Projected impacts of 21st century climate change on the distribution of potential habitat for vegetation, forest types and major conifer species across Russia

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Fig. 1. Study area, Russia (20-140ºE and 48-72ºN)

Goals. Develop bioclimatic (biogeographic) models of zonal vegetation, climax forest-forming conifers and forest types in Russia and model current and future forest cover in Russia by the end of the current century using an ensemble of three GCMs

Methods. We expanded our Siberian vegetation bioclimatic model (SiBCliM) to a Russian bioclimatic model (RuBCliM);

• RuBCliM predicts zonobiomes (zonal vegetation classes) from three climatic indices (growing degree-days, negative degree-days, and an annual moisture index) and permafrost;

•To verify the ability of RuBCliM to model vegetation, modeled vegetation was compared to the actual vegetation map of Isachenko (1989) using kappa statistics;

•We developed envelope-type bioclimatic models for major forest-forming confers of Russian forests and their forest types;

•All simulations to predict vegetation change across Russia were run by coupling our bioclimatic models with bioclimatic indices and the permafrost distribution for the baseline period 1971-2000 and for the future decades of 2011-2020, 2041-2050 and 2091-2100. To provide a range of warming (the smallest and greatest temperature increases) we used three global climate models (CGCM3.1, HadCM3 and IPSLCM4) and their ensemble under three climate change scenarios (A1B, A2 and B1).

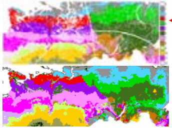

Fig. 2. Map comparison between actual (upper) and modeled (Lower) vegetation over Russia in modern climate

Table 2. Biome distribution (%) in modern and ensemble A2 at 2100

Vegetation	*Ensemble baseline climate*	*Ensemble 2090 climate*	
		B1	A2
Tundra	18.7	3.0	0.9
Forest-tundra	15.5	10.2	2.1
Dark Taiga	15.6	14.9	10.0
Light Taiga	19.6	21.1	13.7
Mixed	2.0	8.6	5.7
Broadleaved	4.4	10.8	24.0
Steppe	9.9	11.8	20.1
Semidesert	14.4	19.7	23.5

Results. The comparison between our modeled and the real (Isachenko 1988) vegetation maps showed that the overall agreement was "fair" (K=0.40) and agreements by separate zonobiomes ranged from "very good" and "fair" to poor (K<0.4). Overall we concluded that RuBCliM does a reasonable job of modeling Russian vegetation distribution at a broad scale (Fig. 2).

Results. Biome simulations resulting from the mild B1 and harsh A2 scenarios indicated that "potential" vegetation in Russia would be sufficiently altered by 2090 (*Fig. 3; Table 2*).

- Tundra would nearly disappear in the A2 climate. Forest-tundra would decrease from 1.5-fold in the B2 climate to 7-fold in the A2 climate.
- Taiga would stay the same in the B1 climate and 1.5-fold decrease in the A2 climate. Mixed and broadleaf forests would increase up to 5 times. Steppes and semideserts would increase 1.5-2 times.

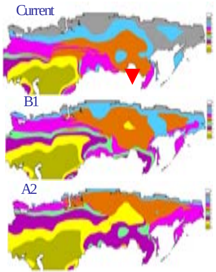

Fig. 3. Modeled vegetation distribution in Russia for current climate and the ensemble B1 and A2 climate scenarios at 2090 ***Vegetation:***
1 – Tundra (*grey*), 2 – Forest-Tundra; 3 – Dark taiga; 4 – Light taiga; 5 – Mixed, 6 – Broad-leaved; 7 – Steppe; 8 – Semidesert

Major conifer distributions (%) in Russia modeled in the ensemble baseline, B2 and A1 2090 climates

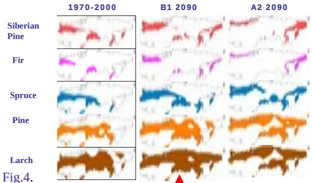

Fig.4.

Results. Fundamental (potential) niches of major Russian conifers in a changing climate are shown in *fig. 4*. Distributions of all conifers would move northwards by 2090 and increase somewhat for dark conifers (Siberian pine, fir and spruce) and significantly for light conifers (pine and larches). Pine would stay on sandy soils. Dahurian larch stays on permafrost, Siberian larch would move on soils freed of permafrost and richer than sandy soils.

•The dryer climate would favor light conifers pine and *Siberian* larch in West Siberia and *Dahurian* larch within the permafrost zone in East Siberia. All light conifers, especially pine, may also develop because they have an advantage over dark conifers due to their stronger resistance to water stress and wildfire.

• A forest type was defined as a combination of a dominant tree conifer and a ground layer modeled from the same climatic indices

Conclusions

• Kappa statistics rated RuBCliM as "fair" in modeling current Russian vegetation;

•With these projected climates, the zonobiomes would need to shift far to the north in order to reach equilibrium with the change in climate;

• Under the warmer and drier projected future climate, most of Russia would be suitable for the forest-steppe ecotone and grasslands rather than for forests.

•Water stress tolerant light-needled taiga (*Pinus sylvestris* and *Larix spp.*) would have an increased advantage over water-loving dark-needled taiga (*Pinus sibica, Abies sibirica, Picea obovata*) in a new climate.

•The permafrost-tolerant *L. dahurica* taiga would remain the dominant forest type in the many current permafrost areas.

•Accumulated surface fuel loads due to increased tree mortality from drought, insects and other factors, especially at the southern forest border together with an increase in severe fire weather would also lead to increases in large, high-severity fires, which are expected to facilitate vegetation progression towards equilibrium with the climate.

Forest types: combinations of tree species & ground layers

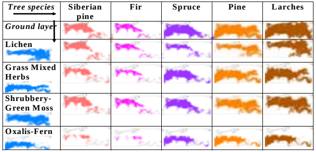

Fig.5.

1. RFFI project 10-05-00941, 2. NASA LCLUC NEESPI program, 3. NASA Interdisciplinary Science Project, NNH09ZDA001N-IDS.