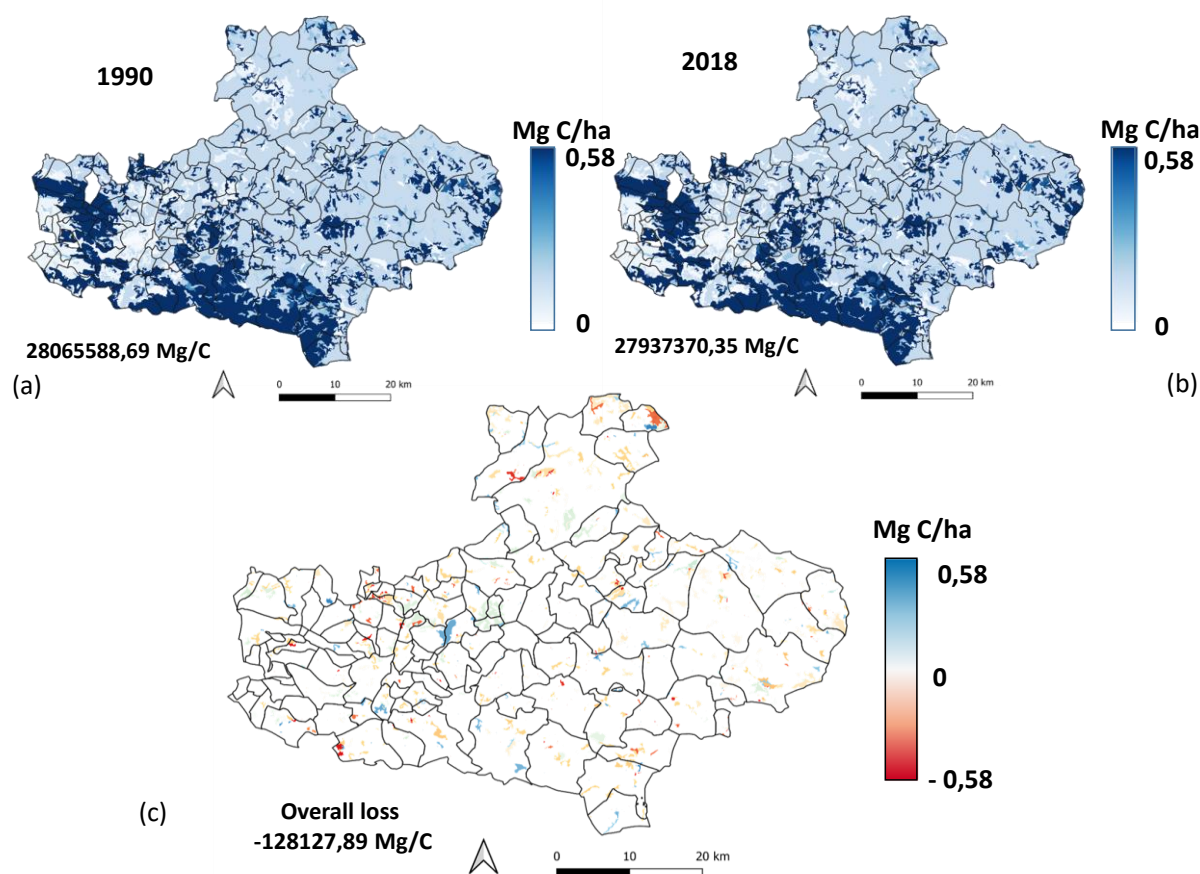


Figure 5. Carbon storage capacity for CLC 1990 (a) and CLC 2018 (b) eco-mosaics and the respective balance (c).

The results of the correlation analysis computed on the 118 municipalities of the study area are shown in Table 4.

Table 4. Correlations between demographic trends and land changes concerning artificial, agricultural and natural areas computed at municipal scale in time window 1990–2018 for the province of Avellino.

Demographic Trend vs. Artificial Areas	Demographic Trend vs. Agricultural Areas	Demographic Trend vs. Natural Areas
−0.02	−0.36 *	0.27

* = correlation coefficient significant at 1%.

