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Forest Soils of Northeastern Yakutia

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Abstract—The soils under larch forests of northeastern Yakutia are described. Particular emphasis is given to the relationships between soils and local topography. The results of chemical and particle-size distribution analyses of the most widespread soils are presented. The approaches to forecasting the evolution of soil and vegetation cover under the impact of global climate changes are formulated.

INTRODUCTION

The soils and northernmost boreal forests of north-eastern Yakutia remain as yet poorly investigated. Meanwhile, this region attracts the attention of scientists in connection with the problem of global climate warming. On one hand, the maximum degree of climate change is expected at high latitudes, on the other hand, forest ecosystems in extreme conditions are the most sensitive to any changes in the environment.

In connection with this, there is an urgent need to organize such a monitoring of boreal forests that would provide opportunities to develop and refine the forecasts of possible environmental changes and to support the decisions aimed at the stabilization of the greenhouse effect and the mitigation of degradation processes in the biosphere. One should realize that the consequences of these processes can be quite disastrous for humankind, though they are not easy to predict.

Northeastern Yakutia is a separated geographical region with specific climate, vegetation, and animal life. This is conditioned by the high orographic barrier of the Verkhoyanskii Ridge that guards against climatic impacts from southern regions; at the same time, low plateaus and lowlands to the east of the ridge are open to the winds from cold East Siberian Sea. It is common knowledge that the coldest place in the northern hemisphere is located in the region considered (the Oimyakon area).

The soil cover of the region is very complicated and remained virtually unstudied for a long period. Reliable information on soils and soil cover of the region together with the soil map [9] has been published only within recent decades [1-4, 7, 8, 10]. The vegetation was described in a number of regional publications [5, 6, 11-13],

In 1990-1993, the All-Union Scientific and Research Center on Forest Resources (VNIITslesoresurs) selected several experimental sites in order to study the impact of global climate change on forest ecosystems of the boreal belt. In particular, the survey of soils and forests was conducted in cooperation with the Dokuchaev Soil Science Institute in the valleys of the Erikit River (the Indigirka River basin) and the Bytangai jand Dzhanky rivers (the Yana River basin) in northeastern Yakutia. This study revealed the dependence of soils and vegetation on local geomorphic conditions (Fig. 1). The description of soils with respect to their ability to support forest vegetation in different geomorphic positions is given below.

LANDSCAPE ELEMENTS OF RIVER VALLEYS

Flood plains are composed of pebbly sands. The proximity of a river improves the temperature regime of soils; these soils do not contain permafrost within the rooting zone. The tree stands are represented by larch and poplars (*Populus suaveolens*); poplars predominate in the zone subjected to frequent regular floods, whereas larch is found further from the streams. The tree canopy density varies from sparse isolated trees to relatively dense (0.7) thickets. These stands belong to the third qualitative category (moderately productive) of forests. The understory is composed of different willows that predominate in the lower part of flood plains and of *Pinus pumila* elfin trees that occupy elevated positions. The ground cover has a spotty pattern; vegetated spots are allocated to the groups of trees. Some legumes (vetch and *Astragalus*) are found in the green forest floor. Larch stands of flood plains have the best quality index in the region.

The first terraces have a distinct soil profile composed of litter (2-3 cm) and a 4-5-cm-thick humus-accumulative horizon (Al) with a weakly developed and very fine granular structure, under which the stratified alluvial sands are found. Icy permafrost occurs at the depth of 80-120 cm (the measurements were conducted in August). The soils are acid, unsaturated with bases, with a relatively high content of extractable phosphorus and low content of extractable potassium and nitrogen. Some data on the chemical properties of these soils are given in Table 1 (pit 9-90).

