

SPATIAL ECOLOGICAL, BIOGEOGRAPHICAL AND LANDFORM DISTRIBUTION OF 2006-2012 LAND COVER AND USE CHANGES IN ROMANIA

PETRIȘOR Alexandru-Ionuț

Abstract. Land cover and use changes are an important form of environmental impact, with socio-economic determinants in the declining economies. Since satellite imagery-derived geospatial data can be used in conjunction with GIS to explore the spatial distribution of changes, this study aims to explore it in relationship to the biogeographical and ecological regions and landforms. The result, based on geo-statistical analyses of CORINE data, simply show the consequences of an unplanned development: forests are cut from the mountain and hill region, but their regeneration occurs only in the hills; floods occur in the floodplain, agriculture is abandoned in the steppe, and urbanization dominates the plain regions.

Keywords: CORINE, biogeographical regions, ecological regions, landforms, elevation, impact assessment.

Rezumat. Distribuția spațială a modificărilor acoperirii și utilizării terenului din perioada 2006-2012 în România pe regiuni biogeografice și ecologice și forme de relief. Modificările acoperirii și utilizării terenului reprezintă o formă importantă de impact asupra mediului, determinată în țările în curs de dezvoltare de factori socio-economici. Având în vedere că datele geo-spațiale derivate din imagini satelitare pot fi utilizate împreună cu sistemele informaționale geografice pentru analiza exploratorie a distribuției spațiale a acestor schimbări, studiul de față își propune analiza lor în relație cu regiunile biogeografice și ecologice și formele de relief. Rezultatele, obținute prin utilizarea unor analize geo-statistice pe baza datelor CORINE, arată consecințele unei dezvoltări neplanificate: pădurile sunt tăiate în zonele de deal și de munte, dar se regenerează doar în zonele de deal; în lunci au loc inundații, culturile agricole sunt abandonate în zona de stepă, iar regiunile de câmpie sunt intens urbanizate.

Cuvinte cheie: CORINE, regiuni biogeografice, regiuni ecologice, forme de relief, altitudine, evaluarea impactului.

INTRODUCTION

The recent advances in the theory of the environmental impact assessment of human activities include introducing the concept of ‘global changes’ (DALE, 1997; DALE et al., 2011) in order to coin all man-induced changes affecting our global environment: land cover and use changes, climate changes, and alterations of the energy flows. The three changes are related (DALE, 1997; DALE et al., 2011; IANOS et al., 2011; PETRIȘOR, 2012c), but the connections are hardly assessable from a quantitative perspective because not all of them benefit upon the existence of data resulted from a continuous monitoring.

This study is focused on land cover and use changes, because they are easy to assess, especially at regional scales, using satellite imagery data in conjunction with the Geographical Information Systems (PETRIȘOR, 2016). These data were an output of the program CORINE (Coordinated Information on the European Environment) (DE LIMA, 2005), available from the European Environment Agency for the periods 1990-2000 and 2000-2006 and Copernicus (2006-2012). Moreover, land cover and use changes reflect socio-economic issues through their underlying transitional dynamics (PETRIȘOR et al., 2010; 2014).

In particular, land cover and use changes are able to reflect the consequences of sprawl, characteristic to man dominated systems. More exactly, as a consequence of socio-economic development, man-dominated systems are sprawling over the natural ones, simplifying and fragmenting them (RAZIN & ROSENTRAUB, 2000; FERNÁNDEZ-JURICIC & JOKIMÄKI, 2001; MARZLUFF & EWING, 2001; JONGMAN, 2002; MELLES et al., 2003; HABERL et al., 2009; PETRIȘOR & SÂRBU, 2010; TUDOR et al., 2013; PETRIȘOR et al., 2016). The two phenomena differ; fragmentation refers to a patched or leap-frog land development, while dispersion refers to the expansion of a city from its core (SCHNEIDER & WOODCOCK, 2008). However, the consequences are similar; the sprawl process results into land cover and use changes (RAZIN & ROSENTRAUB, 2000; GRIMM et al., 2008), and is more prominent around cities than in agricultural areas (MARZLUFF & EWING, 2001). Other consequences include reducing the global resilience (ANDERSSON et al., 2014), fragmenting the habitats (MCMAHON, 2000), decreasing the areal of natural species (MCKINNEY, 2008), altering the ecosystem functions, increasing exposure to other impacts (MARZLUFF & EWING, 2001; GIBB & HOCHULI, 2002) and contributing to the loss of biodiversity (BENEDICT & MCMAHON, 2001; GIBB & HOCHULI, 2002; LUCK & WU, 2002; POELMANS & VAN ROMPAEY, 2009).

