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THE NIVOLOGICAL POTENTIAL OF THE BÂRGĂU MOUNTAINS WITH RELEVANCE FOR THE PRACTICE OF WINTER SPORTS AND RECREATIONAL ACTIVITIES

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ABSTRACT. The Bârgău Mountains are located in the northern group of the Eastern Carpathians and represent a territory with a vocation for practicing winter sports (especially cross-country skiing), but also for sports leisure (hiking, cross-country skiing, freeride). This is due to the snow potential of the mountainous area, especially above 1000 m, where the specific phenomena of winter favor the deposition of a thick layer of snow, which, however, fluctuates in duration and thickness depending on climatic variations affecting the region. The analysis of the snow potential was based on the observations made during 2018-2022, on winter phenomena and snow deposits, and the data obtained were correlated with the morphometric characteristics of the relief, finally establishing the optimal areas for certain sports and leisure activities.

Keywords: *snow cover, snowpack, reliable snow cover, snow section (pit snow), stratigraphic profile, winter sports, winter leisure, winter season, climate change, land reclamation*

REZUMAT. ***Potenţialul nivologic al Munţilor Bârgău, cu relevanţă pentru practicarea sporturilor de iarnă şi a activităţilor recreative.*** Munţii Bârgăului sunt situaţi în grupa nordică a Carpaţilor Orientali şi reprezintă un teritoriu cu vocaţie pentru practicarea sporturilor de iarnă (în special a schiului fond), dar şi a agrementului sportiv (drumeţie, schi de tură, freeride). Acest fapt se datorează potenţialului nivologic al arealului montan, mai ales peste altitudinea

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de 1000 m, unde fenomenele specifice iernii favorizează depunerea unui strat consistent de zăpadă, care, totuși, fluctuează ca durată și ca grosime în funcție de variațiile climatice care afectează regiunea. Analiza potențialului nivologic s-a bazat pe observațiile efectuate în perioada, 2018-2022, asupra fenomenelor de iarnă și asupra depozitelor de zăpadă, iar datele obținute au fost corelate cu caracteristicile morfometrice ale reliefului, în final stabilindu-se suprafețele optime pentru anumite activități sportive și agrementale.

Cuvinte cheie: *cuvertură de zăpadă, depozit de zăpadă, strat fiabil de zăpadă, secțiune prin zăpadă, profil stratigrafic, sporturi de iarnă, agrement de iarnă, sezon de iarnă, schimbări climatice, bonitarea terenului*

Introduction

Nivology is a branch of meteorology that studies the physical and chemical characteristics of snow, namely: density, hardness, stability, changes in state, crystallography, and the influence of atmospheric conditions (pressure, temperature, wind, precipitation, evaporation, sublimation, condensation) which It affects its stability, favoring the onset of avalanches.

Snow is a solid, winter-specific atmospheric precipitation, formed by the deposition on the ground of snowflakes resulting from frozen water crystals. The succession of several episodes of snow causes the formation of a layer of snow, which has several functions:

- insulates and protects the soil from the atmosphere;
- reflects solar radiation;
- reduces the roughness of the ground;
- melting increases soil moisture and river flow;
- ensures the environment for winter sports activities;
- is a tourist attraction and favors the practice of specific leisure activities.

As a result of repeated snowfalls during the winter, the snow deposit is formed, consisting of several layers, which are very changeable and unstable. Its transformations begin immediately after deposition on the ground, it is very sensitive to external influences coming from the atmosphere (frost, melting, wind).

In recent decades, we have witnessed many fluctuations in terms of winter phenomena and the amount of snow deposited, a fact induced by climate change affecting the planet. For Europe, snow-rich periods are linked to the presence of humid Atlantic and Mediterranean air masses, and dry periods are caused by high-pressure air masses (polar-temperate, arctic) coming from the east and north of the continent.

These fluctuations have had important repercussions on sports competitions and leisure activities. In the last 5-10 years, many sports competitions have been held, mostly on artificial snow, and low amounts of snow and melting glaciers threaten the future of tourism in the mountainous areas of the planet (https://www.nationalgeographic.com/environment/article/alps-ski-resorts-desperately-battling-climate-change-local-resistance).

