Economic advantages of innovative technologies for accelerated forest regeneration in Russia

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Abstract. The article discusses the economic benefits of using new technologies for the production of planting material for creating forest plantations. The production costs of creating 1ha forest plantations are identified. A model of the technology of the process of creating forest plantations of fast-growing species, planting material obtained using innovative approaches in the form of contextual diagrams of the main processes is presented. The model organization of the process of creating forest plantations of fast-growing species was created in order to most efficiently use equipment and increase labour productivity. It is proved that the use of planting material obtained using nanotechnological approaches at the stage of microcloning can reduce production costs for creating forest plantations and thus significantly reduce the cost of planting material for plantation cultivation. It has been established that the developed innovative technology for obtaining planting material for creating forest plantations of fast-growing species has economic advantages over the traditional one.

1. Introduction

In the context of growing consumption and demand for wood in the world, the goal of most national economies is to intensify the production of forest resources through intensive methods of forest cultivation and the use of introduced species [1].

In a number of countries, such as Germany, New Zealand, Finland, Sweden, Canada, the USA, China and others. Today, the creation of special plantations of fast-growing wood species is widely practiced. The development of forest plantations in a number of countries is closely connected with the economic model of concentration of wood production in intensively managed forest areas.

For example, in China, the area of forest plantations is more than 338,000 thousand hectares throughout the country. In Germany, the scale of forest plantations with a short turnover is approximately 3 thousand ha [2]. In New Zealand, forest plantations planted approximately 103.8 thousand ha. However, according to the report on timber and deforestation in the tropics, Wood for Good, forest plantations today occupy less than 5% of the world's forests, but represent a significantly larger share in the production of wood products.

The work carried out by scientists from Russia, Sweden, Serbia and America on improving the economic organization of forest reproduction processes indicates sufficient economic benefits of forest
plantations associated with their ability to increase forest productivity and reduce the age of timber cultivation. Morkovina S.S. and Keča L. note that for Russia, the establishment of short-lived forest plantations is a promising activity that can produce Net present value (NPV) of 7659 $/ha, given the risks of forest plantations. Similar results were obtained by scientists on forest plantations in Serbia. NPVs range from 12254 to 15114 $/ha [3].

The main condition for obtaining a successful culture of woody forest plants is the correct selection of areas for their cultivation, as well as the selection of the type and variety of planting material that is optimal in specific climatic conditions [4].

This can only be achieved thanks to the latest advances in forest biotechnology [5]. The experience of recent years shows that in forestry, innovative processes aimed at reproduction of forests are more focused on the use of nanotechnology, which even at the stage of microcloning in vitro of woody forest plants allows to obtain sustainable planting material with desired characteristics. J Banerjee et al. [6] in their studies say that the use of nanostimulants can activate some physiological parameters of forest crops. According to the results of numerous studies of woody forest plants grown on a substrate for cultivation with the addition of nanoparticles E Tsukanova et al. [7] proved their high potential resistance to pathogens. S Agrawal et al. [8] note that the use of innovative technologies, in particular the use of growth nanostimulants, makes it possible to improve the resistance of forest woody plants to diseases, the efficient use of nutrients and their accelerated growth. Studies of the effect of metal nanoparticles on microclonal seedlings of a poplar and aspen hybrid conducted by O Zakharova et al. [9] showed an increase in the survival of microclones of the hybrid form of white poplar and aspen by 6–20%, which indicates the prospects of the considered innovative approach to obtain planting material for creating forest crops.

The work of B Ruttkay-Nedecky et al. [10] showed that nanomaterials in agriculture are becoming popular due to the impressive advantages of heavy metal particles, their bioavailability and lack of phytotoxicity are key characteristics for their mass use. Research results [11] prove that the inclusion of nanotechnology in the production processes for obtaining the target planting material in agriculture and forestry will reduce the environmental and financial impact of operations.

The positive effects of nanotechnological approaches to obtaining forest woody plants make it possible to obtain economically viable forest plantations with predetermined parameters in the shortest possible time, with the highest yield per unit area and much faster than in ordinary forests of artificial and natural origin. However, the use of growth nanostimulators in the microclonal propagation of planting material of forest tree crops in vitro should be justified not only by their environmental friendliness, but also by their high economic efficiency for the possibility of using them in the practice of growing forest tree crops and their further commercialization. The applied in vitro methods of microflora propagation of wood forest plants are expensive, mainly due to the high complexity of the work performed, the high qualification of the work performed and the expensive materials and equipment, so new methods introduced into the traditional methods of producing planting material for forest wood plants should help optimize financial resources necessary for production processes [12].

In agriculture and forestry, specifically in crop production, the use of nanostimulants of plant growth should be justified by their high efficiency and effectiveness. In the work of A A Guseva et al. [13] indicated that the modification of nutrient media with metal-based nanoparticles used in microclonal propagation of woody crops will not only enhance plant growth and morphogenesis, reduce the microbial load on explants, but also reduce the cost of produced planting material, which will significantly increase the attractiveness of the microclonal method breeding for forestry and agriculture.

