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Conception of a tourist information system based on GIS and remote sensing techniques – Case study of Dolina Gasienicowa in Tatra National Park

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ABSTRACT: This paper presents a conception of an Information System, the aim of which is to provide tourists with information about surrounding environment in a simple and clear way. This will increase their consciousness, which in turn will help to protect the fragile mountain environment. In the Tatra National Park, despite many years of research, there is still a lack of easy-to-get information, especially in the field. The system presented is in two parts. The first is an analysis of the landscape attractiveness, which is performed to delineate areas of the highest interest to visitors. In the second part, information boards are proposed to place in the most attractive viewpoints. To accomplish the first task and to provide up-to-date information with more objectivity, remote sensing data are used and analyzed with the help of Geographic Information Systems. The analysis is based on an assumption that the landscape attractiveness increases with its diversity. To choose the most interesting places characterized by the highest diversity and fragmentation, places that can be easily accessed by everyone, the final map was combined with a tourist route network map. In these places information of the surrounding environment should be provided. Placing information boards, made in a local, traditional style and in harmony with nature can fulfil this task. A prototype of such a board is included.

1 INTRODUCTION

Since ages high mountain areas – regions of high tourist, recreational merits – attract masses of people throughout the whole world. The high pressure put on these fragile environments causes immense distress to diverse and very often unique flora and fauna, as well as of characteristic relief forms. Many high mountain areas have been converted into national parks or nature reserves, where protection of the nature and preservation of its original character in of great concern. Reducing the number of visitors is one of the simplest means of decreasing negative influence of tourists on the environment. This is, however, not compliant with another mission of national parks, which is to make it available for everyone.

The Tatra Mountains, the only alpine site in Poland, although spatially not very extensive, provide cultural, historical and spiritual values in addition to their recreational function. Recognized as a national heritage and international Biosphere Reserve (UNESCO Programme on Man and the Biosphere), they constitute an exceptional mountain region, visited by 2.0-2.5 million tourists each year. The limited environmental and tourist capacity of the region covered by the Tatra National Park (TPN) causes restrictions in tourists' activities, especially in summer time (tourism peak). Equally, it is obvious, that not only people's presence, but above all their behaviour in a protected area decide the level of pressure put on this region (Mirek 1996). One of the most effective and recognized forms of protection of the natural environment is ecological education. Some researches indicate that landscape qualities and environmental processes presented and explained in a scientific way increase tourists' consciousness, while at the same time positively influencing environmental protection. Because of the uniqueness and charm of the Tatra Mts, they have attracted scientists for many years. The state of knowledge about this region is quite advanced. The Tatra Museum and the Museum of the Tatra National Park play an educational role. There is also a variety of tourist and nature guides, but these are used by real mountains fans rather than by ordinary tourists.

It seems that in spite of long documented environmental research of the Tatra National Park, little information is provided along the tourist routes themselves. Field tourist information, widespread in Western Europe, USA and recently also in Poland, is of great significance in the field of education, especially for people who are not properly prepared for the site exploration. The idea consists in informing, through boards and booklets directly available in the field, about basic and unique environmental characteristics as well as the natural processes that take place in the area. In the Tatra National Park there is also an “educational path”, but its spatial and informational extent is not yet sufficient.

It is obvious that most visited and most endangered are the areas of highest attractiveness, drawing the highest number of visitors, and usually for longer periods of time. Therefore one of the most important aims of ecological education is to indicate these places, and then to describe them and to explain their functionality to the tourists, which in turn will help in protecting them.

This study proposes the concept of a field Tourist Information System for Tatra National Park. Due to large extent of the whole TPN and to the methodical character of this paper, the study was carried out in a small, though very important and representative valley: Gasienicowa Valley.

In the first step areas of the highest attractiveness were delineated. It consisted of landscape diversity analysis according to an assumption, that areas of higher diversity are considered more attractive (Richling 1992). The second step consists in determining and formulating the content of information that should be available in the field and then in presenting it in a popular, effective and spectacular way. Both tasks were accomplished using Geographic Information System together with the basic data: aerial and satellite images and Digital Elevation Model. This method was chosen because of its high level of objectivity and high informational value. Moreover, the whole study area is covered by available data.