The effects of land cover and use changes can be assessed from two related perspectives: alteration of the green infrastructure and reduction of ecosystem services. The green infrastructure is a “network of open space, woodlands, wildlife habitat, parks and other natural areas, which sustain clean air, water, and natural resources and enrich their citizens’ quality of life” (MCMAHON, 2000). It consists of ecological corridors, urban areas, industrial parks, suburban areas, sustainable drain systems, and coastal areas (BENEDICT & MCMAHON, 2001; GILL et al., 2007; TZOULAS et al., 2007). The green infrastructure provides ecological services (MCMAHON, 2000; PAULEIT et al., 2005; TAYLOR LOVELL & TAYLOR, 2013), can help cities adapting to climate changes (GILL et al., 2007; MELL, 2008), and contributes to ecosystem health by preserving biodiversity (TZOULAS et al., 2007), ultimately

relating to human health (CAMERON et al., 2012). Ecosystem services are the benefits offered by ecosystems to the human society: supply, regulation, cultural, and support (BOLUND & HUNHAMMAR, 1999; ZAKRI & WATSON, 2003; WATSON & ZAKRI, 2005; ERNSTSON et al., 2010; YOUNG, 2010; CILLIERS et al., 2013). They have biophysical, health, environmental justice, economic, social, cultural, and insurance value (PATAKI et al., 2011; GÓMEZ-BAGGETHUN & BARTON, 2013; GÓMEZ-BAGGETHUN et al., 2013), and can reduce global pollution and help adapting to the effects of climate change (LA GRECA et al., 2011). The quality of ecosystem services reflects their normal functioning, as yield depends on the carrying capacity (IANOŞ et al., 2009). However, they depend on biodiversity and ecosystem health (NIEMELÄ et al., 2010; YOUNG, 2010). Urban ecosystem services and ecological infrastructure can help reconnecting cities and people to the biosphere (WICKHAM et al., 2010; GÓMEZ-BAGGETHUN et al., 2013).

Several similar studies carried out in Romania at different spatial scales (IANOŞ et al., 2011; PETRIŞOR, 2012a, b, c; 2015a, b; PETRIŞOR & PETRIŞOR, 2015; PETRIŞOR et al., 2010; 2014), with different aims, focuses and methodologies, but all aimed at pinpointing the main transitional dynamics characteristic to Romania as a transition country. The findings consisted of few antagonistic phenomena: development and abandonment of agriculture, deforestation and forestation – consisting of afforestation, reforestation (DUTCĂ & ABRUDAN, 2010), and colonization of abandoned agricultural land by forest vegetation (AGNOLETTI et al., 2011; PETRIŞOR et al., 2014), urbanization and other less prominent causes, such as the construction of dams, draughts etc., which are in general characteristic to transition economies.

The present study aims to assess the spatial distribution of the most recent changes from an environmental perspective, in relationship with the biogeographical and ecological regions, which are the spatial expression of biological diversity (PETRIŞOR, 2008; 2014).

DATA AND METHODS

The study used several datasets, freely available from European and international sources, presented in Table 1. Data were processed by re-projecting and sub-sampling subsets for Romania, clipping, and ultimately computing areas using the X-Tools extension of ArcView GIS 3.X. The analyses aimed to assess the distribution of different transitional dynamics by the biogeographical and ecological regions and landforms by computing their total areas.

Landforms were classified based on their elevation, similar to the study by PETRIŞOR (2010): floodplain - 0 to less than 20 m, plain - 0 to less than 200 m, hill or plateau - 200 to less than 900 m, and mountain - over 900 m.

The following classes of transitional dynamics were defined, using a methodology combining the previous ones (IANOŞ et al., 2011; PETRIŞOR, 2012a, b, c; 2015a, b; PETRIŞOR & PETRIŞOR, 2015; PETRIŞOR et al., 2010; 2014):

1. Urbanization – refers to urban development within the cities, manifested through changes at the third level of level 1 ‘urban’ class, but also to the transformation of other level 1 classes into ‘urban’
2. Forestation – defined by joining afforestation, reforestation, and colonization of abandoned agricultural land by forest vegetation, forestation is reflected by a level 1 transformation of other classes into ‘forest’ (CORINE classes 311 – coniferous forests, 312 – broadleaved forests, 313- mixed forests) (DE LIMA, 2005), but also by transformations of the ‘natural’ level 1 classes indicating the regeneration of forests
3. Deforestation – defined as a transformation of ‘forests’ (see above) into other ‘natural’ level 1 classes
4. Development of agriculture – includes the level 1 transformation of other classes into ‘agricultural’ and level 3 transformations within the ‘agricultural’ classes indicating the development of agriculture
5. Abandonment of agriculture – refers to level 3 transformations within the ‘agricultural’ classes indicating the abandonment of agriculture
6. Floods – includes the level 1 transformation of other classes into ‘wetlands’ or ‘waters’ .

Table 1. Specifications on the data used in the study: dataset, provider, URL, remarks and transformations.

