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Highmountain Soils of the Khevi Region

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Abstract

Khevi is a region in Georgia that is situated at a high altitude. The mean elevation of relief is 2850 metres above sea level. The lowest elevation is found in Dariali Gorge at an altitude of 1210 metres above sea level, while the highest point is the peak Kazbek, towering at an elevation of 5033 metres above sea level. The orographic features in the Khevi region include the northern slope of the main ridge of the Caucasus, which is characterized by peaks such as Zilgakhokhi, Kadlasani, Lagatisari, Khorisari, and Kvenamta. Additionally, there are several passes in the area, namely, Uristi, Jvari, and Gudamakari. To the north, the Khokhi ridge rises, with notable peaks such as the Jimara (4770 m), Suatisi (4480 m), and Maili (4620 m) ridges, as well as the Shavana and Kuro ridges. Additional orographic features in the Khevi region include the R. Tergi gorge, the cavernous area of Kazbegi, and Sno. The Khevi territory covers an area of 1081.7 square kilometres, which represents 15.9% (6786.2 square kilometres) of the Mtskheta-Mtianeti region. Mount Kazbek is renowned for its exquisite beauty and majestic presence among the European mountain range. The elevation of the object is 5033 metres above sea level. Kazbek is situated in a nival-glacial region and is consistently enveloped by snow and ice. The Kuro, Kidegani, and Shavana ridges are located on the left side of the Tergi River in the meridian direction. The research area is situated in the subalpine and alpine regions. The alpine zone is located at an elevation range of 2100-2300 metres. The alpine natural zone is found at the highest elevations of the Caucasus Ridge. Mountain meadow soils are found in the subalpine and alpine zones. Mountain meadow soils exhibit undifferentiated profiles. The primary diagnostic indicators are a distinct humus layer overlaying a minor weathering layer. The entire area of mountain meadow soils is 1,758,200 hectares, accounting for 25.1% of the country. Mountain meadow soils are found extensively in the subalpine and alpine regions of the Caucasus and the southern mountains of Transcaucasia, ranging in elevation from 1800 (2000) m to 3200 (3500) m above sea level.

Keywords: Soil, Caucasus, Subalpine, Alpine, Highmountain

Introduction

S. Zakharov conducted comprehensive research on high mountain soils and authored a monograph dedicated to this specific soil type. He formulated an extensive categorization of mountain meadow soils, wherein he differentiated between mountain meadow alpine, subalpine chernozem-like raw (found on carbonate rocks), and turf soils (characterized by a robust framework and stones). The examinations conducted by S. Zakharov served as the foundation for extensive research on these soils in the Caucasus and other mountainous areas.

The mountain meadow soils are developed in severe climates, characterized by prolonged winters (with extended snow coverage) and mild summers. The duration of the frost-free period ranges from 3 to 5 months. The duration of the vegetative development phase is 3 to 4 months. The mean temperature in January ranges from -12.0°C to -5.2°C, in April from -1.6°C to 5.6°C, and in July from 7.3°C to 14.4°C. The average yearly air humidity fluctuates between 68% and 81%, with a humidity coefficient of 6-7. However, during warm periods, despite the high summer rainfall, it significantly decreases to 1.1. This can be attributed to significant evaporation. The duration of the snow covers lasts for a period of 5-7 months, with its peak occurring in March. The mountainous climate is distinguished by intense solar radiation. The frigid environment in elevated mountains facilitates extensive rock weathering, resulting in a significant buildup of rock pieces on the surface of the soil [1].

The altitude of the high mountains reflects the impact of different vertical zones. At the higher level, there is a predominance of erosion-denudation relief characterized by the frequency of frost events. In addition, we encounter several types of relief resulting from Quaternary volcanic activity. Erosion gorges are frequently observed at lower elevations, characterized by steep slopes and extensive alluvial plains in certain locations.

