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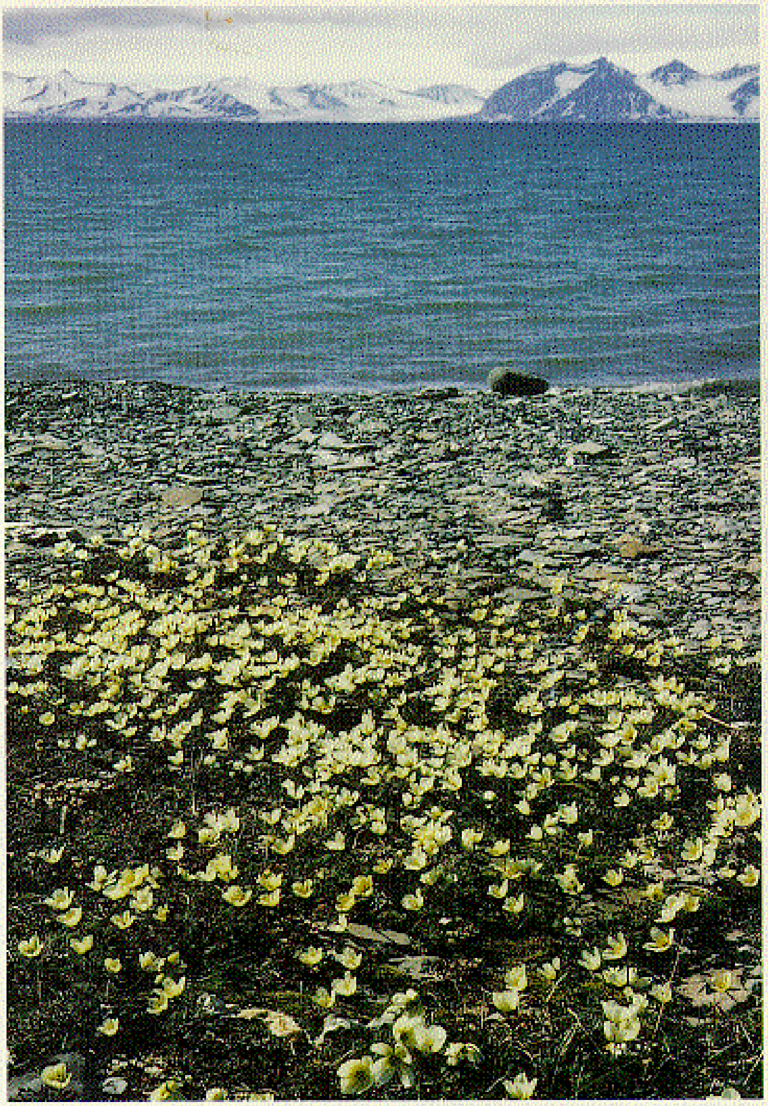

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Possible forest shifts in Yakutia under climate change

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Abtsract

A regional vegetation model for Yakutia was used to evaluate possible shifts of the major vegetation types resulting from projected climate change. The vegetation model predicted vegetation type as a function of temperature sums, precipitation sums of growing periods and the hydrothermal coefficient. The climate change scenario was predicted by the analogue paleoclimate method (Budyko method). Results indicate the potential for enormous shift in the vegetation of Yakutia due to climate change.

Introduction

Vegetation response to climate change is a very important problem for Yakutia, where vegetation cover is very unstable because of the extremely rigorous climatic conditions. Therefore, climate changes can result in its deformation.

Our first objective in this paper was to determine the regularities of the cover zonality of the area in spite of the extremely complicated topography of Yakutia.

Our second objective was to estimate the vegetation zonality shift under regional climate change by the year 2005.

Material and Methods

The Climatic Vegetation Information System (CVIS) was developed to solve the problems in the above objectives. This system is intended for processing of climatic parameters based on meteorological data sets. It is also an adequate tool for combined analysis of vegetation based on cartographic information. CVIS enables the study of spatial distribution of climatic parameters, to investigate the interdependence and correlation between climatic data and distribution of the vegetation within the Yakutia region. CVIS also enables the construction of maps of predicted terrestrial ecosystem change.

CVIS includes the system of factographic data base created in the DBSM FoxPro, cartographic data base, developed with the help of GIS EPPL7. The system of factographic data bases includes climatic characteristics: mean annual data of average monthly temperatures and average monthly precipitation sums, collected from reference books on climate of the USSR, information received from 147 meteorological stations of Yakutia, and geographical coordinates and absolute heights of these meteorological stations.

The cartographic data base consists of a physical-geographical map, a vegetation map of Yakutia from "Agriculture Atlas of Yakutia" scale 1:5,000,000 (1989) and a map of meteorological

stations in Yakutia.
CVIS was used for the estimation of the border shift of vegetation zones within the Yakutia region in relation to regional warming. The impact of climate change on the forests was evaluated through change of climatic parameters, which determine the distribution of vegetation zones and change of their borders. The following climatic parameters were chosen: temperature sums (TS) for the period with average daily temperature above 10°C, precipitation sums for this period (PS), and the hydrothermal coefficient (GTK), which is PS*10/TS. These parameters were calculated on the basis of the means of multi year data (years 1890-1961), involved in data bases and programmes, contained in CVIS.

