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Dynamics and projection of carbon deposition function of Russian forests in relation to Climate Change problem

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Abstract

Retrospective calculation of the Russian forests' carbon balance for the period of 1999-2010 was accomplished using ROBUL system, which is a component of the Russian National GHG Cadaster. The forest carbon projection was developed based on the Canadian model CBM-CFS. Official forest statistics was used as a data source. The results are structured for the regions of Russia.

At the beginning of 1990-ies forests accumulated in their biomass up to 70 mln tons of carbon annually. In the middle of 1990-ies carbon stock increased and its average level has reached 250 mln C per year. The key increase factor was decrease in logging because of political and socio-economic changes in Russia. Climate change and extreme weather resulted in more forest fires in the Southern Siberia and the Russian Far East. In the years of the extreme forest fires (1998, 2003, 2010) the carbon stock decreased down to 50-100 mln tonns. However, the influence of forest fires on the carbon stock is less compared to logging. However, due to aging of forests their potential for carbon accumulation will decrease. At the current rate of forest fires and logging by the middle of 2030-ies the carbon stock of Russian forests will decrease for 50%. Intensive logging may also result into decrease of the carbon stock. Improvement of Russian forest management to increase capacity of forests to accumulate carbon requires development and implementation of large scale measures which have to be supported by international / Russian funding and political will.

One of the most effective measures could be effective prevention and suppression of forest fires. Conservation measures have to be applied to preserve intact forest landscapes. One of the examples could be efforts accomplished by WWF to preserve intact forest landscapes in the Bikin River watershed (the Russian Far East) from logging for alternative traditional livelihoods.

Keywords: forest carbon, carbon stock, carbon balance, boreal forests, forest fire, alternative livelihood, non-timber forest product

Introduction, scope and main objectives

Anthropogenic emissions of greenhouse gases from fossil fuel combustion, agricultural production and land use change are the key driver behind the current global warming. UN Framework Convention on Climate Change (UNFCCC) specifies anthropogenic greenhouse gases (GHG) emissions control as a means to counter global warming. At present, the negotiation process is under way to develop a new global climate agreement beyond 2020. It is very likely, that the new agreement will require more stringent greenhouse gas emission control targets from the developed economies. Therefore, forest management may become increasingly important as a tool for meeting prospective national commitments related to greenhouse gas emissions control. The purposes of this article include a retrospective evaluation of the carbon balance dynamics in Russia's forests; description of the key factors behind this dynamics; and development of carbon balance projections with an account of potential dynamics of the key factors.

The retrospective evaluation was accomplished using a system for regional assessment of forest carbon budget (ROBUL) (Zamolodchikov et al., 2011, 2013a, 2013b). For a number of years this system has been used for the forestry sector reporting in Russian National GHG Cadaster. National reports on GHG sinks and emissions undergo regular and thorough audits by UNFCCC experts, and the audit results confirm that ROBUL complies with the recommendations provided in the Guidance by the International Panel on Climate Change (IPCC, 2003).

CBM-CFS3 model was used for Russian forests carbon balance projections. Development of this model was launched in the early 1990's with support provided by the Canadian Forest Service. Assessments obtained using this model are used for Canada's reporting to the UNFCCC and in decision-making related to carbon balance management in the national forests. The calculation procedures and reporting formats of the model are recognized as complying with the IPCC recommendations (Kurz et al., 2009).

Methodology / approach

Information from the Russian State Forest Registry (SFR) is used as input data in the ROBUL. Data series formation procedures, specific aspects of presenting account information as determined by the dvelopment of the national system of forest management and dynamics of forest fund areas were described in detail in earlier publications (Zamolodchikov et al., 2011). The estimates presented in this article refer to forested areas that have increased in size from 758.7 million to 787.1 million hectares from 1988 to 2008.