Dataset	Provider	URL	Remarks	Transformation
Land cover and use changes data	Copernicus Land Monitoring Services	http://land.copernicus.eu/pan-european/corine-land-cover/lcc-2006-2012/view	ArcView GIS 3.X	Project into Stereo 1970, subsample for Romania
Biogeographical regions	European Environment Agency data services	http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=308	ArcView GIS 3.X; 2001 data	Project into Stereo 1970, subsample for Romania
Ecological regions	European Environment Agency	http://www.eea.europa.eu/data-and-maps/data/digital-map-of-european-ecological-regions	ArcView GIS 3.X	Project into Stereo 1970, subsample for Romania
Landform	Consultative Group on International Agricultural Research – Consortium for Spatial Information	http://srtm.cgiar.org/SELECT/ON/inputCoord.asp	Digital Elevation Model (DEM); Nearly 90 m × 90 m resolution	Import into Arc GIS, then export to ArcView GIS 3.X, project into Stereo 1970, subsample for Romania

RESULTS AND DISCUSSION

The study aimed to assess the spatial distribution of land cover and use changes occurred in Romania during 2006-2012 by the biogeographical regions (Fig. 1), ecological regions (Fig. 2), and landforms (Fig. 3). For each figure, the assessment is carried out from a double perspective: (1) are certain transitional dynamics dominant in certain biogeographical regions, ecological regions, or landforms? and (2) which are the transitional dynamics characteristic to each biogeographical region, ecological region, or landform?

Figure 1 indicates that several transitional dynamics are strongly associated with some biogeographical regions; for the continental region, the main transitional dynamics are the development of agriculture, forestation, and urbanization; for the alpine region, the main transitional dynamic is deforestation (consistent with the results of PETRIȘOR, 2015b); and for the steppic region, the main transitional dynamics are other causes, floods, and the abandonment of agricultural land (the last finding is consistent with REY BENAYAS et al., 2007; KUEMMERLE et al., 2008; PETRIȘOR, 2015a). From the other perspective, there is a strong connection between deforestations and the alpine region.

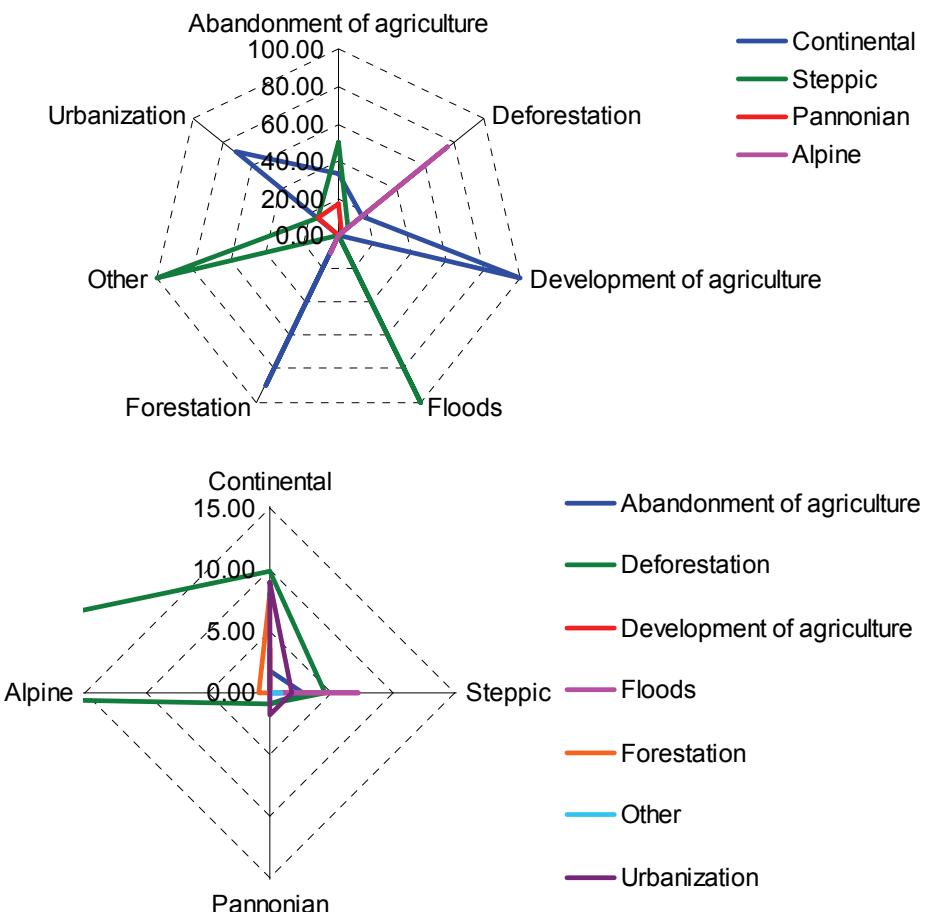


Figure 1. Spatial distribution of land cover and use changes in Romania during 2006-2012 by the biogeographical region, based on CORINE data. The analyses are carried from a double perspective: transitional dynamics by biogeographical region (top) and biogeographical regions by transitional dynamics (bottom).

