STUDIA GEOMORPHOLOGICA CARPATHO-BALCANICA
vol. LIII–LIV, 2019–2020: 85–111 PL ISSN 0081-6434

PIOTR KŁAPYTA[1], KAZIMIERZ KRZEMIEŃ[1], ELŻBIETA GORCZYCA[1],
PAWEŁ KRĄŻ[2], LIDIA DUBIS[3] (KRAKÓW, LVIV)

GEOMORPHOLOGIC EFFECTS OF HUMAN IMPACT ACROSS THE SVYDOVETS MASSIF IN THE EASTERN CARPATHIANS IN UKRAINE

Abstract: Contemporary changes in the natural environment in many mountain areas, especially those occurring above the upper tree line, are related to tourism. The Svydovets Massif, located in the Eastern Carpathians in Ukraine, is a good example of an area that is currently experiencing intense degradation. The highest, NE part of this area is crisscrossed with numerous paths, tourist routes, and ski trails. The strong human impact the area experiences is occurring simultaneously with the activity of natural geomorphologic processes. The processes occur with the greatest intensity above the upper tree line. The development of the discussed area has been occurring gradually since the early 20th century. It started when the region belonged to Austria-Hungary, then Czechoslovakia, and subsequently the USSR. Now that it belongs to independent Ukraine the level of tourism-related development has sharply increased. Comparing it to other mountain areas, such as the Tatras, the Alps, or the Monts Dore Massif in France, the Svydovets Massif is being reshaped much more rapidly due to the damage caused by human impact.

Keywords: human impact, tourism-related deterioration of mountains, high mountains, Svydovets, Eastern Carpathians, Ukraine

INTRODUCTION

Man plays a huge role in the reshaping of the geographic environment and human activity is especially noticeable in the mountains. Contemporary changes in the environment in many mountain areas, especially those located above the tree line, are frequently associated with tourism, the effect of which is observed in the form of numerous tourist facilities such as mountain lodges, hotels, cable cars, aerial trams, ski lifts, groomed ski trails, and tourist paths and other routes (Fidelus et al. 2017). The development of summer and winter tourism causes increased changes in the landscape including transformations of relief. The activity of natural geomorphologic processes and man-induced processes occur in unison (Krzemień 1995, 2008, 2010; Gorczyca 2000; Gorczyca, Krzemień 2012; Fidelus 2014, 2016; Fidelus et al. 2017). Numerous erosional and accumulation landforms develop on mountain slopes and valley floors as an effect of these complex interactions. Therefore, excessive deterioration of mountain relief occurs. The problems just mentioned already occur in various mountain areas all over the world, notably in the Alps (Giessbel 1988; Growcock 2005; Pelfini, Santilli 2006), in the mountains of Japan (Tsuyuzaki 1994), in the Rocky Mountains in the USA (Wilson, Seney 1994), in the Massif Central in France (Candela 1982; Veyret et al. 1990; Krzemień 1995), and also in the Bucegi Mountains in Romania (Mihai et al. 2009), the Andes (Barros et al. 2015), the Western Carpathians (Krusiec 1996; Łajczak 1996, 2002; Prędki 1999, 2000; Gorczyca, Krzemień 2002, 2009, 2010; Buchwał, Fidelus 2008; Fidelus-Orzechowska et al. 2017) and also in the Sudetes in southwestern Poland (Kasprzak, Traczyk 2005). Some efforts are being made to limit the negative effects of human impact on the environment in many mountain areas (Rochefort, Swinney 2000; Fidelus et al. 2017). However, it is not everywhere that such efforts are taking place, especially not outside of legally protected areas (Rozhko 2000; Zinko, Hnatiak 2003; Hnatiak 2004a, b, 2018). Human-induced environmental degradation in the Eastern Carpathians is often shyly admitted, even in strictly protected areas (Zinko, Hnatiak 2009; Rozhko et al. 2011; Brusak 2018). The Svydovets Massif, located in the Ukrainian part of the Eastern Carpathians, is an example of an area that is being intensely degraded due to unregulated, spontaneous development of the tourism sector. The relief and natural geomorphological processes in this area were described in our previous study (Kłapyta et al. 2020). The purpose of this study was to determine:

- the degree of deterioration of the natural environment of the examined massif due to human impact,
- the scale of the human-induced change in the relief of the massif,
- potential methods of limiting human-induced erosion in the Svydovets Massif based on experiences from other geographic areas.

RESEARCH METHODS

The field mapping was performed in the years 2009 and 2019, supplemented with an analysis of topographic maps at the scale of 1:25,000, and orthophotomaps available in the Google Earth application, and the ALOS PALSAR digital terrain model at a resolution of 25 m (source:www.eorc.jaxa.jp), taken all together became the basis for this research work. Fieldwork involved identifying parameters of the main types of paths and roads: ridgetop, mountain or hill slope and valley floor, and of groomed ski trails, using specialized mechanical equipment. Cross-sections, width measurements, measurements of the depth of incisions, and documentation such as sketches of terrain and photographs were prepared for selected sections of the routes mentioned above. The course of paths, roads, and ski trails, and locations of ski lifts were mapped based on remote sensing data that were verified in the field. The pattern of the present-day upper tree line was presented in digital form based on its position on a satellite orthophotomap of 2018 using ArcMap 10.6 software. This way the length of the tree line was calculated along with its average, maximum, and minimum elevation, and the area of the bounded region above the tree line. Moreover, historical (archival) materials and old maps were studied to determine how the tree line changed its position over time. The intensity of the environmental impact of herding was evaluated qualitatively basing on a comparison of the number of grazed meadows in the interwar period (Kubijowicz 1937) with the present number of grazed meadows. The present number of meadows used for grazing was determined based on the presence of herdsman's buildings and traces of herdsmen activity on satellite photos from 2019, available in Google Earth.

STUDY AREA

The Svydovets Massif (1,883 m of elevation) has an area of 1,060 km^2 and is the second, after Chornohora (2,061 m a.s.l.), the highest mountain range in the whole Outer Flysch Carpathians. The Svydovets forms a compact and separate mountain range located in the middle part of the Eastern Carpathians (Kondracki 1989). The Svydovets is located to the south of the main Carpathian ridge, which serves as the water drainage divide between Tisa and Dniester river catchment areas (Fig. 1). The massif is located in the Transcarpathian province (Zakarpattia Oblast) and Rakhiv county in Ukraine.

The geomorphologic boundaries of the Svydovets Massif are associated with deep valleys of tectonic origins as well as structural depressions formed due to lower resistance of geologic formations. The Svydovets is adjacent to the Gorgany Range to the north and northwest (Fig. 1). The Svydovets' eastern border with the Chornohora and Maramures mountains runs along the deeply incised valley of the Black Tisa and Tisa rivers. The Svydovets borders both the Maramures Mountains and Maramures intermontane depression to the south (Fig. 1). The boundary between the Svydovets and the Maramures Depression corresponds to the contact zone between the flysch formations of

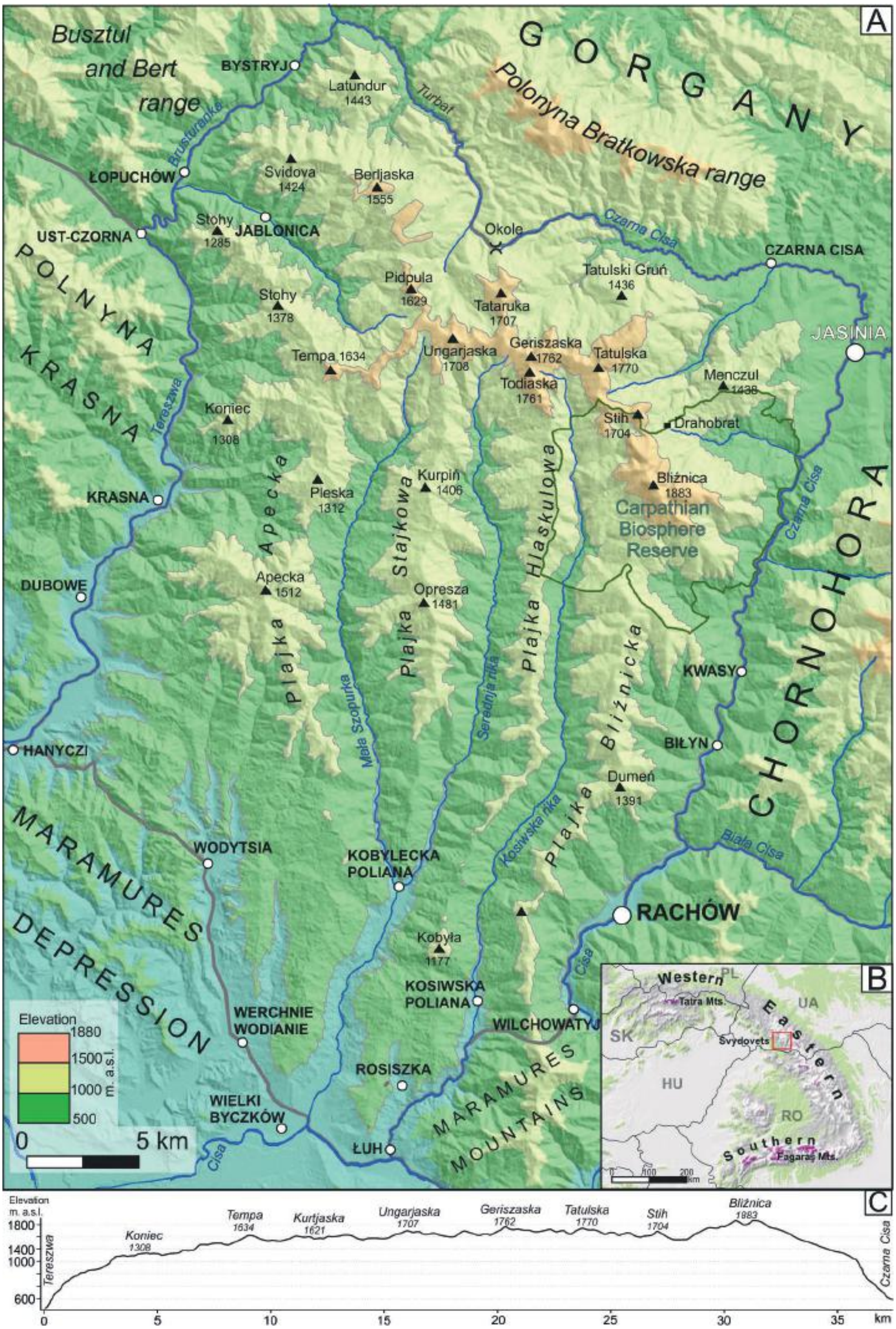


Fig. 1. A – Location and physiographic boundaries of the Svydovets Massif according to J. Kondracki (1989) and P. Kłapyta et al. (2020). B – Location of the Svydovets on the background of the Carpathians. C – Longitudinal profile of the main ridge of the Svydovets

the Carpathians and Neogene molasses that fill the Maramures Depression. The western boundary, with the Polonyna Krasna Range, is formed by the deeply incised valley of the Teresva River (Fig. 1).

