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THE USE OF THE DIGITAL TERRAIN MODEL IN ANALYZING THE NATURAL POTENTIAL OF THE MUNTELE MIC - POIANA MĂRULUI - ȚARCU MOUNTAINS TOURIST AREA TO EXTEND AND PLAN THE SKI DOMAIN

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Abstract

The present study aims at examining the natural potential of the region as a prerequisite for the planning and the expansion of the ski domain, in order to reinvigorate the resorts Muntele Mic and Poiana Mărului. The factors taken into account to identify the best areas for planning new ski tracks are: the altitude, the slope, the orientation of the slopes to the solar radiation, the duration and the thickness of the snow layer, the land use, the risk of snow avalanches occurrence and the degree of accessibility. Because the factors considered don't have the same importance for the favorability, before the combination of the factors, we used the Analytical Hierarchy Process (AHP) implemented by the IDRISI Andes software to assign for each factor a relative weight to use in the analysis. The risk of snow avalanches occurrence was considered as restrictive factor (Boolean factor). The combination of factors by Weight of Evidence method resulted in the creation of the final model, which presents the probability map for new ski tracks. The probability degree varies continuously in space, from a very high probability (255) to a very low probability (0) depending on the combination mode in a certain area of the considered factors and their weight. We considered as optimal areas only the areas with values above 200. The best areas to expand the ski domain are the detached secondary peaks of Muntele Mic towards north and the northern slopes of the Nedeia Ridge. These areas could allow for the development of certain ski tracks at least the same size as the ones of the Prahova Valley. The development of the ski domain in these areas will connect the two resorts, Muntele Mic and Poiana Mărului, and could increase the touristic potential of the study area.

Keywords: *ski areas, GIS, Digital Terrain Model, spatial analysis, Muntele Mic, Poiana Mărului, Țarcu Mountains*

Rezumat

Utilizarea modelului numeric al terenului în analiza potențialului natural al spațiului turistic Muntele Mic - Poiana Mărului - Munții Țarcu, în vederea extinderii şi amenajării domeniului schiabil. Studiul de față îşi propune analiza potențialului natural al regiunii ca premisă pentru amenajarea şi extinderea domeniilor schiabile, în vederea revigorării stațiunilor Muntele Mic şi Poiana Mărului. Factorii utilizați pentru determinarea arealelor optime pentru amenajarea de noi pârtii de schi au fost: altitudinea, panta, expoziția suprafețelor față de radiația solară, durata şi grosimea startului de zăpadă, utilizarea terenului riscul de producere al avalanşelor şi gradul de accesibilitate. Factorii au fost standardizați cu ajutorul familiilor de funcții fuzzy pe o scala de la 0 (nefavorabil) la 255 (extrem de favorabil). Doar riscul de producere al avalanşelor a fost considerat factor restrictiv (boolean). Deoarece factorii considerați nu au aceeași importanță s-a utilizat Procedeul Analitic de Ierarhizare (software IDRISI Andes) pentru a stabili ponderea fiecărui factor în parte. Combinarea factorilor s-a realizat prin metoda Weight of Evidence obținându-se harta de probabilitate a amenajării de noi pârtii de schi. Arealele optime au fost considerate cele cu valori de peste 200. Aceste areale sunt localizate pe versantul nordic al Masivului Muntele Mic și al Culmii Nedeia si ar permite dezvoltarea unor domenii schiabile de talia celor din Valea Prahovei. Totodată deschiderea unor noi pârtii de schi și a instalațiilor de transport aferente ar permite conectarea celor două stațiuni, Muntele Mic și Poiana Mărului, ceea ce ar duce la o creștere a atractivității turistice a arealului analizat.

Cuvinte cheie: *domenii de schi, MNT, analiză spațială, Muntele Mic, Poiana Mărului, Munții Țarcu*

INTRODUCTION

The analysis and the knowledge of the parameters of the terrain are essential for the constitution of a mountain resort, especially for ski practices. In this sense, the completion of the DTM and of the thematic maps of altitude, depth of fragmentation, declivity and aspect (Grimsdóttir and McClung, 2006; Tremper, 2001), but also the analysis of the vegetation and especially of the snow (Beniston, 1997; Beniston *et al.*, 2003; Breiling, Charamza, 1999) serve to establish the indicators of the ski slopes (Țigu, 2001) and to understand the manifestation manner and the frequency of high-risk physical and geographical processes of the ski domain, such as the snow avalanches (Schweizer and Camponovo, 2001; Schweizer and Lütschg, 2001). At the same time the snow cover serves as a climate change indicator (Beniston, 1997; Breiling, Charamza, 1999; Hamilton *et al.*, 2005; Krapf *et al.*, 1999; Lise and Toll, 2002; Scott, McBoyle, 2007; Whetton *et al.*, 1996).

