Evaluating climate severity for human comfort in a changing climate of the 21st century in Asian Russia

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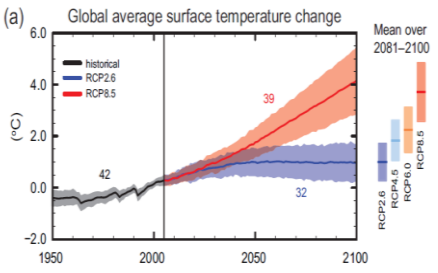

http://www.ipcc.ch/pdf/assessmentreport/ar5/wg1/WG1AR5_SPM_FINAL.pdf

Introduction. In the past, human migrations were associated with climate change. As our civilization developed, humans depended less on the environment, in particular on climate, because technological and economical developments in the span of human history allowed them to adapt to and overcome environmental discomfort of the environment. Russian Asia (Siberia and Far East east of the Ural Mts (60°E) is known to be sparsely populated. As seen from the Earth at Night map, the population is concentrated along the forest-steppe zone in the south, with its comfortable climate and rich agriculture on fertile soils. There are various approaches to characterize an ecological-resource potential of a territory required for human comfort and activities (Figs. 1-2)

Our goal was to evaluate Asian Russia's climate severity and comfort for humans from a view point of winter conditions: degree-days<0°C and presence /absence of permafrost in the current climate and to predict the potential in climate comfort in a warming climate by the 2080s.

Fig. 1. *Population density of Russia*
http://www.statdata.ru/karta/plotnost-naseleniya-rossii

Fig.2*. Climate severity (Zabolotnik, 2010). (see the Legend of Negative Degree Days in Fig.4)*

Methods. Climate data from 1000 weather stations over the study area were used to map degree-days for the 1960-1990 baseline period using a digital elevation model of 1 km resolution using Hutchinson's thin plate splines.

Anomalies of January and July temperature and precipitation were derived from 20 general circulation models CMIP5 (IPCC, 2013). The ensemble anomaly values were calculated as anomaly means of each climate variable. Climate indices: Growing-degree days, Negative-degree days, Annual moisture index, Active layer depth 2 m, Climate severity, and Ecological Landscape Potential were calculated based on January and July temperature and precipitation in contemporary and future climates. Permafrost covers of some 80% of Asian Russia. The continuous permafrost border was approximated as 2 m of the active layer depth and calculated from January and July temperature and precipitation in both current and future climates (Fig. 4).

Ecological Landscape Potential, EPL, by Isachenko (2003) is calculated as a product of a sum of temperature above 10°C (*0.01) multiplied by a moisture index (MI) representing a ratio of annual precipitation to evaporation. Under MI greater than 1 (a moist climate), MI is taken equal 1. Under MI less than 1 (an arid climate), MI is taken with its value decreasing an EPL value (Table 1). Climate severity by Zabolotnik (2010) is calculated as a sum of negative temperatures (Fig.4).

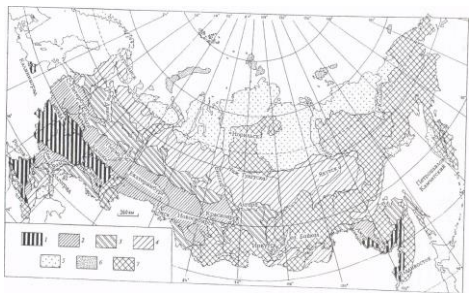

Fig.3*.Ecological Landscape Potential of Russia (ELP) by Isachenko* (see Legend in Table 1)

Table 1. Ecological Landscape Potential of Russia (ELP) by Isachenko (2003)

