Climate change dynamics and its impact on productivity of the Russian forest ecosystems

T. Shulgina[1,2], D. Schepaschenko[3], A. Shvidenko[3], E. Gordov[1,2]

[1]Institute of Monitoring of Climatic and Ecological Systems SB RAS
[2]Siberian Center for Environmental Research and Training, Tomsk, Russian Federation
[3]Forestry Program, International Institute for Applied Systems Analysis, Vienna, Austria

Introduction

It is well known that climate influences the biological processes of various environmental ecosystems and on the forest productivity in particular [1]. At present there are various methods for forest productivity and carbon balance measuring of forest ecosystems such as empirical approach based on the local measurements. But the main weakness of these methods is using of climatic data averaged over long time-periods.

The main purpose of this work is development of the system for assessment of climatic indicators impact on the main components of carbon budget of Russian forest ecosystems for each year. First of all, it is necessary to study the climate change dynamic over the recent decades, and then to assess the impact of the change on the carbon budget of the forest ecosystems.

Problem statement

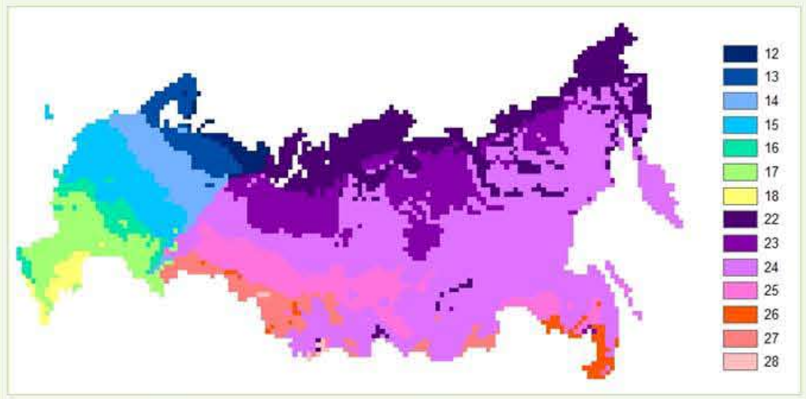
Task 1. Development of climatic indicators database:
- Average, maximum and minimum annual temperature;
- Annual precipitation;
- Amount of days, sum of degree day temperature and precipitation for growth seasons with daily mean temperature greater than 0°, 5°, 10° C;
- Hydro-thermal coefficient by Seljaninov for growth seasons with daily mean temperature greater than 0°, 5°, 10° C;

Task 2. Climatic correction of components of carbon cycle:
- Net primary production;

Data

- ECMWF atmospheric model with 0.5°x0.5° resolution averaged by 10 days period for the time range from 1974 to 2006.

Map of bioclimatic zones of Russian Federation:



Regions: 1 – European part, 2 – Asian part;
Bioclimatic zones: 2 – tundra, 3 – forest-tundra, 4 – middle taiga, 5 – southern taiga, 6 – temperate forest zone, 7 – steppe zone, 8 – semi-desert zone.

