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Quantifying Forest Ecosystems Fragmentation in the Subcarpathians between the Râmnicu Sărat and the Buzău Valleys, Romania, Using Landscape Metrics

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Abstract

The Romanian Subcarpathian space has been the subject of continuous transformation during the last 2 centuries under the double impact of human activities and disruptive natural factors. Time and spatial dynamics of land use and coverage determined a major impact on the structure and functionality of the Subcarpathian landscape. In the Subcarpathians between the Râmnicu Sărat and the Buzău, the main tendencies in land use changes are highlighted by the decrease of forestry areas and increase of agricultural terrains, especially pastures and orchards, a consequence of the deforestation undertaken to answer local human needs. The fragmentation and the pronounced decrease of forestry ecosystems has been quantified by calculating and analysing landscape metrics, using land use and coverage maps derived from the Corine Land Cover 1990 and 2006 database. In the Subcarpathians between the Râmnicu Sărat and the Buzău, there has been registered a deforestation rate of 10.09% in the analysed period, but also an increase in landscape fragmentation. Thus, the number of forest patches increased by 10.96% and their average size decreased by 13.73%, while the shape remained unchanged. Landscape patches became more isolated, as the value of the average proximity index decreased by 42.07%. The study underlines the necessity of elaborating a strategy of protection and preservation for these ecosystems, aimed at increasing the reforestation rate and decreasing the fragmentation degree. A sustainable planning system of land use must be enforced in order to increase forest productivity and the uniformity degree of the Subcarpathian landscape.

Keywords: *landscape ecology, fragmentation, clearcutting, landscape metrics, Subcarpathians Curvature, Romania*

Rezumat. Utilizarea metricilor peisajului în cuantificarea fragmentării ecosistemelor forestiere din spaţiul Subcarpaţilor dintre Râmnicu Sărat şi Buzău, România

Spaţiul subcarpatic din România a fost supus în ultimele două secole unei continue transformări sub impactul activităţilor antropice, care s-au coroborat cu cele induse de factori naturali perturbatori. Dinamica spaţio-temporală a modului de utilizare şi acoperire a terenurilor a exercitat un impact major asupra structurii şi funcţionalităţii peisajului subcarpatic. În Subcarpaţii dintre Râmnicu Sărat şi Buzău, principalele direcţii privind schimbările modului de utilizare a terenurilor sunt evidenţiate de reducerea suprafeţelor forestiere şi creşterea în suprafaţă a terenurilor agricole, în special păşunile şi livezile, consecinţă a defrişărilor efectuate în scopul satisfacerii nevoilor umane. Fragmentarea şi reducerea accentuată a suprafeţei ecosistemelor forestiere a fost cuantificată prin calcularea şi analiza metricilor peisajului, utilizând hărţile de utilizare şi acoperire a terenurilor derivate din baza de date Corine Land Cover 1990 şi 2006. În Subcarpaţii dintre Râmnicu Sărat şi Buzău s-a înregistrat o rată de defrişare a pădurilor de 10,09% în intervalul analizat, concomitent crescând şi fragmentarea peisajului. Astfel, numărul patch-urilor a crescut cu 10,96%, iar dimensiunea medie a scăzut cu 13,73%, forma fiind nemodificată. Fragmentele de peisaj au devenit mai izolate, valoarea indicelui mediu de proximitate diminuându-se cu 42,07%. Rezultatele studiului subliniază nevoia de elaborare a unei strategii de protejare şi conservare a acestor ecosisteme, în scopul creşterii procentului de reîmpădurire şi reducerea nivelului de fragmentare. În scopul creşterii productivităţii acestora şi a gradului de omogenitate a peisajului subcarpatic trebuie implementate acţiuni de planificare durabilă a modului de utilizare a terenurilor.

Cuvinte-cheie: *ecologia peisajului, fragmentare, defrişare, metricii peisajului, Subcarpaţii de Curbură, România*

INTRODUCTION

Landscape transformation represents a consequence of human activities (Dumitraşcu, 2006) and of disruptive natural factors (Hansen and di Castri, 1992; Farina, 1998; Uuemaa et al., 2009).

The time diversification of land use generated contrasting landscapes, with a significant impact on species distribution (Primack et al., 2008).

