



Peculiarities of soils of high mountain (on Khevi example – on the Central Great Caucasus)

Ketevan Gogidze

Agricultural University of Georgia, Mikheil Sabashvili Institute of Soil Science, Agrichemistry and Melioration, 240, David Aghmashenebeli Alley, Tbilisi, 0159, Georgia

Received: 21 January 2019; accepted 12 March 2019

ABSTRACT

The article includes the research in Khevi region of Central Caucasus. Study area was divided by expositions (north and south), inclination (0-10°, 10-30°, >30°) and altitude (1700-2000 m – subalpine forests, 2000-2200 m – subalpine meadows, 2200-2500 m – alpine meadows). The number of soil profiles as a result of division was consisted of 18. By comparing the profiles of high mountain soils to each other, they do not stand out by genetic individuality.

Keywords: Soil, Pasture, Meadow-forest-mountain soils, Meadow-mountain soils, Subalpine, Alpine.

*Corresponding author: Ketevan Gogidze; E-mail address: qetusi86@gmail.com

Introduction

The studying of the soils of High Mountain of the Caucasus was started with great intensity from the beginning of the 20th century. The first researcher was S. Zakharov [1], who investigated the soils of high mountain of Georgia nearby the Lesser (Tskhratskaro) and Main Caucasus (Jvari passes). Subsequently, A. Voznesensky [2] studied mountain-forest soils in Zakatala district, but O. Mikhailovskaya [3] investigated soils of subalpine forests in Samachablo. Subalpine soils of Klukhori district was studied by G. Akhvlediani and S. Tsintsadze [4]. There is a great contribution to study the soils of High Mountain of next researchers, G. Tarasashvili [5], A. Gogatishvili [6] and G. Talakhadze [7]. With using of modern research these soils has been studied by T. Urushadze [8-10]. The aim of his research was the peculiarities of genesis, legislation of geographical distribution and studying of classification of soils. The soils of the highmountains of Georgia also was studied by M. Sabashvili [11, 12], M. Sabashvili and M. Jikaeva [13], Sh. Shubladze [14] T. Urushadze, T. Kvrivishvili [15], T. F. Urushadze, W. E. H. Blum

[16] and others. The high mountain soils were studied quite well, but in their investigations there are given less about comparative characterization of soils in subalpine and alpine belts.

In summer in the Central Caucasus (Khevi region) the pastures are used very intensively by population. Meanwhile, there are some problems of their care and improvement. The biggest problem is overgrazing of the pastures. It is important to study the soils on pasture for their further using and improvement. It is often overgrazing of pastures, it causes worsening of botanic and chemical composition of grass, decreasing of productivity and dismantling of sod [17]. Without studying of ecological conditions (subalpine and alpine belts, exposition, inclination), It is impossible the protection of soils of high mountain and Rational using.

Physical-geographical description of the region

For creating the relief of the Central Caucasus with tectonics, erosion, glacier activity and other widespread factors are karstic processes. Young

volcanism is presented in the Central Great Caucasus. The Central Great Caucasus is built by Mesozoic and Previous Mesozoic tiles.

Khevi region is built by quaternary fluvial and glacial sediments, Tertiary and Quaternary volcanic rocks and Jurassic sedimentary rocks. Kazbegi district is characterized by high tectonic and geomorphologic activities. The neovolcanic center of Kazbek was still active in late Quaternary. Three small apparatuses are localized in area: near Pkhelshe, downward Sioni and mouth of the river Chkheri [18].

Andesite flow of Pkhelshe has a submeridional direction, with endings it covered the old valley of river Tergi on the territory of villages Khurtisi and Pkhelshe and has changed the direction of Tergi to right by character of canyon. Next to flow of Pkhelshe by two rivers (Khurtisistskali and Pkhelshistskali) are made valleys of semicanyon and canyons. The center of flow of Pkhelshe is a volcanic massive Tkarshtismta (3417 m). Next geographical succession is flow of Arsha (andesite), which pouring out on the place of ruins Kazbegi crater and reached to the left bank of river Tergi, village Arsha. Its length is 8 km. Flow of Chkheri starts on the left slope of Kazbegi and reaches 9 km by length, comes down to the west on the left bank of river Tergi, between the villages Gergeti and Saketseti. Middle and upper sides of Arsha, the flows of Chkheri and to the north of Tsdo, together present a massive of lava, and is cutting by valleys of rivers Chkheri and Tsdoistskali. The flow of Tsdo has poured out in region of glacier Abano. Its length is 8 km. It has finished on the left bank of river Tergi near village Tsdo. Flow of Gveleti starts near Archkhoti pass and finishes with two tongues, till Dariali valley. Its length is more than 3-4 km [19].