In Romania, according to ANM, in January and February of 2022, the thickness of the snow layer in the Carpathians, at over 1400 m, exceeded 50 cm, as follows: 160-215 cm at Bâlea-Lac (Făgăraș Mountains); 130 cm at the top. Omu (Bucegi Mountains); 120-144 cm at peak. Tarcu (Tarcu Mountains); 65 cm in Parang (Parang Mountains); 89-95 cm at the top. Răchitiș Călimani (Călimani Mountains); 75 cm at Lăcăuți (Vrancea Mountains); 59-84 cm at Ceahlău-Toaca (Ceahlău Mountains); 54 cm at Iezer Station (Rodna Mountains); 54 cm in the Bucin Pass (Gurghiu Mountains); 60-80 cm at Stâna de Vale in (Vlădeasa Mountains) (https://www.climbromania.com/IstoricNivo.aspx#ShowImage).

For sports and leisure activities to take place in optimal conditions, a reliable layer of snow is needed. For high mountains (above 2000 m) the reliable snow layer is considered to have a thickness of 30-50 cm, at least 100 days a year, in 7 of 10 winters, from December 1 to April 15 (Elsasser, Messerli, 2001). For the mountains in Romania, included in the category of medium and low mountains, we consider that the reliable layer of snow, at over 1000 m, is distinguished by thicknesses of 30-50 cm, at least 75 days a year, from January 1 to March 15.

Methodology

To carry out this study, the following methodological steps were followed:

- consultation of works related to the area of the Bârgău Mountains (Bîca, 2012; Naum, Butnaru, 1984; Rusu, 1998);
- consulting snowology and the impact of climate change on tourism and sports (Beniston, 1997; Bigano et al., 2005; Brugnot, 2017; Elsasser, Messerli, 2001; Fang et al., 2021; Gonseth, 2013; Hallmann et al. al., 2012; Hammond et al., 2018; Martin et al., 2021; Marty, 2013; Moen, Fredman, 2007; Neuvonen, Sievänen, Fronzek, 2015; Nicholls, 2006; Petrović, 2013; Pütz, Gallati, Kytzia, 2011; Rixen et al., 2011; Roussillon-Nadal, 2014; Scott, McBoyle, 2007; Scott, Dawson, Jones, 2008; Steiger, Scott, Abegg, 2019; Weaver, 2011; Zeng et al., 2018);
- performing nivological observations in the period 2018-2022, which aimed at the distribution, thickness, duration, and stability of the snow layer, the stratigraphy of snow deposits, metamorphic transformations of snow, as

well as the quality of snow deposits to capitalize on them in sports activities and leisure;

- a collection of meteorological data from the automatic stations installed in the localities of Piatra Fântânele, Lunca Ilvei, and Prundu Bârgăului for the period December 2021-February 2022;
- geomorphometric and morphographic analysis of the relief (energy, fragmentation, orientation, orographic structure), based on the topographic map of Romania, scale 1: 25000;
- performing observations on the recreational activities practiced within the mountainous area;
- performing sections through snow deposits, in certain representative points (peaks, slopes, plateaus);
- Land improvement by delimiting areas and land surfaces, depending on the characteristics of the snow, for their capitalization through various leisure activities (ski touring, hiking, snowshoeing, sleigh rides).

From a methodological point of view, the paper makes several contributions to the study of snow, namely:

- correlation of the characteristics of snow deposits with the optimal surface type for a certain sports and leisure activity;
- analysis of the stratigraphic profile to establish the favorable parameters for the capitalization of snow in tourism;
- land improvement on specific sports and leisure activities (determination of the tourist value of a land area, based on certain criteria).

Study area

The Bârgău Mountains are located in the northern group of the Eastern Carpathians, between the Someşul Mare valley to the north, the Dornelor Depression to the east, the Bistriţa valley to the south, and the Bistriţa Hills to the west (fig.1). The major relief of the mountainous area is represented by weakly undulating surfaces, modeled on sedimentary formations (sandstones, marls, clay), with altitudes between 1000-1200 m, above which jump intrusive magmatic massifs, made of andesites, with altitudes between 1000-1600 m (Heniu Mare peak, 1611 m). The mountain building is fragmented longitudinally by valleys tributary to Someşul Mare (Ilva, Leşu), and Bistriţa (Bârgău). Due to the low altitudes, the degree of humanization of the mountainous area is high, the settlements being located in valleys, where access is easy (fig.2).

