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Linking Land Use and Land Cover Changes and Ecosystem Services' Potential in Natura 2000 Site "Nordul Gorjului de Vest" (Southwest Romania)

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Abstract: Considering that land use and land cover (LULC) change is one of the most important challenges to biodiversity today, we used Copernicus products to analyze LULC changes at the level of the "Nordul Gorjului de Vest" Natura 2000 site (Romania) from 1990 to 2018. The interpretation of the impact of these changes on areas with very high potential for three regulating ecosystem services (ESs) (local climate regulation, regulation of waste, and water purification) was performed. Forest habitats are the major LULC class category in the "Nordul Gorjului de Vest" Natura 2000 site, with broad-leaved forest as the dominant forest class. In terms of areas lost or gained by the different LULC classes for each analyzed time interval, most transformations took place in the period 2000–2006, changes which were also reflected in the overall study period (1990–2018). During this time frame, the conversion of transitional forest shrubs into broad-leaved forest, which is the second largest transition in terms of absolute area changed, led, in terms of contribution rates, to an increase in the areas with very high potential for two of the three analyzed ESs. The conversion of transitional woodland shrub into broad-leaved forest was conductive only to synergy for all the pairwise interactions between the three ESs.

Keywords: land use and land cover; LULC transition; drivers; forests; ecosystem service

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1. Introduction

Natural landscape patterns are the result of the interaction between the natural environment, with its particular abiotic conditions, and biological and social factors [1,2]. Nowadays, an emergent worldwide problem is that landscapes are facing rapid pattern changes. These changes are the consequences of man-made activities like economic development and urban sprawl [3] and intensive agricultural practices and deforestation [4], alongside the increase in population and, therefore, a boost in consumption patterns [5]. The results of land use changes manifest in the form of ecosystem degradation [6] and land and habitat fragmentation [7]. Land use and land cover (LULC) changes have implications for the storage and exchange of elements in ecological systems [8], leading to alterations in ecosystem services (Ess)' provision and trade-offs [9,10]. ESs are considered tools to promote the goods and services obtained from processes and functions that take place in natural ecosystems to benefit human wellbeing [11–13]. Roy et al. [14] divide ESs into four major categories: provisioning services—food production; regulating services—climate regulation; supporting services—pollination; and cultural services—recreation. Any intervention in land use and land cover made by humans to acquire different ESs that can enhance their health and wellbeing affects other ESs in a positive or negative manner [15]. Maintaining healthy ecosystems [16] and assessing and understanding the changes that occur in landscape patterns are of great use for the conservation of ESs, land resource management, and sustainable development [17–19]. The extent to which composition and structure changes happen in landscape patterns can be quantified using algorithms in the form of landscape metrics [20]. The study conducted by Li W. et al. [21] in mountainous areas reveled that the major component that induced changes in ecosystem health was landscape configuration due to human activities, with a higher degree of change in the higher topographic relief parts. Yohannes et al. [22], based on a landscape structural analysis, carried out research on the Beressa watershed in the Ethiopian Highlands and found that natural vegetation, grassland, and barren land areas had been downsized. Meanwhile, an expansion in farmland, plantation, and settlement mosaic areas had occurred as a consequences of erosion processes that induced changes in landscape configuration.

As legal tools with the purpose of natural landscape conservation, cultural ecosystem services' preservation, and the minimization of pressures from uncontrolled human activities [23–25], protected area networks have been created and applied worldwide [26]. The world's largest coordinated network of protected areas, well known as NATURA 2000, is found in Europe and covers 18.2% of all EU member states' terrestrial areas [27,28]. The Natura 2000 network started from Bird Directive 79/409/EEC and Habitats Directive 92/43/EEC to ensure European biodiversity conservation [29]. The effectiveness of protected areas lies in the implementation of useful management strategies that can monitor and asses the external factors that affect habitat functions [30,31]. Using GIS techniques and land change modeling, Rafaai et al. [32] found that distance from the forest edge, followed by distance from the road and soil type were the most notable factors to induce land use and land cover changes in the Tasek Bera Ramsar Site, Malaysia. Moreover, they concluded that further forest loss was predicted to happen by 2028 due to an increase in agriculturally used areas. Similar findings were reported by Ma et al. [33], where agricultural land expansion was the most significant driver of landscape fragmentation and forest and habitat loss in the studied area of Lishui city in East China. The research conducted by Garcia et al. [5] on different types of protected areas of the Araguaia River Basin in Brazil reveled that different land tenures are the drivers of landscape changes. Within this catchment area, indigenous lands and strictly protected areas exhibited an increase in natural areas with less fragmentation rates of forest and grassland, meanwhile sustainable use had experienced an increase in agricultural areas. In a recent study, Pompeu et al. [34] investigated the landscape fragmentation in the Cerrado area of Brazil and discovered that, even if the northern part of the region, where most of the vegetation was concentrated, showed less fragmentation, habitat loss due to an increase in land-clearing rates might happen. After the communist regime's fall in 1989, Romania underwent major changes in terms of engaging in environmental issues and implementing environmental management strategies [35]. For example, in 1991, Romania created the National Integrated Environmental Monitoring System, with the objective of monitoring the quality of environmental factors and biodiversity. With the accession to the European Union in 2007, Romania became part of the Natura 2000 network and channeled its efforts into the preservation of natural habitats and the survival of endangered species [36]. Nonetheless, changes in LULC can happen, caused by the transfer of ownership, from public to private agents, of many forest areas alongside protected areas [37] and some other external factors like the expansion of road infrastructure projects [38]. Moreover, in 2018, Romania adopted the LULUCF Regulation (EU) 2018/841, updated in 2023, in order to achieve the European Union's objective of reducing greenhouse gas emissions as well as its long-term climate objectives.

LULC change is one of the most important challenges today, occupying a top position as a concern at local, regional, and global scales [39]. In order to understand the trends and human pressure on biodiversity and other natural and anthropogenic processes, LULC datasets provide a starting point [40]. Sustainable development at multiple spatial scales, including urban ones, has ES evaluation as an essential step, based on LULC data and the matrix method [41]. Whether it is about the influence of LULC changes on water quality [42] or the relation between climate change and the distribution of suitable habitats for Himalayan bumblebees [43], LULC data are essential to analyze ESs.

In light of the above, the aim of this study was to analyze how LULC changes (between 1990 and 2018) at the level of the ''Nordul Gorjului de Vest" Natura 2000 site (SW Romania) affected the spatio-temporal variation in the potential for ecosystem services, aiming primarily to establish a simple methodological framework which can be applied on a large scale to every area of this type. The assessment of ESs in Natura 2000 sites is crucial for improving their management effectiveness [44]. Therefore, we addressed the research questions as follows: (1) What is the distribution of each LULC category at the level of the studied area, for each reference year? (2) How does the transition matrix for each time interval appear? (3) What are the net change (gain and loss) in each LULC category for each time step and the annual rate of change? (4) What is the impact of the different drivers on the main LULC net changes, and what is the strength of the interaction between the drivers of LULC net changes? (5) What are the spatio-temporal distribution of ecosystem services and the degree of interaction between them? (6) How are the areas with a very high potential for ecosystem services impacted by LULC transitions? We hypothesized that the most profound transformations took place in the periods when Romania was not covered by an appropriate environmental legislation and that the climate played an important role as a driver in this process. We also expected that the dynamics of the potential for ecosystem services would be influenced by those LULC transitions that would lead to an increase in the area of forests, considering their representation at the level of the studied area.

2. Materials and Methods

2.1. Study Area

The Natura 2000 sites are very sensitive areas with respect to biodiversity, and land use can affect positively or negatively the conservation status of the habitats and/or species. Out of the whole area covered by the Natura 2000 sites in Romania, an important percentage (over 14%) is located in the SW region [45]. The designation of big sites in the north of the Oltenia region (Nordul Gorjului de Est, Nordul Gorjului de Vest, Frumoasa, etc.) created a long corridor of protected areas from the Danube river to the Olt river valley.

In the Natura 2000 site ROSCI0129 "Nordul Gorjului de Vest", structural differentiations can be noted according to the large relief units that follow from north to south: the Carpathian Mountains, the Getic Sub Carpathians, and the Getic Piedmont. The transition from the harder rocks of the Carpathians, with an uneven relief, slopes, and high fragmentation but well protected by forests, to the softer sedimentary rocks, less resistant to erosion, of the Sub Carpathians and the Getic Piedmont, with moderate slopes but lacking the effective protection of the forests, can be captured in a relation of the current dynamics of the relief, in two morphodynamic levels—montane and hilly.

The territory on which the Natura 2000 site ROSCI0129 "Nordul Gorjului de Vest" is located is part of the alpine and continental biogeographical region and the Southern Carpathian ecological region. The area of the site is 873.11 km^2, that is, approximately 0.64% of the total area of Romania (Figure 1). The high elevational amplitude (1748 m) and the predominant slopes of the mountainsides, including the forest fund, which exceed 31°, demonstrate great vulnerability to erosion, landslides, and destructive actions due to the wind. Through the extreme altitudinal values and the hypsometric differences mentioned, the study area holds the absolute record of elevation in relation to other existing natural protected areas in Romania. Among all the types of natural vegetation in this site, forests and meadows have the greatest importance in the region's economy and landscape.

2.2. Data Acquisition

LULC data were acquired as a CORINE land cover product from the Copernicus site (https://www.copernicus.eu/ accessed on 14 September 2023), at a 100 m resolution, in the form of 44 LULC thematic classes, ranging from continuous urban fabric to sea and ocean. These data were available for five reference years: 1990 (temporal extent: 1986–1998), 2000 (2000 +/− 1 year), 2006 (2006 +/− 1 year), 2012 (2011–2012), and 2018 (2017–2018). The analysis was restricted only for the period 1990–2018 due to the limited availability of

Copernicus data. In order to match the LULC classes between the reference years, and for a more comprehensive understanding of the changes between the years, we proceeded to reclassify the original LULC classes, reducing their number to 10: urban areas, agricultural areas, pastures, broad-leaved forest, coniferous forest, mixed forest, natural grasslands, transitional woodland shrub, sparsely vegetated areas, and water bodies. Considering that the site had been planned especially for the protection of forests and their fauna, we did not proceed to reclassify the forest types in a single class.

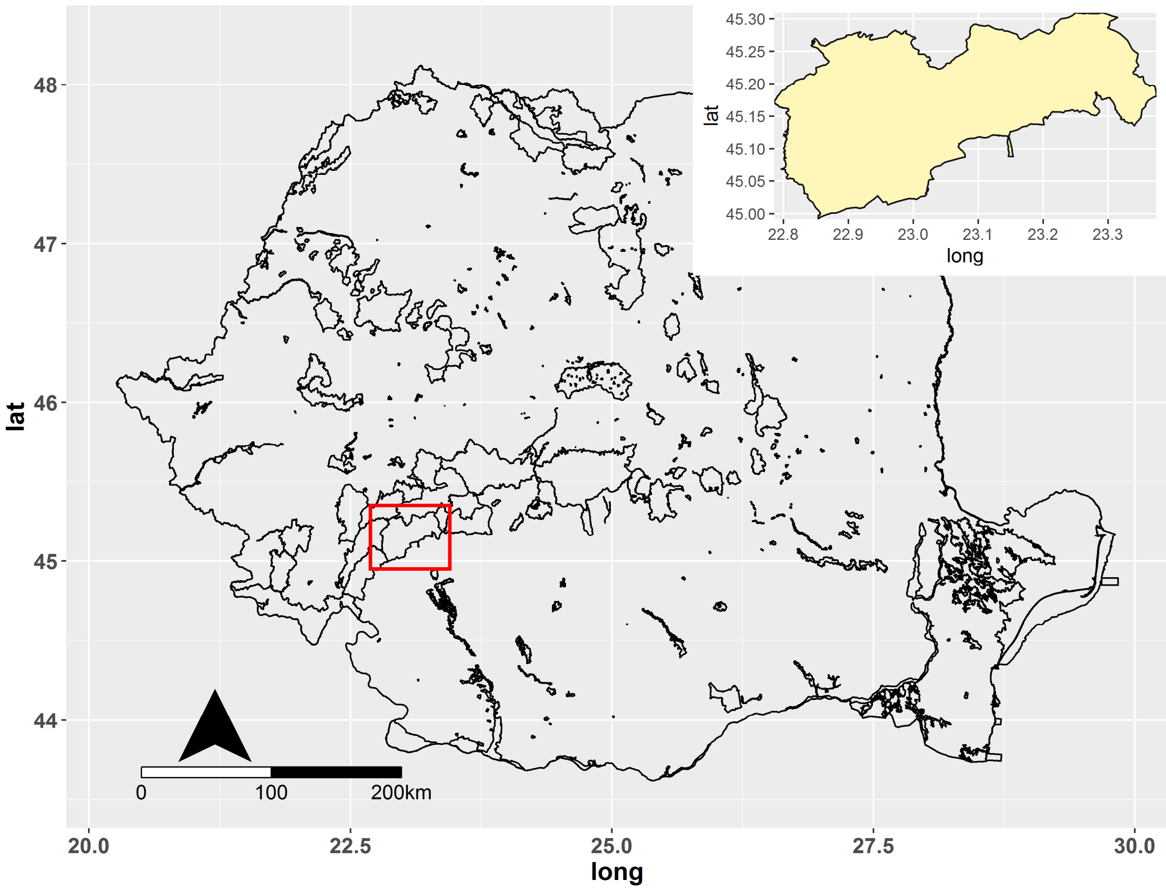

Figure 1. Location of the study area. In the background is displayed the map of Natura 2000 SCI (sites of community importance) of Romania and, in the inset, the "Nordul Gorjului de Vest" site.

