Natural Forest Fragmentation: an Example from the Tatra Region, Slovakia

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1. Introduction

According to land cover change assessment in Slovakia (Feranec and Nováček, in print) deforestation was the largest type of landscape change in Slovakia in the period 2000–2006.

Deforestation is generally considered to be one of the most serious threats to biological diversity. An understanding of relations how different deforestation patterns influence habitat quality of forest patches is essential for effective landscape-ecological management. The overall effect of deforestation on a forest patch depends on its size, shape and location. Zipperer (1993) identified the following types of deforestation patterns:

- internal deforestation that starts within the forest patch and progresses outwardly
- external deforestation that starts from the outside and cut into the forest patch, including indentation, cropping and removal
- fragmentation when the patch is split into smaller parcels

The last type – 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. As the external matrix is physiognomically and ecologically different from the forest patch, an induced edge is formed (Zipperer, 1993, Yahner, 1988, Faaborg et al. 1993). Riitters et al. (2002), leaning on studies of several authors, states that change in area of forests and their increased fragmentation can affect 80 to 90% of all mammals, birds and amphibians.

An important aspect of fragmentation is the scope and structure of fragments (shape, size, spatial arrangement, etc.). These spatial parameters can be assessed using several quantitative methods presented by, for instance, Riitters (2005), Ritters et al. (2002), McGarigal and Marks (1995), Keitt et al. (1997), D'Eon et al. (2002), Kopecká and Nováček (2008). The study of Kummerle et al. (2006) is another example of the study where authors used satellite data and compiled land cover maps followed by computation of fragmentation indexes in boundary regions of Poland, Slovakia and Ukraine.

In the early 1990s, the CORINE Land Cover (CLC) 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 in 1:100,000 scale using the 25 ha minimal mapping unit (Feranec and Oťaheľ 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.

Fig. 1 – Location of the study area

In this contribution we present an example of cartographic expression of qualitative changes in forest fragmentation in a selected study area at regional level related to the years 1990, 2000 and 2006 that are based on CLC data assessment. 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 survive in the study area.

2. Study Area

The Tatra region (Slovakia) was selected as a study area to illustrate forest fragmentation changes. In November 2004, the territory was affected by calamity whirlwind which destroyed around 12,000 ha of forest at altitudes between 700 m to 1,350 m above sea level and substantially changed the vegetation cover in the whole area of the Tatra National Park. The study area covers the entire Slovak part of the Tatra Mountains (High, Belianske and West Tatras) and a part of the Podtatranská Kotlina basin (Fig. 1). The Slovak-Polish frontier runs to the north of the study area. In the west the limits of the territory coincide with the mountain range of Skorušinské Vrchy and in the east with the Spišská Magura Mountains. Part of the study area that is situated in the basin Podtatranská kotlina and covers 8 orographic sub-units: Tatranské podhorie, Matiašovské Háje, Smrečianska Pahorkatina, Hybianska Pahorkatina, Štrbská Pahorkatina, Kežmarská Pahorkatina, Vojanské Podhorie and Popradská Rovina. The total studied area is 1,359.75 km².

3. Methodology of Forest Fragmentation Assessment

The CORINE Land Cover data layers CLC90, CLC 2000 and CLC 2006 converted to raster format were used as the input data in the process of forest fragmentation assessment. For the purpose of assessing forest fragmentation in the selected model territory, the methodology presented by Vogt et al. (2007) was applied. Morphological image analysis was applied using the Landscape Fragmentation tool (LFT) developed by Parent and Hurd (2008). LFT maps the types of fragmentation present in a specified land cover type (in our case it was forest).

CLC data layers are accessible in vector format. For identification of forest fragmentation using LFT conversion into raster format was needed. The preparatory steps consisted of data selection for the model territory and their conversion to the grid reclassification of classes. The module *Polygrid* with 25m 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 and LANDSAT 7 ETM+, satellite images with the resolution capacity of 25 m were used.

As the LFA tool requires a 3 class land cover map as input, 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 the following values:

- 1 = fragmenting land cover – residential, commercial, urban, pastures, orchards, fallows (on the study area CLC classes 112, 121, 124, 131, 134, 142, 211, 222, 231,242, 243, 321, 322, 324, 333)
- 2 = non-fragmenting land cover – water, rocks, ice, snow, sand (CLC classes 411, 511, 512 and 332)
- 3 = forest (CLC classes 311, 312 and 313)

Forest is classified into four main fragmentation components – *patch*, *edge*, *perforated*, and *core* (Fig. 2). "Core forest" is relatively far from the forest–nonforest boundary and "patch forest" comprises coherent forest regions that are too small to contain core forest. "Perforated forest" defines the boundaries between core forest and relatively small perforations, and "edge forest" includes interior boundaries with relatively large perforations as well as the exterior boundaries of core forest regions.