The results indicate a significant anticorrelation among population and agricultural areas. The decrease in the number of inhabitants corresponds to an increase in areas classified as agricultural lands. The whole investigated area extends over nearly 2800 km² and land use changes over the period 1990–2018 affected about 90 km², corresponding to 3.2% of the study area. These changes have characterized 104 municipalities (≈88%) with percentage values mainly included in the range 0.1–10%. The municipalities can be grouped into four classes according to the percentage of the municipal surface that has changed (Table 5).

Table 5. Partition of Irpinia municipalities in four classes on the basis of the percentage of municipal area that has undergone land cover changes in the period 1990–2018.

Group	Range	Number	%
C1	0%	14	11.9
C2	0–2%	39	33.1
C3	2–10%	60	50.8
C4	>10%	5	4.2

Excluding the class C1, characterized by land use stasis, Table 5 shows that the class C2 includes municipalities (39 out of 118 corresponding to 33.1%) where land changes are rather limited, affecting only surfaces covering less than 2% of the municipal area, while the largest class is C3, populated by municipalities (60 out of 118 corresponding to 50.8%) experiencing land cover changes ranging between 2% and 10% of the municipal area. Only five municipalities show remarkable land changes exceeding 10% of the municipal area.

To analyze and highlight specific spatial dynamics, we compared for each municipality the demographic balance and the changes in the identified macro-classes (artificial (ART), agricultural (AGR), forested (FOR) and water (WAT)), separating municipalities with a positive demographic trend from those affected by depopulation.

Within the C2 class, 30 municipalities show negative demographic trends (range [−0.8%; −46.0%] and mean value −19.4%) associated with land use changes involving the ART, AGR and FOR classes; on the contrary, the remaining nine municipalities are characterized by demographic growth (range [+0.1%; +65.6%] and mean value +17.3%) and land use changes are totally concentrated in the ART class, with the exception of the municipality of Solofra where changes are quite exclusively linked to agricultural covers.

A similar behavior is observed for the C3 class. Notably, 48 out of 61 municipalities show a negative demographic trend (range [−0.3%; −46.5%] and mean value −21.2%) with land use changes distributed between the ART and AGR classes, while in the municipality of Conza della Campania (hosting a dam intended for irrigation and drinking uses), depopulation is associated with changes in the WAT class. In the other 13 municipalities of the C3 class, the demographic trend was positive (range [+0.8%; +54.0%] and mean value +16.1%) and land transformations concerned mainly the ART class, with the exception of Roccascaerana, where land changes involved only the FOR class and Grottolella where the changes were all linked to agricultural transformations (in Figure 6, we show an example of this municipal profiling focusing on municipalities of the C3 class exhibiting population growth in the investigated period).

Of particular interest are the municipalities of the C4 class: four out of five show an upward demographic trend associated with land use changes of natural areas (BOS class)

with the exception of San Michele al Serino, where the notable demographic growth is linked to changes in the ART class. Just one municipality (Lapio) exhibits a population loss and an increase in the FOR class.

