DETECTING HOTSPOTS OF CHANGES IN SPATIAL PATTERN OF FOREST FRAGMENTATION IN THE ROMANIAN CARPATHIAN MOUNTAINS

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INTRODUCTION

With a total area of about 210.000 km², the Carpathian Mts represent one of the largest natural regions of the Europe, comprising the most representative forest ecosystems in Europe with about 300.000 ha of natural forests and 20.000 ha of primary beech forests (*WWF Report, 2001*). The Carpathian mountain range connects 8 Eastern European countries, from Serbia and Romania in the south to Austria, the Czech Republic, Hungary, Poland, Slovakia, and Ukraine in the north (*Björnsen et al 2009*). Romania has about 55% of the entire Carpathian Mts, consisting in the Eastern, Southern and Western Romanian Carpathian ranges. Landscape fragmentation is the expression of patchiness and spatial heterogeneity of land cover pattern. After the breakdown of the socialism regime in 1989, Romania has undergone significant changes at the level of political, institutional and socio-economic profile, which determined researchers to consider this country an experimental territory for land use and landscape research. The aim of this study is to is to detect hotspots of changes of forests landscape fragmentation patterns in the Romanian Carpathian Mountains between 1990 and 2018.

STUDY AREA

The regional-scale study area is the Romanian Carpathians (***Figure 1***), about 107.000 km² of mountainous terrain with elevations up to 2544 m. It has a temperate-continental climate, with a mean annual temperature of about 7ºC and a mean annual rainfall between 750 and 1400 mm (*Mihai et al 2007; Muller et al 2009*). Major soils include podzols in the mountain zone and Cambisols in the foothill zone (*FAO, UNESCO, and WRB 1988*). In the Romanian Carpathian Mts there were distinguished five vegetation zones: (1) lower mountain zone with pure beech (*Fagus sylvatica* L.) stands; (2) middle mountains zone with mixture of spruce (*Picea abies*), silver fir (*Abies alba*) and beech (*Fagus sylvatica*) stands; (3) upper mountain zone with pure spruce (*Picea abies*) stands; (4) subalpine grassland zone; (5) alpine grassland zone. The dominant tree species in Romanian Carpathian forests are *Picea abies, Fagus sylvatica, Abies alba*, *Pinus* sp., *Larix europaea*. About 65% from total area of Romanian forests are situated in the mountains and, in terms of contribution to the total coverage; the conifers contribute with 25%, broadleaves forests with 50% and mixed forests with 25% (*Badea et al., 2004*).