The main human activities with a major impact upon the structure and functionality of landscape are: the intensification of agricultural activities, deforestation, the abandonment of agricultural lands in under-developed areas, but also the chaotic development of local communities (Farina, 1998; Burel and Baudry, 1999).

Habitats fragmentation induces negative effects upon a large number of animals and plants species (Farina, 1998), especially by increasing the isolation degree of habitats (Debinski and Holt, 2000; Watson et al., 2004).

Fragmentation implies the dissolution of habitats or large terrain units in smaller size units (Forman, 1977), the quantification of landscape fragmentation being the main method of analysis used for landscape structure dynamics (Bunce et al., 1993; Burel and Baudry, 1999).

The present study analyses land use and coverage changes in the forestry areas from the Subcarpathian region between the Râmnicu Sărat and the Buzău, during the 1990 – 2006 period.

MATERIALS AND METHODS

Study area

The study area is located in the Curvature Subcarpathians, in Buzău and Vrancea Subcarpathian units (Posea and Badea, 1984), overlapping Buzău and Vrancea counties (Fig. 1).

The analysed space is characterised by a deep rural character induced both by the absence of urban poles, the development of settlements with rural functions and aesthetics (Pătroescu and Niculae, 2010), but also by the prevailing agricultural land use (Pătroescu, 1996).

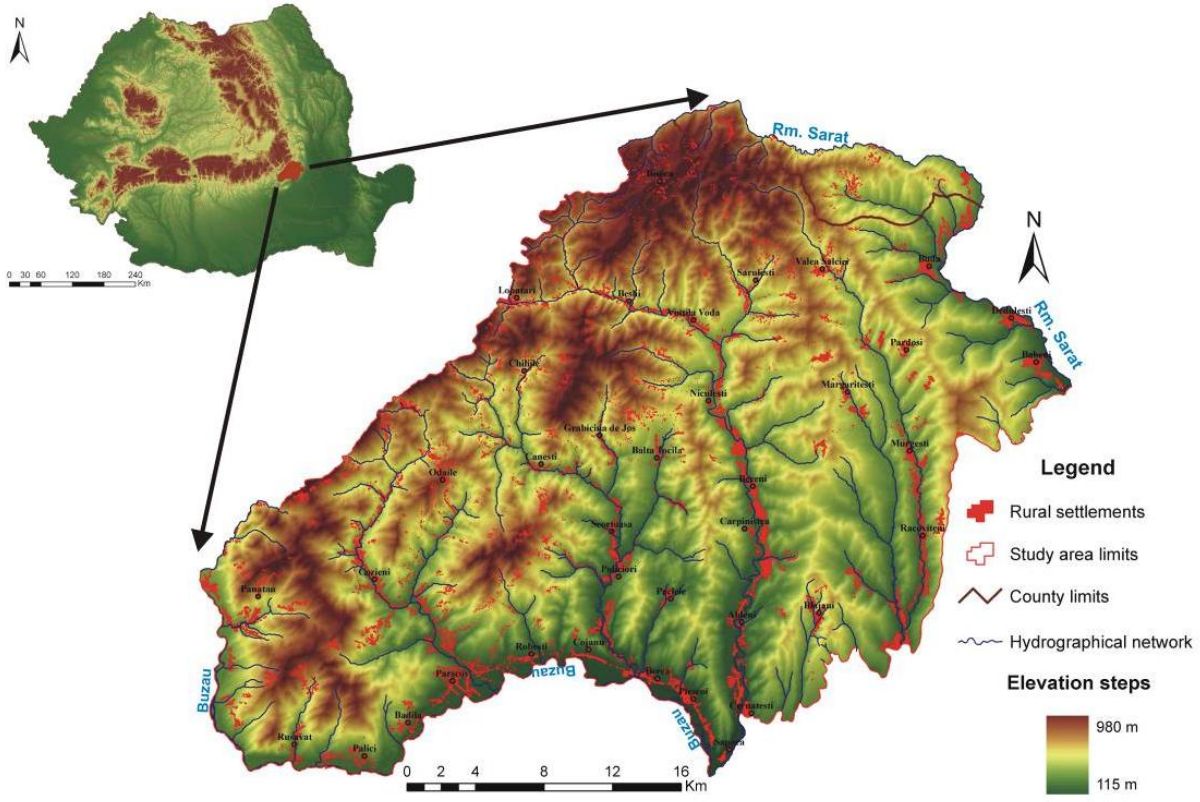

Fig. 1. Study area

Approximately 30% of the total area is represented by forests, while pastures and orchards cover about 33% of the area.

