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Article

Vegetation of the northern Far East in cartographic models

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Abstract

The article summarizes results of a vegetation study in the extreme northeastern Eurasia based on data of aerial visual evaluation and cartographic modelling. Analysis of large- and small-scale cartographic models based on results of digital surveys is set within the information system frame. Major vegetation patterns have been revealed; a new zonation map based on plant community data is proposed.

Keywords: northern Far East, vegetation, vegetation maps, vegetation zonation

Introduction

The northeastern part of Eurasia, which includes Kamchatka Oblast, Magadan Oblast, and Chukotka Autonomous District, has been traditionally considered a distinct region called the northern Far East (Fig. 1).

The combined influences of the surrounding cold seas, orographic barriers, permafrost, and atmospheric circulation create the climatic conditions that promote the wide distribution of tundra, forest-tundra, and northern taiga vegetation complexes in this region. Two botanical-geographical zones, tundra and forest, including Siberian dwarf pine (*Pinus pumila* Reg.) subzone, are encountered within the region. Latitudinal changes of zonal vegetation complexes are observed only in the central part, zonal boundaries being shifted to the south in the rest of the region. The configuration of the zones is close to meridional. Due to mountainous topography, the dominating vertical zonation significantly obscures latitudinal zonation patterns. High humidity and low temperature indices are characteristic for the northern Far East. Arctic barrens and tundra, larch (*Larix cajanderi* Mayr) forests, sedge-cottongrass hummock tundra, Siberian dwarf pine thickets, and complex swamps are widespread. Other vegetation elements are shrub alder (*Duschekia fruticosa* (Rupr.) Pouzar, syn. *Alnus fruticosa* Rupr.) thickets, forests and woodland of rock birch (*Betula ermanii* Cham.), poplar-willow (*Populus suaveolens* Fish. ex Loudon and *Salix arbutifolia* Pall. (=*Chosenia arbutifolia* (Pall.)

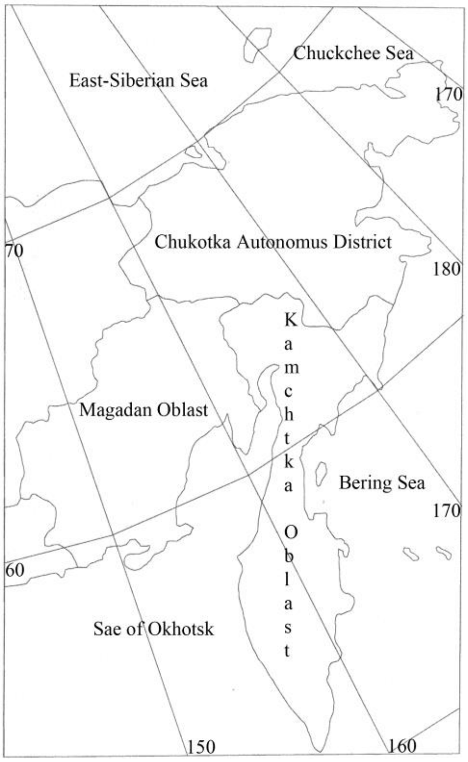

Figure 1. The northern Far East

A.K.Skvortsov) riverine forests, and meadows. A number of trees and shrubs have their northern or eastern limits within the region. Siberian spruce (*Picea obovata* Ledeb.) is found only within the Yama River basin (Magadan Oblast). Ajan spruce (*Picea ajanensis Fisch.* ex Carr.) and graceful fir (*Abies gracilis* Kom.) occur only on the Kamchatka Peninsula. Major altitudinal zonation units are Arctic lichen barren heights, mountain tundra, mountain *P. pumila* thickets, and also larch (*L. cajanderi)* and birch (*B. ermanii*) mountain forests and woodland.

Within the tundra zone, two major altitudinal zones can be distinguished: barren heights (goltsy), featuring alpine tunra vegetation above the timberline, and territories inferior and adjacent to the barren heights and known as subgoltsy. While goltsy are represented by Arctic lichen barrens; subgoltsy within the tundra latitudinal zone mostly comprise mountain tundra. Within the forest latitudinal zone, *P. pumila* thickets play an important role in the formation of the subgoltsy vertical zone together with mountain tundra. Further downslope, the subgoltsy zone gives way to the forest zone (represented by larch woodland and forest subzone as well as that of rock birch woodland and forests) or else directly by the latitudinal zone of *P. pumila* thickets and sub-Arctic tundra (subzone of *P. pumila* thickets). Vertical zone expression certainly depends on topography and altitude, but is also influenced by the pertinent latitudinal zone. Due to that, some vertical zones, such as mountain tundra and *P. pumila* thickets, are frequently fragmented.

