

Bioclimates And Distribution of Zonal Types of Boreal Vegetation in Northeast Asia

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Abstract

Bioclimatic ranges of phytosociological units confirmed the biotemperature thresholds of major biogeographical zones found by Hämet-Ahti et al. (1974), Kira (1977), Fang & Yoda (1990). The critical warmth index values of 15, 45°, 55° and 85° correspond respectively to the southern borders of subarctic, boreal and northern temperate and middle temperate subzones of temperate zone. The formation of vegetation cover of North Asia is controlled by polar, boreal and temperate macroclimates. Basic intrazonal variations of vegetation cover along the gradient of continentality depend on the variations of the yearly heat and precipitation distribution and can be classified into 7 climatic types: hyperoceanic, oceanic, suboceanic, maritime, continental, subcontinental and ultracontinental. Climatic factors, especially the amount of heat, longevity of growing season and amount of precipitation in a growing season appear to be major contributors into the zonal and sectoral differentiation of vegetation complexes. The use of global bioclimatic classification of Rivas-Martínez (1999) in combination with phytosociological knowledge and a concept of zonal sites (Pojar et al. 1987) provides a powerful tool for three dimensional arrangement of vegetation along the latitudinal, longitudinal and altitudinal gradients and for distinguishing the particular climatic factors limiting the development of each zonal vegetation type.

Keywords: Enter up to six keywords on this line, alphabetized and separated by semicolons.

Introduction

Large-scale vegetation studies are one of the fundamental aspects of ecology and biogeography and a key to the clarification of modern as well as past processes in vegetation cover. The understanding of vegetation changes that follow the climatic fluctuation in different time scales has become the one of the most important question for the simulation and prediction of biota development. This study focuses at the problem of indication of climatic gradients by boreal vegetation complexes at local and regional scales and aims to quantify the local and regional scale relations of vegetation units, their complexes and climatic parameters within subarctic and boreal vegetation zones in Northeast Asia.

Study area

The Russian Far East, northeast China, Japanese archipelago and Korean peninsula represent the northeast edge of the Asian continent. The whole area covers approximately 5,000,000 km², ranging from 35°N to 73°N latitude and from 100°E to 169°W longitude. Elevations range between the sea level and 4885 m a.s.l. (Klyuchevskaya Sopka, Kamchatka).

Material and methods

The problem is approached by analysis of extensive phytosociological (over 5000 relevés) and climatic (1802 climatic stations) databases. Identification of bioclimates was made in accordance with S. Rivas-Martínez et al. (1999) approach using different climatic parameters that include Kira's warmth (WK) and coldness (CK) indices, continentality index (CI), ombro-evapotranspirational (OEI) index and winter precipitation (WP). General

multiple slope linear regression models were developed to predict bioclimatic indices on the basis of geographical variables: latitude, longitude and elevation. Because of numerous compensational effects of edaphic or local climatic factors on community development (over-moisture, over-droughts, high insolation, temperature inversions) the finding the relationships between community types and a regional climate is possible by comparison of communities on the sites, which are equal in environmental characters. A link between regional climate (Major 1963) and vegetation units can be found with an aid of a concept of zonal site formulated by Pojar et al (1987).

Results and discussion

A preliminary prodromus of boreal forest vegetation of Northeast Asia comprises 48 syntaxa of the association, 12 of alliance, 7 of order and 3 of class ranks (Krestov 2006). The application of a 'zonal site filter' allowed to select for further analysis only 22 listed below associations of forest communities that occur on zonal sites.

Class

Order

Alliance

Association

Betuletea glanduloso-divaricatae prov.

Larici cajanderi-Betuletalia divaricatae prov.

Larici gmelinii-Betulion divaricatae prov.

Flavocetrario cuculatae-Betuletum divaricatae

Salici krylovii-Laricetum gmelinii prov.

Vaccinio-Pinetalia pumilae

Vaccinio-Pinion pumilae

Vaccinio-Pinetum pumilae

Ledo decumbentis-Pinetum pumilae

Vaccinio-Piceetea

Lathyro humilis-Laricetalia cajanderi
Lathyro humilis-Laricion cajanderi
Lathyro-Laricetum cajanderi
Ledo palustris-Laricetalia cajanderi
Ledo palustris-Laricion cajanderi
Ledo-Laricetum cajanderi
Rhododendro aurei-Laricion cajanderi
Sanguisorbo-Laricetum cajanderi
Abieti-Piceetalia jezoensis
Pino pumilae-Piceion jezoensis
Vaccinio-Piceetum jezoensis
Abieti nephrolepidis-Piceion jezoensis
Oplopanaco elati-Piceetum jezoensis
Philadelpho-Piceetum jezoensis
Thujo koraiensis-Abietetum nephrolepidis
Piceion jezoensis
Piceo jezoensis-Abietetum sachalinensis
Asaro heterotropoidis-Abietetum sachalinensis
Maiantho-Tsugetum diversifoliae
Abietion mariesii
Abietetum veitchio-mariesii
Abietetum mariesii
Betulo ermanii-Ranunculetea acris
Betuletalia ermanii
Pino pumilae-Betulion ermanii
Salici arcticae-Betuletum ermanii

