CONDITIONS FOR THE CREATION OF FOREST CULTURES IN THE TERRITORY OF THE NORTHEASTERN FOREST-STEP OF UKRAINE

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The exploitation of forest resources and scientifically based forestry management are inextricably linked with reforestation and afforestation. According to calculations, on our planet annually forests are cut down on an area of more than 10 million hectares. Even more significant areas of the world's forests are annually covered by fires. In conditions where opportunities for reforestation are possible, sufficiently high reforestation rates are created, as a rule, in a natural way to optimize the accounts of types of felling, methods of clearing felling sites, technology for forest work, as well as measures to promote natural reforestation. Protest, on large-scale fires, with white seed trees, as well as on disturbed lands, afforestation is possible only in a rapid way.

One of the most important tasks of the forestry sector of Ukraine is the timely and high-quality reproduction of forests, increasing their productivity and biological stability with the involvement of economically valuable species of woody plants and reducing the terms of growing operational forests. The creation of forest crops ensures the formation of stands of the desired composition, high productivity and stability. In addition, reforestation is a promising strategy for containing global warming, which is based on the ability to bind carbon dioxide, while simultaneously providing key ecosystem services, including clean air and water. However, the creation of sustainable forest crops can be ensured only if there is high-quality planting material and a correctly selected technology for creating crops. The solution to this issue is relevant and requires detailed study.

Based on the analysis of survival and conservation, as well as growth indicators of forest crops, develop proposals for improving artificial reforestation in the State Enterprise "Forests of Ukraine", a branch of the Sumy Forestry of the Nedryhaylivka Forestry.

The research was based on the method of trial plots (TP) and model trees. In addition, other proven methods used in silviculture, forest taxation and soil science were used during the research.

Modern Trends in Forest Regeneration

The goal of forest regeneration, as stated in current regulatory documents, is to revive depleted, dead and damaged stands by natural, artificial or combined means. Artificial reforestation is carried out in cases where natural reforestation is unattainable or impractical, or when it is necessary to introduce economically valuable tree species. In addition, it is used in areas where forest crops have died due to various factors.

Afforestation in forestry practice is understood as the process of planting trees on non-forest lands in order to expand the forest fund. This includes the creation of protective forest plantations on lands of various types: agricultural, industrial, transport, water fund, as well as on lands of industrial activity. The loss of forest areas on our planet is a cause for concern: according to estimates, 36 football fields disappear every minute. Deforestation is caused by a variety of factors, including fires, clearing for agriculture or urban development, and mining. Forests play a crucial role not only as habitats for diverse flora and fauna, but also as a vital resource for people around the world, providing timber, paper, food, and components for a variety of products such as medicines and cosmetics. Forests are also essential for the well-being of the planet, as they contribute to the water cycle, prevent soil erosion, and absorb significant amounts of carbon dioxide, mitigating the effects of climate change.

To combat deforestation, numerous organizations around the world are engaged in massive tree planting and forest ecosystem restoration. There is now a growing global movement and hype around tree planting, driven by a desire to achieve a variety of ambitious goals. These goals include restoring forest cover to mitigate climate change, as well as providing other environmental benefits such as soil stabilization, watershed protection, and wildlife habitat.

Notable initiatives of this movement include the World Economic Forum's One Trillion Trees Initiative, the Bonn Challenge, the UN Decade of Ecosystem Restoration, and the recently established US Interagency One Trillion Trees Council. Reforestation has the potential to sequester an average of 6 metric tons of CO_2 per hectare annually, but it is important to consider the other benefits of reforestation, such as cycling and evapotranspiration. The importance of reforestation cannot be overstated.

There is a consensus among researchers that artificial forest plantations are superior to natural ones in terms of productivity. Therefore, increasing the share of artificial reforestation and afforestation is considered a promising strategy for increasing forest productivity. Here are the advantages of artificial reforestation compared to natural.

Artificial reforestation and afforestation offer several advantages, including a higher growth rate of plantations at a young age and a faster rate of wood accumulation up to a certain age. In addition, they can reduce the period of plantation cultivation by 10-20 years and delay the onset of competition between trees until the crowns close.