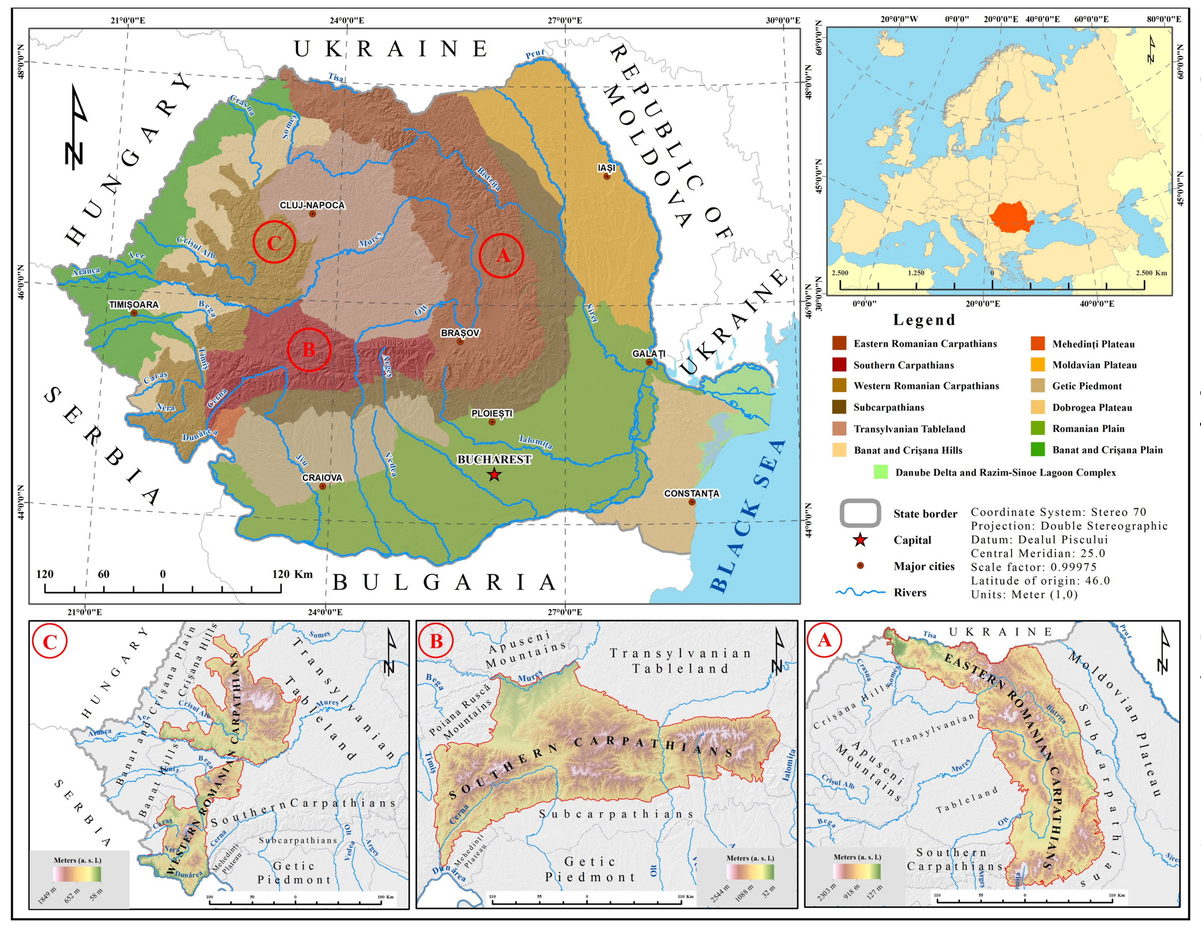


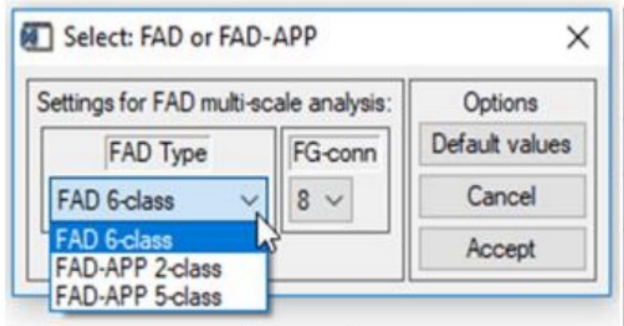
Figure 1. Geographical position of the Romanian Carpathian Mountains within main landform units

MATERIALS AND METHODS

In order to meet our demand we applied a holistic approach to assess the multiple teleconnections between forest cover changes and the degree of fragmentation at regional scale for two distinct periods that make up the 1990-2018 period: (1) 1990-2006 (land restitution period or transition period to the market economy) and (2) 2006-2018 (post-accession period to the European Union).

The analysis were carried out using freely available time series CORINE Land Cover data of 1990, 2006 and 2018 provided by Copernicus Land Monitoring Services. The initial spatial datasets were processed with the help of Geographic Information Systems (GIS), while GUIDOS, a free software toolbox dedicated to quantitative analysis of digital landscape images, was used to generate spatial and statistics data of the degree of forest landscape fragmentation (***Figure 2***).

Finally, the presentation, the analysis and the interpretation of the results obtained represented the third phase of the research. In this way, we apply a cartographic approach in order to highlight the spatial and temporal pattern of land use/cover changes occurred at the level of the study area, on the one hand, while a statistical and graphical approach were employed for the presentation of the data strings, on the other hand.



