Economic assessment of the carbon sequestration potential of plantation forests

A Ivanova

Department of Management and Economics of Entrepreneurship, Voronezh State University of Forestry and Technologies named after G. F. Morozov, 8 Timiryazeva Street, 394087, Voronezh, Russian Federation

E-mail: meetvgltu49@vglta.vrn.ru

Abstract. The goals set by Russia for the implementation of the Paris Agreement on Climate Change Mitigation, taking into account the absorptive capacity of forests, have become an additional incentive for the creation of carbon-saving forest plantations, while the formation of a voluntary carbon market has made it possible to receive income from the sale of carbon from such climate forest projects. However, in the absence of experience in the implementation of such projects in Russia and the long-term return on investment in them, associated with the specifics of forestry and the existing risks of obtaining the final result, it has become an unattractive activity. This problem can be solved by creating carbon-depositing forest plantations using fast-growing seedlings of planting material obtained by innovative biotechnological methods. The study determined the costs of creating 1 hectare of carbon-depositing forest plantations, forecasting the possible additional income from 1 hectare per year from forest plantations for the implementation of net primary production. It is concluded that even with conservative net primary production and low carbon prices, the use of planting material obtained in vitro clonal micropropagation when creating carbon-depositing forest plantations will reduce the payback period of climate forestry projects to 5 years.

1. Introduction
Carbon (C) storage and sequestration in many developing countries must be accompanied by socio-economic improvements. The plantations of forest tree crops can be a potential way to combine climate change mitigation and economic development through carbon sequestration and the supply of wood and non-wood products to simultaneously meet domestic and international market needs [1]. This provision was reflected in the Paris Climate Agreement (December 2015), which replaced the Kyoto Protocol [2].

According to the National Inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not regulated by the Montreal Protocol sector Land use, land-use change, and forestry (LULUCF) [3] compensates for 36.6% of total carbon emissions in other sectors. Under the rules of the United Nations Framework Convention on Climate Change (UNFCCC) [4], countries only report on managed forests, i.e. for those forest areas where economic activity is carried out.

The results of the preliminary research show that at present the most promising country among the countries where it is possible to carry out forest climate projects is Russia. Throughout the entire period 1990-2018 in the LULUCF sector, carbon removals by the controlled forests of the Russian Federation prevailed over emissions (figure 1). In 1990, the net absorption was 204,400,000 tons (t) of
CO₂; in 2018, the sector provided net absorption of greenhouse gases from the atmosphere in the amount of 619,600,000 tons of CO₂ [5].

While embarking on the implementation of the Paris Agreement [2], it is necessary to take into account the experience of work under the Kyoto Protocol. The economic approach to solving the problem of global climate change under the Kyoto Protocol, which was limited to 2012, assumed two mechanisms for reducing the costs associated with the implementation of national obligations under the Kyoto Protocol to the UN Framework Convention: the collection of a “carbon” tax and a system of trading emissions quotas [6].

In 2003, the European Commission, based on the provisions of the United Nations Framework Convention on Climate Change, the Kyoto Protocol and the Marrakesh Agreements, adopted a directive on the organization of a greenhouse gas emissions trading system. In accordance with the European Union (EU) directive 2003/87, it is necessary to first carry out a joint implementation project, then convert the units of assigned amounts into project emission reduction units and only then sell them on the European market [6]. In turn, the Government of the Russian Federation, in order to develop the specified provisions of the Kyoto Protocol, developed and adopted Resolution No. 780 dated September 15, 2011 “On Measures to Implement Article 6 of the Kyoto Protocol to the UN Framework Convention on Climate Change”, designed to regulate the approval and implementation procedure in Russia JI projects (figure 2).

Thus, the preparation of climate forestry projects turned out to be a very time-consuming process, and in the absence of experience, it was also the costliest. The United Nations Framework Convention on Climate Change (UNFCCC) approval process for forest climate projects is very strict. Some of the biggest difficulties are in particular in documenting how much C growing trees will absorb.

In addition to the costs of the project implementation, the applicant bears additional costs for preparing all the necessary special project documentation in accordance with international requirements, conducting all examinations for compliance with international requirements and registering the Joint Implementation Project with the UN in the amount of 178,560-238,010 USD (figure 3).
Figure 2. Process “Procedure for the selection, approval and verification of the project implementation carried out in accordance with Article 6 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change”.

Moreover, the cost implementation is provided for at the initial stage of preparation of special project documentation by the applicant, before the assessment by the operator of carbon units and its
approval by the Coordination Center. It is a limiting factor for sufficiently low-profit forestry activities.