Figure 2 shows that the abandonment of agriculture and floods are characteristic to the Pontic steppe, deforestation and forestation to the Carpathian montane coniferous forests, abandonment of agriculture, urbanization and forestation to the Pannonian mixed forests, development of agriculture and urbanization to the Balkan mixed forests, and other transitional dynamics to the central European mixed forests. From the other perspective, most deforestation occurred in the region of the Carpathian montane coniferous forests and fewer in the Pannonian mixed forests, and floods are associated to the Pontic steppe.

The results presented in Figure 3 indicate that the transitional dynamics characteristic to the plain are urbanization, development of agriculture and ‘others’. Floods are characteristic to the plain, deforestation to the mountain regions, and forestation to the hills. From the other perspective, the most important associations are between mountains and hills and deforestation, floods and the floodplain, forestation to the fills, and urbanization to the plain.

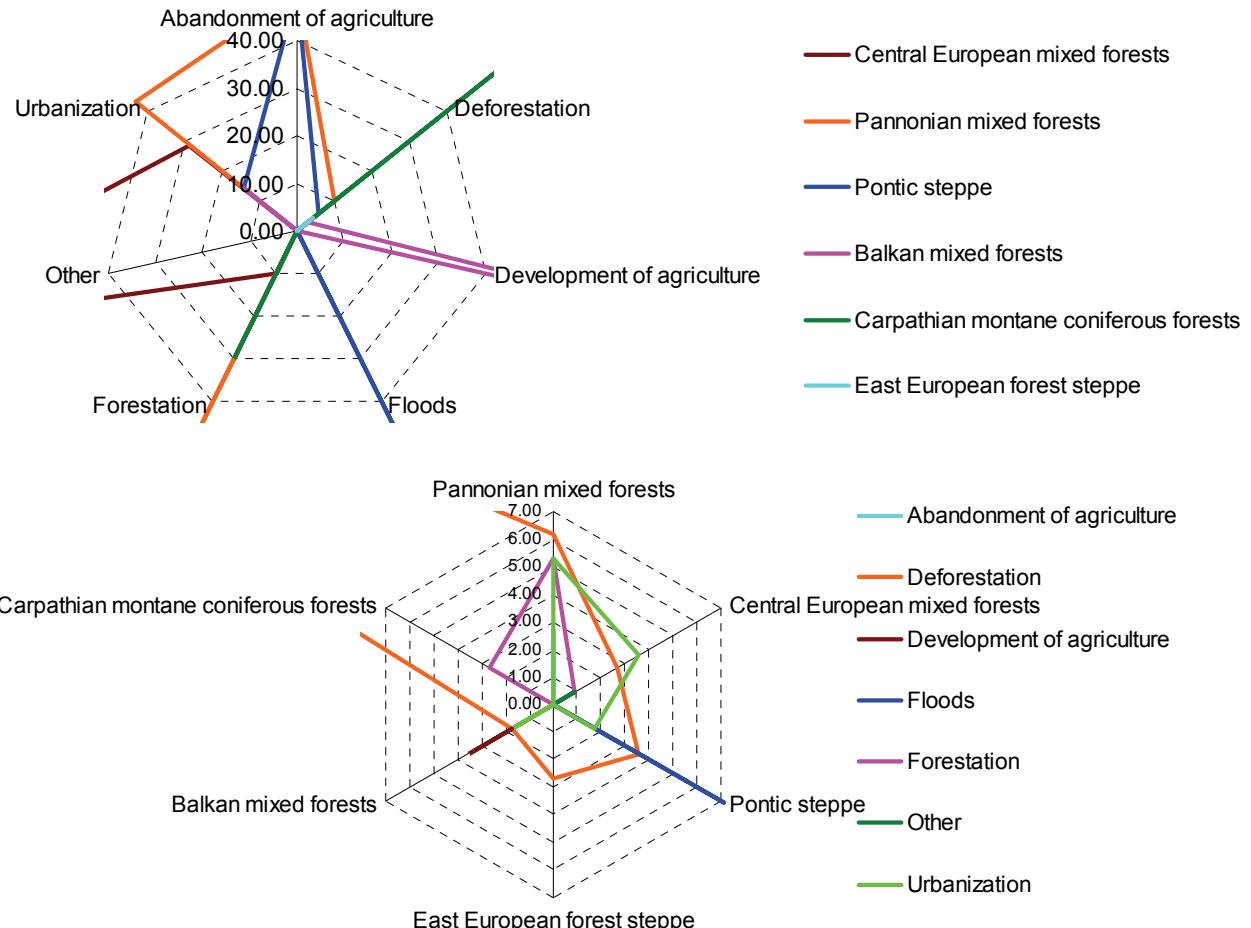


Figure 2. Spatial distribution of land cover and use changes in Romania during 2006-2012 by the ecological region, based on CORINE data. The analyses are carried from a double perspective: transitional dynamics by ecological region (top) and ecological regions by transitional dynamics (bottom).