The geological composition of the high mountains in East Georgia is primarily composed of clay-schists and sandstones. The principal components consist of volcanic rocks, which form the peaks of the mountains. Greater quantities of sediments can be found in the upper Caucasus region. The vegetation in high alpine regions exhibits distinct zonality. The vegetation in the subalpine belts exhibits significant heterogeneity. Shrubs, mixed grasses, and communities of mixed grasses are the dominant vegetation in the subalpine belt. The high highlands are characterized by a dense and tall grass cover,

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primarily consisting of various mesophilic species. Under rather arid conditions, the mesophilic high grass flora undergoes a transition to xerophytic vegetation.

The subalpine vegetation comprises secondary meadows that are produced near the higher boundary of the forest due to forest clearings.

Within the alpine belt, two dominant types of vegetation prevail: alpine carpet, which consists of turf-forming grasses with a mixture of several grass species, and grass vegetation.

The soils found in mountain meadows have a composition that ranges from loamy to clayey. They exhibit an acidic or weakly acidic reaction and have a significant amount of humification, which extends to deep layers. In some cases, the lower horizons of these soils contain more than 1% humus. The humus is classified as fulvate or humate-fulvate, consisting mainly of water-soluble components and lacking adequate nitrogen. The concentration of silicate iron increases as depth increases, and this is influenced by the overall bioclimatic conditions found in high mountain regions. This relationship is supported by the limited occurrence of active weathering and soil formation. The spatial distribution of amorphous iron in the profiles exhibits significant irregularity.

The mountain meadow soils exhibit shallow depth on average, with a surface layer composed of turf material. They have a loamy or clayey texture and tend to be predominantly acidic or weakly acidic in nature. These soils also display a significant degree of humification, with a deep layer of organic matter. Base saturation is generally low or moderate, and there is an uneven distribution of mineral fractions and total oxides. Additionally, these soils undergo a type of weathering known as siallitic weathering. The primary soil formation processes in mountain forest meadow soils are siallitization and humus development.

The soil profile exhibits limited differentiation and shallow depth, with a notable presence of high base saturation that diminishes with increasing depth. Additionally, the lower horizons of the soil profile demonstrate reduced water permeability compared to the upper horizons. They possess a significant concentration of humus. The primary soil formation processes include humus formation, sod formation, and structure formation. The primary procedure is leaching. Humus siallitization is characterized by a significant increase in humus formation and accumulation. The clay formation exhibits no discernible indications of illuviation. Sod processes are distinguished by the substantial generation and storage of humus due to dense grass cover [2-4].

Methods and Materials

During field activities, the soil has been studied with a description of morphological signs. The morphological signs are observed visually. The following indicators were described: GPS coordinates, altitude, slope, exposition, and human influence on the environment.

In the alpine meadow zone, 7 soil pits have been made there. The following analyses were performed in the laboratory: pH, humus, hygroscopic H2O, CaCO3, cation exchange capacity, and soil texture.

The alpine meadow zone is situated at an elevation of 2200-2500 metres above sea level. The south-facing slope is covered by steppe grass, which is challenging to access.

Results

In village Tsdo soil has following build soil profile composition: A-B-BC (Pr. 3). Soil has well developed sod, glacier stones are on the surface. The soil is characterizing with weak acid reaction (pH 4, 0 – 5, 6), in 100g soil the sum of absorbed cation capacity is 12, 4 - 7, 11 mg. eqv. from absorbed bases Ca predominates Mg, content of humus is 4,0 – 5,6 % (Table 1).

In village Pansheti soil has following build soil profile composition: A – AB – B – BC (Pr. 7). Soil has well developed sod. The acid reaction of soil (pH 5, 4 – 6, 2), in 100g soil the sum of absorbed cation capacity is 19, 01 – 15, 99 mg. eqv. from absorbed bases Ca predominates Mg, content of humus is 0,75 – 8,80 % (Table 1).

