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Forest fragmentation in the Tatra Region in the period 2000–2006

Monika Kopecká*, Jozef Nováček

Slovak Academy of Sciences, Institute of Geography, Štefánikova 49, 842 73 Bratislava, Slovak Republic

Abstract: The calamity windstorm in November 2004 caused dramatic changes of land cover in the Tatra Mountains. The bora have destroyed then more than 12,000 ha of forest and principally affected the habitat structure in the Tatra National Park. The aim of this contribution is to quantify changes in forest fragmentation in 2000 and 2006. We present forest fragmentation maps related to the years 2000 and 2006. The CORINE Land Cover data layers CLC 2000 and CLC 2006 converted to raster format were used as the input data in the process of forest fragmentation assessment. Forest pixels were classified according to fragmentation indices measured within the surrounding landscape as the forest core, forest patch, forest edge, and perforated forest. Decrease of the compact forest areas (forest core) by about 9% was recorded. On the other side, increased percentage of disrupted forest areas was observed. Decrease of the area of the CLC forest classes (classes 311, 312 and 313) on land cover maps from 2000 and 2006 was connected with an increased number of transitional woodland/shrubs polygons (CLC class 324). These results suggest a temporary fragmentation with possible forest regeneration. On the other hand, forest destruction in the National Park facilitated the development of travel and tourism (new hotels, ski parks, etc.). An increased number of construction sites (CLC class 133) indicate that an urban sprawl associated with a permanent forest fragmentation can be also expected in the future.

Key words: forest fragmentation, CORINE Land Cover, landscape change, windstorm calamity, Tatra region

Introduction

In November 2004, a calamity windstorm destroyed around 12,000 ha of forest at altitudes between 700 m to 1,350 m above the sea level in the Tatra region. The storm did not only affect the very susceptible spruce monocultures, but also damaged to some extent mixed forests, including close-to-nature stands believed to have higher resistance against wind damage (Crofts *et al*., 2005). Dramatic changes in the landscape configuration have raised concerns about habitat fragmentation and its impact on biodiversity.

Forest fragmentation results in both quantitative and qualitative loss of habitat for species originally dependent on forest. As a consequence, the originally present abundance and diversity of species often decline. Fragmentation not only reduces the area of available habitat but also can isolate populations and increase edge effects. Large forest areas are rapidly becoming fragmented as a result of human activities as well as the natural disasters. Immediately following fragmentation, remnant patches represent the forest habitat, where the species composition and its genetic diversity are comparable to a continuous forest population.

Forest fragments thus can potentially function as important sources of biodiversity for the immediate recolonization and reforestation of the surrounding area. Importance of changes associated with the forest remnants themselves (e.g. decreased forest area, increased isolation of forest patches) should be, therefore, always considered with regard to the surrounding non-forest habitats. Kupfer *et al*. (2006) stress that matrix can take on a variety of forms in a given landscape and can contain a range of varying habitat quality. According to the habitat types of matrix, Faaborg *et al*. (1993) recognize permanent fragmentation that resulted in islands of forest surrounded by dissimilar habitat types (e.g. urban

* e-mail: geogmari@savba.sk

areas) and temporary fragmentation occurs through timber harvest practices, which create holes of young forest within a matrix of mature forest. Although the effects of the temporary fragmentation are generally less severe than permanent fragmentation, detrimental effects still exist. From this point of view, the topical and reliable information about land cover and its changes are important input data for the forest fragmentation assessment.

In the early 1990s, the CORINE Land Cover (CLC 90) database became an essential source of land cover information in the project concerning the majority of the EC countries as well as the PHARE partner countries from Central and Eastern Europe. Standard methodology and nomenclature of 44 classes were applied to mapping and database creation at the scale of 1:100,000 scale, using the 25 ha minimal mapping unit (Feranec & O aheľ, 2001). The need for the updated databases became the impulse for the realization of the CLC2000 and CLC2006 projects. All participating countries used a standardized technology and nomenclature to ensure the compatibility of results for the environmental analysis, landscape evaluation and changes.

