Economic feasibility of obtaining wood phytomass through accelerated cultivation of pine wood on postagrogenic lands

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Abstract. The paper examines economic efficiency of obtaining wood biomass through accelerated cultivation of pine on postagrogenic lands of the Leningrad Region of Northwest Russia. In experimental pine plantations, we selected model trees and calculated the stem wood biomass of 11-year old stands with different stem densities. Assessments of the economic efficiency of the production of wood chips from pine wood grown on postagrogenic lands were based on a set of machines and mechanisms, consumables and wages. A break-even point was determined for the production of wood chips in plantations with different stem densities. In the variant with a stand density of 2900 trees per hectare, it is possible to make a profit, because a break-even point was obtained for the investments made. Pine stands of such density can be taken as a prototype, when creating and growing short rotation plantations. Based on the results of the study, it is possible to predict a further increase in pine wood biomass in a plantation on post-agrogenic soils. On postagrogenic lands, marketable wood pulp can be obtained within a short period of time; thus such lands will be involved in an economic turnover.

1. Introduction
Lands taken out from agricultural use have high soil fertility, which creates suitable environmental conditions for the restoration of natural landscapes [1-5]. Productivity of forest plantations on such lands can be quite high. To speed up the production of wood phytomass on post-agrogenic lands, silvicultural activities should support forest regeneration or be aimed at creation of forest plantations [6-9]. At the same time, the efficiency of using financial, labor and material resources of the organization characterizes its performance; the latter should be aimed at increasing profitability of a tree plantation as an intensive growing model [10-16]. A commercial organization, when switching to new promising technologies and types of products when growing such plantations, requires investments in which profitability indicators may temporarily decrease, however, with proper strategic planning, the costs incurred will pay off in the future [17-20].
Statistical and dynamic methods for assessing the profitability of investment projects can help to make an informed investment decision when creating short rotation plantations for bioenergy production. These methods are quite effective both for improving the management of an enterprise during the implementation of an investment project, and for substantiating the feasibility of an investment project as a whole.

The main purpose of economic feasibility assessments is planning the current and future economic activities of an enterprise in accordance with the market demands for wood pulp and possibilities of obtaining the necessary resources for creating and growing wood biomass for the needs of both bioenergy and wood chemistry.

Wood biomass is a source of renewable energy. It contains organic substances formed as a result of the life cycle activities of woody plants [21-23].

When burned, biofuel produces heat energy which can be converted to electricity. The main types of solid biofuels are firewood, briquettes, fuel pellets, and wood chips. The most promising type of biofuel is wood chips [11, 13, 18, 21, 24]. Wood chips can be safely called the most stable energy carrier from the class of non-traditional solid fuel types of raw materials. Efficient use of tree plantations, development of market relations, meeting the demand for wood, and increasing economic profitability demands constant reduction of the costs of growing, harvesting and restoring forest resources [3, 4, 7, 9, 10].

With a prompt response to the existing market demand for one or another wood product, including its species structure, the relevance of the efficient use of the potential productivity of postagrogenic soils for a particular tree species increases. One of the options for increasing the forest stand productivity is plantation forestry [13, 17-19]. Tree plantations grown according to intensive technology will differ significantly in structure and species composition from forest stands of natural origin. Artificial stands are undoubtedly in demand for highly efficient forestry production, as a raw material base at the present time and in the future. Differentiation of cultivated plantations by species composition, based on the potential productivity of postagrogenic soils, will allow planning the possibility of saturating the market with wood products [18, 20, 22, 23].

In modern economic conditions, an effective and stable operation of enterprises and their competitiveness are largely determined by the quality of profit planning and forecasting. The mechanism of effective profit management should help improve production efficiency and stimulate its development. The most important task of the organization's profit management is to analyze the composition and dynamics of profit [25-27]. To obtain a profitable volume of wood biomass in a short period of time, it is necessary to make financial investments in the development of all production stages.

The purpose of the study was to determine the economic feasibility of growing pine pulp wood in plantations on postagrogenic soils in Northwest Russia.

