BIOSPHERIC CONTEXT OF SIBERIAN DEVELOPMENT

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The Soviet planners are sometimes criticized for distorting economic geography by allocating cities, factories and universities in Siberia that formed a burden for the market economy of the modern Russia. Such criticism leads to conclusion that Russia must contract its economic geography, concentrate its population, improve connection between cities, and even move them to warmer, more productive places[1]. Here, we evaluate the pathways for Siberian development in the biospheric context: take into account human appropriation of Earth's net primary productivity[2,3,4,5] and introduce a threshold beyond which sustainable development is not achievable.

The total terrestrial net primary production (NPP) is estimated to be 60 PgC y^{-1}. This number shows biosphere potential to supply primary food energy source for all non-autotrophic species including humans. Human appropriation of terrestrial net primary production is assumed to be from 8 to 15 PgC y^{-1} in total[3]– that is, 1-2 tC $person^{-1}$ y^{-1}. As it can be seen from the Figure 1, there are many places in the world where NPP per capita is less than 2.5 tC $person^{-1}$ y^{-1}. One may only strive for a *survivable* development[6] there for at this level of NPP per capita nothing or little remains for other non-autotrophic species. The world average level of NPP per capita, about 10 tC $person^{-1}$ y^{-1}, means that humans appropriate approximately 20% of NPP. Even in the well-populated regions of Siberia, NPP per capita exceeds the average level several times suggesting the window of opportunity for sustainable development.

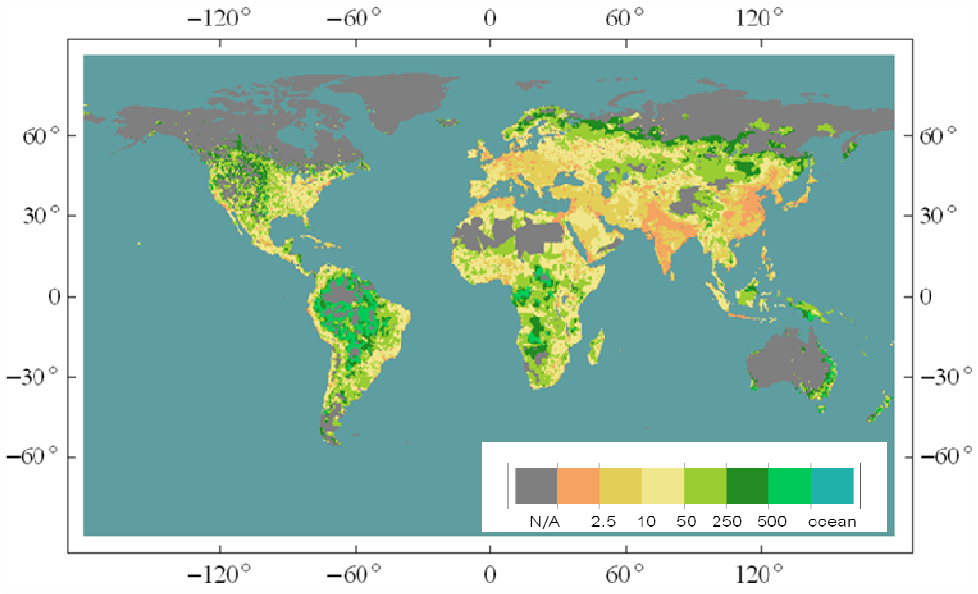

Figure 1.The global pattern of NPP per capita, in tC $person^{-1}$ y^{-1}

Taking into account the ecological footprint[7] of a city – the area of productive land required for supporting its activity in a sustainable way – implies certain limits for concentrating population on low-productive lands. The Figure 2 shows that ecological footprints increase 10 times at low-productive lands as compared to high-productive lands. This also implies increase in sustainable distance between cities. The distance between cities in the north of Siberia should be double that in the south of Siberia.