The major periods of the vegetation cover study in the northern Far East were characterized by M.I.Tatarchenkov (1971), and generalizations on vegetation were first published by B.P.Kolesnikov (1961; 1963) and later on by A.T.Reutt (1970). Spatial distribution of vegetation in Russia has been depicted on small-scale survey vegetation maps (Lavrenko and Soczava, 1954; Soczava, 1977; Ogureeva, 1999; Gudilin, 1980; Kotova, 1990; CAVM, 2003) as well as within vegetation zonation schemes (Lavrenko, 1947; Alexandrova, 1977).

Our goal was to employ large-scale cartographic models based on generalizations from aerial visual surveys of the entire region in order to depict spatial distribution of vegetation in the northern Far East. On the basis of these cartographic models and with the help of information system technology, maps of the ranges of the major mezocombination vegetation types have been prepared for the first time. The limits of mezocombinations dominated by *P. pumila*, *L. cajanderi* and *B. ermanii* as well as zonal and subzonal boundaries have been adjusted (Polezhaev, 2010; 2012a; 2012b).

A digital vegetation map is useful for management of regional biological resources (Polezhaev, 2009). A large-scale vegetation survey map (1:200000) of the northern Far East, including a digital version, was created for the first time as a part of an information system project. With the help of this map, a few thematic maps based on information systems and depicting reindeer ranges for Magadan Oblast and Chukotka and Koryak Autonomous Districts were prepared (Polezhaev *et al*., 2006).

Material and Methods

A generalised large-scale (1:200000) vegetation map of the northern Far East created in the Botany Laboratory (Institute of Biological Problems of the North) is based on the results of our 40-year-long research. This map has not been published and exists in the printed and digital form as a part of the GIS project. It was employed as a facility for the cartographic modelling, serving as the graphic basis of cartographic models, while data on the composition and vegetation structure obtained through visual evaluation from a helicopter were used as the attributive basis. Small-scale cartographic models created by the method of scaling within the GIS project were then used for the vegetation analysis. The maps and illustrations for this article were created within the same project.

The large-scale GIS map is based on results of my own work as well as archived vegetation inventories conducted between 1970 and 1990 in accordance with the method of aerial visual evaluation devised by V.N.Andreev (1952; 1971). According to this method, a visual survey is undertaken from an aircraft flying at an altitude of 300–400 m. A ratio (in percent) between different types of vegetation complexes is determined within each visually segregated contour (polygon). Between 1950 and 2000, this method was widely employed in Russia, including the northern Far East, for assessments of reindeer forage base. The entire territory of the northern Far East was covered by routine aerial visual surveys of vegetation.

Chorological units of vegetation cover at the mezocombination level are shown on the GIS map as separate contours (numbering 84100), which are then superimposed on a topographic map. The names of mezocombination types and their variants (with a total of 163) are listed in the legend. The map consists of 300 sheets. Attributes characterizing structure, composition, and other characteristics of each mezocombination are included in the contour inventory record.

ArcView was employed in order to make the map more user-friendly and at the same time facilitate its further analysis and development.

The project includes vector polygonal coverage maps based on the attribute coverage database. Vector polygonal coverage is produced by digitisation of contours from separate sheets of the author's large-scale vegetation map (1:200000), which are then joined together. Adjusted polygonal coverage was included in the information system project. Ratios from contour inventory records were arranged in the database of polygonal coverage values. Cartographic models were created on the basis of attributes selected from the database of polygonal coverage values, with some corrections applied to the colour key where necessary. The databases of attributive indices were analysed in Excel (Microsoft Office).

Aerial visual vegetation cover assessments for every contour are included in the contour inventory records. Contour inventory records consist of separate assessments provided for every contour, each in the form of a ratio depicting percentage of vegetation complex types. The ratios had been obtained employing Andreev's methodology. Reliability of results obtained by this method is 70-75% (Andreev, 1952; 1971).

The basic working unit is an inventory combination. It is defined as a plot of vegetation cover territorially restricted to certain typical elements of mezo-relief. The area of a chorological unit is, on average, 0.015-0.03 km^2. A contour enclosing an area of 0.4-0.8 mm^2 corresponds to the above area on the map at the scale of 1:200000. Such detail is barely achieved, neither necessary for the purpose of our research. Therefore, elementary vegetation combinations are not mapped. Instead they are used to define larger chorological subdivisions of vegetation cover, i.e., mezocombinations. Depending on peculiarities of vegetation cover, mezocombinations' size may vary from 5 to 60 km^2 (10-15 km^2 on average). On the 1:200000 map, mezocombinations are shown as separate contours; in the digital version they are depicted as polygons. Boundaries of mezocombinations coincide approximately with contour lines on the topographic map; however, their areas are usually much smaller than those delineated by topographic contours.

