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QUANTIFYING LANDSCAPE CHANGES AND FRAGMENTATION IN A NATIONAL PARK IN THE ROMANIAN CARPATHIANS

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Abstract: The main goal of this study was to quantify landscape changes and fragmentation in the Nera Gorges-Beuşniţa National Park and its vicinity, using CORINE land cover data (1990 – 2012 period) and to emphasise the importance of protected area status for the reduction of the fragmentation process and the loss of the benefits rendered by ecosystems. Landscape analysis is the primary framework to build harmonious human-environment relationships and to implement sustainable development measures. For this purpose, ten landscape metrics were calculated to highlight the landscape composition, shape, and configuration. Five landscape change processes were also analysed: dissection, shrinkage, attrition, aggregation and creation. The results highlight minor landscape changes, as well as a tendency to homogenise landscapes by reducing landscape fragmentation and by involving the population in the implementation of a reliable strategy for the development and promotion of tourism, aiming to ensure sustainable development of this area. The results of the study are especially important because they provide a very good example of how to manage a protected area, particularly if we consider the numerous dysfunctions (i.e., illegal deforestation, accessibility of restricted areas for conservation) that occur in Romania.

Keywords: landscape changes, landscape fragmentation, landscape metrics, protected area, CORINE land cover data, Nera Gorges-Beuşniţa National Park, Romanian Carpathians

1. INTRODUCTION

Romania, due to its rich biodiversity (five biogeographic regions: Continental, Alpine, Pannonian, Pontic, and Steppe regions), had 7.55% of its territory included in the category of natural protected areas (before the admission to EU), thus contributing significantly to the Natura 2000 European Ecological Network. However, although the proportion of protected areas in Romania is one of the most significant at the European level, it ranks 26th internationally in overall management (Manea, 2003). Before the admission of Romania to the European Union in January 1st 2007, the government had adopted several legislative measures to expand natural protected areas. Since that important date, actions serving to increase the extent of the protected areas have been considerably enhanced. An important role in this matter has also been played by the Natura 2000 Network, within which Romania can continue to offer suggestions on the protection of other natural areas. The declaration and recognition of European Natura 2000 areas in Romania was still an ongoing process having its deadline in 2016 (Geacu et al., 2012). In 2011, according to the Order of Ministry of Environment and Forests, the Natura 2000 Netwok was extended to 22.68% of the country's territory (Geacu et al., 2012), with 408 Sites of Community Importance (SCIs) and 148 Special Protection Areas (SPAs). These sites have been designated based on well-defined ecological and biogeographic criteria (i.e., Mallinis et al., 2011) designed to implement proper preservation actions intended to ensure the functioning of ecosystem services. These services also depend on the way in which the lands are exploited (Bastian, 2013). Many ecosystem services, particularly those related to tourism and leisure activities, may be lost or significantly diminished if these ecosystems are intensively and irrationally exploited (IEEP, 2002; Špulerova et al., 2016). In that regard, landscape quantification represents a notable current issue for post-communist Romania, particularly because of the importance of landscape in the quality of human life and because of the active role of landscape as a beneficial resource for economic activities (Déjeant-Pons, 2006; Sims, 2014; Gavrilidis et al., 2015).

The fall of the communist regime and the interactions between economic, political, technological, and demographic factors have generated significant changes in the Land Cover/Land use (LCLU) classes (Popovici et al., 2013; Gavrilidis et al., 2015). The major changes occurred especially in the plain area where the agricultural land was abandoned and replaced by less profitable categories while, in the mountain area, the forest begun to diminish. Thus, pasture and meadowland (less profitable categories) have expanded, whereas most areas, including arable land, orchards, and vineyards (profitable categories) have been abandoned (Bălteanu & Popovici, 2010). In light of these findings, it is clear that the intensity of landscape dynamics varies from lower-elevation to higher-elevation areas (Wood & Handley, 2001). By identifying and understanding these changes, we may obtain valuable information about the processes (flows) that may contribute to landscape change (Feranec et al., 2010; Dobos et al., 2014), which can be summarized as follows: the intensification and extensification of agriculture, urbanisation (industrialisation), enlargement or exhaustion of natural resources, afforestation, deforestation, and other landscape changes (Popovici et al., 2013). Furthermore, many countries (including Romania) have reported the abandonment of mountain regions, which are now subject to reforestation, and the intense exploitation of lower-elevation regions, particularly lowlands (Geri et al., 2010). Therefore, an understanding and comprehensive grasp of the processes that cause landscape changes and that have been identified and analysed in previous similar studies (Forman, 1995; Feranec et al., 2007; Szilassi et al., 2010) represent a prerequisite for both the preservation of biological diversity and the management of ecosystems or of the environment under specified policies (Hu et al., 2008; Bodesmo et al., 2012).

In view of these considerations, this study attempted to estimate the rates of LCLU changes (implicitly, landscape changes) and to quantify the level of landscape fragmentation within a protected area, Nera Gorges-Beușnița National Park and its vicinity. The protection status on land changes and in conservation biodiversity depends on many factors, such as optimal design, optimal conservation strategies, adequate implementation of management activities (Iojă et al., 2010). Even if the inclusion of the study area in the Natura 2000 Network should facilitate the protection, small land changes occur, especially because some anthropogenic activities are allowed in such sites (e.g. traditional agricultural practices, limited grazing and logging), (Gaston et al., 2008; Iojă et al., 2010). Therefore, Nera Gorges-Beuşniţa National Park may very well provide a firm basis for the sustainable development process because it is able to yield valuable resources for different types of economic activities. It thus provides essential leverage for economically disadvantaged areas (i.e., the Anina, Sasca Montană, and Bozovici areas). This analysis was based on the correlation between LCLU changes and human activity (Lindenmayer & Cunningham, 2013) and involved the calculation of certain metrics based on several socio-demographic variables. We considered that these aspects are relevant because, if the socio-demographic pressure increases, the landscape fragmentation gets bigger values (Pătru-Stupariu et al., 2015) and has negative effects on humans and nature (Forman et al., 2002; Pătru-Stupariu et al., 2015; Ampofo et al., 2016). Consequently, we attempted to answer several questions whose goals are to incite the construction of harmonious human-environment relationships (Zha et al., 2008) and promote sustainable landscape management (Bodesmo et al., 2012): (i) Is the status of a protected area sufficient to avoid losing or diminishing ecosystem services that depend, to a large extent, on the changes occurring in the LCLU classes? (ii) Does depopulation reduce human impact on the environment, and does it minimise the concern for environmental preservation and protection? (iii) Did the economic reorganisation that occurred after the 1990's cause the conversion of the landscape matrix to more homogeneous systems? The answers to these questions are particularly important because we know that sustainability includes the preservation of both natural resources and geographical patterns of land use, which are beneficial from ecological, social, and economic perspectives (Leitão & Ahern, 2002; Zanon & Geneletti, 2011; Dobos et al., 2014).

