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Snow Avalanche Danger of Samtskhe-Javakheti Region (Georgia)

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Abstract *– Snow avalanches are one of the most dangerous meteorological phenomena. 56% of the territory of Georgia is covered by avalanche-prone slopes. The first assessment of the avalanche danger in Georgia can be based on the experience of the population living in mountainous region, they avoided settling in avalanche prone area and chose a residential area that would be the most protected from avalanches. Proper operation of the road infrastructure is an important stage of the country's development and largely depends on the nature of a number of meteorological phenomena. Snow avalanches are one of the most dangerous natural phenomena for highways.*

The object of our research is Samtskhe-Javakheti region (Georgia). On the basis of the data processing obtained as a result of the conducted research and expeditionary works, the avalanche prone highways of the Samtskhe-Javakheti region and their climatic-geographical characteristics have been studied. On the basis of data analysis, geo-informational schematic maps of the region for avalanche-prone highways were created. The obtained results will help the preparation and implementation of the planned anti-avalanche works on the highways of the mountainous region of Georgia.

Index Terms – Avalanche, Climate, Geoinformation maps. Natural disaster, Road infrastructure

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I. INTRODUCTION

1882 under the conditions of the relief of Georgia, 338 settlements, pass section, and highways are under the threat of an avalanche. Of these, 63% of the total number of such settlements are located in Western Georgia, and 37% in Eastern Georgia [1].

Therefore, it is important to conduct research phenomena such as snow avalanches. The grant project Avalanche danger on the road of the mountainous region of Georgia and recommendations for its mitigation (grant number – FR-21-1677) is dedicated to research in this direction. Within the framework of the grant, we have already competed studies for several regions of Georgia [2-5].

The period of winter, during which the height of the snow cover exceeds the critical value, is considered an avalanche-risk period. The critical height of snow is the exceeded by the snow moving forces (gravity, etc.), the snow will fall into motion, and avalanche will occur.

The degree of avalanche danger in the territory of Georgia is evaluated according to the quantitative characteristics of avalanche danger: active territory in terms of avalanche formation; number of avalanches per area unit; number of avalanches per unit area; frequency of avalanches in one winter and the duration of the avalanche period. Therefore, especially strong (3%), strong (8%), medium (33%), week (12%), and non-avalanche-risk (44%) areas are allocated to the territory of Georgia (fig. 1) [1].

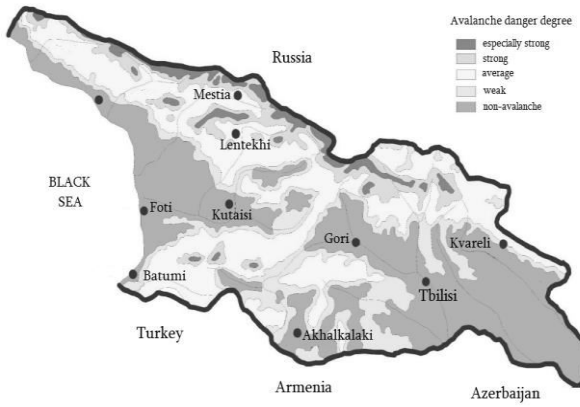

Fig. 1 Schematic map of avalanche hazard quality of Georgia [6].

For the territory of Georgia, the degree of avalanche danger and the level of avalanche risk are determined according to the area of the avalanche deposits (ha), the impact force of the avalanche (t/m^2) and the expected result (Table 1) [7].

Tabe 1. Disaster risk level according to avalanche impact force, area of avalanche and expected result in Georgia

Risk classification	Avalanche impact force, t/m^2	Area of the avalanche, ha	Expected result of an avalanche
Week	<20	>0.5	Human casualties, slight damage buildings, as well as light wooden structures and other things, disruption of traffic, damage to forest and orchards, killing of livestock.