Atmospheric precipitation in the Svydovets massif is higher than that on the northern face of the Carpathians. About 40% of the precipitation occurs in the summer months. The annual precipitation total at the foot of the eastern face of the Svydovets (Jasinia) is 1,074 mm (Lanko et al. 1969; Anan'iev1981), whereas on ridges it is estimated to be about 1,400 mm. The Svydovets region encompasses the largest area of montane grasslands (called polonynas) in the Ukrainian Carpathians. The present-day tree line runs at a relatively low elevation in the entire massif, on average at 1,300 m (Malynovskyi 2003a, b). Human impact on the environment caused the upper tree line to gradually shift downwards over time, and in effect, it is found at its present elevation. The position of the tree line became lowered by 100 to 200 meters (Holubets 1978), and even by 200 to 300 meters (Malynovskyi 2003a, b) concerning its original position.

The southeastern part of the studied massif (surface area: 8,687 ha) is the westernmost part of the Carpathian Biosphere Reserve (Karpackij Biosfernyj Zapovidnyk), partly included in the UNESCO World Heritage and European Wilderness Network (The Svydovets Case, 2019). The Carpathian Biosphere Reserve was established in 1992 and assigned to the IUCN "Ia category" (Strict Nature Reserve) (World Database 2019), which means in practice that it is a "strictly" protected natural area reserved for scientific and monitoring purposes. The Svydovets area was also included in the international Emerald Network in November 2018 for the sole purpose of biodiversity conservation as well as to "synchronize" Ukrainian environmental legislation with the legal standards of the European Union (The Svydovets Case, 2019).

HUMAN IMPACT ACROSS THE SVYDOVETS MASSIF

ANIMAL HERDING ACROSS THE SVYDOVETS MASSIF

The herding of cattle and sheep, which relied on summer grazing across mountain pastures, has been the most important, traditional form of human economic activity in the Eastern Carpathians since the 14th century (Lavruk 2005). The area's herding-centred economy has greatly contributed to any changes in its natural environment (Troll, Sitko 2006). The Svydovets Massif used to be one of the most important areas of high mountain animal herding in the Eastern Carpathians, which relied on vast montane grasslands used as pastures, forming a seminatural elevational landscape zone created by destroying subalpine shrubs and forests in the process (Troll, Sitko

2006). The Svydovets Massif is an area with the largest expanse of meadows in the Ukrainian part of the Carpathians. Mountain meadows presently cover 110.91 km^2, which is 10.5% of the area of the massif (Fig. 2). Natural alpine meadows are located exclusively in the region of Bliźnica (elevation: 1,883 m a.s.l.). According to data sets remaining from the 1930s (Kubijowicz 1937), the number of animals herded across the Svydovets was 29,880, which made it the largest herding area in the Ukrainian Eastern Carpathians (Tab. 1).

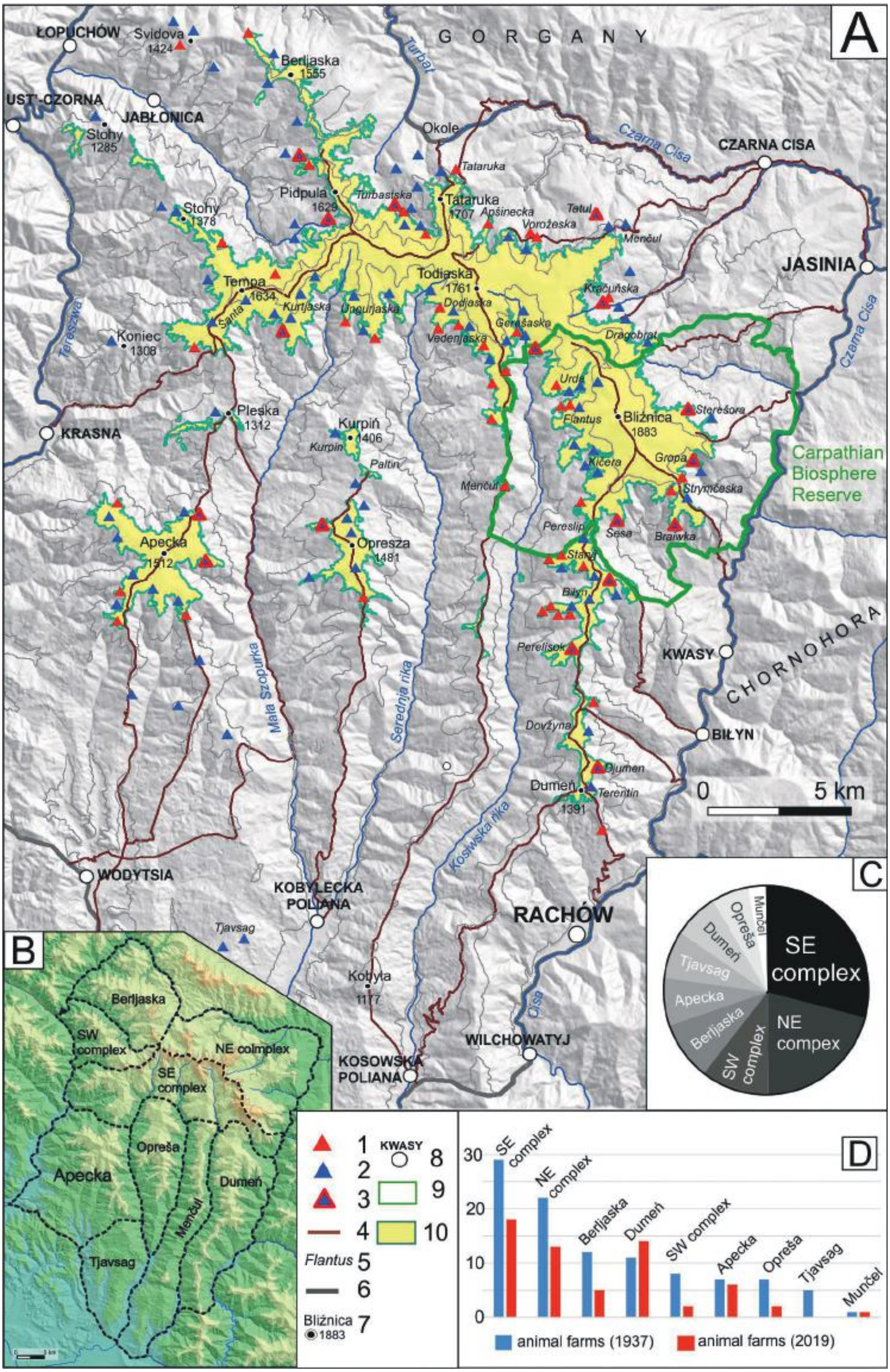
Sheep and goats grazing on the pastures played a key role in the herding-centred economy of the region, and their number (73% of the total number of grazing animals) was larger than the number of heifers (18%), cows (5%), and horses (4%) (Tab. 1) (Kubijowicz 1937). Traditional Hutsul sheep herding dominated in the Transcarpathian part of the Hutsul region, as 35% of the total number of sheep concentrated in that region (Lavruk 2005).

Table 1.

The number of grazing animals in the ranges of the Ukrainian part of the Eastern Carpathians in the interwar period according to W. Kubijowicz (1926, 1937). The PL – former Polish part of the mountains, CS – former Czechoslovak part of the mountains

Rank	Mountain range	Sheep and goats	Horses	Cows	Heifers	Total
2	Svydovets	21,590	1,270	1,590	5,430	29,880
1	Gorgany PL	21,220	–	8,130	–	29,350
3	Gorgany CS	17,630	950	470	4,320	23,370
4	Góry Czywczyńskie	13,200	920	730	2,320	17,170
5	Połoniny Hryniawskie	12,300	380	1,120	2,050	15,850
6	Borżawa	10,860	1,210	20	3,710	15,800
7	Chornohora PL	12,800	450	590	1,510	15,350
8	Polonyna Krasna	6,700	910		2,810	10,420
9	Chornohora CS	4,630	100	1,710	1,020	7,460
10	Góry Marmaroskie CS	6,020	70	280	360	6,730
11	Polonyna Rivna	–	670	40	2,270	2,980
Total area		125,460	6,710	14,680	25,170	17,2020

Fig. 2. Agricultural use of the Svydovets montane meadows, called polonynas, in the interwar period (according to W. Kubijowicz, 1937) and at present (A). Legend: 1 – montane meadows presently used for grazing, 2 – montane meadows used for grazing in the interwar period, 3 – montane meadows used presently and in the interwar period, 4 – main herding tracks used in the interwar period, 5 – names of the more important montane meadows, 6 – boundaries of the Svydovets Massif, 7 – important peaks, 8– towns and settlements, 9 – boundaries of the Carpathian Biosphere Reserve (the Svydovets Massif), 10 – area presently located above the upper tree line. B – named groups of the Svydovets montane meadows according to W. Kubijowicz (1937). C – breakdown of the number of grazing animals by grazing area on Svydovets meadows in the interwar period – according to W. Kubijowicz (1937). D – number of animal farms in particular grazing areas, called complexes, in the 1930s and at present


A
GORGANY
ŁOPUCHÓW
UST'-CZORNA
JABŁONICA
CZARNA CISA
JASINIA
KRASNA
KWASY
CHORNOHORA
BIŁYN
WODYTSIA
KOBYLECKA POLIANA
RACHÓW
WILCHOWATYJ
KOSOWSKA POLIANA
Carpathian Biosphere Reserve
0
5 km
B
Berljaska
SW complex
NE colmplex
SE complex
Opreša
Apecka
Dumeń
Menčul
Tjavsag
C
SE complex
NE compex
SW complex
Berljaska
Apecka
Tjavsag
Dumeń
Opreša
Munčel
D
animal farms (1937)
animal farms (2019)
1
2
3
4
Flantus 5
6
Bliźnica 1883 7
KWASY 8
9
10

The Hutsuls used to inhabit the region and their economy focused on herding animals. A total of 102 animal farms were operated across the Svydovets – which were concentrated in nine meadows "complexes" (Kubijowicz 1937) (Fig. 2). The grasslands of the Svydovets were most intensively grazed by animals grazing on its southern face, where the meadows belonged to villages located in the Maramures Depression (Niżna Apsza, Hruszovo, Slatina, Teresva) and in the foothills of the massif (known as Kosovska Polana), located 40 to 50 km away, yet connected with it by the most important herding routes leading to the massif (Fig. 2).