The concentration of more trees in the central steps of the thickness also leads to weaker tree differentiation. In addition, artificial reforestation helps prevent unwanted species change and allows for the creation of plantations for different purposes. It also improves forest vegetation conditions by cultivating the soil and ensuring a uniform distribution of trees on the site. In addition, it accelerates the targeted selection of tree species and allows for the simultaneous settlement of the cultivated area. In addition, artificial afforestation makes it possible to grow plantations in areas where tree species did not previously exist or where natural sources of fertilization are absent. This method also accelerates the reclamation of disturbed lands and contributes to the formation of aesthetically attractive landscapes.

The creation of artificial plantations can be achieved by sowing or planting methods. Each approach has its own advantages and disadvantages when it comes to the creation of forest crops. However, experts widely accept that plantations created by planting demonstrate better characteristics. These include higher survival and conservation rates, faster growth, lower density and increased resistance to competition from undesirable species, undergrowth and depletion of the topsoil. Therefore, it can be concluded that forest crops established by planting prove to be more effective and efficient in the field of forestry, as confirmed by various sources.

The process of creating artificial plantations is associated with numerous difficulties. In particular, afforestation and reforestation by planting requires the use of high-quality planting material suitable for certain zones. For this, it is necessary to create seed storage facilities and create nurseries for growing uniform planting material. In addition, the implementation of a comprehensive set of agrotechnical and forestry measures is crucial for the successful cultivation and maturation of forest crops. As a rule, planting material is grown in forest nurseries takes about 2-3 years, which emphasizes the need for cultivation techniques that take into account regional natural and economic conditions. In addition, it is necessary to take effective measures to combat not only weeds, but also pests and diseases. Based on extensive forestry knowledge, it has been established that when restoring Scots pine, priority should be given to forest crops. However, some aspects of its cultivation, including the treatment of sandy soils, methods of mixing with other tree species, determining optimal density and placement of planting sites, continue to be the subject of debate.

Advantages and Disadvantages of Different Forest Crop Creation Technologies

A variety of alternative methods for establishing forest crops are currently available in different countries around the world. These methods include direct seeding, bare-root planting, and closed-root planting, including those made from biodegradable bio-pots. The advantages of direct seeding include the ability to quickly sow large areas, lower costs compared to planting seedlings, and the development of a well-structured root system in established crops. The positive side of seed sowing is its similarity to natural conditions, which leads to increased resilience of these plantations. In addition, from an economic point of view, this method is more advantageous, since it requires only one worker with a hoe or hand seeder, while two workers are required to plant seedlings. In addition, the cost of growing one seedling significantly exceeds the cost of the seeds.

On the other hand, there are several potential disadvantages of direct seeding. These include problems in obtaining sufficient quantities of viable seeds, lack of information on the most effective sowing methods, variations in the timing and duration of seed germination, and the risk of predation of seeds and seedlings by insects, birds and rodents. In addition, competition from existing vegetation, particularly grasses and shrubs, can be a significant obstacle.

An alternative approach is to use bare-root seedlings, which are dug up, stored and transported without any soil around them. Planting bare-root seedlings is a cost-effective and simple method, as this type of planting material has the property of adapting well to changing field conditions.

The success of artificial afforestation is greatly influenced by the caliber of planting material used to establish forest crops. This, in turn, depends on the size and proportions of the underground and above-ground components of the seedlings and saplings, as well as on the weight of physiologically active roots. To increase the mass of active roots, special methods of growing planting material have been developed when using seedlings or saplings with an open root system. In addition, measures have been taken for the safe transportation and storage of dug seedlings and saplings to prevent drying out.

To ensure the availability of first-class planting material in our country, an extensive system of forest nurseries has been created, both temporary and permanent, including basic ones, as well as greenhouses. The advantage of using greenhouses for growing planting material is that they contribute to the creation of ideal conditions for seed germination and seedling growth. Thanks to the use of a greenhouse, it becomes possible to sow seeds a month earlier compared to open ground conditions, as a result of which planting material is obtained in one year, which is comparable in size to standard two-year seedlings.

There were several noticeable disadvantages associated with the use of seedlings grown in forest nurseries for planting both in open ground and in greenhouses. The use of seedlings or young trees with an open root system greatly limited the timing of planting. Any delay in the planting process can lead to dehydration of the topsoil, which will eventually lead to the death of the newly planted vegetation or a significant decrease in survival rates. In addition, the root system of seedlings (or young trees) dries out during planting, especially in hot and windy weather, which leads to their premature death.