In village Gergeti soil has following build soil profile composition: A′ - A′′ - AB – BC (Pr. 4). The acid reaction of soil (pH 5, 8 – 6, 8), in 100g soil the sum of absorbed cation capacity is 25, 3 – 10, 21 mg. eqv. from absorbed bases Ca predominates Mg, content of humus is 1,69 – 9,40 % (Table 1).

In Stepantsminda soil has following build soil profile composition: A – BC (Pr. 8). The acid reaction of soil (pH 4, 3 – 5, 8), in 100g soil the sum of absorbed cation capacity is 12,71 – 12,07 mg. eqv. from absorbed bases Ca predominates Mg, content of humus is 1,69 – 9, 40 %.

In village Achkhoti soil has following build soil profile composition: A′ - A″ - AB – BC (Pr. 10). The acid reaction of soil (pH 5,0 – 5,8), in 100g soil the sum of absorbed cation capacity is 34,1 – 12,8 mg. eqv. from absorbed bases Ca predominates Mg, content of humus is 5,0 – 5,8 %.

In village Sno soil has following build soil profile composition: A – BC (Pr. 37). The acid reaction of soil (pH 4,2-4,4), in 100g soil the sum of absorbed cation capacity is 24,47 – 22,35 mg. eqv. from absorbed bases Ca predominates Mg, content of humus is 3,30 – 10,23 %.

In villages Sno (Pr. 37) and Achkhoti (Pr. 33) (Table 2) the soil has light loam texture, number of roots and moisture become more with increasing of the slope, much roots, and vegetative cover is presented by steppe grass.

Table 1. Main characteristics

Objects, Profile №	Horizon, depth (cm)	pH (H_2O)	Humus, %	Hygr. H_2O %	Cation exchange capacity, mg/equivalent in 100 g. soil				% from Sum		
					Ca^{++}	Mg^{++}	H^+	Sum	Ca	Mg	H
3 Tsdo	A 0-20	4,0	10,18	1,02	5,30	4,60	2,5	12,4	40	35	25
	B 20-65	5,2	8,15	1,02	6,60	4,42	5,35	16,55	39	35	26
	BC 65-100	5,6	0,94	1,02	4,01	2,60	0,5	7,11	53	35	12
7 Pansheti	A 0-10	5,4	8,80	1,04	12,60	5,31	1,1	19,01	63	20	17
	AB 10-30	5,5	5,6	1,03	10,11	5,39	1,6	17,1	59	31	10
	B 30-50	6,5	1,11	1,02	8,70	4,35	1,6	14,65	65	25	10
	BC 50-80	6,2	0,75	1,03	10,03	4,56	1,4	15,99	60	23	17
4 Gergeti	A′ 0-10	5,8	9,40	1,05	17,65	7,35	0,3	25,3	65	28	7
	A″ 10-20	5,5	7,30	1,03	8,50	4,78	0,2	13,48	40	23	37
	AB 20-40	5,8	6,40	1,03	8,03	2,36	0,5	10,89	65	15	20
	BC 40-58	6,8	1,69	1,03	5,10	4,01	1,1	10.21	55	37	8
8 Stepan-tsminda	A 0-20	5,8	8,05	1,02	8,12	3,55	0,4	12,07	67	31	2
	BC 20-40	4,3	3,12	1,02	9,36	3,35	0	12,71	74	26	0
10 Achkhoti	A′ 0-20	5,8	10,77	1,08	25,55	6,75	1,8	34,1	65	18	17
	A″ 20-45	4,4	8,46	1,04	6,40	3,55	8,3	18,25	35	15	50
	AB 45-55	4,8	5,32	1,04	3,35	1,4	5,1	9,85	30	18	52
	BC 55-65	5,0	2,11	1,04	6,10	2,30	4,4	12,8	42	18	40
37 Sno	A 0-15	4,4	10,23	1,03	15,65	4,8	2,4	22,85	60	38	2
	BC 15-40	4,2	3,30	1,04	13,85	5,02	5,6	24,47	47	25	28