Geranio erianthi-Betuletum ermanii
Artemisio opulentae-Betulion ermanii
Artemisio opulentae-Betuletum ermanii
Streptopo-Alnetalia maximowiczii
Athyrio brevifrontis-Weigelion middendorffianae
Weigelo middendorffii-Betuletum ermanii
Dryopterido-Alnetum fruticosae
Glycerio alnastereti-Alnetum fruticosae

Analysis of indices calculated with an aid of developed models showed the significant differences of vegetation units of the order rank in bioclimatic ranges. In combination with the analysis of community distribution along elevation gradient this allowed the finding of association indicating bioclimatic region (Table 1).

WK decreases from values over 75 in the middle temperate zone (*Saso-Fagetalia*, *Aceri-Quercetalia*) to the values less than 20 in subarctic zone. Among boreal vegetation units the orders of *Betulo-Ranunculetea* have the lowest warmth index that can be explained by cool summer in conditions of oceanic climate. CK varies between values of -25 and -150 within boreal and temperate zones with prevalence of deciduous broadleaved, mixed and evergreen broadleaved forests (Fig. 1)

Table 1. Zonal associations / community types (Ermakov et al. 2002; Ermakov & Alsynbaev 2004, Ermakov 2003, Krestov & Nakamura 2002; Krestov et al. 2006, 2008) characteristic to bioclimatic regions and vertical belts of Northeast Asia (after Krestov & Nakamura 2007)

Macrobioclimate / Thermotype		Continental sectors				
		Ultrabontinental	Continental	Maritime	Suboceanic	Oceanic
Polar	Suprapolar	--	--	<i>Cryptogam comm.</i>	<i>Carex comm.</i>	<i>Cassiope comm.</i>
	Mesopolar	--	<i>Betula exilis comm.</i>	<i>Eriophorum vaginatum comm.</i>	<i>Vaccinio-Empetretum nigrae</i>	<i>Vaccinio-Empetretum nigrae</i>
	Thermopolar	<i>Flavocetrario-Betuletum divaricatae</i>	<i>Salici krylovii-Laricetum gmelinii</i>	<i>Ledo-Pinetum pumilae</i>	<i>Dryopterido-Alnetum fruticosae</i>	<i>Artemisio-Arnacetum unalascensis</i>
Northern boreal	Crioroboreal	<i>Kobresia spp. comm.</i>	<i>Dryas comm.</i>	<i>Dryas comm.</i>	<i>Carex comm.</i>	<i>Cassiope comm.</i>
	Oroboreal	<i>Flavocetrario-Betuletum divaricatae</i>	<i>Ledo-Pinetum pumilae</i>	<i>Vaccinio-Pinetum pumilae</i>	<i>Dryopterido-Alnetum fruticosae</i>	<i>Dryopterido-Alnetum fruticosae</i>
	Supraboreal	<i>Flavocetrario-Betuletum divaricatae</i>	<i>Flavocetrario-Betuletum divaricatae</i>	<i>Salici krylovii-Laricetum gmelinii</i>	<i>Salici arcticae-Betuletum ermanii</i>	<i>Dryopterido-Alnetum fruticosae</i>
	Mesoboreal	<i>Ledo-Laricetum cajanderi</i>	<i>Ledo-Laricetum cajanderi</i>	<i>Saussureo-Laricetum gmelinii</i>	<i>Geranio erianthi-Betuletum ermanii</i>	<i>Dryopterido-Alnetum fruticosae</i>
	Thermoboreal	<i>Lathyro-Laricetum cajanderi</i>	<i>Ledo-Laricetum cajanderi</i>	<i>Moneco-Piceetum jezoensis</i>	<i>Artemisio opulentae-Betuletum ermanii</i>	<i>Glycerio-Alnetum fruticosae</i>
Southern boreal	Crioroboreal	<i>Kobresia spp. comm.</i>	<i>Dryas comm.</i>	<i>Dryas comm.</i>	<i>comm. of Loiseleurio-Vaccinetea</i>	--
	Oroboreal	<i>Betula rotundifolia comm.</i>	<i>Vaccinio-Pinetum pumilae</i>	<i>Vaccinio-Pinetum pumilae</i>	<i>Vaccinio-Pinetum pumilae</i>	--
	Supraboreal	<i>Larici-Pinetum pumilae</i>	<i>Larici-Pinetum pumilae</i>	<i>Sanguisorbo-Laricetum gmelinii</i>	<i>Weigelo-Betuletum ermanii</i>	--
	Mesoboreal	<i>Ledo-Laricetum cajanderi</i>	<i>Ledo-Laricetum cajanderi</i>	<i>Philadelpho-Piceetum jezoensis</i>	<i>Asaro-Abietetum sachalinensis</i>	--
	Thermoboreal	<i>Lathyro-Laricetum cajanderi</i>	<i>Vaccinio-Piceetum jezoensis</i>	<i>Oplopanaco-Piceetum jezoensis</i>	<i>Piceo-Abietetum sachalinensis</i>	--