According to Parent and Hurd (2008) forest area classification is based on a specified edge width. The edge width indicates the distance over which other land covers (i.e. urban) can degrade the forest. The core pixels are outside the "edge effect" and thus are not degraded from proximity to other land cover types. Edge and perforated pixels occur along the periphery of tracts containing core pixels. Edge pixels make up the exterior peripheries of the tracts whereas perforated pixels make up the interior edges along small gaps in the tracts. Patch pixels make up small fragments that are completely degraded by the edge effect.

Changes in forest fragmentation were further assessed according to the following types:

- Type 1: Continuous forest changed into discontinuous forest (Core in forest fragmentation map from 1990 changed into Patch, Perforated or Edge in 2006)
- Type 2: Continuous forest changed into non-forest (Core in forest fragmentation map from 1990 changed into Fragmenting land cover in 2006)
- Type 3: Discontinuous forest changed into non-forest (Patch, Perforated and Edge in 1990 changed into Fragmenting land cover in 2006)

4. Results

Between 1990 and 2000, land cover in the Tatra National Park was relatively stable. Recorded landscape changes were connected especially with changes of abandoned agricultural land (pastures, arable land) into woodland scrub and with the changes of transitional woodland scrub into forest by natural development.

In the period 2000–2006, a remarkable decrease of forestland on the study area was recorded (Fig. 3). 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 Tab. 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 and Oťaheľ 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) indicates that an urban sprawl associated with a permanent forest fragmentation can be expected in the future.

The main reason for these changes was the calamity whirlwind of November 2004, which has substantially changed the vegetation cover in the whole area of the Tatra Mountains (Fig. 4). In 2005, large wildfires aggravated environmental problems of the territory affected by the windthrow disaster. These actions were the main reasons for the dramatic forest fragmentation in the Tatra National Park in the period 2000–2006 (Fig. 5).

Tab. 2 and Fig. 6 demonstrate 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.

The assessment of different types of forest fragmentation showed that the changes of continuous forest in favour of non-forest (Type 2) was dominant (61%). Fig. 7 also demonstrates that Type 3 – discontinuous forest changed into non-forest covered 22% of the changed territory and the percentage of continuous forest changed into discontinuous forest (Type 1) was 17%.

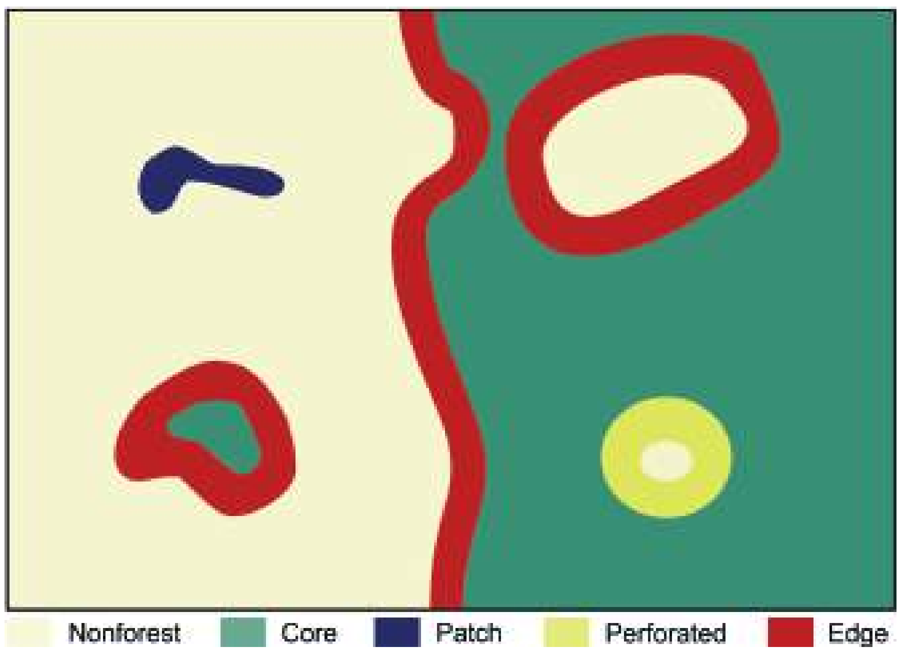

Fig. 2 – Illustration of four types of spatial pattern on an artificial map (Vogt et al. 2007)

