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Abstract. Forests are the most important regulator of greenhouse gas balances, being the depositor of most of the carbon in the world. At the same time, forests perform many other functions that are needed both in terms of preserving the integrity of the planet's ecosystem and in the context of human development. Climate change has become a new global challenge, increasingly perceived by society as a whole and a certain part of the scientific and expert community as a source of undoubted danger to the population and material assets accumulated by mankind over the entire period of development. In this paper, we aim to review the studies conducted to date on the problem of ecological end economic modelling of the forestry considering both climatic and institutional factors of its development. The main outcome of our research is the concept of a future mathematical model of imitational type that will help to deeply understand the interactions between economy and ecology of the Russian forestry.

Keywords: forest economics, climate change, ecological and economic modelling, Russian forest sector, carbon balance, institutions

1. Introduction

Forests play an important role in the global carbon cycle, providing the bulk of the carbon flow into plant ecosystems, and thus balancing the Earth's climate system. Forests are also important as a provider of ecosystem services to society. International negotiations to limit greenhouse gas emissions require an understanding of the current and potential role of carbon emissions and the carrying capacity of forest ecosystems in both managed and unmanaged forests.

In recent decades, climate change has become a new global challenge, increasingly perceived by society as a whole and a certain part of the scientific and expert community as a source of undoubted danger to the population and material assets accumulated by mankind over the entire period of development.

According to the research conducted by the UN Intergovernmental Panel on Climate Change (IPCC), the twentieth century, namely its second half, was the warmest in the last thousand years. Since the beginning of the last century, the average daily temperature has increased by 0.76±0.19°C [1]. According to the IPCC forecasts based on multi-model analysis, by the end of the XXI century the temperature increase may amount to 5°C. The effects of global warming can affect not only public

welfare, but also the natural environment, which serves as both a human habitat and a resource base for meeting the needs of society.

The carbon budget is one of the most informative indicators reflecting the physiological condition, productivity and vitality of forest ecosystems, as well as the degree of influence of the main factors of the environment and anthropogenic impact on them. Understanding the main mechanisms regulating the processes of accumulation and consumption of carbon by ecosystems is the theoretical basis for the management of the carbon budget and, therefore, the most important prerequisite for the development of rational strategies for transition to adaptive forestry and the justification of the system of measures to mitigate undesirable climate change by means of forestry. In this sense, the most important element of the global carbon budget is the ecosystems located on the territory of Russia, which is explained by the vast territory of its territory and the richness of its forest reserves (about 21% of the total forest covered area of the Earth).

Global carbon budget research has been intensively conducted throughout the world over the past few decades. Russia's participation in the implementation of the goals of the Paris Agreement on Climate 2015 requires an in-depth analysis of its consequences considering the interests of the country's economic development.

As Russia is the 4th largest emitter of greenhouse gases in the world, the issues of correct assessment of its carbon budget and economic consequences of making decisions in the field of sustainable development management policy are of particular importance in the context of implementation of national security priorities.

2. Hypothesis and method

The main focus of our research is on the Russian Federation whose territory is densely covered with forest and is one of the most important elements of the carbon cycle of the planet. It is here that the largest resource base of the Russian forestry sector is concentrated, whose development prospects are directly related to the dynamics of ecosystems and climate change processes.

We aim to review the studies conducted to date on the problem of ecological end economic modelling of the forestry considering both climatic and institutional factors of its development. The main outcome of our research is the concept of a future mathematical model of imitational type that will help to deeply understand the interactions between economy and ecology of the Russian forestry.

3. Ecological and Economic Modelling of the Forestry: A Literature Review

The intense discussion about the causes of global warming has led to a number of studies to determine the share of supporters of the hypothesis of anthropogenic causes of this phenomenon in the overall pool of experts on climate change. The range of estimates of such a share varies from 90 to 100%, and the latest and most influential work on this issue, which analyzed more than 11,000 relevant articles indexed by the bibliometric database Web of Science, states that the consensus is at least 97% [2, 3].

Modelling of the economic aspects of the forestry activities of individual countries or geographic regions has been carried out by different teams since the 1980s. [4,5]. Four basic models are known to which modern forest sector economic models are methodologically derived: (1) TAMM - North American wood market valuation model [6]; (2) PAPYRUS - North American pulp and paper market model [7]; (3) IIASA GTM - global model of trade in forest products developed by the International Institute for Applied and Systemic Research [8]; and (4) TSM - wood supply model. A series of models have also been developed for selected countries and regions that are derived from the above: France, Norway [9], Finland [10, 11]. The models described above belong to the class of partial economic equilibrium models and do not explicitly accounts for changes in the external geophysical and environmental conditions of changing resource base characteristics.