2. STUDY AREA

The Nera Gorges-Beuşniţa National Park is located in the Banat Mountains, a branch of the Western Romanian Carpathians, covering nearly 1029.09 km² and extending over the territory of eight administrative-territorial units in Caraş-Severin County (Fig. 1). This strongly rural region presently includes 40 communities, 2 of which (Oraviţa and Anina) are urban areas. The population has decreased significantly since the fall of the communist regime, from 40,086 inhabitants in 1990 to 32,136 inhabitants according to the last census survey in 2012. This decrease is due to several factors, including the termination of mining activities in the area, the flight of the population from rural areas, the ageing of the population, and the decline in the birth rate.

Over 930.85 km² of the area covered by our analysis belongs to the Nera Gorges-Beuşniţa National Park. The administrative-territorial areas incorporated into this site include the following: Lăpuşnicu Mare (74%), Cărbunari (42%), Anina (41%), Ciclova Română (39%), Sasca Montană (37%), Bozovici (22%), Şopotu Nou (22%), and Oraviţa (20%), (Fig. 1). Being one of 13 national parks in Romania, the Nera Gorges-Beușnița National Park is also a very important protected area at the national level because it harbours unique landscapes, habitats, and species of community interest. The park was established in 1943, became a natural protected area under the provisions of Law 5/2000 and it was subsequently included in the SPA category within the Natura 2000 Network. We selected this study area because almost all of the settlements located in the area adjacent to the national park had an industrial profile focussed on coal mining activities (Anina, Sasca Montană, Bozovici etc.) and after 1990's, the economic profile of the settlements changed (in an agricultural or touristic profile). Therefore, we wanted to see if these changes had some significant consequences on LCLU categories and landscape fragmentation in the administrative-territorial areas incorporated into this national park.

3. MATERIALS AND METHODS

3.1. Data used

To highlight the LCLU changes and the landscape fragmentation occurring in the study area, we used three categories of data. The first category is represented by the datasets of the European Environmental Agency (EEA) in the context of the CORINE Land Cover (CLC) project for time steps 1990 and 2012.

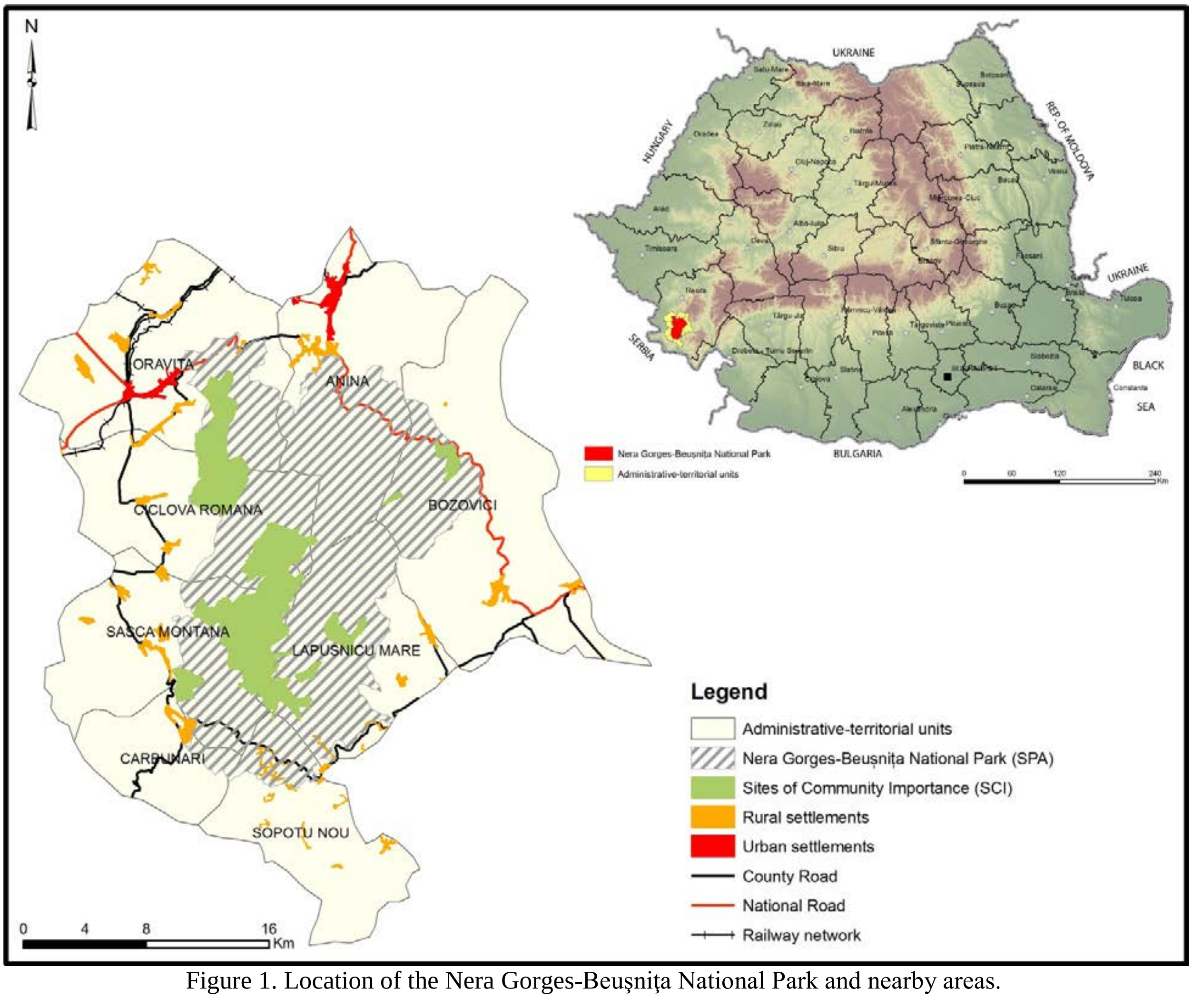

Figure 1. Location of the Nera Gorges-Beuşniţa National Park and nearby areas.