The main activities with direct impact on the fragmentation of Subcarpathian rural landscapes are: pasturage, orchards development and wood processing (Pătroescu, 1996).

Land use and coverage is conditioned by the morphologic and morphometric features of the relief, corroborated with the geological structure of

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the Subcarpathian area. Altitudes are between 115 and 980 meters, with the highest values being concentrated in the Northern and North-Western areas, at the contact with the mountainous Carpathian units.

Data

In the analyse it has been used the spatial database of the European Environmental Agency (EEA) as part of the Corine Land Cover (*CLC*) project, for the years 1990-2006, (*CLC 1990* and *CLC 2006*, data available at http:// www.eea.europa.eu/ data-and-maps /data/ corine -land- cover-1990 - raster and http:// www. eea.europa.eu/ data-and-maps/ data/ corine- land-cover-2006- raster).

Initial data have been reprojected in the Stereo 70 projection system, using ArcGis 9.3.

The 20, and respectively 19 classes, of land use and coverage specific to the studied area, resulting from the 1990 and 2006 CLC models have been reclassified in 5 main classes according to the system terminology for the CLC model, level 2 (Geri et al., 2010) joining polygons with the same land use (Table 1).

Table 1. Description of the land use and cover classes

Land use and land cover class	CLC 1990-2006 Level 2	Description
Forest	3.1	Broadleaf forests, evergreen forests and mixed, associated with shrubs, trees canopy covering >50% of the area
Seminatural areas	3.2-3.3	Natural pastures, shrubs, temporary water courses, beaches along the river beds, lands affected by erosion, bare rocks, badlands with rare vegetation
Agriculture areas	2.1-2.2-2.3-2.4	Arable lands, pastures, orchards, vineyards
Water areas	5.1	Water-courses, natural lakes
Urban areas	1.1-1.3-1.4	Built areas, transport infrastructure, extraction sites

Source: Bossard et al., 2000

Fragmentation analysis

Landscape fragmentation, as well as land use and cover changes in the analysed time period were studied using three different methods: 1) landscape metrics calculation and analyse; 2) analysing changes in the number of small units, specific to forestry surfaces and 3) quantification of land use/coverage changes for forestry surfaces.

The first method used for quantifying landscape fragmentation requires the calculation and analyse of landscape metrics (Apan et al., 2000). A series of 8 indices (Table 2) were selected for analysing landscape configuration (Turner et al., 2001). The indices quantify class surface, the number, shape and size of landscape units. Patch Analyst 4 (Grid), an extension for ArcGis 9.3, was used, as it includes in the analyse the FRAGSTATS program, elaborated by (McGarigal and Marks, 1994).

Table 2. Landscape metrics

Landscape indices	Symbol	Description	Range
Class area (ha)	CA	Total surface of the forests class	CA >0, no limits
Number of patches	NumP	Total number of forest patches	NumP ≥ 1, no limits
Mean patch size (ha)	MPS	Average size of forest patches	MPS > 0, no limits
Largest patch index%	LPI	Percent of the largest forest unit from the landscape	0 <LPI<100
Mean shape index	MSI	Average ration between perimeter and surface	MSI ≥ 1, no limits
Mean patch fractal dimension	MPFD	Average fractal dimension; indicates the complexity degree	1<MPFD<2
Mean nearest neighbour distance (m)	MNND	Average distance between a forest unit and the nearest forest unit; indicates the isolation degree	MNND>0, no limits
Mean proximity index	MPI	Measures the isolation degree of units and the fragmentation level	MPI ≥ 0

Source: McGarigal and Marks, 1994

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The second method requires analysing changes in the number of small surfaces units, covered by forestry vegetation and their quantification. By applying this method, it was compared the number of units with a surface of one, two, three, four and five hectares between 1990 and 2006.

This method assumes the grouping of adjacent regions using the ArcGis program and the four orthogonal neighbours rule, defining the connectivity between cellules characterised by forestry vegetation, only on horizontal and vertical, and not including diagonal cellules.

