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LANDFORM EVOLUTION IN MOUNTAIN AREAS

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RELIEF ACCESSIBILITY MAPPING AND ANALYSIS IN MIDDLE MOUNTAIN AREAS. A CASE STUDY IN THE POSTAVARU–PIATRA MARE–CLABUCETELE PREDEALULUI MTS (CURVATURE CARPATHIANS)

Abstract. This paper consists in an ensemble of GIS-integrated case analysis. The first one proposes a new map: the map of the mountain relief accessibility. The other one tries to correlate the relief fragmentation — mapped as a stream frequency indicator — with the communication network frequency. The first map combine mountain terrains having different accessibility degrees: very accessible, accessible, average accessibility areas and low accessibility-heavy accessible areas. Another analysis following the accessibility map have as main purpose to evaluate by digital method what are the most isolated mountain terrains.

Key words: Postavaru–Piatra Mare–Clabucetele Predealului, relief accessibility mapping, GIS analysis and geostatistics

INTRODUCTION

Mountain areas have three essential properties (Jodha 1999): limited accessibility, vulnerability and marginality, diversity and local personality/originality. First feature is the most important, because it generates or limits mass and energy streams and finally draws the space structure (Ianos 2000; Mihai 2000). Mountain sustainable development policies depend on isolation, infrastructure and mobility prices, on the limited access to information, products, on difficulties in the resources use process (Ives 1997, Ives and Messerli 1990). Accessibility influences also the knowledge degree of a mountain space and the quality of life (Bosdorf 1999).

Relief accessibility can be defined as a feature which enable or restrict the human penetration in the mountain landscape by different specific works (settlements, industrial districts, dams, airports etc.) (Clark 1990) and allows man to cross this area using the most complex terrestrial communication devices (road-highway, railroad, cable etc.).

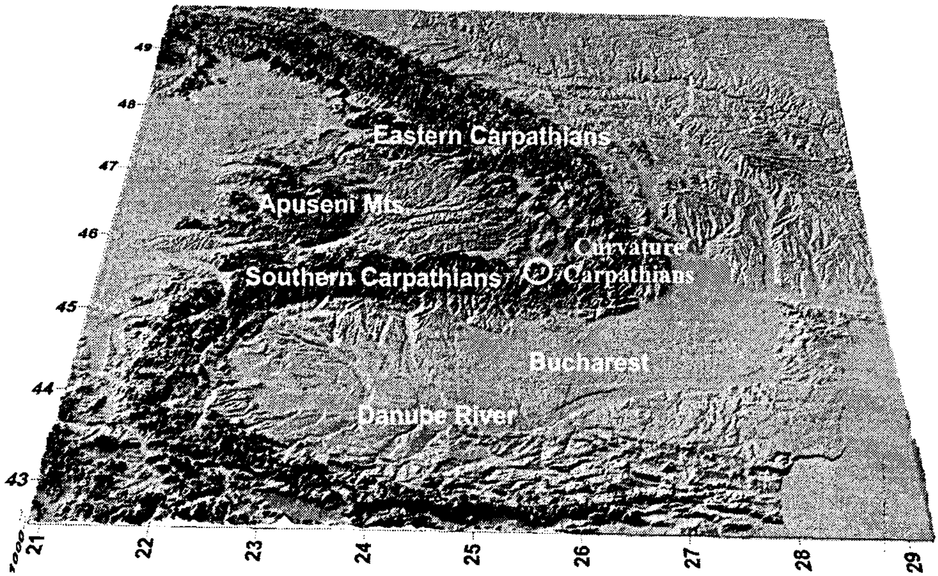

Fig. 1. Location map. Study area on the background of Carpathian Arc

This paper consists in an ensemble of GIS-integrated case analysis. The first one proposes a new map, the mountain relief accessibility map. The other one tries to correlate the relief fragmentation — mapped as a stream frequency indicator — with the communication network (road, railway) frequency.

The mapped area refers to a middle mountain region with an altitude that is no higher than 1,840 m (1,843 m in Piatra Mare Peak). On an average surface of about 370 km^2, the relative altitude is more than 1,200–1,300 m, on a complex structural and lithological background (limestone, conglomerate, flysch). The Postavaru–-Piatra Mare–Clabucetele Predealului mountains lies in the westernmost area of the Curvature Carpathians (Fig. 1), and includes the oldest part of the Brasov town and two of the biggest skiing areas in Romania (Predeal, Poiana Brasov) (Ciangă 1997). Important planning issues make interesting this approach since 1992: urban areas, motorways, skipaths and cablecars, reservoirs etc.