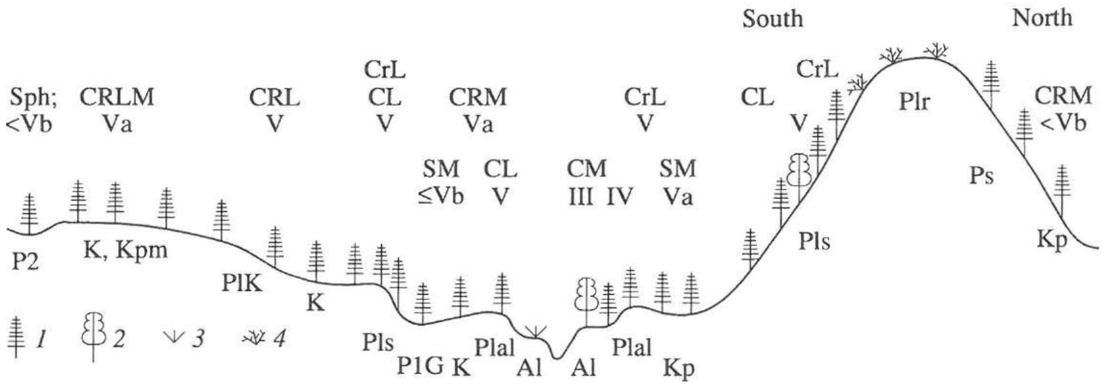

Fig. 1. Geomorphologic profile. Scales: horizontal–1 : 20000, vertical–1 : 5000. Types of larch forests: (CrL) crowberry-lichen, (CL) cranberry-lichen, (CM) cranberry-moss, (CRL) cranberry-wild rosemary with lichens, (CRLM) cranberry-wild rosemary with lichens and mosses, (CRM) cranberry-wild rosemary with mosses, (SM) sedge-moss, and (Sph) sphagnum. Soils: (K) cryozem (typical), (Kp) peaty cryozem, (Kpm) peaty-mucky cryozem, (P1K) pale cryozem, (Pis) pale soils on schist, (Plal) pale soil on alluvium, (Plr) ruptic pale soil, (Ps) peaty soil on schist, (PIG) peaty-gley soil, (P2) peat soil, and (Al) alluvial deposits. The symbols under the indices of forests (III, IV, V) designate the quality class (bonitet) of stands; tree species: (1) larch, (2) poplar, (3) willow, and (4) *Pinus pumila*.

The first terraces are occupied by larch stands of the fourth quality class, with maximum canopy density reaching 0.8–0.9. The most typical forest type is larch stand with mountain cranberry and *Hypnum* mosses. The understory is composed of *Pinus pumila* and currant. The main species of spotty ground cover are mountain cranberry (*Vaccinium vitisidaea*), *Pyrola, Cladonia*, and Hypnum moss (*Rhytidiadelphys* sp.).

High terraces represent slightly undulating plains above the flood-plain level. These plains can be subdivided into three parts. The areas adjacent to terrace brows (within 10–50 m) have the best drainage conditions. Mesomorphic pale (palevye) loamy soils underlain by pebbly sands form in this zone. The typical soil profile is composed of the Oi, OA1, Bm, BC, and C horizons. The thickness of litter does not exceed 5 cm. Permafrost is found at the depth of 1-1.5 m. The soil is well drained, has an acid reaction and a low degree of base saturation (Table 1, pit 8-90).

Pit 8-90. The right bank of the Arga-Yurekh River near its junction with the Erikit River. The brow of the river terrace. Larch forest with *Vaccinium vitisidaea* predominating in the ground cover. *Pinus pumila*, willow, and dog rose shrubs are found in the understory. Reed grass, sedges, and *Cladonia* lichens are found in the ground cover together with mountain cranberry.

AOi–2 cm. Dry, slightly decomposed larch litter.

OA1 2–4 cm. Gray, slightly dry sandy loam; very fine (powder-like) loose granular structure; loose; abundant roots and charcoals; the transition is clear.

Bm 4–14 cm. Light brown, slightly dry loam with weak granular structure; loose; many roots; rounded medium-size pebble is evenly covered by brownish films; charcoals; the transition is clear.

BC 14–40 cm. Light gray loam; compacted; many roots; pebble inclusions; the transition is gradual.

C 40–50 cm. Light gray color; large- and medium-size pebble compose up to 90% of the volume.

Such sites are occupied by cranberry-lichen larch forests of class V (very low) quality; the density of tree canopy is about 0.2–0.4. *Betula middendorffii* and *Pinus pumila* (near the brows) prevail in the understory. Small shrubs are dominated by *Vaccinium vitisidaea* and *Empetrum nigrum*. The total coverage reaches about 70%. Different lichen species (*Cetraria cucullata, Cladonia rangiferina, Cladonia alpestris*, and *Cladonia silvatica*) are well developed.