FAD 6-class	Color	FAD range
1-Rare		FAD < 10%
2-Patchy		10% ≤ FAD < 40%
3-Transitional		40% ≤ FAD < 60%
4-Dominant		60% ≤ FAD < 90%
5-Interior		90% ≤ FAD < 100%
6-Intact		FAD = 100%

FAD-APP 5-class	Color	FAD range
1-Rare		FAD < 10%
2-Patchy		10% ≤ FAD < 40%
3-Transitional		40% ≤ FAD < 60%
4-Dominant		60% ≤ FAD < 90%
5-Interior		90% ≤ FAD ≤ 100%

FAD-APP 2-class	Color	FAD range
1-Separated		FAD < 40%
2-Continuous		40% ≤ FAD ≤ 100%

Figure 2. *Summary of FAD/FAD-APP fragmentation class thresholds, names, and color assignment. FAD is a per-pixel classifier while FAD-APP summarizes the average density value per patch*

RESULTS AND DISCUSSIONS

Forest fragmentation is scale dependent and observer dependent. In this way, we applied a fragmentation analysis scheme in FAD (Forest Area Density) form at five observations scales using a moving window analysis with square neighborhood areas of length 7, 13, 27, 81, 243 pixels. Finally, the five fragmentation maps are aggregated into a summary map, showing the average FAD value calculated over all 5 observation scales, which is displayed color-coded into the respective fragmentation class, the proportion of forest pixels in each fragmentation class is calculated and summarized in a bar plot showing forest fragmentation over observation scale (***Figure 3***).