All described lavas are belonged to andesites and andesitedacites. The lateral center of Kazbegi massive N. I. Skhirtladze recognizes mountain Kichugzeri (3500 m a. s. l.), is located on the west slope of cone. The area of modern ice age on Kazbegi massive is 29, 44 km².

In study area mudflows are natural hazard and hot points are in Tergi river basin. So this location is in a zone of medium landslide hazard [20,21].

The gorge of river Snoistskali by morphology is erosive and deeply fragmented (Khorkhi, Kvenamtistskali, Chaukhistskali, Shinostskali), on their mouth and slopes are too much hearths of avalanche and downpour, because of it, village Juta is torn off from Stepantsminda about four months.

The gorge of Dariali near estuary of river Chkheri is presented by avalanche and rockfall. One of the main reason of retention of Dariali was river Chkheri downpour. In this process role had carried out snowy material of glaciers Ortsveri and Abano. In retention of Tergi participated Kuros Khevi, and from right side it united Tergi gorge in this place and has brought demolished material of Kuro massive, which is built with unsustainable schist for erosion [23].

Subalpine zone is characterized by short cool summers and severe long winters. The winter is cold with much snow. The duration of the vegetative season is from three to four months. The period without frost is from one to two months. The precipitation maximum occurs in spring and summer. The average annual relative air humidity reaches 70 to 79%. In the area of the subalpine forest dominates a high-mountain erosive-denudative relief with additional influence of former glaciation. Some relief forms were created by quaternary volcanism. Erosive gorges are located on steep slopes. Clay-shales, sandstones, limestones and moraine sediments are mainly met in East Georgia. Due to unfavorable ecological conditions subalpine forests are presented by specific species, structure and forms of the vegetation [24].

On the steep slopes in some places are a wide territories of alluvial plains. In the high mountains is forming the following kind of relief: 1) old peneplain-level ("cut") ranges; 2) glacial relief – care, circus, terrace areas; 3) volcanic relief – plateaus (south mountains) and 4) erosion relief. Rock fragments and stones mainly cover Glacial and erosion high mountain reliefs, but the turf covers elements of the old peneplain and volcanic relief.

In the Main Caucasus above of the forest belt we have business with high mountain, where in the main part is spread out mountain-meadow soils. Among them is more important subalpine forest zone (with bound or woodland forests), which is transitional between forest and high mountain. Here are spread mountain-forest-meadow soils.

The subalpine forest is characterized by a limited growth, and as rule low productivity. These forests protect tall forests and agricultural land, in lower positions against mountain torrents, landslides, winds and snowfall and regulate the water regime.

The mountain-forest-meadow soils are formed under extreme climatic conditions, which are characterized by long winters and cool summers.

The period without frost lasts 3-5 months. The period of vegetation growth is 3-4 months. The cold climate of the high mountains supports an intensive weathering of the rocks and because of it an accumulation of a great number of rock fragments are on the soil surface [25].

There are several examples of dividing of high mountain. For example, M. Sakhokia marked out next zones:

1. Forests of middle zone of mountain (1000-1500 m a. s. l.)
2. Forests of upper zone of mountain (1500-1750 m a. s. l.)
3. Subalpine zone (1750-2300, 2500 m a. s. l.)
4. Alpine zone (2300-3000, 3100 m a. s. l.)
5. Two sub zones: lower alpine (2300-2700 m a. s. l.) and upper alpine (2700-3000 m a. s. l.); subnival (3000-3600 m a. s. l.)
6. Nival zone (above 3600 m a. s. l.) [26].