The central part of terraces develops in conditions of insufficient drainage. Cryogenic hummocky topography ensures differentiation of the soil cover into the soils of earth hummocks and cryogenic troughs. Hummocks occupy up to 85–90% of the area. The soils of hummocks are composed of a relatively thick organic horizon that can be subdivided into three parts (peaty, peaty-mucky, and mucky) by the degree of decomposition of plant residues, and underlying weakly differentiated mineral mass. Mineral layers often contain the fragments of organic material buried under the impact of cryoturbation. The thickness of the active layer reaches 40–80 cm. Ice-rich permafrost contains ice lenses, wedges, and veins. The soils do not manifest any signs of clay differentiation or eluvial–illuvial redistribution of SiO_2 and R_2O_3; they have an acid reaction and are impregnated with humic substances; some accumulation of the latter is observed directly above the permafrost (Tables 1-3). The soil profile in the cryogenic trough is composed of a series of peat horizons (O1, O2, etc.) with a total thickness of 20-45 cm, underlain by an ice-rich loamy permanently frozen layer.

Several varieties of cryozems (Cryosols) can be distinguished in such sites: gleyic cryozems have some gley features in the BC horizon; peaty (histic)

Table 1. Chemical properties of soils

Horizon	Depth, cm	Humus, %	pH		Total acidity	Exchangeable cations		P_2O_5	K_2O	Easily extractable N	Fe	
			H_2O	KCl		Ca^{2+}	Mg^{2+}				dithionite extraction	oxalate extraction
					mg-equiv/100 g soil			mg/100 g soil				
Pit 19-9la. Peaty-mucky sandy loamy cryozem plateaus and gentle slopes												
Oi	0-3	nd	4.32	3.22	81.37	2.90	1.01	0.01	22.27	18.6	5.47	3.88
Oi	3-9	6.00	4.52	3.25	27.57	1.51	0.48	4.25	9.27	10.25	4.99	2.73
BC	12-22	2.30	5.27	3.80	8.75	1.70	0.71	8.57	4.82	4.66	2.63	1.23
BC	34-44	1.63	6.14	4.41	3.06	2.56	1.12	19.28	5.42	3.73	2.27	0.63
Pit 6-90. Peaty sandy loamy cryozem plateaus and gentle slopes												
Oi	4- 6	nd	5.21	4.51					nd			
Oi	7-13	″	5.62	4.80					″			
Oi	13-18	3.01	5.51	4.38	7.64	8.46	1.74	26.60	5.54	5.59	nd	
BC	30-40	4.62	5,86	4.75	7.92	12.26	1.85	9.95	6.98	7.22	″	
Pit 1-91. Loamy sandy pale cryozem with gleyic features above permafrost table plateaus and gentle slopes												
Oi	0-2	nd	5.58	4.95					nd			
AB	2-8	3.93	4.92	3.65	12.86	4.17	1.66	2.75	7.83	7.92	2,86	1.04
Bm	20-30	0.67	6,49	5,16	1.4	4.26	1.89	22.98	4.09	3.72	2.97	0.36
BC	60-70	0.45	7.32	6.36	0.5	4.87	1.95	27.33	9.03	2.9	2.69	0.27
Gh	110-115	1.08	8.42	7.62	0.08	17.19	4.01	20.88	12.04	7.92	2.68	2.29
Pit 12-90. Peaty-gley loamy sandy soil on old alluvium terrace backswamp												
Oi	2-12	nd	5.00	4.29					nd			
OiB	17-20	2.16	5.72	4.58	8.83	14.36	2.26	12.70	9.39	11.65	nd	
BCG	21-25	1.99	5.82	4.52	3.64	4.86	0.64	17.65	4.33	4.66	″	
Pit 8-90. Pale sandy loamy soil on alluvial cobble brows of terraces												
Oi	0-2	nd	5.23	4.42					nd			
OiOa	2-4	″	5.85	5.25					″			
Bm	5-14	2.33	5.27	4.06	9:38	6.56	1.58	24.10	11.07	7.46	nd	
BC	25-35	1.76	5.46	4.16	6.09	4.97	1.37	31.50	8.19	4.66	»	
C	40-50	2.16	5.04	4.02	7.01	5.44	1.40	19,15	6.98	5.13	»	
Pit 10-91. Pale silty loamy soil on schist steep slopes of southern aspect												
Oi	0-1	nd	5.46	4.55					nd			
A1	1-2	″	5.02	4.09	52.20	14.87	5.69	0.01	39.73	15.37	4.93	1.42
B1m	4-9	10.94	4.56	3.44	22.08	5.82	3.84	0.01	20.47	10.25	7.02	1.09
B2m	15-25	1.23	5.66	3.92	7.26	7.28	5.59	0.01	9.03	5.82	5.80	0.77
BC	50-60	1.18	6.62	4.85	3.06	11.60	6,98	3.25	8.43	-	6.14	0.71
Pit 31-90. Peaty soil on schist steep slopes of southern aspect												
Oi	5-15	nd	4.47	3.41					Не определялось			
BC	20-25	4.10	4.50	3.57	62.79	5.77	2.29	-	17.57	22.60	nd	
Pit 9-90. Alluvial sandy soil the first terrace												
OiOa	0-2	nd	5.48	4.74					nd			
A1	2-6	″	5.49	4.77					″			
Al_2	11-18	0.59	6.08	4.87	1.64	2.43	0.56	1.64	2.43	0.56	nd	
Al_2	23-33	0.68	6.24	5.14	1.18	2.49	0.67	1.18	2.49	0.67	″	

