land

Article

The Design and Application of a Regional Management Model to Set Up Wind Farms and the Adaptation to Climate Change Effects—Case of La Coruña (Galicia, Northwest of Spain)

Blanca Valle [1], Javier Velázquez [2,3,4], Derya Gülçin [3,5], Fernando Herráez [2,3], Ali Uğur Özcan [3,6], Ana Hernando [3,7], Víctor Rincón [8,*], Rui Alexandre Castanho [3,4,9,10] and Kerim Çiçek [3,11,12]

1 Tragsatec, Calle Julián Camarillo, 6A, 28037 Madrid, Spain; bvv@tragsa.es
2 Catholic University of Ávila, Calle Canteros s/n, 05005 Ávila, Spain; javier.velazquez@ucavila.es (J.V.); fernando.herraez@ucavila.es (F.H.)
3 TEMSUS Research Group, Catholic University of Ávila, 05005 Ávila, Spain; derya.yazgi@adu.edu.tr (D.G.); auozcan@karatekin.edu.tr (A.U.Ö.); ana.hernando@upm.es (A.H.); acastanho@wsb.edu.pl (R.A.C.); kerim.cicek@ege.edu.tr (K.Ç.)
4 VALORIZA-Research Centre for Endogenous Resource Valorization, Polytechnic Institute of Portalegre (IPP), 7300 Portalegre, Portugal
5 Department of Landscape Architecture, Faculty of Agriculture, Aydın Adnan Menderes University, Aydın 09100, Türkiye
6 Faculty of Forestry, Department of Landscape Architecture, Çankırı Karatekin University, Çankırı 18200, Türkiye
7 Polytechnic University of Madrid, Calle Ramiro de Maeztu s/n, 28040 Madrid, Spain
8 Department of Pharmacology, Pharmacognosy and Botany, Faculty of Pharmacy, University Complutense of Madrid, Plaza de Ramón y Cajal, s/n, 28040 Madrid, Spain
9 Faculty of Applied Sciences, WSB University, 41-300 Dąbrowa Górnicza, Poland
10 Advanced Research Centre, European University of Lefke, Lefke, Northern Cyprus, TR-10 Mersin, Türkiye
11 Section of Zoology, Department of Biology, Faculty of Science, Ege University, Izmir 35040, Türkiye
12 Natural History Application and Research Centre, Ege University, Izmir 35040, Türkiye
* Correspondence: virincon@ucm.es; Tel.: +34-920-251-020

Abstract: The implantation of wind farms in the European territory is being deployed at an accelerated pace. In the proposed framework, the province of La Coruña in the autonomous community of Galicia is tested, with a wide deployment of this type of infrastructure in the territory initiated in the 80s, representing the third autonomous community with the largest exploitation of wind resources, which provides sufficient information, extrapolated to the entire community, to demonstrate the practical usefulness and potential of the method of obtaining the territorial model proposed in this article The regional has been used as the basic administrative subunit of the study variables, considering that the territory thus delimited could have common physical and cultural characteristics. The methodology presented in this article involves the collection and processing of public cartographic data on various factors most repeatedly or agreed upon in the consulted bibliography based on studies by experts in the technical, environmental, and environmental areas, including explanatory variables of risk in a broader context of climate change as the first contribution of this study. Another contribution is the inclusion in the model of the synergistic impact measured as the distance to wind farms in operation (21% of the total area of the sample) to which an area of influence of 4 times the rotor diameter of each of the wind turbines im-planted has been added as a legal and physical restriction. On a solid basis of selection of explanatory variables and with the help of Geographic Information Systems (GIS) and multi-criteria analysis (MCDM), techniques widely documented in the existing literature for the determination of optimal areas for the implementation of this type of infrastructure, a methodological proposal is presented for the development of a strategic, long-term territorial model, for the prioritization of acceptable areas for the implementation of wind farms, including forecasts of increased energy demand due to the effect of climate change and the population dynamics of the study region that may influence energy consumption. This article focuses on the use of multivariate clustering techniques and spatial analysis to identify priority areas for long-term sustainable wind energy projects. With the proposed strategic territorial model, it has been possible to demonstrate

Citation: Valle, B.; Velázquez, J.; Gülçin, D.; Herráez, F.; Özcan, A.U.; Hernando, A.; Rincón, V.; Castanho, R.A.; Çiçek, K. The Design and Application of a Regional Management Model to Set Up Wind Farms and the Adaptation to Climate Change Effects—Case of La Coruña (Galicia, Northwest of Spain). *Land* **2024**, *13*, 2201. https://doi.org/10.3390/land13122201

Academic Editor: Weiqi Zhou

Received: 11 November 2024
Revised: 6 December 2024
Accepted: 11 December 2024
Published: 16 December 2024

that it is not only capable of discriminating between three categories of acceptable areas for the implementation of wind farms, taking into account population and climate change forecasts, but also that it also locates areas that could require conservationist measures to protect new spaces or to recover the soil because they present high levels of risk due to natural or anthropic disasters considered. The results show acceptable areas for wind energy implementation, 23% of the total area of the sample, 3% conservation as ecological spaces to be preserved, and 7% recovery due to high-risk rates. The findings show that coastal regions generally show a more positive carrying capacity, likely due to less dense development or regulatory measures protecting these areas. In contrast, certain inland regions show more negative values, suggesting these areas might be experiencing higher ecological disturbance from construction activities. This information highlights the importance of strategic site analysis to balance energy production with conservation needs. The study provides insights into wind farm deployment that considers the visual and ecological characteristics of the landscape, promoting sustainability and community acceptance. For this reason, these insights can be effectively used for advancing renewable energy infrastructures within the European Union's energy transition goals, particularly under the climate and energy objectives set for 2030.

Keywords: wind farms; carrying capacity; risk; climate change; management categories; priority areas

1. Introduction

Addressing climate change and meeting global sustainability targets significantly depend on the mandatory adoption of renewable energy sources, particularly wind energy. The widespread implementation of renewable energy sources is crucial to the energy transition plans of the European Union (EU) [1]. Data from the Eurostat [2] shows that in 2022, 37% of renewable energy production was from wind. The REPowerEU targets expect the wind energy capacity of 221 GW in 2023 to nearly double to 393 GW by 2030 [3]. However, this projected capacity of 393 GW by 2030 does not meet the climate and energy objectives of the EU reaching 425 GW. For this reason, the implementation of wind farms in the EU is being deployed at an accelerated pace, even without taking into account the relative environmental impacts.

Previous studies have provided evidence of the wide-ranging environmental consequences associated with the establishment of wind farms. Concerns have been raised about the extensive land use and significant changes in land cover that accompany wind farm installations, with specific attention on how these factors affect land cover and topography [4]. Some studies in regions such as Brazil have identified positive ecological effects, demonstrating how wind power expansion has altered land use patterns [5]. Conversely, other research highlights beneficial effects on local vegetation, which can enhance regional ecosystems [6]. The transition towards renewable energy sources such as wind power is relevant for mitigating climate change impacts; however, this transition must also consider its implications for biodiversity conservation and the advancement of a green economy [7–9].

European countries share common objectives in their energy policies, which aim to reduce the use of fossil fuels, minimize the environmental impact of the energy sector, promote the supply of renewable energy sources, and encourage business development. These goals are essential for advancing toward more sustainable and resilient energy systems, addressing climate change while fostering innovation and economic growth. This collaborative approach is crucial for meeting long-term sustainability targets and enhancing energy security across Europe [10]. However, the rapid implementation of this type of infrastructure requires not only an evaluation of wind resource potential and biodiversity impacts but also an integration that is visually and environmentally compatible with the landscape. On the other hand, there is a growing public discourse on the requirements, capabilities, impacts, and siting of these infrastructures.

Climate change could potentially impact the performance of wind turbines by affecting factors such as air density and wind speed, which are crucial for their power conversion capabilities [11–14]. Factors such as wind frequency and direction play a crucial role in the selection of wind farms by developers [15]. However, when considering the maximum power that a wind turbine can extract from a free air stream, it becomes apparent that the density of the air, influenced by factors such as humidity, can significantly affect this capacity. It is therefore clear that climate change, which can alter air density and other atmospheric conditions, is likely to affect the performance of wind turbines [16]. Although both the variable power density (expressed in average wind energy over one square meter, W/m^2) and wind speed (meters per second) could perfectly be explanatory variables of the suitability of the territory by the availability of wind resources and available free of charge and publicly available in the World Wind Atlas, the available power density could provide a more real determination of the energy potential of the territory when using instantaneous speeds, in the short term, so it is considered that this variable should be used at a local scale. On the other hand, at the regional level, average wind speed is revealed as the variable most agreed upon by experts; the wind turbine is designed to generate energy in a limited range of wind speeds, starting with a shear speed (approx. 3–4 m/s), in which there would be no resource use and ending with a shear speed (ca. 25 m/s) [17,18] to save the integrity of the machine and for safety in its surroundings, circumstances that have been taken into account in this work. Winds are intensely influenced and reformed by vegetation cover, water bodies, land-use patterns, local terrain, climatic conditions, and numerous additional characteristics [19], all of which have been considered in the study, so the inclusion of this variable, in interaction, contributes to a more detailed estimate. For the adaptation of the wind cartography used to this regional scale, statistical models of downscaling reduction have been used [20], this method consists of interpolating the nearest grid points, in this case, the Digital Elevation Model (DEM) downloaded from the National Catalog of Geographic Information cut for the province of La Coruña at a scale of 1:25,000.

Optimization theory-based planning for clustered wind farms emphasizes the importance of maximizing energy benefits by selecting sites with rich wind resources [21]. Accurate quantification of power losses due to wind turbine wakes in different wind climates and layouts is vital for optimal wind farm design [22]. Considering community perceptions and scenic effects are crucial in wind farm planning to ensure social acceptance and support [23].

As the presence and scale of wind farms expand, their potential impact on local and regional weather systems becomes more significant, necessitating updates to mesoscale meteorological models to better predict these effects [24]. Employing GIS and considering climate change is vital for the strategic long-term development of wind energy [25,26]. Understanding how wind farms affect surface temperatures and vegetation is critical for effective regional management and adaptation to climate changes [27]. Here, analytic hierarchy process (AHP) methods have been used to tackle the complexities of site selection for wind farms by integrating GIS with multi-criteria decision-making techniques to evaluate factors like wind potential, environmental impacts, and socio-economic conditions [28–31]. By integrating GIS with multi-criteria decision-making methods, various factors can be assessed, such as wind potential, environmental impact, economic feasibility, and social constraints, to identify optimal sites for wind farms [32,33]. These analyses involve sophisticated models that consider multiple phases of wind projects, including pre-development, installation, operation, and decommissioning [8].

Galicia, situated in the northwest of Spain, is a notable example of global wind energy advancement due to its distinct climatic conditions [34]. The Integrated Regional Energy and Climate Plan supports the optimal use of natural resources within its limitations, consistent with the Galician Climate Change and Energy Strategy 2050, specifically priority axis number 5, EGCC [34].

This study examines the key variables and criteria for constructing wind farms at a specific scale, offering valuable guidance for developers of such projects. In this context, it focuses on developing and implementing a territorial management model for establishing wind farms in La Coruña, Galicia, while addressing the challenges posed by climate change. Although it provides insights at a local level, it does not eliminate the necessity for public and private entities and stakeholders to conduct specialized studies as mandated by Law 21/2013 on environmental impact assessment and Royal Decree-Law 6/2022 to approve projects that mitigate the vulnerability of the territory. Therefore, before investing in a wind farm, it is essential to develop and implement strategies that conform to EU regulations, national laws, and local attitudes towards energy efficiency to reduce environmental impacts, thus helping to accelerate the planning and implementation process. Consequently, this paper emphasizes the importance of following regulatory frameworks, conducting environmental impact assessments, and involving the community to ensure sustainable energy development practices.