A complete set of ROBUL equations and parameters are provided in (Zamolodchikov et al., 2011, 2013a, 2013b). The initial stage of calculations using the ROBUL methodology includes estimation of carbon stored in the forest stand by age groups and dominant species. Assessments of carbon stored in phytomass and wood debris pools build on the growing stock data obtained from the SFR and the sets of conversion coefficients; estimations of carbon stored in leaf litter and soil pools rely on the size of areas occupied by forest forming species obtained from the SFR and on the typical average values. Assessments of carbon stores by forest stand age groups allow for the computation of carbon absorption by any pool using age group intervals.

Information on the forest area annually affected by disturbances (logging, forest fires, or other events that cause forest stands to die) and on the carbon retained by various categories of forest vegetation helps assess annual carbon loss. Annual scale of destructive disturbances can be estimated using one of the two methods (Zamolodchikov et al., 2013a, 2013b): one based on the total size of burned areas and clear cuts and time needed for filling up with vegetation, the other based on the annual rates of burned areas and the scale of logging. The first option only relies on the information obtained from the SFR for computation. The second method requires additional information, namely, the area of clear cuts and burned forested land for each year of the period in question. The ROBUL uncertainty estimate is based on the standard error of the mean of equations parameters and rules of error transformation. Selected uncertainty (standard error of the mean) is correspondent to 68% confidence interval. Carbon budget calculations were accomplished for the 1988-2009 period by regions of the Russian Federation.

The CBM-CFS3 model is a software system with a user interface (Kull et al., 2011). We have accomplished preliminary adaptation of the CBM-CFS3 model to the conditions of the Russian Federation, namely, to the forests of Vologodskaya Oblast, the Far East, and the North Caucasus (Bakaeva et al., 2009, Zamolodchikov et al., 2008). The results obtained through model runs were verified by comparing them against the results obtained using ROBUL for the same regions. A good reproducibility of the results obtained using ROBUL and CBM-CFS3 model, both for the pools and for a number of carbon flows, allowed for a conclusion that the CBM-CFS3 model can be applied to Russia's forests.

Logging and forest fires are the most important disturbances observed in the Russian forests. In the late 1980's, annual clear cut area amounted to nearly 2 million hectares (Fig. 1). Social and economic reforms of the early 1990's drastically reduced the level of logging (in 1998, the minimum of 0.5 ha was reported). Since the mid-2000's, this level has been eventually growing (to reach 1.2 million ha in 2009).

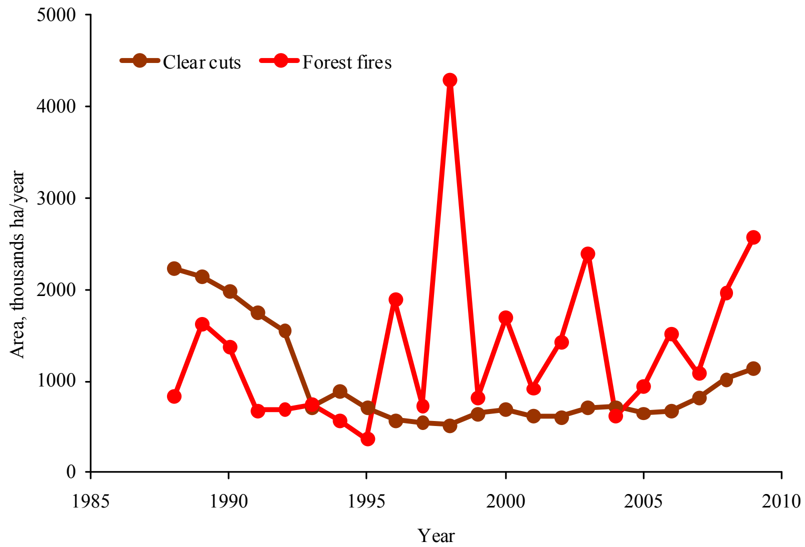

Fig. 1: Dynamics of key disturbances in Russian forests

While officially reported clear cut area data are quite reliable and can be directly used in ROBUL computations, the same is not true for forest fire statistics. Since the early 2000's, some studies have been attempting to estimate areas affected by forest fires in Russia (Conard et al., 2002, Soja et al., 2004) using the Earth remote sensing results. These estimates exceed the official fire statistics by several times.