Table 2. Particle-size distribution in the fine earth fraction, % of the absolutely dry soil mass

Horizon	Depth, cm	Hygro-scopic moisture, %	Loss on treatment with HCl, %	Content of fractions, %; size of separates, mm						
				1.0-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001	<0.01
Loamy sandy pale cryozem with gleyic features above permafrostt; underlain by an ice wedge (pit 1 -91) plateaus and gentle slopes										
AB	2-8	0.72	1.49	0.73	59.06	19.13	6.02	4.57	9.00	19.91
Bm	20-30	0.19	1.04	0.003	59.45	25.31	0.99	2.82	10.39	14.54
BC	60-70	0.09	1.01	0.09	67.39	20.99	2.13	4.62	3.77	10.79
Gh	110-115	0.15	2.23	0.13	63.63	22.72	4.66	5.29	1.34	11.84
Peaty sandy loamy cryozem (pit 6-90) plateaus and gentle slopes										
OiOa	13-18	0.41	1.70	0.39	28.80	51.66	5.95	7.11	4.39	17.86
BC	30-40	0.38	1.85	0.20	20.84	51.17	9.09	9.24	7.61	26.35
Pale sandy loamy soil on alluvial cobble (pit 8-90) brows of terraces										
Bm	5-14	0.44	1.85	10.64	23.40	41.91	6.59	5.87	9.74	22.58
BC	23-35	0.49	2.64	2.66	43.93	28.95	7.07	8.36	6.39	22.13
C	40-50	0.08	1.51	2.23	25.78	46.35	6.88	12.21	5.04	24.53
Peaty-gley sandy loamy soil on old alluvium (pit 12-90) terrace backswamp										
B	17-20	0.08	3.03	2.90	25.06	42.96	8.09	9.37	8.61	26.53
BCG	21-25	0.03	2.54	0.19	18.96	60.61	6.99	4.78	5.93	18.04
Pale silty loamy soil on schist (pit 10-91) steep slopes of southern aspect										
B1m	4-9	0.30	1.17	9.34	43.92	10.26	11.08	11.34	12.89	35.70
B2m	15-25	1.50	2.45	17.07	36.52	12.29	8.35	12.97	10.35	31.99
BC	50-60	0.33	2.54	2.85	57.97	11.74	3.78	12.38	8.74	25.30
Peaty-mucky sandy loamy cryozem (pit 19-9la) plateaus and gentle slopes										
OiOa	3-6	2.15	0.72	5.01	35.57	10.11	8.25	11.96	28.38	49.04
OiOa	6-9	0.16	1.75	6.38	45.26	19.40	4.49	11.64	11.08	27.61
BC	12-22	0.37	1.17	8.67	60.46	18.15	2.71	2.12	6.72	11.86
BC	34-44	0.01	1.17	6.38	55.48	22.49	3.20	9.22	2.06	14.90

cryozems are distinguished when the thickness of peat material reaches 8-16 cm; peaty-mucky cryozems have a mucky horizon of 2-7 cm in thickness. When these specific features are not expressed, the soil can be referred to as a typical cryozem.