In other words, the main disadvantage associated with the use of bare-root planting material has been the limited timing of planting of forest crops, which is largely dependent on weather conditions. When it comes to large-scale artificial afforestation or reforestation projects, even with the use of mechanized planting technologies, significant problems have arisen in achieving optimal planting within the specified time frame.

In order to overcome the limitations associated with bare-root planting material, it is important to explore approaches to mitigate these limitations. In the 1960s, attempts were made to create a technology that would allow obtaining planting material from CRS. As a result, planting material from CRS was launched. This specific type of planting material included seedlings or saplings in which their root system was enclosed in the substrate. Undoubtedly, planting material from CRS had a number of noticeable advantages compared to material from ORS. It is noteworthy that it showed increased drought resistance. The presence of water supply in the substrate coma extended the duration during which the material could be stored and transported without the need for additional watering.

It is worth emphasizing that theoretically, planting material with a closed root system has the ability to withstand a long period without atmospheric moisture when planted in forestry areas. Therefore, more and more attention is paid to improving the technologies for obtaining planting material from CRS.

Such planting material has numerous advantages compared to conventional seedlings and saplings. In particular, seedlings with CRS better adapt to difficult forest conditions, demonstrate resilience during long-distance transportation and, most importantly, allow for a longer harvesting season. In addition, other benefits of using seedlings include a shortened growth period for large-scale projects.

The use of improved planting stock has been shown to increase the survival of some tree species, including Scots pine. This allows for successful establishment of forest crops in difficult vegetation conditions, such as rocky areas, quarries, and other damaged lands. With high survival rates of these forest crops, it becomes possible to reduce the number of plantings per unit of forestry area and optimize the use of selected seeds. The use of container seedlings for reforestation and land restoration offers a more consistent and uniform approach. By transplanting these seedlings, established forest crops can avoid early environmental and biological stress, which will ultimately lead to earlier maturity compared to bare-root or seed plants. It is important to emphasize that minimal post-planting depression promotes rapid growth of forest crops, thereby reducing the need for extensive agrotechnical care. The growing trend of using closed-root planting material in forestry is not accidental, as it has gained popularity both domestically and internationally.

The use of "container seedlings" from CRS in European countries, particularly in Finland, has made it possible to reduce planting costs and extend the planting season. However, this planting technique initially encountered problems. Some Scots pine (Pinus sylvestris) and lodgepole pine (Pinus contorta) seedlings suffered from severe root deformation, which led to impaired growth and reduced stand stability. Consequently, considerable efforts were made to improve container design and prevent root deformation. Various container designs were tested, such as containers with a downward slope to guide the roots, and containers treated with copper or open to the air so that the tips of the roots did not reach the edge of the container.

In the market of Northern European countries, container-grown seedlings occupy a significant share. However, bare-root seedlings have certain advantages, primarily their larger size and increased resistance to damage caused by the pine weevil (Hylobius abietis). As a result, bare-root seedlings continue to be widely used, especially in the southern regions.

In regions located in the northern hemisphere, where the land is fertile and rich in vegetation, there is a significant threat posed by the pine weevil and other destructive pests. However, when comparing seedlings grown with a closed root system (CRS) and seedlings grown with an open root system (VRS), it can be seen that the latter take longer to establish a strong connection between their roots and the soil, thus delaying the onset of water absorption. As a result, CRS seedlings often show greater height growth during the first and second years after planting than ORS seedlings. However, studies have shown that this height discrepancy becomes less pronounced 3-5 years after planting. The use of very small mini-seedlings, which has been tested in Finland, Sweden and Canada, represents another potential option for reducing the costs associated with seedlings and planting. These trials initially focused on Scots pine seedlings, but later in subsequent field experiments, Norway spruce seedlings were included. According to Johansson et al. (2007), if mini-seedlings successfully root, they show comparable or even better growth compared to larger seedlings. However, they are more susceptible to the conditions of their planting environment and require careful care. In addition, other researchers have found that mini-seedlings suffer less damage from pine weevils compared to one-year-old seedlings, possibly due to the release of limonene, a known repellent for these pests. The use of closed-root planting material in the cultivation of productive and resilient stands has been widely recognized in numerous publications. However, the production and transportation of seedlings for this method can be more expensive and complicated. In this regard, its implementation in Ukraine has not become widespread. On the contrary, other countries have been successfully using this technology for the past four decades. Currently, in Europe and the USA, approximately 90% of all seedlings are grown in CRS. Studies by foreign scientists have shown that in some cases, growing planting material from CRS can be more economically profitable compared to traditional open ground methods. The profitability of using this method depends on the amount of production and the specific area of forest vegetation. For example, in the southern regions of the

United States, growing planting material in containers is becoming increasingly profitable when the production volume reaches 2-6 million seedlings per year.

