Possible climate warming effects on forests, trees, biotic disturbances, desertification and agriculture in Siberia, recently and in the future

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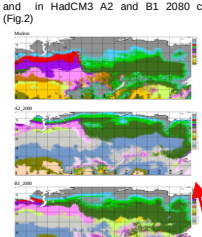
Fig. 1. The study region: Siberia (a rectangular within 60-140E and 50-75 N) and central Siberia (Krasnoyarsky Kray and adjacent in the south Republics of Khakassia orange) and Tyva (blue)

Goals Our goal was to summarize results of research we have conducted for the last couple decades in the context of climate warming and its consequences for biosystems: forests, trees, insect infestation and pathogen in forests, agriculture and desertification in Siberia.

Forests and major tree species

Static envelope-type large-scale bioclimatic models of the forests and tree species, were developed that simulate Siberian zonal vegetation and the forests from three bioclimatic indices: GDD_5; NDD_5, and AMI. Additionally to climatic indices, SIBCLIM included permafrost, a significant factor in Siberia.

Both ioclimatic models were applied to climatic indices in different time frames: current (upper) and in HadCM3 A2 and B1 2080 climates (Fig.2)



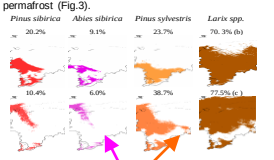


Fig. 2. The forests and major conifers (Fig. 3) distributions in central Siberia in current and future climates

Biotic disturbances

The Siberian moth, *Dendrolimus erans sibiricus* Tschtv. (*Lepidoptera: Lasiocampidae*), is one of the most severe defoliators of coniferous forests in Northern Asia

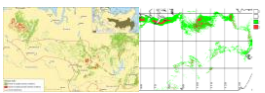


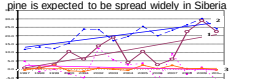
Fig. 4. Bioclimatic model of the Siberian moth range shows suitable (green) or highly favorable (red) conditions in current (left) and future (right) climates. The red line shows the present range of the moth that nicely overlaps its predicted range

The forest zones could decrease and shift northwards as far as 600-1000 km and forest-steppe and steppe could dominate 50% (Fig.2)

With the warming and drying climate, habitats should become increasingly more suitable for drought-resistant, light conifers, 2 times for *Pinus sylvestris* and 10% the *Larix* genera as a whole with *L. gmelinii* retreating with permafrost (Fig.3).

The modeled distribution of the pest closely matches to the existing distribution in Siberia. Both climate change scenarios HadCM3 A2 and B1 showed that the environment for the moth would considerably shrink in the future leaving suitable habitats only in highlands of mountains and the northern coast of Eurasia (Fig.4). The potential distribution is limited by future mild winter conditions because for successful overwintering, larvae require continuous cold winters.

Needle-cast of *Pinus sylvestris.* One third of the forests in Siberia is killed by diseases, half of which is the most spread needle-cast of pine *Lophodermium pinastri* Chev. Data collected in pine nurseries in Krasnoyarsk kray for 1997-2010 showed that tree mortality depends on 2-year (previous and current) precipitation (R^2=0.46 p<0.007). In the future dry climate, needle-cast of pine is expected to be spread widely in Siberia



Fog. 5. Dependence of needle-cast of pine (% of disturbance, 1) on: аномалий суммы осадков за два года (2), July temp. departure (3) and January temp. departure (4) for 1997-2010

Desertification

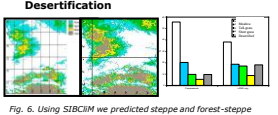


Fig. 6. Using SIBCliM we predicted steppe and forest-steppe vegetation significant enlargement due to climate aridization by 2080. Areas of different steppe types – tall-grass, short-grass and dry (desertified) steppes will increase twofold by the end of the century except moist meadow steppes

Agriculture. by the end of the century and at least half of central Siberia would be occupied by steppe and forest-steppe and may become climatically suitable for agriculture. Together with soil potential, suitable deep and fertile soils, these future climates would allow for farming

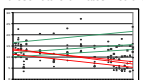


Fig. 7. Observed trends of grain crops, centner ha-1 , for 1966-2009 in the forest-steppe zone (green, three farming regions) and steppe zone (red, three farming regions).

With warming, crop production increases with sufficient moisture in forest-steppe and reduces as the climate becomes dryer in steppe.

We constructed simple agri-climatic regression models (R2=0.2-0.7) that predict the geographic range and yields of annual agri-crops from the two summer climatic indices: GDD, base 5°C, and AMI. Production of many traditional may increase by twofold as climate warms by 2080.

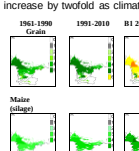


Fig.8. Predicted crop yields (centner ha -1) for traditional grain (upper) and maize silage (lower) for the present and 2080

Conclusions.

• In the warmer and drier climate projected, **Siberian forests** are predicted to decrease and shift northwards and forest-steppe and steppe ecosystems are predicted to dominate 50% of central Siberia by 2080. Despite the large predicted warming, permafrost is not predicted to thaw deep enough to sustain dark (*Pinus sibirica*, *Abies sibirica*, and *Picea obovata*) taiga. Over eastern Siberia, larch (*Larix dahurica*) taiga is predicted to continue to dominate on continuous permafrost. Light conifers may get an advantage before dark conifers and may cover a larger area in the near future due to their stronger resistance to water stress and wildfire. The model predicts new temperate broadleaf forest and forest-steppe habitats

• **Desertification and agriculture.** Half of central Siberia is predicted to be climatically suitable for agriculture although potential croplands would be limited by the availability of suitable soils. Crop production may increase by twofold; traditional crops (grain, potato, maize for silage) could gradually shift northwards (about 50-70 km per decade) and new crops (maize for grain, apricot, grape, gourds) may be introduced in the far south, depending on winter conditions, and these would necessitate irrigation in a drier 2080 climate;

•Desertification is expected in extreme southern Siberia as a result of a decrease in precipitation under dramatic increase in temperature

• **Biotic disturbances.** The environment for the Siberian moth may considerably shrink in the future leaving suitable habitats only in montane highlands and northern Eurasia. Moth habitats would be limited in a warmer climate and Siberian moths may not be considered a threat in climates with mild winters because larvae require continuous cold winters;

Needle-cast of *Pinus sylvestris* caused by *Lophodermium pinastri* Chev was found to be strongly related to precipation including snow depth rather than summer temperature. In the predicted dryer climate, *Lophodermium pinastri* Chev would shift northwards followed sufficient water.

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