Climatic indicators

Average temperature for growth season with daily mean temperature > 5°C

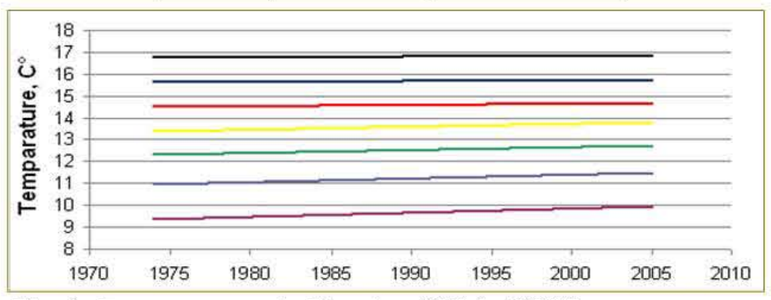


Fig.1. European part, Russia, 1974 - 2005

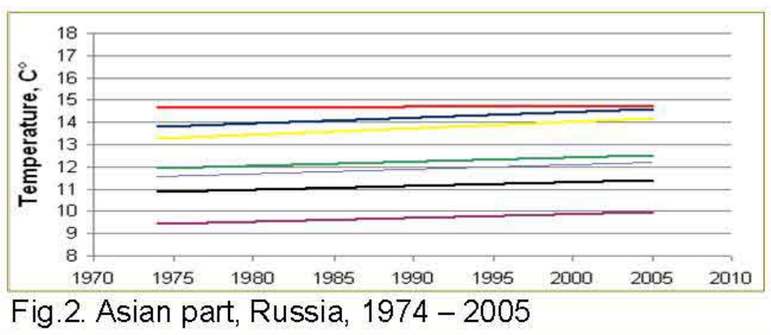


Fig.2. Asian part, Russia, 1974 – 2005

Precipitation for growth season with daily mean temperature > 5°C

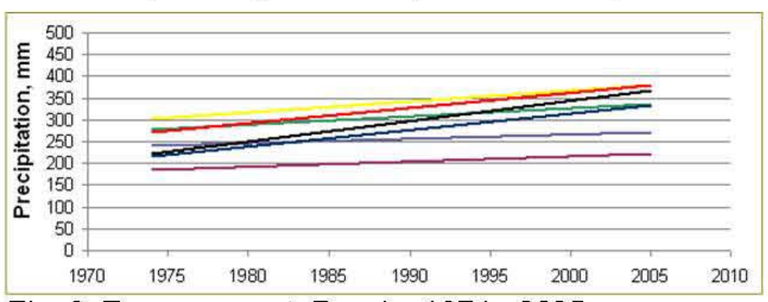


Fig. 3. European part, Russia, 1974 - 2005

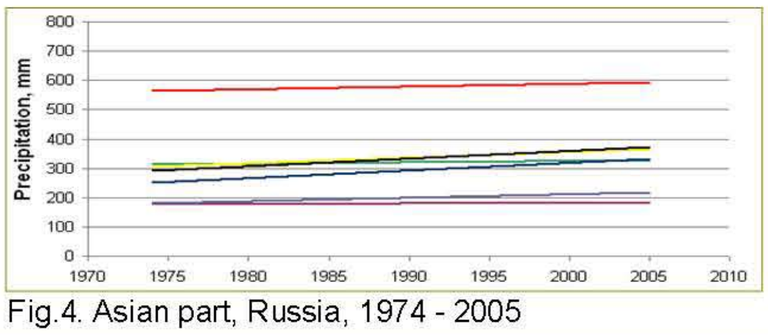


Fig.4. Asian part, Russia, 1974 - 2005

Amount of days for growth season with daily mean temperature > 5°C

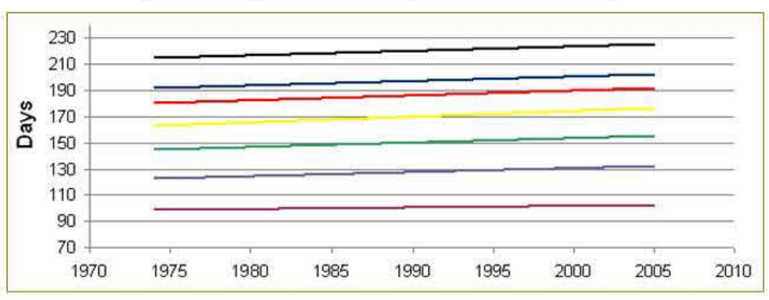


Fig. 5. European part, Russia, 1974 - 2005

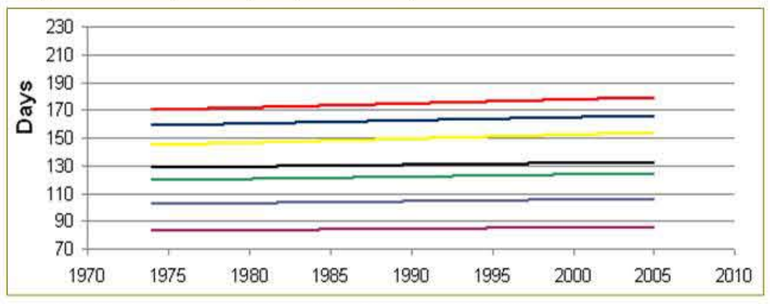


Fig.6. Asian part, Russia, 1974 - 2005

Tundra — Forest-tundra — Middle taiga — Southern taiga — Zone of temperate fores — Steppe zone — Semi-desert zone

Correction of carbon cycle components

At present various methods of forest carbon accounting exist. Net primary production can depend on atmosphere temperature, CO2 concentration in atmosphere and precipitation.

$$NPP_{cor,yr} = NPP_{bas} \cdot f(T) \cdot f([CO_2]) \cdot f(P)$$

Formula of net primary production dependence on temperature is following:

$$f(T) = Q_{10}^{\left(\frac{T_{yr} - \bar{T}}{10}\right)}, \qquad Q_{10} = 1.7$$

where Q – correction coefficient, usually equals 1.7, though in the some paper Q equals 2.

At this point of work the correction of net primary production dependence only on atmosphere temperature has been done.

As an example, results of correction of net primary production for 1998 year are presented (Fig.7-9). The increase equals approximately 70 g/m2, which is about 20% of basic one.

Also these correction values have been calculated for several years and averaged for 7 bioclimatic zones. Calculation results are presented in the tables 1-2. Obtained results show change of net primary production in the individual years. It can be noted the results obtained for recent years are considerably less than ones for 1998, as well as they are significantly different from net primary production averaged over 40 years. Also increase of net primary production in the south taiga on the whole territory of Russia is observed.