The principal difference between an inventory combination and mezocombination can be described as follows. The former is characterized by predominance of a single plant community type (which, in most situations, is the case in the tundra or forest-tundra). The latter is understood as an actual association of plots, each of them containing a certain inventory vegetation combination, so that the mezocombination is characterized by the composition and quantity of these vegetation combinations. Certain natural associations of vegetation combinations are restricted to certain relief forms, soil types, and hydrological conditions. Therefore, mezocombinations are usually characterized by either the dominance of a single type of vegetation combination or an association of two major types with inclusion of others to a variable extent. Classification of inventory vegetation combinations is based on composition and structure of the dominant plant community. Additionally, topographical position, position on a topological line, ecotopic factors, such as soil type, microtopography, hydrology, extent of erosion, nival situations, permafrost processes, and other factors were taken into account, which resulted in distinguishing variants of type combinations.

Dominant life forms, type of vegetation, and species-indicators are obligate parameters for combination types listed in the GIS map legend. The nomenclature of mezocombination types is based on characteristics of their composition and structure defined by combination types. According to the elements' association type and general pattern of their distribution, we distinguish mezocombinations dominated by one, two, or three and more vegetation combination types with approximately equal share. The mezocombination type is defined by the inventory combination of the type dominating within that mezocombination. If a few combination types co-dominate, then the mezocombination type is defined as complemental.

The legend for the vegetation map GIS project is structured so as to take into account both zonal and ecotopic vegetation patterns. In the legend, each mezocombination type is characterised by the dominant (>50%) type of inventory combination within that mezocombination. The legend includes 163 subdivisions comprising 65 mezocombination types and 98 variants of mezocombination types. The map contains four major divisions: (1) Arctic vegetation with 39 subdivisions consisting of 21 complexes of mountain vegetation (comprising 2 barren height types, 18 mountain tundra types, and a single alpine meadow) and 18 complexes of zonal vegetation (comprising 3 Arctic tundra and 15 sub-Arctic tundra types); (2) boreal vegetation, including 45 subdivisions consisting of 26 mountain vegetation complexes (10 types of *P. pumila* mountain thickets, 8 mountain forest and woodland types, and 8 shrub thickets), and 19 complexes of zonal vegetation (comprising 11 woodland and forest types and 8 *P. pumila* thickets); (3) intrazonal vegetation with 67 subdivisions consisting of 24 vegetation complexes with dominance of forest or woodland located in river valleys, lowlands, and on the coastal plain, 4 *P. pumila* thicket types, 7 types of shrub thickets, 8 meadows, 8 tundra types, and 16 bogs; (4) vegetation that is stressed due to impact of environmental factors, either natural or anthropogenic, containing 12 subdivisions: 1 ornithogenic, 2 grazing-related, 7 pyrogenic, and 1 technogenic. Agricultural land is also included in this division. On the GIS map, large glaciers, ice crusts, and lakes are shown as separate polygons. Occurrences of endangered or otherwise protected species and plant communities are specially marked. The full version of the legend has been published elsewhere (Polezhaev, 2012b).

The plant names are checked according to International Plant Name Index (IPNI:- http://www.ipni.org/) and World Checklist of selected families (http://apps.kew.org/wcsp/).

Results and Discussion

Generalisation and zonation provide insight into general vegetation patterns. Vegetation distribution has been depicted on small-scale vegetation maps. Small-scale cartographic models of vegetation of the northern Far East have been created within an information system by means of generalization and scaling. A small-scale vegetation map of the northern Far East, the result of scaling of the 1:200000 digital map is presented in Fig. 2. The legend for this cartographic model is generalized to mezocombination type groups.

The scaling method is useful for creating maps depicting ranges of vegetation complex types and also for vegetation zonation providing zonal and subzonal boundaries (Figs. 3–7).

The boundaries of vegetation zones (and subzones) were outlined via comparison of the range maps of the major woody plant communities, i.e., those dominated by *L. cajanderi*, *P. pumila*, and *B. ermanii* (Fig. 5, 6, and 7, respectively). Distribution of vegetation complexes dominating on the plain, in the mountains, and in river valleys was taken into account.

Fairly large ecotone areas between the forest and sub-Arctic tundra are observed in situations where forest sub-zones are encountered within the zonal tundra vegetation (Fig. 8). Forest and tundra vegetation types may co-occur in these transitional areas, wherever such ecotones are located on the drained plain. Subzones of Siberian dwarf pine thickets are often found within ecotone areas. V.D.Alexandrova, in her zonation scheme of the Arctic vegetation (1977), placed the vegetation of the territory within Anadyr-Penzhina Sub-Province of Chukotka-Alaska Province in the sub-Arctic tundra. However, on the Circumpolar Arctic Vegetation Map (CAVM, 2003), this territory is not included in the tundra zone. When assigning an ecotone area to one or another vegetation subzone, we prioritized the forestforming woody vegetation, such as *P. pumila* thickets, *L. cajanderi*, or *B. ermanii* forests, wherever they were present on the flat interfluve, over the tundra vegetation complexes.