In terms of climate, the Bârgă Mountains are characterized by a temperate-mountain climate of medium mountains (1000-1600 m), with average winter temperatures between -4^{0}C and -6^{0}C (between 1000-1600 m), average daily temperatures below 0^{0}C, between October 1 and April 1, and average annual rainfall between 700-800 mm below an altitude of 1000 m (e.g. Tihuța (897 m) 888 mm; Colibița (793 m) 789 mm; Poiana Ilvei (490 m) 672 mm; Prundu Bârgăului (465 m) 778 mm), and 800-1000 mm at over 1000 m altitude. The absolute minimum temperatures recorded were -34.3^{0}C at Poiana Stampei and -29.4^{0}C at Prundu Bârgăului (1950-1990), and the number of frosty days (minimum temperatures below 0^{0}C) was 179.4C at Poiana Stampei.

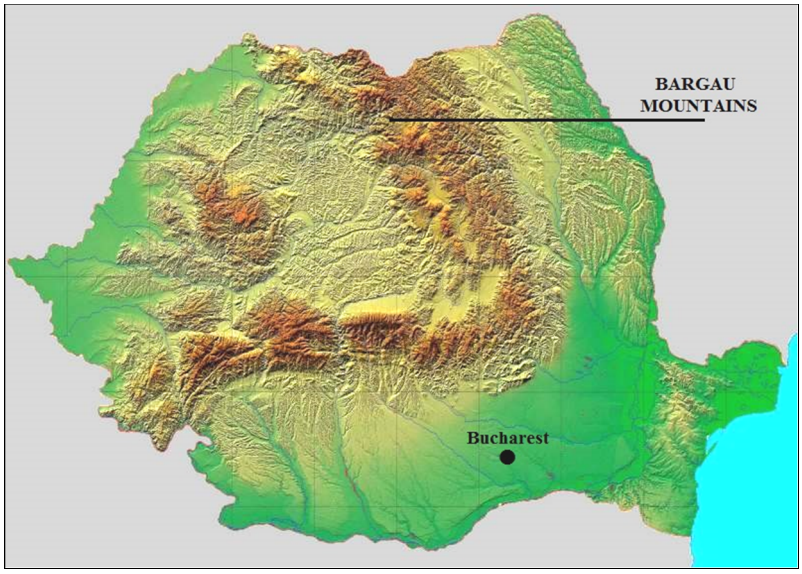

Fig. 1. The geographical position of the Bârgău Mountains in the Romanian Carpathians (source: https://greatnews.ro/wp-content/uploads/2015/08/harta-fizica-a-romaniei.jpg-with changes)

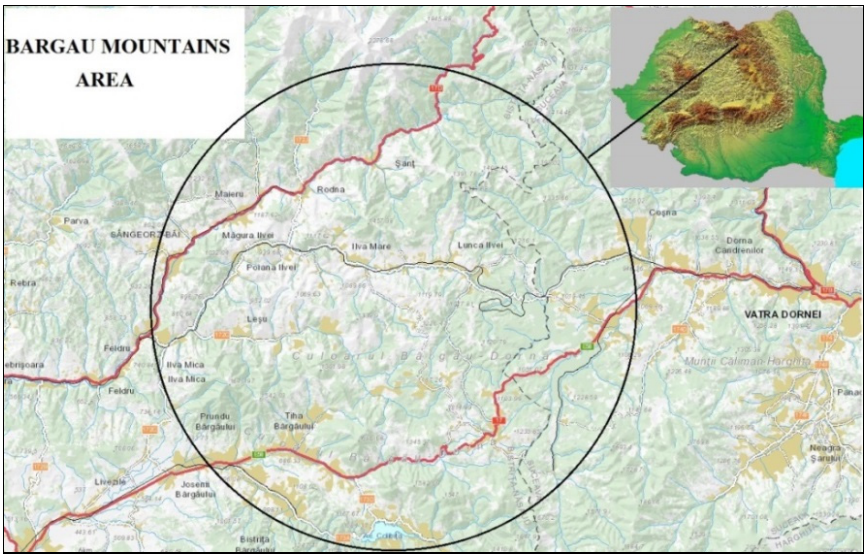

Fig. 2. The limits of the Bârgău Mountains
(source: INIS Viewer-with changes)

The permissiveness of the relief and the snow potential are elements that established the Bârgău Mountains as a favorable location for organizing sports competitions, such as cross-country skiing, in the 7th and 8th decades of the twentieth century. Based on this fact, in recent years these sports competitions have been resumed (e.g. The cross-country skiing and biathlon festival in Piatra Fântânele) and new ones have appeared, which make full use of the snow layer (e.g. The mushing competition from Piatra Fântânele).