Therefore, the choice of planting system depends on many factors, such as the intended purpose of planting, the associated costs, the productivity of the crops grown and the economic value of the plantation.

Natural Conditions of The Study Area

Located on a vast expanse of the Earth’s surface known as the East European Platform, Sumy Oblast is home to a unique geological feature. Underneath layers of sedimentary rocks 600 to 700 meters thick lies a solid Corinthian bedrock known as the crystalline basement. This geological formation is located in the Sumy district, not far from the city of Sumy.

The relief of the eastern part of Sumy Oblast consists mainly of spurs of the Central Russian Upland, which extend to the northeast of the region. As a result, the entire region slopes from northeast to southwest.

The average elevation in this area is about 200-220 m. The relief of this region is also influenced by surface rocks, in particular loess, which is a light brown porous carbonate rock. These loess deposits are easily eroded by water, leading to the formation of ravines and gullies. Thus, the territory of this region is quite fragmented, both flat areas and areas with erosion signs.

A very intricate network of spring beams can be found throughout the region. The eastern border of the region is part of the Central Upland, on which the noticeable Khotyn-Sumy Plateau stands out. Within the Sumy region, the Khotyn-Sumy Plateau reaches its highest points of 228 m in the upper reaches of the Loknya River and 224 m in the upper reaches of the Oleshnya River (located northeast of the village of Korchakivka). Descending to the southwest from these peaks, the plateau smoothly drops to 204 m in the watershed of the Sumka and Oleshnya rivers. In general, the plateau consists of an elevated plain crossed by rivers that flow radially outward. The Loknya, Snagost rivers and their left tributaries flow to the north, and the Kryga River to the west. The Oleshny River in the middle and lower reaches stretches to the south-southeast, and the Huyva River flows to the east along a beam-shaped valley. On the southern side, the plateau steeply descends to the Psel River valley, forming its right bank, dissected by deep branched beams. On the northern side, the plateau has a more gentle slope and is not so divided by beam-shaped river valleys. The valleys of these rivers and the watersheds between them create a slightly undulating relief. In the north, there are mainly sod-podzolic soils, and in the south - typical chernozems, including deep low-humus, medium and light loamy and leached medium-humus chernozems. Sod-meadow soils prevail in the floodplains of the rivers. Sumy region has an extensive river network, through the territory of which 1,543 rivers flow. All these rivers belong to the Dnieper basin and are mainly its left tributaries. The Great Desna River flows through the region for 37 km, and six medium-sized rivers flow through the territory of Sumy region.

The region boasts an impressive number of water bodies, including 25 large lakes, 2,191 smaller ponds and 43 reservoirs, which together contain a staggering volume of almost 223 million m^3 of water. Beneath the surface, the region's subsoil is rich in a variety of valuable minerals. Notably, it is rich in fuel and energy resources such as oil, natural gas and peat. In addition, non-metallic minerals such as phosphorites, rock salt, quartzites, chalk, marl, as well as raw materials for the production of bricks, building sand and stone are also found in significant quantities in the region.

The climate of the region is temperate continental. In 2023, the average temperature was 8 - 9°C, exceeding the annual average by 2-2.5°C. The peak air temperature of 35-35.5 °C occurred in the north of the region in July-August, and the coldest temperatures of 21-24 °C were recorded in January-February. The annual amount of precipitation was 476-659 mm, which was 74-109% of the average annual norm.

Reforestation and Afforestation

Forest management is a key function of a forestry enterprise, which includes the cultivation, restoration and protection of forests, as well as increasing their productivity and component quality. The economic activity of a forestry enterprise is aimed at the economical use of forest resources, improving the condition of forest plantations, developing recreational activities in forests, preserving and strengthening their sanitary, hygienic, aesthetic and protective functions.

Efforts are aimed at increasing forest productivity and improving the composition of forests by implementing forest restoration methods. This involves growing economically valuable tree species and implementing effective methods of forest management. In addition, measures are being taken to protect forests from fires, pests and diseases.