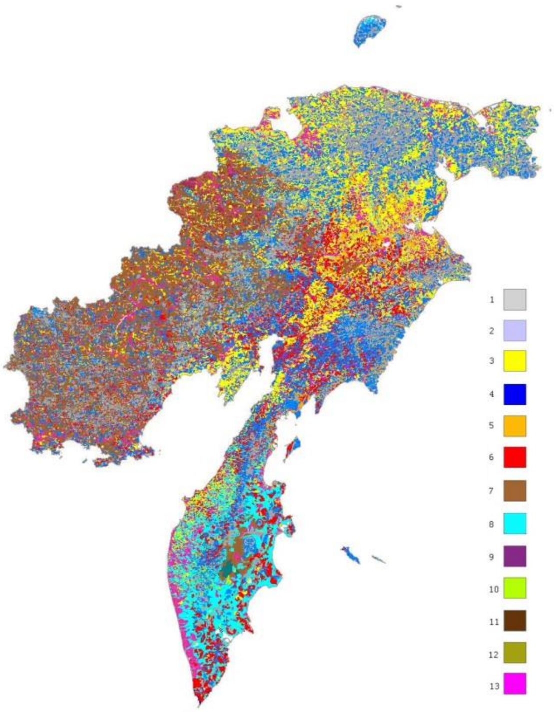

Figure 2. Vegetation map of the northern Far East

Arctic vegetation. Mountain vegetation: 1 – epilithic lichen Arctic barrens and their combinations with fragments of mountain tundra, meadows, willow thickets, *Pinus pumila* thickets, and open woodland; 2 – lichen and dwarf shrub mountain tundra, grass-forb alpine meadows. Vegetation of flat interfluves and gentle slopes: 3 – forb, dwarf shrub, and shrub tundra.

Boreal vegetation. Mountain vegetation: 4 – *Duschekia fruticosa/P. pumila* and *P. pumila* mountain thickets; 5 – larch, spruce, and birch mountain woodland and forest; shrub thickets. Vegetation of flat interfluves and gentle slopes: 6 – *P. pumila* thickets; 7 – larch forests, 8 – birch forests.

Intrazonal vegetation. Vegetation of river flood plains, lowlands, and coastal plain: 9 – willow/chosenia, poplar, and alder open woodland and forest; 10 – willow, birch, and alder shrub thickets; *P. pumila* thickets; meadows, tundra; 11 – larch, chosenia/larch, birch/larch, spruce/larch open woodland and forest; 12 – coastal meadows; 13 – tundra-bogs and bogs.

Figure 3. Distribution of Arctic vegetation complex types

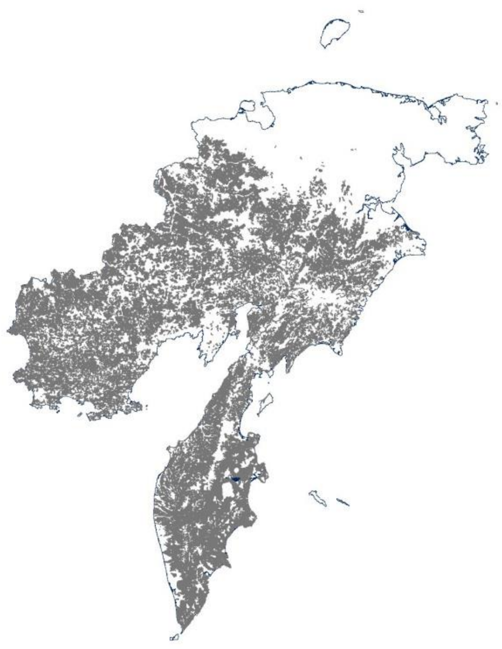

Figure 4. Distribution of boreal vegetation complex types

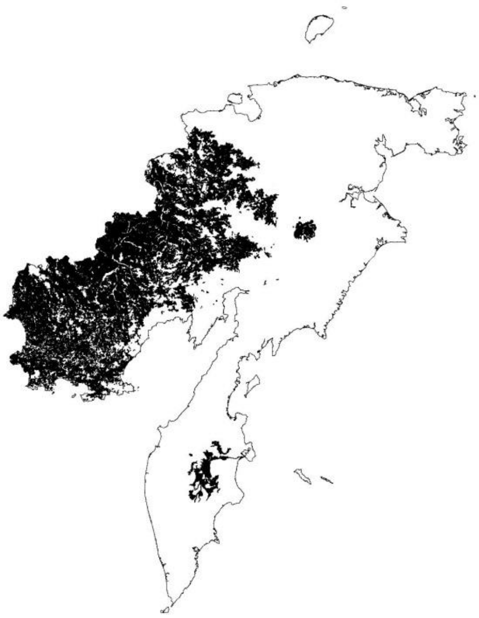

Figure 5. Distribution of vegetation complex types dominated by Cajander larch *Larix cajanderi*