Thus, the creation of forest crops by planting material obtained by the in vitro method of clonal micropropagation based on the use of nanotechnological approaches requires a comparative study of costs with standard biotechnological approaches to obtain similar innovative products for their rational use in reforestation.

2. Materials and methods
The feasibility study of the process of obtaining forest woody plants using nanotechnological approaches
is based on a differentiated study of the cost of working time for the execution of individual elements of the operation. Methods of technical regulation scientifically substantiated the norms of time and norms of production for key and non-standard operations of the process of obtaining forest wood plants using nanotechnological approaches. For each operation of innovative technology, the detailed composition of the equipment necessary to carry out the work, labor costs of the workers, the need for material resources, taking into account normative factors, are determined by the method of detailed calculation. The basic composition of the equipment meets the normative conditions for obtaining planting materials in vivo birch.

Planning and implementation of specific volumes of work on the creation of forest plantations of fast-growing species in settlement-technological maps was carried out on the basis of regulatory legal and regulatory technical documents in the field of reforestation, in force at the time of the work. When constructing and developing settlement and technological maps, methods of photographing working time, timing observations, and rationing were used.

In settlement-technological maps determined the scope of work, production conditions, regulatory factors, indicated production rates, tariff categories of work and tariff rates, the need for equipment, labor costs of workers in person-days, the need for materials.

Production costs of creating 1 ha of forest plantations were determined using a regulatory approach based on the preparation of settlement-technological maps and calculation of cost items:
- remuneration of workers directly involved in production;
- equipment maintenance (depreciation);
- acquisition of materials and fuel;
- consumed electricity.

In order to estimate the costs of creating forest crops with planting material obtained by the in vitro method of clonal micropropagation using nanotechnological approaches, we calculated the costs of 1000 units of the final finished product, as well as the cost of one seedling for birch and poplar using two technologies - innovative (using nanotechnological approaches) and basic.

The economic efficiency of the considered innovative technology of forest crops was assessed using planting material obtained by in vitro clonal micropropagation using the indicator – net present value of income (NPV). This is a relative indicator that characterizes how the income from capital investment covers the cost of it. It is calculated by the formula:

\[
NPV = IC - \frac{\sum CF}{(1 + i)^t}
\]

where \(IC\) – initial investment; \(CFt\) – cash flow discounted over time; \(i\) – is the discount rate (percent).

The decision on this criterion is made as follows:
- NPV > 0, then the project is accepted, since the income from the investment project exceeds its costs;
- NPV <0, then the project is rejected, since the income from the investment project is less than the estimated costs;
- NPV = 0, then the project is considered neither profitable nor unprofitable.

When developing a model for managing the process of creating innovative products in forestry, a process approach and modeling were used. The study presents a technology model of the process of creating forest plantations of fast-growing species, planting material obtained using nanotechnological approaches, implemented using the Business Studio 4.0 software product, which is a series of contextual diagrams of processes and subprocesses in time and space, providing visibility and ease of use and allowing get an idea of production and quickly make a logical conclusion from a large amount of data obtained.

To build a model for managing the process of creating innovative products in forestry, we used studies of growing wood species using nanostructured growth stimulators using the in vitro method.

The model includes a technological description and composition of processes, characteristics of consumed resources (material, labor and financial), the sequence of operations of the process of
obtaining forest woody plants using nanotechnological approaches.

3. Results and discussion
The organization of the process of creating forest crops with planting material obtained by in vitro and in vivo clonal micropropagation using nanotechnological approaches, aims to create the best conditions to meet the needs of consumers, as well as the most efficient use of technology and increase labor productivity.

The process of creating forest crops using nanotechnological approaches is time-consuming and includes production planning, preparation of components and resources, obtaining primary explants in vitro of forest tree plants, rooting of isolated shoots and their multiplication (clonal micropropagation) in vitro; adaptation of microplants in non-sterile soil conditions in the laboratory and growing in closed ground conditions (greenhouse); growing microplants in open ground (on hardening fields) with a closed root system (CRS) to obtain standard material, planting seedlings with CRS on a forest crop area, a system of agrotechnical care for woody plants (figure 1).

The production cost of forest planting planting material obtained by in vitro and in vivo clonal micropropagation using nanotechnological approaches includes the wages of employees, depreciation, expenses for materials, electricity and fuel.

Summary data on the cost of one seedling of planting material (obtaining planting material in vitro and in vivo) obtained using nanotechnological approaches was calculated and presented by us in table 1.

