Agro-climatic potential across central Siberia in an altered 21st century

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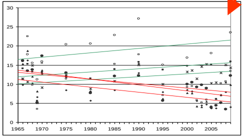
Fig. 1. The study region Krasnoyasrky Kray and adjacent Republic of Khakassia (hereafter Khakassia) and the Republic of Tyva, (hereafter Tyva, bottom). Arable land (brown) currently ranges across Russia.

Introduction. World concerns about food security are growing as the result of observed and projected climate change impacts on agriculture. The scientific community agrees that climate change consequences differ for agriculture depending on geography; northern countries may benefit from global warming (Russia, northern China), and in the absence of adaptation measures, southern countries and continents (Africa, Australia) may find their food security at risk due to climate warming.

Goals are: to predict 'hot spots' of potential agricultural change in the pre-2010 climate and in the future using Hadley 2020 and 2080 climate change scenarios; and to model future crop potential that may evolve as the climate changes in south-central Siberia, Krasnoyarsk Kray and adjacent Republics of Khakassia and Tyva (Fig.1).



Methods. Our hypothesis is based on previous work (Tchebakova and Parfenova et al.; Soja et al.), which showed the Siberian taiga would shift northwards 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.

Data from 21 weather stations from 1961-2010 in three southern vegetation zones (forest-steppe, steppe, and dry steppe) are used to evaluate climate change trends and climatic indices: growing degree days (**GDD**) >5°C and annual moisture index (**AMI** - a ratio between GDD>5°C and annual precipitation). All data are derived from reference books on climate and crops.

Results. From available data, we found that crop output increased during the last half a century (1960-2010) in southern Siberia, (Fig.2). This crop increase may be associated with stable positive trends in both summer and winter temperatures (Fig. 3) that prolonged the growing season up to 1 month over 50 years. Crops decreased in regions where the climate became dryer.

Fig. 2. 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.

Methods. We constructed simple agri-climatic regression model models that predict the geographic range and yields of annual agri-crops from the two summer climatic indices: GDD, base 5°C, and AMI.

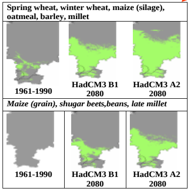
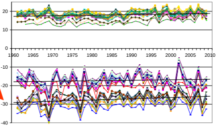


Fig. 4. Potential climatic range (green) of traditional and new crop (italic) species in central Siberia in the 2010 and HadCM3 B1 and A2 2080 climates



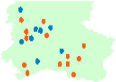


Fig.3. January and July temperature trends for 1961-2010 were positive and showed that north of 51° N, January temperatures increased 1-2°C and July temperatures increased 0.7-1.5°C over the last 50 years. In Tyva, both January and July temperature increases were two times greater, 2-4°C and 1.4-3.2°C, respectively. Blue points mark the moisture increase and orange points mark moisture decrease (right).

Results. The crop range and yield models were applied to climatic indices in different time frames: pre-1960; 1960-1990; 1990-2010 (using observed data); and in HadCM3 B1 and A2 2020 and 2080 climates (using climate change scenarios) to predict potential crop transformation for 150 years in a changing climate (Fig. 4 and Fig. 5). Climatically potential crops are restricted by soil potential, which is accepted as limited by sufficiently developed and fertile soils in the southern taiga, located north of sub-taiga and forest-steppes. Thus, we use the northern border of the southern taiga as limiting potential agriculture.

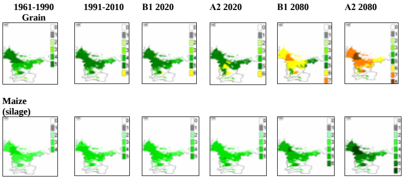


Fig.5. Predicted crop yields (centner ha^{-1}) for traditional grain and maize silage for historic and future periods (Hadley Center climate change scenarios) over the study regions.
***Grain**: 0. beyond the area of suitable soils; 1. <5; 2. 5-10; 3. 10-15; 4. 15-20; 5. 20-25; 6. 25-30; 7. 30-35; 8. > 35;*
***Silage**: 0. beyond the area of suitable soils; 1. <100; 2. 100-200; 3. 200-300; 4. 300-400; 5. 400-500; 6. 500-600; 7. > 600.*

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A ripe wheat field in Khakassia, southern Siberia

Conclusions.

- 50-85% of central Siberia is predicted to be climatically suitable for agriculture at the end of the century although potential croplands would be limited by the availability of suitable soils within the steppe, forest-steppe, sub-taiga and southern taiga zones.
- Climatic factors control crop distribution and production in southern Siberia (R^2 = 0.2-0.7).
- Crop production may increase by twofold as climate warms during the century.
- Traditional crops (grain, potato, maize for silage) could gradually shift as far as 500 km northwards (about 50-70 km per decade) and new crops (maize for grain, apricot, grape, gourds) could be introduced in the far south depending on winter conditions and these would necessitate irrigation in the drier 2080 climate.
- Agriculture in central Siberia would likely benefit from climate warming.

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