In Russia, about 300 global initiatives have been implemented, developed and adopted for the practical implementation of the UN Framework Convention on Climate Change, and only 2 forest projects approved by the UNFCCC. According to the results of the Report on Monitoring Climate Forest Projects Implemented in accordance with Article 6 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and an independent expert opinion on the verification of the report data for the period from January 1, 2008 to June 30, 2012, it was possible to achieve a reduction in greenhouse gas emissions in the aggregate of 5,075,000 tons of CO₂ equivalent (figure 4) [7,8].

![Figure 3. Cost structure for the preparation of the necessary special project documentation in accordance with the international project requirements carried out in accordance with Article 6 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change.](image)

![Figure 4. Reduction of greenhouse gas emissions by forest climate projects of joint implementation of the Russian Federation, mln t CO₂.](image)

- Preparation of special project documentation in the format approved by the UN, %
- Independent examination for compliance of special project documentation with international requirements, %
- Verification (verification of the correctness of calculation) of emission reduction units before the buyer, %
- Registration of the Joint Implementation Project in the UN, %
The Organization for Economic Co-operation and Development (OECD) estimates the required level of payment for 1 ton of C emissions in the range from 11.7 to 23.4 USD. It turns out, if we consider at an average price of 15 USD per ton of a reduced emission unit, then the Kyoto Protocol brought into the Russian economy in the process of implementing forest climate projects for 2009-2012. about 89,010,000 USD.

The RUSAL pilot climate forestry project currently being implemented within the framework of the Paris Agreement in the period from 2019 to 2024 involves planting 500,000 seedlings on a selected area of 250 hectares (ha) (in the Krasnoyarsk Territory – 120 ha in the Dzerzhinsky forestry and the Irkutsk Region – 125 ha in the Kirovsky forestry), additions and cares. According to the design documentation of the climatic forest project, the cost of 1 ha is 268,717 USD, and the low intensity of achieving the planned average absorption of 5 tons of C per 1 ha per year by young forests, which is achieved only in the 13th year of its implementation, determines the achievement of payback only after 16 years with a projected cost per unit of emission reduction of 46.6 USD/t C.

As a result, the forest climate project has become unattractive for investors due to the high cost of implementing the project and the long-term return on investment associated with the specifics of forestry and the existing risks of obtaining the final result – the implementation of carbon dioxide emission reduction units on the market. Chugunkova A V and Pyzhev A I note that the creation of artificial (plantation) forest plantations has a low ability to significantly change the prospective carbon balance of forests [9]. According to experts, the real return from the creation of such plantations comes only after 10-20 years [10].

However, today innovative biotechnological approaches to the creation of forest carbon-depositing plantations using fast-growing seedlings of planting material (obtaining planting material in vitro), which will actively deposit carbon already in the first years of life, are already known. Therefore, today, at the stage of formation of guidelines in Russia on mitigating the effects of climate change, taking into account the absorptive capacity of forests, it becomes important to assess the costs and economic efficiency of creating climate forest projects in order to determine incentive actions. According to Morkovina S S et al., the development and practical application of innovations is constrained primarily by the lack of information on the economic efficiency of the use of innovative technologies [11].

Thus, this study aims to substantiate the prospects for creating forest climate projects using innovative biotechnological approaches, taking into account the negative experience in similar projects under the Kyoto Protocol and the actively used institutional forms of state financial support used in the EU.

2. Methodology

The assessment of the potential economic efficiency of climatic forest projects for the creation of carbon-depositing forest plantations with planting material obtained by in vitro clonal micropropagation was carried out using the indicator – net present value of income (NPV) per ha. This is a relative indicator that characterizes how income from capital investments cover their costs. The decision on this criterion is made as follows: if NPV > 0, then the climatic forest project is accepted, since the carbon revenues for the project exceed the costs for it; if NPV < 0, then the climate forest project is rejected, since the carbon revenues for the project are less than the estimated costs; if NPV = 0, then the climate forest project is considered neither profitable nor unprofitable.

Forecasting the cash flows of climate forest projects was carried out using methods of economic and mathematical modeling of the possible income from the sale of emission reduction units. The cash flow was modeled in deflated prices, including all cash receipts and expenses associated with the implementation of the climate forest project for the billing period with data aggregation: an inflow equal to the size of cash receipts (sales in value terms) at this step; an outflow equal to the payments at this step; balance equal to the difference between inflow and outflow. Using the methods of technical standardization and modeling of processes, we determined the costs of work on the creation of carbon-depositing forest plantations with planting material of 2 types of tree species obtained by in vitro
clonal micropropagation and characterized by the maximum ability to absorb carbon – birch and poplar.