2. Materials and Methods

2.1. Study Area

The study area is the province of La Coruña, located in the northwest of the Iberian Peninsula, within the Autonomous Community of Galicia (see Figure 1). It consists of 94 municipalities, covering a total area of 7950.4 km^2, with elevations ranging from 49 m in Mugardos to 607 m in Toques. According to the Galician Institute of Statistics, the population in 2020 was 1,121,815, spread across 18 regions. This represents 27% of Galicia's total area and 42% of its population. By 2022, over 80 wind farms were registered, as reported by the Galician Institute of Statistics. The location of wind turbines, along with the legal and physical influence zones, has been considered as a constraint in this study.

2.2. Data

The methodology adopted in this study involves the use of multivariate clustering and spatial analysis to identify suitable locations for the development of sustainable wind energy projects. This approach represents a significant advance in the field of site selection, combined with techniques agreed upon by the scientific community for the analysis of spatial data. The role of GIS and multi-criteria decision-making techniques (MCDC) as tools is well documented in the existing literature [23,24,27–32,35–37]. Due to the fact that the result of territorial planning can vary substantially depending on the variables used for the hierarchical analytical process, the present work has a previous diagnosis of variables and criteria extracted from an extensive reference bibliography in which the variables most mentioned in published research that uses multicriteria analysis and GIS for the location of optimal areas for wind exploitation have been analyzed and that, in addition, could be more explanatory on a regional scale, specifically, for the province of La Coruña, in order to use criteria of suitability, impact, risk and climate change of homogeneous and in line with the scientific community. However, MCDC approaches face major challenges. However, MCDM approaches face several challenges. To address these issues, the integration of machine learning (ML) techniques holds promise. However, existing studies have not yet employed an independent ML-based approach for this purpose [38]. Artificial Intelligence (AI) could be a very powerful weapon in the sense of providing greater precision in the data that feeds the variables, already proposed in an attempt to continuously improve over time [39].

The current official cartography in Spain offers a wealth of data (See Table A1 in Appendix A). The delimitation at the county level has been obtained from the cartographic viewer of the Xunta de Galicia [40], to which the statistical data from the Galician Institute of Statistics [41] has been associated for calculating densities and population projections within the 2019–2035 horizon.

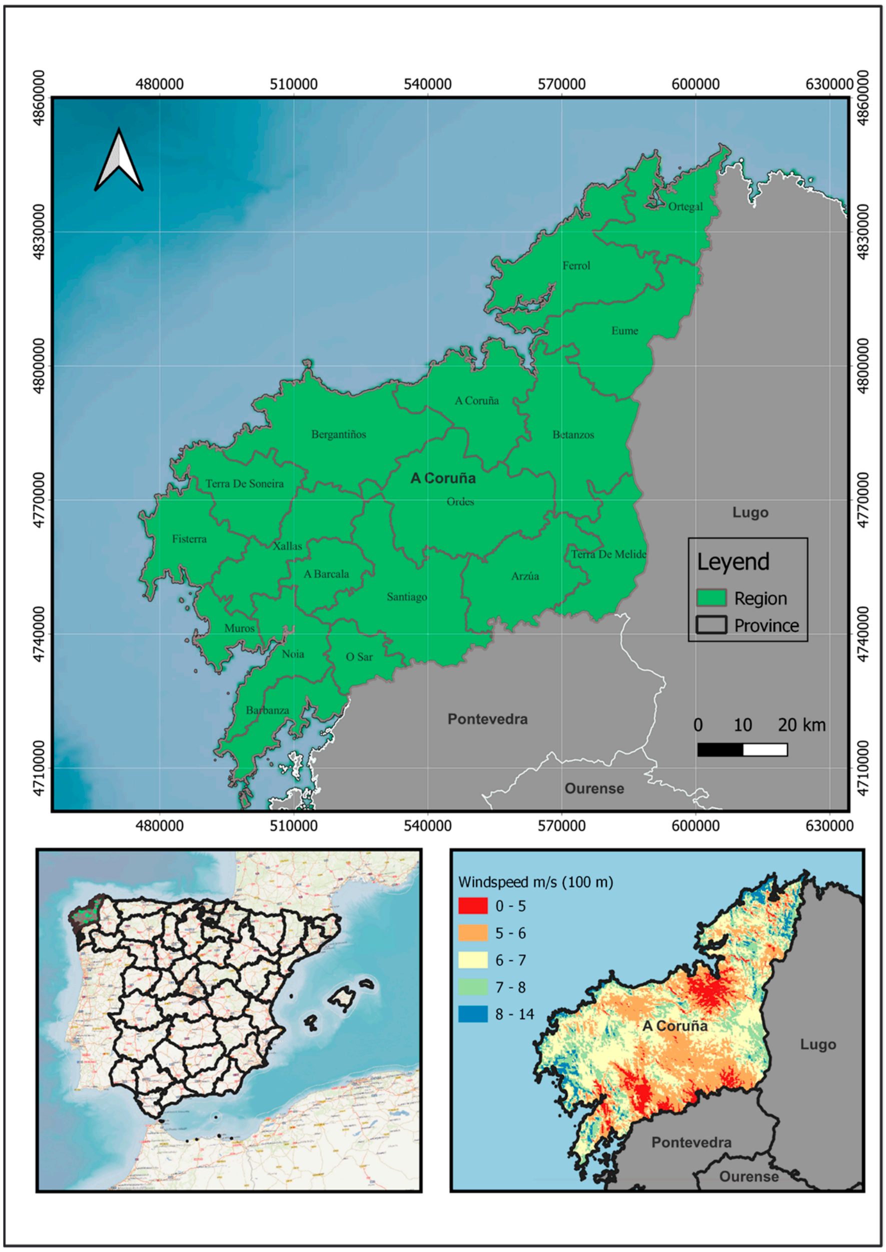

Figure 1. Geographical location of the study area.

The study includes wind resource data in the model (average wind speed in m/s) from the cartographic data provided by Global Wind Atlas [42] at a height of 100 m. The Galician Wind Register, Xunta de Galicia, has provided the location, characteristics, and rotor diameter of each wind turbine already installed in the province. For the adaptation of the wind cartography used to this regional scale, statistical downscaling models have been used. This method entails interpolating the closest grid points, specifically using the Digital Elevation Model (DEM) obtained from the National Geographic Information Centre [43], which has been clipped to the province of La Coruña at a 1:25,000 scale. The National Center and Geographic Information of Spain website provides thematic topographic maps in digital format at a scale of 25,000. From the viewer of the Galician Health Service [44], different vector layers of the Autonomous Community of Galicia can be downloaded in shapefile format, including the digital map of the productive capacity of the soils of Galicia [45].

Natural, anthropic, and technological risks have been evaluated based on the different Special Plans prepared by the General Directorate of Emergencies and Interior of the Xunta de Galicia: the Civil Protection Plan against the Risk of Snowfall [46], the Civil Protection Plan against the Risk of Floods [47], the Special Civil Protection Plan against Seismic Risk in Galicia [48], the Civil Protection Plan for the Prevention and Defense of Forest Fires in Galicia [49], and the Civil Protection Plan against Accidents in the Transport of Dangerous Goods [50].

The climate change scenarios are provided by the State Meteorological Agency [51] via the "AdapteCCa climate change scenario viewer" [52], which utilizes the Euro-Cordex regional projections with a resolution of 10 km. Four periods are represented, corresponding to the time horizons specified in the risk projections for extreme weather events, which are considered in this study: historical-present, near future (2040), medium future (2070), and far future (2100). For the future periods, two scenarios are defined: RCP 4.5, which assumes a reduction in emissions to intermediate-low levels, and RCP 8.5, which assumes that emissions remain high. The analysis was conducted using QGIS 3.40.1 software and GRASS 7 version 2.0, with the datum (ETRS89/UTM 29N).

2.3. Methodology

The methodology developed for prioritizing areas for wind farm implementation in the region consists of three phases. Figure 2 illustrates the methodological framework.

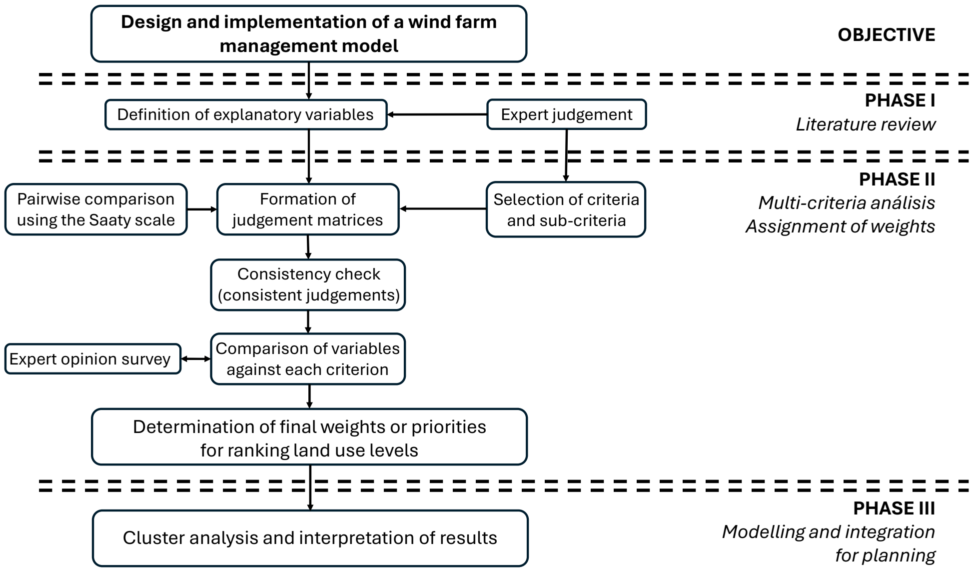

Figure 2. Methodological flowchart.

This paper uses GIS to rigorously analyze the interrelationships of various territorial variables, assigning them the appropriate weight and proportionality as needed. Any attribute contained in each of the information layers of a GIS can be weighted as a positive or negative element according to a certain object. It can also be valued in conjunction with others and, depending on this, counterbalanced, enhanced, or canceled. Spatial clustering is proposed for this study, whose objective is to create contiguous groups or clusters (clusters, k-means) with the maximum homogeneity of data within each of them, combined with the elbow method of Thorndike [53]. These clusters or patterns are subsequently used as model regions for the optimization of the energy system. This task could be carried out thanks to a cluster analysis through QGIS 3.40.1 software and GRASS 7 version 2.0 and, specifically, the tool "K-Means Clustering for Raster" of SAGA; the K-means algorithm or hierarchical handles a large amount of data and is fast in producing contiguous regions and performs clustering using more than one statistical element. The clustering method was executed in several steps applied to the relevant elements: Step1: Clustering of the raster using k-means to determine the number of clusters *ki*. The output of k-means is a raster that is polygonized into a vector shapefile format. Step 2: Identification of the raster value with the highest average relative standard deviation. Step 3: Selection of the number of clusters using Thorndike's elbow method. Step 4: Analysis, interpretation, and representation of the obtained outputs.

2.3.1. Variables Selected from Previous Literature

Due to the enormous number of interrelated variables with cartographic representation for the optimal location of a wind farm, the final result of territorial planning can vary substantially; therefore, the literature of related studies has been consulted in order to select the variables that, according to the authors consulted, turn out to be the most explanatory. A total of 26 related variables were selected (See Table A2 in Appendix A). Seven variables were discarded. The final column of the table shows the grouping of the criteria according to A = Suitability, I = Impact, R = Restriction, and RCC = Risk and Climate Change.

2.3.2. Identification of Suitable and Unsuitable Sites—Criteria and Variables

Due to the extensive number of inventoried variables mapped out cartographically, which is beyond the scope of this study, it was decided to overlay the most influential factors in blocks for the development of wind farms. The standardized unit used was a scale from −1000 to 1000, where −1000 represents the minimum value, and 1000 is the maximum value. The variables, evaluation criteria, and consulted sources are given in Table A3.