The influence of climatic factors (solar radiation, air temperature, water) on net primary production growth and other forest productivity indicators has been studied in some detail [12].

Economic studies of forest management issues are necessary for the sustainable development of the industry, which is low-profit compared to other natural resource management sectors [13]. A number

of papers are devoted to the problems of the Russian forest sector, which provide a description and general analysis of key contradictions and structural imbalances in the current stage of the industry development (see, for example, [14–17]).

The problems of interrelation of climate change processes and economic activities of natural resource sectors in Russia have been studied relatively poorly. An important exception in this regard is staging [18]. However, no comprehensive work involving economic and mathematical modeling of this interaction has been carried out, which makes it possible to justify the need for such work.

The most well-known mathematical models of the relationship between economy and climate at the macro level are the DICE models and its regional version RICE [19]. These models are based on the preconditions of neoclassical economic theory of growth and are aimed at maximizing the inter-temporal function of public welfare [20].

Studies of the indirect impact of climate change on the economy without considering the feedback direction are also known, based mainly on econometric estimates and general computed equilibrium models [21–23].

The results of most studies show that, on the forecast horizon of 100 years or more, the main beneficiaries of climate change will be the countries of the northern hemisphere, while the countries of the southern hemisphere will be significantly affected by droughts and floods [24–27].

Of course, the results of the studies cited above, when carried out at the macro level, have a lack of bias due to aggregation errors and inevitable simplifications in modelling individual relationships due to the high degree of complexity and uncertainty of the systems under consideration and their elements. Therefore, it is important to study the local and sub-national (intra-regional) levels.

Important results of this kind have been obtained to identify the relationship between climate change and technical availability of forests on the example of the Tikhvin district of the Leningrad region. It is shown that the duration of the harvesting season in the model area is reduced due to gradual warming [28]. The same reason predetermined the gradual melting of permafrost and the subsequent increase in storms and spring floods in Central Siberia, which is a factor in increasing the flow of alloy wood carried away by the flow of the river [28]. Yenisei in the Arctic Ocean [29, 30].

4. Results and Discussion

Forests are the most important regulator of greenhouse gas balances, being the depositor of most of the carbon in the world. At the same time, forests perform many other functions that are needed both in terms of preserving the integrity of the planet's ecosystem and in the context of human development.

The general logic of the analysis is based on the premise that the forest economy is in a mutual, i.e. two-way relationship with the climate change process. On the one hand, human economic activity leads to significant and rapid changes in the state of forests due to harvesting, which affects the sustainability of ecosystems (biomass reproduction processes, carbon storage, etc.). On the other hand, natural and anthropogenic climate changes are able to influence qualitative and quantitative characteristics of forest resources (species composition, areas of growth, growth rate, impact of forest fires and forest pests, etc.). Thus, the analysis of the problem should consider the diverse nature of interactions between climate change and human activities.

As it is shown above, there are still no complex works on applied economic and mathematical modeling of the processes occurring in a forestry of Russia, that allows to execute statement of such problem. It is necessary to emphasize that such modeling should be carried out with a special attention to the peculiarities of development of institutions of different genesis, which influence the development of the forest complex. It is also important to consider the block related to the dynamics of climate change processes, which have a mutual impact on the development of forestry around the world.

There is a need for a new imitation model of forestry in Russian macro-regions. Such a model should be based on the synthesis of achievements in the development of such regional models. The model should be based on the premise that it is necessary to maximize the public welfare function, which considers not only the direct current economic benefits of society, but also the ecosystem

effects, including those related to climate change. A separate element of the model is the foreign trade block, which accounts for the global price environment for forest products and existing trade flows. The model should be based on the knowledge of the nature of the relationship between economic and environmental indicators obtained at the first stage of work.

The ultimate goal of the simulation model is to predict the development of the Siberian forestry economy under the condition of various assumptions about changes in macroeconomic and macroecological exogenous characteristics, including fire activity and the spread of phytophages. To build such forecasts, a set of different scenario conditions will be formed, which can be considered within the framework of available knowledge about the dynamics of ecosystems, as well as possible options for changing the macroeconomic conditions of the forest sector.

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