Multi-temporal analysis of forestation changes in Tatra National Park using SPOT images

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1. Abstract

The goal of this work is the identification of afforestation changes in the Tatra National Park and multi-temporal analysis based on satellite images SPOT 5 and SPOT 6 in period 2002-2012. The whole idea of this study refers to the earlier research made in 1992 (1), which results cover the period 1934-1992 and consists in connection of both experiments.

To identify land cover types occurring in the area of interest the photointerpretation key was developed based on SPOT images. Subsequently, a spatial database in GIS technology was created and eventually 11 classes of land cover using photointerpretation were distinguished. Analysis of changes included a comparison of separated classes of land cover, including afforestation evident in image from different years. Furthermore the trend of its changes was studied as well. The analysis of changes in afforestation was made using digital elevation model with respect to the absolute height, aspect and slope of the terrain. With regard to the results of earlier studies, executed evaluation is gaining wider context. In the years 1934-1992 there was a significant deforestation of the Tatra National Park. However, the changes that have been occurring over the last 10 years are beneficial and forested areas slightly increased comparing to 1992. Thereby the positive process of forest succession was proved.

2. INTRODUCTION

Poland is one of the European leaders in terms of percentage of forest area in relation to other forms of coverage within the administrative borders of the country. The forest covers are still growing and has increased from 21% in 1945 to 29.2% today. From 1995 to 2011 the forest area rose by 388k ha. Currently, the area overgrown with 9,1 mln ha (4). The basis of the work of afforestation is the "National Programme for increasing forest cover", assuming an increase forest cover to 30% in 2020 and to 33% in 2050. Monitoring the condition of tree stand can be carried out and evaluated with the help of remote sensing data and advanced GIS tools. Studies of forest cover in Poland using remote sensing methods are very rich and have a long tradition, and the very first studies was even performed on analog aerial photographs (6).

This paper concerns the determination of the spatial distribution of land cover changes occurring in the area of the Tatra National Park (TPN) and it is a continuation of forest cover change research undertaken in the early 90's (1).

Tatra National Park was created in 1954 in the Tatra mountains, which are the only area in Poland with a typically high mountain character (5). The sole and primary purpose of the operation of the Park is a protection of Tatra's nature. Park complies with a variety of social functions, which are subject to restrictions as defined in the legislation in force in the TPN territory. The most important include: scientific research, tourism, sport, recreation, protection of cultural heritage, artistic inspiration and natural education. All of these features are implemented with full respect for the principle of the primacy of nature conservation. Strict protection and thus the protection of the processes occurring in the natural environment, is covered almost 11,5k ha, including an entire floor of halls and crags, mountain pine floor and partly also of the upper and lower subalpine forests. The aim of

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this study was to analyse changes in forest cover in the period of 2002-2012, and references to earlier studies performed for years 1934-1992 (1). Overall, this study presents the results of changes in afforestation for the 78 years.

METHODS

Research method determining changes in forest cover in the first place implies the development of a spatial database of land cover for the TPN area using satellite images: SPOT 5 (2002) and SPOT 6 (17.10.2012). Image processing included the verification process of geometrical correction SPOT 5 (RMSE=0,96 m), SPOT 6 (RMSE=0,74 m), contrast modification and colour composition.

Both images have been processed in order to expose the classes of land cover, and then subjected to photointerpretation accordance with a key developed following Corine Land Cover scheme. Due to the specific nature of the area, i.e. the occurrence of floors vegetation, the classes adopted in the Corine Land Cover were modified. Two classes of forests: coniferous and deciduous forests were combined into single one and two classes of asphalt and no-asphalt roads were also aggregated. Finally, land cover types were divided into 11 classes: turn, halls, dwarf mountain pine, forests, water, meadows and pastures, bare soil, windbreaks, built-up areas, farmlands and roads. As a result of this process the geodatabase consistent with the assumptions of the model and metadata was established. Following INSPIRE: each class object has a defined name, code, list of attributes, the coordinate system EPSG:2180-ETRS89 / PolandCS92. The geodatabase has collected vector data of land cover from 2002 and 2012, processed satellite images SPOT6 and SPOT5 and also digital terrain model (DTM) with the vertical accuracy of 5m (obtained from a topographic map 1:50000). DTM was used to analyse changes in afforestation with respect to height of the terrain, aspect and slope of the terrain.