Medium	21-40	0.5-1.0	Human casualties, destruction of wooden buildings and auxiliary structures, derailment of vehicles, damage the buildings and pipelines, destruction of plantations and small areas of forest.
Intensive	41-60	1.1-1.0	Human casualties, destruction of all the kinds the structures, disruption of movement, damage to vehicles, roads, cattle and small livestock, perennial crops and forest.
Especially strong	>60	>10	Human casualties, destruction of all the kinds of buildings (including reinforced concrete), damage to railways, disruption of traffic, destruction of livestock, plantations, and forest.

II. AREA UNDER STUDY

Samtskhe-Javakheti regio is located in southern Georgia (Fig. 2). The area of Samtskhe-Javakheti region is 6412 km^2. There are 353 settlements in the region including: 5 cities, 7 township, 258 villages. According to the data of 2024, the population is 142.1 thousand, among them 88.8 thousand live in a rural area [8].

Samtskhe-Javakheti region (Georgia) [9].

The climate of the region is formed by a whole complex of natural factors. Among them, solar radiation, atmospheric circulation and the nature of the subsurface are worth mentioning. A particularly important role is played by the nature of the sub-layered surface – the degree of surface fragmentation, the alternation of ridges and valleys, rocky outcrops, forest cover. The air in a large part of Samtskhe-Javakheti region is continental, the region is surrounded by high ridges, which determines the continentality of the air (Fig. 3). An important orographic barrier for Samtskhe-Javakheti is formed by the

Arsiani and Adjara-Imereti ridges, the slopes which are heavy precipitation. In winter the temperature in month is negative or close to 0°C in the whole area, which is due to the invasion of cold air masses from the west and east. Atmospheric precipitation in the form of snow is high in the highlands of the region, where solid precipitation is expected throughout the year, and in the lower parts only in September-May. The height of the snow cover is high in the western parts of region, while the eastern parts of the region stand out for the duration of the snow cover (Table 2) [10].

Table 2. Maximum height of the snow cover in Samtskhe-Javakheti region

Weather station	Altitude of Weather station, years of observation	Maximum snow height, cm	Recurrence of snow cover height of more than 50 cm, cm/year		
			>50-100	101-200	<200
Borjomi	798 (66)	85 (1965)	12	-	-
Akhaltsikhe	982 (76)	89 (1988)	4	-	-
Adigeni	1185 (53)	187 (1988)	20	3	-
Abastumani	1265 (69)	144 (1965)	29	2	-
BAkuriani	1665 (62)	130 (1956)	39	10	-
Akhalkalaki	1716 (70)	95 (1990)	5	-	-
Ninotsminda	2077 (27)	42 (1992)	-	-	-
Faravani	2100 (44)	147 (1986)	9	3	-

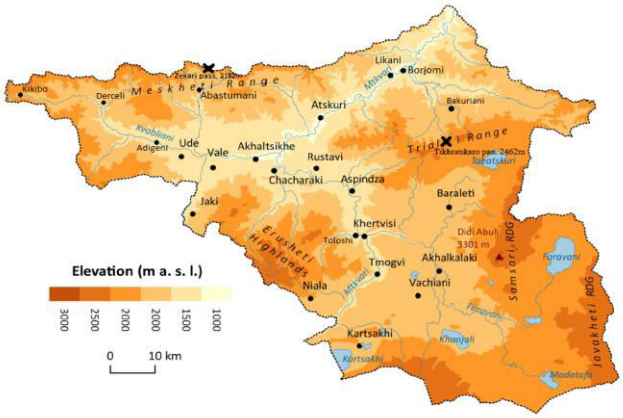

Fig. 3 Samtskhe-Javakheti region [11].