The spatial data provided by the Ministry of Environment and Forests of Romania, with reference to the Natura 2000 sites, their typology and limits, have been added to this category. The second category of data used in this study is represented by the topographic data that we gathered by analysing four 1:100,000 scale maps. These maps cover the entire surface of the study area (maps: L-34-104 Reşiţa 2, L-34-105 Orşova 1, L-34-116 Reşiţa 4 and L-34-117 Orşova 3) and were used for establishing the limits of the study area and the location of the settlements. The third category of data is geo-demographic, based particularly on the yearly statistics provided by the Romanian National Institute of Statistics for 1990 & 2012 and used for calculating the indicators that highlight the human impact on different categories of LCLU.

3.2. Data processing

3.2.1. Analysis of landscape change

The spatial data provided by the Ministry of Environment and Forests of Romania were used to precisely delineate the borders of the Nera Gorges-Beușnița National Park. The accuracy of the information was then verified with reference to the topographic data (used as ancillary data) by georeferencing the four 1:100,000 scale maps from 1986 and digitising the borders of the study area. We subsequently constructed land-use maps for 1990 and 2012 based on the spatial data from the EEA. Thus, land use patterns were derived from the CORINE land cover classes in the scale of 1:100,000. The initial data were re-projected with the Stereo 70 projection system, specific to Romania, using the ArcGIS 10.2 software program. The maps that resulted, in vector format, comprised 15 LCLU classes, pursuant to the terminology system for the CORINE Land Cover pattern, level 3 (Geri et al., 2010), joining the polygons with the same land use based on physiognomic attributes (shape, size, colour, texture and pattern) as well as spatial relationships of the landscape objects (Feranec et al., 2005).

We chose the more detailed LCLU categories (level 3) in order to better highlight the landscape change to a small scale. The surface area (ha) for every LCLU class was calculated and compared with the data collected from the Romanian National Institute of Statistics. The land-use maps, in vector format, were subsequently converted to raster format with 100-m resolution and then to ASCII format to allow them to be imported and then processed using the Idrisi Selva program. It is well known that the source data for CLC inventory were satellite images and it was assumed that the smallest cartographic unit was 25 ha with the minimum width of 100 m, mapping scale being 1:100,000. After the vector database conversion into grid format, each grid cell was assigned the CLC code according to the land cover polygon it overlaps. Further, the analysis was performed with Idrisi Selva integrated software, namely, The Land Change Modeler for Ecological Sustainability. This software has been proven very useful in the analysis of land conversions and in the preservation of biodiversity (Eastman, 2009). Using the Land Change Modeler for Ecological Sustainability software, we overlapped the two land-use maps and identified the changes that occurred during the period 1990-2012. This phase of the analysis did not consider locations with surface areas less than 200 ha in which changes occurred because, according to the cartographic principles and taking into account the large surface of the study area, too many LCLU classes with insignificant changes in surface area, could complicate the analysis.

The Change Process option compared the two maps and measured the nature of the change underway within each LCLU class, comparing the number of land cover patches present within each class between the two time periods to changes in their areas and perimeters. Applying this function of the Land Change Modeler for Ecological Sustainability software, resulted in a map in which each LCLU class was identified in terms of the category of change that it exhibited: *dissection* (the number of patches is increasing and the area is decreasing), *shrinkage* (the area and perimeter are decreasing but the number of patches is constant), *attrition* (the number of patches and area are decreasing), *aggregation* (the number of patches is decreasing, but the area is constant or increasing), and *creation* (the number of patches and area are increasing), (Leitão et al., 2006; Eastman, 2009).

Because forest landscape is predominant in the Nera Gorges-Beușnița National Park, we calculated the rate of deforestation for the period analysed in this study, applying the formula presented by Watcharakitti (1987) (Equation 1) and used in other similar studies (Trisurat, 2009; Lele & Joshi 2009):

$$r = \left[1 - (A_t/A_0)^{\frac{1}{t}}\right] x\ 100 \qquad (1)$$

where r is the annual rate of deforestation, A_0 is the land-use coverage in the initial year (1990), A_t is the land-use coverage in the final year (2012), and t is the duration in years (22 in this study). The proportion of forested land in the study area and the level of human impact on the forest landscape were highlighted using the Naturality Index (Equation 2) (Pătru-Stupariu, 2011):

$$NI = \text{forest (ha)/overall (ha)} \qquad (2)$$

where *forest (ha)* represents the forest surface currently existing in the study area and *overall (ha)* represents the total surface of the study area. The impact of human activities on the landscape of the studied region was also emphasised with a set of metrics defining the human pressure on the landscape in terms of the manner in which the lands were used and occupied (Pătru-Stupariu, 2011) during the two reference years. We applied the formula (Equation 3) defined by the Food and Agriculture Organisation (FAO):

$$Pclass = Sclass\ (ha)/N \qquad (3)$$

where *Pclass* is the human pressure on an LCLU class, *Sclass* is the surface area (ha) occupied by that particular class, and N is the number of inhabitants. This indicator essentially reflects the manner in which the population places pressure on the environment or landscape through a specified LCLU class. We applied these indices to agricultural lands, non-agricultural lands, and woodlands.