RELIEF ACCESSIBILITY MAPPING — A GIS ANALYSIS

The first GIS case study tried to explain what are the key role factors in defining relief accessibility and what is their implication within the cartographic definition of this notion. Considering five digital layers as essential, the analysis uses map algebra operations. These were reclassified using field features in the following order:

— slope declivity;

— land suitability for different works (buildings, roads, skipaths — obtained from a previous GIS analysis);

— the geomorphic risk (obtained from a previous GIS analysis);
— the land use (extracted by interpretation from a SPOT-PAN satellite scene);
— hipsometry.

These sensitive variables (Latulippe and Peiry 1996) have a key role in defining relief accessibility, but the main problem is to evaluate their contribution. The reclassification of the grid cells values starts from the land features. They strongly depend on each morphological feature (Table 1).

Table 1

Classification conditions for assessing relief accessibility in Postavaru–Piatra Mare–Clabucetele Predealului Mountains

Layer	V.D.A.	D.A.	A.D.A.	E.V.E.A.A.
Slope/gradient	> 30°	20–30°	10–20°	< 10°
Land suitability	no suitable	roads, skipaths	roads, buildings	buildings, roads
Geomorphic risk	high risk	moderate risk	average risk	low risk
Land use	steep slope, crest, forest	forest, meadow	forest, meadow, eroded land	settlements, meadows, riverbeds, eroded land
Hipsometry	1,500–1,850 m	1,200–1,500 m	800–1,200 m	550–800 m

V.D.A. — very difficult area, D.A. — difficult area, A.D.A — average difficult area, E.V.E.A.A. — easy and very easy access area

Slopes have the key role in determining this potential of the mountain relief. Mountain definitions (Veyret and Veyret 1962; Chardon 1989) consider slope, declivity and inclination as key words. Slope declivity introduces probably the most important technical barrier for the access inside the mountain. Altitude has a secondary role in this direction. We proposed the maximum of points for this feature.

Land suitability for different purposes results from a separate GIS analysis. The mountain area accessibility is related to good conditions for building and/or roads (Ungureanu 1998–1999). Land suitable for building is the expression of an easy access, while the areas suitable only for footpaths (and roads) is related to an average level of accessibility, with different natural restrictions.

The geomorphic risk is a map layer, integrating: slope declivity, morphodynamic potential (geomorphic hazard occurrence), land use (vulnerability to risks and lithology). Risk, as a product between hazard and vulnerability (Panizza and Piacente 1993), which enables or restricts accessibility everywhere, is a limiting factor in every human intervention. Costs increase with risk, leading to a technical barrier (Laurini 2001).

Land use can restrict or help the relief accessibility. Forest which is a frequent feature of the mountain landscape is always a barrier, while meadow encourage it. This layer has been obtained using satellite data. Geographical interpretation of a July 1997 SPOT panchromatic satellite scene, helped us to obtain a new data layer. Fieldwork helped us to bring accurate data.

Hipsometry has a secondary role, but we appreciate it to be a limit one. Mountain definition considers this factor to be a key-notion. In this situation, altitude (550 m to 1,843 m) introduces some threshold values: 1,160 m for permanent settlement, 1,793 m for chalets and road access, 1,033 m for railways.

The final map (Fig. 2) combine mountain terrains having different accessibility degrees:

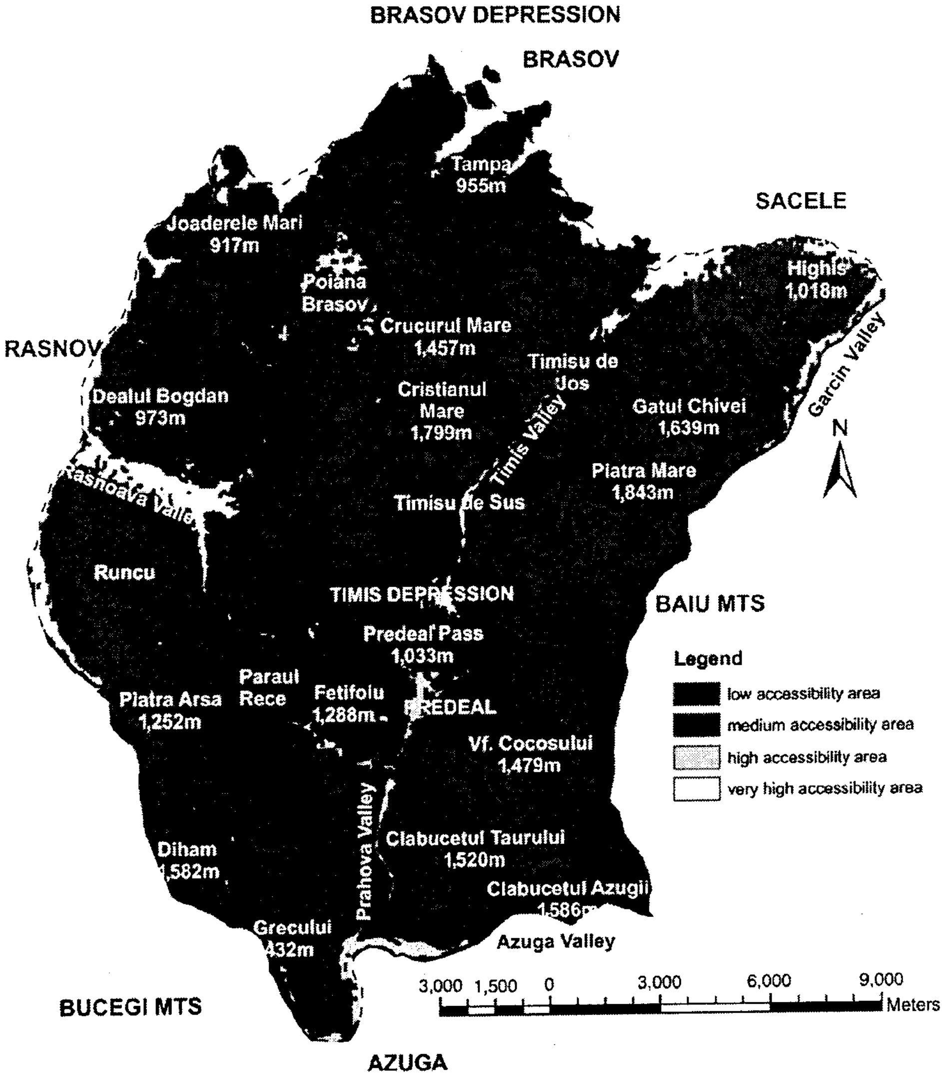

Fig. 2. Accessibility map of Postavaru–Piatra Mare–Clabucetele Predealului Mts

— very accessible (mountain fringes to the Brasov Depression border, glacis–slopes and big alluvial fans); here there are almost all the archaeological sites in the area, since the Neolithic times (13.2% of the area);
— accessible (main valley corridors, small erosion and tectonic depressions like Timisu de Sus); these are covering 3.11% of the mapped surface;
— average accessibility areas (afforested slopes especially), represents slopes and narrow rounded shaped ridges (67%), because of the Pleistocene–Holocene stream network cutting, as an effect of the Brasov Depression subsidence;
— low accessibility–heavy accessibility areas, have 16.5% of the mountain area, especially steep slopes and crests on limestone and conglomerates, debris fans and glacis slopes etc.; these are the remnants of the periglacial morphodynamics during Pleistocene and partly, above 1,000–1,400 m, during Holocene (Ielenicz 1972).

The main conclusion is that the border glacis areas and the biggest transcarpathian axis (and their derivations) are the most accessible terrain. On the second place there are the Pliocene erosion surfaces of ± 1,000 m (Predeal and Poiana Brasov). Steep slopes and heavy fragmented slopes are on the opposite and put difficult accessibility problem. To keep them in a natural configuration may be the best solution. Map shows also the relationship between lithological, structural and tectonic features and the human impact areas. Detailed mapping in urban areas is useful in the terms of facilities management (Mac and Râpeanu 1995).

Long time ago, since the 14–18th centuries, this mountain area has been almost inaccessible. Only footpath along ridges ("plaiuri" in Romanian — C. Giurcaneanu 1998) and some larger valleys made possible the penetration, especially along the Brasov Depression limit, between Rasnov–Brasov to Sacele. Transcarpathian road (1847) and railroad (1879) building made an important change in the accessibility problem perception, even the area has been before 1918 a border area.