The attractiveness of landscape can be conceived and understood in many ways. Anyhow, its assessment certainly remains subjective. Inability of the observer to isolate himself from environment, to examine it “from outside” deprive him of the possibility of achieving enough objectivity (Szewczyk 1994). One of the best options in this situation is to employ ranking of individual attributes and qualities of the landscape. This allows conversion of the characteristics from qualitative to quantitative. Nevertheless, there still exists some subjectivity. Another option is to automate the whole process of landscape analysis. Although the absolute level of objectivity is not achieved, it is possible to compare attractiveness of different regions analysed automatically using the same ranking scale and the same presumptions. Such an approach was used during the process of creating the presented Tourist Information System. Thanks to using remote sensing methods, Geographic Information Systems and various landscape indices, it was possible to classify the study area taking into account the diversity of its relief and land cover, including also anthropogenic elements that positively or negatively influence landscape perception. Based on the assumption that landscape attractiveness increases with its diversity, areas of highest tourist interest were delineated. In order to familiarize visitors with nature in these places, the scheme of information boards has been designed. These boards, placed in the most attractive points, will help tourists to gain knowledge about all the main processes that take place in the described environment.

2 STUDY AREA

To test the method presented in this study, the analyses were conducted in a small part of the Tatra National Park, covering Gasienicowa Valley and adjoining parts of Sucha Woda Valley, Olczyska Valley and Jaworzynka Valley (fig. 1). The easy accessibility of this region (nearby town of Zakopane, ski lift), well developed tourist infrastructure and high natural values of the whole region causes relatively high attendance of people. Anthropogenic pressure measured both qualitatively and quantitatively is one of the greatest in the Tatra National Park (Mirek 1996). It is expected therefore that the selection of this area will allow practical application of the results of this study.

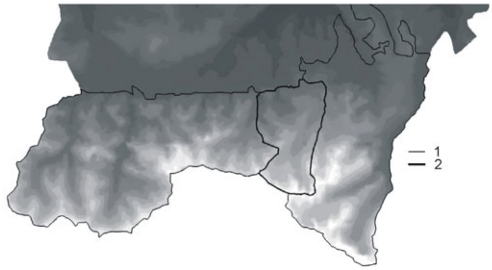

Figure 1. Location of the study site on the background of Digital Elevation Model of Tatra: 1 – boundaries of Tatra National Park; 2 – study area

The study area is located about 8 km to the south of Zakopane and covers an area of 2700 ha. Here can be found a variety of vegetation and animal species. Within its border all montane belts: starting from lower montane belt (up to 1250 m a.s.l.) through upper montane belt (1250-1550 m a.s.l.), subalpine belt (1550-1800 m a.s.l.), alpine belt (1800-2250 m a.s.l.), until subnival belt (above 2250 m a.s.l.). The postglacial character of Tatra Mts relief can be seen in the richness of alpine relief forms. At the same time one can observe many karst forms. Also the presence of many montane lakes composing the most numerous concentration in the whole TPN, is absolutely riveting. It is not surprising then that Gasienicowa Valley, being representative for

Tatra Mountains, has also the biggest complex of tourist routes. Moreover, a mountain shelter situated in this area means that it is the perfect starting point for short excursion to the nearest peaks and ridges.

3 DATA

The implementation of Geographic Information Systems allowed integration of different data as an input. The following data were used: Landsat 5 Thematic Mapper image, colour aerial images at a scale of 1:30 000 and Digital Elevation Model with 10 m XY resolution. Additionally topographic maps at a scale of 1:10000 and 1:50000 were employed.

A of Landsat 5 TM satellite image (scene 187/26) was acquired on 6th August 1992, at 8:49 GMT (fig. 2).

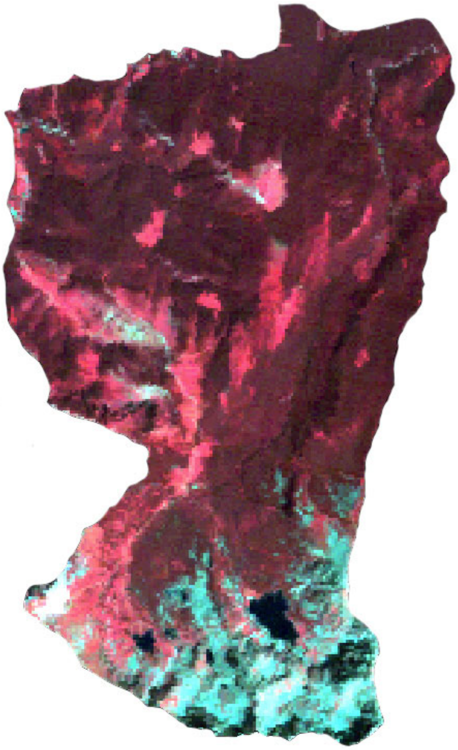

Figure 2. Study site on satellite image of Landsat 5 TM. Pseudocolor composite; bands: 4 (IR), 3 (R), 2 (G)