The "complex" of meadows that were grazed by the largest number of animals in the interwar period was a group of meadows found on the southeastern face of the massif (Kubijowicz 1937), extending from the Koniec group of meadows in the west to the Bahriwka meadows in the east (Fig. 2), where the total number of grazing animals was 8,610, which comprised 29% of the total number of animals on the massif (Fig. 2C). The shepherding pressure in Svydovets range decreased since the 1990s as the result of the collapse of the socialist economic system (Kricsfalusy et al. 2008). At present, the scale of human impact related to animal herding is significantly decreased. The total number of animal farms has decreased by about 40% and differences have emerged in terms of the number and distribution of animal farms in the various groups of meadows (Fig. 2D). The only area, where the number of animal farms has increased is the Dumeń "complex" of meadows situated to the north of the town of Rakhiv (Fig. 2D). Animal farms are presently located in the elevation zone stretching from about 1,000 to 1,480 m a.s.l., whereas the greatest number of them are found in the elevation zone stretching from 1,300 m a.s.l. to 1,350 m a.s.l., as they tend to concentrate in the transition zone where the montane forest meets the subalpine elevation zone (Fig. 2).

THE LOWERING OF THE UPPER TREE LINE

The arrangement of elevational vegetation zones and the tree line (the upper tree line) in the Svydovets massif area were significantly changed by human economic activity (Nesteruk 2001). The average elevation, where the tree line is now found on the Svydovets, is 1,310 m a.s.l. The tree line runs at higher elevations on the northern face (1,385 m a.s.l.) than on the southern face (1,234 m a.s.l.). These atypical differences in tree line elevation are most likely related to additional lowering due to intense animal herding and grazing on the southern face of the massif. The original (climate-based) tree line has been almost destroyed across the Svydovets massif due to human impact (Nesteruk 2001; Malynovskyi 2003a, b). According to data published by K. Malynovskyi (2003a, b), the tree line in the Carpathians has been lowered by 200 to 300 m. Its original elevation range in the Svydovets may be found by tracing the highest preserved fragments of the original upper tree line at an elevation of 1,683 m a.s.l. on the northern face and at an elevation of 1,572 m a.s.l. on the southern face (Tab. 2), which correspond to values provided in the literature (Holubets 1978; Malynovskyi 2003a, b). The uppermost spruce forest on the southern face of the massif has been destroyed, and the upper tree line is formed by beech forest, the upper limit of which has shifted downwards to an elevation of 900 m a.s.l. on the southern face due to human impact. On the northern and northeastern face of the massif, the tree line is formed by spruce forest.

Table 2.
Characteristics of the upper tree line across the Svydovets massif (present state).

	Svydovets	N and NE face	S face
Length [km]	496.7	178	318.7
Average elevation [m a.s.l.]	1,309	1,384.6	1,234
Maximum elevation [m a.s.l.]	1,683	1,683	1,572
Minimum elevation [m a.s.l.]	900	1,101	900
Elevation range	783	582	672
Area above the upper tree line [km^2]	110.9	39.5	71.4

The lowering of the tree line is also associated with degradation of the subalpine zone originally covered by dwarf mountain pine (*Pinus mugho*) and green alder (*Alnus viridis*) which has also been lowered or entirely destroyed due to burning and forest clearing just as it is the case across much of the southern face (Nesteruk 2001). The natural subalpine zone was transformed into semi-natural grasslands with mat-grass swards (*Nardus stricta*) or communities dominated by blueberry (*Vaccinium myrtillus*) with very low plant diversity (Kricsfalusy et al. 2008).

The greatest role in the lowering of the tree line was played by herding. As much as 70% to 80% of animal farms within the Svydovets area are located in the belt area, where the montane forest borders the subalpine zone. This causes significant destruction of the forest by harvesting timber for both domestic and farm use. It is estimated that one animal farm harvests about 100 m^3 of timber during one season just to burn it for heating purposes (Nesteruk 2001). The lowering of the tree line could have significantly contributed to the increase in avalanche activity (Shushniak 2006), however, due to the lack of organized monitoring of avalanche processes in this area, no quantified data on avalanches are available.

During the 19th century mainly due to railway development large areas of beech forests were clear-cut and reseeded with particularly monodominant spruce stands which made forest to be more vulnerable to natural hazards (Kricsfalusy et al. 2008). Intensive exploitation of mountain forests in the Ukrainian Carpathians was recorded during the Soviet time. This lead to a marked reduction in the area of upper mountain forests and krummholz, as well as increased susceptibility to erosion and natural hazards (Kricsfalusy et al. 2008). In the 1950s, the proportion of forested land in the study area was the lowest for the last 200 years. A comparison of the tree line altitude in 1852 and 2000 AD in the Svydovets massif (Kricsfalusy et al. 2008), shows that the general area of montane grasslands decreased by 1094.4 ha (14.7%) and the altitude of the tree line became higher by 47.5 m.

THE TOURISM AND SKIING INDUSTRY

The first tourists and researchers appeared in the Svydovets massif area in the 19th century. The study area was part of the country of Austria-Hungary at the time – a country that existed until 1918. The possibility of exploration of the mountain terrain was made easier thanks to helping from local guides who were often also herdsmen and the availability of herdsmen' huts for lodging (Romer 1905; Dyląg 2018). The development of tourism in the area occurred gradually. The lodging facilities built and developed by the Hungarians at the end of the 19th century served as an early base for summer guests and spa patients coming primarily from the Austrian region of Galicia – visiting natural alkaline mineral water springs and swimming facilities in the settlement of Kwasy (Tiszaborkut) and Rakhiv (Akna Raho) (Fig. 1) (Gąsiorowski 1933). The names provided in parentheses are Hungarian names of towns. Numerous roads in the area, which were originally constructed for herding and forest management, were also used as tourist trails. Only the tourist paths leading to highest peaks had to be designed and developed from the ground up. Summer and winter tourism increased when the first tourist lodging facility was built over the Okole mountain pass (1,256 m a.s.l.) in the 1880s (most likely in 1889) by the Hungarian state forest service and inspired by MKE-UKV (Vosyka 1929; Goetel 1936; Dyląg 2018). After World War I the Svydovets area was assigned to Czechoslovakia. The KČST Turistický dům Hotel was built in the town of Rakhiv in 1932. It had 13 rooms and a hall with 400 seats. The hotel was developed further and expanded in 1938 when 17 rooms were added. Another tourist lodging facility was built in the higher parts of the Svydovets massif in 1935. The Utulnia KČST mountain lodge was built on Dragobrat glade below Bliźnica Mt. This tourist lodge was furnished with 12 beds (Dyląg 2018). The Dragobrat tourist lodge was built in 1956 and belonged to the Edelwejs tourist facility in Yasinya. The development of lodging facilities on Dragobrat site started in 1974 through a state-sponsored development program. However, the development plan was not implemented. In the 1980s the Svydovets area was the place where summer schools, training and camps for sportspeople were organized at the foot of Bliźnica Mt. A surface-type ski lift of the length of 1,000 m was built on the slope of Stih Mt. at the time. The rapid development of tourism in the region occurred in the 1990s, after the dissolution of the USSR when the Winter Sports Station was created on Dragobrat site. Today the area still lacks basic infrastructure, and a spatial development plan has not been accepted that would manage growth in the region. A network of asphalt roads is found only in the close vicinity of the Svydovets massif. On the massif itself, there are gravel roads or rutted dirt tracts leading tourists to higher elevations (Fig. 3). Old roads used by horse-driven vehicles in the past are now used by off-road vehicles and trucks (Photo 1). All the roads in the area are in effect degraded by the movement of vehicles and activity of geomorphic processes (Photo 1). This kind of human impact is a huge problem under present conditions, as it causes the degradation of relief across the studied massif. Land degradation occurs even in the vicinity of Bliźnica Mt. (1,883 m a.s.l.), which is a strictly protected area in Ukraine (Figs 1, 3) (Krzemień et al. 2019).

Photo. 1. Unpaved mountain road on the western slopes of the Stih Mt. (1,704 m a.s.l.) used to take tourists to a postglacial lake situated below the Todjaska Mt.