Research, which is concerning the landscape structure changes in natural calamity areas, affords important information for landscape planning. Fal an & Saksa (2007) and Fal an & Bánovský (2008) realised large-scaled research of land cover changes after windthrow disaster, based on CORINE methodology at chosen localities in the Tatra National Park (Strbske pleso – Stary Smokovec).

The aim of this paper is to present changes in forest fragmentation in the Tatras in the period 2000 and 2006 using the CLC data. The applied methodological procedure makes it possible not only to quantify the scope of forest diminishment, but also to detect qualitative changes in forest biotopes that survived in the selected study area.

Study area

The study area covers the entire Slovak part of the Tatra Mountains (High, Belianske and West Tatras) and a part of the Podtatranska Kotlina basin. The Slovak-Polish frontier runs in the north of the study area. In the west, the limits of the territory coincide with the mountain range of Skorušinske Vrchy and in the east with the Spišska Magura Mountains. Part of the study area that is situated in the Podtatranska kotlina basin covers eight orographic sub-units: Tatranske podhorie, Matiašovske Haje, Smrečianska Pahorkatina, Hybianska Pahorkatina, Štrbska Pahorkatina, Kežmarska Pahorkatina, Vojanske Podhorie, and Popradska Rovina. The total studied area is 1,359.75 km^2.

Methodology of forest fragmentation assessment

For the purpose of assessing forest fragmentation in the selected model territory, the Riitters' (Riitters *et al.*, 2002) methodology was applied. The used input data consisted of information on land cover from the CLC2000 and CLC 2006 data layers. GIS analysis was processed in the ArcGIS 9.1 software product. Source data were in vector format – shp. The methodological procedure was divided into three principal stages:

1. Data preparation
2. Computation of Forest connectivity (C_f) and Forest proportion (P_f)
3. Interpretation of results.

CLC data related to two time horizons were used: CLC 2006 and updated data layer CLC 2000. Both data layers are accessible in vector format. For identification of forest fragmentation, Riitters *et al.* (2002) proposed the method based on raster data. Raster data represent the abstraction of the real landscape as a matrix of raster cells (pixels) stands for the spatial data. The data are not continuous, as they consist of disjoint regular units what is an advantage in some types of spatial analysis and modelling.

The preparatory steps consisted of data selection for the model territory and their conversion to the grid reclassification of classes. The module *Polygrid* with 25 m cell size was used in conversion of the vector format to raster – grid. Cell size was opted for with regard to fact that in interpretation of land cover the LANDSAT 4 TM a LANDSAT 7 ETM, satellite images with the resolution capacity of 25 m were used.

Pursing the Riitters' methodology (Riitters *et al.*, 2002), it was necessary to aggregate land cover classes in order to discern forest and other than forest areas, i.e. to reclassify land cover classes so that the grids input into the analysis contains values: 0 for areas other than forest (Non-forest), 1 for Forest and NoData. The module *Reclassify* was used for reclassification.

Riitters *et al.* (2002) observed two indicators: Forest proportion (P_f) and Forest connectivity (C_f) in order to establish the fragmentation rate. Pf stands for the share of raster cells representing forest areas in the overall number of the cells in the evaluated grid window. In computation of the Cf value, it is necessary to identify the number of real forest boundaries in each grid window and the number of inner boundaries between forest-forest raster cells, while C_f expresses the number of inner boundaries divided by the sum total of real and inner boundaries.

First of all, it was necessary to find out about the neighbouring relationships of individual raster cells (pixels), the forest-forest (FF), and the forest and non forest (FN) relationships. The tool *Focal Statistics* was used for the purpose. The resulting rasters contained two values. Value 1 represented the neighbour relationship FN and value 2 stood for FF. For the sake of clarity, the values were selected for independent rasters, which were further processed applying the *Extract by Attributes* tool. Then, the total sums of cells within the window sized 5×5 cells (corresponding to 125×125 m) were found applying the *Block Statistics* tool. As far as the setting the parameters are concerned, this tool is similar to *Focal Statistics,* but it works basing on other principle (Kopecká & Nováček, 2008).