Let us compare forest fire area estimate series (see Fig. 1) that build on the archive of statistical materials against the values obtained using the Information forest fire remote monitoring system of the Federal Forestry Agency (ISRM). According to the statistics, fire area in 2002-2009 averaged to only 34.3% of the relevant values in ISRM. Such discrepancies between the official and remote monitoring data related to forest fires in Russia are a serious problem for the carbon balance development. Forest fire statistics are used in ROBUL with an assumption that all fires are destructive, i.e. cause forest stands to die. Actual forest fires area is approximately 3 times the value reported in the statistics, yet only one third of them are destructive. Therefore, official statistical value can, indeed, be used as a rough estimate of destructive forest fire area.

Results

Fig. 2 shows the dynamics of carbon budget of Russian forests with carbon loss assessed based on the size of clear cuts and burned areas. It is to be recalled, that this estimation option builds only on the information available from the SFR and does not require any additional data on annual clear cuts or forest fires. Absorption is current carbon increments in all pools of the forest ecosystem (phytomass, wood debris, leaf litter, soil layer 0-30 cm). In 1988-2009, it averaged 381±48 mln. t C/year. One can see a certain ascending trend for annual carbon absorption from 353±44 mln. t in 1988 to 397±50 mln. t in 2003 with subsequent stabilization. Carbon loss from forests is more variable, than carbon absorption (Fig. 2). Throughout the 1990's, a carbon loss reduction trend was observed (from 273±26 mln. t in 1988 down to 176±18 mln. t in 2000) with subsequent stabilization in the 2000's at around 170 mln. t C/year. And the reason for that is reduction of harvest area (see Fig. 1). Let us highlight, that calculation of carbon loss based on the size of clear cuts and burned areas smoothes out the interannual variability of carbon loss; therefore, fire impact variations do not show in Fig. 2. In 1988-2009, average annual carbon loss from Russia's forests amounted to 206±20 mln. t, including 86±8 mln. t (41%) from clear cuts and 121±12 mln. t (59%) from forest fires.

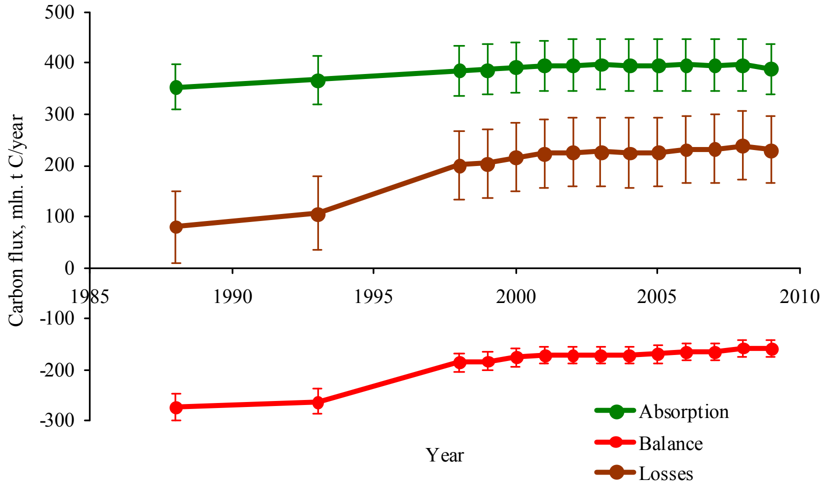

Fig. 2: Carbon absorption, losses, and balance in Russia's forests according to ROBUL with loss estimates based on clear cuts and burned areas

Since carbon absorption by forests is relatively stable, carbon balance trends are determined by carbon loss dynamics (see Fig. 2). In 1988-2009, average sink of atmospheric carbon to Russian forests was 175±69 mln. t C/year. Let us note, that the Russian National GHG Cadaster uses a ROBUL option by which carbon loss calculations build on the size of clear cuts and burned areas, i.e. the one that shows smoothed out carbon loss dynamics.