In this case, we have chosen for analysis the mountainous space of Muntele Mic - Poiana Mărului - Țarcu Mountains, locally and regionally known, but insufficiently exploited. Our work may represent a perspective that can be taken into account in view of the enlargement of the mountain ski domain in this sector, according to the Urban Planning of the Area - Muntele Mic - Turnu Ruieni Settlement (Bocicai, 2006).

The Study Area

Țarcu Mountains, covering a surface of more than1440 square kilometres, are located in the north - west of the Southern Carpathians, in the Retezat - Godeanu Mountains (Badea *et al.*, 2001) (Fig. 1).

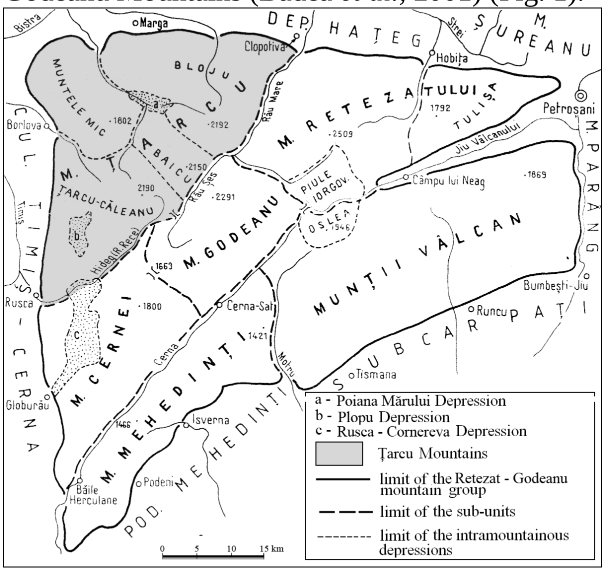

Fig. 1 The position of the Țarcu Mountains within the Retezat-Godeanu Mountains (Badea *et al.*, 2001)

Mainly developed on the crystalline schists of the Danubian Autochthonous and of the Getic Nappe, it unfolds between 300 and 2192 meters of altitude (Pietrii Peak), which places it among the highest mountains in Banat. The altitude and the location of these mountains in a region of oceanic climate influences explains the presence of a substantial snow cover, with an annual average duration of 148 days at Cuntu meteorological station (1450 meters) and 190 days on the highest peaks (Țarcu Peak meteorological station, 2180 meters), which makes the practice of winter sports possible. The presence of the plateau of Muntele Mic (1802 meters), without forests and with gentle slopes, plus the location of the massive near large cities in the western part of the country, explains the practice of skiing in this area since the beginning of last century (Țeposu, Puşcariu, 1932).

Nowadays, this ski area is poorly equipped and modernized as compared to other resorts and the slopes are insufficient in number and in the degree of difficulty. Given the fact that more and more skiers choose other destinations because of the causes mentioned above, this study aims at examining the natural potential of the region as a prerequisite for the planning and the expansion of the ski areas, in order to reinvigorate the Muntele Mic - Poiana Mărului - Țarcu resorts (Photo. 1, a, b).

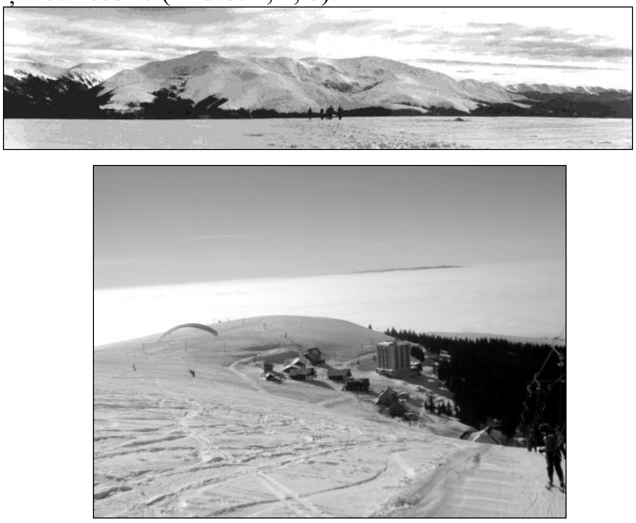

Photo. 1. a, b. Muntele Mic - Poiana Mărului - Țarcu ski areas (photos by Voiculescu and Török, 2008)