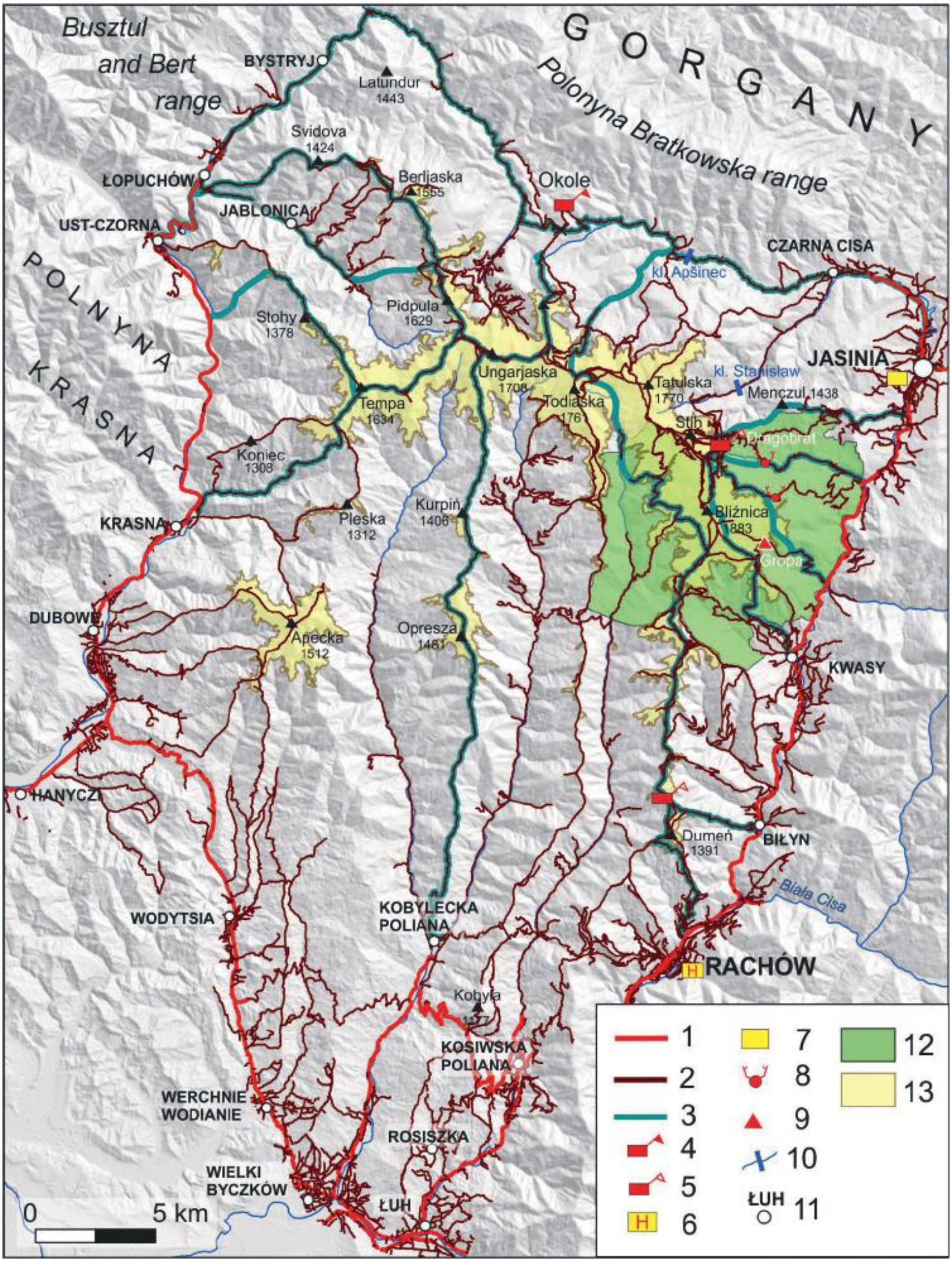


Fig. 3. The roads, tourist patches and tourist industry in the Svydovets massif (at present-day and during the interwar period). 1 – main paved roads, 2 – dirt roads, 3 – tourist trails in the interwar period, overnight lodging infrastructure in the interwar period: 4 – functioning mountain lodges, 5 – vacant mountain lodges, 6 – hotels, 7– overnight tourist lodges, 8 – state forest service lodges, 9 – herdsmen's shack lodges, 10– splash dams, 11 – towns and villages, 12 – boundaries of the Carpathian Biosphere Reserve, 13 – area above the upper tree line

About 70 hotels and 11 ski lifts with a total length of 8,550 m are currently operated on Dragobrat tourist center. Two longest chairlifts are 1,500 and 1,200 m long (Fig. 4). Other ski lifts are surface-type ski lifts. Some of the terrain used for skiing in the winter is used for competitive off-roading by local vehicles in the summer season. Thousands of tourists come to Dragobrat area in the winter season. According to local surveys, there are 4,000 to 4,500 tourists per day at a maximum, and according to official data, there are 3,000 to 3,500 (Department of Economic… 2020).

Commercial construction greatly intensified in the area in the first years of the 21st century. The construction of many buildings was begun but not finished. Now the unfinished buildings are decaying and overgrowing with wild vegetation. Hotel and restaurant buildings, which are currently being used by the tourism industry, range in quality from high to average. The layout of Dragobrat area as a built-up area remains quite chaotic.

Buildings are situated in an unplanned manner. They are not insulated, situated close to stream channels, or even on wet ground. Numerous problems may arise in the future for these very reasons. It appears that in the case

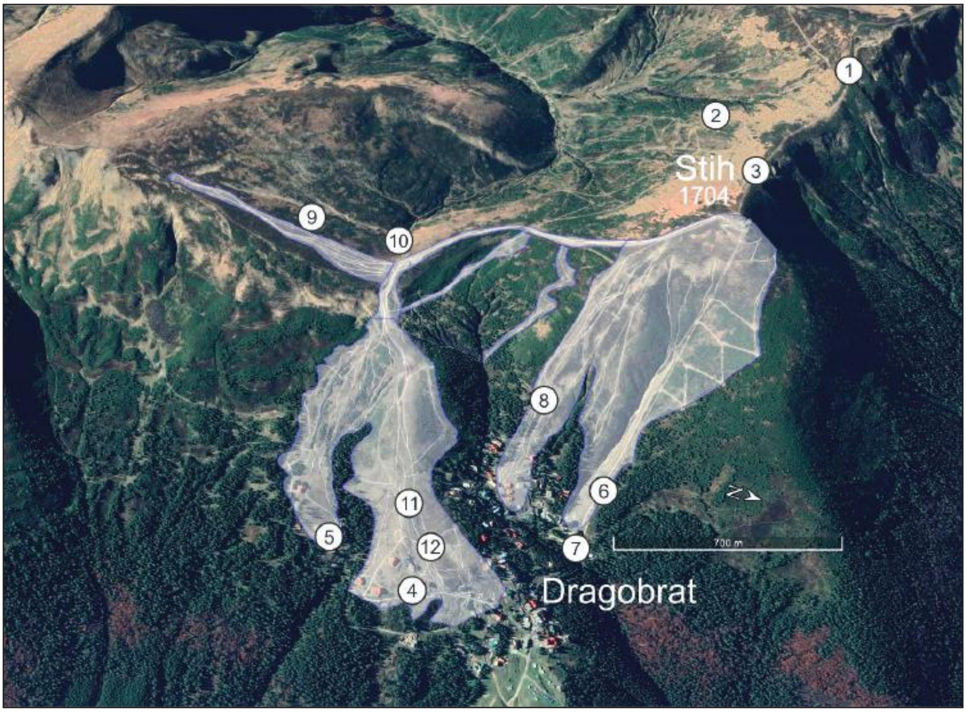


Fig. 4. Location of slopes and ridges, degraded by skiing, with a network of numerous roads and erosional incisions in the Dragobrat area; points 1 to 12 mark research sites and sites where photographs are seen in Figures 5–7 – were taken

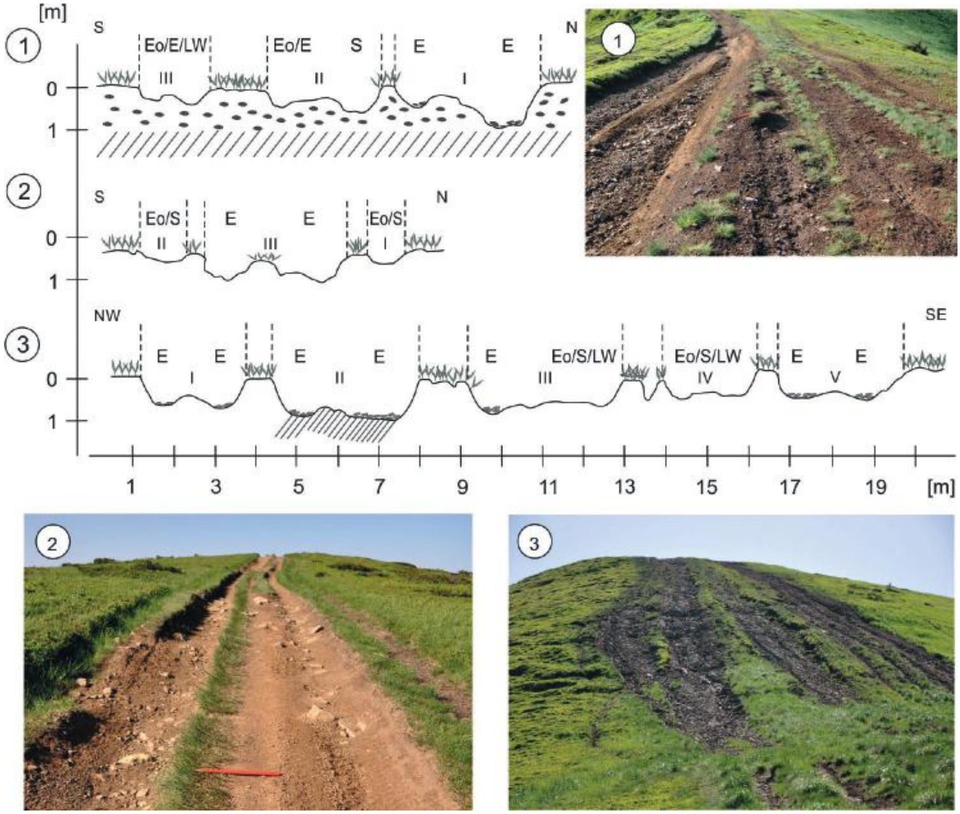


Fig. 5. Cross-sections of degraded ridges in the Dragobrat area. Surface changes on roads and ski trails: 1–3 ridge roads: 1 – the Kracyuneska-Stih ridge, 2 – ridge side in the area of Polana Jaroszeska, 3 – the road onto Stih Mt. Processes: E – linear erosion; S – sheet erosion; Eo – aeolian processes; LW – needle ice

of many buildings, the owners took the initiative in terms of architectural design: the style of some buildings is rooted in the traditions of the region. All roads in the study area are dirt roads (Fig. 3). The lack of asphalt or other well-built, paved road to Jasinia is a major problem for the Dragobrat area. Another problem is that no regulations are prohibiting driving trucks and off-road vehicles over the highest ridges (Photo 1) and prohibiting driving off-road vehicles to the highest peaks such as Bliźnica Mt. (1,883 m a.s.l.), or driving on all, often steep, mountain slopes with no roads. These kinds of driving trips often end tragically.