Fig. 3 shows the results of carbon balance estimation for Russian forests using two methods for carbon loss assessment: based on the size of clear cuts and burned areas (method 1); and based on statistically reported clear cuts and burned areas (method 2). The essential similarity of the results is no surprise. The increase in the carbon sink trend is determined by reduced timber harvest and is obvious in both methods. It is somewhat lagging behind in method 1, because it takes time for reduced timber harvest to show as clear cuts reduction in the SFR.

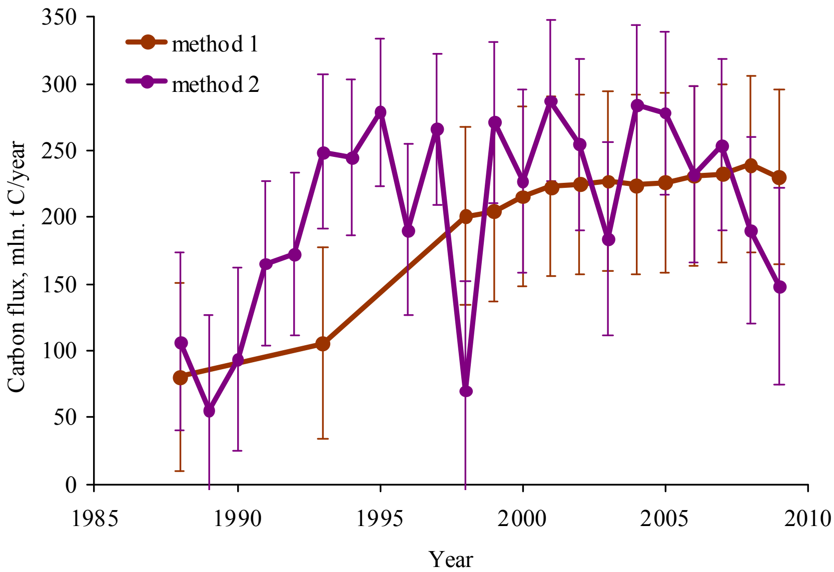

Fig. 3: Carbon balance of Russian forests according to ROBUL with loss estimates based on clear cuts and burned areas (method 1) and statistical data on fires and clear cuts (method 2)

Assessments using method 2 suggest that carbon sink to Russian forests in 1988-2009 averaged 205±65 mln. t per year, varying between 56±71 mln. t (in 1989) and 287±60 mln. t (in 2001). Average carbon balance discrepancies over the period, if estimated using method 1 (clear cuts and burned areas) or method 2 (statistical data), are within the uncertainty range. A higher sink value in method 2 is determined by an earlier manifestation of the absorption increase trend (see Fig. 3).

While developing a prospective evaluation of the carbon balance of Russian forests the authors focused on the timber harvest factor. Four scenarios of forest use were developed. Scenario 1 (business-as-usual) suggests that average harvest levels of 1999-2008 will be maintained. In this scenario, forest use, reforestation, and forest fire protection levels will remain unchanged to and including 2050. Scenarios 2 and 3 were developed building on the innovation scenario of the Forest sector development strategy for the Russian Federation to 2020 (hereinafter referred to as the Strategy), that suggests 57% increase in timber harvest by 2020, i.e. by 5.7% per year. Since the Strategy does not specify, at what rate and up to what level the harvest scale will be growing in 2021-2050, the following assumptions were made for that period. In Scenario 2 (brief moderate growth), forest use level does not increase after 2020, but stabilizes at 157% of the current value. In Scenario 3, (sustained moderate growth), annual harvest levels will keep increasing beyond 2020 by 5.7%, until they have reached allowable cuts volume in 2047 (314% of the current level). In addition, a hypothetical Scenario 4 (fast growth) was considered, which suggests the highest harvest growth rates to reach the allowable cuts volume as early as in 2020.