MATERIAL AND METHODS

The data used for the analysis of the potential ski areas with the help of the geographical information systems (GIS) come from different sources:

- the digital terrain model (DTM) SPOT HRS (High Resolution Stereo) with a spatial resolution of 30 meters, obtained through satellite remote sensing; (Fig. 2) ;

- Landsat ETM + satellite images (bands 1, 2, 3, 4, 5, 7, and 8), date of acquisition: September 8th, 2006, with a resolution of 30 meters multi-spectral and 15 meters for the panchromatic band;

- topographic maps, scale 1:25,000, scanned and georeferenced in the Stereo 1970 national coordinate system;

- climate data from the Caransebeş (201 meters), Cuntu (1450 meters) and Țarcu (2180 meters) weather stations, for the 1980 - 2004 period;

- field data.

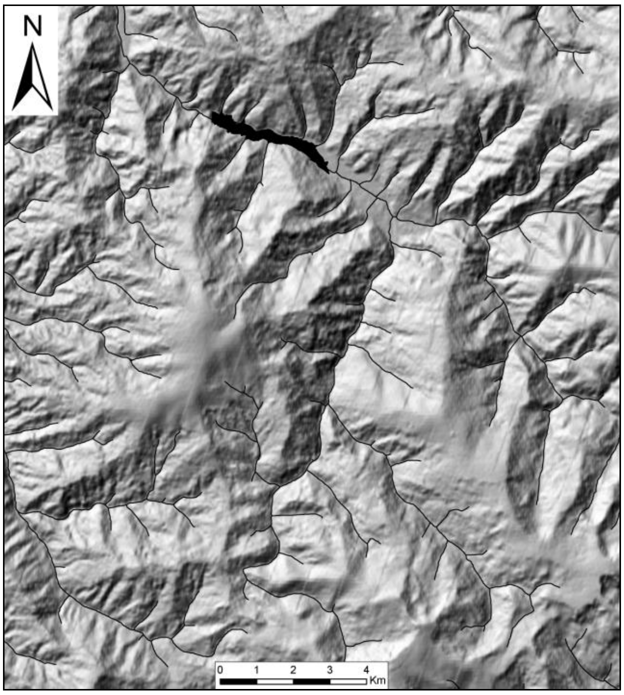

Fig. 2 The Digital Terrain Model (SPOT-HRS, 30m resolution) of the study area.

In the first stage, the factors to be taken into account in order to identify new areas that provide optimal conditions for skiing were established. These factors are: geomorphologic factors (altitude, slope, relief fragmentation density and aspect), climatic factors (the average duration of the snow layer and the exhibition of the areas to the sunlight), biogeographical factors (the type of vegetation and its coverage), risk factors (snow avalanches) and anthropogenic factors (the existing infrastructure).

In the second stage, each factor was represented in the form of a digital map. Because the factors were measured in different units their standardization is necessary. Almost all the analyzed factors vary continuously through space and they are seen as data sets with a continuous character, therefore the best method for standardization is the using of fuzzy membership functions. In this way the factors were standardized on scale of integer numbers from 0 to 255 (bytes).

Because the factors considered have different importance regarding the skiing favorability we assigned for each factor a relative weight. The attribution of the weight is difficult and it is relative when all the factors are simultaneous taken in concern. The distribution of the information in simple comparisons in pairs, in which two criteria are taken in concern at once, may facilitate the weighting process and will provide a much more stabile set of criteria weight. This technique of pair comparison, known as Analytical Hierarchy Process (AHP), is implemented in the IDRISI software. The factors are compared two by two, by giving notes on a continuous scale of nine values.

The combination of the factors by Weight of Evidence method allowed obtaining the final model, which presents the probability map for new ski tracks. The probability degree varies continuously in space, from a very high probability, or very high favorability, (value 204) to a very low probability, or very low favorability (value 0) depending on the combination mode in a certain area of the considered factors and their weight. We considered as optimal areas only the areas with values above 160.

Finally, we selected the most suitable areas for the development of new ski tracks using two criteria: the area (areas greater than 15 ha) and the accessibility (areas situated at a distance of maximum 1000 m from roads).