The third method evaluates land use/cover changes in the analysed period. A cross tabular analyse was realised using the ArcGis 9.3 program, and the Tabulate area function (Spatial analyst). The two datasets were transformed in 100x100 grids and were compared by overlapping land use maps, for 1990 and 2006 (Fig. 2).

The rate of changes for surfaces with forestry vegetation and their directions were identified: the transformation of forest vegetation in other land use/cover classes (e.g. forests into artificial surfaces, agricultural lands, etc.), and the conversion of other land use/coverage classes into forestry vegetation.

RESULTS

Landscape metrics

The values obtained from landscape metrics calculations (Table 3) evidence that in the analysed period, the total surface of forestry vegetation terrains decreased with 1 566 ha (4.28 %), to a total value of 35 015 ha in 2006. The number of patches recorded a small increase, from 146 to 162 units. The Mean patch size index records a decrease in 2006 compared with 1990, and the Largest patch index expresses an obvious decrease, from 11.71 % in 1990 to 5.91 % in 2006.

The value of the Mean shape index is improper in the two analysed years, indicating that the average form of units with forestry vegetation isn't a square one. The two values, 1.94 and respectively 1.98, indicates an insignificant increase of patch form complexity in the case of forestry vegetation from 2006.

The Mean fractal dimension in the two years is 1.08, indicating a reduced complexity for the perimeters of vegetation units.

The Mean nearest neighbour distance decreased by 10.77 m, reaching a value of 163.32 m in 2006. The mean proximity index records a significant decrease, from 1,660.17 in 1990, to 961.69 in 2006.

Table 3. Landscape metrics calculated in the Subcarpathians between the Râmnicu Sărat and the Buzău for the forest class

Indices	**Year**	
Class level: forest	1990	2006
Class area (ha)	36 581	35 015
Number of patches	146	162
Mean patch size (ha)	250.55	216.14
Largest patch index %	11.71	5.91
Mean shape index	1.94	1.98
Mean patch fractal dimension	1.08	1.08
Mean nearest neighbour distance (m)	174.09	163.32
Mean proximity index	1 660.17	961.69

Changes in the number of small units

With the exception of forestry units with a surface of 3 ha, the number of units from the other 4 classes of size evaluated increased in 2006 in comparison with 1990 (Table 4).

Table 4. Number of patches with forestry vegetation corresponding to units with small surfaces

Patch size	Number of patches	
	Year 1990	Year 2006
1 ha	79	91
2 ha	40	47
3 ha	17	17
4 ha	3	8
5 ha	8	9

Quantification of changes in land use/coverage

Analysing the transition matrix (Table 5) it can be observed that in the analysed period *forestry surfaces* converted in other land uses represented 3,692 ha (10.09%), with an average of approximately 230 ha/year, while the conserved surface represented 32,889 ha (89.91% from the total surface in 1990).

In 1990, forestry vegetation covered 31.69 % (36,581 ha) from the total surface of the analysed Subcarpathian area (115 432 ha), with 1.36 % (approximately 1 556 ha) larger than in 2006 (35 015 ha).