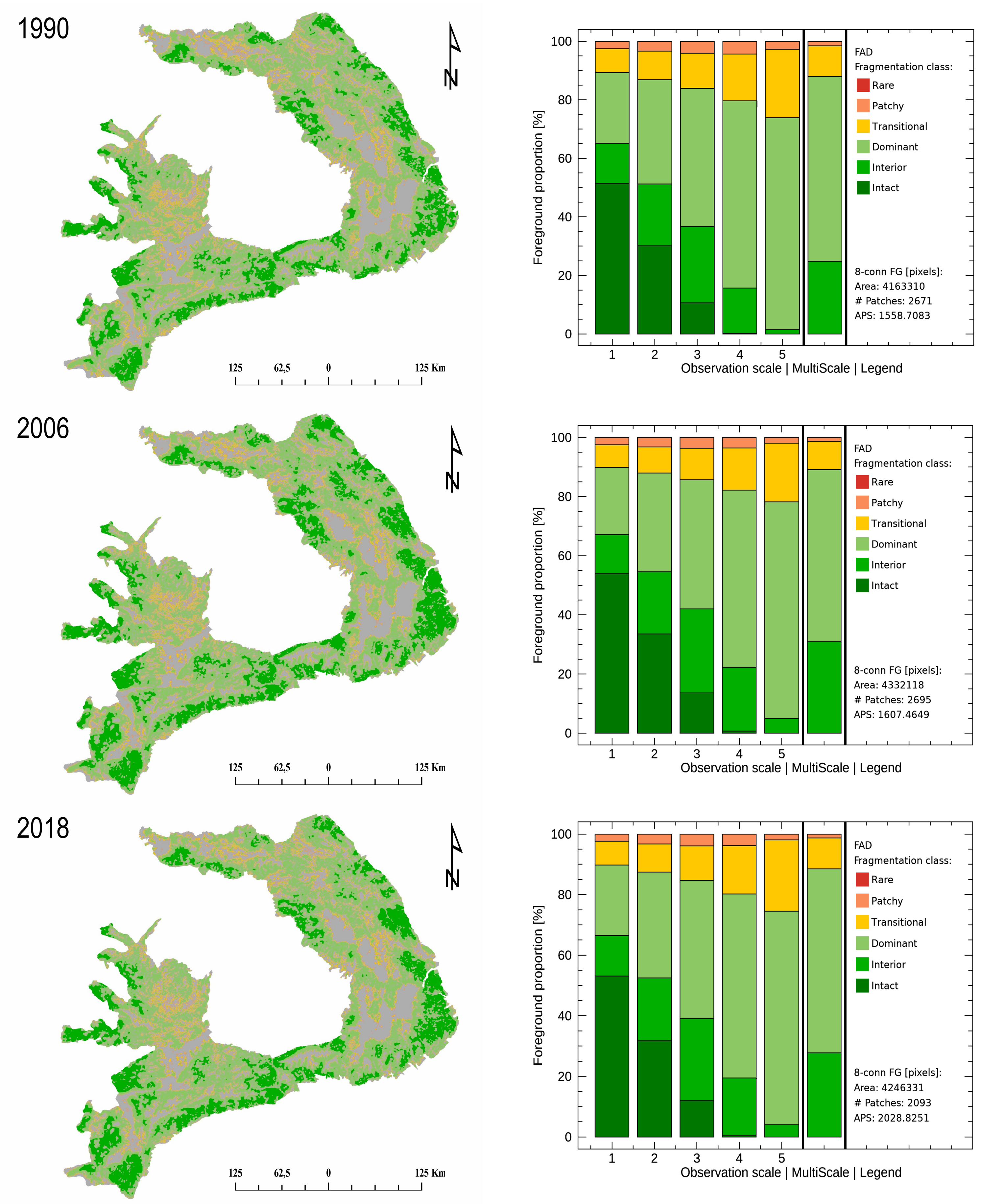


Figure 3. *Aggregated (multi-scale) map of fragmentation classes (left) and bar plot of summary statistics (right) including total amount of forest area, number of forest patches and average patch size (right)*

Our findings indicate that the first period of analysis was more dynamic regarding forest cover changes (***Figure 4***) with a gross area gain of 316 304 ha (7.59%) and a gross area loss of 147 496 ha (3.54%) leading to a net forest area change of 168 808 ha (4.05%) which reflects the level of forest recovery.