Results and discussions

The snow potential of a region includes all the conditions induced by the presence of snow to capitalize on it through winter-specific sports and leisure activities (hiking, snowshoeing, cross-country skiing, tubing, sleigh ride, horse-drawn sleigh rides). It is important to establish the snow potential of the Bârgău Mountains, because, due to the permissive relief and the existing roads, it is a mountain unit accessible to tourists, has a high degree of humanization, has adequate tourist infrastructure (roads, tourist pensions), especially in the two resorts of local interest Colibița and Piatra Fântânele, and has a vocation for practicing winter sports and leisure activities (eg Piatra Fântânele-Tihuța Pass area).

In general, the winter environment of the Bârgău Mountains is distinguished by the following meteorological elements:

a) The period with specific winter phenomena:
-freeze: November-April;
-snow: November-April;
-blizzard: January-February;
-snow layer: December-March;

b) The period with continuous snow cover:
-January, February;

c) The period with a discontinuous layer of snow:
-December, March;

d) The period with spring snow:
-March, April.

Depending on the climatic changes registered at the global and regional levels, the winters in the Bârgău Mountains differ in snow level, from one year to another, but the specific manifestations of winter, regardless of their intensity, are present at over 1000 m altitude (table 1).

Table 1. Winter phenomena in Bârgău Mountains between 2018-2022 years

Year	Falling snowflakes period	Duration of continuous snow cover (days)	Average snow layer thickness (cm)
2018-2019	15.12.2018-01.03.2019	01.01.2019-25.02.2019=56	60
2019-2020	02.12.2019-22.03.2020	03.01.2020-20.02.2020=48	25
2020-2021	19.11.2020-14.04.2021	05.01.2021-25.02.2021=51	30
2021-2022	30.11.2021-17.04.2022	10.01.2022-10.03.2022=59	67

(Source: personal observations)

For the period December 2021-February 2022, the data provided by the automatic weather stations, located in Tihuța Pass, Lunca Ilvei and Prundu Bârgăului, highlighted the following meteorological parameters:

- average temperature: -3,6^{0}C in Tihuța Pass, -2,6^{0}C at Lunca Ilvei, -1,4^{0}C at Prundu Bârgăului;

- minimum temperature: -25,3^{0}C at Lunca Ilvei, -19,6^{0}C at Prundu Bârgăului, -15,4^{0}C in Tihuța Pass;

- maximum temperature: +9,2^{0}C at Prundu Bârgăului, +8,2^{0}C at Lunca Ilvei, +6,4^{0}C in Tihuța Pass;

- minimum temperature below freezing (-10^{0}C): 27 days at Lunca Ilvei, 16 days in Tihuţa Pass, 15 days at Prundu Bârgăului;

- average amount of rainfall: 60 mm at Lunca Ilvei, 47,5 mm at Prundu Bârgăului, and 120 mm at Piatra Fântânele;

-wind speed: 60,5 km/h at Tihuţa Pass, 58,7 km/h at Prundu Bârgăului, and 27,7 km/h at Lunca Ilvei.

For the study of snow deposits on the Bârgău Mountains, several sections were carried out in February-March, in the observations period, in a series of relevant places, at over 1000 m altitude, such as flat surfaces, slopes with northern exposure, and slopes with southern exposure (Table 2). The detailed analysis of the snow deposits revealed the following snow features:

- the individual thickness of the sections was between 60-110 cm, and the average thickness of the snow deposits was 67 cm;

- the stratigraphy of the deposits was made up of 5-8 layers of snow, separated by crusts (fig. 3).

Fig. 3. Snow stratigraphy in Poiana Vulturilor (Bârgău Mountains).
We can see the snow layers delimited by crusts
(source: author)

These crusts formed due to melting during the day and freezing of the deposited snow layers during the night. Everywhere, the base layer was frozen and hard, the middle layers had lower hardness, medium granulation, and ice structures (lenses, columns, etc.), and the top layer came in the form of wind plates;

- the stability of snow deposits on open slopes was high, in general, except on slopes with slopes of more than 40 degrees.