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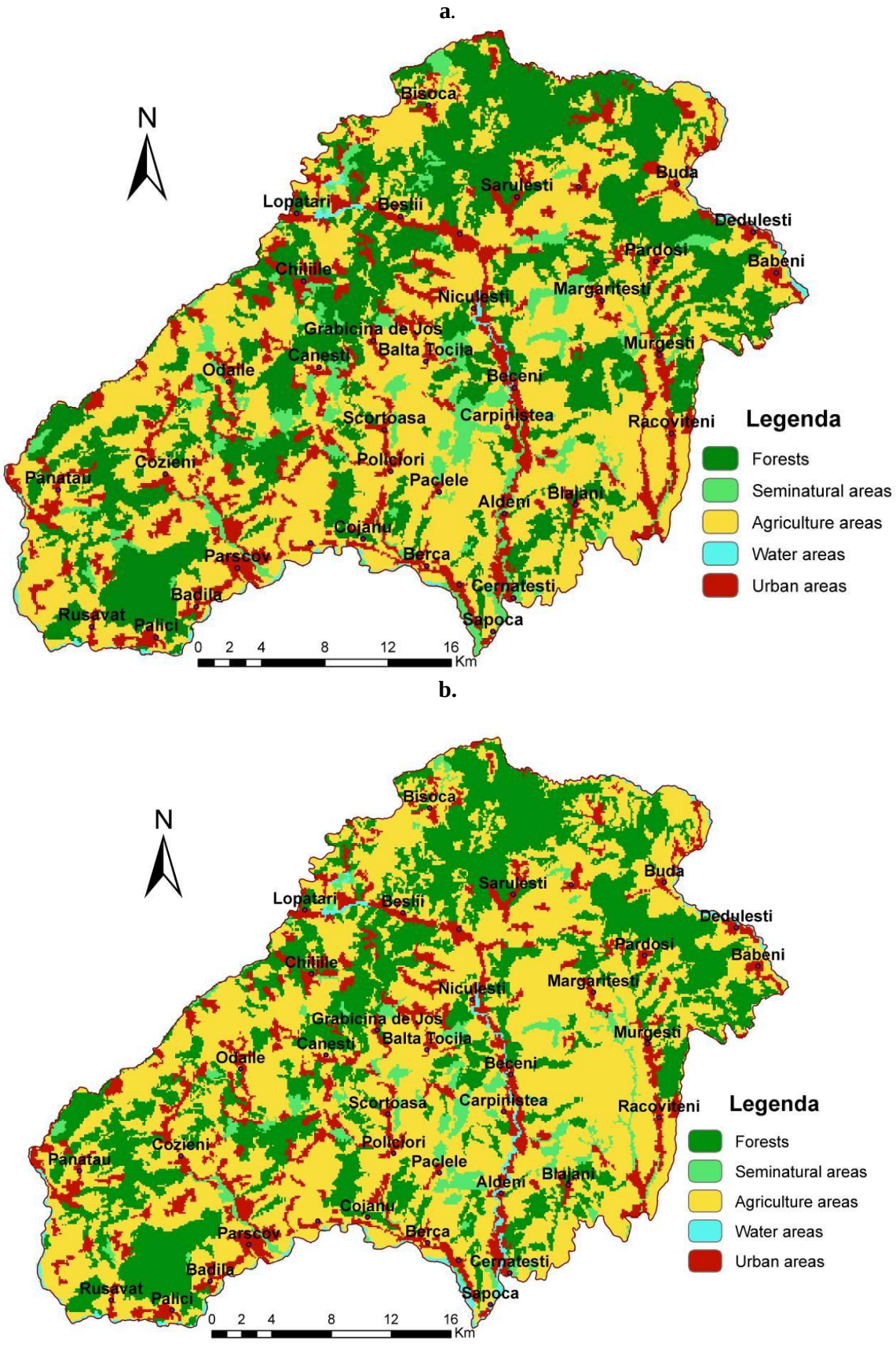

Fig. 2. Land use map in the Subcarpathians between the Râmnicu Sărat and the Buzău (a. Year 1996; b. Year 2006)

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Table 5. Contingence matrix (values in ha and %) corresponding to the two datasets

	1990 ha (%)						
	Class	Forest	Semi- natural areas	Agriculture areas	Water areas	Urban areas	**Total**
2006 ha (%)	Forest	32889 (89.91)	709 (10.07)	1344 (2.39)	4 (0.41)	69 (0.47)	**35015**
	Semi- natural areas	***59 (0.16)***	3367 (47.84)	908 (1.62)	15 (1.54)	165 (1.13)	**4514**
	Agriculture areas	***3500 (9.57)***	2459 (34.93)	53707 (95.4)	57 (5.87)	1319 (9.04)	**61042**
	Water areas	*4 (0.01)*	496 (7.05%)	53 (0.09%)	895 (92.08%)	26 (0.18)	**1474**
	Urban areas	***129 (0.35)***	8 (0.11)	239 (0.42)	1 (0.1)	13010 (89.18)	**13387**
	Total	**36581**	**7039**	**56251**	**972**	**14589**	**115432**

The data from Table 6 express that the largest surface from the total forest surfaces converted in other land uses was transformed into agricultural fields, approximately 3,500 ha (9.57%), and built up surfaces, approximately 129 ha (0.35%). The rest of the transformations, into seminatural and aquatic surfaces, are insignificant (0.17%).