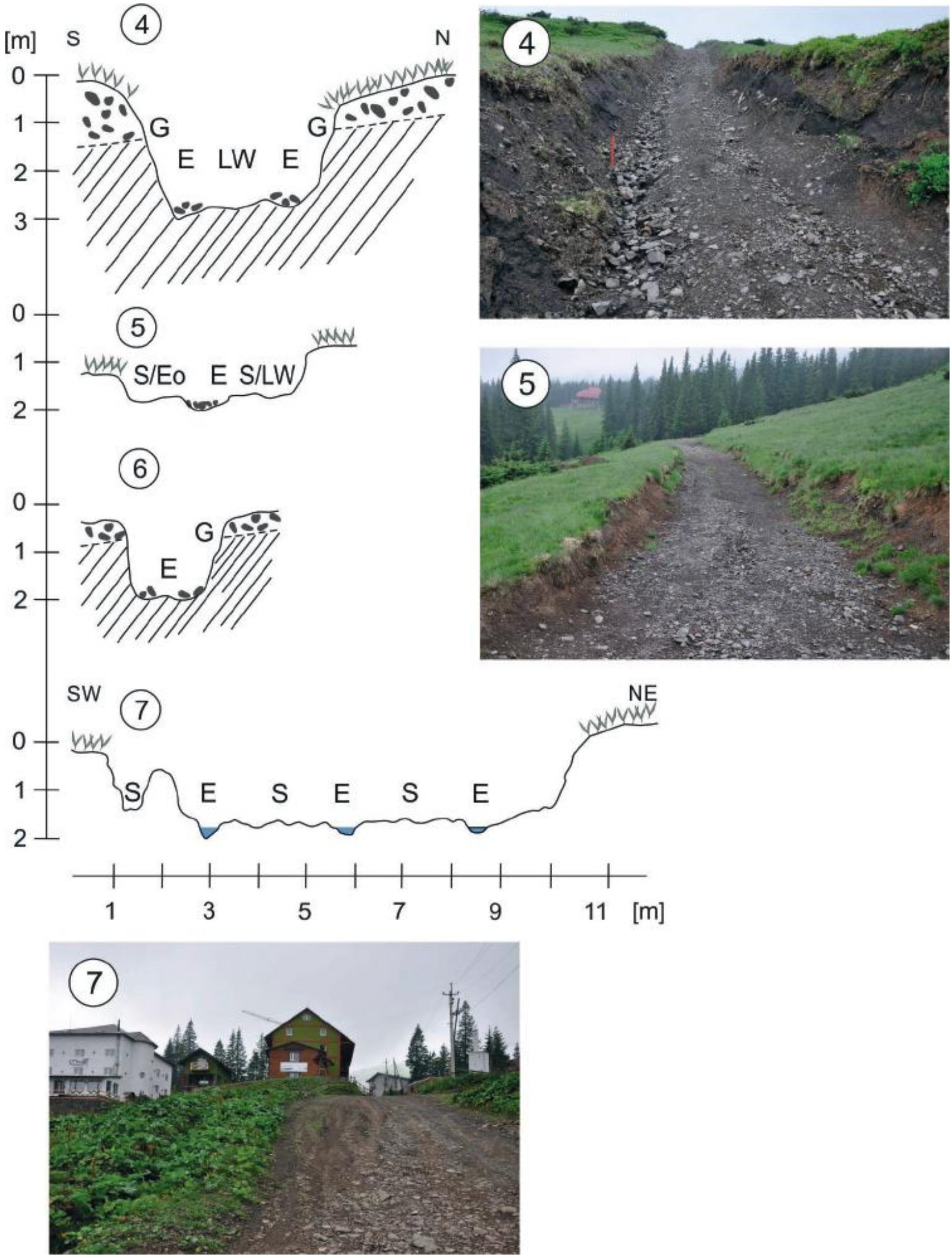


Fig. 6. Cross-sections of deeply incised roads on Dragobrat area. 4–7 hill slope roads, 4 – road in a sunken lane leading to Peremyczka, 5 – the road to Lake Ivor below Mt. Bliznica, 6 – a sunken lane on Dragobrat site, 7 – main road to Jasinia below Dragobrat site. Processes: E – linear erosion; S – sheet erosion; Eo – aeolian processes; LW – needle ice, G – gravity processes

GEOMORPHOLOGIC EFFECTS OF HUMAN IMPACT ACROSS THE SVYDOVETS MASSIF

CHANGES OF MOUNTAIN RELIEF ALONG TOURIST PATHS

Tourist trails in the Svydovets massif were designed to run along tourist paths and dirt roads of different type and varying degree of surface hardness. Currently, the trails are properly marked with clearly visible trail signs. Trail orientation signs are posted at key points, and they include the following sign types: signs at elevation points, topographic name signs, information signs. Tourist paths not coinciding with roads run through areas with diverse relief, especially their very steep sections, along narrow, rocky ridges, across bottoms of glacial cirques, and on mountain slopes covered with large-grained rock debris. These paths do not differ in size from paths found in other areas of the Eastern Carpathians (Prędki 1999). However, they may even be somewhat narrower due to relatively little pedestrian traffic. The paths reach 2.5 m in width in the montane forest zone, and an average of 2 meters in the subalpine zone (Figs 5, 6).

The incisions in the paths increase following the distribution of forces of erosion in the profiles of hill slopes. The depth of the incisions usually reaches 0.5 m. The reshaping of the natural environment occurs along these tourist paths. On the one hand, there is trampling of vegetation and transport of mineral material on the surface. On the other hand, paths are zones where natural geomorphic processes occur including sheet and linear erosion, downhill creep, and the action of needle ice and aeolian processes. Moreover, the structure of the plant cover changes near tourist paths. V. Kyyak (2013) notes that if a path runs on a slope along a contour line at a certain elevation, then the number of plants growing below it decreases, while the number of plants above the path increases. This is related to the action of geomorphic processes on the path and below it.

CHANGES OF MOUNTAIN RELIEF ALONG ROADS

The roads running across the Svydovets massif form a dense network and correspond to historical routes herders used to travel with their animals in this area (Kubijowicz 1926, 1937) as well as to forest management and timber harvesting routes (Fig. 3). Presently, there are 1,557 km of roads throughout the massif area (Tabs 3, 4) within the boundaries marked in Figure 3.

The roads in the study area are of two different types: ridge roads and hill slope roads, and they are distributed very irregularly (Fig. 3). The highest road density is associated with communities at the foot of the massif and in the Dragobrat area. The total length of roads in the Svydovets massif area

Table 3.
Length of roads in the Svydovets Massif area per elevation zone

Elevation interval [m a.s.l.]	The area in elevation interval [km^2]	Share of the area in the total area [%]	Length of roads [km]	Share in the total length of road [%]	Length of roads on ridges and flat ridgetops [km]	Length of roads in valleys and on hill slopes [km]	Road density [km·km^{-2}]
< 400	30.35	2.86	142.45	9.15	0.05	142.40	4.69
400–600	142.88	13.48	334.02	21.45	10.42	323.59	2.34
600–800	206.30	19.46	285.33	18.33	20.11	265.22	1.38
800–1,000	241.38	22.77	239.14	15.36	32.16	206.98	0.99
1,000–1,200	219.99	20.75	178.07	11.44	53.16	124.91	0.81
1,200–1,400	140.35	13.24	205.68	13.21	88.68	117.00	1.47
1,400–1,600	63.99	6.04	120.86	7.76	60.01	60.85	1.89
1,600–1,800	14.58	1.38	48.61	3.12	37.64	10.96	3.33
> 1,800	0.41	0.04	2.84	0.18	2.75	0.09	6.98
TOTAL	1,060.23	100	1,557.00	100	305.00	1,252.00	1.47

Table 4.
Length of roads in selected geo-ecological zones in the Svydovets Massif

Elevation interval [m a.s.l.]	The area in elevation interval [km^2]	Share of the area in the total area [%]	Length of roads [km]	Share in the total length of road [%]	Length of roads on ridges and flat ridgetops [km]	Length of roads in valleys and on hill slopes [km]	Road density [m·km^{-2}]
Above the tree line	110.9	10.46	275.4	17.69	153.2	122.2	2.5
Montane forest zone	781.7	73.73	617.5	39.66	102.1	515.4	0.78
Other, agricultural areas	167.6	15.81	664.1	42.65	49.7	614.4	3.96
TOTAL	1,060.2	100	1,557.00	100	305.00	1,252.00	1.47

(Fig. 3) may be divided as follows: there are 305 km of ridge roads and flat ridgetop roads, and 1,253 km of valley floor roads and hill slope roads near valleys (Tabs 3, 4). The average road density in the study area is 1.47 km·km^{-2}. The highest road density appears to be found in deforested areas near towns in the vicinity of the massif (3.96 km·km^{-2}) and above the upper tree line 2.5 km·km^{-2}) (Tab. 4). Ridge roads are widened and rutted in the areas found on wide ridges, in mountain passes or wet areas. The length of these roads in the study area is 305 km, out of which more than half are found above the tree line (Tab. 4, Fig. 5).

Road width in the study area ranges from 3 m to 19 m, where the surface is trodden and damaged by the wheels of vehicles. (Fig. 5). The area's roads are deteriorated by moving vehicle wheels and natural geomorphic processes such as rill and sheet erosion, linear erosion, needle ice, and aeolian processes. In effect, some roads are cut into the surrounding ground and even solid rock to variable depths (Fig. 5).

Depressed road sections reach 0.8 to 0.9 m in depth along the deepest sections. Ruts which are too deep for vehicles to pass through and depressed road sections too difficult for vehicles to pass through are found in the study area – this is true even for off-road vehicles, and this is why new roads are being built (Fig. 5). Hillslope roads and roads on valley floors form a network that is four times as long (Tabs 3, 4). These roads are usually 4 to 8 m wide if local conditions allow it (Fig. 6). If a road runs in a sunken lane, then it is narrow, 2 to 3 m in width. The depth of sunken lanes may reach 2.5 meters. Such roads are quickly degraded due to steep gradients and rapid degradation caused by linear erosion. Bulldozers and excavators are used in such areas to make the road passable (Fig. 6). In the montane forest zone, roads are degraded by the aforementioned hill slope processes as well as by fluvial processes and mass wasting processes. The closer to the bottom of each main valley, the more human work is put into the maintenance of these roads.