2.3.3. Multicriteria Analysis—Weight Allocation

After calculating the variables and standardizing the criteria to match the values of the proposed scale (in raster format), the multi-criteria evaluation phase was carried out [54]. A panel of eight professionals, including experts in construction, architecture, quantity surveying, environmental science, forestry, agronomy, and agricultural engineering, participated in this study. These experts completed an initial survey, where they performed pairwise evaluations of each criterion that would define the suitability, impact, and risk models. The assignment of weights to the selected criteria was done using the Analytical Hierarchy Process (AHP) developed by Saaty. This method is a flexible discrete multi-criteria decision analysis system. The result of the pairwise comparisons is a square matrix $A = (aij)$, which is positive and reciprocal ($aij * aji = 1$), where the elements aij represent the estimated ratios (wi/wj) between the priorities of the compared elements. The weights for each variable were calculated using the following formula (1):

$$Wij = \sum_{j=1}^{n} aij / \sum_{j=1}^{n} \sum_{i=1}^{n} aij \quad (1)$$

The consistency of each matrix must be checked. In AHP, the decision-maker, or person introducing the judgments, is said to be consistent if the matrix of paired comparisons is consistent, that is, if it verifies that $aij * ajk = aik, \forall\ i, j, k.$ To evaluate the consistency of the decision maker, the so-called consistency ratio (CR) is calculated, a non-statistical index in its initial proposal that is given as the quotient between the consistency index (CI) and the random consistency index (RCI), that is,

$$Consistency\ ratio\ (CR) = \frac{Consistency\ index\ (CI)}{Random\ Consistency\ Index\ (RCI)} \quad (2)$$

where

$$Consistency\ index\ (CI) = \frac{(\lambda - n)}{n-1} = \frac{1}{n \cdot (n-1)} \sum\nolimits_{i \neq j}^{n} (eij - 1) \quad (3)$$

where *eij* = *aij* * *wj/wi* and *n* is the number of variables. The values of the random consistency index (RCI) can be obtained according to the following formula:

$$R_{CI} = \frac{1.98 \times (\,n-2))}{n} \tag{4}$$

In practice, the matrix is consistent if CR < 1; in the event that the consistency ratio exceeds this threshold, it is recommended to review the judgments, correcting the one that deviates the most from the ratio given by the corresponding relative priorities, i.e., comparing *aij* with *wi/wj*. After reviewing the judgments, the matrices were consistent, and therefore, it was possible to validate the assigned weights.

2.3.4. Modeling and Integration for Planning

The information from the suitability, impact, and risk models was combined through linear weighted addition using the values provided by the experts. A distinction was made between "ecosystem carrying capacity" and "territorial carrying capacity," where natural risks were incorporated into the latter two concepts [55]. The following Equation (5) was used to calculate the ecosystem carrying capacity:

$$\text{Ecosystem carrying capacity} = \alpha * \text{suitability} + \beta * \text{impact} \tag{5}$$

Here, "α" represents the average value assigned by the experts to the suitability of the territory for construction on rural land, while "β" is the average value given to the impact when assessing the carrying capacity of the ecosystems. For the territorial carrying capacity, the proposed model is as follows:

$$\text{Carrying capacity of the territory} = \gamma * \text{suitability} + \varepsilon * \text{impact} - \theta * \text{risk} \tag{6}$$

In this model, "γ" is the average value assigned by the experts to the suitability of the territory for construction on rural land, "ε" represents the average value given to the impact, and "θ" is the average value resulting from the integration of the risk variables.

2.3.5. Integration of Carrying Capacities with Climate Change Criteria

For the analysis, a total of 9 elements to be grouped were taken into account (Table A4). The table categorizes various models related to climate change, capacity to receive, and population dynamics. It includes nine models, each identified by a number and grouped by their focus. Models 1 to 6 are climate change models, distinguished by different Representative Concentration Pathways (RCP 4.5 and RCP 8.5) and time frames (near, medium, and distant future). Models 7 and 8 pertain to capacity to receive, specifically ecosystem carrying capacity and territorial reception capacity. Model 9 addresses population dynamics, focusing on the percentage point change in population from 2019 to 2035. The table groups these elements for a carrying capacity optimization model and climate models, considering three future periods: near (2010–2040), medium (2041–2070), and far (2071–2100), along with the population trend for wind farm installation.

3. Results

3.1. Variables and Criteria

Detailed data on various criteria and variables are essential for evaluating the suitability of the province of La Coruña for potential wind farm locations (Figure 3). Table A5 presents attributes such as wind resource utilization, soil-bearing capacity, slope, proximity to energy infrastructure, and roads. For instance, 87% of the area has an average wind speed of 6–8 m/s at 100 m altitude, suitable for wind energy production, while 56% of the region offers high soil-bearing capacity beneficial for the structural stability of wind turbines. Furthermore, the table outlines the potential environmental impacts, including proximity to habitats of priority species and birdlife areas and the agrological capacity of the soil. For example, 36.4% of the area contains humid Atlantic heaths, which are priority conservation habitats, showing the sensitivity of local ecosystems to wind farm development. Risks such as seismicity, floods, mass movements, forest fires, and the transport of dangerous goods are also quantified. Particularly, 66% of the area is classified at high risk for forest fires, highlighting significant safety considerations for wind farm implementation.

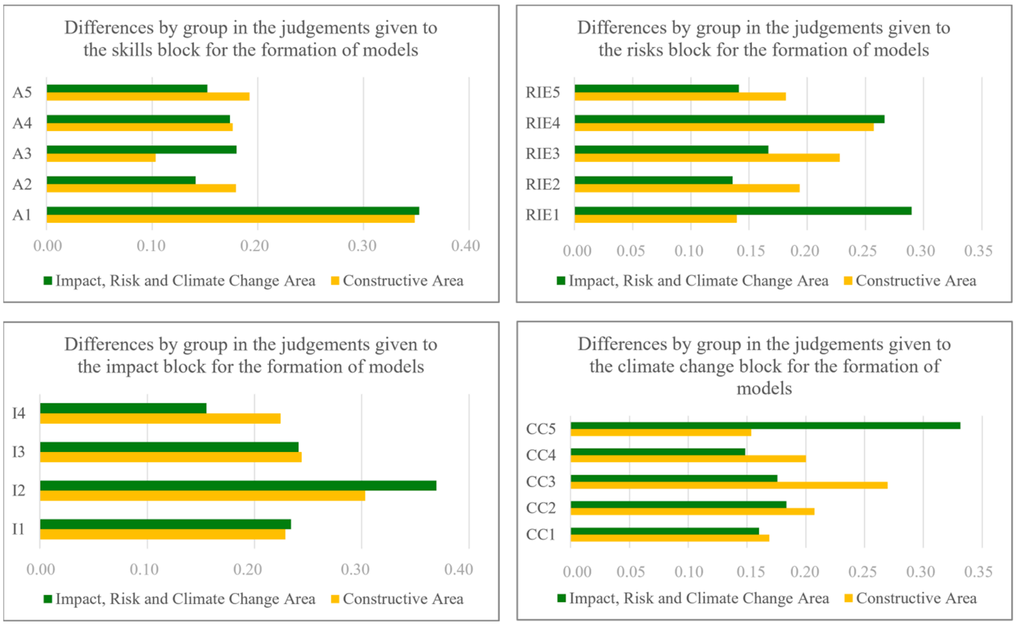

Figure 3. Presents four bar charts compare judgments across different groups for the formation of models in four distinct blocks: skills, risks, impact, and climate change. Each chart contrasts the average scores given by two areas: the Impact, Risk, and Climate Change Area (green bars) and the Constructive Area (yellow bars). The first chart examines the skills block, where group A1 stands out with the highest score from the Impact, Risk, and Climate Change Area, significantly surpassing the Constructive Area's score. Other groups, such as A2, A3, A4, and A5, show a more balanced assessment between the two areas, with slight variances, but no other group exhibits a stark difference like A1. In the risks block, there is a noticeable divergence in the judgments between the groups. RIE1 receives the highest score from the Impact, Risk, and Climate Change Area, while the Constructive Area gives RIE4 the highest score. The other groups (RIE2, RIE3, and RIE5) display varied judgments, with RIE3 and RIE4 showing relatively higher scores from the Constructive Area compared to the Impact, Risk, and Climate Change Area, indicating a more favorable assessment of risks by the Constructive Area. The impact block chart reveals that group I2 receives the highest score from the Impact, Risk, and Climate Change Area, which is significantly higher than the score given by the Constructive Area. Other groups, such as I1, I3, and I4, show closer scores between the two areas, but I3 and I4 receive marginally higher scores from the Constructive Area, suggesting a slight preference in their impact assessment. In the climate change block, CC5 is rated significantly higher by the Impact, Risk, and Climate Change Area compared to the Constructive Area. Groups CC1, CC2, CC3, and CC4 show more varied results, with CC4 receiving a higher score from the Constructive Area and CC3 showing a balanced assessment from both areas.

3.2. Planning for Territorial Management Categories

The following coefficients were applied to the formulas:

Impact model:

(Criterion Proximity to National Habitat Inventory Annex I of Directive 92/43/EEC (HCI) * 0.231)

(Criterion Proximity to Avifauna Priority Areas * 0.336)

(Criterion Agrological Soil Capacity * 0.243)

(Criterion Forest Influence Zone * 0.192).

Risk model:

(Criterion Seismicity * 0.215)
(Criterion Floods * 0.165)
(Criterion Potential for Mass Movements * 0.197)
(Criterion Forest Fires * 0.262)
(Criterion Transport of Dangerous Goods * 0.161).

Climate Change model:

(Heat Wave Criterion * 0.165)
(Cold Wave Criterion * 0.195)
(Strong Winds Criterion * 0.223)
(Drought Criterion * 0.174)
(Extreme Storms Criterion * 0.243).

The carrying capacity of the ecosystems, calculated by integrating the suitability and impact models, is given by the expression:

(0.463 * SUITABILITY MODEL) + (0.537 * IMPACT MODEL).

The territorial carrying capacity, integrating the suitability, impact, and risk models, is expressed by:

(0.3 * M. SUITABILITY) + (0.381 * M. IMPACT) − (0.319 * M. RISK).

The maximum value for the territorial carrying capacity in La Coruña is close to 150 on the scale, although most of the area values fall between 50 and 200, with 44% of the territory having values above 200. Here, it can be concluded that the acceptability values for the implementation of wind farms are reduced when the risk factor is added. Figure 4 shows the territorial capacity model obtained. High-carrying capacity areas suitable for construction are mainly found in regions such as A Coruña, Ferrol, and parts of Betanzos and Eume. In contrast, regions like Terra De Soneira, Xallas, Fisterra, and parts of Muros and Nola have low carrying capacity. Intermediate areas with moderate carrying capacity, such as Santiago, Melide, and Arzúa, provide a balance between development potential and environmental preservation.

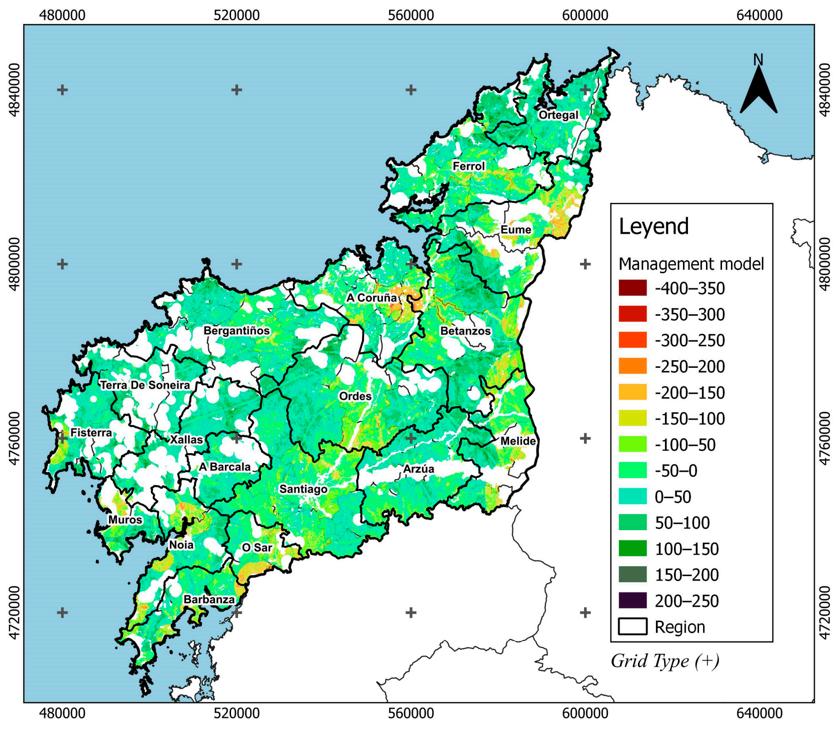

Figure 4. Carrying capacity of the ecosystems of the province of La Coruña for construction.