2.3. Modeling the Drivers of LULC Change

To account for the impact of different drivers on LULC change during the whole studied period (1990–2018), we focused on those transitions that involved the classes that had the largest surface coverage at the level of the studied area (forest classes lumped together) and those classes that had undergone the greatest area change over time (transitional woodland shrub loss, natural grassland gain, and water bodies' loss), excluding the urban ones. In the case of forests, we focused on broad-leaved forest gain and loss, coniferous forest loss, and mixed forest loss (Figure 2). In the case of broad-leaved forest, considering that it was the most widespread type of forest in the studied area, we analyzed both gain and loss under the influence of the drivers in the time interval mentioned above. For this purpose, we fitted a binary logistic regression model for LULC classes' gain and loss during the overall study period (1990–2018), setting the dependent variable as 1 if a given pixel showed gain or loss for the respective LULC class and 0 if that LULC class remained unchanged (persistence). The area under the curve (AUC) of the receiver-operating characteristic (ROC) plot was used to assess the model's accuracy [46]. AUC values between 0.5 and 0.7 were considered low (poor model performance), while values between 0.7 and

0.9 and >0.9 were moderate and high, respectively [47]. The odds ratio, calculated as the exponential of the estimated regression coefficient β, ranged from 0 to 1 when the odds ratio was smaller than 1 (decreasing the odds) and also from 1 to positive infinity, for a coefficient greater than 1 (increasing the odds). An odds ratio coefficient of 1 left the odds unchanged [48].

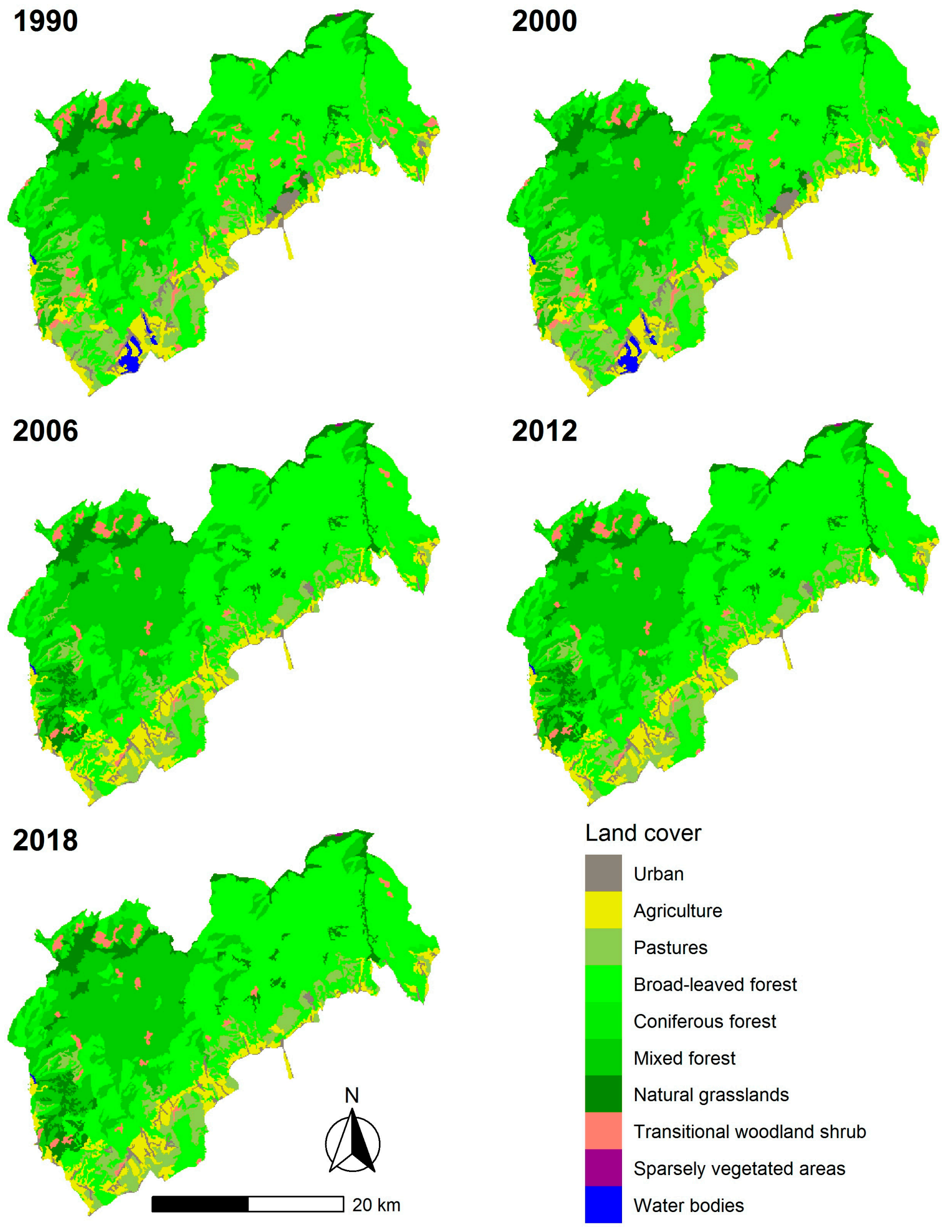

Figure 2. LULC maps by year in the "Nordul Gorjului de Vest" Natura 2000 site.

As independent variables, 28 predictors (drivers) were chosen, clustered in four categories (Table S1): *climatic* drivers (19 bioclimatic variables from the WorldClim database—https://www.worldclim.org/ accessed on 14 September 2023), *biophysical* drivers (6 variables), including soil data (soil organic carbon, nitrogen, and soil pH, from SoilGrids—https://soilgrids.org/ accessed on 14 September 2023) and topographic variability (elevation, aspect, and slope derived from SRTM digital elevation data—https://srtm.csi.cgiar.org/srtmdata/ accessed on 14 September 2023), *anthropogenic* drivers (population density, from WorldPop—https://hub.worldpop.org/ accessed on 14 September 2023), and *location* drivers (distance to roads, distance to water courses). The original resolution of the LULC maps (100 m) was kept for all the predictors. We used a variance inflation factor (VIF) to check the predictors for collinearity with the *usdm* library in R version 1.1-18 [49]. After excluding the collinear variables (correlation coefficient threshold of 0.7), the linear correlation coefficients ranged between 0.003 and 0.690 (Table S2), finally retaining 13 variables with a VIF value lower than 10: bio2, bio9, bio11, bio14, bio15, nitrogen, soil carbon, soil pH, aspect, slope, roads Euclid, water Euclid, and pop dens (Table S1; Figure S2). All statistical analyses were performed using the R software 3.6.2 [50].

2.4. LULC Transition Matrix, Gain and Losses of LULC Classes, Net Change

In order to obtain the main temporal transitions in the studied region between two reference years, we used the *crossTabulate* function in the *lulcc* R package version 1.0.4 [51] to obtain a transition matrix of the LULC maps for the respective years. These computed LULC change matrixes were further used to assess the gains and losses of the LULC categories for each of the periods—1990–2000, 2000–2006, 2006–2012, and 2012–2018—and for the overall study period, i.e., 1990–2018. A transition matrix provides information about an area of the LULC categories that remains unchanged (diagonal of the matrix) and also indicates the area of classes that move to other LULC categories [52,53]. The sum of the values of the rows of the transition matrix represents the area of the LULC classes at time 1, while the sum of the values of the columns lists the area for time 2 [52,53]. Moreover, the difference between the row totals and the values of the matrix's diagonal (persistence) shows the losses of each LULC class, and the difference between the column totals and persistence expresses the gains [52,53]. The net change in an LULC class was calculated as a difference between the gains and losses of the respective class in a particular period of time.

2.5. Annual Rate of Change and Landscape Metrics

The annual rate of change in LULC classes for each period mentioned above was calculated with the formula proposed by Teferi et al. [53]. Significant changes in the LULC classes over the whole studied period (1990–2018) were determined with the chi-square goodness-of-fit test [54].

In order to evaluate the state of fragmentation of the LULC classes present in the studied area for each of the periods, three indices were used: the number of patches (NP), the aggregation index (AI), and edge density (ED). The *landscapemetrics* R library version 1.1 [55] was used. The number of patches (NP) represents all the patches for an LULC class in a reference year. The aggregation index (AI) is an aggregation metric expressed in a percentage and represents the number of like adjacencies divided by the theoretical maximum possible number of like adjacencies for that class. The edge density (ED) is an area and edge metric (expressed in meters/hectare) and shows the sum of all the edges of a class in relation to the landscape area.

2.6. Ecosystem Services' Evaluation

2.6.1. Mapping Ecosystem Services

Through this study, we tried to present a quick way to evaluate the ES in a certain area and integrate this concept with the LULC spatio-temporal changes as a benchmark in Natura 2000 approaches. Therefore, our goal was not to study in detail the ES provided by the study area but to emphasize the link between the distribution and changes in the LULC classes over time and the spatio-temporal distribution of the potential for ES at the level of the studied area, as an essential element, considering the management of Natura 2000 areas. We used a matrix approach [56] in order to map the ES potential at the level of the studied area. This method links the spatial units (e.g., the LULC classes used here) arranged on the *y*-axis with different ESs disposed on the *x*-axis, grouped into three categories (regulating, provisioning, and cultural services) [56]. Three regulating ESs [56] were analyzed: local climate regulation, regulation of waste, and water purification. An ES potential indicates the hypothetical level of an ecosystem service that can be provided in a region, based on current land use and ecosystem conditions [56,57]. Since our study refers to a long period of time (1990–2018), we considered it appropriate to approach an ES from the point of view of its potential, considering that ecosystem service potential is recommended to be viewed for the long-term [57]. This potential was ranked on a relative scale from 0 to 5:0 (no relevant potential), 1 (low relevant potential), 2 (relevant potential), 3 (medium relevant potential), 4 (high relevant potential), and 5 (very high relevant potential) [56]. The mapping of ESs was conducted for each reference year. Furthermore, for each time interval (including the overall study period), the spatial-temporal variations in the three ESs considered in this study were mapped. All these analyses were carried out in R 4.4.0, especially with the *raster* library [58].

2.6.2. Assessing the Effect of LULC Transitions on Ecosystem Service Potential

LULC transitions (different types of land use transfer) influence the change in ESs [59,60]. To evaluate the impact of LULC transfer on changes in areas with a very high potential for the three regulating ESs for the overall study period (1990–2018), we used an approach based on Li and Wu [59] and Pan et al. [60]. Following this method, we obtained the contribution rate (positive or negative) of each LULC transition to the increase or decrease in areas of very high potential for the three ESs. We considered for this analysis only those LULC transitions that had been involved in the modification of areas with a very high potential (for a certain ES), which were related only to forests classes, in the case of local climate regulation and water purification ESs, and with forests and water bodies for the regulation of waste service.