The primary task of the Nedryhaylivka Forestry Enterprise is the constant and purposeful creation of new forest plantations that exceed the area of the felled land. In addition, the farm seeks to preserve these stands, increase their productivity, ensure their rational use, while improving the useful qualities of forests and improving their ecological condition. In 2018, the SE "Nedryhayliv Forestry" carried out large-scale forestry work. During the spring and autumn seasons, forest restoration work was carried out on forest lands with a total area of 69.5 hectares. This includes:

61.5 hectares were allocated for planting and sowing of the forest, another 8.0 hectares were left for natural regeneration. In addition, 3.7 hectares were specially allocated for growing New Year's tree plantations (Fig. 1).

Fig. 1 *Areas of Picea tree plantations*

When reforestation is carried out in modern times, preference is given to the use of planting material with a closed root system. Using this method, it becomes advisable to create stands of trees that are both highly productive and biologically stable throughout the growing season.

The forest farm exceeded the planned harvest in 2019, collecting a significant amount of 22.0 kg of pine seeds and a significant 12 thousand kg. of oak acorns. This surplus is crucial for creating forest seed reserves, ensuring proper accounting for subsequent years with limited or no seed harvests.

To acquire high-quality seed material, the forest farm adheres to a certain set of measures, which includes the collection and processing of forest seeds.

• Quality confirmation in the process;
• Use of already established seeds in nurseries, greenhouses and containers;
• Transplanting seedlings to forest land for the cultivation of productive and environmentally sustainable plantations in the future. As of January 1, 2023, the permanent forest seed base of the forestry consists of certified areas with a total area of 54.9 hectares (forest seed plantations). Approximately 80 percent of the required seeds are obtained from these areas each year.

Fig. 2 *Plot with planting material Quercus robur L*

The forestry includes three nurseries with a total area of 3.5 ha. In addition, there are greenhouses with an area of 0.07 ha, which are responsible for growing approximately 600 thousand trees each year. The main focus of planting material is Scots pine - 300 thousand specimens and common oak - 190 thousand pcs. (Fig. 2.3.3).

Nurseries play a crucial role in the cultivation and sale of ornamental seedlings, meeting the requirements of landscape design projects. A significant number of 20 thousand seedlings, consisting of 56 different species, are grown each year to meet these landscaping needs. In addition, since 2018, the nursery has been operating a greenhouse with an area of 0.02 ha using mist irrigation technology.

Clearing of Felling Areas, Timber Harvesting

To improve the quality of forests, promote their well-being, and strengthen their protective properties, forestry activities such as maintenance felling, sanitary felling, and forest regeneration felling are carried out (Figure 3).

Fig. 3 *Wood harvesting process*

The main activity of the enterprise is the extraction of wood, both for direct use and for logging. In addition to timber harvesting, the enterprise is also engaged in wood processing.

Accurate and reliable information about forest resources is important for the modern economy. To ensure the accuracy and efficiency of forestry operations during forest felling, advanced technologies and equipment are used. These tools significantly simplify the management of forestry operations and increase their quality due to their convenient design and high level of accuracy.

The development and use of a functional and high-quality geographic information system requires the use of modern equipment with high accuracy. This equipment plays a crucial role in performing various cartographic tasks necessary for effective forestry management. These tasks include determining the current coordinates of specific points, plotting turning points and boundaries of forest plots, calculating distances in certain directions, measuring plot areas immediately after the survey, and accurately determining the location of objects or people relative to the forestry tablet on site.

For 1996-2005, the forestry received approval for the estimated volume of final felling of 13.2 thousand m3. Of these, hardwoods - 7.2 thousand m3, conifers - 2.8 thousand m3, softwoods - 3.2 thousand m3. Interestingly, the actual volume of felling per year averaged 98% of the estimated volume of felling for the entire inspection period.

The discrepancy between actual timber production in the commercial sector and forecasted logging indicators is minimal and ranges from 0% to 8% for individual tree species. All areas designated for primary logging have been successfully developed in accordance with the forest management project. This is due to the annual agreement on the allocation of priority logging, which takes place within the framework of the current forest management. The principle of uninterrupted and continuous forest use is reflected in the current estimated timber production and its actual implementation. Insufficient financial resources allocated between 1998 and 2003, combined with the lack of demand for harvested wood, are the main factors contributing to the noticeable discrepancies in the volumes of both clearing and thinning logging. The significant excess of through-cutting in terms of area can be explained by the change in the age composition of forests and the existing demand for wood products. In addition, the significant deviation in the yield of commercial timber during thinning and through-cutting logging can be explained by the large number of dead trees in oak stands.

