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Destruction of the Forest Habitat in the Tatra National Park, Slovakia

Monika Kopecka
Institute of Geography, Slovak Academy of Sciences
Slovakia

1. Introduction

The dynamically changing land cover configuration and its impact on biodiversity have aroused interest in the study of deforestation and its consequences. Deforestation is generally considered to be one of the most serious threats to biological diversity. Awareness of how different deforestation patterns influence habitat quality of forest patches is essential for efficient landscape–ecological management.

The overall effect of deforestation on the forest patch depends on its size, shape and location. Zipperer (1993) identified the following types of the deforestation pattern:

- Internal deforestation that starts in the forest patch and progresses outwardly;
- External deforestation that starts outside and cuts into the forest patch, including indentation, cropping and removal;
- Fragmentation when the patch is split into smaller parcels.

Forest fragmentation is one of the most frequently cited causes of species extinction making it a crucial contemporary conservation issue. The classic view of a habitat fragmentation is the breaking up a large intact area of a single vegetation type into smaller landscape units or simply the disruption of continuity (Fahrig, 2003; Lord & Norton, 1990). This process represents a transition from being whole to being broken into two or more distant pieces. The outcome is landscape composed of fragments (e. g. forest) with something else (the non-forest matrix) between the fragments. Fragmentation of biotopes affects several ecological functions of landscape, first of all the spatial distribution of selected plant and animal species and associations (Bruna & Kress; 2002, Kurosawa & Askins, 2003; Parker et al., 2005). Fragments of original biotopes with reduced area and increased isolation are not capable of securing suitable conditions for life and reproduction of some organisms. Consequences of fragmentation include the species biodiversity decline, functional changes in ecological processes, for instance disruption of trophic chains (Valladares et al., 2006), and genetic changes in organisms (Cunningham & Moritz 1998; Gibbs, 2001).

The history of research focused on the fragmentation consequences reaches to the 1960s when the theory of insular biogeography was published (MacArthur & Wilson, 1963, as cited in Faaborg et al., 1993). The basis of this theory is the recognition that the smaller and more dispersed islands, the lower number of species is capable to find suitable conditions for their permanent existence. However, the phenomenon is not limited only to islands in the geographic sense. As Madera and Zimová (2004) report similar problems were also

observed in case of "islands" in the sense of fragments of natural biotopes in the "sea" of the agro-industrial landscape.

The most frequently studied fragmentation consequences include assessment of the effects on birds. Betts et al. (2006), who investigated dependence of two bird species on fragmentation of their natural biotopes, confirms the hypothesis that landscape configuration is important for selected species only in case of a too small range area and isolated occurrence of suitable biotopes. Faaborg et al. (1993) pointed to the main fragmentation consequences for the neotropical migrating birds and simultaneously presented his proposals how to minimise the negative effects of fragmentation in landscape management. Parker et al. (2005) studied effects of forest areas and forest edges on distribution of 26 species of singing birds and reports that effects of forest fragmentation is negative for many species while the forest area is more important in terms of bird occurrence than its shape (length of edges). Likewise, Trzcinski et al. (1999) emphasize that the effects of the decline in forest area are more serious than fragmentation alone and that the decline of the forest area cannot be compensated by optimisation of spatial arrangement of the remnant fragments. Kuroshawa and Askins (2003) arrived at a similar conclusion and report that preservation of some species in deciduous forest requires occurrence of sufficiently big forest areas. The same authors also consider the forest acreage a suitable indicator of selected bird species frequency.

Fragmentation not only reduces the area of available habitat but can also isolate populations. As the external matrix is physiognomically and ecologically different from the forest patch, an induced edge is formed. Riitters et al. (2002), leaning on studies of several authors, state that a change in area of forest and an increased fragmentation can affect 80 to 90% of all mammals, birds and amphibians. According to 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 areas), and
- Temporary fragmentation that occurs through timber harvest practices, which create holes of young forest within a matrix of mature forest.

Large forest areas are rapidly becoming fragmented not only as a result of human activities, but as a result of natural disasters as well. In November 2004, the territory of the Tatra National Park, Slovakia was affected by a calamity whirlwind that 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. The whirlwind and subsequent logging of damaged timber has radically changed the natural conditions of local fauna and flora.

2. The Tatra National Park

The study area covers the whole of the Slovak part of the Tatra Mountains (High Tatras, Belianske Tatras and West Tatras) and a part of the Podtatranska Basin. The Slovak-Polish frontier runs in the north of the study area (Fig. 1).