2. Study objects

The research was carried out at the experimental facility of the Leningrad Research Institute of Agriculture "Belogorka" in the Leningrad Region of Northwest Russia. Pine plantations under study were created on agricultural lands using different soil cultivation options. The soil on the former arable land is soddy, weakly podzolic, gleyed, loamy on a red-brown sandy loam moraine, the water impermeable layer is at a depth of 45–50 cm. The following variants of soil cultivation were used at the experimental sites: strip chemical treatment with Roundup (4 l / ha) without mechanical cultivation; strip chemical treatment with Roundup (4 l / ha) and plowing using a row-crop PLN-3-35 agricultural plow in a unit with an MTZ-82 tractor; and plowing without chemical soil treatment. For planting, three-year-old pine seedlings with closed root system were used. Planting was carried out using a shovel, the seedlings were planted in the center of treated strips, in the plow layer. Planting density was 3000 plants per hectare. At the age of five, in three-meter-wide strips newly emerged birch and willow trees and shrubs were removed using a secor and a chainsaw. Depending on the method of soil cultivation, plantations with different density and inventory indicators have formed on
the experimental plots by now. In an artificially created 11-year-old pine stands, wood samples were taken from model trees. The trunks of the selected model trees (six in each of the variant of the experiment) were cut into one-meter-long sections, and wood discs were taken [4]. The samples were dried in a drying cabinet at a temperature of 105 ºC to an absolutely dry state and weighed on an electronic scales. Then recalculation was carried out for the basic wood density and stem mass at a moisture content of 12% (Table 1).

Table 1. Forest inventory indicators of pine plantations on postagrogenic soils.

| Soil treatment method | Density , pcs / ha | Dm, 1.3 m | Hm,m | Growing stock, m³ / ha | Basic density, kg /m³ | Stem phytomass at 12% w.c. tons (chips) | Stem phytomass (wood chips), m³ |
|-----------------------|--------------------|-----------|-------|------------------------|-----------------------|------------------------------------------|-----------------------------|
| Pine planted on old arable lands, 11 years of age (three-year-old planting material with closed root system, 0.4 l) | 2 200 | 5.1±0.4 | 4.6±0.2 | 21 | 305 | 8.00 | 11.42 |
| Chemical strip treatment | 2 600 | 5.9±0.2 | 4.7±0.1 | 35 | 305 | 13.00 | 18.56 |
| Plowing without chemical strip treatment | 2 900 | 7.1±0.2 | 5.2±0.1 | 60 | 315 | 22.20 | 31.70 |

3. Methods
The method of efficiency of using the invested capital has a classic form. Evaluation of the investment effectiveness is made using the ratio of expenses and income. In case of a short-term investment project, statistical methods are used, and in case of a long-term project, dynamic methods [25-27].

When calculating the feasibility of growing phytomass on former arable land, an economic, budgetary and financial assessments are carried out; the final results of the enterprise depend on their reliability.

By applying existing methods, a detailed investment analysis can be carried out. The revealed investment efficiency will help to choose the most attractive for investment object in the product chain.

The analysis showed possible options for making profit with a short rotational scheme of growing pine wood for biomass, as a species with the largest phytomass volume.

One of the main indicators of the economic efficiency of phytomass production is profitability.

Profitability comprehensively reflects the efficiency of the use of material, labor, money, and natural resources. Calculation of profitability helps to predict profit, compare a company with competitors and predict the return on investment [25-27].

Profitability of production is calculated as the ratio of the total amount of profit (balance sheet profit) to the average annual cost of fixed and working assets. The formula for calculating the profitability of production is as follows:

$$R_{pr} = \frac{Pr}{Fa + Wa} \times 100$$  (1)

where:
Pr - profit
Rpr - production profitability;
Fa - the average for the billing period, the cost of fixed assets;
Wa - the average cost of working assets.

For a complete view of a future investment project, even at the stage of business planning and assessment of the required production volumes, it is necessary to know the critical point - the break-
even point of production, i.e. the production and sales volumes which will allow the company's expenses be compensated by income; with the production and sale of each subsequent unit of a product, the enterprise begins to make a profit.