2.6.3. Ecosystem Service Interactions

Interactions between ESs have been described at different scales, and LULC transfer affects these interactions [61]. To analyze the interactions for pairwise combinations of ESs, we followed the methods proposed by Gomes et al. [61], which first created a map of temporal changes (1990–2018) for each ES (by subtracting two rasters), tailed by a reclassification of these maps on a scale from −1 (decrease) to 1 (increase). Then, we combined these reclassified maps for each pair of ESs in order to depict the spatial distribution of different types of interactions, expressed in terms of synergies (win–win or both positive changes), trade-offs (positive–negative; negative–positive), or dis-synergies (lose–lose or both negative changes) [61]. Synergies involved a positive improvement in both ESs, trade-offs represented a decrease in one ES in exchange for an increase in another, while dis-synergies represented a loss in both ESs [62]. Moreover, in order to demonstrate the effect of LULC transitions on these interactions, we chose three main transitions at the level of the studied area: transitional woodland shrub → broad-leaved forest, pastures → broad-leaved forest, and broad-leaved forest → transitional woodland shrub. For this purpose, we clipped the reclassified maps (temporal changes) with a mask that contained only the pixels representing a particular transition type between 1990 and 2018, applying the method presented in Gomes et al. [61].

A flowchart of the statistical methodological approach is depicted in Figure S1.

3. Results

3.1. LULC Change Dynamics and LULC Net Change (Gain and Loss)

The LULC maps for the studied period (1990–2018) are shown in Figure 2. Regardless of the analyzed period, the dominant LULC categories in the "Nordul Gorjului de Vest" Natura 2000 site were forests (broad-leaved forest, coniferous forest, and mixed forest), covering 73.559% in 1990, 74.663% in 2000, 76.873% in 2006, 77.244% in 2012, and 77.164% in 2018 (Table 1), and pastures, with 8.679% in 1990, 8.674% in 2000, 7.087% in 2006, 7.247% in 2012, and 7.247% in 2018 (Table 1). From 1990 to 2000, the highest area decrease was observed in the transitional woodland shrub (31.140%; annual rate of deforestation of −3.730, Table 2), which lost 10.36 km^2, with a net loss of 9.56 km^2 (Figure 3, Table 3), while the highest increase was observed in broad-leaved forest (1.898%; annual rate of change of 0.188, Table 2), which gained 8.45 km^2 (net gain of 7.82 km^2) (Figure 3, Table 3). In the following time interval, 2000–2006, water bodies showed the most dramatic area decline (95.281%; annual rate of change of −50.894, Table 2), with a loss of 5.25 km^2 (net loss of 5.25 km^2) (Figure 3, Table 4). Transitional woodland shrub showed the second-highest decrease (37.795%; annual rate of change of −7.912, Table 2), except for urban habitats, with a loss of 14.70 km^2 (net loss of 7.99 km^2) (Figure 3, Table 4), followed by pastures (18.299%; annual rate of change of −3.368, Table 2), which had the highest loss (34.86 km^2) observed in this time frame and a net loss of 13.86 km^2 (Figure 3, Table 4). Natural grasslands registered the greatest area increase (42.103%; annual rate of change of 5.856, Table 2) in this period of time, gaining 22.74 km^2, and a net gain of 16.29 km^2 (Figure 3, Table 4). However, the highest gain was in broad-leaved forest (25.01 km^2), representing a net gain of 15.73 km^2 (Figure 3, Table 4). In the next two time periods, 2006–2012 and 2012–2018, no important decreases in the surface areas of the classes were observed. Nonetheless, between 2006 and 2012, the highest net loss was observed in agricultural land (6.86 km^2) (Figure 3, Table 5), and the highest net gain was in broad-leaved forest (2.94 km^2), followed by natural grasslands (net gain of 1.66 km^2) (Figure 3, Table 5). Between 2012 and 2018, broad-leaved forest registered the highest net loss (0.60 km^2), and transitional woodland shrub registered the opposite (net gain of 0.49 km^2) (Figure 3, Table 6). During the entire studied period (1990–2018), water bodies lost almost their entire area in 1990 (95.264%; annual rate of change of −10.892, Table 2), followed by the transitional woodland shrub class (55.179%; annual rate of change of −2.867, Table 2), while natural grasslands increased the most in terms of their surface area (46.975%; annual rate of change of 1.375. Table 2). In this time interval, the highest net loss was observed in the transitional woodland shrub class (16.94 km^2) and in pastures (12.50 km^2), and the highest net gain was in broad-leaved forest (25.89 km^2) and natural grasslands (18.17 km^2) (Figure 3, Table 7). Only the transitional woodland shrub class and water bodies showed a significant overall (1990–2018) change in the studied area (Table 8).

Table 1. LULC class characteristics of the study area.

Land Cover Type	1990		2000		2006		2012		2018	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Urban	21.31	2.440	21.33	2.442	13.25	1.517	13.69	1.567	13.69	1.567
Agriculture	58.69	6.721	58.60	6.711	58.19	6.664	51.33	5.878	51.33	5.878
Pastures	75.78	8.679	75.74	8.674	61.88	7.087	63.28	7.247	63.28	7.247
Broad-leaved forest	411.98	47.185	419.80	48.081	435.53	49.882	438.47	50.219	437.87	50.150
Coniferous forest	22.16	2.538	22.14	2.535	21.20	2.428	21.31	2.440	21.10	2.416
Mixed forest	208.12	23.836	209.96	24.047	214.47	24.563	214.66	24.585	214.77	24.598
Natural grasslands	38.68	4.430	38.69	4.431	54.98	6.297	56.64	6.487	56.85	6.511
Transitional woodland shrub	30.70	3.516	21.14	2.421	13.15	1.506	13.27	1.519	13.76	1.575
Sparsely vegetated areas	0.20	0.027	0.20	0.027	0.20	0.027	0.20	0.027	0.20	0.022
Water bodies	5.49	0.628	5.51	0.631	0.26	0.029	0.26	0.031	0.26	0.036
Total area	**873.11**	**100**	**873.11**	**100**	**873.11**	**100**	**873.11**	**100**	**873.11**	**100**

Table 2. LULC change trend (percentage difference) and annual rate of change (% in brackets) in the study area.

	(1990–2000)	(2000–2006)	(2006–2012)	(2012–2018)	(1990–2018)
Urban	0.093 (0.009)	−37.880 (−7.935)	3.320 (0.544)	0.000 (0.000)	−35.757 (−1.580)
Agriculture	−0.153 (−0.015)	−0.699 (−0.117)	−11.789 (−2.090)	0.000 (0.000)	−12.540 (−0.478)
Pastures	−0.052 (−0.005)	−18.299 (−3.368)	2.262 (0.372)	0.000 (0.000)	−16.495 (−0.643)
Broad-leaved forest	1.898 (0.188)	3.747 (0.613)	0.675 (0.112)	−0.136 (−0.022)	6.284 (0.217)
Coniferous forest	−0.090 (−0.009)	−4.245 (−0.723)	0.518 (0.086)	−0.985 (−0.165)	−4.783 (−0.175)
Mixed forest	0.884 (0.088)	2.148 (0.354)	0.088 (0.014)	0.051 (0.008)	3.195 (0.112)
Natural grasslands	0.025 (0.002)	42.103 (5.856)	3.019 (0.495)	0.370 (0.061)	46.975 (1.375)
Transitional woodland shrub	−31.140 (−3.730)	−37.795 (−7.912)	0.912 (0.151)	3.692 (0.604)	−55.179 (−2.867)
Sparsely vegetated areas	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
Water bodies	0.364 (0.036)	−95.281 (−50.894)	0.000 (0.000)	0.000 (0.000)	−95.264 (−10.892)

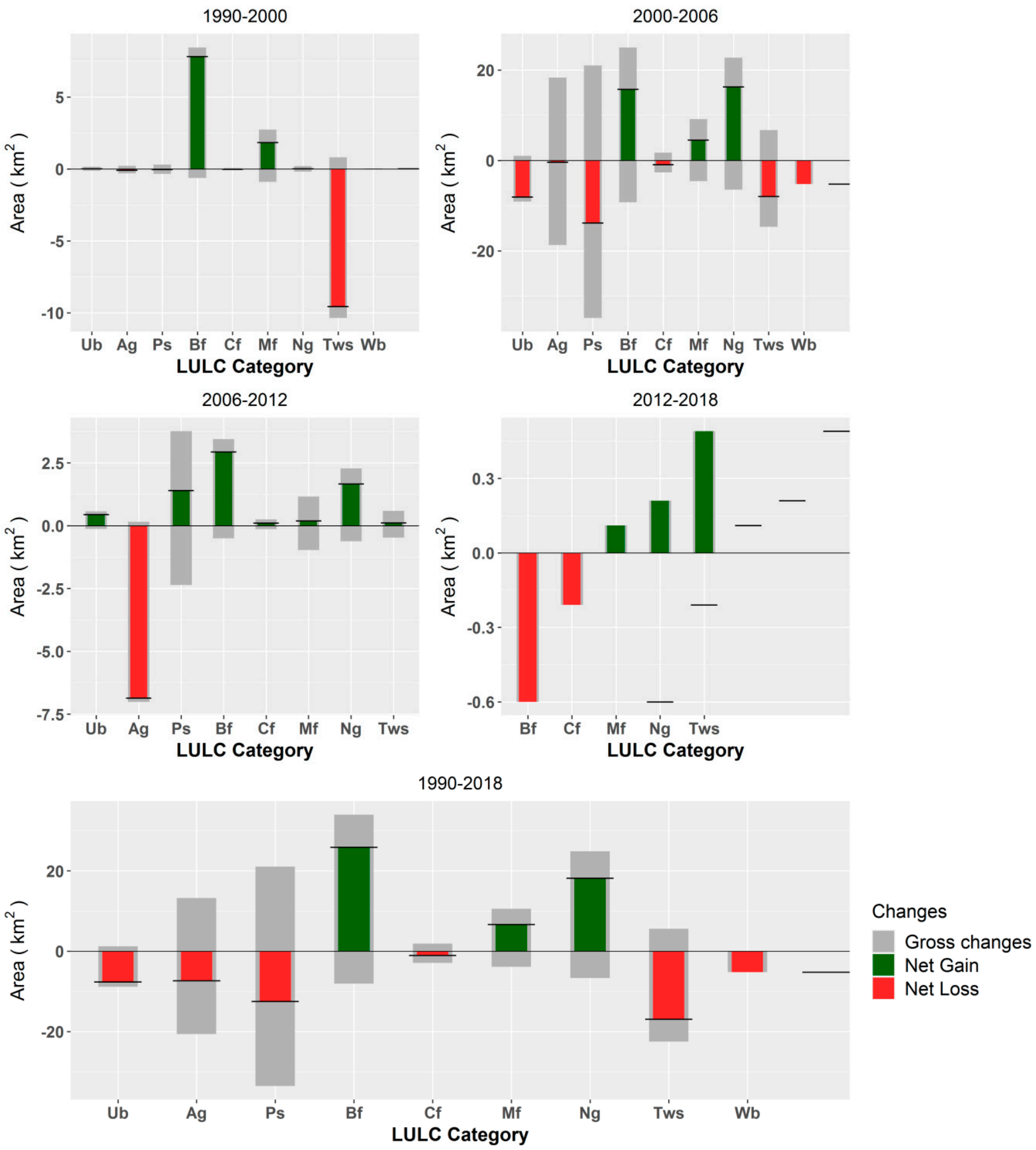

Figure 3. Gross changes (sum of all area gains and losses for a class), net gain, and net loss for each LULC class for the analyzed time intervals. See Tables 2–6 for the LULC class abbreviations.

Table 3. Land use and land cover (LULC) change matrix between 1990 and 2000.