The six maps illustrate the projected climate change impacts on construction in La Coruña under two climate projection models, CPR 4.5 and CPR 8.5, across three time periods: Far Future, Medium Future, and Near Future (Figure 5). The "CPR 4.5-Far Future" map shows moderate impacts spread across the province, with higher values in the western and central areas, particularly around cities like Ferrol and Lugo. The impact levels are represented by varying red colors, with darker areas indicating more significant impacts. As can be seen in the "CPR 4.5-Medium Future" map, the overall intensity of impacts decreases slightly, but the distribution remains similar. Regions such as Ferrol, Lugo, and the areas surrounding Santiago de Compostela still demonstrate notable levels of climate impact on construction. The "CPR 4.5-Near Future" map shows the least intense impacts among the three CPR 4.5 scenarios, with lighter colors of red suggesting that immediate climate effects are less severe. However, there are still pockets of moderate impact, especially in the central part of the province. Under the more extreme CPR 8.5 scenario, the maps illustrate a more severe set of impacts on construction. The "CPR 8.5-Far Future" map shows high-intensity impacts concentrated in the southwestern and central regions, including areas around Santiago de Compostela and A Coruña. The darker red areas indicate that these regions will face significant challenges due to climate change. The "CPR 8.5-Medium Future" map suggests the intensity of impacts decreases compared to the Far Future map but remains more severe than in the CPR 4.5 scenarios. The southwestern and central areas, including the surroundings of Ferrol and Lugo, continue to show considerable impacts. Finally, the "CPR 8.5-Near Future" map, although less severe than the other CPR 8.5 scenarios, still highlights significant climate-related challenges in certain regions of La Coruña. The darker red areas are more visible than in the CPR 4.5 scenarios, indicating that even in the near term, regions like the central part of the province and around Santiago de Compostela may experience substantial climate impacts on construction.

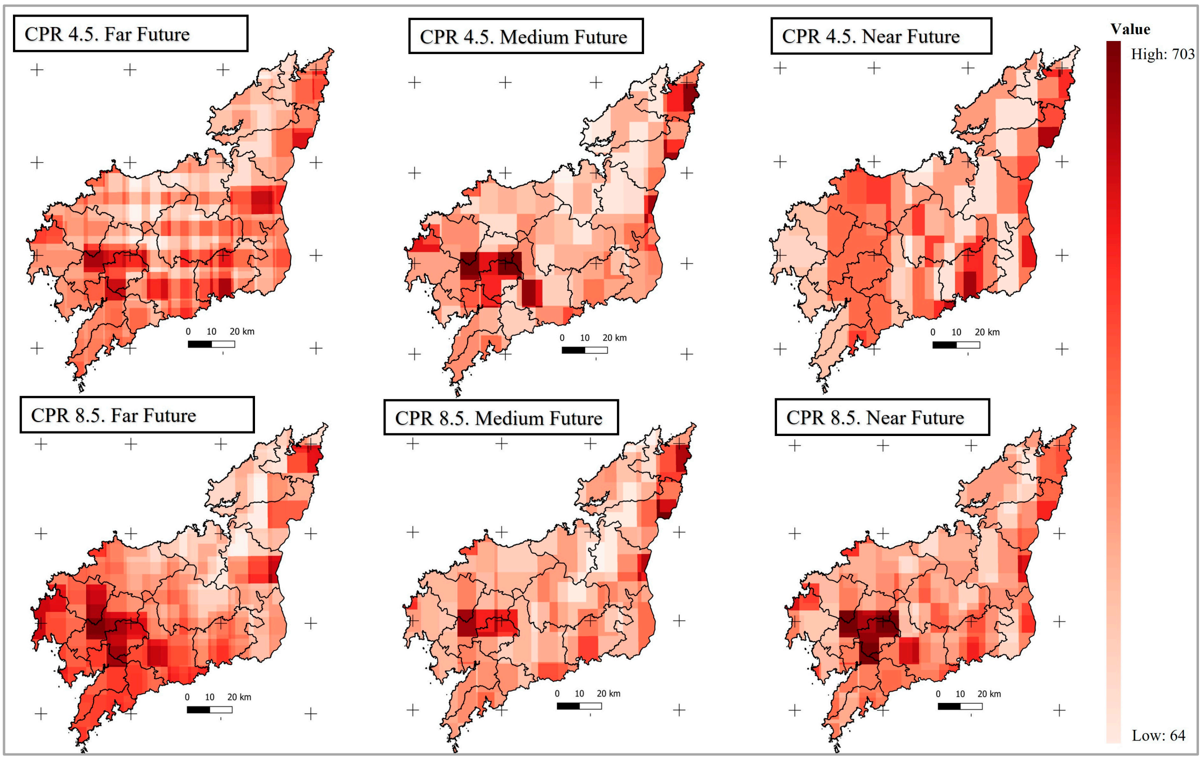

Figure 5. Model of climate change for construction in the province of La Coruña.

3.3. Cluster Analysis

Common patterns have been identified in each of the five resulting homogeneous groups, as shown in Table A6, with maximum values observed in all five groups. The cluster analysis reveals significant patterns across five distinct homogeneous groups, each characterized by unique maximum values for various climate change models, ecosystem carrying capacity models, territorial reception capacity models, and population variation projections from 2019 to 2035. Group I, for instance, displays lower values in the near future climate models under RCP 4.5 (120) and RCP 8.5 (225) scenarios but exhibits a notable increase in distant future projections, particularly under the RCP 8.5 model (463). The ecosystem carrying capacity in Group I is negative (−17), indicating a potential decline in the capacity to support ecological systems. Additionally, the territorial reception capacity model for this group shows a significant negative value (−109), suggesting challenges in accommodating population changes. Similar trends are observed in Group II, where distant future climate projections under the RCP 8.5 model peak at 518, and the ecosystem carrying capacity model reaches a maximum of 185, indicating better ecological support compared to Group I. However, territorial reception capacity is slightly positive in Group II (49), indicating a relatively better adaptation capacity for population changes.

Groups III, IV, and V demonstrate varying dynamics. Group III shows moderate values across climate models, with the highest value for the distant future under RCP 8.5 at 394, while the ecosystem carrying capacity peaks at 154. The territorial reception capacity in Group III is modestly positive (16), indicating a balance in accommodating population changes. Group IV demonstrates the highest values in the RCP 4.5 medium future (382) and distant future under RCP 8.5 (628), with a substantial ecosystem carrying capacity (126) and near-neutral territorial reception capacity (1), suggesting it can manage future ecological and demographic changes relatively well. Lastly, Group V points out balanced values across climate projections, with the highest distant future projection under RCP 8.5 at 504 and a moderate ecosystem carrying capacity of 94. The territorial reception capacity, however, is slightly negative (−28), indicating potential challenges in future population accommodation.

3.4. Territorial Model by Management Categories

According to the zoning criteria defined in the previous section and the information obtained during the territorial diagnosis phase, 21% of the surface area has been excluded due to the presence of existing wind turbines. This exclusion, representing the synergic or cumulative effect of other wind energy infrastructures, suggests that territorial capacity values could have been higher if not for this restriction. This variable will be an indicator of the degree of implementation of these infrastructures over time, which complements the model. On the other hand, this exclusion percentage rises by 5% when considering regulatory or legal areas, such as protected zones within the Natura 2000 Network, and by 4% for areas of cultural interest. Additionally, the distance to population centers, defined as areas with stable human occupation, is considered a restrictive factor in Galicia. A minimum distance of 500 m is imposed from urban or potentially developable land, which significantly increases the total excluded area. However, the main issue highlighted in this study is that the available population entity maps for the province of La Coruña include 17% of the 7486 entities with no registered inhabitants as of 2023, while 62% show records of fewer than 50 inhabitants per entity, which reflects significant depopulation in rural areas. While this indicator is not the focus of the paper, it could be an important factor for future research. Consequently, the distance to population centers requires further investigation. In the most restrictive exclusion scenario, considering the full value of this variable, the total excluded area reaches 273.41 km^2, representing 66% of the total excluded area within the province.

The territorial model by management categories highlights significant changes across different regions for wind energy development. Figure 6 illustrates the spatial allocation of acceptable and unacceptable areas for the implementation of wind farms. The first map (top left) shows extensive conservation areas in red, particularly in the northern and central regions, indicating high levels of protection and unsuitability for wind development, while southern and coastal areas exhibit fewer restrictions. The second map (top right) marks central and eastern regions in yellow as optimal expansion areas for wind energy production, contrasting with the limited expansion zones in the northern and western areas.

The third map (bottom left) identifies central and northern regions as priority production areas in green, suitable for energy production due to higher consumption forecasts, whereas southern and eastern regions are less prioritized. Finally, the fourth map (bottom right) illustrates central and northern areas as production zones in orange, with buffering effects against climate change, and also highlights central and southern regions in purple as recovery areas with development restrictions due to unique characteristics or high-risk factors. Overall, the central and northern regions experience the most significant changes, reflecting a mix of conservation, expansion, and production priorities, while southern and western regions show fewer changes, indicating lower suitability or restrictions for wind energy development.

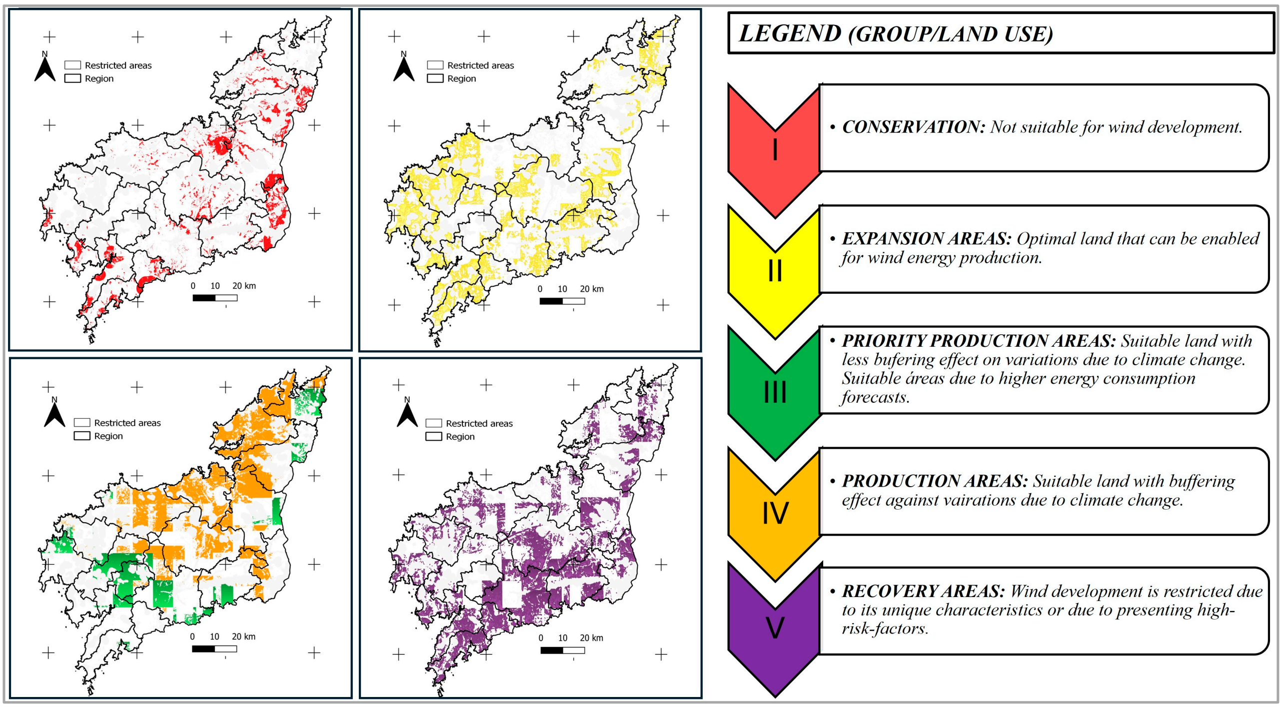

Figure 6. Territorial model by management categories.