Table 2. Quantitative characteristics of the sections made through the snow deposits in the Bârgău Mountains

Current nr.	Geographic place	Geomorphologic surface	Altitude m	The thickness of the snow deposit cm	The stratigraphy of snow deposits
1	Perşa Mountain	Plateau	1400	110	8
2	Măgura Corni-Poiana Berengenilor	Plateau	1200	100	6
3	Măgura Neagră	Northern slope	1100	80	6
4	Miroslava Mountain Poiana Vulturilor	Eastern slope	1250	100	8
5	Măguriţa Mountain Poiana Andreichii	Southern slope	1100	80	7
6	Căsaru Mountains Poiana Tomnaticului	Southern slope	1200	100	6
7	Miroslava Mountain Poiana Făget	Southern slope	1250	60	5
8	Heniu Mountain Poiana Muncel	Northern slope	1300	80	6
9	Dealul Blajei	South-Western slope	1300	80	7
10	Dealul Toader	Plateau	1100	60	7

Given these snow characteristics, in the next stage, we proceeded to the delimitation of optimal land areas for certain recreational activities (fig. 4). For this, we resorted to the analysis of the relief, based on certain criteria, such as fragmentation, energy, slope, and exposure of surfaces, as well as the inventory of current leisure activities.

Finally, the following land areas, leisure, and sports activities for which it is recommended have been established:

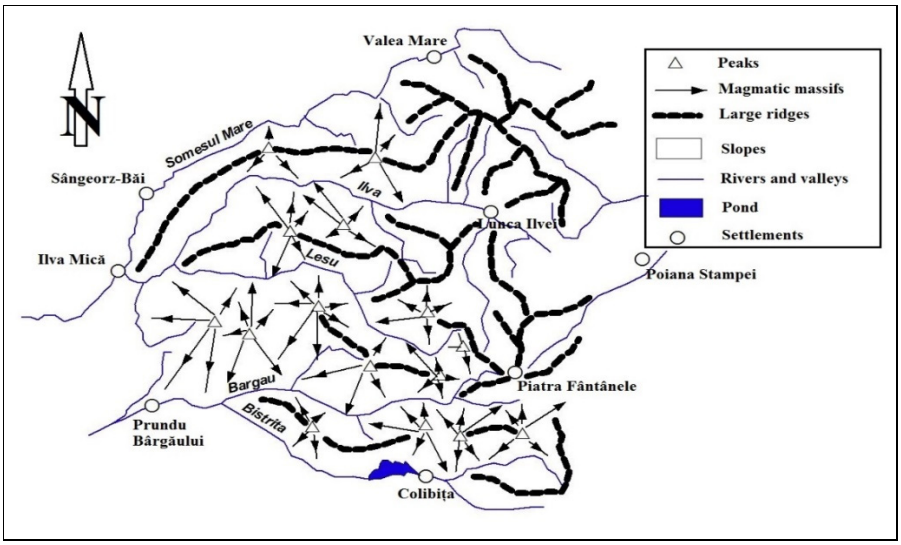

Fig. 4. The main geomorphological surfaces for winter sports and recreational activities in Bârgău Mountains

A) Geomorphological units:

a) Erosional levels:

- the northern, northeastern, eastern and southern area: Valea Ilvei-Valea Coşnei, Piatra Fântânele-Valea Ilvei-Valea Leşului, Plaiul Dosului-Brazii Buni-Strâmba (fig. 5);
- recommendation for backcountry skiing, cross-country skiing, snowshoeing, running, horse-drawn sleigh rides;

b) Magmatic massifs:

1) Northern area:

- Bucnitori, Măgura Mare, Măgura lui Arsente, Chicera Mare, Chicera Mică;
- recommendation for hiking, snowshoeing, and backcountry skiing;

2) Central area:

- Heniu, Dealul Bârgău, Dealul Pietrei, Oala, Lăzăroaia, Zimbroaia, Tăşuleasa, Răchiţeaua (fig. 6);
- recommendation for hiking, snowshoeing, running, horse-drawn sleigh rides, ski touring;