Forest carbon balance is a dynamic parameter that depends, inter alia, on the forest stands age structure. Therefore, it is important to first consider the baseline projection that describes forest carbon budget in the absence of forest use change in compliance with scenario 1. This projection suggests (Fig. 4), that annual carbon sink to Russian forests goes down from the current 250-270 Mt C (which is close to the quoted above estimates made using ROBUL) to 100 Mt c by 2050.

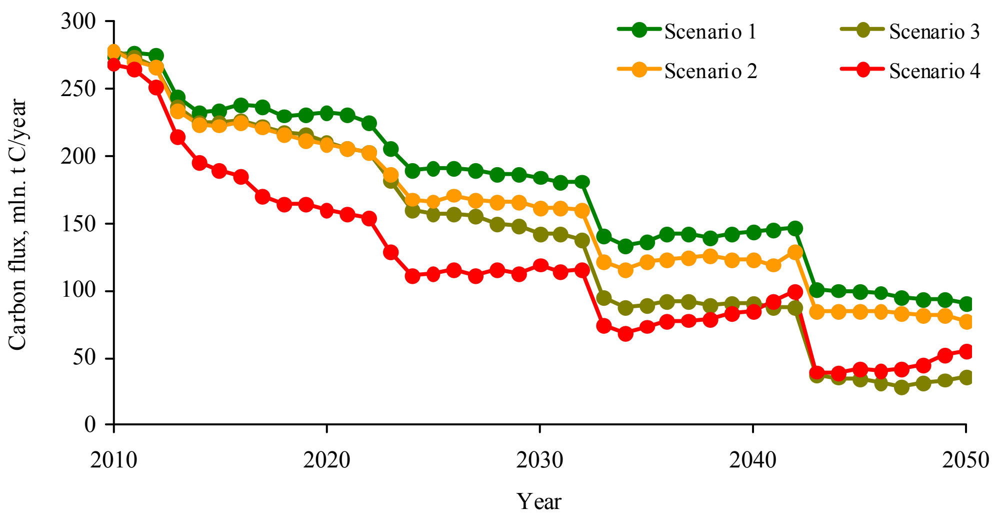

Fig. 4: Forest carbon balance projection for Russia using the CBM-CFS3 model in accordance with the following forest use scenarios: 1 – business-as-usual; 2 – brief moderate growth; 3 – sustained moderate growth; 4 – fast growth

In order to explain the discovered trend let us consider mechanisms that govern the carbon balance of forest lands in more detail. The disturbance level in Russian forests has substantially changed over the recent 20 years. In the early 1990's, annual timber harvest decreased from 350 mln. m^3 to 150 mln. m^3 driven by social and economic reforms, and has been maintained at about that same level to this day. This reduction is the basic factor behind the increase in carbon sink to Russian managed forests to the currently observed 200-250 Mt C absorption values (see Fig. 3). However, Russia's forests are presently adapting to the current timber harvest levels and form a new sustainable age structure with an increased share of the older-aged group. All this eventually leads to the reduction in carbon absorption by forests and edging toward the zero balance state. Projections using the CBM-CFS3 model show, that the stimulating effect of timber harvest reduction on the carbon sink is nearly waning, and by 2050 carbon absorption by Russian forests will approach levels typical of the late 1980's.

Scenarios that suggest enhanced forest use negatively impact forest carbon balance in Russia (Fig. 4). Scenario 2 leads to an insignificant reduction in carbon sequestration in the middle of the projection period. Scenario 3 does not suggest any sizable impacts on the carbon budget in the first half of the projection period, yet its effect is enhanced thereafter leading to the most substantial reduction in carbon sink in 2050. Scenario 4 suggests a dramatic reduction in carbon sequestration in the beginning of the projection period; however, in the end carbon sink is larger, than in Scenario 3.