RESULTS AND DISCCUSION

Comparing the only images of SPOT5 and SPOT6 with each other, it is obvious that the differences that have occurred over the last 10 years are significant (fig. 1).

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year 2002 year 2012

Figure 1: Example of deforestation - on the top and an example of reforestation on the bottom

As a result of the intersection of land cover layers in 2002 and 2012, areas where deforestation or afforestation occurred, were selected and subjected to analysis. In the file 'deforestation' were created 534 objects with a total area of 467 hectares. Reforestation took place for 404 polygons with a total area of 594 hectares (fig. 2).

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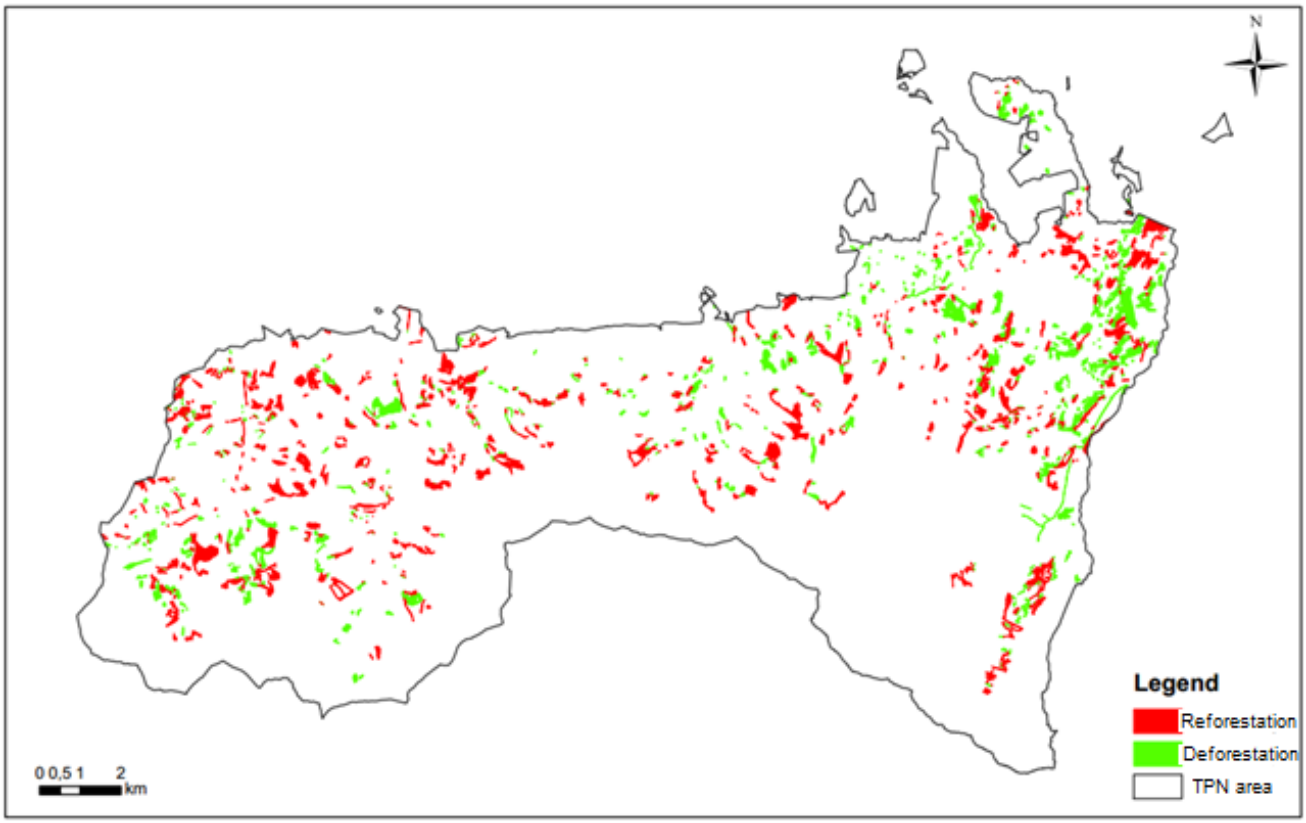

Figure 2. Spatial distribution of deforestation and reforestation polygons.