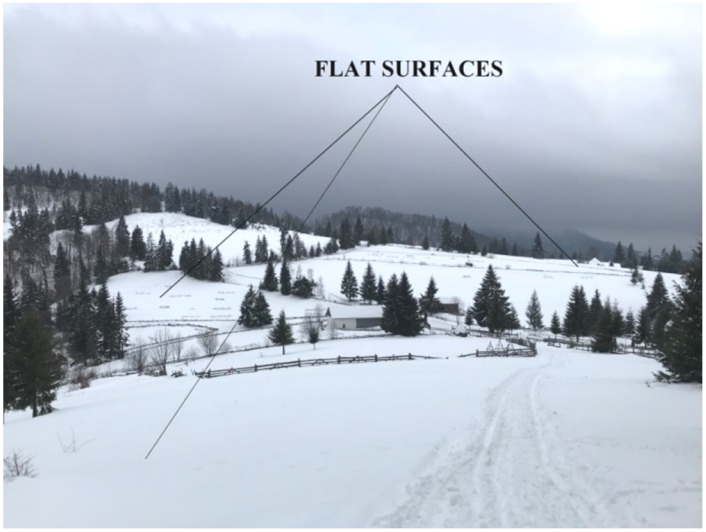

Fig. 5. Erosional levels/Flat surfaces on Ciosa Summit
(source: author)

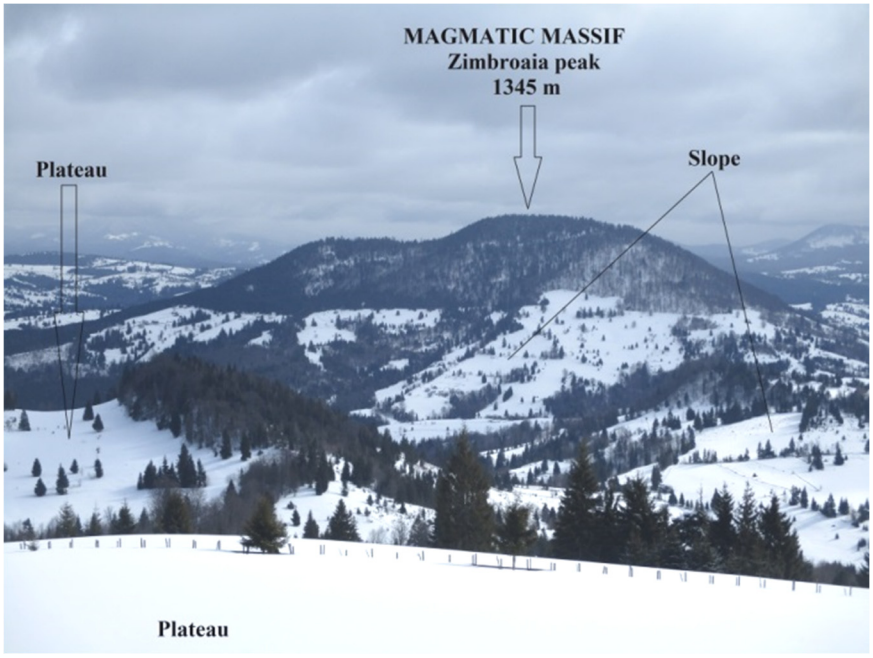

Fig. 6. Magmatic massif and surfaces around it
(source: author)

c) Southern area:
- Căsaru-Măguriţa-Arşiţa-Dealul Ariilor;
- Cornu-Buba;
- Dealul Puşcă-Ariniş-Arşiţa Mare-Bridirei;
- recommendation for hiking, snowshoeing, ski touring;

B) Functional landforms units:

a) Peaks:

- are distinguished by a thick layer of snow, sometimes affected by blizzard (60-300 cm), which is kept until April;
- recommendation for hiking and viewpoints: Heniu, Oala, Căsaru, Măgura Neagră, Dealul Blajei etc.;

b) Summits:

- characterized by a sufficiently thick layer of snow (30-80 cm), forest and agricultural roads;
- recommendation for hiking, ski touring, cross-country skiing, running, horse-drawn sleigh rides;
- distribution: the areas of Valea Ilvei-Valea Coşnei, Piatra Fântânele-Valea Ilvei-Valea Leşului, and Plaiul Dosului-Brazii Buni-Strâmba (fig. 7);