2.1 Natural biodiversity

The Tatras form a geomorphological unit at the extreme top of the arching province of the Western Tatras. In terms of exogenous relief-forming processes, the surface of high-mountain landscape is the glacial georelief. The tallest peaks of the Tatras are over 2,600 m



Fig. 1. Location of the study area

a. s. l. The basin is classified as the type of morphostructure of dell grabens and morpho-tectonic depressions with the relief resting on glacial, glacifluvial and polygenic sediments. The climate of the Tatras is cool to very cool and moist. The mean January temperature in the high-mountain part of the territory is between -7 and -11 degrees of Celsius with the mean annual precipitation totals of 1,200 –2,130 mm. The mean January temperature in the cool subtype oscillates between -6 and -7 °C and the annual precipitation total is between 1,000 and 1,400 mm. The moraine zone in the foreland of the Tatras is classified as the type of cool mountain climate with the mean January temperatures between -5 and -6.5 °C and the mean annual precipitation total between 800 and 1,100 mm. Mean annual air temperatures in the area of the upper timber line in the altitude of 1,600 – 1,800 m above sea level are 2-4 °C; in July it is 10 to 12 °C with the mean annual precipitation totals from 900 to 1,200 mm. The annual course of the air temperature with the minimum in January and the maximum in July prevails in the territory. The lowest temperature instead of occurring in January often moves to February and the highest temperature occurs in August in the highest positions above 2,000 m. n. m. Inversions are typical for the region. The amount of precipitation in the Tatras increases with the increasing sea level altitude. Monthly totals are minimum in winter and maximum in summer. The amplitude of the yearly course depends not only on the sea level altitude but also on exposition of the terrain.

Nature of the Tatras is the unique example of the fully devolved alpine ecosystems on a comparatively small and completely isolated territory lacking any direct links to other alpine mountain ecosystems. It is precisely this feature that makes the Tatras so unique and valuable in terms of natural history not only for Slovakia but also Europe. The great species diversity of fungi, vascular and non-vascular plants in the Tatras is the result of pronounced altitude differences, varied geology but also diverse moist conditions and soils. Endemites of the Tatras, Western Tatras and the Carpathians are the most important representatives of flora. Forest and non-forest plant association linked to five vegetation zones and the substrate exist in this territory.



Fig. 2. Vegetation zones over the Štrbské Pleso Lake in the High Tatras (Photo: M. Kopecká)

The submontane zone covers the lowest part of the region up to the sea level altitude of 800-900 m. The transformed forest is typical while agricultural landscape prevails. The original mixed forests, which once covered the total submontane zone, survive only in inaccessible and mostly wetlogged localities. Spruce-pine and fir-beech woods grow here on acid substrates. The dominant species is the spruce (*Picea abies*). Rare and threatened species like *Ledum palustre, Pedicularis sceptrum-carolinum* and *Iris sibirica* grow in wetland and peat bogs. Among other important species are *Carex lasiocarpa, Carex davalliana, Gymnadenia conopsea, Menyanthes trifoliata, Primula farinosa* and *Pinguicula vulgaris*.

The montane zone is located at the attitude from do 800-900 m a. s. l. to 1,500-1,550 m a.s.l. It includes thick woods with the dominance of *Picea abies*. Broad-leaved forests with dominance of birch and alder trees prevail on the wet soils in the foothills of the Tatras. In altitudes below 1,200 m apart from spruce trees other species like *Pinus sylvestris, Abies alba, Acer pseudoplatanus, Fagus silvatica, Betula pendula,* and *Salix caprea* grow. The most common shrubs include *Lonicera nigra, Lonicera xylosteum, Rosa pendulina* and *Rubus ideaus*. Mountain spruce woods almost exclusively dominate in altitudes above 1,250 m a. s. l. *Sorbus aucuparia, Larix decidua* and *Pinus cembra* thrive on acid soil while *Acer pseudoplatanus* and *Fagus silvatica* prefer calcareous substrates. Peat bogs (*Sphagnum sp*.) with occurrence of many rare species such as *Eriophorum vaginatum, Drosera rotundifolia, Oxycoccus palustris* represent other than forest associations.

Subalpine zone spreads from 1,500-1,800 m. a. s. l. Vegetation consists of continuous growths of *Pinus mugo* and dwarfed trees. In the lower parts of the zone species like *Picea abies, Pinus cembra, Betula carpatica, Ribes alpinum, Ribes petraeum, Sorbus aucuparia* and *Salix silesiaca* occur. Among herbs are *Aconitum firmum* subsp. *firmum*, *Cicerbita alpina* and *Doronicum austriacum*.