Objects and methods

The study area, Kazbegi municipality was divided by expositions (north and south), inclination (0-10°, 10-30°, >30°) and altitude for next zones:

1. 1700-2000 m – subalpine forests
2. 2000-2200 m – subalpine meadows
3. 2200-2500 m – alpine meadows

The number of soil profiles as a result of division was consisted of 18 [27-30]. The soils were studied by the World Reference Base for Soil (WRB). Among them, soil was described by the using of the Munsell Color Scale. During laboratorian examination was made following analysis: mechanic analysis by the pipe method; hygroscopic water, (pH) potential, calcium carbonates with calcimetry, common humus by the volumetric method, calcium and magnum definition via trilon B titre, Soil absorbed hydrogen (Exchange Acidity) [31].

Results and discussions

In the subalpine forests zone on the south, exposition soils have following build: A'-A''-AB-B-BC (Pr. 15), A-AB-B1-B2-BC (Pr. 5¹, 6). The first type of build is characterized for inclination 0-10°, the second type of build – 10-30° and >30°. The soil has light loam texture, vegetation – birch and pine forest, the quantity of roots growing together with the increasing of the inclination. On the south exposition the soils is characterizing with acid

and neutral reaction (pH 5,5-7,3), in 100 g soil the sum of absorbed cation capacity is 3,67-13,86 mg. eqv., from absorbed bases Ca predominates Mg, unsaturated with basis, content of humus is 10,63-0,55%.

On the north exposition, soils have following build: A-AB-BC1-BC2 (Pr. 5), A-B-BC (Pr. 42), A'-A''-BC-CD (Pr. 4). The first type of build is characterized for inclination 0-10°, the second type of build – 10-30° and - >30°. The soil has light and medium loam texture, vegetation – steppe grass, the quantity of roots growing together with the increasing of the inclination. On the north exposition the soils are characterizing with acid and weak acid reaction (pH 5,2-6,18), in 100g soil the sum of absorbed cation capacity is 25,3-11,43 mg. eqv., from absorbed bases Ca predominates Mg, is unsaturated with basis, content of humus is 10,9-15,09%.

In subalpine forest zone south and north expositions have differences: soil build, vegetative cover, where the south exposition is presented by birch and pine forest, but the north – by steppe grass, is with reaction, mechanic content, humus content, in 100g soil with the sum of absorbed cation capacity.

Subalpine meadows are located at 2000-2200 m above sea level. Vegetative cover is presented by steppe grass on the south and north expositions.

In the subalpine meadow zone on the south exposition, soils have following build: A-AB-BC (Pr. 4¹, 3¹), A-AB-B-BC (Pr. 2¹). The first and second type of build are characterized for inclination 0-10° and 10-30°, but the third type - >30°. The soil has light loam texture, well developed sod, glacier stones are on the surface. On the south exposition the soils are characterizing with weak acid reaction (pH 5,5-6,3), in 100g soil the sum of absorbed cation capacity is 4,56-12,78 mg. eqv., from absorbed bases Ca predominates Mg, is unsaturated with basis, content of humus is 9,17-0,55 %.

In the subalpine meadow zone on the north exposition, soils have following build: A-BC (Pr. 29), A'-A''-BC (Pr. 2), A'-A''-AB – BC (Pr. 3). The first type of build is characterized for inclination 0-10°, the second – 10-30° and the third - >30°. The soil has medium loam texture, many roots and skeleton, it is observed biological activity; volcanic stones, steppe grass are on the surface. On the north exposition the soils are characterizing with weak acid reaction (pH 5,5-6,3), in 100g soil the sum of absorbed cation capacity is 7,45-15,7 mg. eqv., from

absorbed bases Ca predominates Mg, is unsaturated with basis, content of humus is 9,91-1,06 %.

In subalpine meadow zone, the south and north expositions have differences: texture, humus content, in 100g soil the sum of absorbed cation capacity, in the north are much roots skeletons, biological activity, volcanic stones and in the south – glacier stones on the surface.

Alpine meadows are located at 2200-2500 m above sea level. Vegetative cover is presented by steppe grass on the south exposition.

In the alpine meadow zone on the south exposition, soils have following build: A'-A''-BC (Pr. 37), A-AB-B-BC (Pr. 9), A'-A''-AB – BC (Pr. 1¹). The first type of build is characterized for inclination 0-10°, the second – 10-30° and the third - >30°. 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. On the south exposition the soils are characterizing with acid and weak acid reaction (pH 4,5-6,1), in 100g soil the sum of absorbed cation capacity is 19,23-7,29 mg. eqv., from absorbed bases Ca predominates Mg, is unsaturated with basis, content of humus is 11,18-0,95 %.