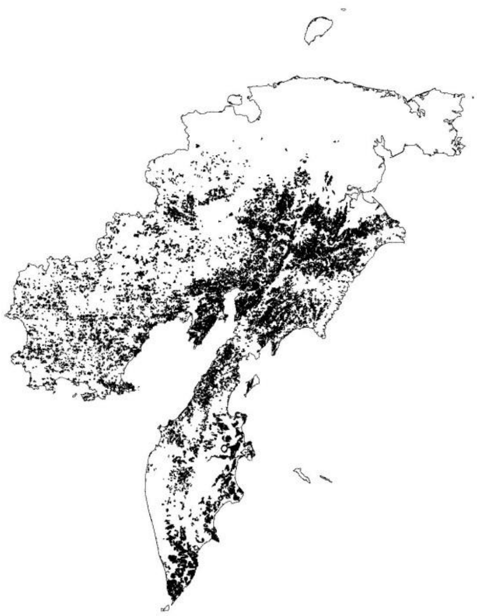

Figure 6. Distribution of vegetation complex types dominated by Siberian dwarf pine *Pinus pumila*

Figure 7. Distribution of vegetation complex types
dominated by rock birch *Betula ermanii*

Figure 8. Latitudinal and vertical vegetation zonation
Tundra zone: A – Arctic tundra subzone, B – sub-Arctic tundra subzone. Forest zone: C prostrate shrubs subzone, D – larch woodland and forest subzone, E – subzone of birch woodland and forest. Vertical zonation: 1 – Arctic barrens, 2 – mountain tundra zone , 3 – prostrate shrubs zone, 4 – larch woodland and forest zone, 5 – birch woodland and forest zone

Figure 9. Vegetation zonation of the northern Far East
Numeration of vegetation districts in the system of zonation units

Tundra Region

Arctic Tundra Subregion, Wrangel-Western North American Province, Wrangel Subprovince 1.Wrangel District Sub-Arctic Tundra Subregion, Chukotka-Alaska Province 2. Chauna District 3. North Chukotka District 4. Central Chukotka District 5. Anadyr Plateau District 6. South Chukotka District

Bering Shrub (Forest-Tundra) Region

Tundra-Shrub Belt 7. Mid-Anadyr District 8. Maina District 9. Parapol District 10. Koryak Forest-Shrub District (forest-tundra) 11. Gizhiga-Penzhina District

Eurasian Taiga Region

East Siberian Larch Forest Subregion, Province of Yakutia, Vitim-Kolyma Subprovince: Larch-Shrub Forest Belt, Lichen-Shrub Lichen/Shrub-Larch Forest Belt, Lichen/Shrub Secondary Larch Forest Belt

12. Kolyma Mountain District 13. Indigirka-Kolyma District 14. Yukaghir District 15. Cherskogo-Verkhoyanskiy Mountain District 17. Shelikhov Coastal District

Moss/Shrub Larch Secondary Forest Belt

16. Okhotsk-Magadan District

Kamchatka Forb/Rock Birch Forest Region

18. West Kamchatka Coastal District 19. Mid-Kamchatka Mountain District 20. Interior Kamchatka District 21. East Kamchatka District 22. Commander Islands