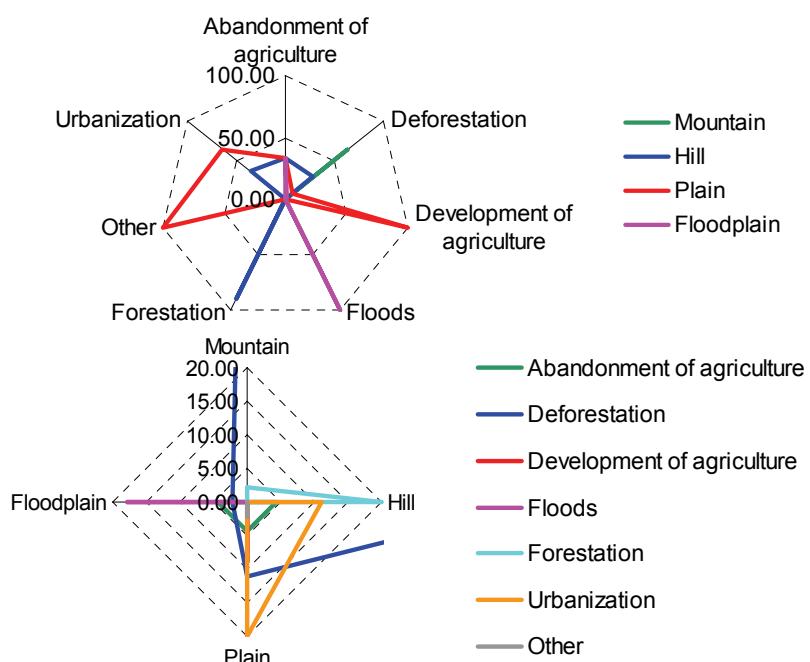


Figure 3. Spatial distribution of land cover and use changes in Romania during 2006-2012 by the landform (defined by elevation), based on CORINE data. The analyses are carried from a double perspective: transitional dynamics by landform (top) and landforms by transitional dynamics (bottom).

The study is subject to limitations characteristic to CORINE data, including misclassification, changes in the classification schemes, and different resolutions from one period to another (JANSEN, 2007; PELOROSSO et al., 2011; VERBURG et al., 2011; PETRIȘOR et al., 2010, 2014), and also to the ones originating in the classification of landforms based on elevation only (for example, Dobrudja mountains would be classified as 'hills' due to their height).

CONCLUSION

The findings of this study are consistent with the previous ones and suggest the lack of planning for development. The main transitional dynamics indicates that negative phenomena are not countered; for example, deforestation occurs in the mountains and hill region, but reforestation only in the latter; as a consequence, floods occur in the plain. The plain areas, situated in the continental region, are under the pressure of urbanization. The steppe, affected by the effects of climate changes, is characterized by the abandonment of agriculture, but the causal relationship of the two cannot be inferred from these data only.