The general condition of the stands, in which no maintenance fellings were carried out during the forest management year, with the exception of a small part of young trees under 20 years of age, was recognized as satisfactory. The quality of maintenance and selective sanitary fellings is also satisfactory. These measures played a significant role in improving the sanitary condition of the stands, which led to a decrease in the number of areas affected by forest diseases and pests. The enterprise carefully keeps records of forest pests and diseases, strictly adhering to sanitary regulations.

The main approach to timber harvesting is a mixed method, which combines basic and grassroots maintenance strategies. Wood obtained from maintenance and sanitary fellings is transferred to enterprises, local organizations and citizens for various purposes, including personal use and processing.

According to inspection reports, during the audit period, reforestation fellings were carried out on an area of 34.3 hectares. This led to the felling of a total stock of 6.8 thousand m3 in mature and mature stands, which lost their protective and other functions.

Key Performance Indicators

In terms of work volume, our company annually reforests an area of 74 hectares. In addition, we carry out logging operations, harvesting approximately 37.4 thousand cubic meters of wood. In addition, we process part of this wood at our own facilities, producing about 3.3 thousand cubic meters. In terms of sales volume, our revenue for 2020 amounted to 42,632.0 thousand UAH. To support these operations, we have a special team of 120 employees, each of whom receives an average monthly salary of 11,343.35 UAH.

There is a lower warehouse at the Southern Railway station, from which wood is exported. A fleet of 24 cars and 15 tractors is involved in this operation. The annual cargo turnover is 27.5 thousand m^3.

To meet the demand for decorative planting material, the forestry has expanded its focus to growing evergreen exotic seedlings in closed conditions. However, the forestry's primary task remains reforestation.

The importance of forestry in the regional economy cannot be overestimated, as it performs many roles, such as supplying wood for local needs and industry, serving as a source of nature protection and recreational activities through forest plantations, and also providing a variety of non-wood products.

Research Methodology

To fulfill the goal and objectives of the study, a work program was developed and implemented, which included the study of the scientific and departmental base for modern forestry production technologies.

Study the environmental factors present in a specific research site.

Our goal is to analyze the practical application of the technology and the number of Scots pine forests grown in the Nedryhaylivka forestry. We seek to assess the stability and preservation of forest plantations created by using bare-root Scots pine seedlings.

Using the results of the research, formulate recommendations aimed at activating the process of artificial reforestation in the Nedryhaylivka forestry.

The survey of forest crops was carried out using the test plot method. When creating all test plots, the instructions set out in GOST 56-69-83 were followed, namely, Experimental forest management areas.

The analysis of silvicultural and taxonomic characteristics of tree species in the composition of forest crops was carried out according to generally accepted methodologies in the field of forestry and forest taxation. This study was supported by the “bookmark method” and systematic recommendations. In addition, the current “Instructions for the design of forestry facilities” provided further justification for the study.

The assessment of the survival of various tree species was carried out in 1-5-year-old plantations created in the Nedryhaylivka forest farm. For this, the selected plots were delimited by rectangular test plots that corresponded to the age of the crops. Each plot was accurately measured using protractors and tape measures and secured at the corners with pegs. During the studies, the number of planting sites, the density of surviving plants, as well as the row spacing and planting interval were determined.

The survival rate of forest crops was assessed at different planting points (PP). Viability, which refers to the percentage of seedlings that successfully survive out of the total number planted during the first year, and survival, a similar measure taken one year after the establishment of the forest plantations, were determined.

Within the framework of mixed-age forest plantations created by manual planting with an open root system, planting sites were selected. These areas had similar relief, forest vegetation conditions, and a consistent history of forest plantation establishment at the time of establishment of the planting points (PPs). To assess the viability of each PP, all surviving Scots pine specimens were measured, including their height, lateral shoot length, number of needles per 5 cm of the axial shoot, and growth over the previous year. A total of 545 measurements were documented. Additionally, 5-10 dead Scots pine specimens were excavated from each PP to determine the causes of their death, if possible, to be found on site.