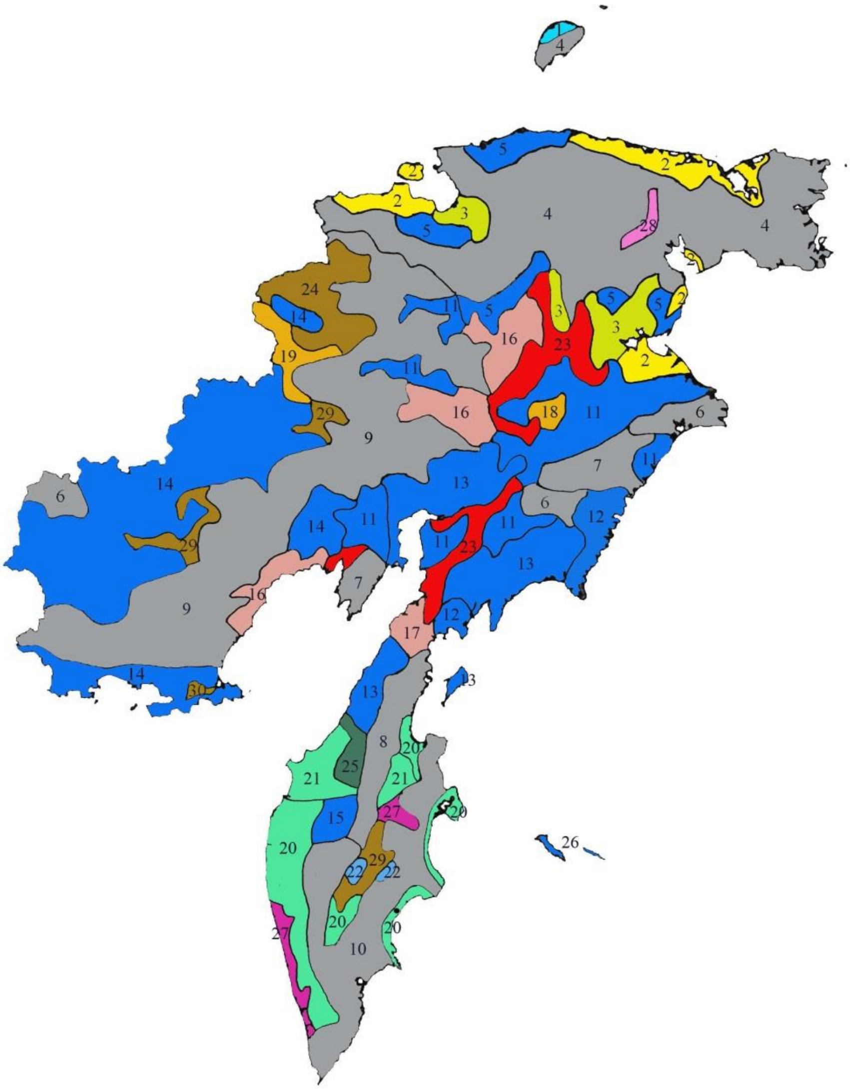

Figure 10. Vegetation of the northern Far East

Vegetation districts are also depicted on the vegetation zonation map of the northern Far East (Fig. 9). In the system of chorological units, districts correlate with vegetation complex types of the megacombination rank. The nomenclature of megacombination types is based on unique characteristics of the composition and structure of pertaining vertical, latitudinal, and intrazonal types of vegetation combinations.

As regards the vegetation zonation, we have followed the system developed by E.M. Lavrenko (1947), while taking into account the results obtained by V.D. Alexandrova (1977) for the tundra zone. All those zonation units ranking higher than the elementary vegetation complex (i.e., microregions, macroregions, and vegetation districts) are characterized by their composition as well as correlation with vegetation combination types of appropriate size.

Territorial units of macrocombination rank were obtained by the method of consecutive map overlay within the areas characterized by dominance of the most common types of vegetation complexes in the mezocombination rank. Prevailing types of vegetation complexes – vertical as well as latitudinal and intrazonal, were identified for each macrocombination. The small-scale map of the vegetation based on detailed zonation in the northern Far East is presented in Fig. 10. The legend to this map, including vegetation subdivisions, is shown in Table 1.

Table 1. Legend to the vegetation map of the northern Far East (Fig. 10)

Vegetation Subdivisions
ZONAL AND EXTRAZONAL VEGETATION
Alpine and subnival vegetation within Arctic Zone
1. Arctic tundra (*Salix polaris; Alopecurus alpinu; Deschampsia borealis; Aulacomnium turgidum; Oncophorus wahlenbergii; Polytrichastrum alpinum; Ochrolechia frigida; Psoroma hypnorum; Thamnolia vermicularis; Stereocaulon alpinum*).
2. Subarctic tussock sedge tundra (*Carex lugens*; *C.soczavaeana*; *Eriophorum vaginatum*).
3. Subarctic shrub tundra (*Duschekia fruticosa; Rhododendron aureum; Salix arctica; S.pulchra; Betula exilis*; *Vaccinium uliginosum; Carex lugens; Eriophorum vaginatum; Aulacomnium palustre; Sphagnum girgensonii; Cladonia rangiferina; Flavocetraria cucullata*).
4. Arctic barren heights (*Ophioparma ventosa; Rhizocarpon geographicum; Umbilicaria arctica; Andreaea rupestris; Scapania undulata; Tetralophozia setiformis; Tortella tortuosa*) in combination with mountain tundra.
5. Mountain tundra (*Alectoria nigricans; A.ochroleuca; Cladonia stellaris; Flavocetraria cucullata; F. nivalis; Stereocaulon alpinum; S. tomentosum; Arctous alpina; Betula exilis; Cassiope ericoides; C. tetragona; Diapensia obovata; Dryas punctate;, Empetrum nigrum; Ledum decumbens; Loiseleuria procumbens; Rhododendron camtschaticum; Salix arctica; S. erythrocarpa; S. phlebophylla; S. Polaris; S. reticulata; S. sphenophylla; Carex lugens; C. soczavaeana; Eriophorum vaginatum*).
Alpine and subnival vegetation within the boreal zone
6. Arctic barren heights (*Ophioparma ventosa; Rhizocarpon geographicum;*