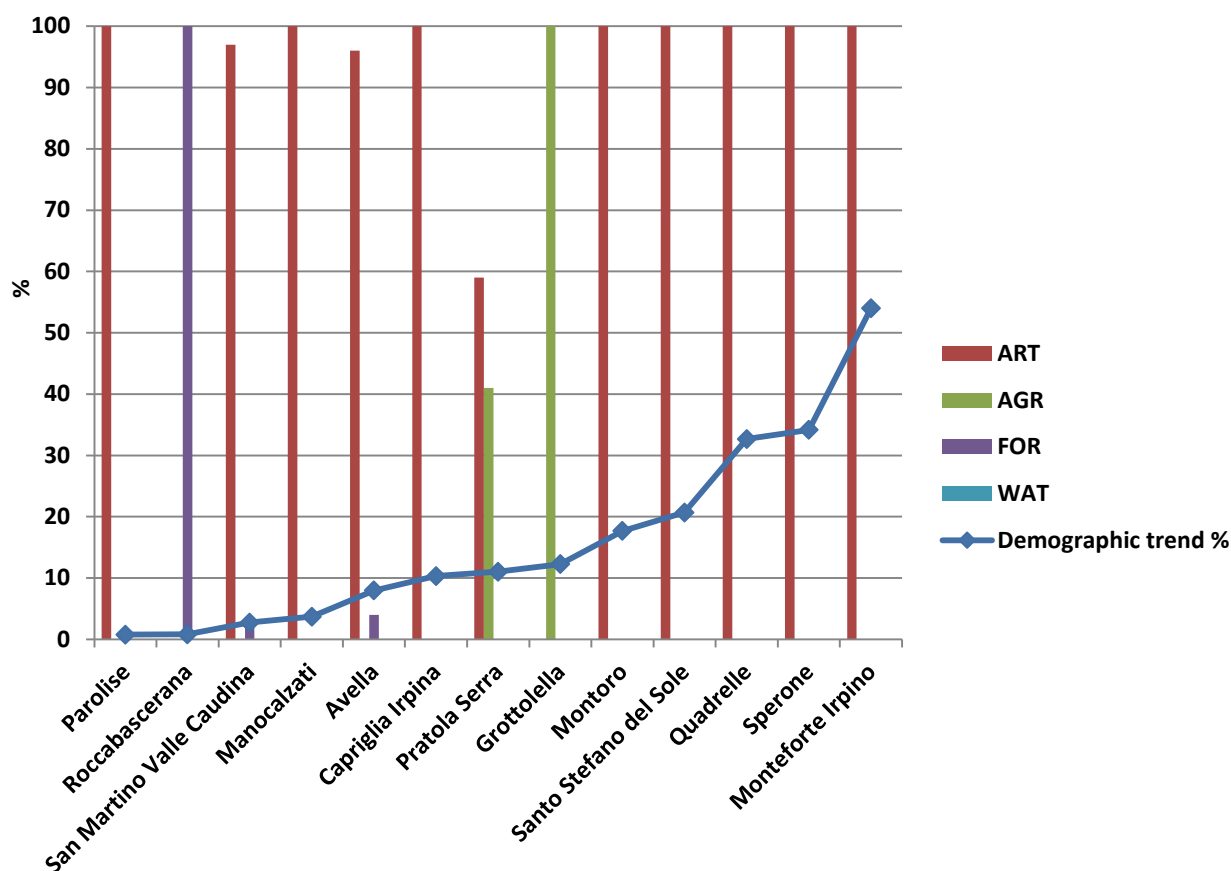


Figure 6. Municipalities belonging to the C3 class showing positive demographic trend.

4. Discussion

The relentless, though uneven, depopulation of Irpinia has intersected with an ongoing process of the abandonment of agricultural areas, as evidenced by the steady decline in the number of farms from 1982 to 2020, mirroring the trend observed at the national level [61] and in many areas of Europe (see e.g., [62,63]).

Moreover, an analysis of the natural and migration rates suggests that the population decline in Irpinia is primarily due to a decrease in birth rates. It is not uncommon to find situations where net migration somewhat mitigates depopulation, particularly in those municipalities where depopulation is occurring at the most alarming rates, such as in prevalently mountainous areas (Alta Irpinia, located in the eastern part of the study area, [37]). It is precisely the migrant population that plays a significant role in the agricultural activity in the era of the tertiary economy; according to recent estimates in fact, a large portion of the workforce employed in the agricultural areas of Campania (the region including the district analyzed), as well as in the rest of Italy, is of foreign origin [64].

The influx of these workers matches several objectives, like the preservation of agriculture and its multifunctional conversion which, in turn, allows its tourism enhancement, as well as the possibility that these workers become inhabitants of these territories, according to the main goal of the SNAI, which is a demographic reversal.

According to the 2023–2027 CAP, agriculture must be preserved not only for its productive value, but also as a barrier to abandonment. In 2021, the European Commission recognized Irpinia as an Area facing Natural and other specific Constraints (ANP), where farms have a lower economic size and income, lower intermediate consumption and

receive more subsidies per hectare compared to non-ANC farms. Overall, ANC payments help maintain extensive and low-input farming systems which, though performing less in an economic term, produce food in and feed more marginal areas (see https://agriculture.ec.europa.eu/common-agricultural-policy/income-support/additional-schemes/anc-payment_en, accessed on 20 August 2024).