III. Materials and Methods

The detection of avalanche-prone sections on the highways of Samtskhe-Javakheti region was based on the exiting materials of many years of field studies, the databases of the National Environment Agency, information and publications published literary sources, and the fundamental studies of the Shota Rustaveli National Science Foundation (grant FR-21-1677). Materials and data Field expeditions carried out in 2023. During the field work, the avalanche hazard of each research road section of Samtskhe-Javakheti region was studied. In particular, a drone (DJI Mavic 3) was use to describe the locations of avalanche arrivals on road sections, the location of avalanche collectors, and collect photo and video materials in area of avalanche danger where it is impossible to reach on foot.

IV. RESULTS

As the analysis of the map of avalanche hazard quality of Georgia presented in figure 1 shows, all five levels of avalanche danger classification are fixed in the territory of Samtskhe-Javakheti region.

The morphometric (beginning and end height, length, focal area, surface slope) and dynamic characteristics of the avalanche (maximum speed and impact force, cone volume, and maximum height of the moving avalanche) of the area avalanche on the highways of Samtskhe-Javakheti region are presented in table 3.

Table 3. Morphometric and dynamic characteristics of the dangerous avalanches of Samtskhe-Javakheti highways

N	Altitude, m		Length, m		Total		Avalanche area, ha	Tilt angle, degree	Speed, m/s	Impact strength, t/m^2	Volume 1000 m^3	Avalanche height,	Length, m	Suspension height, m
	Absolute	Relative	Horizontal	Factual	Horizontal	Factual								
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1	Adigeni municipality, village Kikibo. Left slope of river Kvabliani. Peak height 1692m.													
	1410	30	150	160	1000	1040	0.4	11	0	0	4	14	900	1430
	The avalanche passes by the buildings, crosses the road and stops in the river													
2	Adigeni municipality, village Dertseli. Right slope of Ghaghvistskali river. Peak height 1961m.													
	1475	40	270	270	1090	1140	0.3	8	0	0	4	15	1010	1495
	The avalanche passes by the buildings, crosses the road and stops in the ravine.													
3	Adigeni municipality, township Abastumani. Right slope of Abastumanistskali river. Peak height 1579 m.													
	1250	-20	50	50	620	680	0.4	22	0	0	4	12	660	1240
	The avalanche passes by the buildings, crosses the river, the road and stops on the opposite slope													
4	Adigeni municipality, township Abastumani. Left slope of Abastumanistskali river. Peak height 1621 m.													
	1225	-20	60	60	830	905	0.2	10	0	0	2	12	870	1210
	The avalanche passes by the buildings, crosses the river, the road and stops on the opposite slope													
5	Borjomi municipality, township Bakuriani, Right slope of Bakurianistskali river. Peak height 1975 m													
	1640	25	230	230	1100	1145	0.4	6	0	0	5	16	950	1660
	The avalanche passes by the buildings, stops on the road													
6	Borjomi municipality, village Likani. Left slope of Likaniskhevi river. Peak height 1334 m.													

	845	15	30	80	1160	1240	0.2	11	0	0	2	9	1210	850
	The avalanche passes by the buildings, crosses the road and stops in the river													
7	Aspindza municipality, village Toloshi. Left slope of Mtkvari river													
	1120	20	270	280	1020	1240	0.4	10	0	0	18	6	1060	1130
	The avalanche passes by the buildings, crosses the road and stops in the ravine													

In the table of morphometric and dynamic characteristics of avalanches of Samtskhe-Javakheti highways, columns 2-9 provide data on the absolute and relative height of the avalanche and its separate sections, horizontal and actual length, and surface slope, and area of avalanche center. Columns 10-15 present numerical data on the values of avalanche speed and impact force, avalanche cone volume, moving avalanche snow height, avalanche length, and the absolute height of the avalanche stop on a separate section of the avalanche collector. The last column of each avalanche description indicates the place where Th avalanche will stop, e.g. it will pass by the buildings, cross the river, cross the road, and stop on the opposite slope. In addition to these numerical data, the location of each avalanche is given (river valley, height of mountain, or peak where the avalanche begins). The settlement and the main object of our research

are indicated a road where the avalanche can cause damage. A minus sign in front of the number in the third column indicates that the avalanche crossed the road, ravine, or river and stopped on the opposite slope.