The calculation of production costs for planning and performing specific volumes of work to create 1 ha of carbon-depositing forest plantations with a planting density of 2,000 plants per 1 ha is made in the form of settlement and technological maps. The calculation and technological maps contain information on the composition of work, the technology of growing planting material of tree species obtained by the method of in vitro clonal micropropagation, norm-forming factors, the required material, financial and labor costs.

3. Results
The production costs of creating carbon-depositing forest plantations with planting material of 2 types of tree species obtained by in vitro clonal micropropagation were determined using a normative approach based on the compilation of computational technological maps (RTC) and the calculation of cost items:

– remuneration of workers directly involved in production;
– equipment maintenance (depreciation);
– purchase of materials and fuel;
– consumed electricity (table 1).

Table 1. Production cost of creating 1 ha of carbon-depositing forest plantations with planting material obtained by in vitro clonal micropropagation.

| Technological process                                      | Costs of creating 1 ha of carbon-depositing poplar forest plantations | Costs of creating 1 ha of carbon-depositing birch forest plantations |
|------------------------------------------------------------|---------------------------------------------------------------------|------------------------------------------------------------------|
| Preparation of a silvicultural area, USD                   | 232.52                                                              | 232.52                                                          |
| Plantation laying, USD                                     | 1,219.36                                                            | 1,303.97                                                        |
| Agrotechnical care of forest cultures 1 year, USD          | 388.22                                                              | 388.22                                                          |
| Agrotechnical care of forest cultures 2 years, USD         | 258.81                                                              | 258.81                                                          |
| Agrotechnical care of forest crops 3 years, USD            | 129.41                                                              | 129.41                                                          |
| TOTAL core costs, USD                                      | 2,228.33                                                            | 2,312.93                                                        |

Murphy R et al. note that estimating the cost of carbon sequestration in forest plantations can guide policy-makers in determining the level of effort needed to achieve this form of reduction in greenhouse gas emissions [12]. According to a comparative analysis, the cost of creating 1 ha of carbon-depositing forest plantations of poplar amounted to 2,228.33 USD, birch – 2,312.93 USD. The stage of plantation creation associated with their establishment is the most costly. As noted by Morkovina S S, the amount of costs at this phase determines the type of planting material and the technology used for planting plants on the forest-cultivated area [13]. Our previous studies have allowed us to establish that the high cost of planting material obtained by clonal micro-multiplication in vitro is associated with the use of high-tech equipment necessary for the organization of regeneration operations and selection of transformants [14].

The summary data on the cost of creating 1 ha of forest plantations with a planting density of 2.0 thousand birch seedlings and 1 ha of forest plantations with a planting density of 2,000 poplar seedlings are calculated and presented by us in figure 5. Plantations, a significant share is allocated to the cost of purchasing raw materials and materials (~50%). While assessing income for the creation of carbon-depositing forest plantations, the intensity of absorption of greenhouse gases was taken into account, which depends on the type of forest plants, their growing conditions and age [10,15].
The analysis of expert estimates of the absorptive capacity of artificial (plantation) forest plantations made it possible to reveal the average annual carbon absorption by the biomass of managed forests, expressed by the most important indicator of productivity – net primary production – (net primary production – NPP) in the amount of 0.95-0.99 tC/ha per year (figure 6). The works carried out by scientists from Russia, Belarus, Serbia and America prove the possibility of increasing the carbon productivity of forest plantations up to 50% or more. The creation of forest crops with a short crop rotation allows an increase in the absorption capacity of carbon by 1.40 tC/ha per year, with natural renewal with the use of assistance measures by 0.99 tC/ha per year, with reconstruction with the subsequent creation of forest crops by 1.28 tC/ha per year [15,16].

The results of studies by West Thales A et al. show that to date, focusing on carbon-saving forest plantations with longer rotations is a more cost-effective strategy for conserving additional carbon stock in forests [17-19]. Churakov B P et al. conducted research on the depositing ability in multi-aged artificial plantations in various forest conditions. Scientists have revealed an increase in the annual average indicator of Net primary production in the first 5 years – 0.05 tC/ha, in the next 5 years 2.16 tC/ha [20].