REFERENCES

- AGNOLETTI M., CARNELLO G., GARDIN L., SANTORO A., BAZZOFFI P., SANSONE L., PEZZA L., BELFIORE N. 2011. Traditional landscape and rural development: comparative study in three terraced areas in northern, central and southern Italy to evaluate the efficacy of GAEC standard 4.4 of cross compliance. *Italian Journal of Agronomy.* PAGEPress. Pavia. **6:** 121-139.
- ANDERSSON E., BARTHEL S., BORGSTRÖM S., COLDING J., ELMQVIST T., FOLKE C., GREN Å. 2014. Reconnecting Cities to the Biosphere: Stewardship of Green Infrastructure and Urban Ecosystem Services. *Ambio.* Springer. Heidelberg. **43:** 445-453.
- BENEDICT M. A. & MCMAHON E. T. 2001. *Green Infrastructure: Smart Conservation for the 21st Century.* Sprawl Watch Clearinghouse Monograph Series. Washington. 32 pp.
- BOLUND P. & HUNHAMMAR S. 1999. Ecosystem services in urban areas. *Ecological Economics.* Elsevier. Amsterdam. **29:** 293-301.
- CAMERON R. W. F., BLANUŠA T., TAYLOR J. E., SALISBURY A., HALSTEAD A. J., HENRICOT B., THOMPSON K. 2012. The domestic garden – Its contribution to urban green infrastructure. *Urban Forestry & Urban Greening.* Elsevier. Amsterdam. **11**(2): 129-137.
- CILLIERS S., CILLIERS J., LUBBE R., SIEBERT S. 2013. Ecosystem services of urban green spaces in African countries - perspectives and challenges. *Urban Ecosystems.* EEA Press. Copenhagen. **16:** 681-702.
- DALE V. H. 1997. The relationship between land-use change and climate change. *Ecological Applications.* Ecological Society of America. Ithaca. New York. **7**(3): 753-769.
- DALE V. H., EFROYMNISON R. A., KLINE K. L. 2011. The land use–climate change–energy nexus. *Landscape Ecology.* Springer. Heidelberg. **26:** 755-773.
- DE LIMA N. M. V. 2005. *IMAGE2000 and CLC2000 Products and Methods.* Joint Research Centre (DG JRC). Institute for Environment and Sustainability (IES). Land Management Unit. Ispra. 150 pp.
- DUTCA I. & ABRUDAN I. V. 2010. Estimation of forest land-cover change in Romania, between 1990 and 2006. *Bulletin of the Transylvania University of Brașov Series II: Forestry, Wood Industry, and Agricultural Food Engineering.* Transylvania University of Brașov. Brașov. **52:** 33-36.
- ERNSTSON H., BARTHEL S., ANDERSSON E., BORGSTRÖM S. T. 2010. Scale-crossing brokers and network governance of urban ecosystem services: the case of Stockholm. *Ecology and Society.* Wolfville. Nova Scotia **15**(4): 28.
- FERNÁNDEZ-JURICIC E. & JOKIMÄKI J. 2001. A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. *Biodiversity and Conservation.* Kluwer Academic Publishers. Maryland Heights. **10:** 2023-2043.
- GIBB H. & HOCHULI D. F. 2002. Habitat fragmentation in an urban environment: large and small fragments support different arthropod assemblages. *Biological Conservation.* Elsevier. Amsterdam. **106:** 91-100.
- GILL S. E., HANDLEY J. F., ENNOS A. R., PAULEIT S. 2007. Adapting Cities for Climate Change: The Role of the Green Infrastructure. *Built Environment.* Alexandrine Press. Marcham. Oxon. **3**(1): 115-133.
- GÓMEZ-BAGGETHUN E. & BARTON D. N. 2013. Classifying and valuing ecosystem services for urban planning. *Ecological Economics.* Springer. Amsterdam. **86:** 235-245.
- GÓMEZ-BAGGETHUN E., GREN Å., BARTON D. N., LANGEMAYER J., MCPHEARSON T., O'FARRELL P., ANDERSSON E., HAMSTEAD Z., KREMER P. 2013. Urban Ecosystem Services. In: Elmquist T., Fragkias M., Goodness J., Güneralp B., Marcotullio P. J., McDonald R. I., Parnell S., Schewenius M., Sendstad M., Seto K. C., Wilkinson C. *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. A Global Assessment.* Springer. Amsterdam: 175-251.
- GRIMM N. B., FAETH S. H., GOLUBIEWSKI N. E., REDMAN C. L., WU J., BAI X., BRIGGS J. M. 2008. Global Change and the Ecology of Cities. *Science.* Elsevier. Washington. **319:** 756-760.