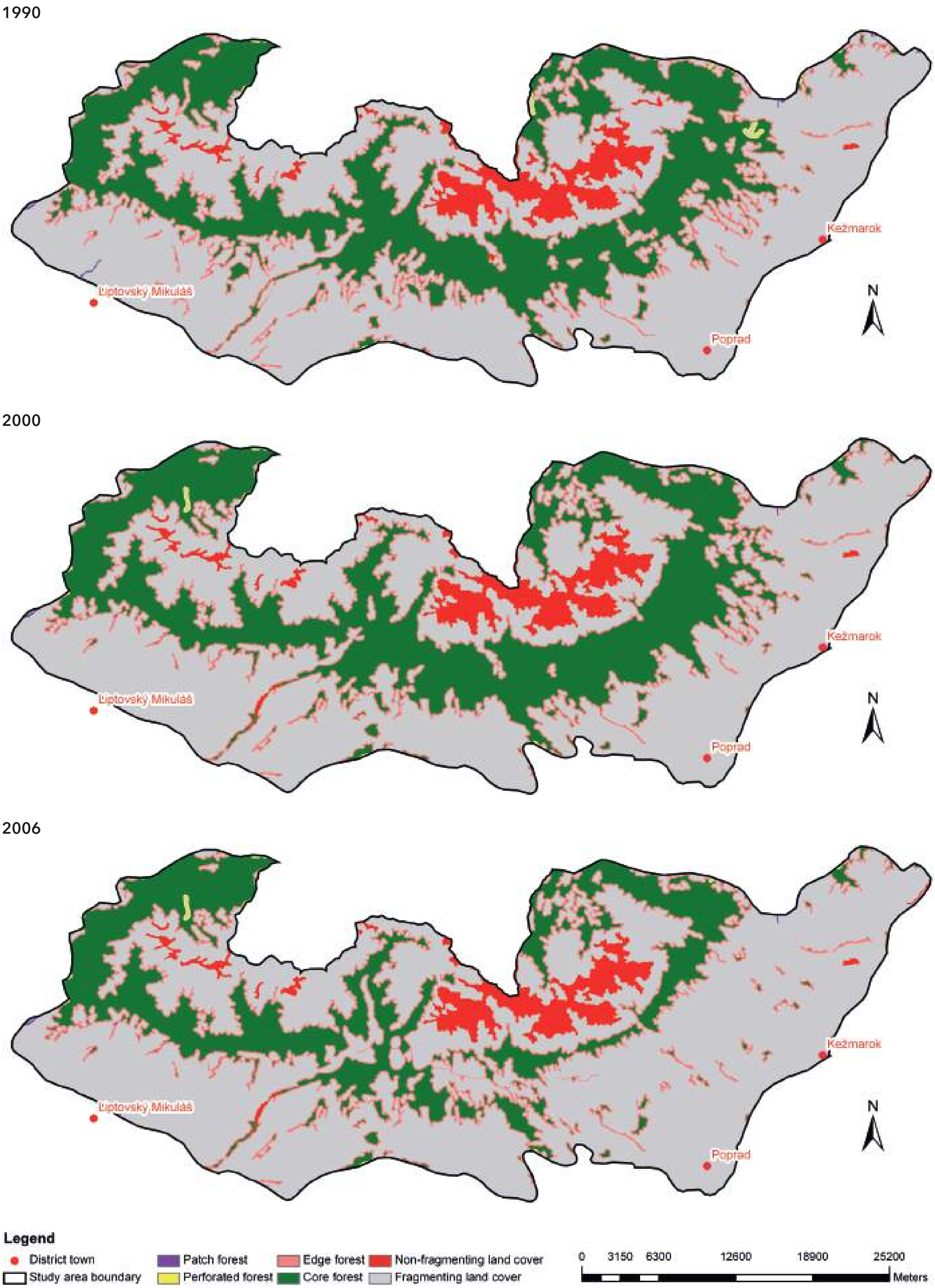

Fig. 3 – Forest fragmentation in the Tatra region in (a) 1990, (b) 2000, (c) 2006