DETERIORATION OF SKI SLOPES

Present-day geomorphic processes of high intensity occur mostly in areas lacking vegetation, especially where the ground is not very compacted. The tourist industry makes it easy for the above processes to intensify. The linkage of natural processes and human impact is best seen along ski trails (Figs 4, 7).surface ski lifts damage the mountain slope because straight-linear incisions are created on the slope along with the ski lift's structural elements that are used for extended periods. This occurs due to the destruction of vegetation cover and the concentration of runoff formed by rainfall or snowmelt water. Even the removal of a ski lift does not stop the process that has

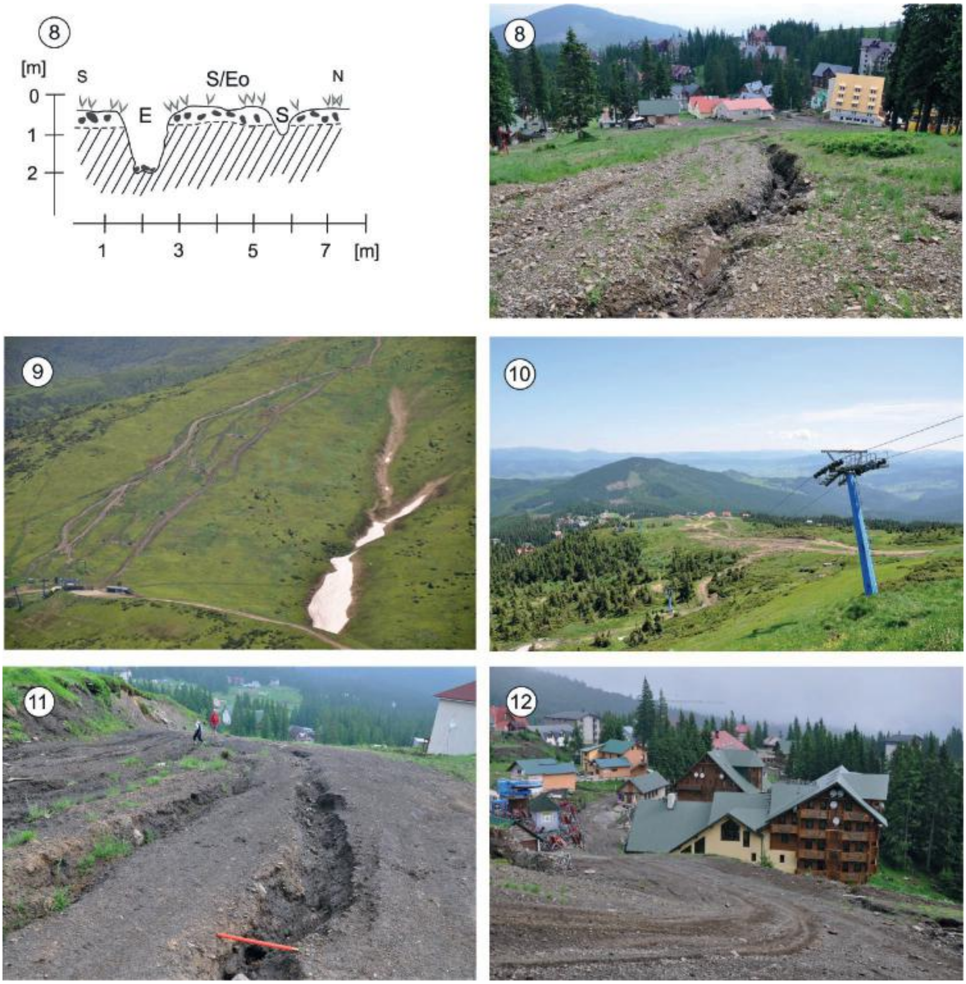


Fig. 7. Cross-section and photographs of hill slopes used by skiers in the winter and by cars and pedestrians during other seasons in the vicinity of Dragobrat area, June 2019. 8 – incisions in the ski trail from Dragobrat area to Stih Mt. (the first from the south), 9 – hill slopes of the Żandarm Mt. in the vicinity of the ski lift, 10 – ski trail to Dragobrat ski area, 11 – ski trail and road to the centre of Dragobrat site, 12 – Dragobrat ski center, the area of the downhill terminal of the ski lift, ski trail and road. Processes: E – linear erosion; S – sheet erosion; Eo – aeolian processes

already started, and the resulting straight-linear gullies may reach 2.0 to 5.5 m in width and 1.0 to 2.5 m in depth after 10 to 20 years (Krzemień 2008, 2010). The damaged slopes occupy an area of about 0.95 km^2 in the vicinity of Dragobrat area (Fig. 4). The slopes are fragmented by numerous gullies and dirt roads and the total length of these incisions in the degraded zone is 32.7 km. The density of incisions and roads in this area is 34.5 km·km^{-2}.

Intense linear erosion takes place in ski trail zones due to the lack of vegetation or scarce vegetation present on the ground (Fig. 7).

Deep incisions in the bedrock of the Dragobrat Mt. area are readily formed due to the geologic structure of the substratum, which is built of weak dark shale and clayey mudstone of the Shipot series (Lower Cretaceous) (Shakin et al., 1976). Numerous downhill ski trails and access roads and paths were built near the ski lifts around Dragobrat area (Fig. 4). The surface of large areas on mountain slopes was graded and levelled out using excavators and bulldozers to make downhill skiing easier for tourists. Ski slopes with a total surface area of 0.95 km^2 were reshaped as a result of preparatory works to make them ready for skiing (Fig. 4). The actions related to ski slope development destroyed vegetation in large areas along the steepest slopes. Trees and other vegetation were removed in these areas in the montane forest and subalpine zones, which could have significantly contributed to the increase in avalanche activity (Shushniak 2006).

Ski trails created with the use of mechanical equipment run on hill slopes along steep downward gradients. The studied ski trails are scarcely covered with grass. This is why linear erosion may cause significant damage, even during a single event (Figs 4, 7). Slopes degraded in the process of ski trail construction and ones used by skiers are characterized by permanent destruction of vegetation and bare ground surfaces.

DISCUSSION

Degraded areas in the Svydovets area include tourist paths, tourist and farm roads, ski lift zones, and ski trails. No restoration or protective measures are being undertaken in these areas. The entire studied massif is not a protected area, and surrounding townships still do not have any programs for the restoration of degraded areas. Deep linear incisions develop on hill slopes within the degraded areas. The size of the incisions reaches 1.5 m in depth (Fig. 7). These types of landforms may develop in mountain areas even during a single event related to rainfall or snowmelt (Krzemień 1995, 2008, 2010; Łajczak 1996, 2002; Gorczyca 2000; Fidelus 2016). The greatest changes in the relief of the study area occur along tourist paths, roads, and ski trails in the spring due to nivation, linear erosion, and deflation as well as in summer and fall because of deflation, and splash and linear erosion. In the winter, the ground surface may become changed by avalanches on some steep slopes (Krzemień 2008, 2010; Fidelus-Orzechowska et al. 2017). According to data provided by Yu.S. Zinko and I.S. Hnatiak (2009), I.M. Rozhko et al. (2011), I. Gnatiak and J.S. Zinko (2015), I. Hnatiak (2017), V.B. Brusak and V.B. Malets (2018), and V.B. Brusak (2018), environmental degradation on main tourist trails in the surrounding Carpathian National Park is strong. Degradation within the main trail areas leading to Hoverla Mt. (2,061 m a.s.l.) – the highest peak in the Ukrainian Carpathians – is very severe, because no action has been taken to stabilize tourist paths. The depth of some erosional landforms, which have developed on the tourist trail leading to Hoverla Mt., reaches about 2.0 m.

Degraded areas in the forest elevational zone and the agricultural zone are mostly roads (Fig. 3). They are degraded primarily due to sheet and linear erosion, and also because of mass wasting processes such as landslides and periodically by mountain streams flowing over their surfaces or by fluvial processes. Roads run along river channels in some valleys. It is there that the road surfaces are being degraded most intensely.

Areas with degraded vegetation, particularly grasslands, experience a state of permanent imbalance (Gorczyca, Krzemień 2009). Cryonival, aeolian and pluvial forms of microrelief develop in such zones (Figs 5, 6, 7). Geomorphic processes occur with increased strength in destroyed vegetation zones. Precipitation and snowmelt water causes the development of gullies on roads and ski trails (Figs 5, 6, 7). The action of needle ice causes fragmentation of hill slope cover, especially in areas deprived of vegetation (Fidelus-Orzechowska et al. 2017). This material is easily transported by aeolian processes or by flowing water during rainfall or snowmelt. Degraded vegetation zones are being reshaped by geomorphic processes (Figs 5, 6, 7). The activity of geomorphic processes can be readily observed in cross-sections of landforms, where the presence of several geomorphic zones differing concerning their dynamics can be observed.

There are sections of longitudinal profiles of roads and ski trails that are characterized by different degrees of surface fragmentation. The differences in the degree of disintegration in different places are related to the resistance of the flysch bedrock, and particularly to the resistance of shale and sandstone (Kłapyta et al. 2020). New infrastructure development in many areas of the studied hill slopes has resulted in the incision of peat cover of a thickness of 1 to 2 m. This caused a change in the direction of overland water flow, and consequently water infiltration into other types of weathered rock. This way, downhill creep and landslide processes were activated in many places. The geologic structure, notably the flysch substratum, makes the construction and development of tourist infrastructure very difficult. The bearing capacity of these rocks is small; hence, they will not support great loads. Additionally, the rocks are saturated with water. Slope degradation in the research area is significant, especially in the spring and summer period, when snowmelts and heavy rainfalls occur. The collection of abovementioned human impact problems continues to deteriorate the investigated massif on a very large scale today comparing it to other mountain areas, such as the Tatras (Gorczyca, Krzemień 2002, 2009, 2010; Buchwał, Fidelus 2008; Fidelus-Orzechowska et al. 2017) or Monts Dore Massif in France (Candela 1982; Veyret et al. 1990; Krzemień 1995).

Another threat to the natural environment of the Svydovets is the planned construction of a new tourist complex, called The Svydovets a winter sports station, in the Dragobrat area (Bortnyk et al. 2018). Winter sports stations are found in many other mountain areas across the world, but they tend to be well-planned, and efforts are made to limit excessive degradation of mountain relief in these other areas in the world (Krzemień 1995; Gorczyca, Krzemień 2009).