It was orthorectified with DEM into Polish local "1992" coordinate system. Six bands were used in all analyses, the thermal band was omitted due to its little use in the present research. Land cover and vegetation are the elements that can be directly seen on these data. However, remotely sensed data reflects all environment elements; it constitutes a "true terrain model". The gray scale tone, structure and texture of the image are results of all environmental geocomponents (Ciolkosz, Miszalski, Oledzki 1986; Oledzki 2001). Thematic Mapper satellite images provide information of both visible and infrared part of the electromagnetic spectrum. This enables identification not only of vegetation, but also soil types and moisture. The spectral and spatial variety of satellite image provide therefore complex information of environment. In this study a Landsat image was used for entropy calculation, which can be used as an index of landscape diversity.

Colour aerial photographs were acquired in September 1999, within the frame of PHARE project. Four images were used with 30% of overlay in both directions (fig. 3).

Figure 3. Study site on colour aerial image

After converting into digital form they were orthorectified, then an orthophotomap was created in the same coordinate system as the satellite image. Subsequently, visual interpretation was performed resulting in a land cover map. This map was used in the analysis of landscape diversity with the use of land cover types ranking and also employing modified index of landscape fragmentation.

A Digital Elevation Model was used for relief diversity analysis (fig. 4). Two morphometric characteristics were taken into account: slopes and altitude difference. DEM was also used in the process of orthorectification of other data.

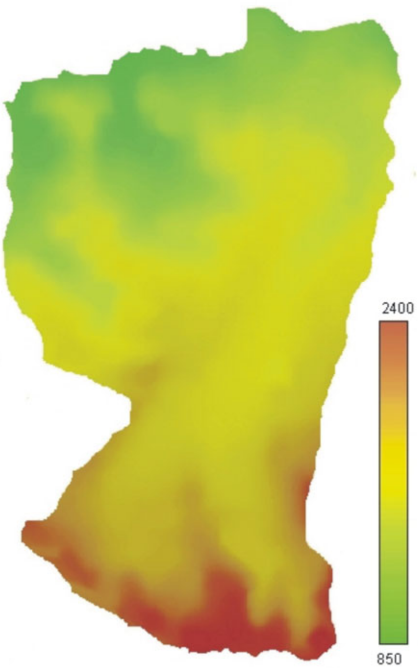

Figure 4. Digital Elevation Model of study area [m a.s.l.]

Topographic maps at a scale of 1:10000 were used as auxiliary data for retrieving elements that cannot be directly identified using remotely sensed data. Point and line features that may positively or negatively influence human perception were delineated. The maps were also used in the aerial images orthorectification, while maps at scale 1:50000 were used during satellite image correction.

4 METHODS

The process of landscape attractiveness analysis was divided into 4 steps (fig. 5), each dealing with different elements of environment: relief, landscape as an average of all its components, land cover and finally topographic features. These steps were realized using the following data, respectively: Digital Elevation Model, satellite image, aerial photographs and topographic maps. The results of each analysis were brought to the same scale of values by employing a unified method of ranking. Subsequently, all resulting maps were joined and formed a final map representing total landscape diversity expressing its attractiveness. It was assumed that landscape attractiveness increases with variety and fragmentation of its analysed components. To assess the input of individual components into the "landscape attractiveness" a scale of values between 0 and 3 were used, where 0 means neutral or no influence, 1 – low, 2 – medium and 3 – high. From this scheme was excluded the assessment of point and line features. These elements, that positively or negatively influence perception of the landscape, were assigned +1 and –1 points, respectively.