The C_f value is determined by the following formula:

$$C_f = FF/(FF+FN)$$

For computation of P_f, the tool *Block Statistics* with window size 5×5 was used and the statistical data sought was the Mean. The processed grid was the product of the *polygrid* conversion and the following *reclassify.* It contains values 0 for non-forest and 1 for forest. Detailed description of the methodical procedure is described in Kopecká and Nováček (2008).

Result interpretation was carried out in the environment of ArcINFO Workstation 9.1, GRID regime, and using the tool *Con.* This tool makes it possible based on given conditions to withdraw the values of the processed grids and to replace them by values set by user. In this case, the values were replaced by:

1 – Core; 2 – Patch; 3 – Perforated and 4 – Edge.

Before the independent use of *Con,* it was necessary to separate the values $C_f = 0.6$ into an independent grid. The obtained resulting grids can be joined into one by means of simple map algebra – merge. Comparison of P_f and C_f values facilitates classification of the observed raster window into one of four defined fragmentation categories, as follows:

1. Core, if $C_f = P_f = 1$
2. Edge if $1 > P_f = 0.6$ and $P_f = C_f$
3. Perforated if $1 > P_f = 0.6$ and $P_f > C_f$
4. Patch if $P_f < 0.6$.

Before the C_f and P_f were compared, they were computed independently for each time horizon.

Results

In the period 1990–2006, a remarkable decrease of forest land in the study area was recorded. Decrease of the area of the CLC forest classes (classes 311, 312 and 313) on land cover maps from 2000 and 2006 was connected with an increased number of transitional woodland/shrubs polygons (CLC class 324, see Table 1). This land cover type is represented by the young wood species that are planted after clear-cuts or after calamities of any origin, forest nurseries and stages of natural development of forest (Feranec & O aheľ, 2001). The change of forest into transitional woodland indicates a temporary fragmentation with possible forest regeneration. On the other hand, forest destruction in the National Park facilitated the development of travel and tourism (new hotels, ski parks, etc.). An increased number of construction sites (CLC class 133) indicate that an urban sprawl associated with a permanent forest fragmentation can be expected in future.

The main reason of these changes was the calamity whirlwind of November 2004, which has substantially changed the vegetation cover in the whole area of the Tatra Mountains. In 2005, large wildfires aggravated environmental problems of the territory affected by the windthrow disaster. These actions were the main reasons of the dramatic forest fragmentation in the Tatra National Park in the period 2000–2006.

Table 2 demonstrates the decrease of the compact forest areas (Forest core) in the period 2000 and 2006. On the other side, increased percentage of disrupted forest areas was observed. Pursuing the applied methodology, these areas were classified into Perforated forest, Forest patches and Forest edge fragmentation components.

Final remarks and conclusion

Natural deforestation is not a new phenomenon in the Tatras. Windthrows have happened in this region also in the past (Zielonka *et al.,* 2009); however, at a much smaller scale. Urbanization connected with human induced deforestation also played important role in the past because of tourism development. The main difference between the ancient practices and current deforestation is the difference in scale and rate of increase.

In the past, small patches of pastures or damaged forest appeared in large forested landscape and they quickly grew back upon abandonment. Results of the bora windstorm in 2004 in the Tatra National Park were the opposite: remnant forest patches were left in the sea of degraded forest landscape. The negative effects of the wind calamity increased when fallen and broken trees were removed to prevent the large-scale bark-beetle damage.

Habitat fragmentation not only reduces the area of available habitat but also can isolate populations and increase edge effects. Some species may be perfectly capable of surviving in a remnant forest, many others may not. A forest patch is not the same as a piece of original forest: edge effects may now en-