Ultimately, the alteration of the ratio of natural areas to human-influenced areas during the period 1990-2012, since the orientation towards a market economy, was calculated with the Environmental Transformation Index (Itre) (Equation 4) defined by the Polish school (Maruszczak, 1988; Pietrzak, 1988). This metric considers both forest areas and meadows, the elements that best reflect the natural character of the landscape and the built-up areas highly artificialized:

$$Itre = S(Forests+Meadows)/Built\text{-}up\ Surface\ (ha) \qquad (4)$$

3.2.2. Calculation of fragmentation indices

The concept of landscape metrics is most frequently used for metrics calculated (e.g., FRAGSTATS and Patch Analyst), whereas landscape indices are more frequently used in a broader sense (McGarigal & Marks, 1994; Uuemaa et al., 2009; Rempel et al., 2012). Because the most useful indicators for monitoring landscape conditions and for implementing landscape preservation and planning actions are the land-use indicators (Voghera, 2011), they were grouped into the following three broad categories: landscape composition, landscape shape, and landscape configuration (Rutledge, 2003). In this study, we selected and calculated several indicators for each of these three categories for 1990 and 2012: seven indicators for the quantification of landscape composition (*Class Area-CA, Number of Patches-NumP, Mean Patch Size-MPS, Total Edge Length-TE, Total Core Area-TCA, Mean Core Area-MCA and Effective Mesh Size-MESH*), two indicators for the measurement of landscape shape (*Mean Shape Index-MSI, Mean Patch Fractal Dimension-MPFD*), and two indicators for the quantification of the landscape configuration (*Mean Nearest Neighbour Distance-MNND, Mean Proximity Index-MPI*). We used the Spatial Statistics function of Patch Analyst 5.2 to calculate the landscape metrics at the Class level from two raster grid layers (e.g., the land-use maps for 1990 and 2012).

4. RESULTS

4.1. Land cover/land use changes

The results of the analysis of the *LCLU changes* that occurred in the Nera Gorges-Beuşniţa National Park and its vicinity from 1990 to 2012 are shown in figure 2, as well as the annual rate of change and the rate of change occurring over 22 years at the class level (Table 1). The results show that forest landscape covered the greatest area throughout the entire study period (62.7% from the total area in 1990 and 69.25% in 2012). The human impact on forest landscape is reflected by several indicators: *the rate of deforestation,* whose values decreased over the 22 year period (-0.76%); the *indicator of naturality,* whose values recorded minor growth (from 0.62 in 1990 to 0.69 in 2012); and the *human pressure on forests,* which increased from 1.60 ha/person in 1990 to 2.21 ha/person in 2012. The values of human pressure on forests increased because this indicator should not be understood as the pressure exerted by a certain number of inhabitants on the forests (in term of population density), but it indicates the number of hectares of forest belonging to a resident of the region (Pătru-Stupariu, 2011). Even if broad-leaved forests gained the greatest area in hectares (6249.28 ha in 2012), the biggest values of the change rate for the entire period (22 years) have been registered for complex cultivation patterns (45.92%, 828.18 ha) (Table 1 & Fig. 2), as a result of the conversion of other LCLU categories such as fruit trees and berry plantations (584.51 ha), land principally occupied by agriculture (255.96 ha), pastures (206.23 ha) etc. The second greatest change rate was experienced by pastures (Table 1), which expanded into area previously covered by the following classes: natural grassland (1601.27 ha), broad-leaved forests, fruit trees and berry plantations, land principally occupied by agriculture and transitional woodland shrub, non-irrigated arable land. The increase (change rates) for other classes were 15.95% for mixed forest, 18.55% for industrial or commercial units, 9.39% for broad-leaved forest, 8.41 for inland marshes and 5.13 for natural grasslands (Table 1). In contrast, the transitional woodland-shrub class incurred the greatest losses of area (5834.84 ha) from 1990 to

2012. This class was gradually replaced by broad-leaved forest (4418.68 ha), pastures (598.42 ha), natural grassland (540.71 ha) and mixed forest (212.01 ha). Other LCLU classes that incurred considerable losses of area during the period of our analysis were: vineyards (almost the entire surface was replaced by other LCLU classes), mineral extraction sites (the change rate of decrease was 98.86%), fruit trees and berry plantations (97.82%) and land principally occupied by agriculture (73.79%) (Table 1 & Fig. 2).

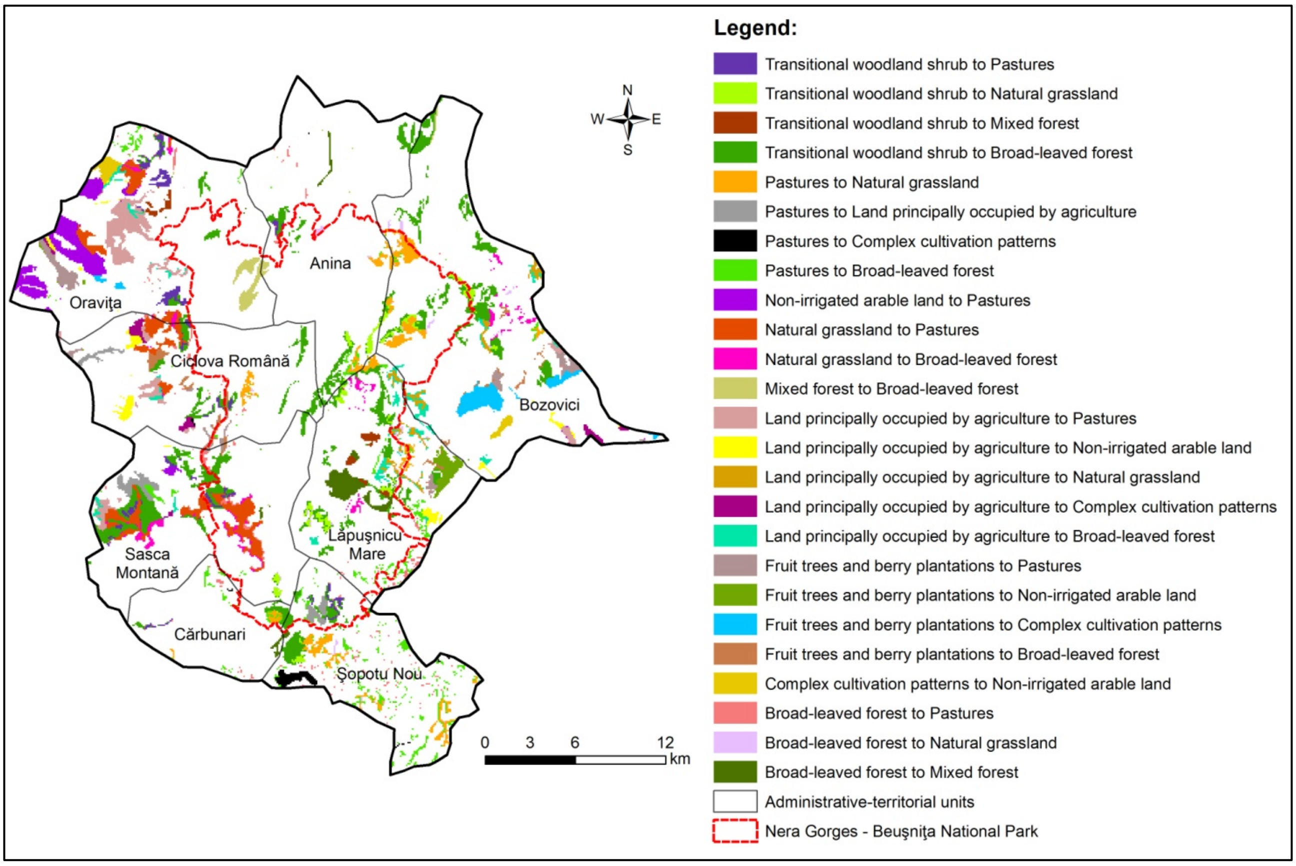

Figure 2. LCLC changes in the Nera Gorges-Beuşniţa National Park and its vicinity (1990-2012 period).