To identify specific conditions of forest vegetation cover and classify forest type, scientists used the established methodology of typological research. Information on the unique characteristics of forest vegetation conditions, methods of creating forest crops and historical prerequisites for their creation were obtained from various silvicultural projects.

The materials of experimental studies were subjected to statistical processing using methods of variational statistics and the Microsoft software package.

Reforestation in Forestry

The forest restoration process in the forest farm has some unique aspects. To facilitate this process, temporary nurseries with an area of 0.56 ha were created, as well as seed plantations with an area of 3.0 ha, intended for growing Scots pine. In addition, a greenhouse with a total area of 0.13 ha is used to grow approximately 1.0 million seedlings each year.

The current need for planting material is sufficiently met by the farm's existing nurseries. In addition, forest schools bring in additional planting material to supplement forest crops. For the effective implementation of the farm's reforestation work over the past two years, an average of 405 kg of seeds was required. For this purpose, these seeds must be collected.

Within the forest farm, the cultivation process takes place in plots. To ensure high-quality planting material with the necessary genetic properties, a specialized forest seed repository has been created in the specialized forest farm. According to the results of the 2022 forest management, the Nedryhaylivka Forestry Enterprise has set the task of restoring forests on a total area of 2,866 hectares (according to Table 3.1.1). The reforestation strategy has designated 81.7% of this area for the creation of forest crops, and the remaining 18.3% is allocated for natural regeneration.

According to the project, Scots pine is the dominant species in forest formation, accounting for 92.7% of newly created plantations. Black alder is in second place, which regenerates naturally - 6.5%. The forest enterprise allocates forest areas for natural regeneration, primarily in forest types B3DS, B4DS, which include Scots pine, as well as in C2GDS, which includes downy birch, and in C3GSD, which includes common oak. The forest enterprise provides for afforestation of 24.5 hectares. Among this area, 56.3% is allocated for artificial creation, and the remaining 43.7% is allocated for natural regeneration in forest areas. The dominant species responsible for forest formation is Scots pine.

According to the results of the survey of open areas, 39.7% fall into the 3rd quality class, 37.2% into the 2nd quality class and only 23.1% into the first quality class.

In the forest farm, forest regeneration measures are carried out according to a carefully developed strategy. The development of forest crops takes into account various elements, including the existence of natural regrowth, distinctive features of the forest and the characteristics of the forest area. Nevertheless, it is important to recognize that the degree of mechanization of such labor-intensive activities as planting and growing crops remains relatively minimal.

Table 1. Projected volumes of reforestation activities on forest areas and fellings not covered with forest vegetation in the revision period, area, hectares

Breeds designed for restoration	Forest area categories			Total
	Not covered with forest vegetation	Logging sites of the revision period		
		Main use	Other logging	
Forest crops				
Pinus sylvestris L	364,6	1972,0		2336,6
Quercus robur L	4,0	2,0		6,0
Total:	**368,6**	**1974,0**		**2342,6**
Natural renewal				
Pinus sylvestris L	316,1	5,0		321,1
Quercus robur L	0,5			0,5
Betula pendula	2,0	14,0		16,0
Alnus glutinosa L	39,8	146,0		185,8
Total:	**358,4**	**165,0**		**523,4**
Total by household:				
Pinus sylvestris L	680,7	1977,0		2657,7
Quercus robur L	4,5	2,0		6,5
Betula pendula	2,0	14,0		16,0
Alnus glutinosa L	39,8	146,0		185,8
Total:	**727,0**	**2139,0**		**2866,0**

The farm uses a traditional approach to planting, using pre-prepared grooves and strips. To prepare the soil for sowing, mechanized methods are used, which include the formation of furrows at a distance of 2.5-3 m from each other with a depth of 15-20 cm. This task is performed using a combined tractor MTZ-82 and a combined forest plow (PKL-70). The actual planting of the forest is carried out manually by individuals using a Kolesov sword.