- HABERL H., GAUBE V., DÍAZ-DELGADO R., KRAUZE K., NEUNER A., PETERSEIL J., SINGH S. J., VĂDINEANU A. 2009. Towards an integrated model of socioeconomic biodiversity drivers, pressures and impacts. A feasibility study based on three European long-term socio-ecological research platforms. *Ecological Economics*. Elsevier. Amsterdam. **68**(6): 1797-1812.
- IANOȘ I., PEPTENATU D., ZAMFIR D. 2009. Respect for environment and sustainable development. *Carpathian Journal of Earth and Environmental Sciences*. North University of Baia Mare. **4**(1): 81-93.
- IANOȘ I., PETRIŞOR A.-I., STOICA I. V., SÂRBU C. N., ZAMFIR D., CERCLEUX A. L. 2011. The different consuming of primary eco-energies and their degradation in territorial systems. *Carpathian Journal of Earth and Environmental Sciences*. North University of Baia Mare. **6**(2): 251-260.
- JANSEN L. J. M. 2007. Harmonization of land use class sets to facilitate compatibility and comparability of data across space and time. *Journal of Land Use Science*. Taylor & Francis. New York. **1**(2-4): 127-156.
- JONGMAN R. H. G. 2002. Homogenisation and fragmentation of the European landscape: ecological consequences and solutions. *Landscape and Urban Planning*. Elsevier. Amsterdam. **58**(2-4): 211-221.
- KUEMMERLE T., HOSTER P., RADELOFF V. C., VAN DERLINDEN S., PERZANOWSKI K., KRÜHLOV I. 2008. Cross-border Comparison of Postsocialist Farmland Abandonment in the Carpathians. *Ecosystems*. Elsevier. Amsterdam. **11**: 614-628.
- LA GRECA P., LA ROSA D., MARTINICO F., PRIVITERA R. 2011. Agricultural and green infrastructures: The role of non-urbanised areas for eco-sustainable planning in a metropolitan region. *Environmental Pollution*. Elsevier. Amsterdam. **159**: 2193-2202.
- LUCK M. & WU J. 2002. A gradient analysis of urban landscape pattern: a case study from the Phoenix metropolitan region, Arizona, USA. *Landscape Ecology*. Springer. Heidelberg. **17**: 327-339.
- MARZLUFF J. M. & EWING K. 2001. Restoration of Fragmented Landscapes for the Conservation of Birds: A General Framework and Specific Recommendations for Urbanizing Landscapes. *Restoration Ecology*. John Wiley & Sons. Chichester. **9**(3): 280-292.
- MCKINNEY M. L. 2008. Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems*. Springer. Heidelberg. **11**: 161-176.
- MCMAHON E. T. 2000. Green Infrastructure. *Planning Commissioner Journal*. Elsevier. Burlington. **37**: 4-7.
- MELL I. C. 2008. Green Infrastructure: concepts and planning. *Newcastle University Forum Ejournal*. Newcastle University. Newcastle. **8**: 69-80.
- MELLES S., GLENN S., MARTIN K. 2003. Urban bird diversity and landscape complexity: Species - environment associations along a multiscale habitat gradient. *Conservation Ecology*. Wolfville. Nova Scotia. **7**(1): 5.
- NIEMELÄ J., SAARELA S.-R., SÖDERMAN T., KOPPEROINEN L., YLI-PELKONEN V., VÄRE S., KOTZE D. J. 2010. Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. *Biodiversity and Conservation*. Kluwer Academic Publishers. Maryland Heights. **19**: 3225-3243.
- PATAKI D. E., CARREIRO M. M., CHERRIER J., GRULKE N. E., JENNINGS V., PINCETL S., POUYAT R. V., WHITLOW T. H., ZIPPERER W. C. 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*. John Wiley & Sons. Chichester. **9**(1): 27-36.
- PAULEIT S., ENNOS R., GOLDING Y. 2005. Modeling the environmental impacts of urban land use and land cover change - a study in Merseyside, UK. *Landscape and Urban Planning*. Elsevier. Amsterdam. **71**: 295-310.
- PELOROSSO R., DELLA CHIESA S., TAPPEINER U., LEONE A., ROCCHINI D. 2011. Stability analysis for defining management strategies in abandoned mountain landscapes of the Mediterranean basin. *Landscape and Urban Planning*. Elsevier. Amsterdam. **103**(3-4): 335-346.
- PETRIŞOR A.-I. 2008. Levels of biological diversity: a spatial approach to assessment methods. *Romanian Review of Regional Studies*. Cluj University Press. Cluj Napoca. **4**(1): 41-62.
- PETRIŞOR A.-I. 2010. GIS-based assessment of the landform distribution of 2100 predicted climate change and its influence on biodiversity and natural protected areas in Romania. *Oltenia. Studii și comunicări. Științele Naturii*. Muzeul Olteniei Craiova. **26**(1): 247-256.
- PETRIŞOR A.-I. 2012a. Dynamics of the environmental transformation processes during 1990-2006 in Romania reflected by land cover and use changes. *Present Environment and Sustainable Development*. „Alexandru Ioan Cuza” University. Iași. **6**(1): 353-365.
- PETRIŞOR A.-I. 2012b. Land cover and land use analysis of urban growth in Romania. *Human Geographies*. University of Bucharest. Bucharest. **6**(1): 47-51.
- PETRIŞOR A.-I. 2012c. Land cover and use changes and predicted climate changes in Romania: connections underlined by their spatial distributions. *Oltenia. Studii și comunicări. Științele Naturii*. Muzeul Olteniei Craiova. **28**(1): 141-148.
- PETRIŞOR A.-I. 2014. Diversity: towards an unifying concept joining theoretical and practical views of ecology and geography under a spatial and statistical framework. *Oltenia. Studii și comunicări. Științele Naturii*. Muzeul Olteniei Craiova. **30**(1): 236-244.