Table 1. LCLU classes in Nera Gorges-Beuşniţa National Park and its vicinity and their coverage (ha).

Land use/land cover classes	*1990*		*2012*		*Total change (ha)*	*Change rate (%)*	
	ha	**%**	**ha**	**%**		**22 yrs**	**Yearly**
Discontinuous urban fabric	1783.18	1.73	1435.43	1.39	-347.75	-24.22	-1.10
Industrial or commercial units	104.11	0.10	127.83	0.12	23.72	18.55	0.84
Mineral extraction sites	481.60	0.46	242.18	0.23	-239.42	-98.86	-4.49
Non-irrigated arable land	9243.63	8.98	8912.89	8.66	-330.74	-3.71	-0.16
Vineyards	392.23	0.38	20.62	0.02	-371.61	-1802.18	-81.91
Fruit trees and berry plantations	3543.21	3.44	1791.06	1.74	-1752.15	-97.82	-4.44
Pastures	8489.81	8.24	11203.23	10.88	2713.42	24.21	1.10
Complex cultivation patterns	975.30	0.94	1803.48	1.75	828.18	45.92	2.08
Land principally occupied by agriculture	3970.42	3.85	2284.54	2.21	-1685.88	-73.79	-3.35
Broad-leaved forest	60280.16	58.57	66529.44	64.64	6249.28	9.39	0.42
Coniferous forest	859.71	0.83	723.26	0.70	-136.45	-18.86	-0.85
Mixed forest	3385.20	3.28	4027.63	3.91	642.43	15.95	0.72
Natural grasslands	2900.36	2.81	3057.35	2.97	156.99	5.13	0.23
Transitional woodland-shrub	6420.30	6.23	584.46	0.56	-5835.84	-998.50	-45.38
Inland marshes	80.01	0.07	87.36	0.08	7.35	8.41	0.38
TOTAL	**102909.23**	**100.00**	**102909.23**	**100.00**	-	**-**	-

Similarly to *human pressure on forests*, other indicators showed considerable increases: *human pressure through the exploitation of non-agricultural lands* (0.13 ha/person in 1990 and 0.16 ha/person in 2012) and *human pressure through the exploitation of agricultural lands* (0.66 ha/person in 1990 and 0.80 ha/person in 2012).

Our analysis of the category of changes incurred by every LCLU class (Fig. 3) showed that a large percentage of the area considered (64.56%) was affected by the *Aggregation Process*. This process was observed to apply to broad-leaved forest, mixed forest and industrial or commercial units.

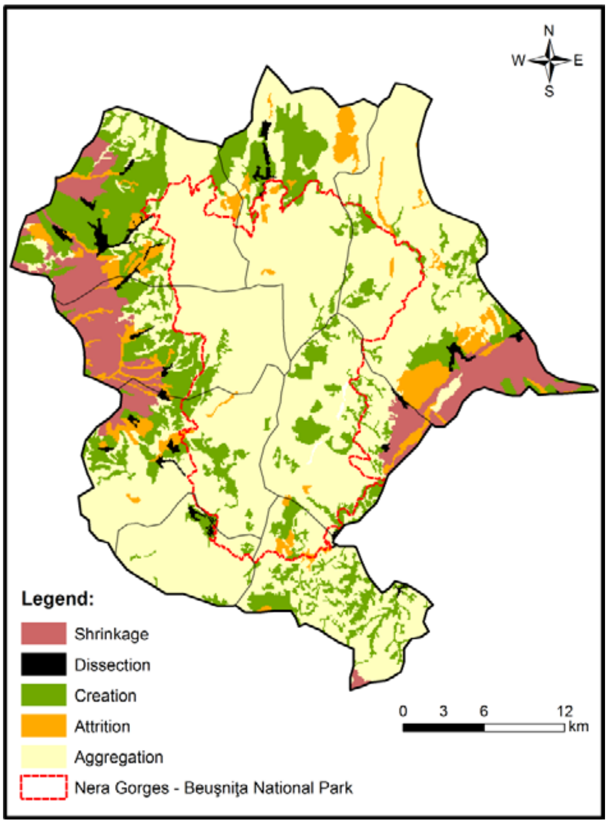

Figure 3. The changes occurring within each LCLU classes (1990-2012).

The *Creation Process* affected 19.57% of the surface of the study area, including pastures and complex cultivation patterns because the number of patches and the areas that have increased. Especially non-irrigated arable lands and coniferous forest were characterised by the *Shrinkage Process* (8.79%) because the area and perimeter are decreasing but the number of patches is constant, while discontinuous urban fabric, fruit trees and berry plantations, land principally occupied by agriculture and transitional woodland-shrub were affected by the *Attrition Process* (5.5%).

Only 1.37% of the overall area was affected by the *Dissection Process* (non-irrigated arable land). For this class, the number of patches is increasing and the area is decreasing.

To evaluate the extent to which the natural area/anthropogenic area ratio changed, we focussed on the *environmental transformation indicator*. The increase in the values of this indicator (2.22 in 1990 and 2.56 in 2012) showed that the natural area was dominant. This characteristic is extremely important for the Natura 2000 sites.

4.2. Landscape fragmentation

The second phase of our analysis aimed to address landscape fragmentation in the protected area and its vicinity and to analyse the temporal evolution of this basic characteristic of the landscape. Landscape fragmentation was investigated with the landscape metrics calculated at class level for 1990 (Table 2) and for 2012 (Table 3). The landscape metrics used were divided into three categories to describe landscape composition, shape and configuration. In the strictest sense, only landscape composition relates to fragmentation. However, we chose to use all three categories because the traditional view of landscape fragmentation encompasses all three as well as loss of area (Rutledge, 2003).