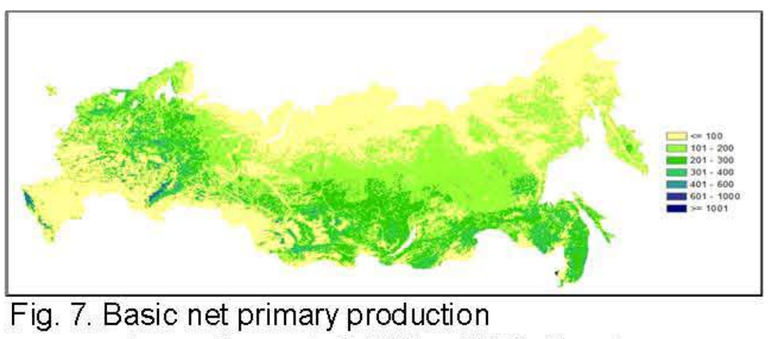


Fig. 7. Basic net primary production averaged over the period 1961 – 2003, Russia

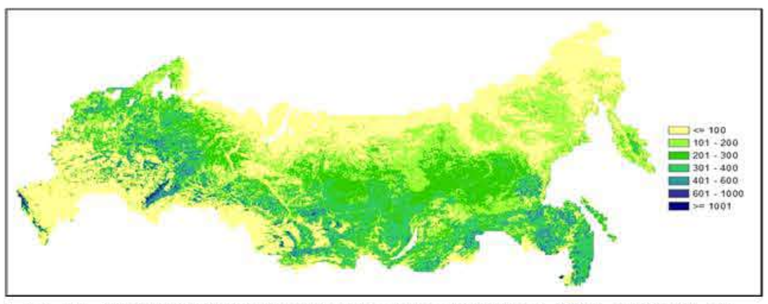


Fig. 8. Net primary production corrected dependent on temperature, Russian Federation, 1998

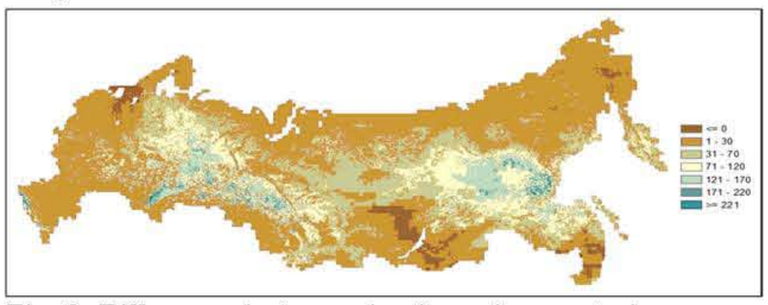


Fig. 9. Difference between basic and corrected net primary production, Russian Federation, 1998

European part	T	F-T	MT	ST	ZTF	SZ	SDZ
NPP BASIC	221	261	444	349	594	609	584
NPP cor 1976	238	262	427	349	570	586	568
NPP cor 1987	214	250	445	351	613	633	589
NPP cor 1998	235	273	458	372	642	656	630
NPP cor 2003	234	268	445	355	579	595	571
NPP cor 2004	238	275	450	361	595	606	565
NPP cor 2005	215	271	447	361	599	628	592

Tab.1. Corrected net primary production for individual years for each bioclimatic zones, European part, Russia

Asian part	T	F-T	MT	ST	ZTF	SZ	SDZ
NPP BASIC	161	188	264	354	433	404	322
NPP cor 1976	159	183	258	353	423	410	314
NPP cor 1987	162	188	262	353	431	412	320
NPP cor 1998	167	202	283	379	434	427	352
NPP cor 2003	164	191	265	369	425	417	310
NPP cor 2004	156	180	260	370	433	438	314
NPP cor 2005	161	190	267	363	440	412	329

Tab.2. Corrected net primary production for individual years for each bioclimatic zones, Asian part, Russia

Conclusion

There are two main results of the work performed.

1. Trends of major climatic indicators have been calculated and their analysis has been done.
2. Introduction of actual climatic indicators in empirical models of basic components of forest carbon accounting was realized. It allowed us to present more correct situation of net primary production change in time.

Plans

1. To present trends of climatic characteristics in spatial scale;
2. To assess the change of net primary production depending on CO2 concentration and precipitation;
3. To correct other components of carbon cycle (heterotrophic respiration).

References:

1. Steven G. McNulty, John D. Aber Climate change impact on Forest ecosystems. News letter of the US National Assessment of the Potential Consequences of Climate Variability and Change
2. World's Largest Atchieve of Climatic Data, National Climatic Data Center http://www.ncdc.noaa.gov/oa/ncdc.html
3. World Data Center for Meteorology, Ashevile http://www.ncdc.noaa.gov/oa/wdc/index.php
4. European Center for Medium-Range Weather Forecast (ECMWF) http://agrifish.jrc.it/marsfood/ecmwf.htm
5. Zukert N. Climatic map and distribution of Russian vegetative zones. Lesovedenie. 2006, № 1, p. 14 – 21