- PETRIŞOR A.-I. 2015a. Land cover and land use changes reflecting the environmental impacts of declining economies. Case study: south-west development region, Romania. *Romanian Journal of Geography*. Romanian Institute of Geography. Bucharest. **59**(1): 29-39.
- PETRIŞOR A.-I. 2015b. Using CORINE data to look at deforestation in Romania: Distribution & possible consequences. *Urbanism Architecture Constructions*. URBAN-INCERC. Bucharest. **6**(1): 83-90.
- PETRIŞOR A.-I. 2016. Geographical Information Systems as environmental, landscape and urban planning and research tools. Romania as a case study. In: Boştenaru-Dan M. & Crăciun C. *Space and time visualisation*. Springer Nature. Geneva: 233-249.
- PETRIŞOR A.-I. & SÂRBU C. N. 2010. Dynamics of geodiversity and eco-diversity in territorial systems. *Journal of Urban and Regional Analysis*. CICADIT. Bucharest. **2**(1): 61-70.
- PETRIŞOR A.-I. & PETRIŞOR L. E. 2015. Assessing microscale environmental changes: CORINE vs. the Urban Atlas. *Present Environment and Sustainable Development*. „Alexandru Ioan Cuza University”. Iași. **9**(2): 95-104.
- PETRIŞOR A.-I., IANOŞ I., TĂLĂNGĂ C. 2010. Land cover and use changes focused on the urbanization processes in Romania. *Environmental Engineering and Management Journal*. Universitaria Press. Iași. **9**(6): 765-771.
- PETRIŞOR A.-I., GRIGOROVSKI M., MEIȚĂ V., SIMION-MELINTE C.-P. 2014. Land cover and use changes focused on the urbanization processes in Romania. *Environmental Engineering and Management Journal*. Universitaria Press. Iași. **13**(4): 847-860.
- PETRIŞOR A.-I., ANDRONACHE I. C., PETRIŞOR L. E., CIOBOTARU A. M., PEPTENATU D. 2016. Assessing the fragmentation of the green infrastructure in Romanian cities using fractal models and numerical taxonomy. *Procedia Environmental Sciences*. Elsevier. Amsterdam. **32**: 110-123.
- POELMANS L. & VAN ROMPAEY A. 2009. Detecting and modelling spatial patterns of urban sprawl in highly fragmented areas: A case study in the Flanders-Brussels region. *Landscape and Urban Planning*. Elsevier. Amsterdam. **93**: 10-19.
- RAZIN E. & ROSENTRAUB M. 2000. Are Fragmentation and Sprawl Interlinked? North American Evidence. *Urban Affairs Review*. Sage Publications. New York. **35**(6): 821-835.
- REY BENAYAS J. M., MARTINS A., NICOLAU J. M., SCHULZ J. J. 2007. Abandonment of agricultural land: an overview of drivers and consequences. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*. CABI. Wallingford. Oxfordshire. **57**(2): 1-14.
- SCHNEIDER A. & WOODCOCK C. E. 2008. Compact, Dispersed, Fragmented, Extensive? A Comparison of Urban Growth in Twenty-five Global Cities using Remotely Sensed Data, Pattern Metrics and Census Information. *Urban Studies*. Sage Publications. New York. **45**: 659-692.
- TAYLOR LOVELL S. & TAYLOR J. R. 2013. Supplying urban ecosystem services through multifunctional green infrastructure in the United States. *Landscape Ecology*. Elsevier. Heidelberg. **28**: 1447-1463.
- TUDOR C. A., IOJĂ I. C., PĂTRU-STUPARIU I., NIȚĂ M. R., HERSPERGER A. M. 2013. How successful is the resolution of land-use conflicts? A comparison of cases from Switzerland and Romania. *Applied Geography*. Elsevier. Amsterdam. **47**: 125-136.
- TZOULAS K., KORPELA K., VENN S., YLI-PELKONEN V., KAZMIERCZAK A., NIEMELÄ J., JAMES P. 2007. Promoting Ecosystem and Human Health in Urban Areas using Green Infrastructure: A Literature Review. *Landscape and Urban Planning*. Elsevier. Amsterdam. **81**: 167-178.
- VERBURG P. H., NEUMANN K., NOLL L. 2011. Challenges in using land use and land cover data for global change studies. *Global Change Biology*. John Wiley & Sons. Oxford. **17**(2): 974-989.
- WATSON R. & ZAKRI A. H. 2005. *Ecosystems and Human Well-being. Synthesis*. Island Press. Washington. 137 pp.
- WICKHAM J. D., RIITTERS K. H., WADE T. G., VOGT P. 2010. A national assessment of green infrastructure and change for the conterminous United States using morphological image processing. *Landscape and Urban Planning*. Elsevier. Amsterdam. **94**: 186-195.
- YOUNG R. F. 2010. Managing municipal green space for ecosystem services. *Urban Forestry & Urban Greening*. Amsterdam. **9**: 313-321.
- ZAKRI A. H. & WATSON R. 2003. *Ecosystems and Human Well-being. A Framework for Assessment*. Island Press. Washington. 212 pp.

Petrișor Alexandru-Ionuț

Department of Urban and Landscape Planning, School of Urbanism and Landscape Architecture
 “Ion Mincu” University of Architecture and Urbanism, Bucharest, Str. Academiei, no. 18-20, sector 1, cod 010014 Bucharest, Romania.
 National Institute for Research and Development in Constructions, Urbanism and Sustainable Spatial Development URBAN-INCERC,
 Sos. Pantelimon, no. 266, sector 2, cod 021652 Bucharest, Romania.
 E-mail: alexandru_petrisor@yahoo.com, Internet: www.environmetrics.ro

Received: January 12, 2017
 Accepted: June 5, 2017