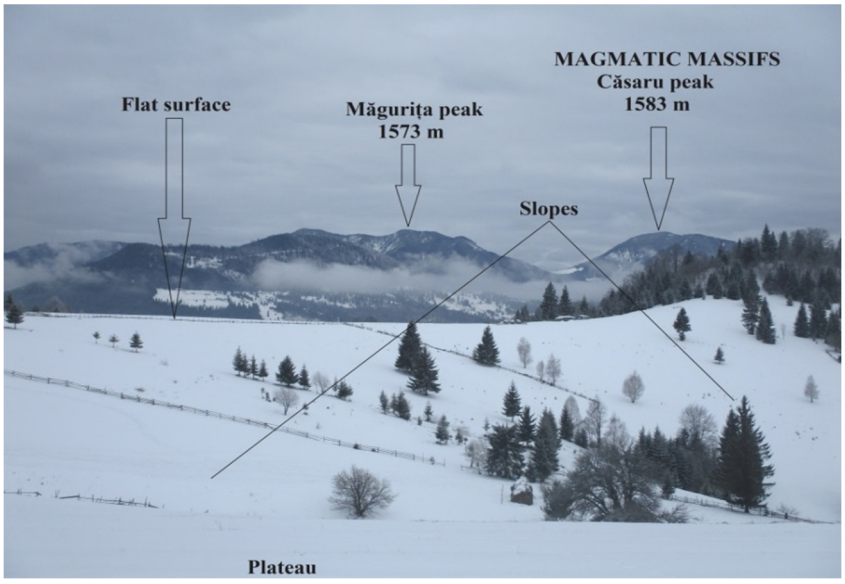

Fig. 7. Flat surfaces on Prislop summit
(source: author)

c) Slopes:

- presents a thick layer of snow (30-120 cm), which is stored for a long time on the surfaces facing north, northeast, and northwest, and on many forest and agricultural roads;
- recommendation for hiking, snowshoeing, and ski touring (fig. 8).

d) Valleys:

- have a sufficiently thick layer of snow (30-60 cm), and numerous forest and agricultural roads;
- recommendation for hiking, horse-drawn sleigh rides, cross-country skiing, ski touring, and running.

Fig. 8. Hiking on Dealul Blajei
(source: author)

Regarding the competitions that are organized within the Bârgău Mountains, we mention the most important ones, held in the winter of 2022, respectively:

1. Cross-country skiing and biathlon festival (fig. 9):

- February, 10th edition;
- location: Piatra Fântânele, Păşunea Rusului;
- participants: 100 (children, juniors, seniors, veterans);
- cross-country skiing competition.

Fig.9. Cross-country skiing and biathlon festival at Piatra Fântânele poster (source: https://www.observatorbn.ro/2022/02/04/festival-de-schi-fond-si-biatlon-la-piatra-fantanele-in-acest-weekend/)

2. The competition of sleighs pulled by dogs Drumul Romanilor:

- January, 5th edition;
- location: Piatra Fântânele, Păşunea Rusului and Drumul Romanilor;
- participants from several European countries (Croatia, Austria, Hungary, Bulgaria, Poland, Switzerland, Slovakia).

Conclusions

Based on the data presented, it results that the Bârgău Mountains area has a high snow potential if the winters are characterized by specific intense phenomena, respectively heavy snow and low temperatures for a longer

period of time. The snow conditions, associated with the permissive relief (large undulating surfaces, dominated by intrusive magmatic massifs) recommend this area for many recreational sports activities (hiking, snowshoeing, cross-country skiing, cross-country skiing, horse-drawn sleigh rides) and even competitive (cross-country skiing, sledding, dog pulling), which is an important factor for the tourist development of the region.

In this context, it is required that the county authorities (Bistriţa-Năsăud County Council, Bistriţa-Năsăud County School Inspectorate) and local authorities (the town halls of Tiha Bârgăului, Bistriţa Bârgăului, Prundu Bârgăului, Ilva Mică, Poiana Ilvei, Măgura Ilvei, Ilva Mare, Lunca Ilvei, Leşu, Rodna, and Şanţ communes), as well as various organizations (sports associations, tourist associations, social and ecological associations) with interests in tourism, or local providers of tourist services to develop strategies for planning and tourism capitalization of the Bârgău Mountains.

Such an approach is more than necessary, because in the localities of the Bârgău Mountains, which have tourist pensions, and in the related resorts (Sângeorz Băi, Colibiţa, Piatra Fântânele) many visitors arrive, who in the absence of attractive facilities and activities opt for short stays.

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