In the alpine meadow zone on the north exposition, soils have following build: A-BC (Pr. 1, 32), A'-A''-AB-BC (Pr. 33). The first and second type of build are characterized for inclination 0-10° and 10-30°, the third - >30°. The soil has medium and heavy loam texture, skeleton increases to the depth, much roots, rocks on the surface. On the north exposition the soils are characterizing with acid reaction (pH 4,7-5,5), in 100 g soil the sum of absorbed cation capacity is 35,45-10,71 mg. eqv., from absorbed bases Ca predominates Mg, is unsaturated with basis, content of humus is 11,23-3,11 %.

Thus, by considering of the main indicators of research objects, high mountain soils in various zones, different expositions and inclination, does not give a clear difference which may have had a genetic meaning. Soils are characterized by general signs - more or less the same capacity, a good expression of the humus horizon, high content of humus, texture and diversity of general properties, this is due to the general ecological resemblance (e.g. severity of climate) and the difference is local nature, it does not related to the peculiarities of genesis.

Table 1. *Main characteristics*

Objects, Profile №	Horizon, depth (cm)	pH	Humus, %	Hygr. H ₂ O %	Cation exchange capacity, mg/equivalent in 100g. soil				Sum %		
					Ca ⁺⁺	Mg ⁺⁺	H ⁺	ჯანდო	Ca	Mg	H
Subalpine forests zone 1700-2000 m a. s. l.											
15 Tsdo S	A' 0-10	6,5	9,22	1,02	10,02	3,67	1	14,69	68	25	7
	A'' 10-40	6,5	5,32	1,02	10,68	6,68	0,6	15,96	67	29	4
	AB 40-55	7,0	3,62	1,03	9,46	4,05	0	13,48	70	30	0
	B 55-95	7,1	2,79	1,02	11,35	5,35	0	16,7	68	32	0
	BC 95-150	7,3	2,02	1,02	10,11	4,04	0	14,15	71	29	0
5 ¹ Gergeti S	A 0 - 15	5,5	10,63	1,06	14,15	8,09	0	22,24	64	36	0
	AB 15 –30	5,5	3,37	1,02	12,13	7,41	1,8	21,34	57	35	8
	B1 30 – 50	5,8	0,75	1,04	11,69	5,01	1,8	18,5	64	27	9
	B2 50-70	5,9	0,75	1,02	13,15	6,74	1,8	21,69	49	43	8
	BC 70-90	6,1	0,55	1,02	12,45	6,36	1,8	20,61	50	41	9
6 Gergeti S	A 0-10	5,0	4,96	1,02	14,32	4,1	1	19,42	74	21	5
	AB 10-25	5,2	1,86	1,06	7,69	4,35	5	14,04	55	31	14
	B1 25-40	5,7	1	1,04	4,01	2,68	1,2	7,89	51	34	15
	B2 40-60	6,5	0,75	1,02	4,01	3,35	1,4	8,76	46	38	16
	BC 60-80	6,5	0,75	1,02	4,34	1,01	1,8	7,15	61	14	25
5 Stepantsminda N	A 0—10	7,1	7,88	1,02	8,18	2,15	1	11,33	73	19	8
	AB 10—22	5,8	5,42	1,04	4,43	2,73	2,6	9,76	45	28	27
	BC1 22—40	5,0	5,42	1,04	6,35	2,01	1	9,36	68	21	11
	BC2 40—60	5,8	3,93	1,06	10,03	5,02	2	17,05	59	29	12