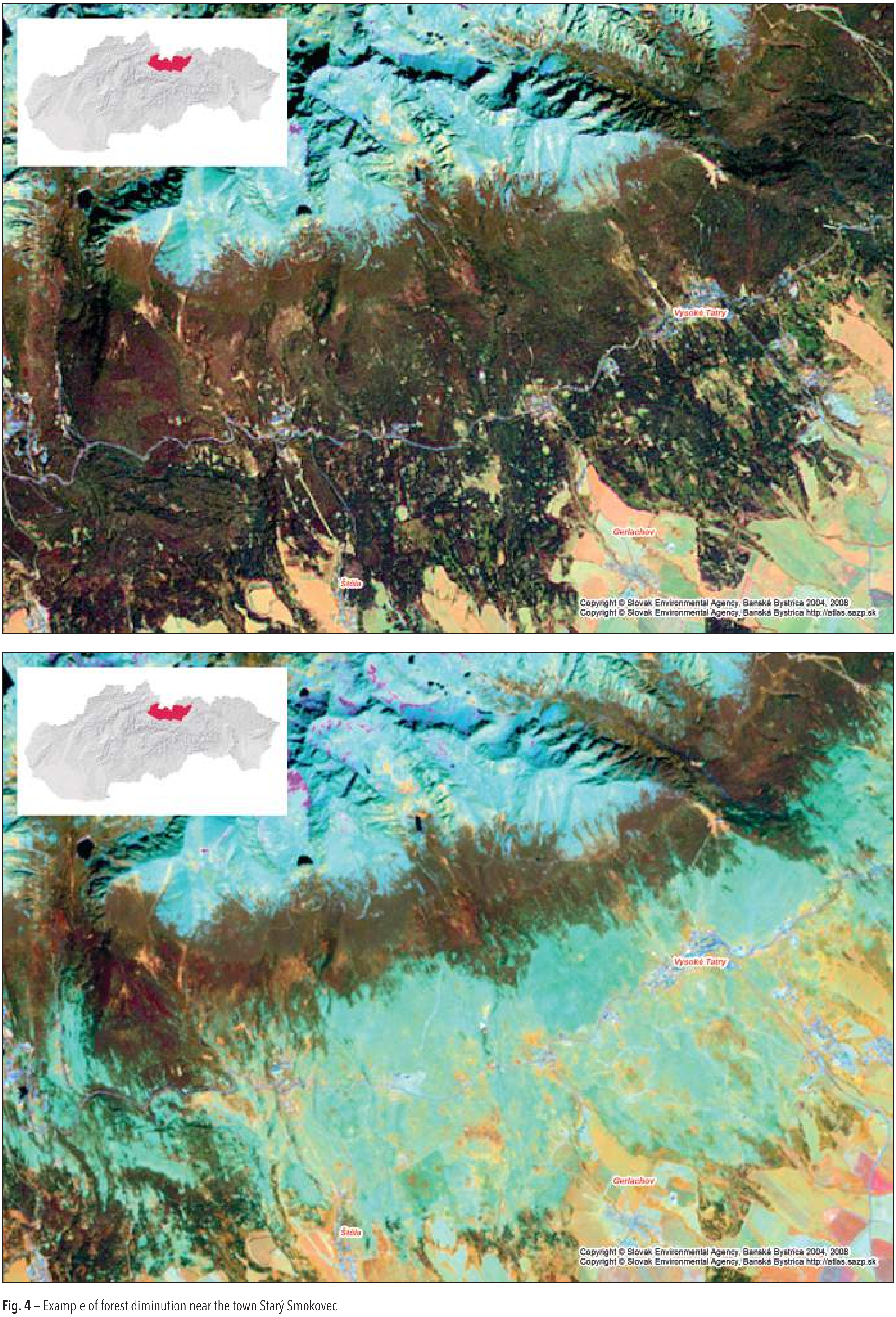

Fig. 4 – Example of forest diminution near the town Starý Smokovec

Tab. 1 – CORINE land cover classes on the study area

CLC class*	2000		2006		Change 2000–2006	
	Number of polygons	Total class area (km^2)	Number of polygons	Total class area (km^2)	Number of polygons	Total class area (km^2)
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	0.00
131 Mineral extraction sites	1	1.26	1	1.26	0	0.00
133 Construction sites	0	0.00	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	0.00
231 Pastures	92	128.49	91	126.98	−1	−1.51
242 Complex cultivation pattern	18	18.04	18	18.04	0	0.00
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	0.00
312 Coniferous forest	26	492.66	36	373.45	10	−119.21
313 Mixed forest	26	20.01	24	18.01	−2	−2.00
321 Natural grassland	27	81.43	27	81.43	0	0.00
322 Moors and heathland	38	91.11	38	91.11	0	0.00
324 Transitional woodland/shrubs	79	51.52	82	174.28	3	122.76
332 Bare rocks	7	60.96	7	60.96	0	0.00
333 Sparsely vegetated areas	40	40.70	40	40.70	0	0.00
412 Peatbogs	1	0.56	1	0.56	0	0.00
511 Water courses	2	1.42	2	1.42	0	0.00
512 Water bodies	1	0.01	1	0.01	0	0.00

*CLC classes are described in Feranec & Oťaheľ (2001).

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

Fragmentation component	1990		2000		2006		Change 1990–2006	
	km^2	% SA	km^2	% SA	km^2	% SA	km^2	% SA
Patch forest	1.112	0.08	0.964	0.07	0.632	0.05	−0.480	−0.03
Perforated forest	2.437	0.18	1.646	0.12	1.689	0.12	−0.748	−0.06
Edge forest	127.199	9.35	129.891	9.56	116.652	8.58	−10.547	−0.77
Core forest	380.006	27.95	357.930	26.32	275.952	20.29	−104.054	−7.66
Non-fragmenting land cover	63.696	4.68	63.695	4.68	62.931	4.63	−0.765	−0.05
Fragmenting land cover	785.311	57.76	805.635	59.25	901.905	66.33	116.594	8.57
Total	1,359.761	100.00	1,359.761	100.00	1,359.761	100.00	0.000	0.00