The alpine zone including alpine meadows stretches to 2,300 m a.s. l (Fig. 3). The only wood species resisting the extreme conditions are the low shrubs of *Salix kitaibeliana, Salix alpina, Salix reticulata, Salix herbacea, Juniperus communis* subsp. *alpina, Vaccinium vitis-idaea, Vaccinium myrtillus, Vaccinium gaultherioides, Calluna vulgaris,* and *Empetrum hermaphroditum, Juncus trifidus, Festuca supina, Campanula alpinum, Hieracium alpinum,* and *Pulsatilla scherfelii* dominate on granite substrate. The most exuberant plant associations with the typical representatives like *Dryas octopetala, Festuca versicolor, Saxifraga caesia, Primula auricula* and *Helianthemum alpestre* grow on the base rocks in the Belianske Tatras and in a part of the Western Tatras.



Fig. 3. Biocenoses in the alpine zone (Photo: M. Kopecká)

The subnival zone, as the only in the territory of Slovakia, reaches to the sea level altitude of 2,300 m. Its area in the High Tatras is about 9.6 km² (Izakovičová et. al, 2008) and it is located in the core zone of the National Park. It is remarkable for the reduced vegetation period and a very thin soil layer. Lichens, mosses and algae prevail in these conditions while the vascular plants are represented by *Gentiana frigida, Silene acaulis, Saxifraga bryoides, Cerastium uniflorum, Saxifraga retusa, Festuca supina, Poa laxa,* and *Oreochlora disticha*. About forty species of vascular plants also occur in altitudes over 2,600 m. a.s.l. and some of them are glacial relicts.

Endemites that occur only in certain spots are among the extremely rare species of the Tatra flora – 57 species represent the Carpathian endemites in the Tatras. Among them is, for instance, *Aconitum firmum* subsp. *firmum*. The West Carpathian endemites include paleoendemites from the Tertiary Era, for instance, *Saxifraga wahlengergii, Delphinium oxysepalum* and *Dianthus nitidus*. The Tatra endemites cover 36 species of genera *Alchemilla*, *Thalictrum minus subsp. carpaticum* and *Cochlearia tatrae*. The endemite of the High Tatras is *Ranunculus altitatrensis* and the one of the Belianske Tatras is *Hieracium slovacum*.

In terms of age structure, the young growths at the age below 40 years and three- or multilayer older growths resist best the winds. The planted spruce monoculture at the age of 40-60 years is prone to snow calamities and 60-100 years old stands are susceptible to wind calamities. Ecologically very stable growths at the age of 140-220 year also occur in the subalpine zone. However, the 80-100 years old growths with low resistance due to single layer prevail in the High Tatras and in the Belianske Tatras. In extremes of the valleys of the montane zone of the Western Tatras there are 100-120 year old ecologically stable growths (Izakovičová et al., 2008). The best resistance is observed in a three-layer forest growth,

which however, is rare in the Tatras. The whirlwind that struck the mountain range in November 2004 damaged prevailingly single-layer spruce or combined larch/spruce growths.

The varied building of zoocenoses of vertebrates and invertebrates depends on varied types of biotopes in individual zones, while there are several endemites and relic species in the Tatras. The montane zone is the richest in terms of wild life. Thanks to high diversity of biotopes (shrubby vegetation, monocultured woods, mixed woods, thin underwood with grasslands) plenty of animal species live in forests. *Capreolus capreolus* and *Sus scrofa* find food not only in the forest but also in the contiguous farm cultures. Typical field species like *Lepus europaeus* and *Perdix perdix* also live there. *Cervus elaphus* is comparatively common. *Ursus arctos, Lynx lynx, Felis sylvestris, Martes martes and Meles meles* represent carnivorous animals in the forest zone. *Tetrao urogallus, Tetrastes bonasia, Accipiter gentilis, Falco subbuteo*, and *Aquila pomarina* are the bird species that stand out in the fauna of the Tatras. *Lutra Lutra*, an eminent indicator of the water environment quality, is rare and threatened. *Salamandra salamandra, Triturus alpestris* and *Triturus montadoni* are the amphibians worth mentioning. The dwarf pine zone is in fact an intermediate phase between the montane and alpine zones. Chamoix descend to this zone in winter in search for food, while several predators from the forest zone ascend here in summer. Because of harsh living conditions only a limited number of animals lives in the alpine zone, among them *Rupicapra rupicapra tatrica, Marmota marmota latirostris*, *Pitymys tatricus, Chionomys nivalis, Tichodroma muraria, Anthus spinoletta, Aquila chrysaetos*, and *Oenanthe oenanthe*.