Figure 6 shows in the least restrictive exclusion scenario (30% of the total target area), an acceptable area for the construction of wind farms of 3,734.4 km^2, not including the distance to population centers, restricted in an area of influence of 500 m, considering that this variable is unapproachable at the regional level and must be considered by the promoter of this type of infrastructure at the local level, attaching to the construction project, socioeconomic and environmental studies with specific measurements of noise and shadow effect for specific commercial wind turbines [56]. In the most restrictive exclusion scenario (66% of the total target area), which would include the distance to population centers in an area of influence of 500 m, the acceptable area for the construction of wind farms would amount to 1,841.5 km^2, 23% of the total area of the province of La Coruña, while the unacceptable areas proposed for conservation and restoration would amount to 273.4 km^2 and 551.84 km^2, respectively.

4. Discussion

A national renewable energy target of up to 50% has been established for each EU member country. In 2023, Spain surpassed 50% in the share of renewable energies compared to other energy sources, leading among EU countries. The Spanish government aims to increase wind energy production to 42 GW by 2025 and 62 GW by 2030, considering both the increase in its share of energy production and the future rise in energy demand, aggravated by high market volatility, derived, among other things, from the tense geopolitical circumstances [57]. Along these lines, Council Regulation 2024/223 of 22 December 2023 establishes a framework to accelerate the deployment of renewable energies to be transposed by the Spanish Government and Competent Spanish Authorities. Given the rapid increase in production over a short period, there may be concerns about how the environmental impact assessment process for wind farms will be managed. It took a long time to recognize the global effects of solid fuels, and the difficulty in transitioning away from them suggests that more careful and scientific steps should be taken.

La Coruña, the study area, is one of the most important locations on Spain's Atlantic coast. Its position on the Atlantic coast makes it significant for wind farming due to climatic factors such as currents, rainfall, and temperature, particularly the strong winds influenced by the Atlantic depression. Compared to other regions of Spain, the province has a higher economic income. Furthermore, the area features rich agricultural production and high biodiversity due to its oceanic climate. As a result, the study region includes areas aimed at maintaining a balance between energy production and environmental preservation.

The presented study allows for mitigating the impact of the implantation of a wind farm, contributing to the decision-making on the planning of a territory based on officially published data applicable to any part of the territory but specific to the study area and in line with the national and regional regulations in force. The importance of assigning weights to the criteria proposed by experts by means of a flexible multi-criteria decision system in the construction and environmental fields has been noted. In this context, the synergy between GIS and MCDM methodologies provides a robust framework for pinpointing optimal wind farm locations.

This study analyzes the trends of a series of relevant indices associated with extreme temperatures, such as heat waves and cold waves (frost) or changes in maximum wind speed at 10 m and maximum precipitation. The change in atmospheric patterns can also affect the maximum wind speed. The variation in this variable is relevant, on the one hand, because of its impact on wind energy generation and, on the other hand, because of the negative impacts that large wind speeds can have on both human health and their properties [58].

The capacity values obtained, which could be considered low to moderate on the scale, are a result of constraints imposed by the normative guidelines of the Wind Sector Plan [59]. These restrictions have limited areas that might have shown higher capacity due to the presence of existing wind turbines. It has been calculated that 21% of a total of 2466.5 km^2, approximately 31% of the total restricted area within the study area, is already occupied by wind turbines. This suggests that the remaining areas may have lower carrying capacity. The regions with the highest surface area values in both ecosystemic and territorial capacities would be those of Santiago, Ordes, Bergantiños, and Betanzos. Finally, it has been observed in the ecosystemic carrying capacity model that part of the provincial surface is located around 50 and 200 positive points of valuation in the scale of study (0–1000), and it seems logical to think that when the risk factor is added this percentage will drop, in fact, by approximately 15%. The largest area in positive values in territorial capacity would be around 100 evaluation points.

Regarding climate change planning, the five homogeneous groups identified using statistical techniques show that groups I and V account for most of the negative values, making these areas more vulnerable to potential risks and less adaptable to climate change. It has also been determined that groups II, III, and IV present acceptable values for the installation of wind farms, with the highest population concentrations found in these groups. However, these values are unevenly distributed: group III is concentrated in the center-north area, while group IV is found in the southern and interior zones. This distribution may be influenced by climate change, which differentiates between coastal and inland areas, with the most significant changes expected in the restrictive 8.5 scenario and for the distant future. A territorial model has been obtained with five management categories according to the proposed uses: production (priority areas for wind energy generation), production, expansion, conservation, and recovery. It was found, therefore, that depending on different patterns or certain climatic and population trends, the ecosystemic and territorial carrying capacity data set varies. The increase or decrease in population largely determines the energy consumption to be assumed by a region, and consequently, the adaptation measure will imply a prioritization of areas due to the prediction of an increase or decrease in the region's energy costs. This study may be useful to promoters of this type of infrastructure for the preparation of executive summaries at a local scale as stipulated in Law 21/2013 on environmental impact assessment and for the development of strategic plans on a larger scale.

Regarding climate change and the adaptation of wind farms as relevant elements in power generation [60], wind and solar resources throughout the year are inverse and, therefore, complement each other (in summer, there is more sun and less wind, and in winter, the opposite: less sun and more wind). For a good adaptation, the wind farm should respond well to cold waves and storms, not only because of the support that hydropower can provide (although relatively because in Galicia, the storage capacity is usually lower than in the rest of Spain) but also because electricity consumption shoots up in both heat waves and cold waves. According to the results of the study, it is very likely that the suitability, impact, and risk criteria will vary because of the modification of climatic conditions in the medium and long term.

With a view to future developments of the design and implementation of this study, the variables and planning criteria for the implementation of wind farms in the province of La Coruña contained in this study could serve as an adaptation measure in itself because it allows a quick response to events that may occur in certain areas but have not yet occurred or as a benchmark to measure the progress of a measure and the achievements of the implementation of wind farms. These criteria are indicators of the achievement of results to obtain continuous improvement over time. For example, the surface area occupied by existing wind turbines could be an indicator of the "degree of massification" of this type of infrastructure within the territory and the surface area balance of this type of energy within the energy mix. However, for this, national, regional, and local administrations should have more homogeneous criteria for the planning of this and other types of renewable energies within the territory. The information contained in this study can serve as a guide for the development of future environmental documents and strategic environmental impact assessments, with adaptation to climate change depending on where they are located and, subjectively, on the perception of the populations in the installation of this type of infrastructure. Within the environmental component that informs the territorial model, socioeconomic factors are included. The reduction in surface area associated with these factors results in an environmental cost for wildlife species, such as raptors and bats [61], as well as for landscape aspects due to the way the population inhabiting these areas perceives the landscape. This includes factors such as the agrological capacity of soils and forest influence zones. Specifically, 69% of the provincial forest area is comprised of plantation forests, according to the Forest Map of Spain.

Within the perceptual or landscape environment, the combination of optimal ground covers for the construction of wind farms has been used, according to the suitability for agricultural use and the wooded cover, in order to avoid altering the production and specific market structure for the study territory, in addition to the characteristic visual quality of the landscape. As suggested by [62], in the "Guide to Landscape Integration Criteria for Wind Farms", agricultural and forestry uses are considered in order to give the model a landscape perspective as an element of the identity of the area of study, giving a vision of economic and social sustainability. The socioeconomic criteria considered in this study are considered fundamental in the implementation of this type of infrastructure due to the visual perception of the landscape and culture of the population that inhabits these areas, unusual factors in this type of evaluation. In addition, architectural and ethnological elements and assets of cultural interest, such as the Camino de Santiago, have been integrated, which function as elements to be excluded according to the current Decree

238/2020 of 29 December, approving the Galician Landscape Guidelines. DOG No. 20, of 2 January 2021.

5. Conclusions

This article examines trends in various significant indices related to extreme temperatures, such as heatwaves, cold spells (frosts), and changes in maximum wind speed at 10 m, as well as maximum rainfall. Changes in atmospheric patterns can also affect the maximum wind speed, which is particularly relevant due to its impact on wind energy production and the potential safety risks posed by high wind speeds to both people and property. The inclusion of these average variables, combined with the criteria outlined, helps to provide a more accurate estimate of uncertainties, especially in the context of high wind resource exploitation and associated risks.

A territorial model was developed with five planning categories based on proposed uses: production (priority areas for wind energy generation), production without alterations due to climate change factors, expansion, conservation, and recovery. In the most restrictive exclusion scenario (covering 66% of the total target area), which accounts for a 500-m buffer zone around population centers, the area suitable for wind farm construction would be 1841.5 km^2 or 23% of the total area in the province of La Coruña. Meanwhile, the areas designated for conservation and restoration would amount to 273.4 km^2 and 551.84 km^2, respectively.

The capacity values obtained, which correspond to low to moderate on the proposed scale, result from the exclusion of 21% of the total regional area in the territorial model. Given this, it seems reasonable that the remaining areas may have lower carrying capacity, extending to 66% in the most restrictive scenario, particularly when considering population entities.

It is also important to protect the population by establishing protective perimeters around major inhabited areas. This is not only a significant variable but is also linked to other factors, such as wind turbine noise emissions and the shadow flicker effect, both of which decrease with distance. These factors should be addressed in localized studies, with specific measurements taken by wind farm developers for the turbines they intend to install according to their size and location.

The regional administrative unit was used as the basic subunit for study variables, as it is assumed that the areas defined this way share common physical and cultural characteristics. Since the results of territorial planning can vary considerably depending on the variables used in the analytical process, this study is based on a preliminary diagnosis of variables and criteria drawn from an extensive reference bibliography. The study includes 26 variables, focusing on those most commonly agreed upon in existing research, as well as proposals such as soil agrological capacity and visual quality of the landscape. These variables provide insight into the potential impact of wind energy on local populations and feed into the territorial model created using multi-criteria grouping techniques and GIS to identify optimal wind energy areas.

Soil classes of high quality for agriculture and forestry are often seen by the population as an alteration to production and market structures, in addition to influencing the landscape's visual quality. The coexistence of agricultural/forestry use and wind energy production is considered a priority in the study territory, though it is typically overlooked in similar research. The urban environment and cultural heritage are treated as legal restrictions in the regional protection framework. In fact, adaptation measures could prove more effective if they are integrated into existing local and sectorial policies, which are applicable across Spain. The variables examined in this study enable the control and mitigation of a wind farm's impact, aiding in territorial planning decisions based on substantial evidence from official data relevant to any part of the territory while adhering to current national and regional regulations. However, it is acknowledged that not all potential regulatory variables can be considered at this scale.

The importance of assigning appropriate weights to the criteria proposed by experts through a flexible multi-criteria decision system within the fields of construction and environmental planning has been confirmed. This process is part of the methodology in this work, for which a dedicated form has been designed, proving to be highly effective for this purpose. The integration of machine learning (ML) techniques holds potential for further improvement. However, no independent ML-based approach has yet been applied in existing studies. Artificial Intelligence could provide a continuous and cyclical improvement loop, allowing for feedback on the proposed territorial model using the suggested evaluation criteria.