Winter conditions have not been considered within our analysis. Local experience and present-day technical conditions eliminates, theoretically, the isolation of different sectors (Gumuchian 1983). Snow layer can reach more than 220 cm thick at 1,790 m and 100–150 cm along valleys and isolation could appear in remotest areas where there is only one forestry road/path to access in. Wind which could have a maximum speed of more than 29 m $\cdot$ s^{-1} (higher than 1,700 m) is another accessibility limit which have not been considered (cable cars situation).

Mountain relief influenced accessibility, first through the slope breaks to the largest landforms like valleys or steep slopes. From the technical point of view these limit disappeared but costs increases when accessibility decreases. Power lines or GSM antennas on isolated peaks or crossing sharp or narrow ridges are good examples (Cristianul Mare, Piatra Mare, M. Clabucet–Muchea Lunga mountain ridges). Forests maintenance and protection, in the remotest slope sections when wind damages or snow damages appears (Timis basin in central Piatra Mare and Postavaru Mts) has difficulties because of the limited access. Fire forest management is the second problem during summer on limestone steep slopes.

RELIEF FRAGMENTATION AND COMMUNICATION NETWORK

Drainage density and communication network maps were drawn using GIS. Drainage density and communication network were calculate as the distance between streams and/or roads/railroads/paths/streets/powerlines etc. (Tucker et al. 2001). Drainage network frequency map correlates the interfluve width with the topography configuration. Communication network frequency map visualise the areas, the remotest points, where is a lack of elementary communication facilities like footpaths or forestry roads.

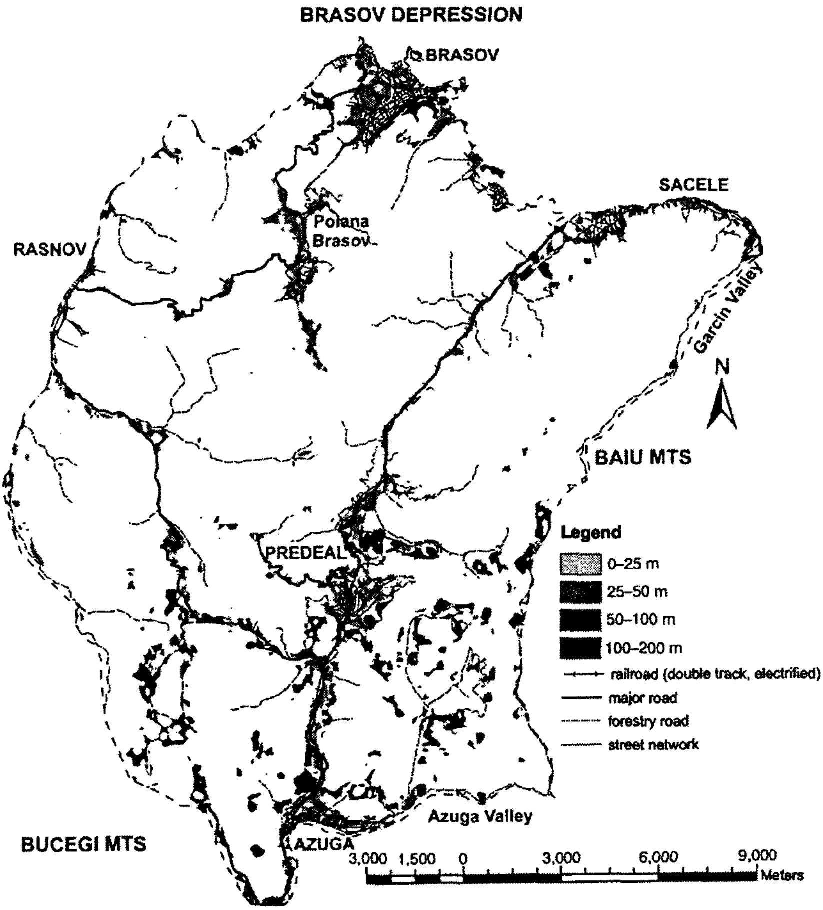

Fig. 3. Areas with equal stream and communication network frequencies

The second step is to explain if streams and rivers have a key role, and to evaluate the optimal stream frequency for communication networks. Equal frequency classes were mapped by crosstabulating the both digital layers (Fig. 3).

A geostatistic analysis and a field/aerial survey recognition made possible to draw the remotest and the most isolated mountain areas.