	Ur	Ag	Ps	Blf	Cf	Mf	Ng	Tws	Swa	Wb	Total 1990	Loss
Ur	**21.18**	0.06	0.03	0.03	-	-	-	-	-	0.01	**21.31**	**0.13**
Ag	0.08	**58.38**	0.06	0.11	0.01	0.03	-	-	-	0.02	**58.69**	**0.31**
Ps	0.03	0.05	**75.44**	0.19	-	0.03	-	0.04	-	-	**75.78**	**0.34**
Blf	0.02	0.08	0.15	**411.35**	-	0.15	0.14	0.09	-	-	**411.98**	**0.63**
Cf	-	-	0.01	0.03	**22.07**	0.04	-	0.01	-	-	**22.16**	**0.09**
Mf	-	0.01	0.03	0.12	0.02	**207.22**	0.06	0.66	-	-	**208.12**	**0.90**
Ng	0.02	-	-	0.12	0.03	0.02	**38.49**	-	-	-	**38.68**	**0.19**
Tws	-	0.01	0.02	7.85	0.01	2.47	-	**20.34**	-	-	**30.70**	**10.36**
Swa	-	-	-	-	-	-	-	-	**0.20**	-	**0.20**	**-**
Wb	-	0.01	-	-	-	-	-	-	-	**5.48**	**5.49**	**0.01**
Total 2000	**21.33**	**58.60**	**75.74**	**419.80**	**22.14**	**209.96**	**38.69**	**21.14**	**0.20**	**5.51**	**873.11**	
Gain	**0.15**	**0.22**	**0.30**	**8.45**	**0.07**	**2.74**	**0.20**	**0.80**	**-**	**0.03**		
Net change	**0.02**	**−0.09**	**−0.04**	**7.82**	**−0.02**	**1.84**	**0.01**	**−9.56**	**-**	**0.02**		

Ur—Urban; Ag—Agriculture; Ps—Pastures; Blf—Broad-leaved forest; Cf—Coniferous forest; Mf—Mixed forest; Ng—Natural grasslands; Tws—Transitional woodland shrub; Swa—Sparsely vegetated area; and Wb—Water bodies.

Table 4. Land use and land cover (LULC) change matrix between 2000 and 2006.

	Ur	Ag	Ps	Blf	Cf	Mf	Ng	Tws	Swa	Wb	Total 2000	Loss
Ur	12.22	3.93	4.96	0.22	-	-	-	-	-	-	21.33	9.11
Ag	0.78	39.87	7.26	7.62	-	0.24	2.43	0.40	-	-	58.60	18.73
Ps	0.11	12.29	40.88	6.70	0.03	1.76	13.75	0.22	-	-	75.74	34.86
Blf	0.03	0.40	1.29	410.52	0.58	2.84	1.15	2.99	-	-	419.80	9.28
Cf	-	-	0.05	0.07	19.47	1.10	0.64	0.81	-	-	22.14	2.67
Mf	-	0.04	0.28	0.92	0.74	205.37	0.32	2.29	-	-	209.96	4.59
Ng	0.01	0.48	2.07	3.41	0.09	0.39	32.24	-	-	-	38.69	6.45
Tws	-	0.18	0.97	6.07	0.29	2.74	4.45	6.44	-	-	21.14	14.70
Swa	-	-	-	-	-	-	-	-	0.20	-	0.20	-
Wb	0.10	1.00	4.12	-	-	0.03	-	-	-	0.26	5.51	5.25
Total 2006	13.25	58.19	61.88	435.53	21.20	214.47	54.98	13.15	0.20	0.26	873.11	
Gain	1.03	18.32	21.00	25.01	1.73	9.10	22.74	6.71	-	-		
Net change	−8.08	−0.41	−13.86	15.73	−0.94	4.51	16.29	−7.99	-	−5.25		

Ur—Urban; Ag—Agriculture; Ps—Pastures; Blf—Broad-leaved forest; Cf—Coniferous forest; Mf—Mixed forest; Ng—Natural grasslands; Tws—Transitional woodland shrub; Swa—Sparsely vegetated area; and Wb—Water bodies.

Table 5. Land use and land cover (LULC) change matrix between 2006 and 2012.

	Ur	Ag	Ps	Blf	Cf	Mf	Ng	Tws	Swa	Wb	Total 2006	Loss
Ur	13.12	0.05	0.08	-	-	-	-	-	-	-	13.25	0.13
Ag	0.42	51.18	3.66	1.79	-	-	1.14	-	-	-	58.19	7.01
Ps	-	-	59.52	1.30	-	0.29	0.77	-	-	-	61.88	2.36
Blf	-	0.09	0.02	435.03	0.01	0.32	0.06	-	-	-	435.53	0.50
Cf	-	-	-	-	21.06	-	-	0.14	-	-	21.20	0.14
Mf	-	-	-	0.12	0.09	213.50	0.31	0.45	-	-	214.47	0.97
Ng	0.15	0.01	-	0.21	0.15	0.10	54.36	-	-	-	54.98	0.62
Tws	-	-	-	0.02	-	0.45	-	12.68	-	-	13.15	0.47
Swa	-	-	-	-	-	-	-	-	0.20	-	0.20	-
Wb	-	-	-	-	-	-	-	-	-	0.26	0.26	-
Total 2012	13.69	51.33	63.28	438.47	21.31	214.66	56.64	13.27	0.20	0.26	873.11	
Gain	0.57	0.15	3.76	3.44	0.25	1.16	2.28	0.59	-	-		
Net change	0.44	−6.86	1.40	2.94	0.11	0.19	1.66	0.12	-	-		

Ur—Urban; Ag—Agriculture; Ps—Pastures; Blf—Broad-leaved forest; Cf—Coniferous forest; Mf—Mixed forest; Ng—Natural grasslands; Tws—Transitional woodland shrub; Swa—Sparsely vegetated area; and Wb—Water bodies.

Table 6. Land use and land cover (LULC) change matrix between 2012 and 2018.

	Ur	Ag	Ps	Blf	Cf	Mf	Ng	Tws	Swa	Wb	Total 2012	Loss
Ur	13.69	-	-	-	-	-	-	-	-	-	13.69	-
Ag	-	51.33	-	-	-	-	-	-	-	-	51.33	-
Ps	-	-	63.28	-	-	-	-	-	-	-	63.28	-
Blf	-	-	-	437.87	-	0.11	-	0.49	-	-	438.47	0.60
Cf	-	-	-	-	21.10	-	0.21	-	-	-	21.31	0.21
Mf	-	-	-	-	-	214.66	-	-	-	-	214.66	-
Ng	-	-	-	-	-	-	56.64	-	-	-	56.64	-
Tws	-	-	-	-	-	-	-	13.27	-	-	13.27	-
Swa	-	-	-	-	-	-	-	-	0.20	-	0.20	-
Wb	-	-	-	-	-	-	-	-	-	0.26	0.26	-
Total 2018	13.69	51.33	63.28	437.87	21.10	214.77	56.85	13.76	0.20	0.26	873.11	
Gain	-	-	-	-	-	0.11	0.21	0.49	-	-		
Net change	-	-	-	−0.60	−0.21	0.11	0.21	0.49	-	-		

Ur—Urban; Ag—Agriculture; Ps—Pastures; Blf—Broad-leaved forest; Cf—Coniferous forest; Mf—Mixed forest; Ng—Natural grasslands; Tws—Transitional woodland shrub; Swa—Sparsely vegetated area; and Wb—Water bodies.

Table 7. Land use and land cover (LULC) change matrix between 1990 and 2018.

	Ur	Ag	Ps	Blf	Cf	Mf	Ng	Tws	Swa	Wb	Total 1990	Loss
Ur	**12.46**	3.50	4.98	0.37	-	-	-	-	-	-	**21.31**	**8.85**
Ag	0.92	**38.09**	7.62	8.50	-	0.23	2.95	0.38	-	-	**58.69**	**20.60**
Ps	0.08	7.91	**42.22**	8.33	0.02	1.80	15.22	0.20	-	-	**75.78**	**33.56**
Blf	-	0.33	1.10	**403.92**	0.27	2.99	1.09	2.28	-	-	**411.98**	**8.06**
Cf	-	-	-	0.07	**19.23**	1.11	0.81	0.94	-	-	**22.16**	**2.93**
Mf	0.01	-	0.15	0.85	0.67	**204.22**	0.46	1.76	-	-	**208.12**	**3.90**
Ng	0.16	0.49	2.10	3.28	0.24	0.41	**32.00**	-	-	-	**38.68**	**6.68**
Tws	-	-	0.98	12.55	0.67	3.98	4.32	**8.20**	-	-	**30.70**	**22.50**
Swa	-	-	-	-	-	-	-	-	**0.20**	-	**0.20**	**-**
Wb	0.06	1.01	4.13	-	-	0.03	-	-	-	**0.26**	**5.49**	**5.23**
Total 2018	**13.69**	**51.33**	**63.28**	**437.87**	**21.10**	**214.77**	**56.85**	**13.76**	**0.20**	**0.26**	**873.11**	
Gain	**1.23**	**13.24**	**21.06**	**33.95**	**1.87**	**10.55**	**24.85**	**5.56**	**-**	**-**		
Net change	**−7.62**	**-7.36**	**−12.50**	**25.89**	**−1.06**	**6.65**	**18.17**	**−16.94**	**-**	**−5.23**		

Ur—Urban; Ag—Agriculture; Ps—Pastures; Blf—Broad-leaved forest; Cf—Coniferous forest; Mf—Mixed forest; Ng—Natural grasslands; Tws—Transitional woodland shrub; Swa—Sparsely vegetated area; and Wb—Water bodies.

Table 8. Chi-square (χ^2) goodness-of-fit test for the LULC changes between 1990 and 2018 in the "Nordul Gorjului de Vest" Natura 2000 site.

Land Cover Type	Area (km^2)					χ^2
	1990	2000	2006	2012	2018	Goodness-of-Fit Test
Urban	21.31	21.33	13.25	13.69	13.69	4.365, df = 4, p = 0.358
Agriculture	58.69	58.60	58.19	51.33	51.33	1.109, df = 4, p = 0.892
Pastures	75.78	75.74	61.88	63.28	63.28	2.977, df = 4, p = 0.561
Broad-leaved forest	411.98	419.80	435.53	438.47	437.87	1.364, df = 4, p = 0.850
Coniferous forest	22.16	22.14	21.20	21.31	21.10	0.050, df = 4, p = 0.999
Mixed forest	208.12	209.96	214.47	214.66	214.77	0.184, df = 4, p = 0.996
Natural grasslands	38.68	38.69	54.98	56.64	56.85	7.492, df = 4, p = 0.112
Transitional woodland shrub	30.70	21.14	13.15	13.27	13.76	**12.726, df = 4, p = 0.012**
Sparsely vegetated areas	0.20	0.20	0.20	0.20	0.20	0, df = 4, p = 1
Water bodies	5.49	5.51	0.26	0.26	0.26	**13.985, df = 4, p = 0.007**

3.2. Landscape Metrics

During the analyzed time periods, no important changes were observed regarding the number of patches (NPs), the aggregation index (AI), and edge density (ED), for any LULC class, except for the transitional woodland shrub class and water bodies (Table 9). In the case of the forest classes, the most dominant habitat in the studied area, the values of the aggregation index were close to 100%, especially for broad-leaved forest and mixed forest, indicating that these classes were near-maximally aggregated, supported also by the not very high values of edge density for these LULC classes (ED) (Table 9). Furthermore, there was no important variation in time for the edge density (ED) of the forest classes, indicating a low deforestation rate over time (Table 9).

3.3. LULC Change Matrix

Between 1990 and 2000, the transitional woodland shrub class experienced the highest transition to other LULC classes, at 33.745% (10.36 km^2; Table 3) of its total area in 1990, especially to broad-leaved forest (60.570% of the total area of land use change; Table 3) and mixed forest (19.058% of the total area of land use change; Table 3), while the other LULC types remained almost unchanged (Table 3). In the second period (2000–2006), 95.281%, 69.534%, 46.025%, and 31.962% of the total areas in 2000 of water bodies, transitional woodland shrub, pastures, and agricultural areas moved to other classes (Table 4). The highest transition (in terms of the area lost compared to the previous year) was that of water bodies, the majority being converted into pastures (3.9% of the total area of land use change; Table 4), followed by the conversion of the transitional woodland shrub class, especially into broad-leaved forest (5.745% of the total area of land use change; Table 4). In this period, the highest transition in terms of absolute area converted was the conversion of pastures into natural grasslands (13.015% of the total area of land use change; Table 4), followed by the conversion of pastures into agricultural land (11.633% of the total area of land use change; Table 4). In the third (2006–2012) and fourth periods (2012–2018), no major changes were highlighted at the level of the LULC classes of the "Nordul Gorjului de Vest" Natura 2000 site (Tables 5 and 6). Considering the entire period of time analyzed (1990–2018), water bodies experienced the highest transition (in terms of the area lost compared to the previous year), the vast majority of this class being replaced by pastures (3.677% of the total area of land use change; Table 7). The second-highest transition was in the transitional woodland shrub class (73.289% of its total area in 1990; Table 7), mostly to the forest classes (15.314% of the total area of land use change; Table 7). Also, 44.286% and 35.099% of pastures' and agriculture's total areas in 1990 were converted into other classes, mostly natural grassland in the case of pastures (13.551% of the total area of land use change; Table 7) and broad-leaved forest (7.568% of the total area of land use change; Table 7) and pastures (6.784% of the total area of land use change; Table 7) in the case of agricultural areas. In terms of the absolute area changed, the highest transition was represented by the conversion of pastures into natural grassland (13.551% of the total area of land use change; Table 7), tailed by the conversion of transitional woodland shrub into broad-leaved forest (11.174% of the total area of land use change; Table 7).