By combining the existing basic data and the data of our expeditionary works, we were able to create a modern, large-scale geo-informational maps of the avalanche danger of highways in Samtskhe-Javakheti region (Fig. 4; fig. 5).

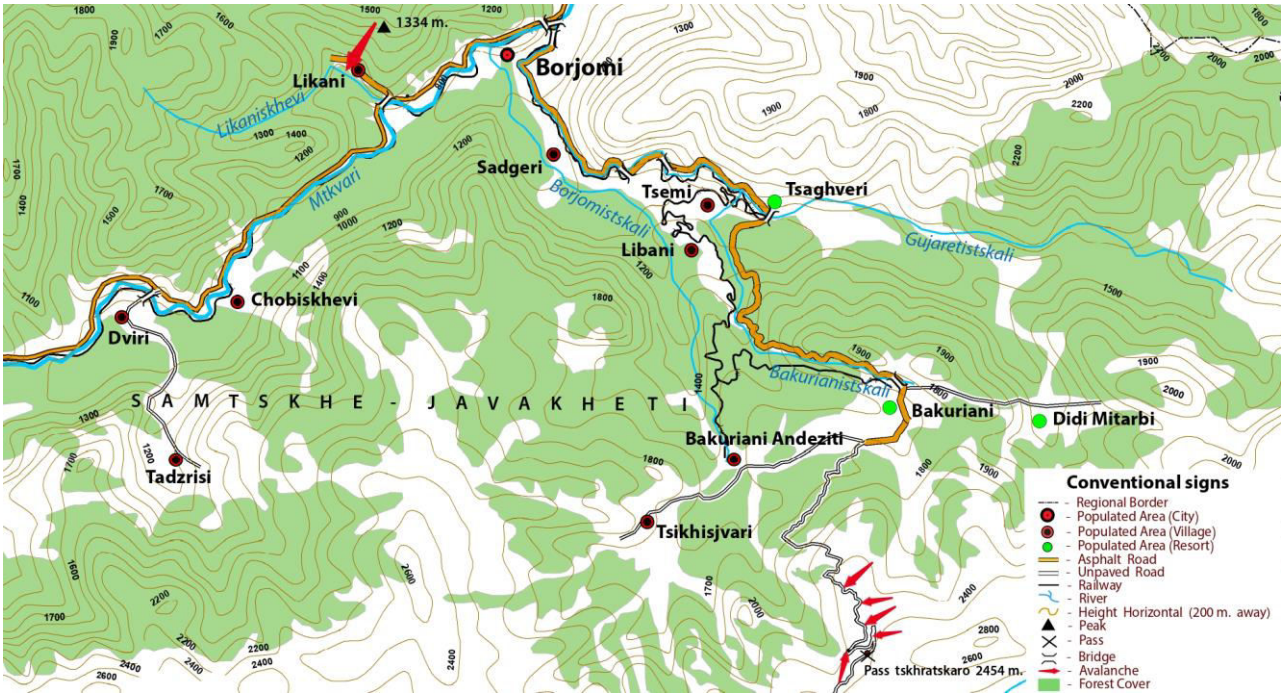

Fig. 4. Avalanche hazard map of Likani-Tskhratskaro section of the highway of Samtskhe-Javakheti region.