SA –study area

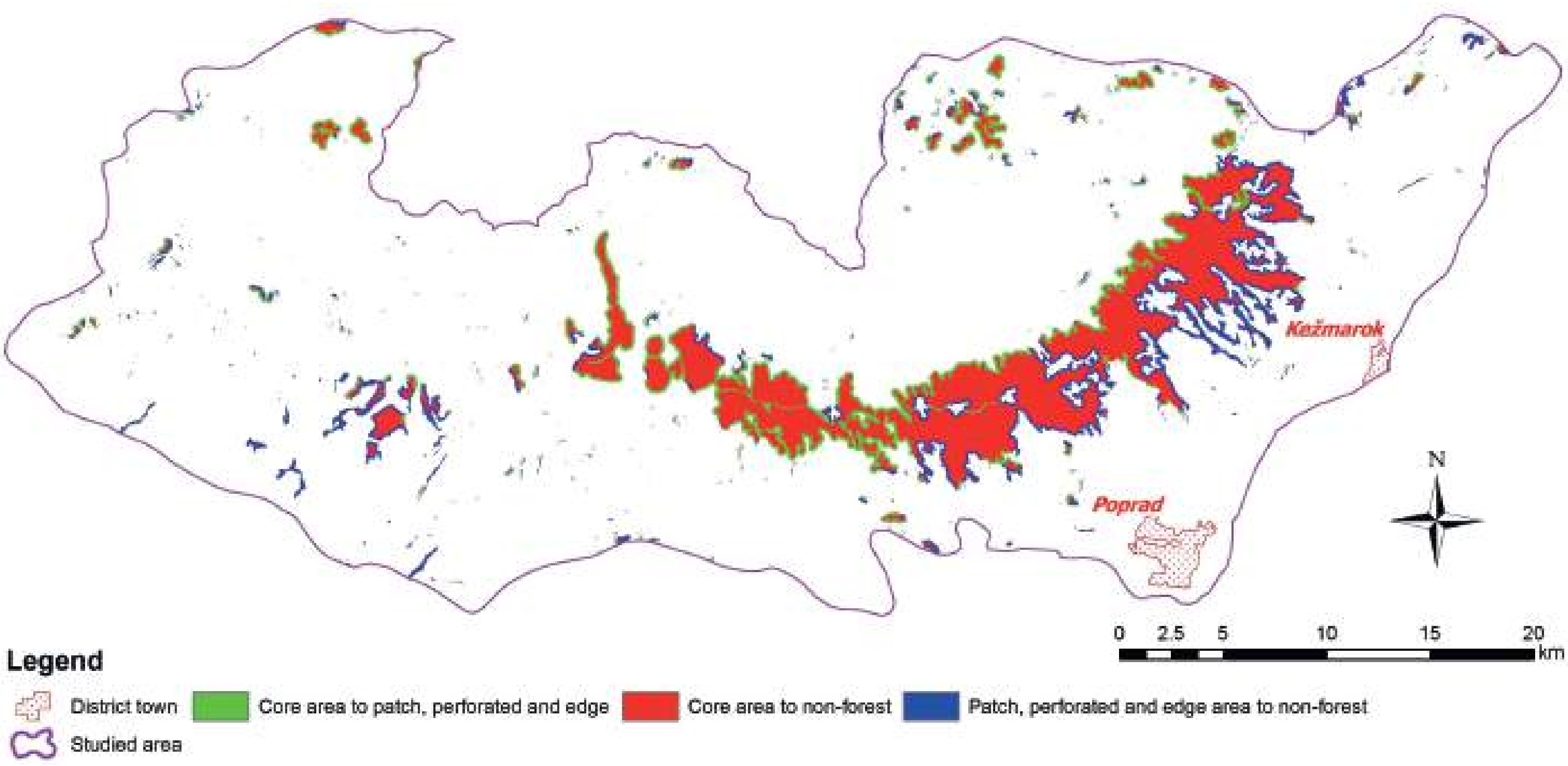

Fig. 5 – Map of changes in forest fragmentation in 1990–2006

5. Final Remarks and Conclusion

Natural deforestation is not a new phenomenon in the Tatras. Windthrows have taken place in this region also in the past (Zielonka et al., 2009) however, on a much smaller scale. Urbanization connected with human induced deforestation also played an 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. Whatever the combination of biotic and abiotic changes, the forest patches generally can no longer sustain the production of biodiversity it once had as a part of the larger forest. Understanding the possible consequences of forest fragmentation is of great concern to conservation biologists and landscape ecologists. 