As shown in Figures 2 and 3, the dynamics of abandonment has mainly affected mountain agriculture (which accounts for 74% of the total agricultural area in the study area, see https://esploradati.istat.it/databrowser/#/en/censimentoagricoltura/categories/it1,z1100agr,1.0/au/it1,df_dcat_censagric2020_ua_crops_1,1.0, accessed on 20 August 2024) and it is in decline almost everywhere across the Apennines [65].

While in the urban–industrial municipalities (the hinterland of Avellino, including the leather district of the municipality of Solofra) the main reason for the reduction in agricultural land is primarily the competition with other land uses, in mountain areas, the cause is the broader process of depopulation and aging. Small-scale agriculture is generally a low-profit activity and generational turnover is an extremely problematic process everywhere, particularly in mountain areas, where the appeal of urban contexts and other types of employment is even greater [66], as evidenced in other districts of Southern Italy [17].

While the decline in agricultural activity associated with demographic decline is immediately understandable, the situation is more complex for those areas that, conversely, experience a demographic decline but simultaneously an increase, although generally moderate, in agricultural areas. These configurations are far from rare, being already observed in other internal areas along the Apennine chain [67,68].

There are multiple factors that can help in clarifying an apparently contradictory phenomenon and they all share a common root, which is the transformation of agriculture into a multifunctional activity, no longer solely dedicated to food production, but entrusted with three topic functions. In addition to its main function of production (health and safety of food, as well as the qualitative diversification of products), agriculture also concerns relationships with the space (environment and landscape) and services (management of rural areas, biodiversity, amenities and tourism), so that the final outputs are partly material goods and partly immaterial goods [69,70].

In particular, the growing demand for short supply chain products and high-quality, organic and healthy foods offers an opportunity to enhance local cultivars and traditional, low-impact processing methods. These play a role not only in the supply chain, but also in the cultural valorization of food, which today is recognized as strategically important in processes of territorial identification and empowerment [71,72]. By exploring ISTAT data on the number of DOP (Protected Designation of Origin) and IGT (Protected Geographical Indication) producers in Irpinia, it is easy to observe that the number of farms with these designations of origin was higher just in those municipalities where demographic decline is coupled with an increase in the Utilized Agricultural Area (UAA). Among the examined municipalities, Montella, Ariano Irpino and Casalbore, with, respectively, 28, 26 and 12 farms, reached the highest values (see https://esploradati.istat.it/databrowser/#/en/dw/categories/it1,z1000agr,1.0/agr_qua/dcsp_dop-igp/it1,101_1077_df_dcsp_dopigp_com_1,1.0, accessed on 20 August 2024).

In the concentric circles of agricultural multifunctionality, local typical products represent one of the key elements for offering experiential, proximity-based and sustainable tourism. This type of tourism is capable of enhancing all available resources in a predominantly rural and mountainous context, where the most immediately marketable elements of intangible heritage are precisely those related to food and wine [73,74]. This feature is shared by many districts of Italy [75,76].

Lastly, as recorded by the 7th General Census of Agriculture, there is a national trend of a noticeable increase or stability in the UAA while the number of farms declines, accompanied by an increase in farm size. This trend is also evident in Campania and in Irpinia, where from 2010 to 2020, the number of farms decreased by approximately 6% (from 25,816 to 24,308), but the UAA only decreased by about 3% (from 122,621.33 to

118,875.72 hectares) [77,78]. The increase in average farm sizes has been driven by two major changes in land management. On the one hand, there has been a growing reliance on leasing due to the reduced importance attributed to land ownership and the difficulties in accessing a land market still characterized by high prices [79]. In 2020, although ownership and leasing each account for nearly 50%, there is a new increase in the area under free use. It is primarily 'mixed' agricultural farms (ownership with leasing and/or free use) that achieve larger and more efficient sizes, in conjunction with the rise of cooperative management, which helps counteract farm fragmentation by increasing farm sizes to face new market challenges and contributing to the conservation of the agricultural area and production [80,81].