4.2.1. Landscape composition

The values obtained by the calculation of the landscape metrics (Tables 2, 3), more precisely the *CA*, emphasise the aspects previously described: the area occupied by forest, pastures and complex cultivation pattern expanded, whereas the areas occupied by transitional woodland-shrub, vineyards, mineral extraction sites, fruit trees and berry plantations and land principally occupied by agriculture decreased. The *NumP* indicator highlights the number of patches of a certain class. The results for this indicator show more significant growth for natural grasslands from 19 patches in 1990 to 68 patches in 2012, followed by complex cultivation patterns and pastures, whereas a major decline in the values of the same indicator was observed for transitional woodland-shrub (from 88 patches in 1990 to 23 patches in 2012) and land principally occupied by agriculture and fruit trees and berry plantations. The values of this indicator remained constant for three LCLU classes: non-irrigated arable land, coniferous forest and inland marshes. The *MPS* index is related to *NumP* and showed increases for 6 of the 15 classes included in our analysis: broad-leaved forest (1477.56 ha), mineral extraction sites (251.43 ha), and fruit trees and berry plantations (198.45 ha), whereas nine LCLU classes showed decreasing values of this indicator, namely natural grasslands (45.47 ha in 2012 compared to 153.06 ha in 1990), transitional woodland-shrub (26.51 ha in 2012 compared to 72.99 ha in 1990) and non-irrigated arable land (806.57 ha in 2012 compared to 924.42 ha in 1990). The *TE* of natural grasslands and pastures increased between 1990 and 2012, with a value of more than 90 km, whereas complex cultivation patterns, mixed forest and inland marshes experienced minor growth. Decreases in the value of this indicator from 1990 to 2012 showed major impacts on the following classes: transitional woodland-shrub, fruit trees and berry plantations and land principally occupied by agriculture. The *TCA* index is important because it defines the degree to which the landscape undergoes extension. The most significant increases in *TCA* values were recorded for broad-leaved forest (from 46,113.28 ha to 51,970.87 ha) and for pastures (from 2757.12 ha to 4066.23 ha). Major declines were recorded for transitional woodland-shrub (from 1715.2 ha to 40.46 ha), fruit trees and berry plantations (from 1984 ha to 1040.4 ha) and land principally occupied by agriculture (from 1292.8 ha to 361.25 ha). The *MCA* index is important because it provides the best indication of the area within a fragment located beyond a specified edge distance (Trisurat, 2009). A considerable increase characterised the broad-leaved forests (from 447 ha to 666.29 ha) and mixed forest, whereas the greatest decrease characterised the vineyards (from 30.2 ha to 0 ha). The analysis of the results provided by the last two indicators shows that broad-leaved forest class (showing positive values of both *TCA* and *MCA* during the study period) have benefited from the most favourable conditions for development in the study area. The most significant indicator used to measure the landscape fragmentation was MESH (Jaeger, 2000). MESH equals the sum of patch area squared, summed across all patches of the corresponding patch type (McGarigal & Marks, 1994; Jaeger, 2000). Because it takes into account the patch size distribution of the corresponding class, holding the patch size distribution constant in a class, MESH for the corresponding class will decrease (McGarigal, Marks, 1994). Thus, the value of this indicator decreased in 2012 for all the LCLU classes excepting industrial or commercial units, non-irrigated arable land, complex cultivation patterns, broad-leaved forest, mixed forest and pastures (Tables 2, 3).

Table 2. Landscape metrics of LCLU classes in 1990.

	Landscape composition							**Landscape shape**		**Landscape configuration**	
Landscape metrics/ Land use/land cover	**CA (ha)**	**NumP**	**MPS (ha)**	**TE (m)**	**TCA (ha)**	**MCA (ha)**	**MESH (km^2)**	**MSI**	**MPFD**	**MNND (m)**	**MPI**
Discontinuous urban fabric	1783.18	42	42.73	161920	353.28	14.1	2.51	1.45	1.05	905.08	13.44
Industrial or commercial units	104.11	4	24.96	10560	7.68	2.56	0.02	1.32	1.04	11472.17	0.01
Mineral extraction sites	481.60	5	94.72	33600	145.92	29.1	1.32	1.68	1.06	859.11	8.92
Non-irrigated arable land	9243.63	10	924.42	314560	5895.68	203	190.95	2.47	1.1	301.58	945
Vineyards	392.23	5	80.38	28480	151.04	30.2	0.37	1.67	1.08	3333.68	5.88
Fruit trees and berry plantations	3543.21	21	167.38	158400	1984	94.4	34.49	1.59	1.06	716.8	37.11
Pastures	8489.81	94	90.85	644480	2757.12	29.6	34.93	1.73	1.07	590.99	73.07
Complex cultivation patterns	975.30	10	96.77	63360	373.76	37.3	1.71	1.66	1.07	1779.39	13.42
Land principally occupied by agriculture	3970.42	51	76.8	298560	1292.8	38.0	16.4	1.68	1.07	708.6	41.62
Broad-leaved forest	60280.16	42	1436.71	136928	46113.28	447	31153.07	1.79	1.06	496.86	8243.39
Coniferous forest	859.71	5	172.54	40000	463.36	92.6	3.47	1.67	1.07	6298.53	1.19
Mixed forest	3385.20	13	259.94	157760	1779.2	93.6	26.84	1.83	1.07	1478.93	47.28
Natural grasslands	2900.36	19	153.06	202880	983.04	32.7	8.4	2.12	1.1	1182.21	37.96
Transitional woodland-shrub	6420.30	88	72.99	524800	1715.2	21.1	12.00	1.72	1.07	447.84	30.4
Inland marshes	80.01	3	25.6	10880	0	0	0.06	1.81	1.09	160	11.19

Table 3. Landscape metrics of LCLU classes in 2012.