RESULTS AND DISCUSSIONS

The altitude is essential for skiing activities and, given the conditions of the temperate continental climate in which our country is located, it has to be of at least 1000 meters (Besancenot, 1990) in order to maintain a favourable snow layer for at least 3 months/year. The altitude factor was standardized using a increase linear fuzzy function with main point 1000 m for 0 values.

The slopes represent a factor of great importance for skiing activities. Also, the slope is the element that separates the practitioners of this activity into two large categories: skiers and beginners. The first category was defined as *users of skis, snowboards or other gravity-propelled recreational devices whose design and function allow users a significant degree of control over speed and direction on snow* (Penniman, 1999, pp. 36); the beginning skiers or the beginners were defined as: *those individuals who are using one or another of these devices for the first time or who possess marginal abilities to turn or stop on slopes with incline greater than 20%* (Penniman, 1999, pp. 36).

According to the declivity degree, there have been established the following categories of skiers: beginners (who make use of slope gradients with a declivity of 11.5º), intermediates (who use the slope gradients between 18º-19º), advanced skiers (who use the slope gradients of 19º), and experts (who use slope gradients that surpass 19º or even 39º) (Borgersen, 1977; Gaylor and Rombold, 1964, quoted by Penniman, 1999).

The optimum slopes for skiing are between 10° and 35°. The standardization of the slope has been made by using a symmetric sigmoid function by establishing as main points the values of 10 degrees

35 degrees for 255 value and the values of 5 and 40 degrees for 0 values (Fig. 3)

The slope orientation to the sun is an important factor in terms of depth and duration of the snow layer (Birkeland and Mock, 2001; Egli, 2008; Fitzharris, 1987; Höller, 2009; McClung, Schaerer, 1993) and it exerts a strong influence on the stability of the snow pack (Ancey, 2001).

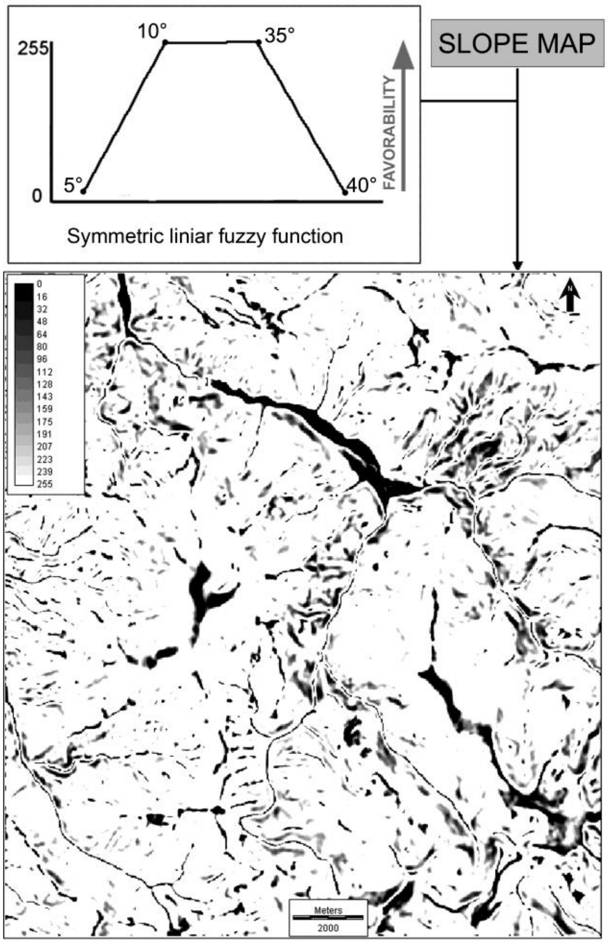

Fig. 3. The standardization of the slopes by using a symmetric linear fuzzy function.

The sun radiation controls the snow surface temperature more than the air temperature (Tremper, 2001). Also the aspect plays a very important role in the snow instability (McClung and Schaerer, 1993) and determines the snow avalanches in this context. We consider that northern slopes (N, NW and NE) are the most suitable because the north faces keep the snow cover compacter and for a longer period than the other faces. The standardization of the aspect has been made by using a symmetric sigmoidal fuzzy function.