In May 2017, the Rakhiv and Tiachiv raions (i.e. Ukrainian administrative regions) approved a decision to allocate 14,000 hectares of land located across the Svydovets massif to be used for recreational purposes, including 1,300 m^2 for the development of a building complex (Shutiak 2019). It is planned that a total of 120 restaurants, 390 lodges, 10 multipurpose centres, and 60 hotels will be constructed in the skiing complex called "The Svydovets". The entire station could accommodate as many as 18,000 tourists (Shutiak 2019). It is proposed that the status and function of 1,187 ha of forests in the area should be changed. It is planned that 430 ha of the forest will be cut down (39% of the area). The construction of many water-based recreational facilities with a total volume of 1,260,000 m^3 is planned. The water use will range from 4,000 to 5,800 m^3 daily. It is also proposed that ski trails with a length of 223.3 km be constructed, which will be then covered with snow using mechanical snowmaking equipment.

Ski lifts will be situated on two levels, at elevations from 800 m a.s.l. to 1,200 m a.s.l. as well as from 1,200 m a.s.l. to 1,750 m a.s.l. (Notification of Planned… 2020). The planned ski trails will cover an area of 630 ha. The average width of ski trails will range from 12 to 45 m, and the width of the ski lift zone will be 15 to 18 m (Notification of Planned… 2020). The population of the area will increase, as 22,000 tourists will be expected to arrive daily, including 18,000 living in The Svydovets Tourist Complex, along with 5,000 service workers. This is 5 to 7 times the number of people recently present at the peak of the winter season. In this new situation, the population density will increase to 1,890 persons per km^2 (*Evaluation*… 2018). This leads to the conclusion that human impact will increase in the future in this geographic area.

CONCLUSIONS

Animal herding played the greatest role in large-scale changes occurring in the natural environment of the Svydovets massif. The impact of herding resulted in the formation of a semi-natural landscape zone of mountain meadows, which was produced by the destruction of subalpine shrubs and forests, which used to cover a surface area of 110.91 km^2. The direct effects of the most intensive animal herding in the Ukrainian Carpathians included the destruction of the area's natural, climate-supported tree line and its lowering by about 300 m, which was most severe on the southern face, as well as transformation and degradation of the subalpine elevational zone due to woodland clearing and burning, and the creation of a dense network of forest tracks and herding routes. The modern-day human impact on this area, especially above the tree line, is primarily concentrated in the Stih-Dragobrat-Bliźnica area and is related to the unregulated tourism industry, leading to excessive degradation of the local natural environment.

Human impact in high mountain areas contributes to the acceleration of the circulation of matter and energy on hill slopes and in entire catchments, which originate in these areas. Different thresholds have to be overcome for the reshaping of tourist paths, roads and groomed ski trails to begin on mountain massifs. This is why the geomorphologic role of human-induced erosion is different in these areas. The Svydovets Massif is an area, which due to the medium and low resistance of its flysch bedrock and great scale of changes related to tourist industry expansion, quickly changes relief. If further degradation of ridges and hill slopes across the studied massif is not limited, it will be very difficult to eliminate erosional incisions and limit their further development. Nature-friendly solutions ought to be planned and implemented in the development process for building complexes and the local community as a whole to avoid an ecological catastrophe in the area. It is important to remember that human-induced erosion increases with the formation of additional erosional landforms. Their further development may cause a construction catastrophe in built-up areas attempting to grow via new construction.

REFERENCES

Anan'iev H.S., 1981. *Geomorphology of the axis zone of the East Carpathian. Moscow University Publishing House.* Moscow

Barros A., Pickering C., Gudes O., 2015. *Desktop analysis of potential impacts of visitor use: A case study for the highest park in the Southern Hemisphere*. Journal of Environmental Management 150, 179–195.

Bortnyk S. Yu., Kovtoniuk O. V., Kravchuk I. V., Lavruk, 2018. *Organization of nature tourism routes on the territory of the central part of the Svidovets massif (Ukrainian Carpathians)*. Fizichna geografija ta geomorfologija 91, 55–65.

Brusak V.B., 2018. *Methodical aspects of research of recreational digression of tourist routes microrelief*. Problems of Geomorphology and Paleogeography of the Ukrainian Carpathians and Adjacent Territories 1, 8, 108–120, (in Ukrainian).

Brusak V.B., Malets V.B., 2018. *Recreational digression on the "To Mount Hoverla" tourist route in the Carpathian National Park*. [in:] *Natural Resources of the Region: Problems of Use, Revitalization and Protection. Proceedings of the international scientific seminar (Lviv, October 5-7, 2018)*. LNU Press, Lviv, 58–63, (in Ukrainian).

Buchwał A., Fidelus J., 2008. *The development of erosive and denudational landforms on footpaths sections in The Babia Góra Massif and The Western Tatras*. Geomorphologia Slovaca at Bohemica 2, 14–24.

Candela R. M., 1982. *Piste de ski et* érosion *anthropique dans les Alpes du Sud*. Méditerranée 3-4, 51–55, (in French).

Dyląg D., 2018. *Schroniska, których nie ma. Obiekty czeskich, ukraińskich, węgierskich i rumuńskich organizacji turystycznych w Karpatach Wschodnich do 1944 r*. [in:] K. Duda, J. Skłodowski (eds.), *Dziedzictwo kulturowe Karpat*. Kraków, 129–149, (in Polish).

Fidelus J., 2014. *The differentiation of tourist traffic in the Polish and Slovak parts of the Tatra National Park*. Folia Turistica 33, 173–192.

Fidelus J., 2016. *Slope transformations within tourist footpaths in the northern and southern parts of the Western Tatra Mountains (Poland, Slovakia)*. Zeitschrift für Geomorphologie 60, 3, 139–162.

Fidelus-Orzechowska J., Gorczyca E., Krzemień K., 2017. *Geomorfologiczne skutki gospodarki turystycznej w Tatrach*. TPN, IG i GP UJ, Kraków, (in Polish).

Gąsiorowski H., 1933. *Przewodnik po Beskidach Wschodnich. Pasmo Czarnohorskie*, Wyd. Książnica Atlas, Lwów-Warszawa, (in Polish).

Giessbel J., 1988, *Nutzungsschaden, Bodendichte und rezente Geomorphodynamik auf Skipisten der Alpen und Skandinaviens*, Zeitschrift für Geomorphologie N.F. Suppl.-Bd.70, 205–219, (in German).

Gnatiak I., Zinko J., 2015. *Monitorowanie mikrowypukłość od szlaków turystycznych Karpackiego Parku Narodowego*. Prądnik 25, 159–172, (in Polish).

Goetel W., 1936. *Przez pasmo Czarnej Połoniny i Świdowca*. *Wspomnienie sprzed 28 lat*. Turystyka w Polsce 12, 5–15.

Gorczyca E., 2000. *Wpływ ruchu turystycznego na przekształcanie rzeźby wysokogórskiej na przykładzie masywu Czerwonych Wierchów i Regli Zakopiańskich*. Zeszyty Naukowe UJ, Prace Geograficzne 105, 369–389.

Gorczyca E., Krzemień K., 2002. *Wpływ ruchu turystycznego na rzeźbę Tatrzańskiego Parku Narodowego*. [in:] W. Borowiec, A. Kotarba, A. Kownacki, Z. Krzan, Z. Mirek (eds.), *Przemiany środowiska przyrodniczego Tatr*. Wyd. TPN, Kraków-Zakopane, 389–394.

Gorczyca E., Krzemień K., 2009. *Rola antropopresji w przekształcaniu obszarów wysokogórskich na przykładzie Tatr i Monts Dore*. Prace i Studia Geograficzne 41, 89–106.

Gorczyca E., Krzemień K., 2010. *Rola dróg i ścieżek turystycznych w modelowaniu rzeźby gór strefy umiarkowanej*. Roczniki Bieszczadzkie 18, 228–242.

Gorczyca E., Krzemień K., 2012. *Erozja i akumulacja w obrębie sieci dolin i dróg w Pienińskim Parku Narodowym (część polska i słowacka)*. Prace Wydziału Nauk o Ziemi Uniwersytetu Śląskiego 77, 164–176.

Growcock A.J.W., 2005. *Impacts of camping and trampling on Australian alpine and subalpine vegetation and soils.* PhD dissertation, Griffith University, 1–241.

Hnatiak I., 2004a. *Morphodynamics of snow cover and relief surface on Skole Beskid ski slopes*. Journal of Ternopil State Pedagogical University. Geography Series 3, 129–136, (in Ukrainian).

Hnatiak I., 2004b. *Pedestrian microrelief of the "Stezhka Dovbusha" ecological path in the Carpathian National Park*. [in:] *Problems of Geomorphology and Paleogeography of the Ukrainian Carpathians and Adjacent Territories: Proceedings of the international seminar dedicated to the 90th anniversary of the founder of the Department of Geomorphology and Paleogeography, Professor Peter Tsis (Skole, September30 – October 3, 2004*). Ivan Franko LNU Press, Lviv, 196–202, (in Ukrainian).

Hnatiak I.S., 2017. *State and prospects of research of morphodynamics of pedestrian microrelief in the vicinity of Chornohora Geographical Station. Problems of Landscape Science in the Context of the Strategy of Sustainable Development and the European Landscape Convention*. [in:] *Proceedings of the international scientific seminar dedicated to the 40th anniversary of the Chornohora Geographical Station, Ivan Franko National University of Lviv. November 3–5, 2017*. Lviv-Vorokhta, 68–70, (in Ukrainian).

Hnatiak I., 2018. *Transformation of the relief of recreational areas and recommended measures to regulate negative processes*. [in:] *Problems of Geomorphology and Paleogeography of the Ukrainian Carpathians and Adjacent Territories*. Ivan Franko LNU Press, Lviv, 149–159, (in Ukrainian).

Holubets M.A., 1978. *Fir-trees of the Ukrainian Carpathians*. Kyiv, Naukova Dumka, (in Ukrainian).

Kasprzak M., Traczyk A., 2005. *Antropogeniczne formy terenu na grzbiecie Karkonoszy w rejonie Łabskiego Szczytu*, [in:] A. Łajczak (ed.), *Antropopresja w górach średnich strefy umiarkowanej i skutki geomorfologiczne, na przykładzie wybranych obszarów Europy Środkowej*. Wyd. Uniwersytetu Śląskiego, 39–45, (in Polish).