Table 1. The total cost of creating 1 seedling of planting material (obtaining planting material in vitro and in vivo) obtained using nanotechnological approaches.

| Indicator                        | The cost of creating 1 ha of forest plantations, $ |
|----------------------------------|--------------------------------------------------|
|                                  | birch (using nanotechnological approaches) | birch (without the use of nanotechnological approaches) | poplar (using nanotechnological approaches) | poplar (without the use of nanotechnological approaches) |
| Maintenance of machinery and equipment | 37.26             | 49.49             | 37.26             | 49.49             |
| The cost of labour production workers | 832.50         | 1353.95          | 832.50         | 1353.95          |
| Raw materials and basic materials | 1612.27           | 1612.27          | 1514.51          | 1514.51          |
| Fuel and energy for technological purposes | 190.50          | 254.93           | 190.50          | 254.93           |
| Total production cost            | 2672.53           | 3270.64          | 2574.77          | 3172.87          |
| Overhead costs                   | 668.13            | 817.66           | 643.69           | 793.22           |
| Total cost                       | 3340.66           | 4088.29          | 3218.46          | 3966.09          |
Figure 1. Decomposition of the context diagram “The process of creating forest crops by planting material obtained by the method of clonal micropropagation in vitro and in vivo on nutrient media with nanoparticle components” into a sequence of processes.

According to a comparative analysis, the costs of creating forest crops with planting material (poplar) obtained by the method of clonal micropropagation in vitro and in vivo using innovative technology (using nanotechnological approaches) are slightly higher compared to the basic technology. The total cost of creating forest crops with planting material (poplar) obtained by the method of clonal micropropagation in vitro and in vivo using nanotechnological approaches will be $3649, planting material (birch) – $4396.8.

It has been established that in the cost structure for the implementation of work on the creation of forest crops by planting material obtained by the method of clonal micropropagation using nanotechnological approaches, a significant share is allocated to the wage fund (40%). This is primarily due to the high complexity of work in vitro and in vivo (figure 2).

When creating forest crops by planting material obtained by the method of clonal micropropagation in vivo, carrying out agrotechnical cares is one of the most important technological operations, the survival rate and growth rate of planting material depends on the method, quality and time of execution...
of which. The developed technology for creating forest crops with planting material obtained by the
method of in vitro and in vivo clonal micropropagation using nanotechnological approaches even at the
stage of microcloning of woody forest plants can significantly reduce the cost of agrotechnical care by
40% due to the reduction in their number compared to the traditional technology for creating forest
plantations.

![Figure 2. The structure of production costs of creating forest crops planting material
obtained by the method of clonal micropropagation in vitro and in vivo using
nanotechnological approaches.](image)

The production cost of agricultural work for 3 project years for planting material obtained using
nanotechnological approaches for planting material producers will be approximately $57.6, for
traditional technologies – $80.6.

In determining the price of 1 seedling CRS, we took a basic profit level of 25%, taking into account
the sale price of poplar seedlings with improved hereditary properties obtained using nanotechnological
approaches will be $1.106. and $1.332. for a birch seedling.

NPV from forest planting activities by planting material obtained by in vitro and in vivo clonal
micropropagation using nanotechnological approaches is $311.7.

Thus, we can consider the considered innovative technology for creating forest crops promising for
the purpose of loess restoration. The applied innovative technologies for creating forest crops with
planting material can be considered effective, because NPV > 0.

4. Conclusion

The feasibility study of the material and labor costs of the process of creating forest crops with planting
material obtained by the method of clonal micropropagation in vitro and in vivo using nanotechnological
approaches allowed us to determine the production cost of creating 1 ha of forest plantation and 1
seedling. It has been proved that reducing the cost of creating forest plantations of fast-growing species
by planting material with improved hereditary properties obtained using innovative approaches
compared to traditional technology is possible by reducing the number of agrotechnical treatments due
to the use of nanotechnological approaches at the in vitro microcloning stage.

Based on the calculation results, it was concluded that the use of nanotechnology at the stage of
microcloning of seedlings reduces the production costs of creating forest plantations.

The developed model of business processes for creating forest crops with planting material obtained
by in vitro and in vivo clonal micropropagation using nanotechnological approaches is a series of
contextual diagrams of processes and subprocesses, descriptions, content of activities, consumed and

![Resource Costs, $ 40%]

![Depreciation deductions for equipment maintenance, $ 28%]

![The cost of reagents for the preparation of culture media, $ 9%]

![The cost of the purchase of materials, dishes and tools, $ 2%]

![Depreciation deductions for the maintenance of premises and structures, $ 1%]

![Salary, $ 20%]
attracted material, labor and financial resources and sequences of actions for obtaining and growing regenerants of woody plants. Visualization of the process of creating forest crops using innovative technologies allows us to identify bottlenecks in the technology under consideration and determine the cost estimate of time losses, revenue reduction and growth in operating expenses. This allows you to include business models in practical recommendations for reforestation and afforestation for governing bodies and the forest business.

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