Virtually all loamy cryozems have thixotropic properties in spring and early summer; many cryozems display thixotropy in the bottom horizons during the whole growing period. A description of a typical cryozem is given below.

Pit 19-91a. The left bank of the Bytantai River (in the middle course). Old terrace. Larch forest with cranberry (*Vaccinium vitisidaea*), wild rosemary (*Ledum palustre*), lichens, and green mosses in the ground cover. The density of the tree canopy is about 0.3. The stand belongs to class Va (very poor) quality. The surface has a typical hummocky pattern. The diameter of hummocks varies from 1 to 1.5 m; the height of micro- elevations reaches 10-20 cm.

Table 3. Bulk elemental composition of soils

Horizon	Depth, cm	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	MnO	TiO_2	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$
Pale cryozem with gleyic features above permafrost; underlain by an ice wedge {pit 1-91) plateaus and gentle slopes												
AB	2-8	75.87	13.91	5.08	0.55	0.76	2.01	0.06	0.77	9.26	7.51	39.72
Bm	20-30	71.58	16.29	6.05	0.65	1.02	2.54	0.06	0.81	7.46	6.03	31.46
BC	60-70	72.32	15.92	5.76	0.64	0.91	2.59	0.06	0.79	7.71	6.26	33.39
Gh	110-115	70.38	16.30	6.17	1.42	1.18	2.67	0.06	0.80	7.33	5.90	30.31
Pale silty loamy soil on schist (pit 10-91) steep slopes of southern aspect												
B1m	4-9	62.42	19.17	12.00	0.55	1.10	2.29	0.07	1.42	5.53	3.95	13.83
B2m	15-25	59.83	20.36	13.08	0.50	1.34	2.39	0.12	1.38	4.99	3.54	12.16
BC	50-60	58.44	20.58	14.01	0.71	1.23	2.37	0.15	1.51	4.82	3.36	11.09
Peaty-mucky cryozem (pit 19-9la) plateaus and gentle slopes												
Oi	6-9	59.37	22.20	11.52	0.46	1.18	3.44	0.06	0.78	4.54	3.41	13.70
PiOa	9-15	66.76	19.97	7.22	0.23	1.00	3.06	0.05	0.72	5.67	4.61	24.59
BC	18-28	71.83	16.74	5.63	0.27	0.98	2.80	0.05	0.71	7.28	6.00	33.92
BC	34-44	72.93	15.67	5.32	0.37	1.18	2.74	0.05	0.73	7.90	6.49	36.43
Peaty sandy loamy cryozem (pit 6-90) plateaus and gentle slopes												
Oi	13-18	70.23	17.15	5.96	1.24	0.90	2.58	0.05	0.88	6.95	5.69	31.31
BC	30-40	69.06	17.25	6.78	1.40	0.89	2.63	0.06	0.92	6.79	5.43	27.07
Pale silty loamy soil on alluvial cobble (pit 8-90) brows of terraces												
Bm	5-14	71.15	16.70	5.88	1.02	0.94	2.34	0.09	0.89	7.23	5.90	32.17
BC	25-35	70.19	16.93	6.35	1.03	1.01	2.58	0.06	0.86	7.04	5.68	29.41
B	40-50	70.92	16.67	6.13	0.94	1.01	2.39	0.06	0.90	7.22	5.85	30.78
Peaty-gley sandy loamy soil on old alluvial deposits (pit 12-90) terrace backswamps												
B	17-20	70.59	16.75	5.78	1.13	1.24	2.56	0.06	0.90	7.15	5.86	32.47
BCG	21-25	74.73	14.98	4.37	0.76	0.88	2.39	0.05	0.85	8.47	7.14	45.46

Oi 0-3 cm. Slightly decomposed forest litter.

OiOa 3-10 cm. Brownish gray sandy loam with very fine (powder-like) loose granular structure; slightly dry; abundant roots; the transition is clear.