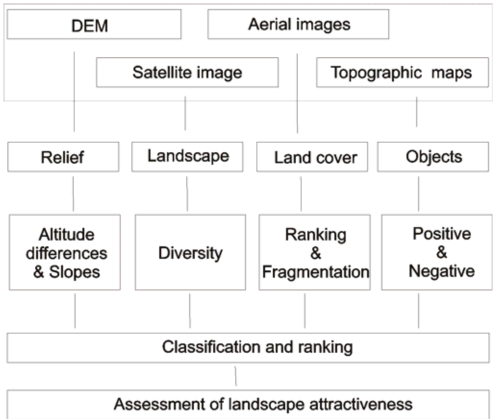

Figure 5. Flow chart of methodology used in landscape attractiveness analysis

4.1 *Relief analysis*

In high mountain environments terrain relief is one of the most important elements influencing landscape perception. High summits neighbouring with deep valleys as well as unique for alpine environment relief form incidence, are of great importance for tourism. In this study two characteristics were analysed: altitude difference and slopes, both on the basis of the Digital Elevation Model.

Altitude differences are the main factor that influence tourists' perception: the greater difference the more attractive is the area. This index was calculated as the difference between the highest and the lowest point within moving, circular window with fixed radius of 75 meters. This size was chosen for two reasons. Firstly, it was accepted that within this distance the perception of the surrounding environment by human beings is greatest. Therefore, an area limited by 150 m perimeter affects human vision remarkably. Secondly, such a window size enabled direct comparison with analysis of Landsat scene made with 5x5 pixels window size (150x150 m in terrain).

In fact, the measure of altitude difference describes surface roughness and characterizes small terrain forms located in the direct neighbourhood of the observer, whereas it doesn't involve visibility analysis, despite the fact that in open areas and in areas of significant altitude different viewpoints are of great importance. Lack of this element in the presented model is due to complex and difficult nature of such analyses for the whole area of interest. Such analyses are mainly performed only for selected points (Young-Hoon Kim et. al. 2002). However, simplified, approximated analysis of visibility was achieved during land cover type ranking.

The result of altitude difference analysis is an image with values between 0 and 360 meters. It was classified into 4 classes. Differences below 10 meters, as the least attractive, were assigned 0 points; areas with differences between 10 and 25 meters received 1 point; with differences from 25 to 90 meters – 2 points; and areas with more then 90 meters of altitude difference were recognized as the most attractive and assigned 3 points (fig. 6). Areas of the highest altitude differences are located in the southern part of study area, while zones of the lowest values are mostly situated in the northern part.

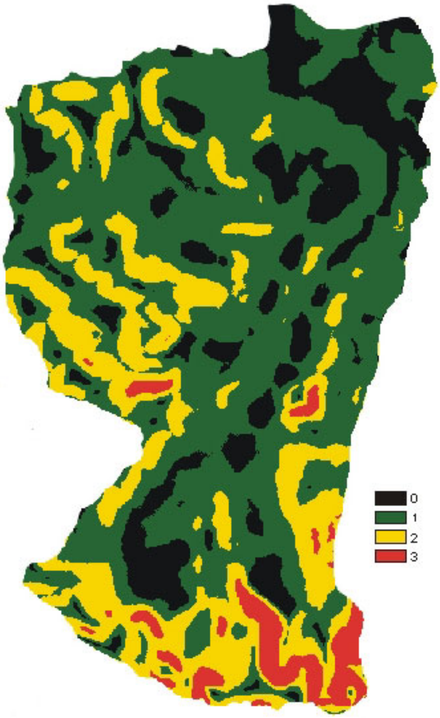

Figure 6. Map of altitudinal differences: 0 – class I (lowest); 1 – class II; 2 – class III; 3 – class IV (highest)

Slopes are very closely correlated with altitude differences. Nevertheless they were included in the analysis due to finer accuracy and higher diversity. Calculations were done based on the standard algorithm, in which a fixed moving window of 3x3 pixel size is used. Thus, the resulting map differs from the map of altitude differences, because it is less generalized and can be identified with level of route difficulty. Therefore slope values are complementary to the information about relief diversity.

The result of this part of the analyses is a map of slope with values ranging from 0 to 90 degrees. This image was also classified into 4 classes: 1st class (0 points) – values between 0° and 3°; 2nd class (1 point) – values between 3° and 10°; 3rd class (2 points) – values between 10° and 35°; 4th class (3 points) – values above 35° (fig. 7). Spatial arrangement of slope values is similar to the distribution of altitude differences, however it is characterized by higher diversity.