2.2 Disastrous whirlwind of November 2004

19. November 2004 between 15:00 and 20:00 hours, the territory of Slovakia was swept by the whirlwind with almost 200 km/hour gusts. It caused the greatest damage in the territory of the Tatra National Park where in a short time more than 12,000 hectares of forest growths were wrecked (Crofts et al., 2005). It is an area greater than the one annually forested in the total territory of Slovakia. The wind uprooted a continuous belt of forest from Podbanské to Tatranská Kotlina at the altitude from 700 to 1,250-1,350 m a.s.l (Fig. 4). The border between the damaged and undamaged forest was almost straight line following the contour line at the altitude of 1,150 m a.s.l., in the eastern and 1,350 m a.s.l. in the western parts of the territory. In the absolute majority of cases the trees were uprooted, broken trees were rare. Orientation of uprooted trees seen on the aerial photographs and in the terrain confirmed that the damage was caused by the north-eastern to northern winds (Jankovič, 2007).

Representation of individual wood species damaged by the calamity was roughly the same as the wood species composition of growths before the event. The share of spruce trees, of course, dominated with 76%, those of pine, larch, and fir amounted to 8%, 7%, and 15 % respectively while the share of damaged broadleaved wood species was 7.5 %. Estimating by the age, the 60-120 year old specimens with almost 60% share in the total calamity damage were the ones most affected (Fig. 5).

Repeated forest fires that are extremely harmful for biodiversity followed several years after the calamity whirlwind. Fire – either caused by humans or natural – impairs and damages all components of forest ecosystems disrupting the production and other functions of the forest. The biggest fire in the history of the Tatras broke out in a year after the calamity whirlwind (2005) in the calamity area. It damaged 230 hectares of forest biotopes along with about 15,000 cubic metres of unprocessed timber and about 14 hectares of live forest (Fig.6).

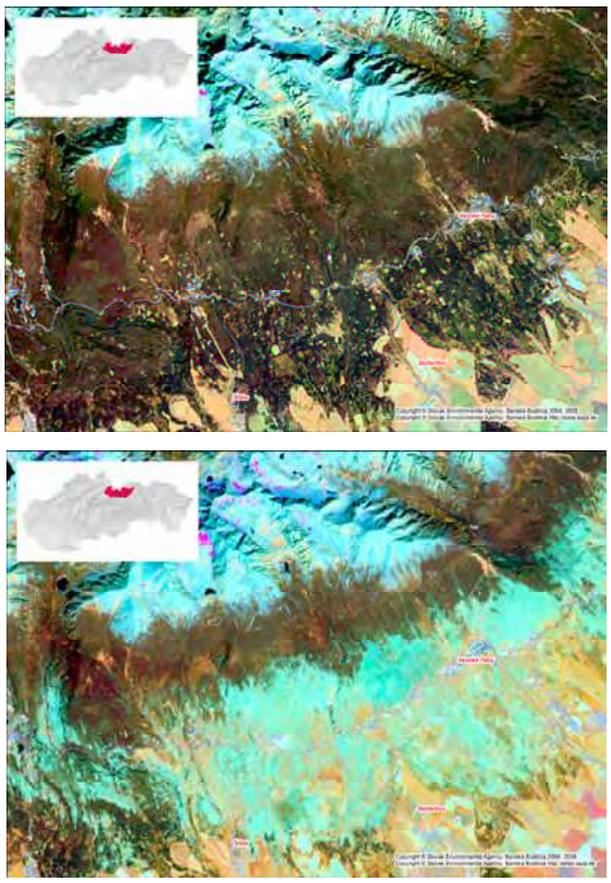


Fig. 4. Diminution of forest near the town of Vysoké Tatry a/ in 2000 b/in 2006



Fig. 5. Thousands of hectares of forest were damaged by the 2004 whirlwind (Photo: P. Barabáš)



Fig. 6. Fire of 2005 damaged 230 ha of forest biotopes (Photo: P. Barabáš)

It also damaged the natural undergrowth and artificially restored growth on an area amounting to about 13 hectares. It was additional factor that contributed to the significant fragmentation of forest in the Tatra National Park.

3. Changes in forest fragmentation

3.1 Methodology

An important aspect of fragmentation is the scope and structure of fragments (shape, size, spatial arrangement and the like). These spatial parameters can be assessed using several quantitative methods (D'Eon et al., 2002; Keitt et al., 1997; Kopecká & Nováček, 2008; McGarigal& Marks, 1995; Riitters, 2005; Ritters et al., 2002). In the study of Kummerle et al. (2006), authors used satellite data and compiled land cover maps followed by computation of fragmentation indexes in the boundary regions of Poland, Slovakia and Ukraine. However, actual and reliable information about the land cover and its changes are important input data for any forest fragmentation assessment.