	Landscape composition							Landscape shape		Landscape configuration	
Landscape metrics/ Land use/land cover	**CA (ha)**	**NumP**	**MPS (ha)**	**TE (m)**	**TCA (ha)**	**MCA (ha)**	**MESH (km^2)**	**MSI**	**MPFD**	**MNND (m)**	**MPI**
Discontinuous urban fabric	1435.43	36	38.93	143480	190.74	11.92	1.37	1.57	1.06	901.13	7.63
Industrial or commercial units	127.83	2	63.58	10540	26.01	6.5	0.09	1.71	1.08	7101.44	0.01
Mineral extraction sites	242.18	1	251.43	15640	83.81	41.9	0.57	2.47	1.12	1	0
Non-irrigated arable land	8912.89	11	806.57	287640	5733.76	191.13	208.37	2.3	1.1	2904.3	260.19
Vineyards	20.62	1	23.12	2380	0	0	0.003	1.24	1.03	1	0
Fruit trees and berry plantations	1791.06	9	198.45	73780	1040.4	94.58	8.59	1.65	1.07	2335.82	9.15
Pastures	11203.23	104	108.12	734740	4066.23	42.36	80.72	1.68	1.06	376.49	79.1
Complex cultivation patterns	1803.48	30	60.11	124440	604.01	31.79	2.87	1.47	1.06	1465.47	8.38
Land principally occupied by agriculture	2284.54	34	68.6	223040	361.25	13.89	4.10	1.93	1.09	481.34	16.35
Broad-leaved forest	66529.44	45	1477.56	129064	51970.87	666.29	39939.52	1.71	1.06	348.35	10063.7
Coniferous forest	723.26	4	181.35	29920	410.38	82.08	3.36	1.55	1.06	3754.45	4.87
Mixed forest	4027.63	16	250.35	159460	2259.98	141.25	31.99	1.68	1.07	1396.57	64.62
Natural grasslands	3057.35	68	45.47	298180	531.76	14.77	4.40	1.62	1.06	514.31	25.21
Transitional woodland-shrub	584.46	23	26.51	68000	40.46	4.05	0.21	1.41	1.05	2253.42	2.48
Inland marshes	87.36	4	22.4	11220	2.89	2.89	0.02	1.48	1.06	520.46	1.51

4.2.2. Landscape shape

The second category of indicators that we calculated (Tables 2, 3) involved those that emphasised the landscape shape: MSI and MPFD. *MSI* is unsuitable for the analysed period, indicating that the average form of units with different LCLU classes is not a square, because it changes. *MPFD* indicates the complexity of the perimeter of a vegetation unit. The complexity of the perimeter of mineral extraction sites units increased (from 1.06 to 1.12), and the complexity of the perimeter of vineyards, natural grasslands and inland marshes units decreased from 1990 to 2012.

Three other LCLU classes showed the same indicator value for 1990 and for 2012 (non-irrigated arable land, broad-leaved forest and mixed forest).

4.2.3. Landscape configuration

The final category of indicators highlights the landscape configuration. In particular, the *MNND* index indicates the distance between patches. The values of this indicator increased over the period of study for non-irrigated arable land (2602.72 m), transitional woodland-shrub (1805.58 m), fruit trees and berry plantations (1619.02 m), and inland marshes (360.46 m) (Tables 2, 3). The patches corresponding to these classes were more isolated than the patches of all other LCLU classes. Another indicator that measures the degree of isolation and fragmentation, the sparse distribution of small patches from clusters of large patches, is the *MPI* (Gustafson & Parker, 1994). The reduction in the isolation of patches increases the proximity index, behaviour-specific to the broad-leaved forests, mixed forest, pastures and discontinuous urban fabric.

5. DISCUSSION

The first phase of our analysis aimed to highlight the changes occurring in the landscape of a protected area as a result of the manner in which the lands were used during the first 22 years after the fall of the socialist regime and in the context of the associated orientation towards a market economy. Usually, for national parks, the greatest threats result from activities of using natural resources (Stanciu & Florescu, 2009) such as agricultural and forestry practices, sectorial activities and conservation policies (Iojă et al., 2016). The impact of including this national park in the Natura 2000 Network is significant because its management suppose the most restrictive function of protection and focuses on human-nature relationships. That's why, the effects about Natura 2000 implementation in Nera Gorges-Beuşniţa National Park can be reported as positive on biodiversity and social participation (Popescu et al., 2014). In fact, the evaluation of the changes in the LCLU classes that occurred over the period 1990-2012 allows for a better understanding of the process of landscape fragmentation (Apan et al., 2002; Shi et al., 2008; Niculae & Pătroescu, 2011). This information facilitates the identification of both the causes of fragmentation and its potential effects on the surrounding environment. Fragmentation has contributed to the changes in the structure of the landscape of the study area. This aspect has been underscored not only by the dynamics of the values of the landscape indicators during the study period but also the pattern of transition to other LCLU types demonstrated by the various classes that we analysed.

The increase or decrease in the area of certain LCLU classes, the changes in their shapes and/or the number of patches and the growth of the degree of isolation indicate a marked intensification of landscape fragmentation after 1990 (Tables 2, 3). Therefore, if we consider the increase in the *NumP* value and the decrease in the *CA* value, we note that the most fragmented class is represented by mineral extraction sites. The simultaneous increase in the *NumP* value and the increase in the *CA* or *TCA* values do not indicate fragmentation of similar magnitude. The finding that landscape fragmentation is still an active process is also supported by the decrease in the *MPS* values and also highlights the loss of area by many LCLU classes, especially for natural grasslands, transitional woodland-shrub, due to reforestation and non-irrigated arable land replaced by pastures. The high degree of landscape fragmentation was also demonstrated by the increase in MESH values, especially for broad-leaved forests and non-irrigated arable land, by the increase in the irregularity of patches for mineral extraction sites, industrial or commercial units, land principally occupied by agriculture and discontinuous urban fabric (*MSI*) or by the *TE*, which indicates an expansion of natural grasslands and pastures to a value of nearly 90 km. The emphasis on landscape fragmentation in the study area is also demonstrated by the results of the analysis of the degree of isolation of the LCLU classes, specifically by the increase in the values of the *MNND* indicator or by the decrease in the interconnectivity between units; this aspect is also reflected by the decrease in the *MPI* values. Based on these results, we observed that the highest degree of isolation and the lowest interconnectivity between units characterised the non-irrigated arable land, transitional woodland-shrub, fruit trees and berry plantations and inland marshes. These classes were separated by forest clusters, pastures, or settlements.