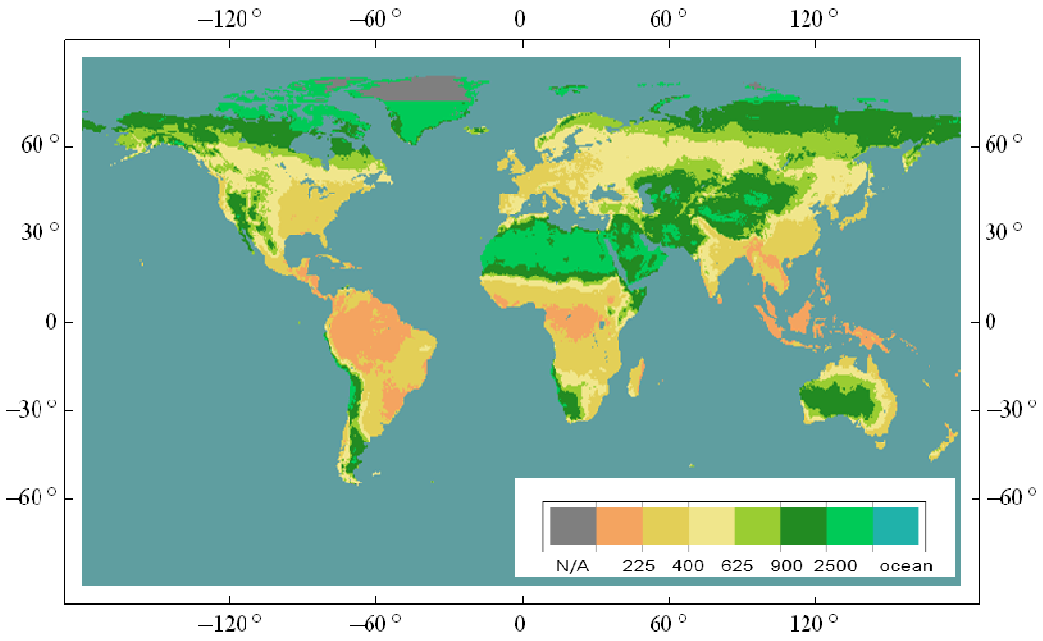

Figure 2.The global pattern of the urban footprint index (UFI) , in km^{-2} – the area of productive land required for supporting sustainable development of a locality with population of 20 000. NB: UFI may be also expressed in terms of distance between the cities (e.g., by taking the square root of the footprint area).

The distance between cities is a serious impediment to economic development. Spreading population centers over vast distances, especially in Siberia, looks like a great error of Soviet planners. Our analysis, however, shows that this pattern of population distribution may stem from the low land productivity. To ensure sustainable development, the average distance between cities in Russia should be longer than that in USA. Moreover, the dominant pattern of NPP per capita (Figure 1) in Russia does not differ from that in USA, France and Spain: red dots (spots of survivable development) are uniformly scattered over the yellow background (zone of sustainable development).

In short words, Soviet planners had a difficult choice -- to concentrate people at the level of survivable development, or to keep them in the cold. They chose the latter. That might be a mistake, but not an obvious one. Nobody knew that people were not born in Siberia could not adapt to its climate. The limits for human adaption to the cold[8] were realized only in 1980s.

The economic collapse occurred in 1990s highlighted the ethnographic aspect of the problem. Despite the lack of any incentives for staying in the areas of climatic discomfort, “siberyaki” did not migrate to warmer, more

productive places. The migration flows of 1920-1980 seemingly formed a vigorous ethnos which is well-adapted to specific conditions of Siberia[9] and numbers 20 millions.

What can the sibiryaky expect in the 21st century? Global warming and the growth of the world's population form conditions for the accelerated development of Siberia and further migration waves. Hence, Russian economists face the same challenge as Soviet planners: which criteria to use in evaluating the directions for Siberian development.

Some economists believe that the ecological sustainability of a city is the factor that declines in importance at a time of economic globalization. Since urban population depends largely on global markets, the state of the global markets is more important for city growth than the state of surrounding ecosystems. This forms an impression that ecological limits to city growth are disappearing.

However, this is a false impression. The limits are not disappearing. In order to see them we need to answer the question: "How much of the biosphere's productivity we can appropriate before the planetary systems begin to break down?" [5]. It is unlikely that the global markets can resist the break down of the planetary systems. We already appropriate 20% of the biosphere's productivity. How far away are we now from the threshold at which the global markets begin to break down?

The role of local ecological limits can be seen at a time of an economic collapse. The fact that siberyaki survived the crisis of 1990s allows us to assume that it would be more easy for them to adapt to anticipated global changes, if the population density would be in balance with the natural productivity of Siberian ecosystems – that is, if the development of Siberia would pursue sustainability goals.

Methods. The gridded data on NPP per capita were derived from gridded data on the normative productivity of the global vegetation (version 1.13)[10] and gridded data on the population of the world[11] at half-degree resolution. The gridded data on UFI were calculated from the gridded data on normative productivity mentioned above using the equation: $UFI = n \times s/NPP$, where n=20 000 is the minimal population of a locality to be named as city according to UN recommendation, s=10 tC person^{-1} y^{-1} is sustainable level of NPP per capita.

NB. This is an author's write-up of research results (that is, preprint). Some of the results appeared in the *EKO*, All-Russian economic journal (http://econom.nsc.ru/ECO/INDEX.htm), which should be cited as follows.

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