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 generation of the database in 1:100,000 scale using the 25 ha minimal mapping unit (Feranec & Oťaheľ 2001). The need of updated databases became the impulse for 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. An example of cartographic expression of qualitative changes in forest fragmentation in the selected study area on the regional level related to the years 2000 and 2006 that are based on CLC data assessment is offered here. 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.

CLC 2000 and CLC 2006 data layers were used as the input data in the process of forest fragmentation assessment. With the aim to assess the degree of forest fragmentation in the selected model territory, the methodology presented by Vogt et al. (2007) was applied. In the process of morphological image analysis we used the Landscape Fragmentation tool (LFT) developed by Parent and Hurd (2008). LFT is able to perform the fragmentation analysis to

clasify a land cover type of interest into four main fragmentation components. Although originally intended for forest fragmentation analysis, the LFT is also aplicable to any land cover type of interest.

CLC data layers are accessible in vector format. For the identification of forest fragmentation, conversion of LFT into the 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 25 m cell size was used for the conversion of the vector format to raster – grid. Cell size was opted taking into account the 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.

As the LFA tool requires a 3 class land cover map as an 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.7). 'Core forest' is relatively far from the forest/non-forest boundary and 'patch forest' comprises coherent forest regions that are too small to contain core forest. 'Perforated forest' defines the boundaries between the core forest and relatively small perforations, and 'edge forest' includes the interior boundaries with relatively large perforations as well as the exterior boundaries of the core forest regions.

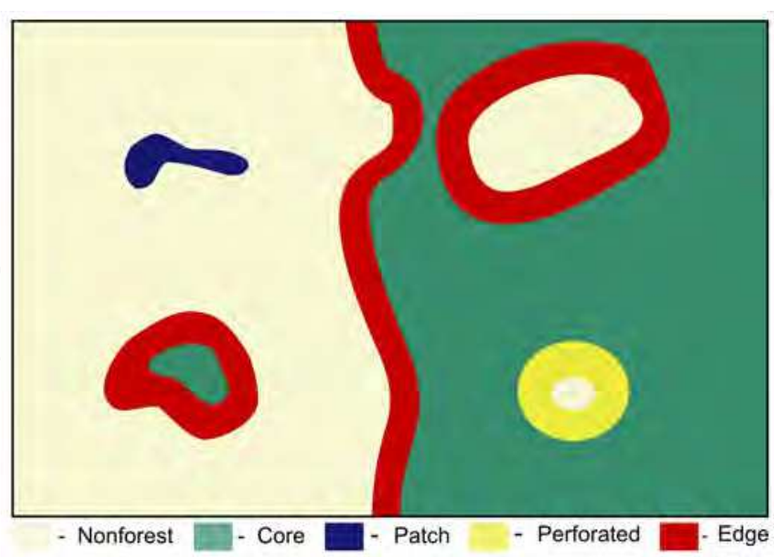


Fig. 7. Illustration of four types of spatial pattern on an artificial map (Vogt et al., 2007)

The forest area classification is based on a specified edge width (Parent & Hurd 2008). The edge width indicates the distance over which other land covers (i.e. urban) can degrade 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 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 2000 changed into Patch, Perforated or Edge in 2006)
- Type 2: Continuous forest changed into non-forest (Core in forest fragmentation map from 2000 changed into Fragmenting land cover in 2006)
- Type 3: Discontinuous forest changed into non-forest (Patch, Perforated and Edge in 2000 changed into Fragmenting land cover in 2006)

According to experts, the fraze *habitat fragmentation* should be only used in connection with particular plant and animal species regarding the definition of the *habitat*. Franklin et al. (2002) stress that although the notion of *habitat* in connection with a particular species often represents a particular vegetation type, for instance forest interior which can satisfy all ecological demands of the particular species, in many cases it is a combination of several vegetation types (for instance a meadow and a forest while forest provides the living space and the meadow satisfies the reproductive needs of the species). Regarding the above-said, it should be emphasized that CLC databases make it possible to assess fragmentation of selected land cover classes (for instance forest fragmentation) not fragmentation of stands or biotopes of particular species. Another problem in assessment of biotope fragmentation is the fact that the division of the selected area affects species in a different way. Franklin et. al. (2002) use the example of narrow road that can cause fragmentation of the biotope of amphibians but would not alter that of birds of pray. For this reason, the cited authors consider indispensable to define the hierarchic level where the fragmentation is assessed. Fragmentation on the supranational level affects spatial distribution of individual populations, fragmentation on the regional level influences dynamics of population and that on the local level modifies living conditions and reproduction of particular individuals. CLC databases regarding the minimum size of the mapped area (25 ha) makes it possible to assess fragmentation on the regional level.