Table 2. Soil texture

Profile №	Location, exposition, altitude	Horizon, depth (cm)	Fractions, %						
			1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	<0,01
37	Sno	A 0--30	5	38	13	20	13	11	44
		AB 30--70	0.6	53.4	26	7	5	8	20
		BC 70--100	29	45	4	6	2	14	22
33	Achkhoti	A′ 0--10	17	33	1	36	9	4	49
		A″ 10--25	5	17	22	16	34	6	56
		AB 25--40	4	26	18	3	11	38	52
		BC 40--60	4	27	31	13	18	7	38

Mountain meadow soils are widely distributed in subalpine and alpine zones of the Caucasus and the Transcaucasia southern mountains, at 1800 (2000) m to 3200 (3500) m asl. The mountain meadow soils are formed under extreme climatic conditions, which are characterized by long winters (with long snow cover) and cool summers. The period without frost lasts 3-5 months. The period of vegetation growth is 3-4 months. The average temperature of January fluctuates between -12°C and -5,2°C, in April between -1,6°C and 5,6°C, and in July between 7,3 and 14,4°C. The average annual air humidity ranges from 68% to 81% with a humidity coefficient of 6-7, but in warm periods, despite the summer maximum precipitation, it sharply drops to 1,1. This may be explained by the high evaporation.

The vegetation of the high mountains is characterized by a sharply expressed zonality. The vegetation of the subalpine belts is quite inhomogeneous. In the vegetation cover of the subalpine belt, shrub, shrub-mixed grass and mixed grass communities predominate. The grass cover of the high mountains is dense and high and is mainly represented by different mesophilic species. In comparatively dry conditions, the mesophilic high grass vegetation changes to xerophytic vegetation.

In the alpine belt, two types of vegetation predominate – alpine carpet, turf forming grasses with elements of mixed grasses and grass vegetation.

Alpine meadow zones with different exposures and inclinations are characterized by well-expressed humus horizons. These soils are characterized by weak acid reactions (pH 4,5-6,1) and very high humus contents (0,94-11,23%).

Figure 1. Soil profile of town Stepantsminda

Figure 2. Soil profile of vil. Achkhoti

Discussion

Mountain meadow soils are loamy to clayey and have an acid or weakly acid reaction, with high and deep humification; in lower horizons, the content of humus sometimes exceeds 1%. The type of humus is fulvate or humate-fulvate, with predominantly water-soluble fractions and insufficient nitrogen. The content of silicate iron increases with depth, which combines with the general bioclimatic conditions of the high mountains and is proven by limited active weathering and soil formation. The distribution of amorphous iron in the profiles is very irregular.

Thus, the mountain meadow soils are characterized by average or little depth, loamy or clayey texture, mainly acid or weakly acid reactions, high and deep humification, low or average base saturation, an unequal distribution of mineral fractions and total oxides, and a siallitic type of weathering. The basic soil-forming processes of mountain forest meadow soils are siallitization and humus formation.

The soil profile is characterized by weak differentiation and little depth, high base saturation (which decreases with depth) and high-water permeability (which also decreases in the lower horizons). They contain a high amount of humus. The main soil-forming processes are humus formation, sod formation and structure formation. The main process is leaching. During humus siallitization, intensive humus

formation and humus accumulation are visible. The clay formation is without noticeable signs of illuviation. Sod processes are also characterized by intensive humus formation and humus accumulation under the influence of dense grass vegetation.

The alpine vegetation conditionally includes secondary meadows that are formed at the upper forest border as a result of forest cuttings [5, 6].

Conclusion

Upon evaluating the primary indicators of research subjects, it is noted that high altitude soils in alpine regions do not display a discernible variation that could have had a genetic importance. Soils have characteristic traits such as comparable capacity, a fully developed humus layer, abundant humus content, and varied characteristics. The primary variables influencing these traits are ecological, particularly climate severity, while local variations are not associated with distinct genesis peculiarities.

Competing interests

The author declares that there are no competing interests.

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