Table 1. CORINE land cover classes in the study area

CLC class*	2000		2006		Change 2000–2006	
	number of polygons	total class area (km²)	number of polygons	total class area (km²)	number of polygons	total class area (km²)
112 Discontinuous urban fabric	58	37.99	58	38.44	0	0.45
121 Industrial or commercial units	9	6.01	10	6.26	1	0.25
124 Airports	1	1.53	1	1.53	0	0
131 Mineral extraction sites	1	1.26	1	1.26	0	0
133 Construction sites	0	0	5	2.36	5	2.36
142 Sport and leisure facilities	13	10.07	13	10.26	0	0.19
211 Non-irrigated arable land	34	278.02	36	275.01	2	–3.01
222 Fruit trees and berry plantations	1	0.07	1	0.07	0	0
231 Pastures	92	128.49	91	126.98	–1	–1.51
242 Complex cultivation pattern	18	18.04	18	18.04	0	0
243 Land principally occupied by agriculture with significant areas of natural vegetation	69	34.42	69	34.14	0	–0.28
311 Broad-leaved forest	6	3.46	6	3.46	0	0
312 Coniferous forest	26	492.66	36	373.45	10	–119.21
313 Mixed forest	26	20.01	24	18.01	–2	–2
321 Natural grassland	27	81.43	27	81.43	0	0
322 Moors and heathland	38	91.11	38	91.11	0	0
324 Transitional woodland/shrubs	79	51.52	82	174.28	3	122.76
332 Bare rocks	7	60.96	7	60.96	0	0
333 Sparsely vegetated areas	40	40.70	40	40.70	0	0
412 Peatbogs	1	0.56	1	0.56	0	0
511 Water courses	2	1.42	2	1.42	0	0
512 Water bodies	1	0.01	1	0.01	0	0

*CLC classes are described in Feranec & O ahel’ (2001)

Table 2. Changes in forest fragmentation in the period 2000–2006

Fragmentation component	2000		2006		Change 2000–2006	
	km²	% SA	km²	% SA	km²	% SA
Forest core	435.219	32.01	312.297	22.97	–122.922	–9.04
Perforated forest	14.765	1.09	15.500	1.14	0.735	0.05
Forest patches	73.313	5.39	77.000	5.66	3.687	0.27
Forest edge	37.687	2.77	38.562	2.84	0.875	0.07
Total	560.985	41.26	443.359	32.61	–117.626	–8.65

SA – study area

croach upon or even traverse the whole patch. Whatever the combination of biotic and abiotic changes is, the forest patches generally can no longer sustain the production of biodiversity it once had as a part of the larger forest. Understanding of the possible consequences of forest fragmentation is of great concern to conservation biologists and landscape ecologists. For example, Repel (2008) analysed breeding bird assemblage structure; nesting, foraging and migrating guilds; bird and habitat relationship and the sea-