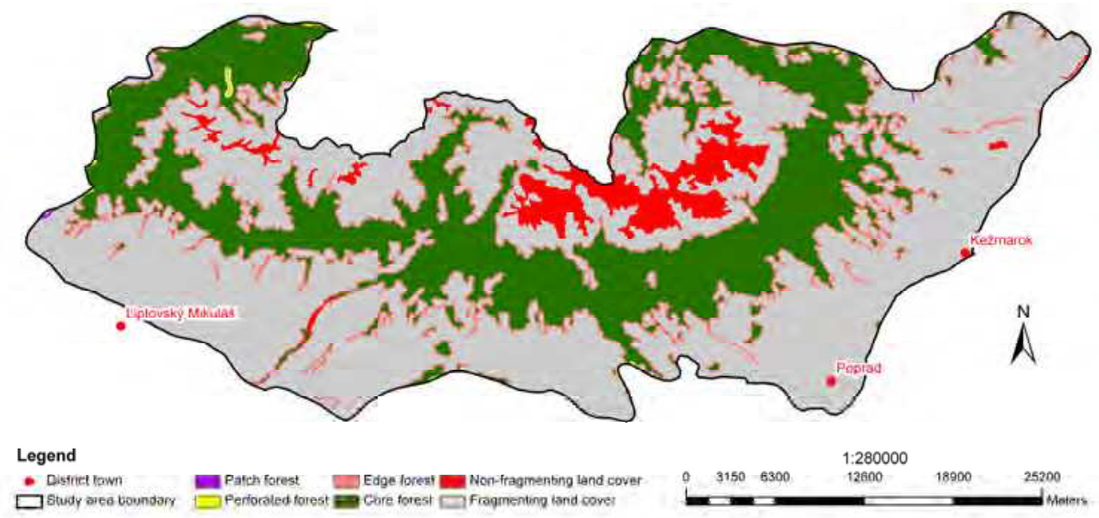
3.2 Results

Between 1990 and 2000, land cover in the Tatra National Park was relatively stable (Kopecká & Nováček, 2008, 2010). Recorded landscape changes were particularly connected with changes of abandoned agricultural land (pastures, arable land) into woodland scrub and with changes of transitional woodland scrub into forest by natural development. In the period 2000-2006, a remarkable decrease of forestland 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 the natural development of forest (Feranec & 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) indicate that urban sprawl associated with permanent forest fragmentation can be expected in future.

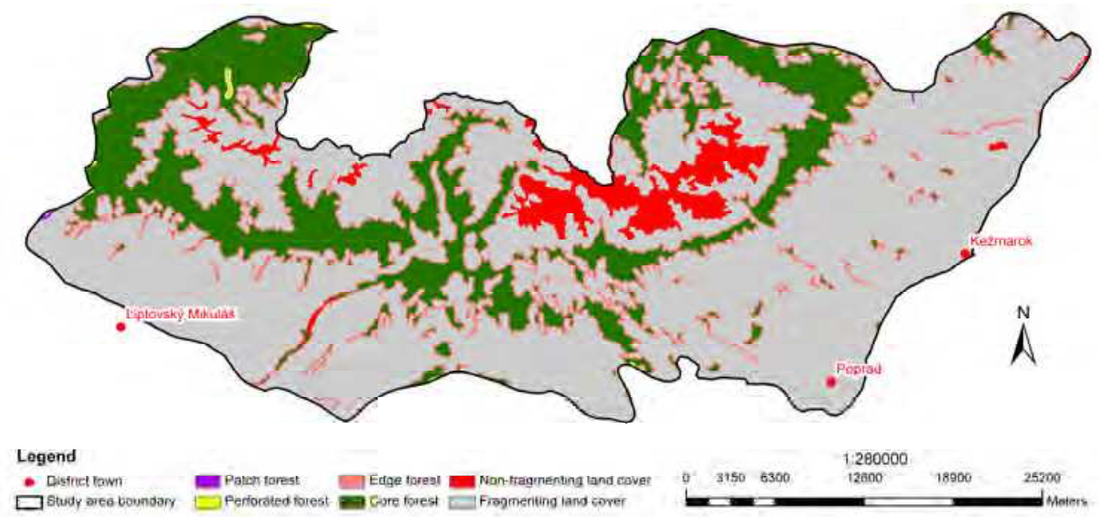
CLC class*	2000		2006		Change 2000 - 2006	
	Number of polygons	Total class area (km²)	Number of polygons	Total class area (km²)	Number of polygons	Total class area (km²)
112 Discontinuous urban fabric	58	37,99	58	38,44	0	0,45
121 Industrial or commercial units	9	6,01	10	6,26	1	0,25
124 Airports	1	1,53	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	40,7	40	40,7	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 & Oťaheľ (2001).