42 Akhaltsikhe N	A 0--12	6,4	10,91	1,04	17,05	7,85	0,4	25,3	67	31	2
	B 12--30	5,0	9,43	1,02	6,02	4,01	1,4	11,43	53	35	12
	BC 30--65	5,2	3,37	1,02	6,69	3,68	1,8	12,17	55	30	15
4 Stepantsminda N	A' 0-10	6,2	7,9	1,02	10,01	4,35	0,4	14,78	66	33	1
	A'' 10-20	5,7	8,9	1,04	9,21	5,11	0,8	15,12	61	34	5
	BC 20-40	5,5	1,73	1,02	10,57	6,82	1,2	18,59	57	37	6
	CD >40	-	-	-					-	-	-
Subalpine meadows zone 2000-2200 m a. s. l.											
4 ¹ Gergeti S	A 0-14	5,6	8,43	1,06	4,01	5,35	0,8	10,16	39	53	8
	AB 14-35	6,0	2,85	1,02	5,25	7,68	0,7	13,63	53	29	18
	BC 35-50	6,3	0,85	1,02	8,23	4,05	0,8	13,08	49	48	3
3 ¹ Gergeti S	A 0-13	5,8	9,17	1,02	9,36	5,32	0,4	15,08	58	35	7
	AB 13-30	5,4	5,94	1,04	11,86	4,45	2	18,31	47	35	18
	BC 30-55	6,0	1,77	1,04	9,35	5,04	2	16,39	65	25	10
2 ¹ Gergeti S	A 0-20	5,9	8,39	1,02	11,56	8,32	0,4	20,28	48	34	18
	AB 20-35	5,8	3,78	1,02	15,26	8,27	2,3	25,83	65	20	15
	B 35-50	6,2	0,75	1,04	12,35	9,03	0,6	21,98	47	45	8
	BC 50-80	5,7	0,55	1,02	10,68	6,68	0,6	15,96	50	38	12
29 Pansheti N	A 0--10	5,8	9,91	1,02	8,02	3,68	0,4	12,1	66	33	1
	BC 10--30	6,3	2,47	1,02	9,36	3,35	0	12,71	74	26	0
2 Stepantsminda N	A' 0-20	4,7	8,6	1,02	27,27	6,38	1,8	35,45	65	20	15
	A'' 20-35	5,1	4,5	1,02	6,48	3,75	8,8	19,03	53	42	5
	BC 35-50	5,3	4,6	1,04	3,41	1,7	5,6	10,71	45	52	3
3 Stepantsminda N	A' 0-20	5,5	9,4	1,02	14,32	4,1	1	19,42	74	21	5
	A'' 20-40	5,7	6,5	1,04	4,01	2,68	1,2	7,89	51	34	15
	AB 40-60	5,9	3,13	1,06	4,34	1,01	1,8	7,15	61	14	25
	BC 60-80	5,9	1,06	1,02	4,01	5,35	0,8	10,16	39	53	8
Alpine meadows zone 2200-2500 m a. s. l.											
37 Sno S	A' 0--25	4,5	11,18	1,04	5,45	4,78	2,8	13,03	42	37	21
	A'' 25--65	5,4	8,27	1,02	6,69	4,65	5,35	16,69	44	36	20
	BC 65--100	5,6	0,94	1,02	4,01	2,68	0,6	7,29	55	37	8
9 Pkhelshe S	A 0--12	5,9	8,85	1,02	12,69	5,34	1,2	19,23	66	28	6
	AB 12--30	5,5	5,11	1,03	10,11	5,39	1,6	17,1	59	31	10
	B 30--58	6,0	1,21	1,03	8,76	4,38	1,4	14,54	60	30	10
	BC 58--100	6,1	0,95	1,03	10,11	4,71	1,4	16,22	62	29	9
1 ¹ Gergeti S	A' 0-5	5,6	8,90	1,02	17,05	7,85	0,4	25,3	67	31	2
	A'' 5-20	5,5	8,03	1,04	8,86	4,78	0,2	13,84	45	21	34
	AB 20-30	5,7	6,46	1,04	9,03	2,34	0,6	11,97	75	20	5
	BC 30-55	6,4	1,77	1,04	6,02	4,01	1,4	11,43	53	35	12
1 Stepantsminda N	A 0-18	5,1	8,12	1,02	8,02	3,68	0,4	12,1	66	33	1
	BC 18-40	5,4	3,12	1,06	9,36	3,35	0	12,71	74	26	0
33 Achkhoti N	A' 0--10	5,5	10,77	1,08	27,27	6,38	1,8	35,45	80	18	2
	A'' 10--25	4,6	8,97	1,04	6,48	3,75	8,8	19,03	34	20	46
	AB 25--40	4,8	5,32	1,04	3,41	1,7	5,6	10,71	32	16	52
	BC 40--60	5,2	3,11	1,04	6,14	2,44	4,4	12,98	47	19	34
32 Achkhoti N	A 0--15	5,4	11,23	1,04	15,69	5,8	2,2	23,69	66	24	10
	BC 15--30	4,7	3,37	1,02	14,05	6,02	6,6	26,67	53	23	24