Discussion

One possible method for independent verification of results is to see how these results correlate with the global data. According to the findings by the Global Carbon Project (Le Quere et al., 2013), global carbon sink to the aboveground ecosystems was 2.4 bln. t per year in 2000-2009. This estimate was obtained based on the balance of anthropogenic emissions, dynamics of atmospheric CO_2 stock, and absorption by the oceans. This Project also provides an alternative assessment of carbon sink to terrestrial ecosystems (2.6 bln. t C/year) obtained using a set of nine Dynamic Global Vegetation Models (DGVM). Therefore, there is a good correlation between the field measured data (balance) and the model results (DGVM). For Russia, a similar set of eight DGVM suggested 199 mln. t annual carbon sink in 1990-2008 (Dolman et al., 2012). According to ROBUL, annual carbon sink to Russian forests equaled 220±63 mln. t over the same period, overlapping with the DGVM assessment within the uncertainty ranges.

Projection results of our works look pessimistic in terms of forest use for atmospheric carbon absorption. Even with forest use maintained at a low level, carbon sink to Russian forests will be decreasing, whereas an increase in timber harvest would inevitably result in accelerated reduction of carbon sink. Therefore, if a high level of carbon sink to Russian forests is to be maintained, large-scale targeted silvicultural measures are required, for example, enhanced forest fire protection, altered logging technologies, modified approaches to artificial reforestation.

One of the good examples of large scale activities to avoid carbon losses in forests is Bikin Climate Project, implemented since 2009 by the WWF-Russia and WWF-Germany, in partnership with the indigenous peoples' enterprise "Tiger", a cooperation of the Udege, a local indigenous tribe living in the Bikin area. The Bikin valley forests are the last tract of virgin temperate coniferous-broadleaf forests in the Far East of Russia, and the largest undisturbed temperate mixed forest massive in the Northern Hemisphere. They are home to the Udege and Nanai indigenous peoples, as well as the Amur tiger. The project was funded by the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU) through the German Development Bank (KfW) in the framework of the International Climate Initiative of the German Government.

In 2009 the Climate Project, 461 154 hectares of the Bikin nut-harvesting zone and riparian forest buffer in the middle reaches of the river were leased to the indigenous peoples' enterprise "Tiger" for 49 years for the purpose of non-timber forest products collection (pine nuts, Siberian ginseng, ferns, mushrooms, berries, etc.). That was a basis for climate additionally of the project which used free of logging scenario. It is estimated that the conservation of biomass in the virgin forests in the Bikin valley annually prevents the emission of 183 000 tons of CO_2 (or 0.5 mln. tons CO_2 from 2009 to 2012). That climate effect were realized through the system of certification and quality assurance of the Kyoto Protocol. In 2013 indigenous peoples' enterprise "Tiger" has received from purchaser British company CF Partners more about 0.4 mln Euros. The funds used by the indigenous Udege commune to implement both environmental protection activities and social. So, total outcome of the project are multifunctional. First it positively affects tiger habitats on protecting it from logging, poaching and fires. Core social aspects of the indigenous commune like electric line repairing and housing development were also partly covered by investments from received climate funds.

The results of the Bikin Project supported the start of a new multicomponent climate project ("CEDAR") in 2011 which is also financially supported by the International Climate Initiative of the German Government. The most important component of the project is to create relevant climate financial scheme and modeling for high conservation value forests under moratorium of FSC certified companies. The results of Bikin climate project and preliminary results of CEDAR climate project shows huge potential for implementing forest climate approaches in temperate and boreal forests with getting multifunctional effects.

Conclusions / outlook

Since 1990, Russian forests have been annually removing from the atmosphere around 220 million tons of carbon and storing it as organic matter. Since the mid-1990'es, the role of forests as a carbon sink has enhanced, primarily due to the decreasing levels of timber harvest. However, this enhancement is temporary: as forests grow older, their carbon sequestration capability goes down. With the current harvest and forest fire protection levels maintained, the amount of carbon sinking to Russian forests will halve by the mid-2030's. With sustainably growing harvest levels this amount will be decreasing even faster. If a high level of carbon sink to Russian forests is to be maintained, large-scale targeted silvicultural measures are required and should be supported by international or domestic sources of funding. Enhanced fire prevention and combat, primarily in the southern regions of Siberia and the Far East, is recognized as having the largest potential in maintaining the role of forests as carbon sinks.

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