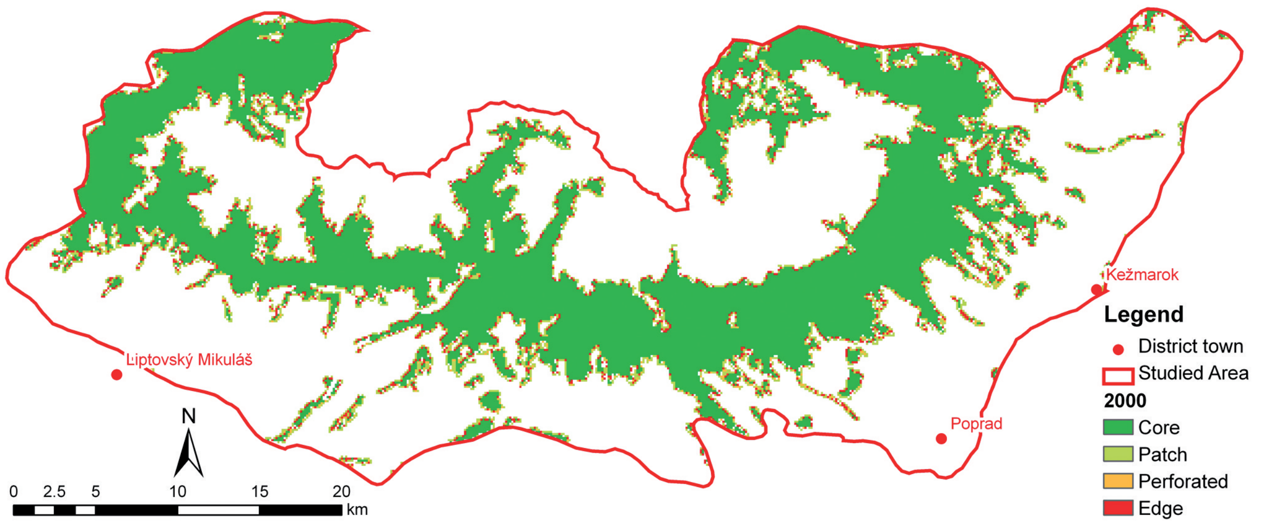

Fig. 1. Forest fragmentation in the Tatra region in 2000

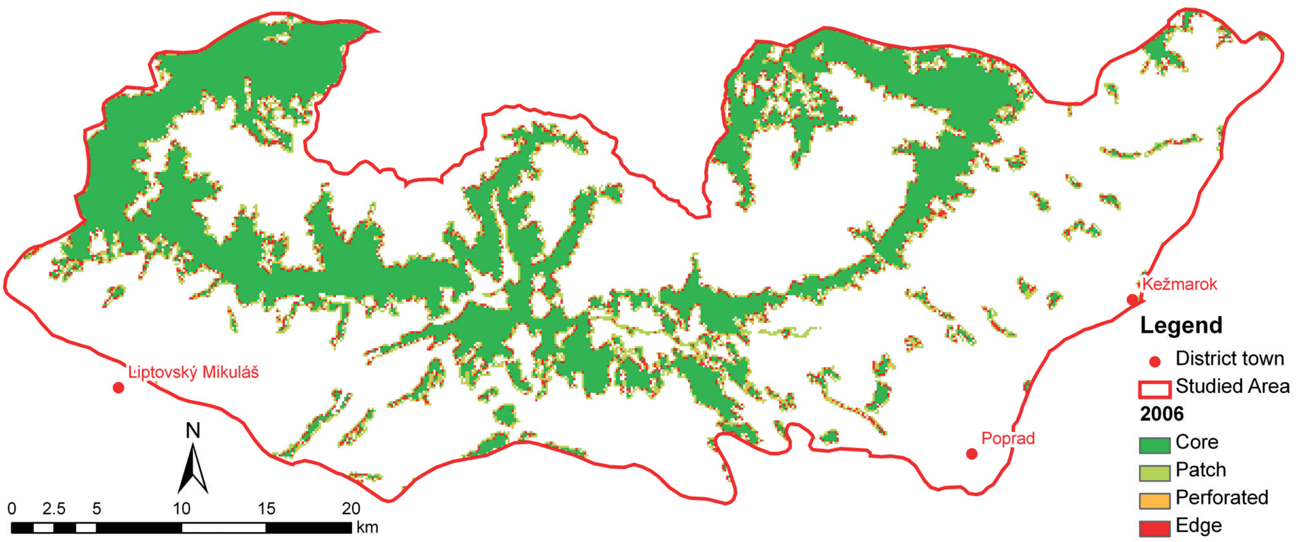

Fig. 2. Forest fragmentation in the Tatra region in 2006

sonal dynamics of bird assemblages within four research plots assigned by the management of the Tatra National Park:

- reference stand, not affected by windstorm calamity
- plot with extracted wood
- post wild-fire plot
- not extracted plot.

The average density of breeding bird assemblages in reference stand was much higher than in the plot with extracted wood and wildfire plot. The assemblages on the not extracted plot had the highest average density. The structure of the breeding bird assemblages was most influenced by the portion of the undisturbed forest stands in the plot, number of live standing trees, proportion of dead wood in form of twig heaps, proportion of lying dead wood, and proportion of stones/stone fields in research plots. The use of forest fragmentation indices in the analysis of forest landscapes offers a great potential for integration of spatial pattern information in the landscape-ecological management processes, but requires understanding of the limitations and correct interpretation of results. Further monitoring of forest fragmentation based on remote sensing data together with the terrestrial monitoring of natural vegetation development and dynamics of indicative plant and animal species is necessary to realize optimal revitalization activities and to mitigate negative effects of the calamity windstorm in the Tatra region.

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