The main contributions of this study are as follows:

- The development of a territorial model that incorporates risk mitigation over a broader time frame, adapting to climate change. This approach considers various scenarios in territorial planning, whether caused by internal natural processes, changes in external factors, or persistent anthropogenic changes to the atmosphere or land use. The inclusion of this climate change factor aims to reduce the vulnerability of the territory should the acceleration of extreme atmospheric conditions predicted in publicly available climate change models become a reality.
- For evaluating climate evolution trends, the study also considers population trends based on official data from 2019 to 2035. These results are comparable with short-term or stabilization climate change scenarios, where temperatures are expected to remain below a 2 °C increase.
- The capacity values obtained, which are considered low to moderate on the proposed scale, are partly due to the exclusion of 21% of the region's total area in the territorial model. As a result, it is logical that the remaining areas may have a lower carrying capacity, extending to 66% in the most restrictive scenario, especially when considering population entities.
- It was found that different climatic and population trends affect the data on ecosystem and territorial reception capacity. Changes in population levels significantly influence regional energy consumption, meaning that adaptation measures will prioritize areas based on projected shifts in regional energy costs.
- Socioeconomic criteria are considered crucial in implementing this type of infrastructure, particularly due to the population's visual perception of the landscape and cultural factors that are not often taken into account in such evaluations.

This study can serve as a valuable reference for the development of strategic plans for renewable energy acceleration zones. It helps moderate potential damage from their implementation or take advantage of opportunities linked to climate change, where prior knowledge guarantees predictability. Additionally, this knowledge can simplify administrative procedures for granting streamlined authorizations, ensuring equitable access to energy for the common good. This study is also useful for revising early warning plans in disaster risk management, ecosystem management, and the creation of local climate change adaptation plans.

Author Contributions: B.V.: Writing—Original draft preparation, Visualization, and Investigation. J.V.: Conceptualization, Methodology, and Investigation. D.G.: Writing—Reviewing and Editing, and Supervision. F.H.: Data curation, Writing—Reviewing and Editing, and Supervision. A.U.Ö.: Writing—Reviewing and Editing, and Supervision. A.H.: Writing—Reviewing and Editing. V.R.: Writing—Reviewing and Editing. R.A.C.: Writing—Reviewing and Editing. K.Ç.: Writing—Reviewing and Editing. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by national funds through the Fundação para a Ciência e a Tecnologia, I.P. (Portuguese Foundation for Science and Technology) by the project UIDB/05064/2020 (VALORIZA-Research Centre for Endogenous Resource Valorization).

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: Author Blanca Valle was employed by the company Tragsatec. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A

Table A1. Data used, format, and scale level.

Data	Format	Scale	Data	Format	Scale
Provinces	Shapefile	State	High Fire Risk Areas (HFRA)	Shapefile	Regional
Regions	Shapefile	State	Forest Map of Spain	Shapefile	State
Municipalities	Shapefile	State	Municipal dangerous goods transport risk	Shapefile	Regional
Average wind speed (100 m)	Raster	Worldwide	Heat wave (95th percentile of the maximum daily temperature)	Raster	State
Digital Terrain Model (scale 25,000)	Raster	State	Cold wave (5th percentile of minimum temperature)	Raster	State
Lithology	Shapefile	State	Strong winds (average speed between 41 and 70 km/h)	Raster	State
Power substations	Shapefile	State	Drought (5th percentile of the daily maximum temperature)	Raster	State
Power lines (132 y 400 kV)	Shapefile	State	Extreme storms (95th percentile of daily maximum precipitation)	Raster	State
Highways	Shapefile	State	Natura 2000 protected areas network	Shapefile	Community
Main and secondary roads	Shapefile	State	National Parks	Shapefile	State
Priority Habitats of Community Interest (Annex I to Directive 92/43/EEC)	Shapefile	Community	Natural Parks	Shapefile	Regional
Golden eagle critical areas (unacceptable for wind development)	Shapefile	Regional	Protected wetlands	Shapefile	Regional
Unique trees of special protection	Shapefile	State	Natural Monuments	Shapefile	Regional
Priority areas for threatened birds (Annex I of the Resolution of 18 October 2021)	Shapefile	State	Protected landscapes	Shapefile	Regional
Bird protection areas against high-voltage power lines (Royal Decree 1432/2008, of 29 August)	Shapefile	State	Existing wind farms	Shapefile	Regional
Recovery and Conservation Plans for Species of flora and fauna	Shapefile	State	Population entities	Shapefile	State
Agrological capacity of the soil	Shapefile	Regional	Ocean coastline	Shapefile	State
Areas of Significant Potential Flood Risk (ARPSI)	Shapefile	State	Rivers	Shapefile	State
Municipal seismic hazard	Shapefile	Regional	Ethnographic heritage	Shapefile	State
National Soil Erosion Inventory	Shapefile	State	Archaeological Heritage	Shapefile	State
Map of average density per thunderstorm (discharges/km^2/year)	Shapefile	State	Airports, helipads and aerodromes	Shapefile	State
Municipal risk map for frost	Shapefile	State	Population projection (2019–2035)	csv	Regional

Table A2. Prioritization of the most frequently mentioned variables extracted from the bibliography consulted (*) A = Suitability, I = Impact, R = Restriction, and RCC = Risk and Climate Change.

Criteria	No. of Times Mentioned in the Bibliography	Scoring According to Authors	Priority (%)	Type (*)
Average wind speed (m/s)	5	193	27.67	A
Terrain slope (%)	6	63	8.98	A
Distance to mains (m)	5	56	7.95	A
Distance to highways and main roads (m)	8	37	5.35	A
Exposure (Degrees)	1	14	2.00	A
Altitude (m)	4	55	7.90	A
Land cover/land use	5	43	6.18	I
Distance to protected natural areas (m)	3	31	4.39	I
Distance to forest (m)	1	3	0.43	I
Distance to urban areas (m)	8	70	9.95	R
Number of wind turbines to be installed	1	25	3.60	R
Area required for the wind farm	1	21	3.00	R
Distance to airports (m)	3	11	1.59	R
Noise	1	8	1.13	R
Distance to rivers (m)	3	6	0.86	R
Shadow flicker	1	6	0.84	R
Distance from protected cultural values (m)	1	4	0.63	R
Distance to wetlands (m)	2	4	0.57	R
Distance to rural areas (m)	1	3	0.43	R
Distance to the coast (m)	1	3	0.36	R
Distance to wells and springs (m)	1	0	0.01	R
Distance to opening aqueducts (m)	1	0	0.01	R
Rainfall (mm)	1	26	3.65	RCC
Temperature (°C)	1	13	1.83	RCC
Distance to fault lines (m)	2	4	0.57	RCC
Seismic acceleration (m/s^2)	1	1	0.11	RCC

Table A3. Prioritization of the most frequently mentioned variables extracted from the consulted literature.

<table>
<tr><th colspan="3">Criteria/Variables</th><th>Ranking</th><th>Values</th><th>Normalized Values (Scale 100–1000)</th><th>References</th></tr>
<tr><td rowspan="17">Aptitude</td><td rowspan="6">A1</td><td rowspan="6">Wind resource utilization. Wind speed (m/s) at 100 m</td><td>Discarded</td><td colspan="2">Start-up: <3–4 m/s;
Cut-off: >25 m/s</td><td rowspan="6">[16–18,63–74]</td></tr>
<tr><td>Download</td><td><5</td><td>100</td></tr>
<tr><td>Low-Medium</td><td>6</td><td>250</td></tr>
<tr><td>Media</td><td>7</td><td>500</td></tr>
<tr><td>Medium-High</td><td>8</td><td>750</td></tr>
<tr><td>High</td><td>9–14</td><td>1000</td></tr>
<tr><td rowspan="5">A2</td><td rowspan="5">Soil bearing capacity (Types Lithology)</td><td colspan="2">High</td><td>1000</td><td rowspan="5">[35,73]</td></tr>
<tr><td colspan="2">Media</td><td>750</td></tr>
<tr><td colspan="2">Download</td><td>500</td></tr>
<tr><td colspan="2">Very low</td><td>250</td></tr>
<tr><td colspan="2">Null</td><td>100</td></tr>
<tr><td rowspan="5">A3</td><td rowspan="5">Slope (%)</td><td>Steep</td><td>>50</td><td>250</td><td rowspan="5">[17,18,63,69,72–79]</td></tr>
<tr><td>Very strong</td><td>30–50</td><td>300</td></tr>
<tr><td>Strong-Moderate</td><td>10–30</td><td>500</td></tr>
<tr><td>Soft</td><td>5–10</td><td>750</td></tr>
<tr><td>Trowel</td><td><5</td><td>1000</td></tr>
</table>

Table A3. *Cont.*

Criteria/Variables			Ranking	Values	Normalized Values (Scale 100–1000)	References
Aptitude	A4	Proximity to 132 to 400 kV substations and lines (m)		<500	1000	[17,18,63,69,72,75–79]
				500–1000	750	
				1000–5000	500	
				5000–10,000	250	
				>10,000	100	
	A5	Proximity to roads (m)		<500	1000	[17,18,63,69,71,75–79]
				500–1000	750	
				1000–5000	500	
				5000–6000	250	
				>6000	100	
Impact	I1	HCI proximity		0–100	1000	[36,71]
				100–400	750	
				1500–2500	500	
				>2500	100	
	I2	Proximity to priority birdlife areas		>2500	100	[58,68,80]
				0–2500	1000	
	I3	Agrological capacity of the soil	A–B			[45,69,74]
			C–E		250	
			F–G		100	
	I4	Forest Influence Zones (FIZ)		0–400	500	[36,77,81]
				400–1500	250	
				>1500	100	
Risk	RIE1	Seismicity		Low	100	[35,78]
				Media	500	
	RIE2	Flooding		Very high	1000	[35,47]
				High	750	
				Medium	500	
				Under	250	
				Very low	100	
				No risk	0	
	RIE3	Mass movements		Very high	1000	[36]
				High	750	
				Media	500	
				Low or moderate	250	
				Physical impossibility	0	
	RIE4	Forest Fires		ZAR High fire risk zones	1000	[49]
				ZMR Medium fire risk areas	500	
	RIE5	Transport of dangerous goods		High	1000	[50]
				Under	100	

Table A4. Elements to be grouped for the carrying capacity optimization model and climate models (*) Near (2010–2040), medium (2041–2070), and far (1971–2100) future and population trends for the installation of wind farms.

Model	No.	Groupings
Climate Change	1	Climate change model. RCP 4.5. Near future. *
	2	Climate change model. RCP 4.5. Medium future. *
	3	Climate change model. RCP 4.5. Distant future. *
	4	Climate change model. RCP 8.5. Near future. *
	5	Climate change model. RCP 8.5. Medium future. *
	6	Climate change model. RCP 8.5. Distant future. *
Capacity to receive	7	Ecosystem carrying capacity.
	8	Territorial reception capacity.
Population dynamics	9	Percentage point change population H-2019–2035.

Table A5. Most significant results of the studied variables.

Criteria/Variables			Surface Representation and Typologies
Aptitude	A1	Wind resource utilization. Wind speed (m/s) at 100 m	87% between 6–8 m/s average speed at 100 m altitude. Excluding average starting and cutting speeds (less than 3 and greater than 25 m/s).
	A2	Soil bearing capacity (Types Lithology)	56% High
	A3	Slope (%)	55% Very steep slopes, 19% Steep, 14% Steep, rest 12%
	A4	Proximity to energy infrastructure (m)	62.7% between 1 and 5 km
	A5	Proximity to roads (m)	62.7% > 6 km
Impact	I1	National Habitat Inventory of Annex I of Directive 92/43/EEC (HCI) proximity	A 36.4% occupied by humid Atlantic heaths of temperate zones of Erica ciliaris and erica tetralix, catalogued as priority species developed on humid soils. By municipalities Sobrado (25%) and Toques (24%).
	I2	Proximity to priority birdlife areas	The municipalities with the highest priority surface area for affecting birdlife are Sobrado and Toques, with 25% and 24%, respectively.
	I3	Agrological capacity of the soil	Agrological classes B and C (19% each) and E (22%) classified with a high-medium impact.
	I4	Forest Influence Zones (FIZ)	86% of the available area is in the range of 0–400 m distance. The forest area is represented by plantation forests (69%) Eucalyptus globulus (40.7%) and Pinus pinaster (22.32%); 27.8% of forest, mainly Quercus robur (12.1%) and Pinus pinaster (10.3%); gallery forest (2.9%) and coppices.
Risk	RIE1	Seismicity	Low risk due to seismicity, although if we take into account the vulnerability of the buildings denoted by Civil Protection in their Emergency Plans, the risk will rise to medium in 72.6% of the categorized surface area.
	RIE2	Floods	The same is true for flood risk, where 44% of the provincial surface could be considered a medium-low risk.
	RIE3	Mass movements	50% medium risk. 3% physical impossibility. By counties, Eume has the largest area at very high risk, although it does not exceed 1%, while Ordes has the highest percentage of area at medium risk (8.24%). In general, the area at medium risk is fairly distributed among the counties.
	RIE4	Forest Fires	66% in high fire risk areas, the remaining 34% in medium risk areas.
	RIE5	Transport of dangerous goods	80% low risk.