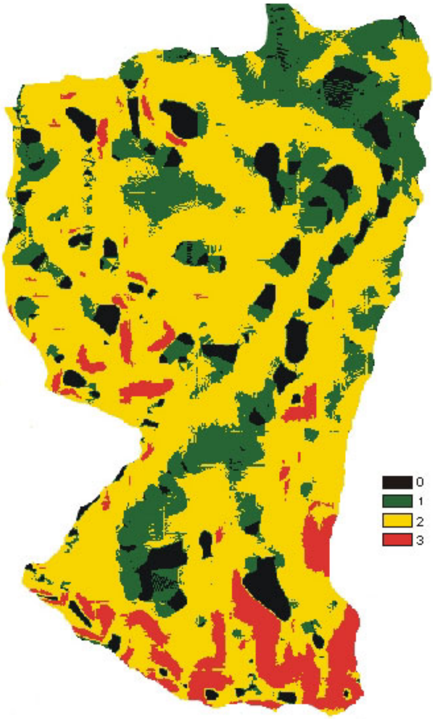

Figure 7. Map of slopes: 0 – class I (lowest); 1 – class II; 2 – class III; 3 – class IV (highest)

4.2 *Complex landscape analysis*

The satellite image was used in the assessment of complex landscape diversity. As a measure of this characteristic an entropy index was used, also known as Shannon Diversity Index (Shannon, Weaver 1949). Entropy describes the degree of disorder and equals 0 when the landscape contains only one patch (there is no diversity). Entropy increases as the number of different patch types increases or the proportional distribution of area among patch types becomes more equitable. There is no upper limit for entropy. The formula is as follows:

$$E = -\sum_{i=1}^{n} p_i \log_2 p_i$$

where:

E – entropy

p_i – likelihood of patch occurrence

n – total number of patches in the landscape

To avoid calculation of entropy for all six bands of the Landsat image, compression of data was applied. In order to include in the subsequent calculation the maximum of information and at the same time limit the number of bands, Principal Component Analysis (PCA) was performed. Six new principal component bands were created, from which two first contained 97,8% of total information from the original 6-band image. Analysis of entropy was carried out using the weighted average of two first principal components. Content of original information was used as the weighting factor. Calculations were performed in 5x5 pixels (150x150 m) moving window. Resulting entropy values ranged from 0.16 to 3.16 and were classified into 4 equal classes and, as in previous analyses, an appropriate number of points (from 0 to 3) was assigned to each class (fig. 8).

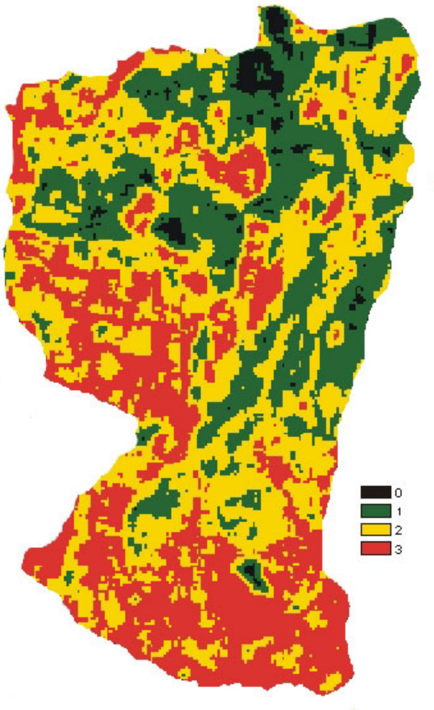

Figure 8. Entropy: 0 – class I (lowest); 1 –class II; 2 – class III; 3 – class IV (highest)

4.3 *Land cover analysis*

Land cover analysis was performed very carefully, using methods of photo-interpretation and digital processing. The preprocessing step involved orthorectification and creation of images mosaic. Based on the resulting orthophotomap visual interpretation of land cover types was carried out. Nine classes were identified: urban areas, forest, dwarf pine, clearings, meadows, alpine meadows, rocks, bare soils, water (fig. 9). Land cover types significantly influence landscape perception. In the analysis of attractiveness ranking of individual land cover types was performed using unified range of points, from 0 to 3 (fig. 10). The assessment of each class type was based on two land cover characteristics: naturalness and uniqueness in the scale of Poland. Visibility from within each class type was also taken into account.