Table 9. Number of patches (NPs), aggregation index (AI), and edge density (ED) at the class level, between 1990 and 2018.

Land Cover Type	1990			2000			2006			2012			2018		
	NP	AI	ED	NP	AI	ED	NP	AI	ED	NP	AI	ED	NP	AI	ED
Urban	51	73.8	2.72	50	73.8	2.72	62	60.3	2.51	60	60.7	2.57	60	60.7	2.57
Agriculture	53	81.4	5.29	51	81.4	5.28	52	78.5	6.00	43	79.3	5.13	43	79.3	5.13
Pastures	45	83.1	6.20	44	83.0	6.22	44	81.9	5.43	46	82.3	5.43	46	82.3	5.43
Broad-leaved forest	39	92.8	14.4	39	93.0	14.3	50	93.5	13.9	42	93.7	13.6	43	93.7	13.6
Coniferous forest	18	84.3	1.78	18	84.3	1.78	22	83.2	1.81	19	83.2	1.82	19	82.9	1.83
Mixed forest	44	93.2	7.10	45	93.0	7.38	48	92.8	7.73	46	92.8	7.66	46	92.8	7.66
Natural grasslands	40	82.5	3.34	41	82.5	3.33	46	81.2	5.01	46	81.2	5.15	46	81.2	5.17
Transitional woodland shrub	56	76.6	3.49	47	74.3	2.64	29	78.8	1.41	17	79.6	1.37	28	79.6	1.42
Sparsely vegetated areas	1	93.5	0.02	1	93.5	0.02	1	93.5	0.02	1	93.5	0.02	1	93.5	0.02
Water bodies	4	86.6	0.43	4	86.6	0.43	1	78.0	0.04	1	78.0	0.04	1	78.0	0.04

3.4. Drivers of LULC Changes

For broad-leaved forest, according to the logit model, the area under the ROC curve (AUC) was 0.791, indicating a good explanatory power of the selected drivers in explaining the gain of this class between 1990 and 2018 in the "Nordul Gorjului de Vest" Natura 2000 site (Table 10). The probability of broad-leaved forest gain increased especially with the increase in the annual mean diurnal range (bio2) and soil pH, being 5.105 time more likely at rising values of the annual mean diurnal range (bio2) and 1.260 more likely in areas with a high level of soil pH (Table 10). The same driver factors were involved in broad-leaved forest loss too, for the same time interval, showing that the probability of broad-leaved forest loss decreased with the increase in the annual mean diurnal range (bio2) values and increased with an increasing soil pH, the logit model having a good explanatory power, with an AUC value of 0.832 (Table 11). We found a weak positive correlation between these two variables (Table S2). Two climatic variables (precipitation of the driest month—bio14; precipitation seasonality—bio15) and soil pH increased the odds of mixed forest gain between 1990 and 2018 by factors of 1.156 (precipitation of driest month), 1.311 (precipitation seasonality), and 1.203 (soil pH) (Table 12). These three variables were weakly correlated (Table S2). The loss of coniferous forest increased with precipitation seasonality (bio15) and soil pH by factors of 1.133 and 1.219, respectively, and decreased with the increase in the pop dens variable (Table 13), the logit model having a good power (AUC = 0.838). There was no strong interaction between these variables (Table S2). The ROC test statistics for transitional woodland shrub loss (mostly to the forest classes) between 1990 and 2018 were good (AUC = 0.797; Table 14), indicating that precipitation seasonality (bio15) can be an important factor in these transitions, with most of the other driving factors' odds ratio near 1 (Table 14). The natural grasslands' gain (mostly from pastures) increased with the increasing in the mean temperature of the coldest quarter (bio11) and the precipitation of the driest month (bio 14) and decreased with an increasing annual mean diurnal range (bio2) and soil pH (Table 15), this logit model having the greatest explanatory power (AUC = 0.972). In the case of water bodies, the logit model did not produce any conclusive results.

Table 10. Maximum likelihood estimates of the logistic regression of **broad-leaved forest gain** between 1990 and 2018. β represents the regression coefficients between the land use types and the driving factors. See Table S1 for the drivers' description.

	Dependent Variable:		
	Broad-Leaved Forest Gain		
	Estimate (β)	**Std. Error**	**Odds Ratio**
aspect	−0.002 ***	0.000	0.998
bio11	−0.002 **	0.001	0.998
bio14	0.023 ***	0.006	1.023
bio15	0.037 ***	0.012	1.038
bio2	1.630 ***	0.151	5.103
bio9	−0.001 ***	0.000	0.998
nitrogen	−0.003 ***	0.000	0.997
pop dens	0.018 ***	0.001	1.018
roads Euclid	0.000 ***	0.000	1.000
slope	−0.013 ***	0.003	0.987
soil carbon	−0.002 ***	0.000	0.997
soil pH	0.231 ***	0.016	1.260
water Euclid	−0.000	0.000	0.999
Constant	−146.697 ***	12.563	0.000
Observations		30,700	
Log Likelihood		−7014.776	
Akaike Inf. Crit.		14,057.550	
AUC		0.791	

Note: ** $p < 0.01$; and *** $p < 0.001$.

3.5. Ecosystem Services' Evaluation

The maps of the three assessed regulating ESs—local climate regulation, regulation of waste, and water purification—for all the considered years, are depicted in Figures S3–S5, indicating that the "Nordul Gorjului de Vest" Natura 2000 site has a large area with high and very high relevant potentials for ESs, in particular due to the large percentage of forest habitats which cover the area. Figures 4–6 indicate the spatial-temporal variations in the potential for the three ESs analyzed. As a general characteristic, these variations were more pronounced in 2000–2006, for all three services, a spatial pattern which also appeared in the overall study period (1990–2018). Each analyzed time interval indicated a percentual increase and decrease in these ESs' potential, with the highest increase in the case of the water purification ES, in the period of 1990–2018, and the highest decrease between 2000 and 2006 for the regulation of waste ES (Table 16).

Table 11. Maximum likelihood estimates of the logistic regression of **broad-leaved forest loss** between 1990 and 2018. β represents the regression coefficients between the land use types and the driving factors. See Table S1 for the drivers' description.

	Dependent Variable:		
	Broad-Leaved Forest Loss		
	Estimate (β)	**Std. Error**	**Odds Ratio**
aspect	−0.003 ***	0.001	0.997
bio11	−0.010 ***	0.002	0.990
bio14	0.097 ***	0.011	1.102
bio15	−0.025	0.024	0.975
bio2	−0.458 **	0.227	0.632
bio9	−0.003 ***	0.001	0.997
nitrogen	0.0002	0.001	1.000
pop dens	−0.077 ***	0.009	0.925
roads Euclid	0.0002 ***	0.00002	1.000
slope	−0.040 ***	0.006	0.960
soil carbon	−0.004 ***	0.001	0.995
soil pH	0.379 ***	0.030	1.461
water Euclid	−0.0001 ***	0.00001	0.999
Constant	15.785	19.224	7,163,980.64
Observations		28,794	
Log Likelihood		−2215.201	
Akaike Inf. Crit.		4458.403	
AUC		0.832	

Note: ** $p < 0.01$; and *** $p < 0.001$.

Table 12. Maximum likelihood estimates of the logistic regression of **mixed forest gain** between 1990 and 2018. B represents the regression coefficients between the land use types and the driving factors. See Table S1 for the drivers' description.

	Dependent Variable:		
	Mixed Forest Gain		
	Estimate (β)	**Std. Error**	**Odds Ratio**
aspect	−0.005 ***	0.000	0.995
bio11	0.063 ***	0.007	1.065
bio14	0.145 ***	0.011	1.156
bio15	0.271 ***	0.018	1.311
bio2	2.795	203.674	16.362
bio9	−0.005 ***	0.001	0.995
nitrogen	−0.002	0.001	0.998
pop dens	−0.118 ***	0.018	0.888
roads Euclid	−0.000	0.000	1.000
slope	−0.063 ***	0.006	0.938
soil carbon	−0.003 ***	0.001	0.997
soil pH	0.185 ***	0.028	1.203
water Euclid	−0.001 ***	0.000	0.999
Constant	−257.654	16,701.270	1.26558×10^{-112}
Observations		14,995	
Log Likelihood		−1926.298	
Akaike Inf. Crit.		3880.597	
AUC		0.879	

Note: *** $p < 0.001$.

Table 13. Maximum likelihood estimates of the logistic regression of **coniferous forest loss** between 1990 and 2018. B represents the regression coefficients between the land use types and the driving factors. See Table S1 for the drivers' description.

	Dependent Variable:		
	Coniferous Forest Loss		
	Estimate (β)	**Std. Error**	**Odds Ratio**
aspect	0.002 ***	0.001	1.002
bio11	−0.032	0.039	0.968
bio14	−0.025	0.047	0.975
bio15	0.125 **	0.051	1.133
bio2	-	-	-
bio9	0.004	0.014	1.003
nitrogen	0.007 ***	0.002	1.007
pop dens	−0.531 ***	0.087	0.588
roads Euclid	0.000	0.000	1.000
slope	0.009	0.013	1.009
soil carbon	0.004 **	0.002	1.003
soil pH	0.198 ***	0.060	1.219
water Euclid	−0.000	0.000	0.999
Constant	−16.026 *	8.405	0.000
Observations		1562	
Log Likelihood		−484.142	
Akaike Inf. Crit.		994.283	
AUC		0.838	

Note: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

Table 14. Maximum likelihood estimates of the logistic regression of **transitional woodland shrub loss** between 1990 and 2018. β represents the regression coefficients between the land use types and the driving factors. See Table S1 for the drivers' description.

	Dependent Variable:		
	Transitional Woodland Shrub Loss		
	Estimate (β)	**Std. Error**	**Odds Ratio**
aspect	−0.005 ***	0.001	0.994
bio11	0.021 **	0.009	1.021
bio14	0.008	0.015	1.007
bio15	0.145 ***	0.030	1.155
bio2	15.412	376.007	4,935,224.174
bio9	−0.002 *	0.001	0.998
nitrogen	−0.005 ***	0.001	0.995
pop dens	−0.029 ***	0.006	0.971
roads Euclid	−0.0001 **	0.00003	0.999
slope	0.009	0.009	1.008
soil carbon	0.003 ***	0.001	1.002
soil pH	−0.058	0.041	0.943
water Euclid	0.000 ***	0.000	1.000
Constant	−1267.072	30,832.550	0.000
Observations		2156	
Log Likelihood		−890.878	
Akaike Inf. Crit.		1809.755	
AUC		0.797	

Note: * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

Table 15. Maximum likelihood estimates of the logistic regression of **natural grasslands loss** between 1990 and 2018. β represents the regression coefficients between the land use types and the driving factors. See Table S1 for the drivers' description.

	Dependent Variable:		
	Natural Grasslands Gain		
	Estimate (β)	**Std. Error**	**Odds Ratio**
aspect	0.004 ***	0.001	1.003
bio11	0.222 ***	0.011	1.248
bio14	0.100 ***	0.020	1.104
bio15	0.079 *	0.037	1.082
bio2	−0.259	0.297	0.771
bio9	0.005 ***	0.001	1.005
nitrogen	−0.005 ***	0.002	0.994
pop dens	0.022	0.019	1.021
roads Euclid	0.000	0.000	1.000
slope	0.092 ***	0.009	1.096
soil carbon	−0.001	0.001	0.998
soil pH	−0.457 ***	0.048	0.633
water Euclid	−0.000 ***	0.000	0.999
Constant	−1.781	25.248	0.168
Observations		3977	
Log Likelihood		−803.585	
Akaike Inf. Crit.		1635.171	
AUC		0.972	

Note: * $p < 0.05$; *** $p < 0.001$.