This is in line with what was found also by [82], which affirms that collective initiatives are favored over individual actions in areas with high land fragmentation. However, these initiatives may require external support to be successfully established and to effectively combat land abandonment. These considerations highlight that even in the less advanced districts of Italy, the multi-functionalization of agriculture and the tourism transition, steadily supported by the National Recovery and Resilience Plan (PNRR), have penetrated and transformed local economies [83]. These areas, afflicted by processes of de-anthropization much more severe than those in the large agricultural plains of northern Italy [84], host agricultural activities that are increasingly disconnected from settlement dynamics. In these territories, primary production is no longer directly related to living conditions but is rather configured as a vehicle for agritourism enhancement processes, aimed at generating new economic activities from the appeal that marginal landscapes increasingly exert on travelers interested in local agricultural traditions [85,86]. This perspective requires serious cultural and political reflections on the future of these places, which, in the absence of efforts to restore livability, risk being relegated to a sterile musealization, a precursor to their definitive emptiness.

5. Conclusions

In this study, we conducted an analysis of land use/land cover changes and the related demographic dynamics in Irpinia, a marginal district of southern Italy, over a thirty-year period (1990–2018), also investigating the ecological consequences of these transformations.

What emerged is that the Irpinia area experienced a significant increase in land consumption for primarily urban/industrial purposes during the investigated period, leading to a considerable loss in terms of carbon sequestration (approximately 128,000 tons). The expansion of urban uses mainly occurred at the expense of natural areas (pastures and shrub–woodland transition zones), while agricultural areas remained largely the same in terms of extent, with some internal transformations.

The loss of land is generally associated with low-density expansions of both a residential and commercial/industrial nature, which can be conceived as sprawl phenomena, increasingly affecting the urban fabric of southern Italy. This dynamic is concerning, especially in light of demographic trends, as the study area experienced a total population decrease of about 23,000 inhabitants from 1990 to 2018, corresponding to a decline of over 5% of the initial population.

More specifically, the analyses conducted show that the municipalities around the city of Avellino experienced moderate, and in some cases, significant demographic growth due to their proximity to the province of Naples and the development of new industrial areas that brought new job opportunities. In contrast, most of the inner municipalities, located farther from the provincial capital, experienced a sharp demographic decline.

Another noteworthy phenomenon is the decoupling between agriculture and the population. In the more urbanized municipalities, which are better developed in terms of industrial and commercial activities and have experienced demographic growth, the population is employed more on tertiary or industrial sectors, causing a shift of the workforce from unprofitable agricultural activities to the above-mentioned jobs. However, there are many municipalities where a moderate increase in agricultural land corresponds to a

significant demographic decline. This trend can be explained by the new configurations that land systems have assumed in these areas, with multifunctional agriculture becoming a lifeline for an economy that remains somewhat stagnant. In marginal areas, this approach attempts to leverage natural beauty and local products to develop slow tourism, increase profitability and act as a barrier against land abandonment, in line with the 2023–2027 CAP strategies (see e.g., [87]).

In general, this work can support local decision-makers by identifying critical issues in the socio-ecological system under examination, providing useful knowledge to apply in local development policies. It can be combined with national and European frameworks (e.g., CAP) to manage the new economic challenges in marginal areas, while adopting planning actions compliant with the goal of zero net land take by 2050 [88]. The integration of the different factors investigated in this work (land use/cover, ecosystem services and demographic changes) has provided useful insights and represents a background knowledge on which more layers can be added for further territorial analysis able to identify new underlying socio-economic processes. These layers can be extracted from different sources, such as census databases (population living in each census zone, data on tourist flows concerning arrivals and average length of stay) and the Chamber of Commerce (farm size and ownership to understand the fragmentation level of the property and the nature of the owners: local actors or large acquisitions made by big companies outside the region), which is useful to refine the current analysis. Lastly, this effort can be capitalized on for future comparative studies to read the ongoing territorial transformations on the scale of the Mediterranean inland peripheries.

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