The maps for TS, PS and GTK were constructed with the help CVIS. The climatic division of the Yakutia area was done on the basis of these maps and uniform clusters of the climatic parameters mentioned above. Ten climatic clusters were marked.

Initially, 79 vegetation types from the vegetation map of the "Agriculture Atlas of Yakutia" (1989) were aggregated into 10 vegetation zones by their general similarity, for input for the vegetation map to system CVIS in format EPPL7. The vegetation map was constructed by A. Pryazhnikov, a research worker of the laboratory of biosphere functions of The forest of the Centre for Problems of Forest Ecology and Productivity, Russian Academy of Science.

A scheme based on the correlation between maps of climatic clusters and generalised vegetation maps, was created. This scheme was taken as a basis for the vegetation model of Yakutia.

Results and Discussion

The Yakutia model was used to construct a map of predicted current vegetation. The map of predicted vegetation was compared with the initial CVIS map. The accuracy of coincidence between these two maps was equal to 70%. In general, within the Yakutia region we can mark two main vegetation zones: Tundra and Forest zones, with Taiga types dominant. These zones contain various types of vegetation: from arctic to forest with inclusions of meadow and steppe types. Arctic and subarctic zones are characterised by moss, lichen, shrub and grassland types. The forest zone divides on Northern Taiga and Middle Taiga with conifer types, in which Siberian larch is dominant.Northern Taiga is different from Middle Taiga which is sparse and has forests with lower productivity. In theMiddle Taiga in southern regions, spruce and pine grow, and in arid regions the gaps with steppe and meadow vegetation are marked.

Division within zones was determined by temperature conditions. The border between forest and grassy types was associated with the value of 1 for GTK.

The main peculiarity of the current vegetation zonality in Yakutia is the presence of boreal vegetation in areas with climatic conditions typical for steppes in other regions of Eurasia, where GTK = 0.7 and TS=1000-1600. In Yakutia, steppe vegetation exist only as small spots within the boreal vegetation, on gaps in the permafrost. This peculiarity is determined by the existence of permafrost.

The Yakutia model was used to evaluate the potential change in the distribution of vegetation zones, as the response to possible changes in the distribution of climatic clusters in Yakutia by the year 2005.
The original research of air temperature trends was done over many years for 49 meteostations of Yakutia to predict the vegetation shift. The results of the research showed an increase of 3.5°C in winter, mean annual temperatures of 2.0°C, and an insignificant increase in summer temperatures of 0.5°C from the end of 70's to the 90's covering the whole area of Yakutia. It has confirmed the Budyko idea about future climate warming in this region (Budyko, 1988).

Therefore, the Budyko analogue paleoclimate method was used as a scenario of the regional climate change to the year 2005 (Budyko, 1988). The paleoclimate scenario is based on three warm geological periods with estimated future levels of the concentration of CO_2 applied to them. The results of the scenario for a doubling of CO_2 were very similar to those obtained by the numerical simulations (GCM). This scenario was used to make predictions of climate change for regions in Northern Eurasia to the year 2005.

Table 1. Area comparisons between the current climate map and the climate change scenario, using the Yakutia model.

	Area Comparison (units=1000 km^2)	
Vegetation Zone	Current Climate Map	Climate Change Map
Arctic Tundra	44.6	13.1
Subarctic Tundra	313.8	20.5
Stony Deserts & Mountain Tundra	133.6	19.2
Forest Tundra open Woodland	120.0	36.0
Northern Taiga open Woodland	850.0	376.6
Middle Taiga	839.7	1262.7
Middle Taiga with Steppe	137.4	577.0
Mountain Forest Tundra	36.8	15.4
Mountain Northern Larch Taiga	438.7	461.8
Mountain Middle Taiga	188.6	320.9
Totals:	3103.2	3103.2

Predictions of TS, PS and GTK values were calculated on the data of deviations in winter and summer temperatures and annual precipitation for Northern Eurasia obtained from Budyko's scenario. The simulated values (TS, PS, GTK) for the future were used to create the model of future potential vegetation zones in Yakutia. The change of vegetation zones areas are shown in table 1.

The northward shift of the vegetation zones was determined by the analysis of the shift in climatic clusters. The arctic tundra area will occupy only arctic islands, subarctic tundra will be left as a narrow belt on the arctic coast, and the southern border of northern taiga will coincide with 70°N. The main area of Yakutia will be occupied by middle taiga, with increased areas of steppe types.

In the present work, the distribution of potential vegetation zones predicted by the Yakutia model was compared with the earlier results of Emanual, Shugart and Stevensohn (1985). The general features in changes of borders and areas of vegetation zones are markedly similar. However, it is necessary to note that in this work (Emanual, Shugart and Stevensohn, 1985), the changes in vegetation were all over the globe and in the more remote future, while the present work investigates the regional changes of vegetation zones in the near future. Therefore, total conformity cannot be observed. The results of our research are more comparable with data from the work of Monserud, Denissenko, Tchebakova (1993). They analysed the potential change of vegetation zones in Siberia. However, there are also some differences between this work and ours which can be explained by the use of different models of climate change, as well as by the difference in period of projection of these models. Therefore, in the work of Monserud, Denissenko, Tchebakova (1993), it is assumed that the whole southern Yakutia will be occupied by steppe. In present work is predicted that areas of steppe will be increase, but middle taiga will not turn into steppe.

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