The snow is an economic resource for winter tourism activities (Beniston, 1997; Beniston et al., 2003; Breiling, Charamza, 1999). Its minimum thickness that allows smooth ski practices must be at least 30 centimeters (Agrawala, 2007; Besancenot, 1990; Becken, Hay, 2007; Freitas, 2005; Hall Higham, 2005). In order to build the model of the average duration of days with snow layer, there were used the DTM and the values of average duration of days with snow layer recorded at the weather stations within the area, i.e. Caransebeș, Cuntu and Țarcu. The linear regression was calculated between the average duration of days with snow layer and the altitude of the meteorological stations:

$$\text{No. days with snow} = 48{,}120 + (0.006251 * \text{Altitude}) \quad [1]$$

The value of the correlation coefficient, i.e. 0.998, demonstrates the close relationship between the two parameters and allows the use of this equation to construct the digital model of the average duration of days with snow layer. With the help of map algebra, and using the equation [1], in which the DTM was introduced as the altitudinal variable, we obtained the digital model of the average duration of the snow layer for the study area (Fig. 4). For skiing activities are necessary at least 120 days with snow cover so we standardized this factor using an increasing sigmoidal fuzzy function with two control points, 100 days for 0 values and 150 days for 255 values.

The vegetation type is important in order to establish weather deforestations are necessary for future developments and because the vegetation is an important geomorphologic factor that can enhance or diminish the erosion processes affecting slopes when snow is missing. Landsat ETM satellite images were used for vegetation mapping.

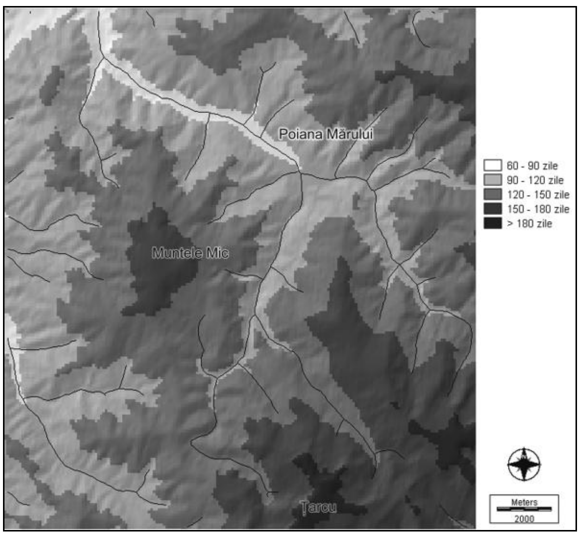

Fig. 4. Muntele Mic - Poiana Mărului - Țarcu ski areas - the multi-annual average duration of the snow layer

As in the mountain areas with rugged terrain, such as Țarcu Mountains, the topographic effect is particularly severe and leads to the distortion of values of the reflectance issued by the same type of vegetation, the next step was to eliminate this effect. Because of the efficient outcome we used the modelling of the effect of illumination method based on the digital terrain model (Eastman, 2007).

The map of the present land cover was obtained from the corrected bands by the supervised classification of the satellite images, using the maximum likelihood classification (Idrisi Andes software). The map includes the following categories: rocky, alpine and mountain meadows, water (glacial and dam lakes), coniferous forests, deciduous forests and settlements. The areas covered by the alpine and mountain pastures were considered optimal for the development of the future ski infrastructure because they no longer require deforestation works (maximum favourability, value 255). The lakes, the settlements and the rocky steep slopes were considered "barriers" for the development of the ski domain (minimum favourability, value 0).

The risk of snow avalanches is an essential element that must be taken into account in planning new tracks because, if neglected, it could endanger the lives of the tourists and can cause serious damages. The skiing practices are an important factor influencing snow stability in the mountain areas (van Herwijnen and Jamieson 2007; Quinn and Phillips 2000) and, at the same time, they trigger snow avalanches (Grimsdóttir and McClung, 2006; Schweizer and Camponovo, 2001; Schweizer and Lütschg, 2001). That is why the snow avalanche map is very important to the development of zoning criteria: „*do not prevent avalanches; they reduce the probability of damage*" (Höller, 2007, pp. 96).

Identifying no risk, low risk, medium risk and high risk areas was possible by using the overlay technique and by combining the following factors: altitude, slope, aspect, presence/absence of the forest and the average snow layer thickness (Butler, 1979; Butler, Stephen, 1990; Stethem *et al.*, 2003). Only the areas with no risk or low risk of snow avalanches were considered favourable for skiing. Thus, it appears that the most exposed areas are typical for the Țarcu Mountains, where the high relief, the slope and the snow layer favour the starting of snow avalanches. In the Muntele Mic - Poiana Mărului ski areas, these processes are not characteristic, the skiing resort activities taking place in good conditions (Fig. 5).