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 a correct interpretation of the results. The Landscape Fragmentation tool that we used in our analyses was designed to analyse fragmentation in forests. However, this approach can be used to map fragmentation in any land cover of interest.

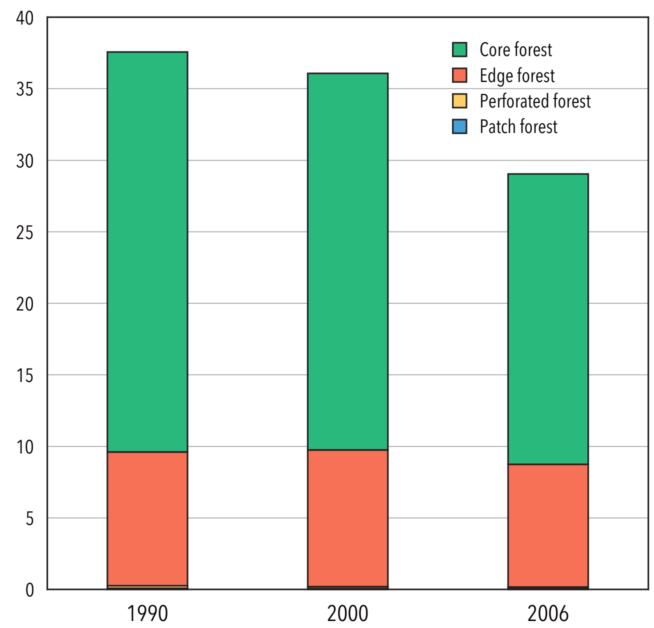

Fig. 6 – Changes in proportion of forest fragmentation components in the landscape structure

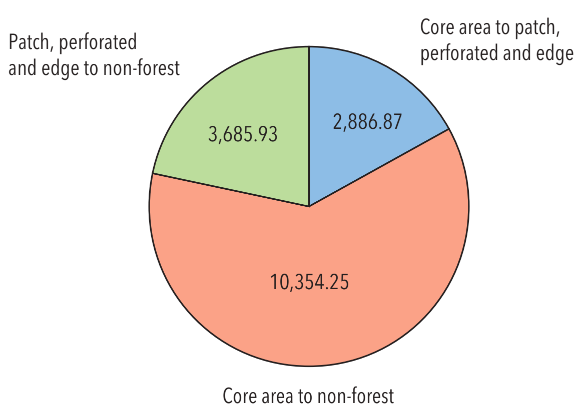

Fig. 7 – Proportion of different types of forest fragmentation in the period 1990–2006 (in ha)

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