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
Subalpine forest zone 1700-2000 m a. s. l.									
15	Tsdo, S	A' 0-10	9	47	19	5	8	12	25
		A'' 10-40	17	39	15	11	8	10	29
		AB 40-55	12	37	29	5	12	5	22
		B 55-95	15	47	13	9	7	9	25
		BC 95-150	10	44	25	2	14	5	21
42	Akhalsikhe, N	A 0--12	18	24	13	18	24	3	45
		B 12--30	10	23	22	14	28	3	45
		BC 30--65	12	26	25	10	10	17	37
Subalpine meadows zone 2000-2200 m a. s. l.									
4 ¹	Gergeti, S	A 0-14	4	45	18	9	15	9	33
		AB 14-35	8	29	29	13	13	8	34
		BC 35-50	5	46	4	11	20	14	45
29	Pansheti, N	A 0--10	34	43	4	6	6	7	19
		BC 10--30	61	20	2	7	7	3	17
Alpine meadows zone 2200-2500 m a. s. l.									
37	Sno, S	A '0--25	5	38	13	20	13	11	44
		A'' 25--65	0.6	53.4	26	7	5	8	20
		BC 65--100	29	45	4	6	2	14	22
33	Achkhoti, N	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

Conclusion

1. Subalpine forests zone on different exposition and inclination are characterized by well-expressed humus horizon (A'-A''-AB or A-AB). These soils are characterized by acid and neutral reaction (pH 5,2-7,3), high content of humus (0,55-10,91 %), loam texture. In various ecological conditions, soils do not differ by nature of genesis.
2. Subalpine meadows zone on different exposition and inclination are characterized by well-expressed humus horizon (A-AB or A'- A''). These soils are characterized by acid and neutral reaction (pH 5,5-6,3), high content of humus (0,55-9,91 %), loam texture. In various ecological conditions, soils do not differ by nature of genesis.
3. Alpine meadows zone on different exposition and inclination are characterized by well-expressed humus horizon (A-AB or A'- A''). These soils are characterized by weak acid reaction (pH 4,5-6,1), very high content of humus (0,94-11,23 %), loam texture. In various ecological conditions, soils do not differ by nature of genesis.
4. Thus, comparing the high mountain soils to each other, they do not stand out by genetic individuality, which can be explained by general similarities of ecological conditions, which is not expressed in the genetic identity of individual objects.

Acknowledgments

This work was supported by Shota Rustaveli National Science Foundation (SRNSF) [grant # PhD_F_17_117, Studying of genetic peculiarities of soil in Kazbegi Municipality].