Table A5. *Cont.*

Criteria/Variables			Surface Representation and Typologies
Climate Change	CC1	Heat wave	Higher temperature increases due to extreme events in the most restrictive scenario (RCP 8.5) are much more pronounced in the inland, western and southwestern regions and less pronounced in the northwestern regions.
	CC2	Cold wave	An increase in minimum temperatures of 2–3 °C and therefore a decrease in the number of frost days. More pronounced variations are observed in inland areas.
	CC3	Strong winds	In the RCP 4.5 scenario, no major changes are expected in the short and medium term, with peaks around 21 m/s compared to the current period. However, in the most restrictive scenario, in the case of not reducing emissions, it is observed in the medium term that the maximum wind speed could move to 24–25 m/s in a higher percentage of the surface, this would imply, with the current design of the turbines, the cut of their movement, although the technology in this sector is advancing by leaps and bounds so this could not be an obstacle in a few years. By regions, in the inland regions there are more topographic obstacles for wind circulation, they show less fluctuations, between 20–23 m/s, while in those located further west on the coast, such as Fisterra, Terra de Soneira, and Xallas, they seem to reach higher gusts, up to 28 m/s. In the northwestern and southwestern regions, the maximum gusts reach up to 25 m/s.
	CC4	Drought	Changes in temperature and precipitation are observed, especially for extreme events. As in the case of heat waves, maximum temperature increases in the 5th percentile are expected to be more pronounced in the RCP 8.5 scenario.
	CC5	Extreme storms	In the case of the RCP 4.5 scenario, essentially the same patterns are obtained as in the case of the RCP 8.5 scenario, but more smoothed (4). Maximum values of up to 44 mm/day in the southwestern counties. These levels do not exceed the threshold values taken as a reference for the issuance of current warnings or emergency expected between 120 and 60 mm.

Table A6. Maximum values of climate, demographic, and carrying capacity models by homogeneous groups obtained by k-means. Source: Own elaboration.

Groupings	I	II	III	IV	V
Climate change model. RCP 4.5. Near future.	120	130	107	148	130
Climate change model. RCP 4.5. Medium future.	284	289	258	382	281
Climate change model. RCP 4.5. Distant future.	333	354	271	451	358
Climate change model. RCP 8.5. Near future.	225	226	199	321	230
Climate change model. RCP 8.5. Medium future.	317	329	286	388	322
Climate change model. RCP 8.5. Distant future.	463	518	394	628	504
Ecosystem carrying capacity model.	−17	185	154	126	94
Territorial reception capacity model.	−109	49	16	1	−28
Model of percentage point variation in population H-2019–2035.	−0.9	−1.2	−0.9	−1.0	−0.9

Table A6. *Cont.*

Groupings	I	II	III	IV	V
Maximum values of statistical variables by homogeneous groups obtained by k-means.					
Groupings	I	II	III	IV	V
Elements (No.)	1,126,737	1,919,050	2,917,364	1,140,570	2,113,792
Elements (%)	12	21	32	12	23
Standard deviation	148	109	113	147	108

References

1. *Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as Regards the Promotion of Energy from Renewable Sources, and Repealing Council Directive (EU) 2015/652. Directive—EU—2023/2413 EN Renewable Energy Directive*; EUR-Lex: Luxembourg, 2023.
2. Eurostat. Renewable Energy Statistics. Available online: https://ec.europa.eu/eurostat (accessed on 10 December 2024).
3. WindEurope. Wind Energy in Europe: Scenarios for 2030. Available online: https://windeurope.org (accessed on 10 December 2024).
4. Diffendorfer, J.E.; Compton, R.W. Land cover change within and around wind energy facilities in the USA. *PLoS ONE* **2014**, *9*, e104899. [CrossRef]
5. Turkovska, O.; Castro, G.; Klingler, M.; Nitsch, F.; Regner, P.; Soterroni, A.C.; Schmidt, J. Positive ecological effects of wind power expansion in Brazil: Changes in land use patterns. *Renew. Energy* **2021**, *171*, 1233–1242. [CrossRef]
6. Xu, K.; He, L.; Hu, H.; Liu, S.; Du, Y.; Wang, Z.; Li, Y.; Li, L.; Khan, A.; Wang, G. Positive ecological effects of wind farms on vegetation in China's Gobi desert. *Sci. Rep.* **2019**, *9*, 6341. [CrossRef] [PubMed]
7. Zhang, D.; Wang, J.; Lin, Y.; Si, Y.; Huang, C.; Yang, J.; Huang, B.; Li, W. Present situation and future prospect of renewable energy in China. *Renew. Sustain. Energy Rev.* **2017**, *76*, 865–871. [CrossRef]
8. Gasparatos, A.; Doll, C.N.; Esteban, M.; Ahmed, A.; Olang, T.A. Renewable energy and biodiversity: Implications for transitioning to a Green Economy. *Renew. Sustain. Energy Rev.* **2017**, *70*, 161–184. [CrossRef]
9. Jager, H.I.; Efroymson, R.A.; McManamay, R.A. Renewable energy and biological conservation in a changin world. *Biol. Conserv.* **2021**, *263*, 109354. [CrossRef]
10. *Commission Regulation (EU) 2022/720 of 10 May 2022 on the Application of Article 101(3) of the Treaty on the Functioning of the European Union to Categories of Vertical Agreements and Concerted Practices (Text with EEA Relevance)*; EUR-Lex: Luxembourg, 2022.
11. McCarthy, J.J.; Canziani, O.F.; Leary, N.A.; Dokken, D.J.; White, K.S. *Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2001.
12. Martinez, A.; Iglesias, G. Climate change and wind energy potential in South America. *Sci. Total Environ.* **2024**, *957*, 177675. [CrossRef]
13. Pryor, S.C.; Barthelmie, R.J. Climate change impacts on wind energy: A review. *Renew. Sustain. Energy Rev.* **2010**, *14*, 430–437. [CrossRef]
14. Carta, J.A.; Mentado, D. A continuous bivariate model for wind power density and wind turbine energy output estimations. *Energy Convers. Manag.* **2007**, *48*, 420–432. [CrossRef]
15. Orosa, J.A.; Costa, A.M.; Roshan, G.; García-Bustelo, E.J. Wind turbines design corrections for next Galicia climatic conditions. *Sci. Iran.* **2017**, *24*, 926–932. [CrossRef]
16. Iberdrola-Berdoias. Initial document—Berdoias Wind Farm Project and Its Evacuation Infrastructure. Muxía, Vimianzo, Dumbría, Zas, Santa Comba, Val do Dubra, Tordoia, Trazo, Cerceda, Ordes and Carral (Province of A Coruña). Available online: https://sede.miteco.gob.es/portal/site/seMITECO/navServicioContenido (accessed on 5 February 2021).
17. Khalaf, O.F.; Uçan, O.N.; Alsamarai, N.A. Utilizing Multivariate Clustering and Spatial Analysis for Selecting Suitable sites for Sustainable Wind Energy. *Res. Sq.* **2024**. [CrossRef]
18. Moradi, S.; Yousefi, H.; Noorollahi, Y.; Rosso, D. Multi-criteria decision support system for wind farm site selection and sensitivity analysis: Case study of Alborz Province, Iran. *Energy Strategy Rev.* **2020**, *29*, 100478. [CrossRef]
19. Zorita, E.; von Storch, H. The Analog Method as a Simple Statistical Downscaling Technique: Comparison with More Complicated Methods. *J. Clim.* **1999**, *12*, 2474–2489. [CrossRef]
20. Wang, Y.; Zhang, N.; Kang, C.; Xu, Q.; Li, H.; Xiao, J.; Wang, Z.; Shi, R.; Wang, S. Ordinal Optimization Theory Based Planning for Clustered Wind Farms Considering the Capacity Credit. *J. Electr. Eng. Technol.* **2015**, *10*, 1930–1939. [CrossRef]
21. Barthelmie, R.J.; Jensen, L.E. Evaluation of wind farm efficiency and turbulence intensity from single and multiple wakes. *Wind. Energy* **2010**, *13*, 573–586. [CrossRef]
22. Fischereit, J.; Brown, R.; Larsén, X.G.; Badger, J.; Hawkes, G. Review of Mesoscale Wind-Farm Parametrizations and Their Applications. *Bound.-Layer Meteorol.* **2021**, *182*, 175–224. [CrossRef]
23. Xu, Y.; Li, Y.; Zheng, L.; Cui, L.; Li, S.; Li, W.; Cai, Y. Site selection of wind farms using GIS and multi-criteria decision making method in Wafangdian, China. *Energy* **2020**, *207*, 118222. [CrossRef]
24. Demir, A.; Dinçer, A.; Ciftci, C.; Gülçimen, S.; Uzal, N.; Yilmaz, K. Wind farm site selection using GIS-based multicriteria analysis with Life cycle assessment integration. *Earth Sci. Inform.* **2024**, *17*, 1591–1608. [CrossRef]
25. Roy, S.B.; Traiteur, J.J. Impacts of wind farms on surface air temperatures. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 17899–17904. [CrossRef]
26. Saaty, T.L. A scaling method for priorities in hierarchical structures. *J. Math. Psychol.* **1997**, *15*, 234–281. [CrossRef]