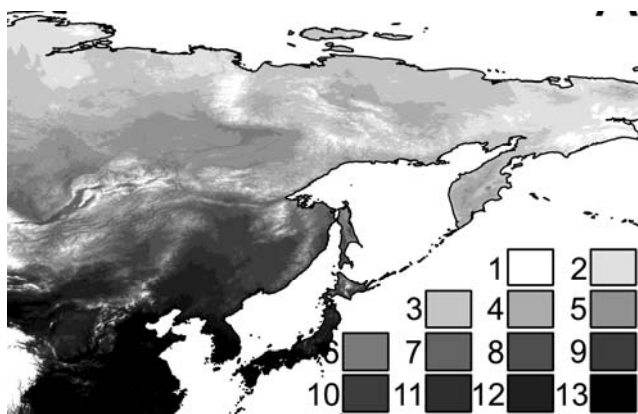


Figure 1. Distribution of Kira's warmth index in Northern Asia: 1: 0-10; 2: 10-15; 3: 15-20; 4: 20-25; 5: 25-30; 6: 30-35; 7: 35-40; 8: 40-45; 9: 45-55; 10: 55-65; 11: 65-85; 12: 85-100; 13: >100 (after Krestov et al. 2008).

The boreal orders *Lathyro-Laricetalia* and *Ledo-Laricetalia* representing boreal deciduous coniferous forests are characterized by very low values of coldness index that, in this case, is comparable to that of subarctic orders.

The ranges of orders along the continentality gradient are reflected by changes of vegetation types within a zone with proximity to the ocean. In boreal zone the lowest values of CI are characteristic to the class *Betulo-Ranunculetea*, and deciduous coniferous orders *Lathyro-Laricetalia* and *Ledo-Laricetalia* developed in conditions of maximum of the whole North Asia continentality. Vegetation of subarctic zone is characterized by moderate values of CI due to the influence of Arctic Ocean.

The distribution of OEI among vegetation orders shows that boreal *Lathyro-Laricetalia* and *Ledo-Laricetalia* and partly subarctic order *Larici-Betuletalia* are developed in critical conditions of significant moisture deficit that normally does not support forest vegetation. The existence of forests in dry areas of temperate zone is supported by the edaphic moisture accumulating on the north-faced mountain slopes. Most important source of water in dry areas of boreal zone is melting permafrost. A significant peak of IOE for the subalpine order *Weigelo-Betuletalia* is caused by monsoon character of precipitation in the mountainous areas of Hokkaido and Sikhote-Alin, where the high summer precipitation is enforced by low evapotranspiration due to the low temperatures in subalpine belt.

The relationships of vegetation units with snow cover become significant in the conditions of oceanic sector of boreal zone, where the strong accumulation of snow causes 2-3 week delay of its melting and a considerable shortening of growing season. The communities of *Betula ermanii*, *Alnus fruticosa* and tall-forb meadows are characteristic to the regions with slower-melting heavy snow deposits.

Comparative floristic analysis showed that southern and coastal floras as well as floras of mountainous regions include the most of taxa of northern and continental floras. Zonal subarctic vegetation is represented by communities of provisional class *Betuletea glanduloso-divaricatae* composed of species complexes of Pacific coastal mountainous regions. In boreal zone, vegetation of Asian

ultracontinental to maritime sectors is represented by communities of *Vaccinio-Piceetea*, Asian suboceanic to hyperoceanic sectors – by communities of *Betulo-Ranunculetea*. The boreal classes were likely differentiated in Pre-Pleistocene time due to the well developed floristic centres under the different climatic situations.

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