From the total seminatural surfaces existent in 1990 (7,039 ha), 709 ha (approximately 10%) were transformed in forests, while approximately 1,344 ha (2.39% from agricultural fields existent in 1990, respectively 56,251 ha) of agricultural fields were converted into forest surfaces.

Table 6. Forest surfaces conversion in other land uses, in the 1990- 2006 period

Thematic change		Area	
		(ha)	%
A.	No change	32 889	89.91
B1.	Forest to seminatural areas	59	0.16 (1.60)*****
B2.	Forest to agriculture areas	3 500	9.57 (94.80)
B3	Forest to water areas	4	0.01 (0.11)
B4	Forest to urban areas	129	0.35 (3.49)
Total B1-B4		**3 692**	**10.09**
Grand total (A and B1-B4)		**36 581**	**100**

** the numbers in brackets represent percents of the total forest surface converted in other land uses*

DISCUSSIONS

The present study reveals a fragmentation of forestry surfaces during the analysed period, process which obviously contributed to the modification of the Subcarpathian landscape structure. This aspect is clearly emphasized by the temporal dynamics of landscape metrics and the values from the transition matrix.

The evaluation of land use and land cover changes in the analysed period allows a better understanding of the landscape fragmentation process (Apan et al., 2000), prioritizing both its causes and possible effects.

Landscape indices represent a tool for identifying and characterising spatial differences in landscape structure (Echeverria et al., 2006) and time changes in the landscape mosaic.

Changes in the number of forest units, their shapes and size, and the increase of the isolation degree for forestry vegetation, reveal an intensification of the fragmentation process, beginning with 1990.

The increase of forest units with small surfaces, between 1 and 5 ha, confirms the increase of fragmentation, as also demonstrated by increases in the total number of patches and decreases in the total surface of the forests.

The decrease of the Mean patch size index, from 250.55 in 1900 to 216.14 reveals an obvious surface reduction of most of the forest units, and corroborated with the decrease of the Largest patch index (from 11.71% to 5.91%), and with the Largest patch dimension which decreased in 2006, demonstrate that the fragmentation of the Subcarpathian landscape represents an active process.

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Fragmentation intensification is also revealed by an increase in the irregularity of patches, evidenced by the increase of the Mean shape index in the analysed period, the fractal dimension of units maintaining at 1.08.

The decrease of the Mean nearest neighbour distance of the closest patch from the same class reveals that in 2006, forestry units are more isolated than in 1990, decreasing the interconnectivity between units, a fact also sustained by the value of the Mean proximity index, diminished in 2006 compared with 1990.

The obtained transition matrix following the cross tabular analysis for the two thematic maps, exemplified for forestry surfaces all changes directions and rates, into agricultural lands, seminatural surfaces, water bodies and built surfaces.

The largest forest surfaces were transformed into agricultural fields. The enforcement of territorial legislation allowed retrocessions with lands in the old emplacements for the inhabitants, amplifying the fragmentation degree of habitats and subsequently, the Subcarpathian rural landscape.

Forestry surfaces were clearcutted in favour of agricultural land, especially of surfaces for pasturing, the main activity of local inhabitants, but also in order to obtain fuel needed in domestic use (Muică et al., 2000).

Alongside clearings realised by permanent residents, the Subcarpathian area suffered a reforestation process, both with natural determinant, but also as a result of the activities of local authorities which aimed at increasing the naturalness degree and revitalising degraded areas.

CONCLUSIONS

The present study quantifies and analyses major changes in forestry surface from the Subcarpathian area between the Râmnicu Sărat and the Buzău valleys, in the 1990–2006 period, identifying the directions of landscape transformation.

The causes and effects of changes were evidenced, being induced mainly by human factors, following the pursuit of satisfying human needs, and adjusting activities to the specificity of the Subcarpathian area.

Landscape fragmentation, and subsequently that of forest surfaces was, and continues to be induced by the local rural population, especially by amplifying and diversifying human activities, and materialised by an increase density of settlements, wood exploitation, expansion of pasture surfaces etc. Landscape structure changes were induced mainly by the intensification of forestry fragmentation in time, reflected especially by shifts in the forest units' number, form, size and degree of isolation.