Umbilicaria arctica; Andreaea rupestris; Scapania undulate; Tetralophozia setiformis; Tortella tortuosa) in combination with mountain tundra.

7. Arctic barren heights (*Ophioparma ventosa; Rhizocarpon geographicum; Umbilicaria arctica; Andreaea rupestris; Scapania undulata; Tetralophozia setiformis; Tortella tortuosa*) in combination with mountain tundra, mountain Siberian dwarf pine (*Pinus pumila*) thickets.

8. Arctic barren heights (*Ophioparma ventosa; Rhizocarpon geographicum; Umbilicaria arctica; Andreaea rupestris; Scapania undulate; Tetralophozia setiformis; Tortella tortuosa*) in combination with mountain tundra, Siberian dwarf pine (*P. pumila*) mountain thickets, and shrub alder (*Duschekia fruticosa*) thickets.

9. Arctic barren heights (*Ophioparma ventosa; Rhizocarpon geographicum; Umbilicaria arctica; Andreaea rupestris; Scapania undulata; Tetralophozia setiformis; Tortella tortuosa*) in combination with mountain tundra, Siberian dwarf pine (*P. pumila*) mountain thickets, and larch (*Larix cajanderi*) mountain woodland and forest.

10. Arctic barren heights (*Ophioparma ventosa; Rhizocarpon geographicum; Umbilicaria arctica; Andreaea rupestris; Scapania undulata; Tetralophozia setiformis; Tortella tortuosa*) in combination with mountain tundra, Siberian dwarf pine (*P. pumila)* thickets, shrub alder (*Duschekia fruticosa*) thickets, and mountain woodland and forest of larch (*L. cajanderi*) and birch (*Betula ermanii*).

11. Mountain tundra *(Alectoria nigricans; A.ochroleuca, Cladonia stellaris; Flavocetraria cucullata; F. nivalis; Stereocaulon alpinum; S. tomentosum; Arctous alpina; Betula exilis; Cassiope ericoides; C. tetragona; Diapensia obovata; Dryas punctata; Empetrum nigrum; Ledum decumbens; Loiseleuria procumbens; Rhododendron camtschaticum; Salix arctica; S. erythrocarpa; S.phlebophylla; S.polaris; S.reticulata; S.sphenophylla; Carex lugens; C. soczavaeana; Eriophorum vaginatum*) in combination with Siberian dwarf pine (*P. pumila*) thickets.

12. Mountain tundra *(Alectoria nigricans; A.ochroleuca; Cladonia stellaris; Flavocetraria cucullata; F. nivalis; Stereocaulon alpinum; S. tomentosum; Arctous alpina; Betula exilis; Cassiope ericoides; C. tetragona; Diapensia obovata; Dryas punctata; Empetrum nigrum; Ledum decumbens; Loiseleuria procumbens; Rhododendron camtschaticum; Salix arctica; S. erythrocarpa; S.phlebophylla; S. Polaris; S. reticulata; S. sphenophylla; Carex lugens; C. soczavaeana; Eriophorum vaginatum)* in combination with alder (*Duschekia fruticosa*) thickets.

13. Mountain tundra *(Alectoria nigricans; A.ochroleuca; Cladonia stellaris; Flavocetraria cucullata; F. nivalis; Stereocaulon alpinum; S. tomentosum; Arctous alpina; Betula exilis; Cassiope ericoides; C.tetragona; Diapensia obovata; Dryas punctate; Empetrum nigrum; Ledum decumbens; Loiseleuria procumbens; Rhododendron camtschaticum; Salix arctica; S. erythrocarpa; S. phlebophylla; S.polaris; S. reticulata; S. sphenophylla; Carex lugens; C. soczavaeana; Eriophorum*