BC1 10-28 cm. Gray sandy loam with curdled structure; slightly dry; compacted; contains moderate amount of roots; the transition is clear.

BC2 28-50 cm. Gray sandy loam; structureless; wet; thixotropic; contains some roots.

> 50 cm. Frozen horizon with ice crystals and small ice veins (the length of which is about 5 mm and diameter about 1 mm).

This soil is defined as a peaty-mucky cryozem with sandy loamy texture. It develops on hummocks.

Pit 19-9lb. The same site. The pit exposes the soil developed in the cryogenic trough.

Oi 0-14 cm. Slightly decomposed litter.

BC 14-22 cm. The same horizon as in the soil of the hummock.

> 22 cm. Frozen horizon with more pronounced ice veins.

This soil is defined as a peaty cryozem with a sandy loamy texture.

The soils described above are characteristic of cran-berry-blueberry larch forests with mosses in the ground cover. The density of the tree canopy ranges between 0.2 and 0.3. These stands are qualified as stands of class Va quality. The understory composed of *Betula exilis* is poorly developed. Small shrubs (cranberry, blueberry, wild rosemary) form the ground canopy. Hydrophilic green mosses develop on the soil surface; in microdepressions, the mosses are composed of sphagnum species.

The somewhat lower back part of the same terrace (terrace backswamp) develops in conditions of poor drainage. Such positions are marked in the soil cover by the development of hydromorphic bog soils with shallow permafrost (Histic Gelisols, or Gelic Histosols).

Pit 12-90. The right bank of the Erikit River, 2 km upstream from the river mouth. The pit is located in the hollow within the terrace surface. The soil develops under sedge-moss larch forest of class Vb quality (the worst one); the density of the tree canopy is about 0.2.

Oi 0-17 cm. Slightly decomposed remains of green and sphagnum mosses; the transition is gradual.

OiB 17-20 cm. Brown, with dark mottles; wet; contains the inclusions of organic material in the sandy loamy mineral mass; loose; penetrated by roots; contains the inclusions of charcoal. The transition is gradual.

BCG > 20 cm. Grayish dove, with some brownish mottles; sandy loam; structureless; the roots are virtually absent. Permafrost with large ice veins was registered at 23 cm.

The soil is defined as sandy loamy peaty gleysol developed from old alluvial deposits.

The tree stand of such sites is composed of sparse and thin larch forests (class Vb quality) with *Betula exilis* in the understory and moderately developed small shrubs (wild rosemary, cranberry), sedges, and cloudberry. The soil surface is completely covered by sphagnum with some admixture of green mosses.

Interfluve areas represent gently undulating plains (plateaus) and rolling slopes with a 3°-7° gradient. Peaty cryozems predominate in the soil cover. The typical soil profile consists of an 8-16-cm-thick histic horizon underlain by a homogeneous BC horizon. A table of ice-rich permafrost is found at the depth of 30- 60 cm. The soil is acid and unsaturated with bases (Table 1, pit 6-90). Cryogenic hummocky topography is well manifested. Larch stands of class Va quality have a canopy density ranging from 0.3 to 0.5. Cranberry and wild rosemary predominate among the shrubs. *Betula middendorffii, Betula exilis*, and dwarf willows are found in the understory. *Vaccinium vitisidaea, Ledum palustre*, and *Vaccinium uliginosum* develop in the shrub canopy. *Alaucomnium palustre* forms the moss cover.

Brows and relatively steep slopes (5°-10°) within the interfluves have somewhat better drainage conditions. This ecological niche is occupied by pale cryozems – the soil transitional from cryozems to pale metamorphic soils. They have moderate heat supply and moderate drainage. Pale cryozems are composed of thin (up to 8 cm) litter underlain by the AB horizon impregnated with iron and humus; this horizon gradually transforms into yellowish gray Bm horizon. Below, the BC horizon with the same morphology as cryozems is developed. The depth of permafrost ranges between 60 and 100 cm. The acidity of pale cryozems varies from strongly acid in the topsoil to slightly acid and neutral in the bottom horizons; the soils have moderate nutrient supply (Table 1, pit 1-91). The degree of base saturation varies in conformity with the natural variation in composition of embedding schist. The description of a typical profile of pale cryozem is given below.