Table 1. CORINE land cover classes on the study area



(a)



(b)

Fig. 8. Forest fragmentation in Tatra region in a/ 2000, b/2006 (Kopecká & Nováček, 2010)

Fig. 8 and Table 2 demonstrate the decrease of the compact forest areas (Forest core) in 2000 and 2006. On the other side, an increased percentage of disrupted forest areas was observed. Pursuing the applied methodology, these areas were classified as Perforated Forest, Forest Patches and Forest Edge fragmentation components.

	2000		2006		Change 1990-2006	
Fragmentation component	km²	%	km²	%	km²	%
Patch forest	0,964	0,07	0,632	0,05	-0,332	-0,02
Perforated forest	1,646	0,12	1,689	0,12	0,043	0
Edge forest	129,891	9,56	116,652	8,58	-13,239	-0,98
Core forest	357,930	26,32	275,952	20,29	-81,978	-6,03
Non fragmenting land cover	63,695	4,68	62,931	4,63	-0,764	-0,05
Fragmenting land cover	805,635	59,25	901,905	66,33	96,27	7,08
Total	1359,761	100,00	1359,761	100,00	0	0

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

The assessment of different types of forest fragmentation (Fig. 9) showed, that the change of continuous forest into the non-forest area was dominant (61%). Discontinuous Forest changed into non-forest area amounted to 22% of the changed territory and the percentage of continuous forest changed into discontinuous forest was 17%.

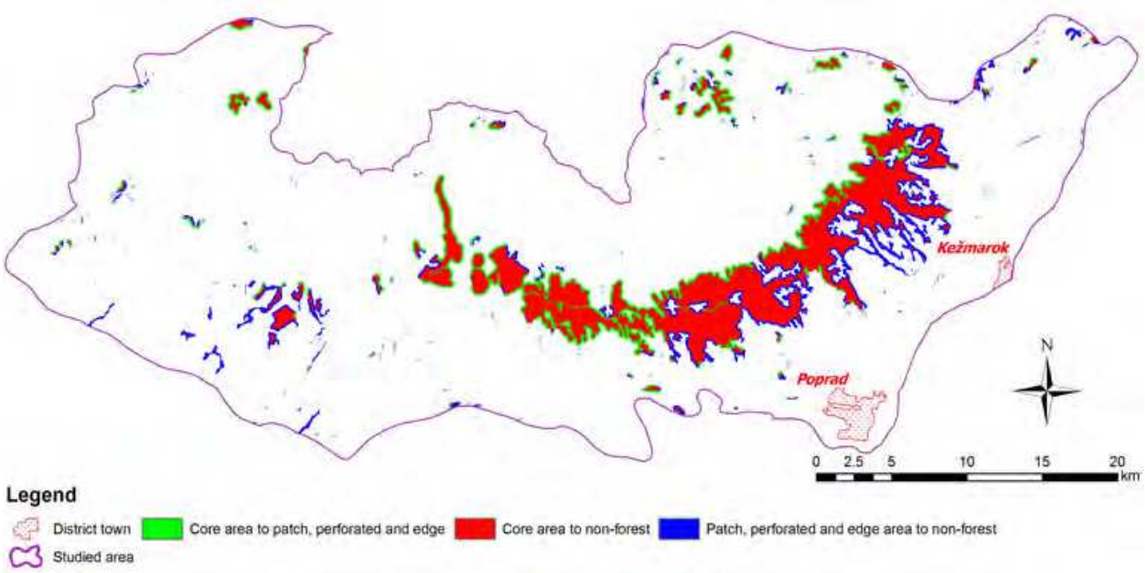


Fig. 9. Map of changes in forest fragmentation in 2000–2006 (Kopecká & Nováček, 2010)

The negative effects on forest biotopes increased when the fallen and broken trees were removed by heavy machinery in order to prevent the large-scale bark-beetle damage. Despite of this, bark beetles destroyed more than 1,700,000 trees before the year 2010 (Fig. 10). This forest habitat changes were not included in the fragmentation analysis based on CLC 2006.