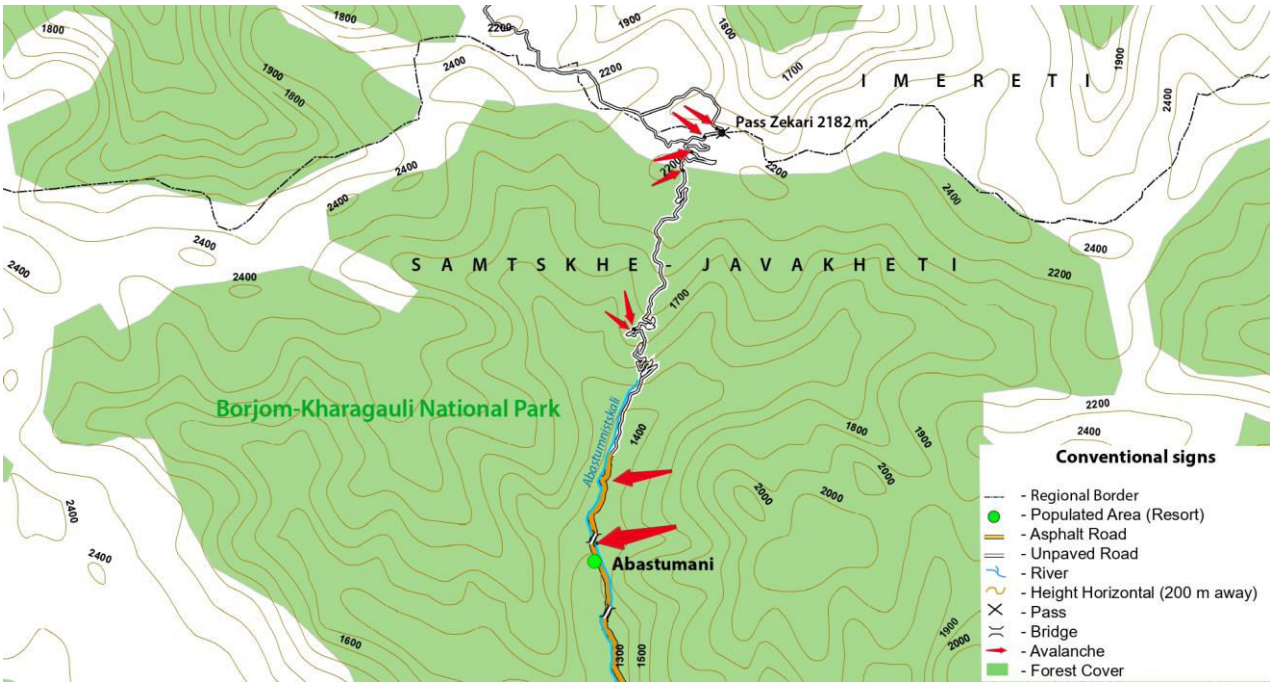

Fig. 5. Avalanche hazard map of Abastumani-Zekari section of the highway of Samtskhe-Javakheti region.

V. DISCISSION

In the municipality of Adigeni of Samtskhe-Javakheti region, the danger of the avalanches on the roads is manifested in the village Kikibo and Dertseli of Abastumani township, from where avalanches descend in the snowless winter. Dertseli is a village in southern Georgia, on the slope of the Meskheti mountain range, on the river. It is located on the right side of Ghaghvistskali River (the left tributary of the Kvabliani river) and 1520 m above sea level. Village Kikibo is a village of the Dertseli community in the east of the Arsiani ridge and the river. It is located to the left of Kvabliani river. Avalanche danger in Borjomi district village, it is possible I the territories of Didi Mitarbi, Bakuriani township and Likani resort, and Aspindza district near Toloshi village (Table 4).

Table 4. Villages and rivers with avalanche danger of highways section according to municipalities

Villages and with avalanche danger of highways section according to municipalities		Rivers with avalanche slopes
municipality	Village*/Township**	Kvabliani Ghaghvistskali Abastumnistskali Bakurianistskali Likaniskhevi Mtkvari
Adigeni Borjomi Aspindza	Kikibo* Dertseli* Abastumani** Bakuriani** Likani* Toloshi*	