The break-even point can be determined in units of production, in monetary terms, or in terms of the expected profit margin. After passing the break-even point, each subsequent sale of manufactured products brings profit.

When calculating the break-even point in physical terms, we use the formula:

\[ \text{Ver (nat)} = \frac{AFC}{P - AVC} \]  \hspace{1cm} (2)

Ver (nat) - break-even point in physical terms; 
AFC - the average fixed cost per unit of output; 
P - the price of the product; 
AVC - the average variable cost per unit of output.

Knowing the volume of production, you can calculate the break-even point in monetary terms, using the formula:

\[ \text{Ver (mon)} = \frac{\text{Ver (nat)}}{P} \]  \hspace{1cm} (3)

Ver (mon) - break-even point in monetary terms; 
Ver (nat) - break-even point in kind; 
P - the price of the product.

The proceeds from sales (the cost of all manufactured products) are calculated using the formula:

\[ R = Q \times P \]  \hspace{1cm} (4)

R - revenues from sales; 
Q - the volume of production; 
P - the price of the product.

Net income is calculated using the following formula:

\[ NP = GP - EX \]  \hspace{1cm} (5)

NP - net profit; 
GP - gross profit; 
EX - expenses.

4. Results
It should be noted that pine plantations created on postagrogenic lands are characterized by large values of average height and diameter, as well as growing stock: one and a half to two times higher compared to pine plantations created on a former hayfield in a study area of the same age [4]. A comparative analysis showed that by this age the stock of stem phytomass was formed, which exceeded the one in plantations of the same age [4]. Pine is a species that grows well on postagrogenic soils in artificial plantations. With an increase in stand density, it has a tendency to an increase in wood density (Table 1).

Assessments of the economic efficiency of production of wood chips from pine wood grown on postagrogenic lands included a set of machines and mechanisms, consumables and wages.

A preliminary analysis showed possible options for making a profit with a short rotation scheme for growing pine wood for biomass. The following assumption was made: the costs of creating a plantation and caring for it were not taken into account [26, 27].
**Table 2.** A set of equipment necessary for the production of chips, technical characteristics, and productivity.

| Description | Brand | Book value, rub | Productivity, m³/hour | Annual depreciation, 20%, rub | Number of working days, year | Depreciation / shift, 8 hours, rub |
|-------------|-------|-----------------|------------------------|-------------------------------|-------------------------------|----------------------------------|
| Pick-up     | LP-23 | 3000000         | 9                      | 600000                        | 264                           | 2272.73                          |
| Chipping machine (mobile) | Valmet | 2000000         | 10                     | 400000                        | 264                           | 1515.15                          |
| Chip truck /forest truck | Kamaz 53212 | 3500000       | 54 (1 turn)            | 700000                        | 264                           | 2651.51                          |
| Total       |       | 8500000         |                        | 1700000                       |                               | 6439.39                          |

**Table 3.** Cost of fuel and lubricants, salary of workers for the production of wood chips.

| Description | Fuel consumption, l / hour | Cost of fuel and lubricants, l / rub | Cost of fuel and lubricants, rub / hour | Worker's salary, 8 hours, rub / shift | Worker's salary, rub / hour |
|-------------|----------------------------|--------------------------------------|----------------------------------------|--------------------------------------|----------------------------|
| Pick-up     | 8.2                       | 45                                   | 369                                    | 900                                  | 112.5                      |
| Chipping machine (mobile) | 32 | 45                             | 1440                                    | 900                                  | 112.5                      |
| Chip / timber carrier | 32 | 45                             | 14.4 (1 km)                             | 800                                  | 100                        |

Based on the data obtained on the pine stem phytomass, a break-even point was quantified for the production of wood chips from wood grown on postagrogenic lands, depending on the stand density and growing stock by the variants of the experiment [26, 27].

In two variants of the experiment with a planting density of 2200 and 2600 pieces per hectare, all other conditions being equal, the costs of harvesting and removal of the resulting chips do not bring income and have a negative balance (Tables 4 and 5).