River junction areas are correlation spaces where the stream high frequency superposes with road–paths–street networks and urban structures (Azuga, Predeal, Timis Valley). Steep slopes and sharp ridges can be considered as natural, untouched areas which must remain in this situation as an effect of the poor accessibility.

The most fragmented areas (lower 30 m stream) frequency are the most isolated, like the Varna–Crucur ridge in northern Postavaru Mts, as a declivity effect.

Prahova–Timis transcarpathian axis has a bigger communication network frequency, lower than 15 m, especially in the narrow valley sector between Timisu de Sus and Dambul Morii. Along Prahova Valley, downstream from Predeal, this values decrease gradually with the stream frequency.

In Clabucetele Predealului area, stream frequencies of 50–100 m generates communication network frequencies higher than 300 m, as an effect of rill and gully erosion on a forested flysch area landscape.

Faults and diaclases crosses limestones and conglomerates in Postavaru–Piatra Mare Mts and steep slopes made necessary the adaptation of the road and footpath network. In these high declivity sectors, stream frequency is about 5–10 m and roads-paths use saddles, flat ridges or erosion outliers. Spaces like Muchea Cheii ridge, eastern Piatra Mare slopes or the Sipoae basin appears to be different isolation degree areas.

Bold erosion remnants, where stream frequency is of about 100–300 m can be key points in different works. They rarely occur and the land use is forest and/or rock, as an effect of a difficult accessibility, along narrow and deep (300–500 m) valleys. A lot of forestry roads stop on low altitudes because of the upstream steep slope occurrence (northeastern Postavaru Mts). In limestone areas, on plateaus, water supply introduced a new barrier (Chardon 1994), like for example in Poiana Brasov Mts, where grazing and forestry are an important land use structure on the biggest surface (Poiana Cristianului).

Forestry roads usually appear in very fragmented areas (0–30 m). In the upper Timis basin, road and footpath frequency is of about 300–400 m, in an high relative altitude mountain area (300–500 m).

The regression graph confirm a less representative relationship between roads/footpaths and drainage network (0.45). This is the result of the important valley cutting during Quaternary which created quite young valley (tributaries to Timis, Rasnoava, Garcin rivers etc.).

Practical issues results from this second case study in the framework of forestry. The remotest and isolated zones appear to be very forested spaces, on steep slopes. Forest management in case of wind-snow damage or fires needs urgent action at distances of more than 1–2 km from a road or a footpath, like in northern Piatra Mare. In this situation, drowned trees must be transported outside the slope or fire to be stopped urgently. Temporary cable installation needed a forest clearing on a corridor shape, an aspect that intensified wind damages, on north and north-westernwards direction.

Tourism is also strongly related to the road and footpath networks. Isolated areas still preserve a big naturality degree of the landscape. Some of them are important for tourism, but the access is difficult, which could be an advantage for a sustainable development in the future. Steep slopes and rocks cover, for example about 0.3% of the area. Accessibility problem made an increasing human pressure by tourism in some areas (Predeal, Poiana Brasov, Azuga, Rasnoava Valley, Dambul Morii etc.). Rill and gully erosion affect in this location large meadow and forested land.

CONCLUSIONS

Slope is a key factor in defining accessibility and is introduced in all the complex analythic maps (geomorphic risk, land suitability).

Digital data layers have a different contribution in the relief's accessibility assessment; in this problem subjectivity appears, but field survey can bring a helping element.

Mapping and investigating this feature allow planners and decision makers to observe what are the areas where future developments needs special investments (motorway, dam, skiing areas, forestry road, GSM antennas or hotels-chalets) or some areas where infrastructure costs more than in other areas (houses in average accessibility areas, roads along gorges and narrow valleys which diminish the degree of accessibility eg.: Timis Valley between Timisu de Sus and Brasov).

Accessibility is a result of the relief fragmentation of the mountain area and the correlation can show us that an average stream frequency helps in optimal conditions the accessibility.

This case study illustrates that deep and dense valley network limits accessibility, while flat and long ridges are sustaining the mountain area penetration (a typical example results from the development of Poiana Brasov–Predeal Pliocene planation surfaces at 1,000–1,100 m altitude).

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REFERENCES

Bosdorf A., 1999. *La qualité de vie dans les villes alpines. Le cas d'Innsbruck.* Révue de Géographie Alpine 87, 4, Grenoble, 81–91.