ELP 0.01 ($DD_{>10}$)/I_B) I_B=1 if I_B>1; I_B= I_B if I_B<1	**Population Density, people/km²**	**Landscapes**
1. The highest (>20)	**60.6**	Front-Subropical northern Caucauses broad-leaved forests and Ciscaucasian broad-leaved forest, forest-steppe, and southern East European subtaiga
2. Relatively high (16-20)	**22.1**	East European SubTaiga (without southern regions); West Siberian Forest-Steppe; East European typical Steppe ; southern taiga (except Central Siberia)
3. Medium (12-16)	**6.6**	Middle Taiga (except central Yakutia); central Siberian Southern Taiga; trans-Volga and West Siberian typical Steppe; East European dry Steppe
4. Low (8-12)	**2.4**	Northern Taiga (except East Siberian); central Yakutian Middle Taiga; Siberian dry Steppe; Semideserts
5. Very low (<8)	**0.9**	East Siberian Northern taiga; SubArctic (forest-tundra, tundra; Deserts
6. Extremely Low (~0)	**0.02**	Arctic
7. Irregular (0-20)	**1.2**	High mountain belts

Contemporary climate	2080-s	
	rcp 2.6	rcp 8.5
July temperature, °C		
1: < 2; 2: 2 - 4; 3: 4 - 6; 4: 6 - 8; 5: 8 - 10; 6: 10 - 12; 7: 12 - 14; 8: 14 - 16; 9: 16 - 18; 10: 18 - 20; 11: 20 - 22; 12: 22 - 24; 13: 24 - 26; 14: 26 - 28; 15: 28 - 30; 16: > 30		
January temperature, °C		
1: < -45; 2: -45 - -40; 3: -40 - -35; 4: -35 - -30; 5: -30 - -25; 6: -25 - -20; 7: -20 - -15; 8: -15 - -10; 9: -10 - -5; 10: > -5		
Annual precipitation, mm		
1: < 200; 2: 200 - 400; 3: 400 - 600; 4: 600 - 800; 5: 800 - 1000; 6: 1000 - 1500; 7: 1500 - 2000		
Permafrost (active layer depth 2m)		
1 - permafrost, 2 – permafrost-free		
Climate severity		
1. < absolutely extreme (-6250) , 2. extreme (-6250 – (-5000), 3. Severe (-5000 – (-3750), 4. Unfavorable (-3750 – (-2500) 5. Moderate (-2500 – (-1250), 6. Relatively favorable (> (-1250)		
Ecological Landscape Potential (ELP)		
1. Highest (>20), 2. Relatively high (16-20), 3. Medium (12-16), 4. Low (8-12), 5. Very low (<8), 6. Extremely low ((~0)		
ELP improvement by 2080s		
1. by one category. 2. by categories, 3. by three categories		

Fig. 4. January and July Temperature, Precipitation, Permafrost border, Climate severity, and Ecological Landscape Potential in current and future climates (rcp 2.6 and rcp 8.5) by the 2080s.

Results and Conclusions.

- 20 GCM-based ensemble means of January and July temperature and precipitation indicate both temperature and rainfall increase over Asian Russia: 3.4°C (rcp 2.6) – 9.1°C (rcp 8.5) in mid-winter; 1.9°C (rcp 2.6) – 5.7°C (rcp 8.5) in mid-summer; 60 mm (rcp 2.6) – 140 mm (rcp 8.5).
  As predicted from the CMIP5 models, Asian Russia would be characterized by milder and more moderate climates with less permafrost coverage by the 2080s.
- The prevailing categories of current climate (extreme severe, severe, and unfavorable) would change for moderate, relatively favorable categories in future climate. However, permafrost as an inertial system would retreat slower due to its reaction to temperature increase as in power ½.
- The correlation between Ecological Landscape Potential (ELP) and the population density shows that the improvement in EPL by one category favors an increase in the population by 3-fold (Isachenko, 2003). We found that ELP would increase from 1 (rcp 2.6) to 2 (rcp 8.5) categories over most Asian Russia that may lead to a 5-7-fold improved capacity of the territory for the humans and may be attractive and followed by migrations during the century.

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