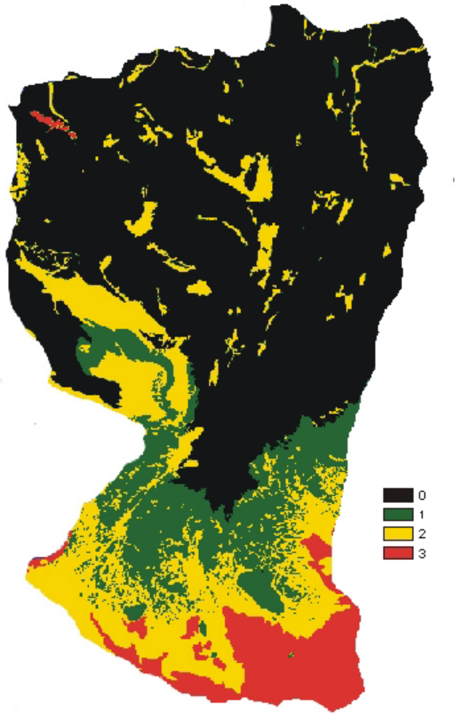

Figure 10. Map of land cover type ranking: 0 – class I (lowest); 1 –class II; 2 – class III; 3 – class IV (highest)

As the least attractive were classified areas of the strongest anthropogenic influence: urban areas and meadows (0 points). In spite of undoubted charm of forests, this class also achieved 0 points, due to the fact that this class type is present in many other mountain areas in Poland, and moreover trees considerably limit the visibility, which in alpine landscapes is of great importance.

Dwarf pine and lakes (water) obtained 1 point, while alpine meadows and clearings – 2 points, due to connection with traditional shepherding – one of cultural heritages in Tatra Mountains. As the most attractive were classified unique, alpine rocky areas (3 points).

There is no doubt that this part of attractiveness analysis is mostly subjective – it was however impossible to avoid such an approach.

The second step of land cover analysis consisted in the calculation of the modified landscape fragmentation index that takes into account both the number of different patch types and the number of individual patches, in fixed, circular, moving window of 75 m radius. The circular shape of the window was chosen as the most natural. The index formula is as follows:

$$F = \frac{n-1}{c-1} \cdot \frac{m-1}{c-1}$$

where:
F – landscape fragmentation
n – number of different patch types
m – number of individual patches
c – number of analyzed pixels (in this case: 4293)

The minimum number of individual patches in the window equalled 1, while the maximum reached 24. The minimum number of patch types also equalled 1, but the maximum number was only 5. The resulting image was classified into 4 classes (fig. 11).

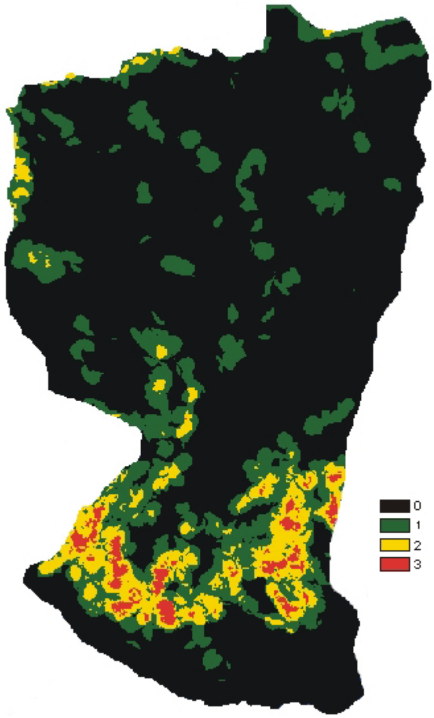

Figure 11. Landscape fragmentation index: 0 – class I (lowest); 1 –class II; 2 – class III; 3 – class IV (highest)

4.4 *Point and line features analysis*

The interpretation of satellite and aerial images does not reveal all terrain objects, especially those of relatively small extent or poor contrast. In spite of spatial dimensions of these elements they can influence the observer's perception considerably, due to e.g. cultural or historical significance. Identification of these objects was carried out with the use of 1:10000 topographic maps. Series of line and point features were identified, both positively and negatively influencing landscape perception. Round and along each element were created buffer zones within which these elements can still affect tourists. Buffer size was established individually for each object type, depending on its character and size (tab. 1).