Pit 1-91. The pit is located on the southern slope (5°), 25 km to the southwest of the settlement of Verkhoyansk, on the bank of the Dabdary Lake. The surface is covered by cranberry-wild rosemary larch forest with green mosses; the density of the tree canopy is 0.4. The forest stand belongs to class V quality.

Oi 0-2 cm. Forest litter.

AB 2-7 (10) cm. Brownish pale slightly dry loamy sand with fine granular structure; many roots; loose; the transition is gradual.

Bm 7 (10)-38 cm. Brownish gray slightly dry loamy sand with loose angular blocky structure; many roots; moderately compact; the transition is gradual.

BC 38-110 cm. Gray loamy sand with dark gray and brownish mottles; slightly dry in the upper part and moderately wet in the lower part; structureless; moderately compact; contains some roots; the transition is distinct.

Gh 110-115 cm. Steel gray loamy sand; structureless, satiated. At the depth of 124 cm, the soil is underlain by a large (several meters in thickness) ice wedge.

The soil is defined as a loamy sandy pale cryozem with gleyic features above the permafrost.

This soil supports more productive forest stands than on the rest of the plateau. Such plant species as dog rose and juniper appear in the understory.

Pale cryozems form microassociations (complexes) with typical cryozems. Thus, we have described the complexes of pale cryozems on hummocks and typical cryozems in cryogenic troughs near the mouth of the Dzhanky River (the middle part of the Yana River basin), not far from the settlement of Ust'-Kuiga.

Steep (10-30°) slopes of northern and southern aspects were specially investigated. The embedding rocks are composed of schist. The northern slopes have insufficient heat supply; often, they are covered by high-moor bogs. Peaty soils underlain by schist develop within these bogs. The thickness of the peat layer is about 15—25 cm; it is underlain by weathered rock debris with a small amount of fine earth. Permafrost is found at the depth of 15-30 cm. These soils are strongly acid and unsaturated with bases (Table 1, pit 31-90). Sparse larch stands with a low canopy density (< 0.1) and very low height (1.5-2.0 m for 100- year-old trees) develop here. The understory is composed of *Pinus pumila, Betula exilis*, and alder shrubs. Blueberry and wild rosemary predominate among small shrubs. The soil surface is completely covered by green mosses (*Hylocomium proliferum, Pleurozium Schreberi*) and lichens (*Cladonia and Cetraria genera*). Sphagnum mosses develop in microdepressions.

Loamy pale soil develops on the slopes of the southern aspect. This soil is composed of thin (2-3 cm) forest litter underlain by the A1 humus or mucky-humus grayish pale horizon. The lower lying soil thickness is undifferentiated into horizons and represents a homogeneous layer with a gradual lightening of color (from grayish pale to pale and light pale). The permafrost has a low ice content; ice is represented by small separate crystals. There are no horizons with temporally perched water; gley features are absent. The topsoil has an acid reaction; bottom horizons are slightly acid. There is some accumulation of clay particles in the topsoil. Data on bulk chemical analysis and oxalate extraction (Table 3) attest to the absence of eluvial-illuvial redistribution of substances within the soil profile. At the same time, some accumulation of mobile sesquioxides, especially iron, is observed in the upper horizons. This feature is associated with the aridity of the climate. The morphological description of a typical profile of pale soil is given below.

Pit 10-91. The pit is located on the southern slope with a 10° gradient, not far from the top of the mound. The plot is occupied by a larch forest of class V quality; mountain cranberry and lichens are found in the ground cover.

Oi 0-1 cm. Litter of larch, lichens, and crowberry.

A1 1-2 cm. Dark gray raw-humus horizon with loose crumbly structure; sandy silt loam; loose; slightly dry; contains abundant roots; the cobble content is about 10%; the transition is distinct.

Blm 2-11 cm. Reddish brown sandy silt loam with loose crumbly structure; slightly dry; the cobble content is about 10%; all the sides of cobble are covered with dark brown films; the transition is distinct.

B2m 11-34 cm. Reddish yellow-brown, with less distinct structure; the fine earth of silt loamy texture; slightly dry; contains some roots; the cobble content is about 80-90%; cobbles are evenly covered by thin films; the transition is gradual.