Table 16. Temporal variation (%) in ecosystem service potential. It should be noted that the same pattern is observed in the case of each ecosystem service, with the greatest increase and decrease in the 2000–2006 period (reflected also in the overall studied period).

	Ecosystem Service		
Local climate regulation			
Period	Increase	No change	Decrease
1990–2000	1.270	98.561	0.169
2000–2006	7.414	89.640	2.946
2006–2012	0.596	98.796	0.608
2012–2018	-	99.919	0.081
1990–2018	8.272	88.867	2.861
Regulation of waste			
1990–2000	1.271	98.54	0.165
2000–2006	5.309	89.236	5.455
2006–2012	0.815	98.888	0.297
2012–2018	0.012	99.908	0.080
1990–2018	6.378	88.655	4.967
Water purification			
1990–2000	1.269	98.561	0.167
2000–2006	7.634	89.265	3.101
2006–2012	0.718	98.671	0.611
2012–2018	-	99.920	0.080
1990–2018	8.533	88.444	3.023

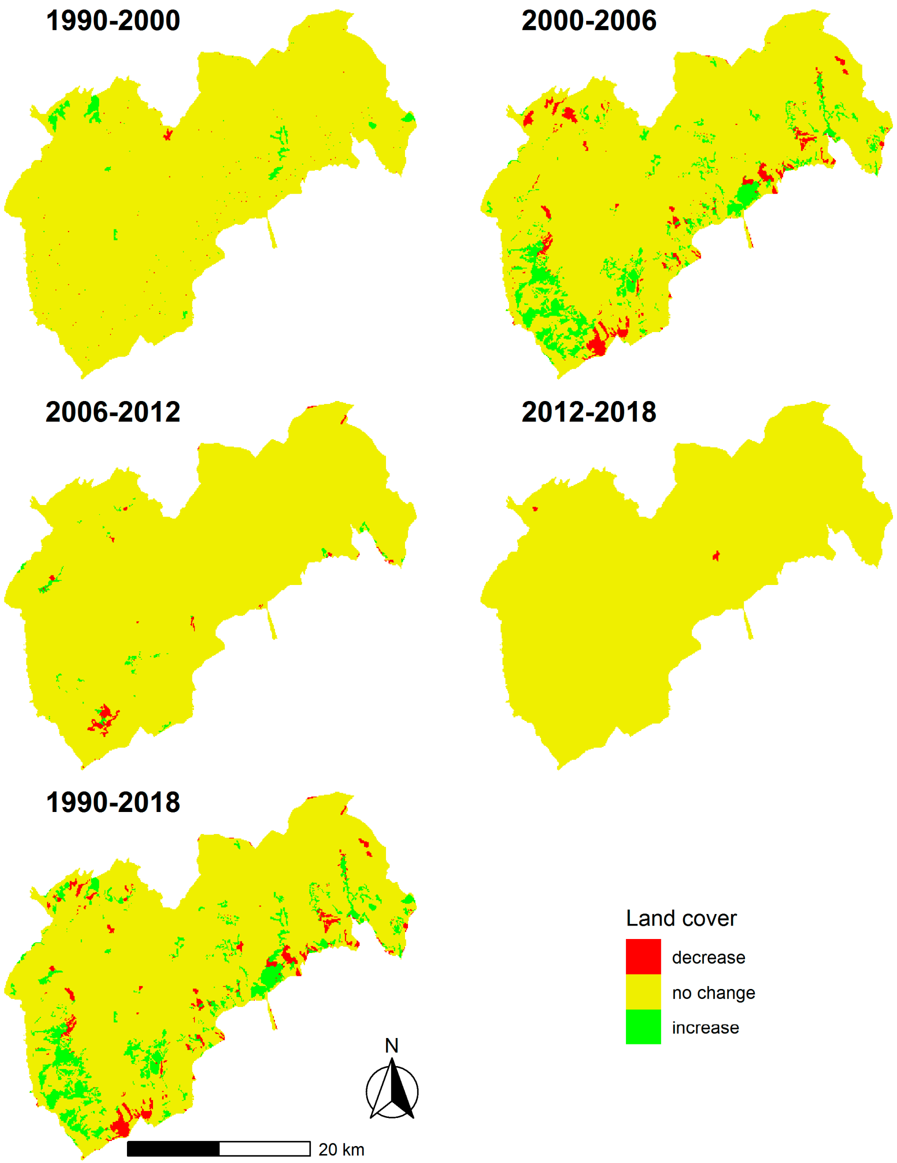

Figure 4. Spatio-temporal variation in the potential for the local climate regulation ES in the "Nordul Gorjului de Vest" Natura 2000 site.

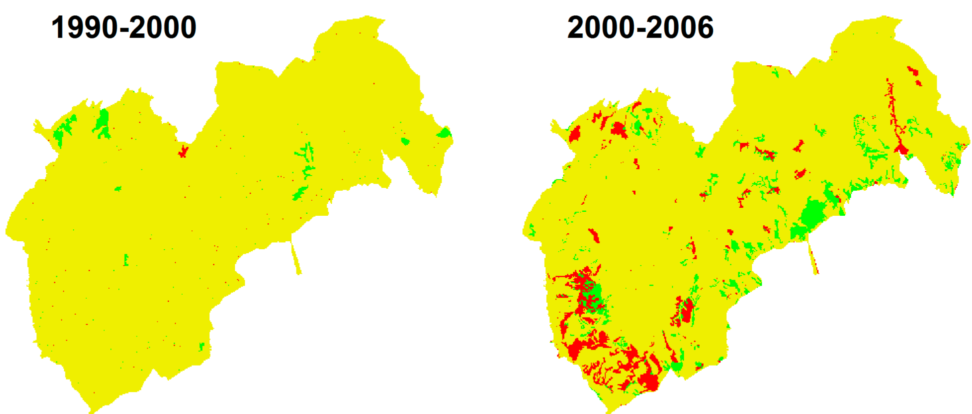

Figure 5. *Cont.*

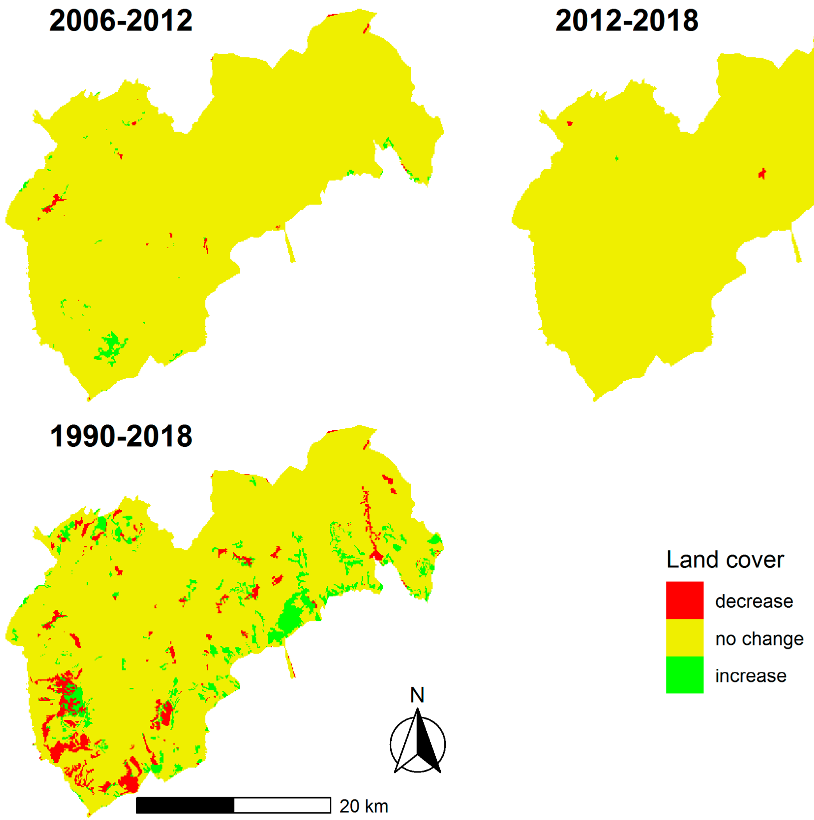

Figure 5. Spatio-temporal variation in the potential for the regulation of waste ES in the "Nordul Gorjului de Vest" Natura 2000 site.

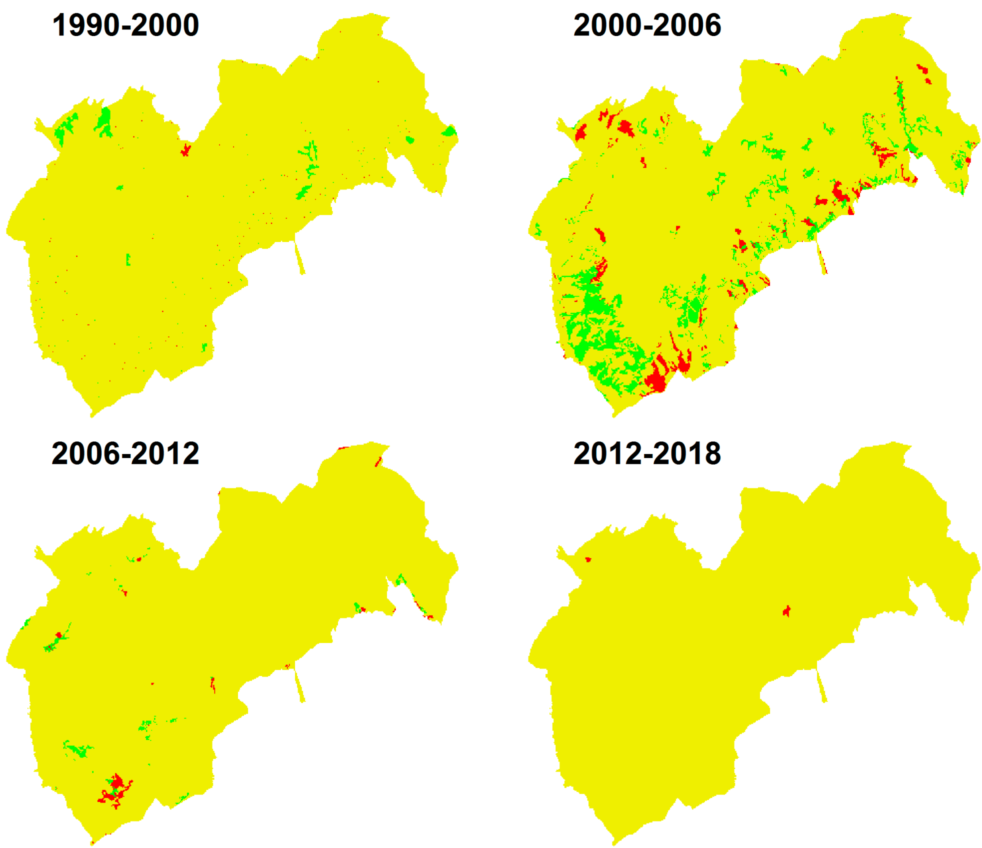

Figure 6. *Cont.*

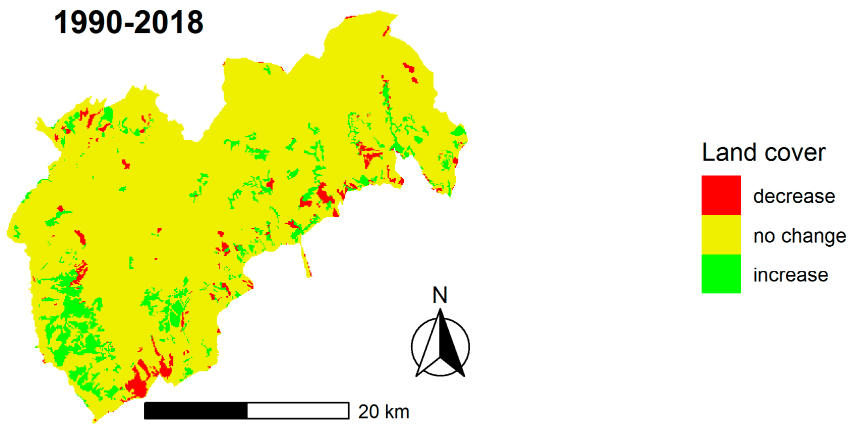

Figure 6. Spatio-temporal variation in the potential for the water purification ES in the "Nordul Gorjului de Vest" Natura 2000 site.