Kłapyta P., Dubis L., Krzemień K., Gorczyca E., Krąż P., 2020. *Rzeźba i współczesne procesy morfogenetyczne wysokogórskiego masywu Świdowca (Karpaty Wschodnie)*. Roczniki Bieszczadzkie 28, 161–190, (in Polish).

Kondracki J., 1989. *Karpaty*. Wydawnictwa Szkolne i Pedagogiczne, Warszawa, (in Polish).

Kricsfalusy V., Mróz W., Popov S., 2008. *Historical changes of the upper tree line in the Carpathian Mountains, Ukraine*. Mountain Forum Bulletin 8, 1, (https://lib.icimod.org/record/12763).

Krusiec M., 1996. *Wpływ ruchu turystycznego na przekształcanie rzeźby Tatr Zachodnich na przykładzie Doliny Chochołowskiej*. Czasopismo Geograficzne 67, 303–320, (in Polish).

Krzemień K., 1995. *Le rôle du tourisme dans la transformation des versants du Massif des Monts Dore*. Zeszyty Naukowe UJ, Prace Geogr. 99, 23–33, (in French).

Krzemień K., 2008. *Contemporary landform development in the Monts Dore Massif, France*. Geographia Polonica 81, 1, 67–78.

Krzemień K., 2010. *Les transformations contemporaines du relief du massif du Mont-Dore*, [in:] D. Ricard (ed.), *Developpment durable des territories: de la mobilisation des acteurs aux demarches participatives*. Presses Universitaires Blaise Pascal, Clermont-Ferrand, 353–378, (in French).

Krzemień K., Kłapyta P., Gorczyca E., Krzemień P., Nesteruk J., Troll M., 2019. *Ochrona przyrody nieożywionej w okresie II Rzeczypospolitej i współcześnie w południowo-wschodniej Polsce i w zachodniej Ukrainie*. Roczniki Bieszczadzkie 27, 197–231, (in Polish).

Kubijowicz W., 1926. Życie pasterskie w Beskidach Wschodnich. Prace Instytutu Geografii UJ, 5, 1–143, (in Polish).

Kubijowicz W., 1937. *Pastýřsky* život *v Podkarpatské Rusi*. Bratislava, Zemépisne Prace 10, 1–74, (in Czech).

Kyyak V. 2013. *Changes in the structure of populations of rare and endemic plant species in the highlands of the Carpathians under the influence of anthropogenic factors*. Scientific Foundations of Biodiversity Conservation 4, 11, 1, 111–122, (in Ukrainian).

Łajczak A., 1996. *Wpływ narciarstwa i turystyki pieszej na erozję gleby w obszarze podszczytowym Pilska.* Studia Naturae 41, 131–159, (in Polish).

Łajczak 2002. *Slope remodelling in areas exploited by skiers: case study of the Northern Flysch slope of Pilsko Mountain, Polish Carpathian Mountains*. [in:] R.J. Allison (ed.), *Applied Geomorphology: Theory and Practice*. Willey, Chichester, 91–100.

Lanko A.I., Marynych O.M., Shcherban M.I., 1969. *Physical Geography of the Ukrainian RSR.* Radianska shkola, (in Ukrainian).

Lavruk M.M., 2005. *Hutsuls of the Ukrainian Carpathians (ethnogeographical study*). Ivan Franko LNU Press, Lviv, (in Ukrainian).

Malynovskyi K. 2003a. *Carpathian mountain meadows and mountain meadow economy*. Ecological Problems of the Carpathian Region, Papers of T. Shevchenko Scientific Society. Lviv, Ecology 12, 293–309, (in Ukrainian).

Malynovskyi K. 2003b. *The current state of the upper border of the forest and alpine vegetation*. Ecological Problems of the Carpathian Region, Papers of T. Shevchenko Scientific Society. Lviv, Ecology 12, 66–80, (in Ukrainian).

Mihai B., Reynard E, Werren G., Savulescu I., Sandric I., Chitu Z. 2009. *Impacts of tourism on geomorphological processes in the Bucegi Mountains in Romania*. Geographica Helvetica 64, 3, 134–147.

Nesteruk J., 2001. *Szata roślinna wschodniokarpackich połonin i ochrona strefy wysokogórskiej*. [in:] J. Gudowski (ed.), *Pasterstwo na Huculszczyźnie. Gospodarka, kultura, obyczaj*. Wyd. Akad. Dialog, Warszawa, 63–78, (in Polish).

Pelfini M., Santilli M., 2006. *Dendrogeomorphological analyses on exposed roots along two mountain hiking trails in the Central Italian Alps*. Geografiska Annaler A, 88, 3, 223–235.

Prędki R., 1999. *Ocena zniszczeń środowiska przyrodniczego Bieszczadzkiego Parku Narodowego w obrębie pieszych szlaków turystycznych w latach 1995-1999 – porównywanie wyników monitoringu*. Roczniki Bieszczadzkie 8, 343–352, (in Polish).

Prędki R., 2000. *Przemiany właściwości powietrzno-wodnych gleb w obrębie pieszych szlaków turystycznych Bieszczadzkiego Parku Narodowego*. Roczniki Bieszczadzkie 9, 225–235, (in Polish).

Rochefort R.M., Swinney D.D., 2000. *Human Impact Survey in Mount Rainer National Park: Past, Present and Future*. USDA Forest Service Proceedings RMRS-P15, 5, 165–171.

Romer E., 1905. *Epoka lodowa na Świdowcu*. Rozprawy Akademii Umiejętności 3, 6, 1-71, (in Polish).

Rozhko I. M., 2000. *Recreational assessment of mountain natural-territorial complexes for the needs of tourism (by the example of the Ukrainian Carpathians)*. Doctoral dissertation self-abstract, speciality 11.01.11 – constructive geography and rational use of natural resources, Lviv, (in Ukrainian).

Rozhko I.M., Matviiv V.P., Brusak V.B., 2011. *Geographical and Ecological Routes of Chornohora*. Textbook. Ivan Franko LNU Press, Lviv, 223 pp., (in Ukrainian).

Shakin V.A., Burov V.S.,Vyalov O.S., Glushko V.V., Kruglov S.S., Pietrashkiewich M.I., Temeniuk F.P., 1976. *Geologicheskaya karta Ukrainskikh Karpat i prilegayushchikh progi, bov, 1:200,000*. Ministerstvo Geologii USSR, Kiev, (in Russian).

Shutiak A., 2019. *Land Management*: *Environmental and Legal Aspect.* (in Ukrainian).

Shushniak V., 2006. *Peculiarities of spatio-temporal differentiation of exogenicgeomorphic processes in the Ukrainian Karpaty*. Bulletin of Lviv University, Geographical series 33, 454–458, (in Ukrainian).

The Svydovets case 2019. How oligarchs are planning to destroy one of Ukraine's most pristine natural landscapes. Bruno Manser Fonds, Basel. https://freesvydovets.org/wp-content/uploads/2019/08/report_the_svydovets_case.pdf.

Troll M., Sitko I., 2006. *Pasterstwo w zachodniej Czarnohorze (Karpaty Ukraińskie) w ujęciu przestrzenno- czasowym*. [in:] M. Troll (ed.), *Czarnohora. Przyroda i człowiek*. Instytut Geografii i Gospodarki Przestrzennej UJ, Kraków, 111–140, (in Polish).

Tsuyuzaki S., 1994. *Environmental deterioration resulting from ski-resort construction in Japan*. Environment Conservation 21, 121–125.

Veyret Y., Hotyat M., Bouchot B., 1990. *L'érosion d'origine anthropique dans un milieu de moyenne montagne: le massif montdorien*. La terre et les hommes. Mélanges offerts à Max Derruau, Faculté des Lettres et Sciences humaines de l'Université Blaise Pascal, Nouvelle série 32, 545–556, (in French).

Vosyka R., 1929. *Týden na Podkarpatské Rusi*. Krásy Slovenska 8, 22-29, (in Czech).

Wilson J.P., Seney J.P., 1994. *Erosional impact of hikers, horses, motorcycles and off-road bicycles on mountain trails in Montana*. Mountain Research and Development 14, 1, 77–88.

World Database on Protected Areas, 2019. WDPA Consortium, Copyright World Conservation Union (UICN) and PNUMA-World Conservation Monitoring Centre (PNUMA-WCMC)

Zinko Yu.V., Hnatiak I.S., 2003. *Recreational assessment of relief and its transformation in the Ukrainian Carpathians*. [in:] *Current Problems and Trends in the Development of Geographical Science, Proceedings of the international conference dedicated to the 120th anniversary of geography at Lviv University (September 24-26, 2003)*. Ivan Franko LNU Press, Lviv, 241–243, (in Ukrainian).

Zinko Yu.V., Hnatiak I.S., 2009. *Ecological and geographical problems of functioning of tourist routes in the upper reaches of the Prut river*. [in:] *Natural Complexes and Ecosystems of the Upper Prut River. Functioning, Monitoring, and Protection*, Ivan Franko LNU Press, Lviv, 291–294, (in Ukrainian).

Department of economic development and trade of the Eranscarpathian regional administration. Online: https://carpathia.gov.ua/view_company/40)

Evaluation of the Svydovets project. 2018. Online: http://eia.menr.gov.ua/uploads/documents/288/reports/0406ca88fa754998830eb6c3a30d1905.pdf

Notification of planned activities to be assessed for environmental impact. Transcarpathian Regional State Administration. Registration number 2018314288. Online:http://www.carpathia.gov.ua/ sites/default/files/imce/180319_nerws-11-59.pdf (in Ukrainian).

Piotr Kłapyta, Kazimierz Krzemień, Elżbieta Gorczyca
Jagiellonian University, Faculty of Geography and Geology,
Institute of Geography and Spatial Management,
Gronostajowa 7, 30-387 Kraków, Poland

Paweł Krąż
Institute of Geography Department of Sustainable
Development and Shaping of Geographic Environment
Pedagogical University of Krakow
Podchorążych 2, 30-084 Krakow

Lidia Dubis
Ivan Franko National University of Lviv,
Faculty of Geography, Department of Geomorphology and Paleogeography;
79000, Lviv, str. Doroshenka 41, Ukraine;

e-mail of the coresponding author: piotr.klapyta@uj.edu.pl