References

- [1] S. A. Zakharov, To the Characteristics of the Soils of Mountainous Countries, fifth ed., Institute of Separation of Konstantinovsky, Moscow, 1914 (in Russian).
- [2] A. Voznesensky, The soils of I and II divisions of steppe of Karaysky, Scientific Research Institute of Water Management. 11 (1935) 65-72 (in Russian).
- [3] O. N. Mikhailovskaya, On the Question of the Genesis of Soils of Highmountains, Academy of Sciences of the USSR, Moscow, 1936 (in Russian).
- [4] G. D. Akhvlediani, S. I. Tsintsadze, The Soils of Klukhori District, Works of Institute of Soil Science and Agrochemistry GSSR, Tbilisi, 1949 (in Russian).
- [5] G. M. Tarasashvili, The Soils of Mountain-Forest and Mountain-Meadows of East Georgia, Academy of Science of Georgia, Tbilisi, 1956 (in Georgian).
- [6] A. D. Gogatishvili, To the question of studying of cenosis of soils of transitive subalpine zone, Institute of Soil Science. 9 (1958) 85-98 (in Russian).
- [7] G. R. Talakhadze, The Main Types of Soils of Georgia, "Tsodna", Tbilisi, 1964 (in Georgian).
- [8] T. Urushadze, The Soils of Forest of Georgia, "Soviet Georgia", Tbilisi, 1972 (in Georgian).
- [9] T. F. Urushadze, The Soils of Some Pine Forests of Georgia, "Lesovedenie", Tbilisi, 1974 (in Russian).
- [10] T. F. Urushadze, The Mountainous Soils of the USSR, "Agropromizdat", Moscow, 1989 (in Russian).
- [11] M. N. Sabashvili, The Soils of Georgia, Institute of Soil Science of GSSR, Tbilisi, 1948 (in Russian).
- [12] M. N. Sabashvili, M. A. Jikava, About of mountain-meadow soils of Kazbegi district, Academy of Science of GSSR. 11 (1950) (in Russian).
- [13] M. N. Sabashvili, M. A. Jikava, About of mountain-meadow soils of Kazbegi district, Academy of Science of GSSR. 11 (1950) (in Russian).
- [14] Sh. K. Shubladze, The Genetic Characteristics of the Soil of highmountains of the Central Caucasus, The Thesis of Agriculture, Tbilisi, 1987 (in Russian).
- [15] T. Urushadze, T. Kvirivishvili, The Guideline of Soils of Georgia, "Mtsignobari", Tbilisi, 2014 (in Georgian).
- [16] T. F. Urushadze, W. E. H. Blum, Soils of Georgia, Nova Publishers, New York, 2014.
- [17] T. Urushadze, A. Korakhashvili, O. Kvirikashvili, L. Ninua, Some Aspects of Interdependence Between Soils and Pastures in the Central Caucasus, M. Sabashvili Institute of Soil Science, Agrochemistry and Reclamation, Tbilisi, 1984 (in Georgian).
- [18] L. I. Maruashvili, The Geomorphology of Georgia, Academy of Science of GSSR, Tbilisi, 1971 (in Russian).
- [19] B. Goishvili, Khevi, National Academy of Science of Georgia, Tbilisi, 1981 (in Georgian).
- [20] T. Hanauer, C. Pohlenz, B. Kalandadze, T. Urushadze, P. Felix-Henningsen, Soil distribution and soil properties in the subalpine region of Kazbegi; Greater Caucasus; Georgia: Soil quality rating of agricultural soils, Annals of Agrarian Science. 15 (2017) 1-10.
- [21] I. V. Bondyrev, Geodynamical processes, in: I. V. Bondyrev, Z. V. Davitashvili, V. P. Sinng (Eds.), The Geography of Georgia, World Regional Geography Book Series, Springer International Publishing, Switzerland, 2015, pp. 67-80.
- [22] I. V. Bondyrev, Geodynamical processes, in: I. V. Bondyrev, Z. V. Davitashvili, V. P. Sinng (Eds.), The Geography of Georgia, World Regional Geography Book Series, Springer International Publishing, Switzerland, 2015, pp. 87-95.
- [23] R. Khazaradze, K. Kharadze, Geographical Environment and Ongoing Geodynamic Processes in Kazbegi Municipality, National Academy of Science of Georgia, Tbilisi, 2012 (in Georgian).
- [24] L. B. Makhatadze, T. F. Urushadze, The

- Subalpine Forests of Caucasus, Academy of Sciences of the USSR, Moscow, 1972 (in Russian).
- [25] M. Kordzakhia, Climate of Georgia, Geography Institute of Vakhushti, Tbilisi, 1961 (in Georgian).
- [26] G. Agladze, P. Chkheidze, Natural Mowing and Pastures of Mtkheta-Mtianeti Region, Their Meaning in Resolve Problems of Livestock, National Academy of Science of Georgia, Tbilisi, 2012 (in Georgian).
- [27] K38-54-A, Ministry of Geology of USSR, Geological Map M 1:50 000, 1983 (in Russian).
- [28] K38-54-B, Ministry of Geology of USSR, Geological Map M 1:50 000, 1983 (in Russian).
- [29] K38-54-G, Ministry of Geology of USSR, Geological Map M 1:50 000, 1962 (in Russian).
- [30] K38-54-V, Ministry of Geology of USSR, Geological Map M 1:50 000, 1983 (in Russian).
- [31] K. Mindeli, L. Guntaishvili, N. Machavariani, D. Kirvalidze, Kh. Mindeli, L. Gamsakhurdia, Practical-Laboratory Manual of Soil Science, Tbilisi, 2011 (in Georgian).