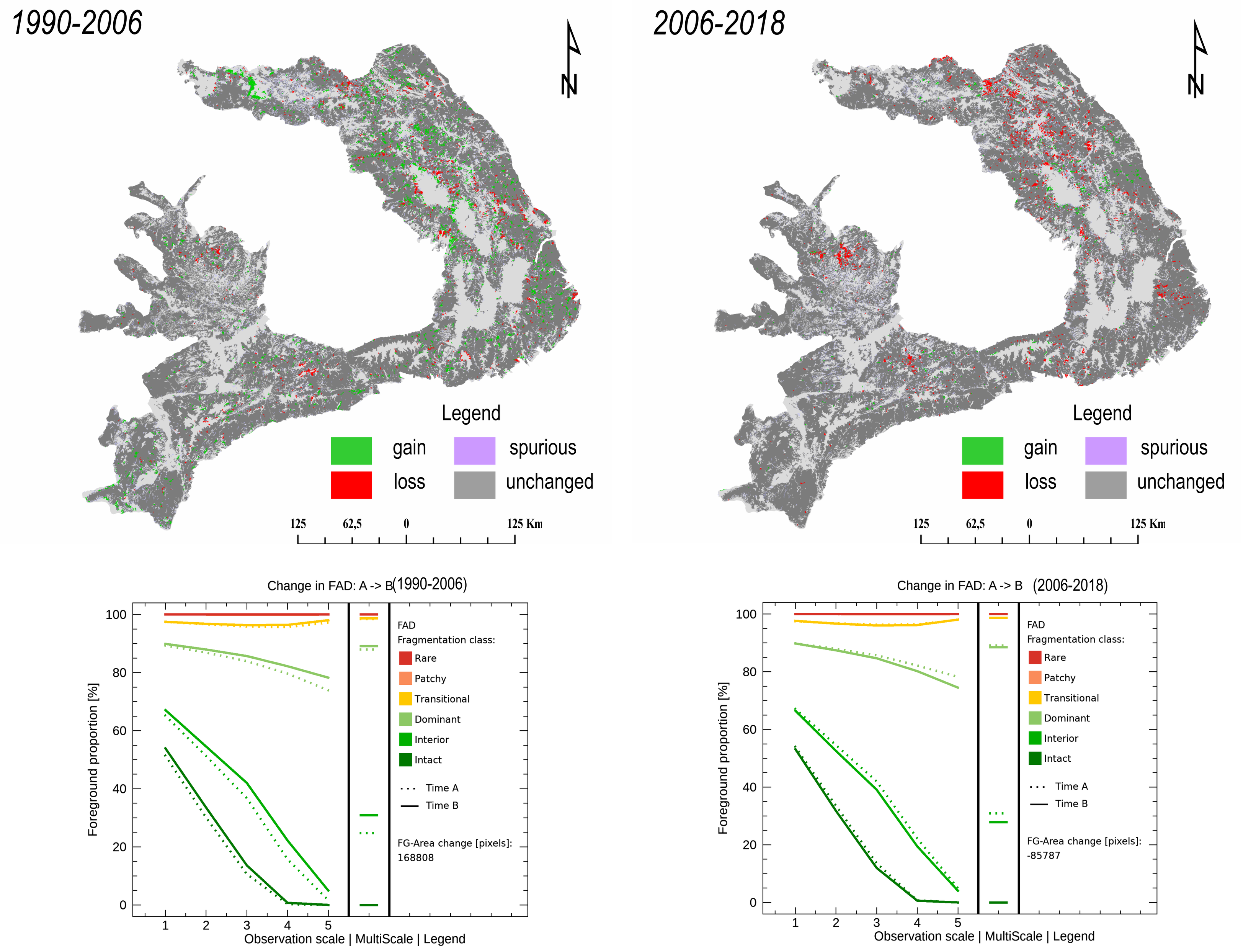


Figure 4. *Morphological change analysis showing locations of forest area gain and loss between 1990-2006 (top left) and 2006-2018 (top right) Changes in the proportions of forest fragmentation classes for the years 1990, 2006 and 2018 for multi-scale assessment in the 1990-2006 period (bottom left) and 2006-2018 period (bottom right)*

The change pattern of fragmentation classes showed that 332 045 ha (71.47%) of fragmentation decrease is found for the transition of dominant forest in 1990 into the less fragmented class interior in 2006, while 67 418 ha (65.10%) of all fragmentation increase is found for transition from interior in 1990 to dominant in 2006. The other side, for the period from 2006 to 2018 we found a gross area gain of 127 146 ha (2.93%) and a gross area loss of 212 933 ha (4.91%) leading to a net forest area change of -85 787 ha (-1.98%) which emphasizes the level of forest loss. In the same time frame, the high values of fragmentation pattern have been registered for the same classes, 56.82% for fragmentation decrease and 70.60% for fragmentation increase, respectively.

The results highlight the reversible impact of land use change on land cover pattern, spatially shaped through afforestation in the first period of analysis and through deforestation in the second period. The afforestation process were determined by high rate of external migration, abandonment and natural succession while deforestation process is a consequence of land restitution laws (Law no. 247/2005) and by weak institutions and law nforcement, which resulted in increased illegal logging.

CONCLUSIONS

This study aimed to produce new insights into the mechanisms of forest landscape fragmentation by including maps produced with advanced pixel-based image analysis techniques in order to show forest cover changes at a regional scale in an extensive mountain ecosystem.

Overall, forest cover in the Romanian Carpathians showed a net increase of 10.551 ha/year in 1990–2006 and a net drecrease of 7.149 ha/year in 2006–2018.

The study emphasizes the impacts of land use policies and land management practices on the pattern of forest landscape and the usefulness of Guidos Toolbox, a universal digital image object analysis, to detect hotspots of changes at regional scale.

REFERENCES

- **Badea, O., Tanase, M., Jianu, G., Lazar, A., Peiov, A., Uhlirova, H., Pajtik, J., Wawryoniak, J., Shparzk, Z.,** 2004: *Forest health status in the Carpathian Mountains over the period 1997–2001. Environ. Pollut., 130: 93–98.*
- **Knorn, J., Kuemmerle ,T., Radeloff ,V.C., Szabo ,A., Mindrescu, M., Keeton, W.S., Abrudan, I., Griffiths, P., Gancz, V., Hostert, P**. 2012. *Forest restitution and protected area effectiveness in post-socialist Romania.* Biological Conservation 146:204–212.
- **Vogt, P., Riitters, K.,** 2017. *GuidosToolbox: universal digital image object analysis.* European Journal of Remote Sensing 50:1, 352-361, DOI: 10.1080/22797254.2017.1330650.
- *https://land.copernicus.eu/pan-european/corine-land-cover (accessed 11 November 2019).*