Additionally, we note that landscape fragmentation is still active but has not yet reached alarming levels in the study area because of the decrease in human activity resulting from the ageing of the population, the rural exodus, the low birth rate, and the termination of mining activities, which have caused a significant depopulation of the area from 40086 inhabitants in 1990 to 32136 inhabitants in 2012. Even if the indicators of human pressure on an LCLU class (forest, agricultural land etc.) get bigger values in 2012, it highlights only the number of hectares of a certain LCLU class belonging to a resident of the region, not an increasing in human activity. Furthermore, the changes in the study area have been characterised by the expansion of forest landscapes, both naturally (natural reforestation of abandoned lands) and as a result of initiatives by the local authorities (Caraş-Severin County Council et al., 2007), whose aimed to increase the naturality level of the area and to revitalise degraded sites. The expansion of forest is in fact beneficial for the study area, particularly if we recognise that these ecosystems are extremely important for the preservation of biodiversity (Heinimann et al., 2007), the preservation of a stable supply of oxygen, the regularisation of watercourses, and the prevention of soil erosion. The reduction of the forest landscape would represent "*one of the most important human-induced disturbances that contribute to global environmental and climate change*" (Evrendilek & Ertekin, 2002; Kilic et al., 2006). Moreover, it is well known that broad-leaved forests, which are predominant in this area, have a higher water storage capacity than do coniferous forests (Bastian, 2013). Therefore, as demonstrated by the increase in the naturality indicator from 1990 (0.58) to 2012 (0.69), the Nera Gorges-Beuşniţa National Park and its vicinity are characterised by an ecologically well-balanced landscape, similar to the initial landscape. This finding is also supported by the Human-Pressure-on-Forests Indicator. The value of this indicator for 2012 was 2.21 ha forest/person, a desirable outcome in terms of the value of 0.3 ha forest/person prescribed by the FAO for the preservation of ecological equilibrium. Although the values of the other indicators (human pressure on agricultural and non-agricultural lands) increased, these values served to characterise the area as a well-balanced rural and slightly unbalanced landscape characterised by a predominance of natural elements (the increasing values of the environmental transformation indicator, from 2.22 in 1990 to 2.56

in 2012, clearly verify this outcome). The principal cause of these changes was not the changes in LCLU classes but, rather as we mentioned earlier, geo-demographic effects such as the decline in the population after 1990's, a phenomenon occurring throughout the country and specifically found in most of the former communist states.

Similar studies have been conducted for other areas of Romania, primarily for rural regions (Armaş et al., 2003; Dumitraşcu, 2006; Pătroescu & Niculae, 2010; Pătru-Stupariu, 2011; Ionuş et al., 2011; Zarea & Ionuş, 2012). Protected areas and mountain areas have been relatively neglected and have been the focus of fewer studies (Manea, 2003; Bogdan et al., 2007). However, the results of the current study differed slightly from the results of these previous studies. Indeed, in this study an increased degree of naturality of the landscape was observed. In contrast, previous studies have emphasised the acceleration of human pressure on the landscape, particularly through the expansion of built-up areas and through the intensification of human intervention in natural ecosystems (e.g., excessive grazing, deforestation).

For the future, we intend to continue the analysis for other national parks too, to see if the economic profile of the settlements located nearby influence or not the landscape fragmentation.

6. CONCLUSIONS

The Nera Gorges-Beuşniţa National Park is one of the 556 Natura 2000 sites in Romania. Moreover, it represents a protected area of high importance for the sustainable development process due to the variety of landscapes, habitats, and species of community interest that it harbours as well as the ecosystem services that it provides. The area may also represent a reliable alternative that can facilitate development activity benefitting the neighbouring disadvantaged areas (i.e., the Anina, Sasca Montană, and Bozovici areas) that resulted from the economic reorganisation that occurred after the 1990s. Together, the analysis of the changes occurring in the landscape of the protected area and its vicinity and the analysis of the landscape fragmentation that host various species represent the primary framework for the implementation of sustainable development measures.

The results obtained in this study helped us further confirm that the role played by protected areas is extremely important for the prevention of landscape fragmentation and LCLU changes. In fact, "*the protected areas mitigate fragmentation*" (Garcia et al., 2017). This aspect is supported by a good management of the national park provided by the traditional land use that not come into conflict with the conservation rules (Iojă et al., 2016), few economic activities that are still practiced and no many stakeholders groups that have interest in the area (excepting those related to tourism activities). Furthermore, it is evident that the protected area status of the Nera Gorges-Beuşniţa National Park is sufficient to prevent wasteful effects on the services provided by the area's ecosystems. This conclusion is also supported by the minor changes occurring in the LCLU classes. The annual rates of change observed for the study area showed significant losses of area for vineyards, transitional woodland-shrub, mineral extraction sites, fruit trees and berry plantations and a considerable expansion of mixed and broad-leaved forests. The same classes also showed substantial rates of change over the entire period on which we focused (22 years), a finding that reflects the economic reorganisation implemented after 1990. Among all of the LCLU classes considered in this study, the highest rate of change recorded in the protected area was observed for the forest ecosystems, whose area has increased significantly over the past 22 years. Their expansion, as well as their degree of fragmentation, is demonstrated by a series of indicators, such as the low deforestation rate for 1990-2012 and a moderate increase in the Naturality Indicator, which characterises an ecologically well-balanced landscape in this case, similar to the initial landscape.

In contrast, the largest losses in area were incurred by the transitional woodland-shrub, vineyards, mineral extraction sites, fruit trees and berry plantations, as most of these land-use types were converted to pastures and broad-leaved forests. Overall, these results demonstrate that landscape fragmentation remains an active but minor process in the study area and that its intensity is greater on the borders of the Nera Gorges-Beuşniţa National Park, where the density of population and settlement is higher. The dominant role of *aggregation* and *creation* processes on 84.13% of the area, as well as the values of the landscape metrics at the LCLU class level, show the same reduction in fragmentation. The depopulation of the area has clearly reduced the human impact on the landscape. Landscape fragmentation and economic reorganisation have implicitly shifted the conversion of the landscape typology towards a more homogeneous system, a beneficial outcome for the Natura 2000 site. These processes have not affected our concerns regarding the preservation and protection of the area. On the contrary, they actually furnish a solid basis for building a strategy for the development and promotion of touristic activities in the Nera Gorges-Beuşniţa National Park without jeopardising the quality and integrity of the landscape.

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