In determining the price of emission reduction units obtained from 1 ha of carbon-saving forest plantations, we adopted the recommended values published in the report of State and Trends of Carbon Pricing 2020 World Bank [21].
Figure 7. Net discounted income from 1 ha of carbon-depositing forest plantations with birch planting material obtained by in vitro clonal micropropagation.

Figure 8. Net discounted income from 1 ha of carbon-depositing forest plantations with poplar planting material obtained by in vitro clonal micropropagation.
In line with the goals of the Paris Agreement, the Interagency Working Group on Social Cost of Carbon (USA) has estimated a CO₂ cost of at least 40-80 USD per ton by 2020 and 50-100 USD per ton by 2030. The Organization for Economic Co-operation and Development (OECD) today estimates the required level of payment for 1 ton of CO₂ emissions at the level of 35.8 USD and above [21].

Thus, at the cost of creating 1 ha of carbon-saving birch forest plantations of 2,312.9 S, the project’s net present value (NPV) will be 665,273 USD (figure 7), which will provide a payback period for a climate forest project in 11.4 years. The net present value of income (NPV) from 1 ha of creating carbon-saving poplar forest plantations is 740,293 USD, the payback of the climatic forest project will come in 11.1 years (figure 8).

The income from the forest creation traditionally came from the sale of wood. In recent years, with the formation of a voluntary carbon market, it has become possible to receive additional income from the sale of carbon. Even with conservative net primary production indicators and low carbon prices, the use of planting material obtained by in vitro clonal micropropagation in the creation of carbon-depositing forest plantations will reduce the payback period of climatic forest projects by 3-5 years.

Thus, the creation of carbon-saving forest plantations using innovative methods of obtaining planting material in vitro has good prospects for participation in carbon markets with climatic forest reforestation projects in achieving the goals of the Paris Agreement, but infrastructural constraints, as well as social and economic competition with other goals of land use and management and natural disturbances can continue to restrict the implementation of climate forestry projects [22,23].

4. Conclusion
To get the maximum benefits for our country within the framework of the Paris Agreement, taking into account the experience of the Kyoto Protocol in Russia, it is necessary to create conditions for project activities to reduce and absorb greenhouse gas emissions.

The economic incentives play an important role in the success of climate forestry projects, especially in the early stages, as it takes a little over 10 years to generate net present value from carbon-bearing forest plantations. In the EU countries, the initiatives are being actively implemented to finance climate forestry projects at all stages: from the development of project documentation to the practical project implementation. For example, the participation of climate forestry projects in accordance with the UK Woodland Carbon Code guidelines [24] has some costs associated with validation, modification of project data and conversion of assigned amount units to project emission reduction units. However, the applicants can reimburse part of its costs and receive no more than 41,631 USD for the draft plan for forestry in accordance with the UK Forestry Standard under the Woodland Creation Planning Grant.

Once the plan is completed and approved, the applicant can use it to apply for support for the planting of large productive woodlands under the Woodland Carbon Fund in the amount of a one-time payment of 1,387 USD per ha in the 5th year after its successful creation. The scheme offers capital financing for the creation of new productive forests for carbon sequestration and includes the planting of seedlings in a forestry area, a system of agronomic care for woody plants. Thus, within the framework of the EU grant financing system, an applicant for the development of project documentation and the practical implementation of a climate forest project can receive from 55,508 USD. Since the inception of the UK Woodland Carbon Code, 250 forest climate projects have been approved with an area of 16,200 ha, with an expected carbon sequestration of 3,400,000 tons of CO₂.

Thus, in the formation of guidelines for the implementation of climate forestry projects that will make possible the turnover of carbon units, it becomes important to simplify the procedure for their preparation, since the need to comply with a number of requirements significantly affects their cost, which the developers cannot afford to pay. This became at one time one of the obstacles to the mass implementation of forest projects in the Kyoto period of 2008-2012, attracting investments in this industry.
References

[1] Kongsager R, Napier J and Mertz O 2013 The carbon sequestration potential of tree crop plantations. *Mitig. Adapt. Strateg. Glob. Chang.* 18(8) 1197 doi: 10.1007/ s11027-012-9417-z

[2] Paris Agreement 2015 United Nations treaty collection, available at: https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en

[3] Greenhouse Gas Emission Statistics – Emission Inventories Eurostat statistics explained, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Greenhouse_gas_emission_statistics_-_emission_inventories

[4] Kyoto Protocol 1997 to the United Nations framework convention on climate change (Kyoto, Japan), available at: https://unfccc.int/resource/docs/convkp/kpeng.pdf

[5] Directive 2003/87/EC of the European Parliament and of the Council 2003 Establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (Text with EEA relevance), available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32003L0087