The anthropogenic factor taken into account was the distance from the communication routes (Fig. 6). In this respect, there was drawn up a map of distances (in meters) from the following communication routes: modernised roads, forest roads and cable transport infrastructure (Fig. 6).

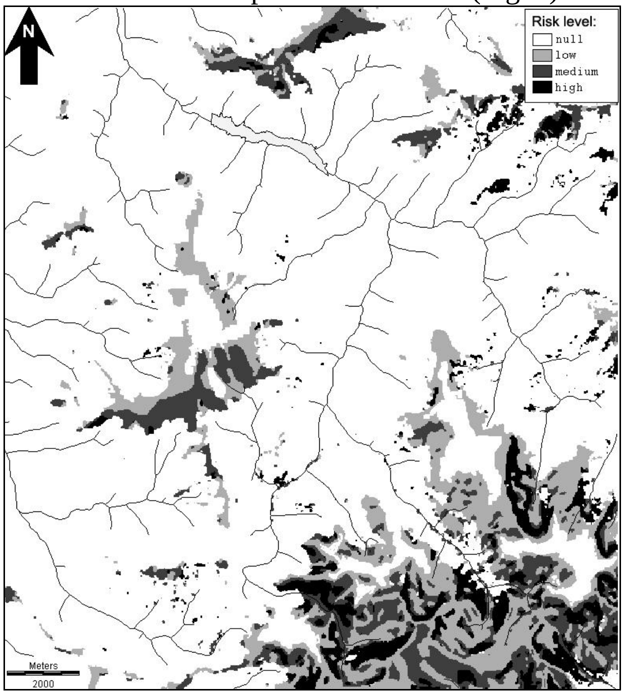

Fig. 5. Muntele Mic - Poiana Mărului – Țarcu ski areas - snow avalanche risk map

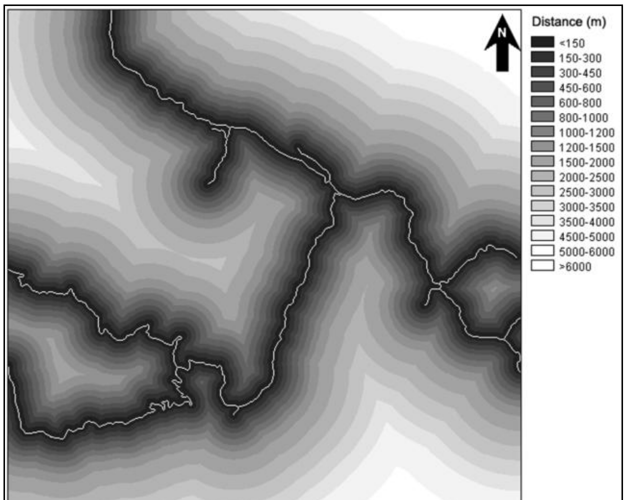

Fig.6. Muntele Mic - Poiana Mărului – Țarcu ski areas – distance from roads.

The combining of all standardized factors by using the Weight of Evidence method (Idrisi Andes software) allowed us to obtain a model which presents the favorability for developing new ski tracks (Fig. 7). The values vary continuously in space, from a very high favorability, (value 204) to a very low favorability (value 0) depending on the combination mode in a certain area of the considered factors and their weight. We considered as optimal areas only the areas with values above 140.