The largest reforestation took place on meadows and pastures (352 ha), which represents 59,2% of the total area of reforestation. A large reforestation also occurred on the first floor of halls and dwarf mountain pine (about 70 ha). The deforestation have been transformed mainly into the classes of bare soil, meadows and pastures, and amounted to almost 400 ha (83,6% of the total deforestation).

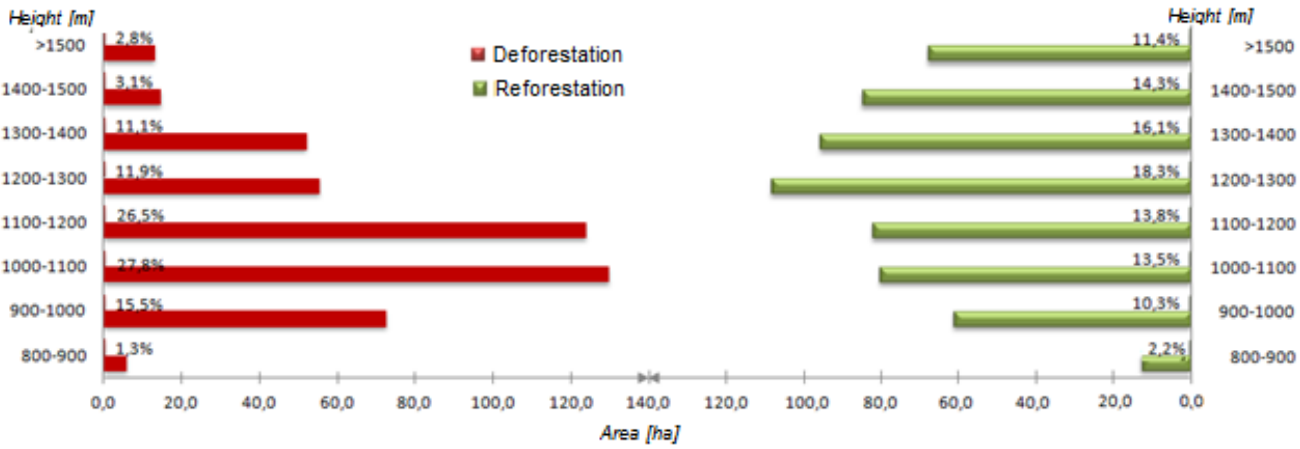

Figure 3: Changes in forest cover in the area of the TPN over the years 2002-2012, depending on the altitude

Depending on the height level

For most sites (over 50%), deforestation has been occurred at the height of 1000-1200 m ASL. The phenomenon of reforestation is spread out more evenly. It can therefore be concluded that the

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trees comes in equal measure, and the amplitude of change is less than 10% between the levels of height. With regard to research for the years 1934-1992 deforestation has a similar character in relation to height. The reforestation shows a lot more dynamic changes in the higher areas (fig. 3).

Depending on the slope

Both deforestation (45%) and reforestation (62%) had the largest areas located in areas of slope from 19° to 45°, then in the areas of slope 9°-19° (respectively 30% and 25%). In other classes, the changes in afforestation are small. Comparing the results of the previous study period 1934-1992, deforestation occurred to the greatest extent in the same classes of slope (9°-45°). This is due to the fact that in these areas the most of the forests are growing, so the changes are the greatest. In addition with increasing decline, the slopes are more vulnerable to leaching soils. Reforestation whereas in years 1934-1992 was followed most often on the decline of 4°-19°, which is a much gentler slope. This may indicate the overgrown high mountain glades and raising the upper limit of the forest.