[6] Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) 2020 National report on the inventory of anthropogenic emissions by sources and by sinks removals of greenhouse gases not controlled by the Montreal Protocol for the 1990–2020 years (Moscow, Russia), available at: http://www.igce.ru/performance/publishing/reports/>

[7] Autonomous Non-Profit Organization Center for Environmental Innovation 2012 Greenhouse gas emission reduction monitoring report, available at: http://www.carbonunitsregistry.ru/reports/Carbon%20sequestration_Monitoring%20report_01.08.2008-30.06.2012_rus.pdf

[8] Greenhouse Gas Emission Reduction Monitoring Report Joint implementation project Bikin Tiger carbon project permanent protection of otherwise logged Bikin Forest, in Primorye Russia, available at: http://www.carbonunitsregistry.ru/reports/Bikin_Determination_eng.pdf

[9] Chugunkova A V and Pyzhev A I 2020 Impacts of global climate change on duration of logging season in siberian boreal forests. *Forests* 11 7 doi: 10.3390/f11070756

[10] Chugunkova A V 2020 Modeling of logging industry dynamics under the global climate change: The evidence from Siberian Regions. *Journal of Siberian Federal University. Humanities and Social Sciences* 13 11 doi: 13 11 10.17516/1997-1370-0691

[11] Morkovina S S, Panyavina E A, Isakov I Yu and Altunina L K 2019 Functional-cost analysis: application of the technique in the production of forest seedlings in vitro. *International Business Information Management Association Conference* (Madrid: IBIMA Publishing) p 546

[12] Murphy R, Gross M and Jaccard M 2018 Use of revealed preference data to estimate the costs of forest carbon sequestration in Canada. *For. Policy Econ.* 97 41 doi: 10.1016/j.forpol.2018.06.008

[13] Morkovina S, Kunickaya O and Dolmatova L 2021 Comparative analysis of economic aspects of growing seedlings with closed and open root systems: The experience of Russia. *Asian J. Water Environ. Pollut.* 18 2 doi: 10.3233/AJW210015

[14] Ivanova A V and Malitskaya V B 2019 The economic aspect of new ways of obtaining innovative forest biotechnology products. *IOP Conf. Ser.: Earth Environ. Sci.* 392 012023 doi: 10.1088/1755-1315/392/1/012023

[15] Karelin D V, Tel’nova N O and Zamolodchikov D G 2020 The effect of tree mortality on CO₂ fluxes in an old-growth spruce forest. *Eur. J. For. Res.* 140(3) 1 doi:10.1007/s10342-020-01330-3

[16] Filipchuk A, Moiseev B, Malysheva N and Strakhov V 2018 Russian forests: A new approach to the assessment of carbon stocks and sequestration capacity. *Environ. Dev.* 26 68 doi:10.1016/j.envdev.2018.03.002
[17] West Thales A, Wilson C, Vrachioli M and Grogan Kelly A 2019 Carbon payments for extended rotations in forest plantations: Conflicting insights from a theoretical model. *Ecol. Econom.* **163** 70 doi: 10.1016/j.ecolecon.2019.05.010

[18] Forestry Commission 2017 *Assessing the investment returns from timber and carbon in woodland creation projects*, available at: https://forestry.gov.scot/publications/sustainable-forestry/economic-research

[19] Almulqu A A 2017 Dynamic growth model simulation for carbon stock management in dry forest. *Biosyst. Divers.* **25**(3) 249 doi: 10.15421 / 011738

[20] Churakov B P, Paramonova T A, Mitrofanova N A, Tumanov V A 2013 Deposition of carbon by pine stands related to their infestation with red rot. *Lesovedenie* **2** [in Russian]

[21] World Bank 2020 *State and trends of carbon pricing 2020* (Washington, USA), available at: https://openknowledge.worldbank.org/handle/10986/33809

[22] Domke G M, Oswalt S N, Walters B F and Morin R S 2020 Tree planting has the potential to increase carbon sequestration capacity of forests in the United States. *Proc. Natl. Acad. Sci. USA.* **117**(40) 24649 doi: 10.1073/pnas.2010840117

[23] Lewis S L, Wheeler C E, Mitchard E T and Koch A A 2019 Restoring natural forests is the best way to remove atmospheric carbon. *Nature* **568**(7750) 25 doi: 10.1038/d41586–019–01026–8

[24] Forestry Commission 2013 *UK woodland carbon code retrieved*, available at: https://woodlandcarboncode.org.uk/