**Table 4.** Variant of the experiment: a pine plantation with a density of 2200 pieces per hectare, 11 years of age.

| Description            | Wood stock, m³/ha | Production, hour | Cost of work, rub | Salary of workers, rub |
|------------------------|-------------------|------------------|-------------------|------------------------|
| Pick-up                | 21.00             | 2.33             | 859.77            | 262.13                 |
| Chipping machine (mobile) | 21.00       | 2.10             | 3024.00           | 236.25                 |
| Chip / timber carrier  | 21.00             | 1.00             | 1440.00           | 200.00                 |
| Total                  |                   |                  | 5323.77           | 695.38                 |

Produced 11.42 m³ of wood chips.

The cost of 1 m³ of chips is 450 rub / m³
Sales revenue 11.42 × 450 = 5139.00 rub
Net profit 5139.00 - 5323.77 - 695.38 = (-) 880.15 rub (loss)
Table 5. Variant of the experiment: a pine plantation with a density of 2600 pieces per hectare, 11 years of age.

| Description             | Wood stock m$^3$/ha | Production, hour | Cost of work, rub | Salary of workers, rub |
|-------------------------|---------------------|------------------|-------------------|------------------------|
| Pick-up                 | 35.00               | 3.88             | 1431.72           | 436.50                 |
| Chipping machine (mobile) | 35.00             | 3.50             | 5040.00           | 393.75                 |
| Chip / timber carrier  | 35.00               | 1.00             | 1440.00           | 200.00                 |
| Total                   |                     |                  | 7911.72           | 1030.25                |

Produced 18.56 m$^3$ of wood chips
The cost of 1 m$^3$ of chips is 450 rub / m$^3$
Sales revenue 18.56 × 450 = 8352.00 rub
Net profit 8352.00 - 7911.72 - 1030.25 = (-) 589.97 rub (loss)

In the variant of the experiment with the density of pine trees of 2900 pieces per hectare, it is possible to make a profit, because a break-even point was obtained for the investments made. Pine stands of such density can be taken as a prototype, when creating and growing shot rotation plantations.

Table 6. Variant of the experiment: a pine plantation with a density of 2900 pieces per hectare, 11 years of age.

| Description             | Wood stock m$^3$/ha | Production, hour | Cost of work, rub | Salary of workers, rub |
|-------------------------|---------------------|------------------|-------------------|------------------------|
| Pick-up                 | 60.00               | 6.66             | 2457.54           | 749.50                 |
| Chipping machine (mobile) | 60.00             | 6.00             | 2214.00           | 675.00                 |
| Chip / timber carrier  | 60.00               | 1.00             | 1440.00           | 200.00                 |
| Total                   |                     |                  | 6111.54           | 1624.50                |

Produced 31.70 m$^3$ of wood chips
The cost of 1 m$^3$ of chips is 450 rub / m$^3$
Sales revenue 31.70 × 450 = 14265.00 rub
Net profit 14265.00 - 6111.54 - 1624.50 = (+) 6528.96 rub (profit)

Figure 1. Graphical expression of the break-even point (linear function), the variant of the experiment with a density of 2900 pieces per hectare, 11-year-old pine.

Investments in the amount of 8,500,000 rubles will pay off:
When processing the area: 8,500,000 / 6,528.96 = 1301.89 ha;
When processing $1,301.89 \times 60 = 78,113.40 \text{ m}^3$ of wood.

5. Conclusion

Based on the results of the study, it is possible to predict a further increase in pine wood biomass in an artificial plantation on postagrogenic soils. On postagrogenic lands, marketable wood pulp can be obtained within a short period of time; thus such lands will be involved in an economic turnover.

To address a global energy shortage, it is necessary to use non-traditional heat carriers, e.g. small-size timber grown on postagrogenic lands. This is in line with the current trends in the energy sector.

From the ecological point of view, the amount of gases emitted during combustion of wood raw materials is several times less than when burning traditional fuels. The waste from the production of heat and electricity using wood is wood ash – an environmentally friendly fertilizer for agriculture and forestry.

Profitability assessments of the production of wood chips from wood grown on postagrogenic lands show that in a 11-year-old pine plantation with a density of 2900 pieces per hectare, it is possible to obtain a profitable volume of raw materials.

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