Depending on the aspect

The spatial analysis has showed that most areas has been deforestation on the slopes of the eastern, north-eastern and south-eastern direction. The highest degree of reforested areas were on the slopes of the northern and eastern regions. However, differences in the wooded area between the directions of aspect are far less diverse than in the case of deforestation. Clearly less trees came in areas with southern aspect. Comparing the results of the previous study period 1934-1992, the nature of changes depending on aspect significantly changed. Previously clearly, both of deforestation (32%) and afforestation (40%) areas were the largest in the north. These changes are strongly dominated by the changes in the other directions. Currently, most deforestation takes place towards the east (29%). The phenomenon of reforestation changes are much more homogeneous. The only thing that connects the changes over the years 1934-2012, the presence of minimal changes in a southerly direction (from 1% to 6%).

About deforestation can state clearly that the smallest took place on the slope of the exposure south and south east regardless of the height and at altitudes in the range of 800m-900m and 1400m-1600m above sea level in all directions of the world. The greatest value of deforestation reached at the height of 1000 m-1100 m above sea level in East direction. Deforestation is the biggest problem at altitudes from 900 m to 1200 m above sea level at east and north-east direction. These areas are, as many as 37% of all the changes that have taken place in the area of TPN. On the east side, the deforestation are much larger than the west side. Compared with deforestation, reforestation has a much more uniform process. Besides the flat areas, on which the changes are close to 0 ha, in all other height intervals, the changes range from a few to a maximum of 20 ha. The largest reforestation took place at an altitude of 1200-1300 m above sea level and reached up more than 100 ha. A large continuous forested area occurred in areas with eastern face, especially at altitudes from 900 m to 1400 m (13,1%). At altitudes 1200-1400 m ASL it happened up to 34,3% of all changes. The smallest reforestation took place in areas with southern and south-west direction, and at the lowest altitude from 800 m to 900 m.

3. CONCLUSIONS

Comparing together the results of analysis conducted on data from the years 1934-1992, and data from the years 2002-2012 was observed a significant difference. One of them is a change of trend of forest cover in the TPN with a substantial loss of forest (738 ha) to modestly increase (127 ha). During the years 2002-2012 the phenomenon of reforestation was much bigger and reached 594 ha, but at the same time there has been loss of forests on 467 ha (tab. 1). The amount of land with the largest reforestation has increased. Previously, most such changes occurred at altitudes 1000-1200 m above sea level. Currently, forest cover comes at an altitude of 1200-1400 m ASL.

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This is due to the rise in the upper limit of the forest by stopping the mountain pasture and vegetation regeneration (2, 3).

Tab. 1. Results of deforestation and reforestation in periods 1934-1992 and 2002-2012

	deforestation				reforestation			
altitude	**1934-1992**		**2002-2012**		**1934-1992**		**2002-2012**	
[m]	**ha**	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
800-900	27	3	6	1	1	1	13	2
900-1000	124	13	73	16	36	15	61	10
1000-1100	143	15	130	28	51	22	80	14
1100-1200	162	17	124	27	62	26	82	14
1200-1300	155	16	55	12	42	18	108	18
1300-1400	148	15	52	11	31	13	96	16
1400-1500	103	11	15	3	11	5	85	14
>1500	114	12	13	3	3	1	68	11
total	**975**	100	**467**	100	**237**	100	**594**	100

For the main causes of negative impact in the woods still are blamed the movements of the masses, frosts and snow loads, pests, CO_2 emissions, as well as the strong windstorms. Windstorm is a cyclical phenomenon, typical of the Tatra Mountains. The recorded most strong windstorms with a top speed almost 300 km/h occurred in the Tatra Mountains in 1968. At that time 150 ths. m^3 of trees was fallen. More recently, in December 2013 for this area of interest there was windstorm, which caused massive destruction within the forests. Approximately 165 ha in the vicinity of Zakopane were damaged by the wind (http://emergency.copernicus.eu/mapping/list-of-components/EMSR064). According to Tatra National Park authority 153 ths m^3 of trees were felled. The last recorded strong mountain blew in 2002, the loss was estimated at 50 thousand m^3. This is proof that, regardless of the policy and conducted long-term programs aimed at supporting afforestation and conservation, within a few hours the forces of nature can destroy significant amount of trees. Hence the importance of the work being undertaken to renew forest stand in the TPN and its cyclical monitoring and analysis of ongoing changes such as proposed in this paper.

4. ACKNOWLEDGEMENTS

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