Chardon M., 1989. *Montagnes et milieux montagnards.* Géographie physique des montagnes, Inst. de Géogr. Alpine, Grenoble, 240 pp.

Chardon M., 1994. *L'exploitation de la haute montagne, l'utilisation des eaux et les changements de paysage dans la région de l'Alpe d'Huez (Alpes, France).* Highland zone exploitation in Southern Europe, Brescia, 9–20.

Ciangă N., 1997. *Turismul în Carpatii Orientali.* Studiu de geografie umană, Presa Universitară Clujeană, Cluj–Napoca, 283 pp.

Clark A, 1990. *Dictionary of geography.* Penguin Books, 362 pp.

Giurcaneanu C., 1998. *Populatia şi aşezările din Carpatii Româneşti.* Ed. Ştiintifică şi Enciclopedică, Bucureşti, 296 pp.

Gumuchian H., 1983. *La neige dans les Alpes françaises du Nord.* Cahiers de l'Alpe, Grenoble, 620 pp.

Ianoş I., 2000. *Sisteme teritoriale. O abordare geografică.* Ed. Tehnică, Bucureşti, 197 pp.

Ielenicz M.,1972. *Consideratii privind evolutia reliefului Carpatilor de Curbură.* Analele Universitătii Bucureşti, Geogr. 21, Bucureşti, 81–88.

Ives J. D., 1997. *Mountains under pressure. Applied Physical geography.* Mountains of the World — A Global priority, Parthenon, 226–265.

Ives J. D., Messerli B., 1990. *Progress in theoretical and applied mountain research, 1973–1989 and major future needs.* Mountain Research and Development 10, 2, 101–127.

Jodha N. S., 1999. *L'agriculture de montagne, Les montagnes dans le monde. Une priorité pour un developpement durable.* Glénat, Grenoble, 279–300.

Latulippe C., Peiry J-L., 1996. *Essai de hiérarchisation des zones de production de matičre en suspension dans le bassin-versant d'un grand cours d'Eau: l'Isčre en amont de Grenoble.* Révue de Géographie Alpine 84, 2, Grenoble, 29–44.

Laurini R., 2001. *Information systems for urban planning.* Taylor and Francis, London–New York, 349 pp.

Mac I., Râpeanu M., 1995. *Premisele geomorfologice pentru localizarea şi dezvoltarea oraşului Predeal.* Studia Univ. Babeş-Bolyai, Geogr. 40, 1–2, Cluj–Napoca, 54–62.

Mihai B., 2000. *Problemele organizării spatiului montan, cu privire specială asupra Carpatilor Curburii.* Comunicări de Geografie 4, Ed. Univ. Bucureşti, 303–312.

Panizza M., Piacente S., 1993. *Geomorphological assets evaluation.* Zeitschrift für Geomorphologie 87, 13–18.

Tucker G., et al., 2001. *Statistical analysis of drainage density from digital terrain data.* Geomorphology 36, 187–202.

Ungureanu I., 1998–1999. *About the natural accessibility of the relief.* An. Şt. Al. I. Cuza, Geogr. 44–45, 2, Iaşi, 37–53.

Veyret P., Veyret G., 1962. *Essai de définition de la montagne.* Rev. Géogr. Alpine 51, 1, 5–35.

STRESZCZENIE

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KARTOWANIE DOSTĘPNOŚCI I ANALIZA RZEŹBY GÓR ŚREDNICH. STUDIUM OBSZARU POSTAVARU–PIATRA MARE–CLABUCETELE W GÓRACH PREDEAL, KARPATY RUMUŃSKIE

Artykuł przedstawia wyniki badań dostępności terenów górskich wykonywanych przy zastosowaniu technik GIS. Badaniami objęto obszar o powierzchni około 370 km^2 o wysokościach względnych rzędu 1200–1300 m. Teren badań położony na południe od Braszowa stanowi dwa największe tereny narciarskie w Rumunii (Predeal, Poiana Brasov).

Zaproponowano nowy sposób kartograficznej prezentacji zagadnień dostępności terenów w postaci mapy (ryc. 2). Wykonano statystyczne analizy uwzględniające rozczłonkowanie rzeźby oraz układy komunikacyjne (ryc. 3). Na mapie wyróżniono 4 stopnie dostępności terenu oraz wskazano najbardziej izolowane obszary górskie.