In recent years, the number and interest of mountain and sky resorts in Georgia has increased, especially from foreign visitors. In Samtskhe-Javakheti territory of our research region, there are two roads that connect to mountain-sky resorts, namely Bakuriani mountain-sky resort and Goderdzi mountain-sky resort. Therefore, the study and assessment of avalanche danger in the region becomes even more important. Bakuriani is located at 1700meters above sea level and was established as a sky resort in 1935. There are 23 different types of sky trails on the territory of the resort, and depending on the skier's level, it creates an opportunity for both beginner and intermediate level, as well as experienced skiers [12]. Bakuriani mountain-sky resort is van international level resort. In 2023, Bakuriani (together with

Gudauri) hosted the World Freestyle Skiing and snowboarding and successfully managed this important event. The mountain-ski resort Goderdzi is located in the mountainous Adjara, on the Goderdzi pass, 2027 meters above sea level, on Batumi-Akhaltsikhe highway. The mountain-sky resort was opened in 2015, 2.5 % of the tracks on Goderdzi are for beginners, 71.5 % for intermediate level, and 26 % - for Above-average level skiers [13]. Currently, the construction of the 45-kilometer modern standard road of Khulo-Zarzma of the Batumi-Akhaltsikhe highway connecting Samtskhe-Javakheti and mountainous Adjara is underway.

There are two pass sections in the territory of the study region, which also indicate the presence of avalanche-prone sections of the region. These passes are the Tskhratskaro Pass and the Zekari Pass. The Tskhratskaro Pass is locatedat an altitude of 2462 m above sea level and connect the municipalities of Borjomi and Akhalkalaki with each other (fig. 6). The Zekari Pass is located an altitude of 2182 m above sea level and connect the regions of Samtskhe-Javakheti and Imereti with each other (fig. 7).

Fig. 6 Avalanche remnants on the Bakuriani-Tskhratskaro highway, 2023.

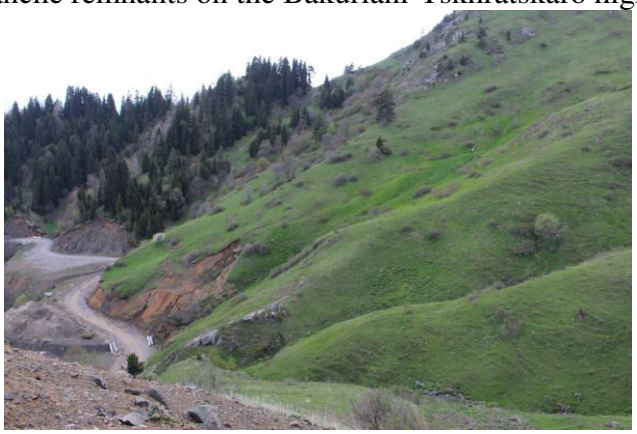

Fig. 7 Avalanche slopes on the Abastumani-Zekari highway, 2023.

Along with the increase flow of tourists, numerous cases of non-observance danger and its safety norms have been observed in Georgia, which often and fatal results. To a large extent, the reason for this is the arbitrarily moving of skiers and mountaineers who are fond of extreme sports in the forbidden zone, in the untracked snow. In 2014-2023, avalanches in Georgia killed 21 people, seriously injured 10, and 46 lives were saved with the help of rescuers. In 2015, village of Adigeni municipality 4 people were caught in an avalanche near Kikibo, 3 were injured and one died. In 2016, during preparation for the championship in Bakuriani, an avalanche that come down due to movement in untracked snow killed a famous Georgian snowboarder, and this year, also in Bakuriani, an amateur snowboarder was killed by an avalanche.

VI. CONCLUSIONS

Based on the data processing as a result of conducted researches and expeditionary works

- The climatic and geographical characteristics of avalanche prone highways in Samtshke-Javakheti region were studied;

- On the basis of data analysis geo-informational maps were created, in particular, schematic maps of the region for avalanche-prone sections of highways;
- The results of the study will help in the preparation and implementation of anti-avalanche works on the highways of the mountainous areas of Samtshke-Javakheti region.

VII. ACKNOWLEDGEMENT

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