27. Mardani, A.; Jusoh, A.; Nor, K.; Khalifah, Z.; Zakwan, N.; Valipour, A. Multiple criteria decision-making techniques and their applications—A review of the literature from 2000 to 2014. *Econ. Res. Ekon. Istraživanja* **2015**, *28*, 516–571. [CrossRef]
28. Yaman, A. A GIS-based multi-criteria decision-making approach (GIS-MCDM) for determination of the most appropriate site selection of onshore wind farm in Adana, Turkey. *Clean. Technol. Environ. Policy* **2024**, *26*, 4231–4254. [CrossRef]
29. Ajanaku, B.A.; Strager, M.P.; Collins, A.R. GIS-based multi-criteria decision analysis of utility-scale wind farm site suitability in West Virginia. *GeoJournal* **2022**, *87*, 3735–3757. [CrossRef]
30. Miller, A.; Li, L. A multi-criteria decision analysis approach for the site selection of offshore wind farms using GIS. *Renew. Energy* **2014**, *66*, 276–284. [CrossRef]
31. Abdul Baseer, M.; Alhems, L. GIS-Based Multi-Criteria Wind Farm Site Selection Methodology. *FME Trans.* **2020**, *48*, 855–867. [CrossRef]
32. Bili, M.; Vagiona, D. GIS-based multi-criteria decision analysis for wind farm site selection: Methodology and case study. *Sustainability* **2018**, *10*, 3282. [CrossRef]
33. Feloni, E.; Karandinaki, E. GIS-based MCDM Approach for Wind Farm Site Selection—A Case Study. *J. Energy Power Technol.* **2021**, *3*, 039. [CrossRef]
34. Pérez Castellanos, S.; Piñeiro Arrivi, I.; Macho Eiras, M.L. Galician Climate Change and Energy Strategy 2050. In Proceedings of the XII International Congress of the Spanish Association of Climatology (AEC): Challenges of Climate Change: Impacts, Mitigation and Adaptation, Santiago de Compostela, Spain, 19–21 October 2022.
35. Gómez Orea, D. *Land Management*, 3rd ed.; Mundi-Prensa: Madrid, Spain, 2013; ISBN 978-84-8476-660-5.
36. Baban, S.M.J.; Parry, T. Developing and Applying a GIS Assisted Approach to Locating Wind Farms in the UK. *Renew. Energy* **2001**, *24*, 59–71. [CrossRef]
37. Aydin, N.Y.; Kentel, E.; Duzgun, S. GIS-based environmental assessment of wind energy systems for spatial planning: A case study from Western Turkey. *Renew. Sustain. Energy Rev.* **2010**, *14*, 364–373. [CrossRef]
38. Khan, K.I.; Nasir, A. Application of artificial intelligence in solar and wind energy resources: A strategy to deal with environmental pollution. *Environ. Sci. Pollut. Res.* **2023**, *30*, 64845–64859. [CrossRef]
39. Atakan, B.; Tümay, A.; Batuhan, K. Explainability in wind farm planning: A machine learning framework for automatic site selection of wind farms. *Energy Convers. Manag.* **2024**, *309*, 118441. [CrossRef]
40. Xunta de Galicia. Download Web Page of the Galician Wind Register Version 20171024. Available online: https://www.arcgis.com/index.html (accessed on 5 February 2024).
41. Galician Institute of Statistics. Available online: https://www.ige.gal/web/index.jsp?idioma=es (accessed on 28 May 2021).
42. Global Wind Atlas. Global Solar Atlas. Available online: https://energydata.info/ (accessed on 5 February 2021).
43. National Center for Geographic Information. Download Center. BTN25. Available online: https://centrodedescargas.cnig.es/CentroDescargas/locale?request_locale=en (accessed on 5 January 2020).
44. Galician Health Service. GIS: Cartography of Galicia in SHP Vector Format for Geographic Information Systems. Available online: https://www.sergas.es/Saude-publica/GIS-Cartografia-Galicia-formato-vectorial-SHP?idioma=es (accessed on 5 February 2021).
45. Corbelle Rico, E. Rural Resources. *Off. J. Inst. Agric. Biodivers. Rural. Dev.* **2014**, *10*, 35–43.
46. *Order of 24 June 2002 Approving and Publishing the Revision and Updating of the Civil Protection Plan for the Risk of Snowfall in Galicia (Nega Plan), Approved by the Galician Civil Protection Commission. DOG No. 143, of 26/07/2002*; EUR-Lex: Luxembrourg, 2002.
47. *Special Civil Protection Plan for the Risk of Flooding in Galicia. Approved by Resolution of October 4, 2016. DOG No. 197, of 17/10/2016*; Galicia Council: Santiago de Comspostela, Spain, 2016.
48. *Special Plan for Civil Protection Against Seismic Risk in Galicia. Approved by Resolution of August 2, 2010, Which Publishes the Special Plan for Civil Protection Against Seismic Risk in Galicia. DOG No. 153, of 11/08/2010*; Galicia Council: Santiago de Comspostela, Spain, 2010.
49. *Law 3/2007, of April 9, on Prevention and Defense Against Forest Fires in Galicia. DOG No. 74, of 17/04/2007. Reference: BOE-A-2007-10022*; Galicia Council: Santiago de Comspostela, Spain, 2010.
50. *Special Civil Protection Plan for Emergencies due to Accidents in the Transport of Dangerous Goods by Road and Rail in Galicia. Approved by Resolution of April 24, 2000, of the General Secretariat of the Department of Justice, Interior and Labor Relations, Which Provides for the Publication of the Emergency Plan for Accidents in the Transport of Dangerous Goods in the Autonomous Community of Galicia (Plan transgal). DOG No. 87, of 24/04/2000*; Galicia Council: Santiago de Comspostela, Spain, 2000.
51. State Agency of Meteorology. Visual Meteoglossary, Illustrated Dictionary of Meteorology. [State Agency of Meteorology. Visual Meteoglossary, Illustrated Dictionary of Meteorology]. Available online: https://meteoglosario.aemet.es (accessed on 8 June 2020).
52. Platform on Adaptation to Climate Change in Spain. Available online: https://escenarios.adaptecca.es (accessed on 8 June 2020).
53. Thorndike, R.L. Who belongs in the family? *Psychometrika* **1953**, *18*, 267–276. [CrossRef]
54. Saaty, R.W. The analytic hierarchy process—What it is and how it is used. *Math. Model.* **1987**, *9*, 161–176. [CrossRef]
55. Moreno Jiménez, J.M. The analytical hierarchical process (AHP). Fundamentals, methodology and applications. *Electron. J. Commun. Work. ASEPUMA* **2002**, *1*, 28–77.
56. Mu, E.; Pereyra-Rojas, M. *Practical Decision Making using Super Decisions v3*; Springer: New York, NY, USA, 2018.
57. *Council Regulation (EU) 2024/223 of 22 December 2023 Amending Regulation (EU) 2022/2577 Establishing a Framework for Accelerating the Deployment of Renewable Energies. Regulation—EU—2024/223—EN*; EUR-Lex: Luxembourg, 2024.
58. Amblar, P.; Casado, M.J.; Pastor, A.; Ramos, P.; Rodríguez, E. *Guide to Regionalized Climate Change Scenarios Over Spain Based on the Results of IPCC-AR5*; NIPO: 014-17-010-8; Ministry of Agriculture and Fisheries, Food and Environment and State Meteorological Agency: Madrid, Spain, 2017.

59. Galician wind Sector Plan. Energy Institute of Galicia. Available online: https://www.inega.gal/es/energias-renovables/eolica (accessed on 10 December 2024).
60. Liu, L.; He, G.; Wu, M.; Liu, G.; Zhang, H.; Chen, Y.; Shen, J.; Li, S. Climate change impacts on planned supply–demand match in global wind and solar energy systems. *Nat. Energy* **2023**, *8*, 870–880. [CrossRef]
61. Atienza, J.C.; Martín Fierro, I.; Infante, O.; Domínguez, J. Guidelines for the Assessment of the Impact of Wind Farms on Birds and Bats (version 3.0). SEO/BirdLife, Madrid. 2011. Available online: https://seo.org/wp-content/uploads/2012/05/MANUAL-MOLINOS-VERSION-31_WEB.pdf (accessed on 10 December 2024).
62. Borobio Sanchíz, M. *Guide to Impact Studies and Landscape Integration*; Institute of Territorial Studies, Galicia Council: Santiago de Comspostela, Spain, 2012; Available online: https://abtemas.es/en/portfolio-item/guide-to-impact-studies-and-landscape-integration/ (accessed on 10 December 2024).
63. Öztürk, B.; Serkendiz, H. Location Selection for Wind Turbines in Balıkesir, NW Turkey, Using GIS. *Int. J. Environ. Geoinform.* **2018**, *5*, 284–295. [CrossRef]
64. Ortega, M.; del Rio, P. Renewable Energy Policy and Market Integration: Implications for the European Union. *J. Renew. Sustain. Energy* **2020**, *12*, 123–145.
65. EDP Renovables España–Carbeira. Initial project document for the Carbeira Wind Farm Project with a Capacity of 62 MW and Its Evacuation Infrastructure in the TT.MM of Cerdido, Moeche, As Somozas, Valdoviño and As Pontes (A Coruña). Available online: https://sede.miteco.gob.es/portal/site/seMITECO/navServicioContenido (accessed on 5 February 2021).
66. Green Capital Power-A Pobra. Available online: https://sede.miteco.gob.es/portal/site/seMITECO/navServicioContenido (accessed on 5 February 2021).
67. Green Capital Power-Lavandeira. Initial Document. Lavandeira Wind Farm Project of 51.975 MW, 30 kV Lines, 30/220 kV Electrical Substation and 220 kV Electrical Line for Evacuation. TT.MM. Vilasantar and Curtis (A Coruña). Available online: https://sede.miteco.gob.es/portal/site/seMITECO/navServicioContenido (accessed on 5 February 2021).
68. Baseera, M.A.; Rehmanb, S.; Meyerc, J.P.; Alamd, M.M. GIS-based site suitability analysis for wind farm development in Saudi Arabia. *Energy* **2017**, *141*, 16. [CrossRef]
69. Sánchez-Lozano, J.M.; Garcia-Cascales, M.S.; Lamata, M.T. Identification and Selection of Potential Sites for Onshore Wind Farms Development in Region of Murcia, Spain. *Renew. Energy* **2014**, *73*, 311–324. [CrossRef]
70. Ali, S.; Taweekun, J.; Techato, K.; Waewsak, J.; Gyawali, S. GIS based site suitability assessment for wind and solar farms in Songkhla, Thailand. *Renew. Energy* **2014**, *132*, 35. [CrossRef]
71. Stojčetović, B.; Živković, Ž.; Nikolić, Đ. AHP application for wind farm site selection: Case Kostolac. In Proceedings of the 6th International Symposium on Environmental and Material Flow Management—EMFM, Bor, Serbia, 2–4 October 2016.
72. Vagiona, D.; Karapanagiotidou, X. Strategic Environmental Impact Assessment for Onshore Windfarm Siting in Greece. *Environments* **2019**, *6*, 94. [CrossRef]
73. Aramburu Maqua, M.P.; Escribano Bombín, R.; Aguiló Alonso, M.; Albaladejo Montoso, J.; Carrasco González, R.M.; Castillo Sánchez, V. *Guidelines for the Preparation of Physical Environment Studies*, 4th ed.; Fundación Conde del Valle de Salazar: Madrid, Spain, 2014.
74. Al-Shabeeb, A.; Al-Adamat, R.; Mashagbah, A. AHP with GIS for a Preliminary Site Selection of Wind Turbines in the Northwest of Jordan. *Int. J. Geosci.* **2016**, *7*, 1208–1221. [CrossRef]
75. Grassi, S. Large scale technical and economical assessment of wind energy potential with a GIS tool: Case study Iowa. *Energy Policy* **2012**, *1*, 61. [CrossRef]
76. Tudela Serrano, M.L.; Molina Ruiz, J. Environmental feasibility study for the location of wind farms in a municipality of the Region of Murcia. University of Murcia. *Geogr. Pap.* **2005**, *41-42*, 41–42;
77. Diaz Cuevas, M.P. GIS-Based Methodology for Evaluating the Wind-Energy Potential of Territories: A Case Study from Andalusia (Spain). *Energies* **2018**, *11*, 2789. [CrossRef]
78. Chamanehpour, E.; Ahmadizadeh, S.; Akbarpour, A. Site selection of wind power plant using multi-criteria decision-making methods in GIS: A case study. *Comput. Ecol. Softw.* **2017**, *7*, 49–64.
79. Guerrero Hoyos, B.G.; Vélez Macías, F.D.J.; Morales Quintero, D.E. Wind Energy and Territory: Geographic Information Systems and Multi-Criteria Decision Methods in La Guajira (Colombia). *Environ. Dev.* **2020**, *23*, 44. [CrossRef]
80. *Resolution of October 18, 2021, of the Directorate General of Natural Heritage, Updating the Delimitation of the Priority Areas of Reproduction, Feeding, Dispersion and Local Concentration of Birds Included in the Galician Catalogue of Endangered Species, and Providing for the Publication of the Existing Protection Areas in the Autonomous Community of Galicia in Which Measures for the Protection of Avifauna Against Collision and Electrocution in High-Voltage Power Lines will be Applied. DOG No. 208, of 28/10/2021*; Galicia Council: Santiago de Compostela, Spain, 2021.
81. Hansen, H.S. GIS-based Multi-Criteria Analysis of Wind Farm Development. In Proceedings of the 10th Scandinavian Research Conference on Geographical Information Science, ScanGis 2005, Stockholm, Sweden, 13–15 June 2005; Hauska, H., Tveite, H., Eds.; Department of Planning and Environment: Stockholm, Sweden, 2005; pp. 75–87.