vaginatum) in combination with Siberian dwarf pine (*P. pumila*) thickets and alder (Duschekia fruticosa) thickets . 14. Mountain tundra (*Alectoria nigricans*; *A. ochroleuca; Cladonia stellaris; Flavocetraria cucullata; F. nivalis; Stereocaulon alpinum; S.tomentosum; Arctous alpina; Betula exilis; Cassiope ericoides; C. tetragona; Diapensia obovata; Dryas punctate; Empetrum nigrum; Ledum decumbens; Loiseleuria procumbens; Rhododendron camtschaticum; Salix arctica; S. erythrocarpa; S. phlebophylla; S. polaris; S. reticulata; S. sphenophylla; Carex lugens; C. soczavaeana; Eriophorum vaginatum*) in combination with Siberian dwarf pine (*P. pumila*) thickets, mountain larch (*L. cajanderi*) woodland and forests. 15. Mountain tundra (*Alectoria nigricans; A. ochroleuca; Cladonia stellaris; Flavocetraria cucullata; F. nivalis; Stereocaulon alpinum; S. tomentosum; Arctous alpina; Betula exilis; Cassiope ericoides; C. tetragona; Diapensia obovata; Dryas punctate; Empetrum nigrum; Ledum decumbens; Loiseleuria procumbens; Rhododendron camtschaticum; Salix arctica; S. erythrocarpa; S. phlebophylla; S. polaris; S. reticulata; S. sphenophylla; Carex lugens; C. soczavaeana; Eriophorum vaginatum*) in combination with Siberian dwarf pine (*P. pumila*) thickets, rock birch (*B. ermanii*) woodland and forests.
Subalpine prostrate tree (krummholz), shrub, and tall-forb vegetation, including subalpine open woodland within the boreal zone 16. Siberian dwarf pine (*P. pumila*) mountain thickets. 17. Siberian dwarf pine mountain thickets (*P. pumila*) in combination with alder (*Duschekia fruticosa*) thickets. 18. Mountain larch (*L. cajanderi*) woodland and forests. 19. Mountain larch (*L. cajanderi*) woodland and forests in combination with Siberian dwarf pine (*P. pumila*) thickets. 20. Rock birch (*B. ermanii*) woodland and forests. 21. Rock birch (*B. ermanii*) woodland and forests in combination with mountain Siberian dwarf pine (*P. pumila*) thickets. 22. Ajan spruce (*Picea ajanensis*) mountain forests.
Coastal dwarf shrub heaths, grasslands, and tall-forb communities 26. Tundra-meadow vegetation of the Commander Islands
AZONAL VEGETATION WITHIN BOREAL ZONE
Wetlands

27. Dwarf shrub (*Betula exilis; Myrica tomentosa*) thickets
Floodplain Vegetation 28. Willow-chosenia (*Salix schwerinii; S. udensis; S. arbutifolia*) woodland and forests in combination with tundra-bogs and bogs. 29. Woodland and forests: larch (*L. cajanderi*), poplar (*Populus suaveolens*), willow (*Salix schwerinii*; *S. udensis*; *S. arbutifolia*) in combination with alder-willow thickets and swamps. 30. Woodland and forests: larch (*L. cajanderi*) with spruce (*Picea obovata*).

Conclusions

Arctic types of vegetation complexes are distributed throughout the region. The relation between boreal and Arctic vegetation complexes is affected by specific features of latitudinal zonation. The northern-northeastern boundary of boreal vegetation complexes is an important botanic-geographic frontier. South of this boundary, a wide ecotone area is noticeable, within which vegetation complexes of the forest and tundra zones tend to co-occur at level interfluves. A subzone of Siberian dwarf pine (*P. pumila*) thickets fits completely within this ecotone area. The most widespread vegetation complex types are those dominated by Arctic barrens, tundra, and Siberian dwarf pine thickets.

Zonal vegetation type complexes situated on level interfluves and in similar topographic situations, such as lowland watersheds, gentle slopes, valleys and terraces near the coast, are represented by Arctic and sub-Arctic tundra, *P. pumila* thickets, and also woodland and forests of larch, *L. cajanderi*, and birch, *B. ermanii*. Bogs dominate among intrazonal vegetation complex types. Valley forests, shrub thickets, and tundra are quite widespread. Transitional complexes, for example, tundra bogs, are also included in this group. Vegetation affected by strong environmental factor influence, natural as well as anthropogenic, is represented by plant communities formed under the impact of bird populations, reindeer grazing, fires, technogenic disturbances, or on agricultural land.

Peculiarities of distribution and configuration of vegetation latitudinal and altitudinal zones in the northern Far East can be attributed to the marginal position of the region within the Eurasian Continent, the impact of the surrounding seas, and also to the elevation range. Cartometric modelling of vegetation has allowed for either confirming or correcting our previous understanding and revealed the major patterns in the vegetation structure. We believe that reliability of vegetation types recognition at the mezocombination level in satellite images can be assessed with the help of our cartographic model.

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