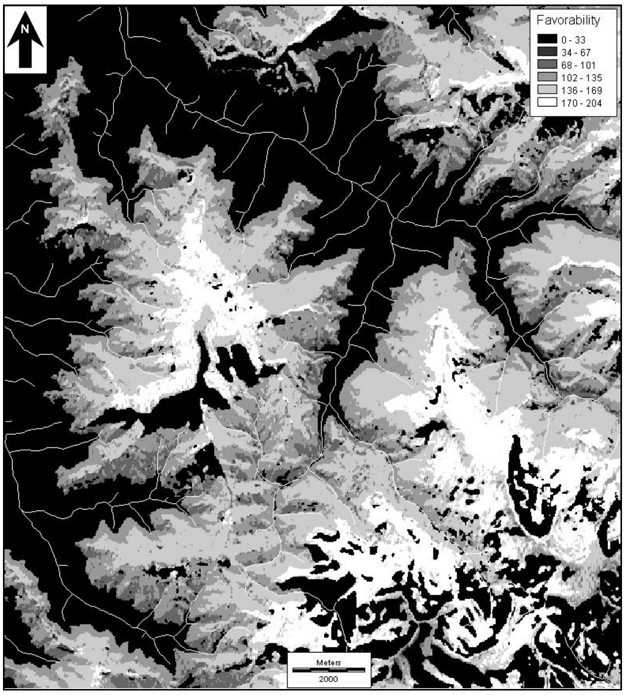

Fig.7. The favourability for the developing of the new ski tracks in Muntele Mic - Poiana Mărului – Țarcu.

Among them, the areas within a distance of less than 1000 meters from the roads and greater than 15 ha were selected as the best ones, thus being identified the five best areas located on the slopes of Nedeia Ridge and on the secondary ridges, which are detached to the north side of Muntele Mic (Fig. 8). For each area there were calculated the main morphometrical parameters: the length, the maximum, minimum and average altitude, the altitudinal difference, the maximum, minimum and average slope and the average number of days with snow layer (Table 1).

CONCLUSION

Following the spatial analysis, there is to be noticed that the best areas to expand the ski domain are the detached secondary peaks of Muntele Mic towards north and the northern slopes of the Nedeia ridge. Their length and the elevation differences, together with the long duration of the snow layer, could allow for the development of certain ski tracks at least the same size as the ones of Prahova Valley, totalling 11,700 meters.

All the five areas are located in the proximity of the roads along the main valleys. There is to be mentioned that we take into account only the most suitable declivity values for skiing so, in reality, the tracks could be even longer, going down to a slope less inclined and arriving near the roads.

The extending of the ski tracks and the cable transport infrastructure in these areas would allow for a greater connection between the mountain resorts Muntele Mic and Poiana Mărului, leading to an important increase of the tourist potential of the region.

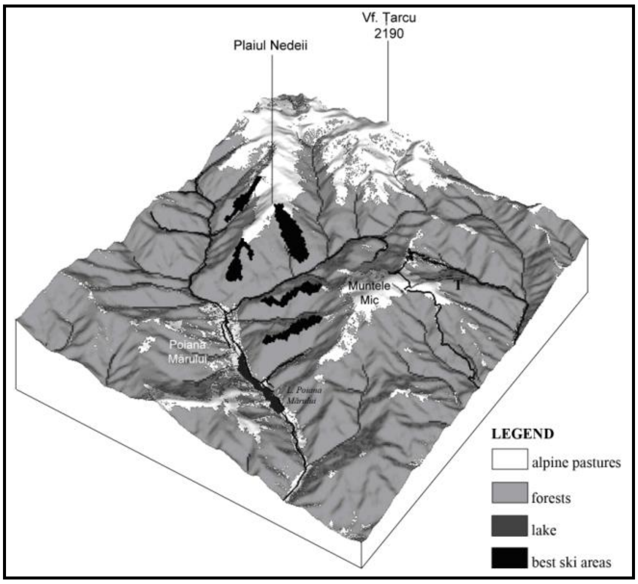

Fig. 8. Optimal areas for the planning of new ski tracks (3D representation) in the Muntele Mic - Poiana Mărului - Țarcu area

The method used in this study allows the complex analysis of the ski potential of the mountains regions through the integration of diverse data from different sources (DTMs, satellite images, topographic maps, climate data etc.), taking into account both the physical and anthropogenic factors. The spatial analysis is, thus, an extremely useful tool to support decision making based on multiple criteria. The method can be adapted to the specific of the study area and can be improved by including additional factors into the analysis.

Table 1. Morphometrical data and average duration of the snow layer for the new ski tracks

Optimum area	**Lenght (meters)**	**Altitude (meters)**			**Slope (º)**			**The average duration of the snow layer (days)**
		Max.	**Min.**	**Average**	**Max.**	**Min.**	**Average**	
1	1682	1536	982	1226.8	10.7	32.9	20.2	129
2	2550	1427	1004	1238.7	9.3	34.7	21.9	130
3	2507	1337	1034	1189.4	10	32.1	21.2	127
4	2408	1779	1112	1414.7	10.9	26.8	19.9	141
5	2553	993	1754	1324.6	5.3	32.1	23.1	136

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