In the case of the local climate regulation ES, areas with a very high potential, which were related only to forests classes, increased in the overall study period (1990–2018) by 4.901%, from 642.26 km^2 in 1990 to 673.74 km^2 in 2018, while the areas with relevant potential decreased by 8.505%, from 133.56 km^2 in 1990 to 122.200 km^2 in 2018. The low relevant ES potential was associated with pastures and sparsely vegetated zones, while areas with no relevant potential were those related to the urban habitat. In the "Nordul Gorjului de Vest" Natura 2000 site, from 1990 to 2018, the area of land use change accounted for 12.863% of the total area, with pastures, broad-leaved forest, agricultural land, transitional woodland shrub, and natural grasslands being responsible for the main changes (Table 7). For example, in this period of time, the conversion of the transitional woodland shrub class into forest habitats (in this case, to broad-leaved forest) was the second main dominant transition (12.55 km^2), representing 11.174% of the total area of land use change, with the transitional woodland shrub class being the second transfer source (after pastures) to other land classes (Table 7). This land use transfer had a proportion of contribution rates to the increase in areas of a very high potential for the local climate regulation ES of 28.506%, being the leading factor in the increase in the quality of this ES between 1990 and 2018 (Table 17). At the same time, the transition between these two land types was the most responsible for the decrease in areas with a very high potential for local climate regulation, with a contribution rate of 24.375% (Table 17). For the regulation of waste ES, during the same time interval, the very high potential areas were related to mixed forests and water bodies. These areas slightly increased from 213.61 km^2 in 1990 to 215.03 km^2 in 2018 as areas with a high relevant potential too, which were associated with broad-leaved forest, coniferous forests, and pastures, from 509.92 km^2 in 1990 to 522.25 km^2 in 2018. For this ES, the areas with no relevant potential and a low relevant potential were related to urban areas and, respectively, sparsely vegetated areas. The conversion of transitional woodland shrub into mixed forests was the primary land transformation that contributed the most (45.289%) to the increase in areas with a very high potential for the regulation of waste between 1990 and 2018 (Table 18), while the transformation of water bodies to pastures and that of mixed forests to transitional woodland shrub were the two most important land transformations with the greatest impact on the reduction in areas with a very high relevant potential for this ES, with contribution rates of 32.890% and 28.0245%, respectively (Table 18). Regarding the water purification ES, the areas with a very high potential increased in the "Nordul Gorjului de Vest" Natura 2000 site, from 1990 to 2018, by 4.901%, from 642.26 km^2 in 1990 to 673.74 km^2 in 2018. As in the case of the local climate regulation ES, these areas of very high potential were related only to forest habitats, while the areas with medium relevant potential were related only to natural grassland. The areas with relevant potential for water purification increased by 46.975% in this time frame, from 38.68 km^2 in 1990 to 56.85 km^2 in 2018. The transformation of transitional woodland shrub to broad-leaved forest and that of pastures to broad-leaved forest were the two primary modes of land change accounting for the increase in areas with a very high potential for water purification, with contribution rates of 30.522% and 25.321%, respectively (Table 19). The transitional woodland shrub land class was also implicated in the reduction in areas with a very high potential for water purification; this was through two land use transfer types, i.e., broad-leaved and mixed forests, with 27.993% and 21.621% (Table 19).

Table 17. Effects of LULC transitions on **local climate regulation** ES (very high potential areas) from 1990 to 2018.

Effect	LULC Conversion Type	Conversion Area (km^2)	Contribution Rate to ES	Percentage of Contribution/%
Positive	Urban → Broad-leaved forest	0.37	0.00288	1.40050
	Agriculture → Broad-leaved forest	8.50	0.03970	19.30558
	Pastures → Broad-leaved forest	8.33	0.05187	25.22369
	Coniferous forest → Broad-leaved forest	0.07	0.0000	0.0000
	Mixed forest → Broad-leaved forest	0.85	0.0000	0.0000
	Natural grasslands → Broad-leaved forest	3.28	0.01532	7.44991
	Transitional woodland shrub → Broad-leaved forest	12.55	0.05862	28.50613
	Pastures → Coniferous forest	0.02	0.00009	0.04376
	Broad-leaved forest → Coniferous forest	0.27	0.00000	0.00000
	Mixed forest → Coniferous forest	0.67	0.00000	0.00000
	Natural grasslands → Coniferous forest	0.24	0.00112	0.544641
	Transitional woodland shrub → Coniferous forest	0.67	0.00312	1.51721
	Agriculture → Mixed forest	0.23	0.00107	0.52032
	Pastures → Mixed forest	1.8	0.01121	5.45127
	Broad-leaved forest → Mixed forest	2.99	0.00000	0.00000
	Coniferous forest → Mixed forest	1.11	0.00000	0.00000
	Natural grasslands → Mixed forest	0.41	0.00191	0.92884
	Transitional woodland shrub → Mixed forest	3.98	0.01859	9.04007
	Water bodies → Mixed forest	0.03	0.00014	0.06808
Total			0.20564	100.00000
Negative	Broad-leaved forest → Agriculture	0.33	−0.00154	3.52806
	Broad-leaved forest → Pastures	1.10	−0.00685	15.69301
	Broad-leaved forest → Natural grasslands	1.09	−0.00509	11.66094
	Broad-leaved forest → Transitional woodland shrub	2.28	−0.01064	24.37572
	Coniferous forest → Natural grasslands	0.81	−0.00378	8.65979
	Coniferous forest → Transitional woodland shrub	0.94	−0.00439	10.05727
	Mixed forest → Urban	0.01	−0.00007	0.16036
	Mixed forest → Pastures	0.15	−0.00093	2.13058
	Mixed forest → Natural grasslands	0.46	−0.00214	4.90265
	Mixed forest → Transitional woodland shrub	1.76	−0.00822	18.83162
Total			−0.04365	100.00000

Table 18. Effects of LULC transitions on the **regulation of waste** ES (very high potential areas) from 1990 to 2018.

Effect	LULC Conversion Type	Conversion Area (km^2)	Contribution Rate to ES	Percentage of Contribution/%
Positive	Agriculture → Mixed forest	0.23	0.00323	3.92609
	Pastures → Mixed forest	1.8	0.01685	20.48136
	Broad-leaved forest → Mixed forest	2.99	0.01399	17.00498
	Coniferous forest → Mixed forest	1.11	0.00519	6.30849
	Natural grasslands → Mixed forest	0.41	0.00575	6.98918
	Transitional woodland shrub → Mixed forest	3.98	0.03726	45.2899
	Water bodies → Mixed forest	0.03	0.00000	0.00000
Total			0.08227	100.00000
Negative	Mixed forest → Urban	0.01	−0.00023	0.39135
	Mixed forest → Pastures	0.15	−0.00070	1.19108
	Mixed forest → Broad-leaved forest	0.85	0.00000	0.00000
	Mixed forest → Coniferous forest	0.67	0.00000	0.00000
	Mixed forest → Natural grasslands	0.46	−0.00646	10.99200
	Mixed forest → Transitional woodland shrub	1.76	−0.01647	28.02452
	Water bodies → Urban	0.06	−0.00140	2.38216
	Water bodies → Agriculture	1.01	−0.01418	24.12796
	Water bodies → Pastures	4.13	−0.01933	32.89093
Total			−0.05877	100.00000

Table 19. Effects of LULC transitions on the **water purification** ES (very high potential areas) from 1990 to 2018.

Effect	LULC Conversion Type	Conversion Area (km^2)	Contribution Rate to ES	Percentage of Contribution/%
Positive	Urban → Broad-leaved forest	0.37	0.00288	1.12469
	Agriculture → Broad-leaved forest	8.50	0.05293	20.67017
	Pastures → Broad-leaved forest	8.33	0.06484	25.32120
	Coniferous forest → Broad-leaved forest	0.07	0.00000	0.00000
	Mixed forest → Broad-leaved forest	0.85	0.00000	0.00000
	Natural grasslands → Broad-leaved forest	3.28	0.01021	3.98719
	Transitional woodland shrub → Broad-leaved forest	12.55	0.07816	30.52290
	Pastures → Coniferous forest	0.02	0.00015	0.05857
	Broad-leaved forest → Coniferous forest	0.27	0.00000	0.00000
	Mixed forest → Coniferous forest	0.67	0.00000	0.00000
	Natural grasslands → Coniferous forest	0.24	0.00074	0.28898
	Transitional woodland shrub → Coniferous forest	0.67	0.00417	1.62846
	Agriculture → Mixed forest	0.23	0.00179	0.69902
	Pastures → Mixed forest	1.8	0.01401	5.47116
	Broad-leaved forest → Mixed forest	2.99	0.00000	0.00000
	Coniferous forest → Mixed forest	1.11	0.00000	0.00000
	Natural grasslands → Mixed forest	0.41	0.00127	0.49595
	Transitional woodland shrub → Mixed forest	3.98	0.02478	9.67704
	Water bodies→ Mixed forest	0.03	0.00014	0.05467
Total			0.25607	100.00000

Table 19. *Cont.*

Effect	LULC Conversion Type	Conversion Area (km^2)	Contribution Rate to ES	Percentage of Contribution/%
Negative	Broad-leaved forest → Agriculture	0.33	−0.00256	5.05032
	Broad-leaved forest → Pastures	1.10	−0.00856	16.88696
	Broad-leaved forest → Natural grasslands	1.09	−0.00339	6.68771
	Broad-leaved forest → Transitional woodland shrub	2.28	−0.01419	27.99369
	Coniferous forest → Natural grasslands	0.81	−0.00252	4.97139
	Coniferous forest → Transitional woodland shrub	0.94	−0.00585	11.54074
	Mixed forest → Urban	0.01	−0.00007	0.13809
	Mixed forest → Pastures	0.15	−0.00116	2.28842
	Mixed forest → Natural grasslands	0.46	−0.00143	2.82106
	Mixed forest → Transitional woodland shrub	1.76	−0.01096	21.62162
Total			−0.05069	100.00000

3.6. Ecosystem Services' Interactions

Regarding the interactions between the ESs for the overall study period (1990–2018), synergy prevailed (Table S3, Figure 7), regardless of the pairs of ESs involved, especially between local climate regulation and water purification (Table S3), followed by dis-synergy and trade-off (Table S3). Moreover, the LULC transitions affected these interactions, with different results. For example, the conversion of transitional woodland shrub into broad-leaved forest led to synergy in all pairwise interactions between ESs, while the conversion of pastures into broad-leaved forest led to synergy in the case of local climate regulation and water purification and no change for the regulation of waste ES. A complete dis-synergy was highlighted in the case of the conversion of broad-leaved forest into transitional woodland shrub.

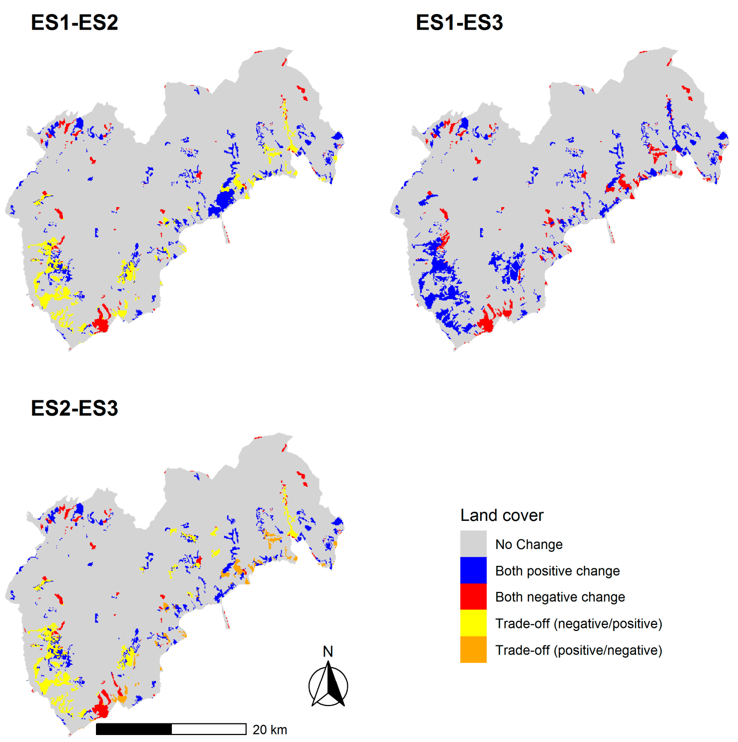

Figure 7. Interaction between ecosystem services in the "Nordul Gorjului de Vest" Natura 2000 site for the overall study period (1990–2018). ES1—local climate regulation; ES2—regulation of waste; and ES3—water purification. See Methodology for the interactions' description.