BC 34-95 cm. Yellowish gray; the cobble content exceeds 90%; the fine earth (sandy loam) and fine gravel form thin films on the surface of cobbles; the horizon is wet; contains few roots. The ice-rich permafrost is found at the depth of 95 cm.

This soil is defined as silt loamy cobbly pale soil on schist.

The middle part of steep southern slopes is characterized by the presence of small groves of aspen stands that belong to class V quality (the density of the tree canopy varies from 0.2 to 0.4). Sometimes, these stands contain the admixture of *Betula platyphylla*. The under- story is composed of juniper, dog rose, and currant. Cranberry, green mosses, and lichens (*Cladonia* and *Ctereocaulon tomentosum*) are found in the ground cover. Some heat-loving plant species, like wormwood, legumes (Astragalus and vetch), and *Scuifraga bronchialis* can be met under aspen stands. The top parts of slopes are very steep (>40°) and are covered by *Pinus pumila* thickets.

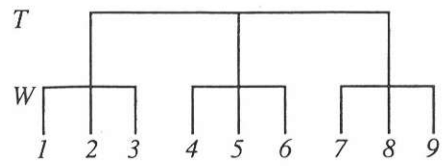

Fig. 2. The division of the objects according to temperature (T, cold, moderate, and warm) and moisture (W; moist, moderately dry, and dry) groups. (1) northern slope, (2, 3) not revealed, (4) a depression within the river terrace (terrace backswamp), (5) the first terrace, the central part of high terraces, and interfluve plateaus, (6) the part adjacent to the brow of high terrace, (7) flood plain, (8) slopes of eastern and western aspects, (9) southern slope.

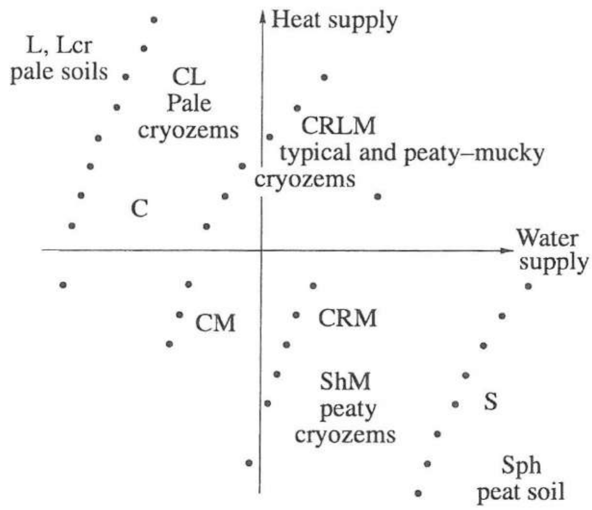

Fig. 3. Ecotopes of different types of larch forests. Types of forest: (L) lichen, (LCr) lichen-crowberry, (CL) cranberry-lichen, (C) cranberry, (CRLM) cranberry-wild rosemary with lichens and mosses, (CM) cranberry-moss, (CRM) cranberry-wild rosemary with mosses, (ShM) shrub (ernik)-mossy, (S) sedge, and (Sph) sphagnum.

FOREST BIOGEOCENOSES AND CLIMATE CHANGE

It is expected that global climate warming would lead to considerable changes in temperature and humidity. These are crucial factors for both the soil-forming processes and the productivity of forest stands. We tried to classify the sites studied with respect to these factors. For this purpose, we made a gradation of each factor into three groups (Fig. 2). In total, there may be nine possible combinations of these groups. The sites studied fall into seven such combinations. The location of different soils and forest stands in the space of hydrothermic and edaphic coordinate axes is shown in Fig. 3. If we take into account the distinctions between the soils studied with respect to heat and moisture supply, we can judge the possible changes in ecosystems during the expected warming of climate.

The results of our studies were used in the *Bytantai* expert system, which would enable us to forecast the development of forest stands in northeastern Yakutia in natural (undisturbed) conditions, after forest fires, and under different scenarios of climate change. This system provides the means for maintaining cartographic and factual databases, including the development of expert forecasts and statistical treatment of data. It can also be used for forecasting the dynamics of forest fires on the basis of available factual material.

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