In this part of the analysis a different ranking method was used. Objects, together with their buffers, that positively influence landscape perception, received +1 point, while "negative" objects received –1 point, decreasing in this way landscape attractiveness.

In spite of significant, negative influence of contemporary architecture and infrastructure, positive elements, both natural and cultural, still predominate (fig. 12a and 12b).

Figure 12. Topographic objects of: a) positive and b) negative influence on landscape perception (including buffer zones, marked in white)

5 RESULTS

After performing all analyses and assigning points to individual classes, corresponding values of all images were summed to assess total landscape attractiveness. The final values obtained by map overlaying ranged from 0 to 15. The resulting image was also classified into four main classes, each containing 4 values. For better discrimination of the highest and most interesting values, the last, most "attractive" class was divided into 4 more classes, each containing 1 original value. Consequently, the outcome has 7 classes describing landscape diversity (fig. 13).

Areas with the highest values are most attractive, according to the accepted assumption about direct correlation between attractiveness and diversity. The highest attractiveness was achieved in areas characterized by uniqueness in the scale of the whole country, i.e. the subalpine and alpine climatic belts. Noteworthy is the fact that a high level of attractiveness was achieved in areas situated on the border of two climatic belts, i.e. in areas of highest diversity. Therefore, despite the great influence of mountain relief (e.g. ridges, peaks), a kind of equilibrium was achieved between typical alpine elements and the rest of landscape components. In the light of these results it seems that used method of classification and ranking, taking into account fragmentation, arrangement, uniqueness, naturalness and visibility, was correct.

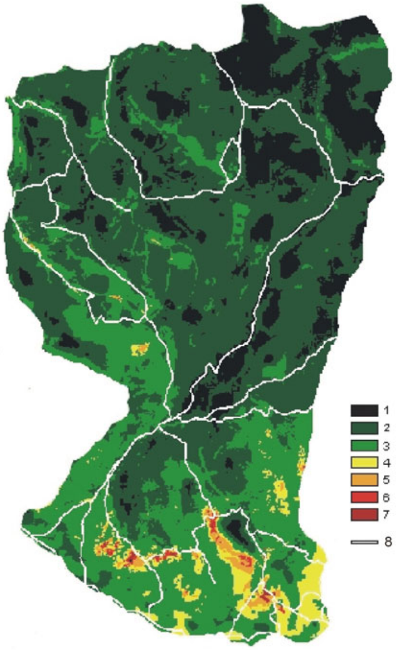

Figure 13. Landscape attractiveness (attractiveness: 1 – class I: low; 2 – class II: neutral; 3 – class III: medium; 4 – class IV: high; 5 – class V: very high; 6 – class VI: outstanding; 7 – class VII: unique; 8 – tourist routes)

The next step of the analysis consisted in the choice of some points of high attractiveness, with a view to creating and setting up information boards. It was assumed, that the proposed boards could be placed only along tourist routes and in harmony with the surrounding environment.

6 INFORMATION BOARDS

It is expected that information boards will be placed in places selected on the base of the method proposed in this paper. These boards should contain information obtained during performed analyses. In particular, 3-dimensional terrain model with overlaid aerial or satellite image can be an interesting element of such a board, creating a vivid panorama of the area. It can be very helpful in case of bad weather (mist etc). Other elements such as information about characteristic, interesting species of flora and fauna, relief forms or cultural and historical information, can be essential.

The layout of each board should be similar, however the final look should depend on the individual character of analyzed area and on information content. Information boards should be made in the characteristic, traditional style of the area of Zakopane.

7 CONCLUSIONS

A method to analyse landscape attractiveness is presented in this paper. Despite some subjectivity, a higher level of objectivity is obtained than by using traditional methods, especially those using questionnaires. The availability of data (satellite and aerial images, Digital Elevation Model, topographic maps) ensure the possibility to create in the future a uniform Tourist Information System for Tatra National Park.

It is worth mentioning that the idea of such a system interests the management of the Tatra National Park. Independently of proposed information boards, the method of landscape attractiveness assessment can also be used to create a widespread system of educational paths available on the internet site of TPN.

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