4. Discussion

The European Union (EU)'s biodiversity strategy, which aims to preserve both biodiversity and ESs, established the Natura 2000 network [63]. In Romania, there are 606 Natura 2000 sites [64], representing 22.56% of Romania's terrestrial area [65], with deforestation as a major threat, together with the extent of urbanization and agriculture [64].

Forests cover 35% of Europe's land [66] and are very crucial in stabilizing the Earth's climate [67]. Due to land cover and land use changes, protected areas remain the main strategy for reducing carbon emissions and biodiversity losses [68], as well as deforestation and forest fragmentation [69].

Forest habitats are the main LULC class category in the "Nordul Gorjului de Vest" Natura 2000 site, accounting for over 70% of the total area's surface during each analyzed year. Broad-leaved forest represents the dominant LULC class in terms of area (Table 1) and a very important characteristic of the study area, meaning that an increase in the broad-leaved fraction of forest will enhance the provision of ESs and mitigate climate change [70]. With the exception of coniferous forests (which declined by 4.783%), both broad-leaved forest and mixed forest increased in the studied area, between 1990 and 2018, by 6.284% and 3.195%, respectively (Table 2). The largest contribution to this growth was the transitional woodland shrub class, followed by agricultural land and pastures (Table 7). The area covered by these two forest classes, in addition to the fact that it grew over time, remained less fragmented, a fact indicated by the high values of the aggregation index and the lack of an increasing trend in the edge density values. On the contrary, the coniferous forest area showed a slight increase in edge density and a slight decrease in the aggregation index over the same time interval, indicating a slight increase in fragmentation (Table 9). In other areas of the country, in some protected areas, such as the "Piatra Craiului National Park", during a quite similar period (1987–2010), 3.25% anthropogenic deforestation was indicated by the increase in the number of forest patches (NPs), while, in the "Bucegi Natural Park", the forest class was not affected by important changes, with the number of forest patches decreasing with time [71]. Furthermore, within the "Maramures Mountains Nature Park", the "Rodna Mountains National Park", and the "Calimani National Park", important forest-dominated protected areas in Romania, in the period 1987–2009, the levels of forest disturbance were 4.20, 4.72, and 4.69%, respectively [37,71], questioning the effectiveness of Romania's protected area network with respect to biodiversity preservation [37]. The annual mean diurnal range (bio2), the soil pH, precipitation seasonality (bio15), and precipitation of the driest month (bio14) were identified as the main drivers of forest class change between 1990 and 2018 (Tables 10–13). In a study regarding the impact of future climate change on the vegetation shift of broad-leaved and coniferous forests [72], precipitation seasonality (bio15) for broad-leaved forest and precipitation of the driest month (bio14) for coniferous forests were found as main predictors of their distribution. In addition, the annual mean diurnal range (bio2) was identified as making a major relative percent contribution to the model for both broad-leaved forests and coniferous forests. The decrease in the loss of broad-leaved forest along with the increase in the bio2 values were due to the very wide thermal niche of this type of forest. Temperate broad-leaved species can tolerate extreme temperatures, up to -42 °C in some cases [73]. Among the most important determinants of tree traits in temperate forests are climatic drivers and soil pH and fertility [74], with climate being more important than soil in predicting a forest's above-ground biomass [75]. However, plant traits are significantly influenced by the interaction of soil conditions with the climate [74]. We did not find a strong association between bio2 and soil pH (Table S2). For example, precipitation seasonality is an important climatic factor that is related to the distribution of beech forests in China [76]. Also, among other climatic variables, precipitation seasonality (bio15) is a factor (although not in a large percentage) that affects the potential distribution of some tree species of Chinese *Pinus tabuliformis* and *Ostryopsis davidiana* mixed forests under the climate change scenario [77]. We found that the loss of coniferous forest increased with the soil pH, considering the fact that conifers prefer more acidic soils, although the differences in soil acidity between coniferous and deciduous forest are not significant [78]. Due to the tolerance of conifers to cold and drought [79], the loss of this type of forest with increased precipitation seasonality (bio15) was supported. Although they did not occupy a large area at the level of the site, water bodies occupied the first place in terms of area decrease (more than 90% between 1990 and 2018, Table 2), accomplishing a significant overall change (Table 8). The reduction in water surfaces in mountain regions is a major problem, considering that mountains are an important source of water worldwide [80]. The first period, 1990–2000, was marked by political, social, economic, and cultural transition in Romania; as a result, it showed the highest proportion of changes in land use types. We should not be surprised by such a huge gap between the last decade of the 20th century and the beginning of the 21st century [81]. The water reservoirs that have been of strategic economic importance ever since the communist period, which are part of the Cerna–Motru–Tismana hydropower system, are shown on maps from 1990 until the year 2000. To these, Izvarna Meadow is added (the whole area is considered a single body of water), known for its springs at the confluence of the Izvarna, Pocruia, and Orlea watercourses and considered to be the most important source of water for the largest city in the SW region from the 1970s until the present day. In the period 2000–2006, the area of these water bodies was reduced on the LUCL maps: on the one hand, this was due to the inclusion of the area in the Natura 2000 network, a process which started much earlier than the year of its declaration (2007); and, on the other hand, it was also due to the capture of natural resources' surface water through underground water adductions. The lands adjacent to the reservoirs and in the meadows of the aforementioned rivers, thus, remained free and were transformed into pastures for the benefit of local communities [45].

The transitional woodland shrub class also experienced a significant overall change (Table 8), being the second-highest LULC class in terms of area change between 1990 and 2018 (−55.179%; Table 2), with 76.445% of the converted area being replaced by forests (Table 7). The main driver of these transformation was precipitation seasonality (Table 14), meaning that we can expect drastic shifts in the potential for vegetation across Europe under the influence of climate change [82]. The transitional woodland shrub LULC class had an important value in the Natura 2000 sites, at least for farmlands with a high nature value, where the transformation of this class into forests was the most predominant transition in the European Union [83]. At the opposite end, natural grasslands recorded the highest overall change in terms of area increase among all the LULC categories (46.975%; Table 2), mostly gained from pastures (64.247%, Table 7) and transitional woodland shrub (17.384%, Table 7). The conversion of transitional woodland shrub into grasslands and vice versa depends on climate and soil texture [84], as this study pointed out, with natural grassland gain relying on climate and soil pH (Table 14). Grasslands, in general, are very important in terms of ESs such as climate regulation and water purification [85]. One way to increase the provision of multiple ESs by permanent grasslands is to prevent their conversion into agricultural areas [85].

Considering the fact that the "Nordul Gorjului de Vest" Natura 2000 site is dominated by forests, the three ESs taken for our analysis prevailed with the conversion of the other LULC categories into forests. The most dramatic changes at the level of the LULC classes took place in the period 2000–2006, almost a third of the transitions being towards forests (31.911% of the total area of land use converted; Table 4), especially into broad-leaved forest (22.268% of the total area of land use converted; Table 4). This fact caused the greatest increase in ES to occur in the same time interval of 2000–2006 (Table 16). Nonetheless, among the three ecosystem services analyzed, the waste regulation ecosystem service experienced the largest decline during the period of 2000–2006, primarily due to the reduction in areas of the LULC categories with high and very high relevant potentials for this ecosystem service (water bodies, pastures, and, to a lesser extent, coniferous forest; Table 4). In the time frame of 1990–2018, the second-highest transition in terms of absolute area changed was the conversion of transitional woodland shrub into broad-leaved forest (Table 7), this transition occupying the first position in terms of contribution rates to enhancing areas with a very high potential for the ESs of climate regulation and water purification (Tables 17 and 19). Moreover, the conversion of transitional woodland shrub into mixed forest was the primary transition that enhanced the most areas with a very high potential for the regulation of waste ES (Table 18). Identifying transitions (in this case, the conversion of the other LULC categories into forests) that increase areas with a high potential for certain ESs is of utmost importance, given that forests play an important role in achieving climate neutrality through the European Union's objectives [86], as well as water purification [87]. Furthermore, the conversion of transitional woodland shrub into broad-leaved forest has led only to synergy for all the pairwise interactions between the three ESs, which is not a random fact, considering the role of forests in the provision of regulatory services [61]. By relating the effect of LULC transitions to the interactions between ESs, we can use better management strategies for a target area to achieve a desired level of ES [61].

5. Limitations of This Study

An important limitation is given by the availability of LULC data. The last reference year for the Copernicus LULC data was 2018. Of course, other starting sources such as MODIS or Landsat can be used, but, to ensure data standardization, uniform sources are needed. Another major limitation is related to the drivers, especially the socio-economic ones. The current work did not aim to cover the entire range of drivers of LULC changes but rather represent a benchmark for similar analyses. Future studies can be carried out by including a larger number of driver categories, in order to obtain a better understanding of the changes in the studied area.

6. Conclusions

The "Nordul Gorjului de Vest" Natura 2000 site is one of the first 10 Natura 2000 areas in Romania in terms of area; it is less known to the general public, instead being an important point of flora and fauna protection. Forests are the most important LULC categories at the level of the site, accounting for over 70% of the area's surface in each analyzed year, with broad-leaved forest as a dominant forest class. Analyzing each time interval from the point of view of the areas lost or gained by the different LULC classes, it can be observed that most transformations took place in the period of 2000–2006, a troubled period from the environmental protection perspective in Romania. After Romania's accession to the European Union in 2007, things began to settle along a normal path with respect to nature conservation, expanding the network of protected areas, a fact which could explain the lack of major changes in time intervals 2006–2012 and 2012–2018 at the level of the "Nordul Gorjului de Vest" Natura 2000 site. During the whole analyzed period (1990–2018), among the LULC classes in the studied area, water bodies lost almost their entire area in 1990, followed by the transitional woodland shrub class, while natural grasslands increased the most in terms of their area. The transitional woodland shrub class and water bodies showed significant overall changes. Between 1990 and 2018, the highest net losses were observed in the transitional woodland shrub class and in pastures, and the highest net gains were in broad-leaved forest and natural grasslands. In terms of the absolute area changed, the highest transition was represented by the conversion of pastures into natural grassland, tailed by the conversion of transitional woodland shrub into broad-leaved forest. The annual mean diurnal range (bio2), soil pH, precipitation seasonality (bio15), and precipitation of the driest month (bio14) were identified as the main drivers of forest class change between 1990 and 2018. By linking the LULC changes to the spatio-temporal variations in the ESs at the level of the studied area, we found that the zones with a very high potential were related mainly to forests. The conversion of transitional woodland shrub into broad-leaved forest occupied the first position in terms of contribution rates that enhanced the areas with a very high potential for two of the three analyzed ESs. This research framework could be applied to other Natura 2000 sites that face changes in the potential for ESs due to LULC transitions.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/land13050650/s1: Table S1: Drivers of the LULC changes in the Nordul Gorjului de Vest Natura 2000 site. Table S2: Correlation matrix between the remaining LULC drivers after excluding the collinear variables. Table S3: Pairwise interactions between the ecosystem services for the overall study period (1990–2018). For the synergy and dis-synergy interactions, also indicated are the areas in which the three ESs increase or decrease together. ES1—local climate regulation; ES2—regulation of waste; and ES3—water purification. Figure S1: Flowchart diagram of methodological approach. Figure S2: Maps of the predictors used in the logistic regression analysis. Figure S3: Maps of the local climate regulation ecosystem service from 1990 to 2018 in the Nordul Gorjului de Vest Natura 2000 site. See Methods for the scale of the ES potential. Figure S4: Maps of the regulation of waste ecosystem service from 1990 to 2018 in the Nordul Gorjului de Vest Natura 2000 site. See Methods for the scale of the ES potential. Figure S5: Maps of the water purification ecosystem service from 1990 to 2018 in the Nordul Gorjului de Vest Natura 2000 site. See Methods for the scale of the ES potential.

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