The total surface occupied by forests decreased from 1990, simultaneously with the increase of landscape fragmentation. The largest forest surface was replaced by agricultural fields, respectively pastures, evidencing the specific of the Subcarpathian local communities.

REFERENCES

Apan, A.A., Raine, S.S., Paterson, M., S., (2000). *Quantifying landscape fragmentation in the Lockyer Valley Catchment*, Queensland: 1973-1997, In AURISA 2000-The 28th Annual Conference of AURISA Hyatt CoolumResort, Coolum QLD.

Bossard, M., Feranec, J., Otahel, J., (2000). *Technical report No. 40*, CORINE land cover technical guide-Addendum 2000, European Environment Agency, Copenhagen.

Bunce, R., G., H., Ryszkowski, L., Paoletti, M., G., (1993).*Landscape Ecology and Agroecosystems*, Lewis Publishers, Boca Raton, USA.

Burel, F. and Baudry, J., (1999). *Ecologie du paysage. Concepts, methodes et applications*, Editions TEC&DOC, Paris.

Debinski, D. and Holt, R., (2000). *A survey and overview of habitat fragmentation experiments*, Conservation Biology 14, 342-355.

Dumitraşcu, M., (2006). *Les modifications du paysage dans la plaine de l'Oltenie*, Editura Universitară, Bucureşti.

Echeverria, C., Coomes, D., Salas, J., Rey-Benayas, J., M., Lara, A., Newton, A., (2006). *Rapid deforestation and fragmentation of Chilean Temperate Forests*, Biological Conservation in press.

Farina, A., (1998). *Principles and methods in landscape ecology*, Chapman & Hall, London.

Forman, R.T.T., (1997). *Land mosaics: the ecology of Landscapes and Regions*, Cambridge University Press, Cambridge.

Geri, F., Amici, V., Rocchini, D.. (2010), *Human activity impact on the heterogeneity of a Mediterranean landscape*, Applied Geography 30, 370-379.

Hansen, A.J. and di Castri, F., (1992). *Landscape Boundaries. Consequences for Biotic Diversity and Ecological Flows*, Springer-Verlag, N.Y.

McGarigal, K. and Marks, B., J., (1994). FRAGSTATS. *Spatial pattern analysis program for quantifying landscape structure*, Version 2.0. Forest Science Department, Oregon State University, Corvallis, OR.

Muica, N., Turnock, D., Urucu, V., (2000). *Coping strategies in rural areas of the Buzău Sub-Carpathians*, GeoJournal 50, 157-172.

Pătroescu, M., (1996). *Subcarpaţii dintre Rămnicu Sărat şi Buzău. Potenţial ecologic şi exploatare biologică*, Ed. Carro, Bucureşti.

Pătroescu, M. and Niculae, M., I., (2010). *The rurality between the Râmnicu Sărat and the Buzău valleys-definitive component of the Subcarpathian landscapes dynamics*, Forum geografic. Studii şi cercetări de geografie şi protecţia mediului no.9/2010, 107-114.

Posea, G. and Badea, L., (1984). *Republica Socialistă România. Unităţile de relief. Regionarea geomorfologică*, Ed. Ştiinţifică şi Enciclopedică.

Primack, R., B., Pătroescu, M., Rozylowicz, L., Ioja, C., (2008). *Fundamentele conservării diversităţii biologice*, Ed AGIR, Bucureşti.

Turner, M.G., Gardner, R.H., O'Neill, R.V., (2001). *Landscape ecology in theory and practice. Pattern and process*, Springer-Verlag, New York, U.S.

Uuemaa, E., Antrop, M., Roosaare, J., Marja, R., Mander, U., (2009). *Landscape Metrics and Indices: An Overview of Their Use in Landscape Research,* Living Reviews in Landscape Research 3, available at http://www.livingreviews.org/lrlr-2009-1, accessed at 7.01.2011.

Watson, J., Whittaker, R., Dawson, T., (2004). *Habitat structure and proximity to forest edge affect the abundance and distribution of forest-dependent bird in tropical coastal forest of southern Madagascar*, Biological Conservation 8, 311-327.

  DOI: 10.5775/fg.2067-4635.2011.037.i