Fig. 10. Bark beetle calamity followed after the windfall (Photo: P. Barabáš)

3.3 Consequences of the forest fragmentation

Ecological succession in an ecosystem represents an organized sequence of association's development including the changes of species composition and processes in time. Succession is considered a dynamic process where the new populations of the same or different species replace the dominant population of one or more species in a particular place. Changes of ecology caused by the sudden damage and subversion of more than 12,000 ha of forest are studied by the international interdisciplinary research often referred to as the "post-calamity" one which concentrates on microclimatic situation, water cycle, bioproduction, succession, species composition, regeneration and restoration processes, biochemical cycles, soil properties, erosion and contamination of the forest ecosystem. The principal aim is to asses the effects of different ways of management applied to damaged growths on the status and development of the model forest association (*Lariceto-Picetum* one), that was most heavily affected and is considered the autochthonous part of the unique anemo-orographic system. Approximately 100 ha areas were delimited with the most

similar conditions possible so that they were comparable in terms of properties and features of the forest ecosystem (Fleischer & Matejka, 2009).

Tabular synthesis confirmed 10 types of phytocenoses, mostly secondary, identifiable in the calamity area by mere visual observation (Fig. 11). They are: 1. *Calamagrostis villosa,* 2. *Chamerion angustifolium,* 3. *Calluna vulgaris,* 4. *Vaccinium myrtillus,* 5. *Avenella flexuosa,* 6. *Picea abies*, 7. *Sphagnum magellanicum,* 8. *Carex rostrata,* 9. *Juncus effusus,* and *10. Veronica officinalis* (Olšavská et al., 2009). Humid substrates are colonized by phytocenoses with the dominating species of *Sphagnum magellanicum* and *Carex rostrata.* The second type of phytocenose is that of associations with increased share of types requiring the higher N level: *Chamaerion angustifolium* and *Veronica officinalis.* Associations with the dominant *Calamagrostis villosa*, are the one most frequent and they form a distinct mosaic along with overgrowths of *Chamaerion angustifolium,* in burnt down places. In future it is expected that *Chamaerion angustifolium*, will be pushed out by *Calamagrostis villosa.* Associations of *Lariceto-Picetum* especially *Vaccinium myrtillus, Avenella flexuosa, Picea abies* and the type of *Calluna vulgaris,* bound to the most acid soil represent the climax stage of forest.



Fig. 11. Natural revitalization of the damaged area (Photo: M. Kopecká)

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 encroach or even traverse the whole patch. For example, Repel (2008) analysed the breeding bird assemblage structure; nesting, foraging and migrating guilds; bird and habitat

relationship and the seasonal 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 not disturbed 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. Kocian et al. (2005) presume that the activity of birds plays an especially significant role in foresting and restoration of forest in the Tatras, as some species (jay, nuthatch nutcracker) propagate natural wood species, such as beech, Swiss pine and hazel.

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 the possible revitalization activities and to mitigate negative effects of the calamity windstorm in the Tatra region.

4. Conclusion

Natural forest fragmentation is not a new phenomenon in the Tatras. Windthrows have repeatedly happened in this region in the past (Zielonka et al., 2009) although in a much smaller scale. Urbanization connected with the human-induced deforestation also played an important role in the past because of tourism. The main difference between the old practices and the current deforestation is the difference in scale and rate of increase. In the past, small patches of pastures or damaged forest appeared in the large forested landscape and they quickly grew back upon abandonment. What happened during the bora windstorm in 2004 in the Tatra National Park was precisely the opposite: remnant forest patches were left in the "sea" of the degraded forest landscape.

Anthropogenic disruption of the natural development of the Tatra forest in the past caused that the status of the forest before the calamity did not correspond to the natural development at all. Wood species composition and structure on the greater part of the affected area were not proper for the place. The majority of growths were mature and resembled an economic forest prepared for harvesting. The growths consisted of slender and tall trees with high-situated crowns, which are unstable and highly susceptible to the wind and snow threats. Reasonable and consistent management should insist on growths of different species and age on small areas, which will ensure ecological stability and functionality of forest in an acceptable time horizon and simultaneously provide optimal biotopes for all naturally occurring species. Revitalization of forest affected by the

windstorm is a very complicated process in terms of expertise, organization and economy. The aim of the present monitoring is to observe the process, to identify and assess the results in individual stages. Successful revitalization calls for a new forest-economic concept that is mosaic growths aided by natural processes and natural succession.

Habitat fragmentation not only reduces the area of available habitat but also can also 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 a larger forest. Understanding of the possible consequences of forest fragmentation remains of great concern to conservationists, 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 also requires understanding of limitations and correct interpretation of results.

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Every ecosystem is a complex organization of carefully mixed life forms; a dynamic and particularly sensible system. Consequently, their progressive decline may accelerate climate change and vice versa, influencing flora and fauna composition and distribution, resulting in the loss of biodiversity. Climate changes effects are the principal topics of this volume. Written by internationally renowned contributors, Biodiversity loss in a changing planet offers attractive study cases focused on biodiversity evaluations and provisions in several different ecosystems, analysing the current life condition of many life forms, and covering very different biogeographic zones of the planet.

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