The silvicultural fund consists mainly of lands that are not forested, as well as areas where sanitary and main use fellings were carried out during the audit period. In addition, it includes low-productive and low-value plantations that are included in the reconstruction fund. The determination of the forestry fund in felling areas in the audit period is based on economic considerations and takes into account the projected fellings in the future audit period. When developing methods for reforestation and afforestation, the direction and success of natural regeneration in different types of forests and categories of land are taken into account. The average regeneration period for areas designated for natural regeneration is usually 2-3 years. In 2021, significant work was carried out to restore forests with a total area of 522 hectares. It should be noted that forest crops were created on a huge area of 470 hectares, which is almost twice as much as last year's - 290 hectares. A feature of the forestry work this year is that 98.7% (464 ha) of newly created Scots pine plantations were established in areas previously affected by intense fires last year. The dominant species responsible for the formation of these forests is the stable Scots pine, which currently occupies a large area of

469 ha. In addition, a 52 ha area has been allocated for natural regeneration, of which 32 ha are for pine growth, 12 ha for flowering downy birch, and 8 ha are thoughtfully planted with alder.

Scots pine forest plantations can be created both in spring and autumn. However, the number of forest crops planted in autumn is minimal, and their chances of survival are also low — from 44% to 81%. Therefore, a larger proportion of these crops require fertilizing compared to those planted in spring. As a result, spring plantings demonstrate better survival, require fewer additives and achieve timely closure. Therefore, in the territory of the Ovrutskyi special forestry enterprise, it is customary to plant pine in the spring, which accounts for approximately 96% to 100% of all established crops. The best time for planting is early spring, using seedlings aged 1 to 2 years. Approximately 4 to 8 thousand pine seedlings are planted per hectare.

The most common forest-vegetation conditions for growing crops are B2 (52%), A2 (29%), Bz (19%). Soil care for forest crops occurs during the first five years of growth and consists of destroying weeds and loosening the rows of forest crops. The frequency of maintenance is as follows: five times in the first year, four times in the second year, three times in the third year, twice in the fourth year and once in the fifth year. 100% of soil care work in forest plantations is done manually.

The duration during which forest plantations reach full closure and transition to forest areas with established vegetation depends on the specific forest type and dominant species. On average, it takes about 6 years for Scots pine, and 7 years for Scots oak. The technical assessment of Scots pine plantations shows that 86.2% (400 ha) are classified as “excellent” and 13.8% (64 ha) are classified as “good”. These results demonstrate the effectiveness of artificial reforestation measures to achieve high productivity.

In order to assess the survival and growth indicators of pine forest plantations, regular bonitization is carried out.

Assessment of Survival and Growth Indicators of Scots Pine Forest Crops

The work assessed the survival and growth indicators of Scots pine forest plantations established in forestry from 2019 to 2023 (Table 2). All surveyed plantations were created on log cabins. The dominant species in all experimental plots was Scots pine, although mixed plantations with birch as an additional component were found in some trial plots. The dominant forms of forest vegetation were fresh and moist soils. The standard planting location, which is usually used, is 3.0 x 0.7. After the introduction of mechanized tillage, plantations ceased to be created manually.

Table 2. Forest crops used for analysis

Quarter	Board	Area, hectares	Main breeds	TFC	Forest area category	Placing	Mixing scheme
1	9(1)	0,9	Сз	B2	Framework	2,5x0,7	3rSz2Bp+Yabl
2	17	2,0	Сз	B3	Framework	3x0,7	10pСз
2	5	1,5	Сз	B2	Framework	3x0,7	10pСз
5	28	1,5	Сз	A2	Framework	3x0,7	10pСз
22	6	1,4	Сз	B3	Framework	3x0,7	3rSz2Bp

The results of the research indicate a significant survival and preservation of forest crops, as evidenced by the data presented in Table 3. In addition, the preservation of crops in the study areas aged from one to three years exceeded the established standard. In particular, the level of preservation of one-year and two-year crops reached 90%, while three-year crops were maintained at a level of 83% in the specified study region.

The preservation of crops for one and two years reached 90%, while three-year crops were maintained at a level of 83% in the specified study region (Table 3).

Table 3. Survival and survival of Scots pine forest crops in trial plots

Quarter	Board	№ TA	Year of planting	Density, thousand pcs./ha	The age of creation of f. cultures	Survival (preservability)
1	9(1)	5	2019	4,8	5	84,2
2	17	4	2020	4,8	4	84,8
2	5	3	2021	4,8	3	85,6
5	28	2	2022	4,8	2	88,1
22	6	1	2023	4,8	1	91,1

The reason for the impressive survival rate can be explained by the timely establishment of these forest crops and the use of state-of-the-art technologies. Interestingly, there was no noticeable difference in viability between pure and mixed crops.

The year of planting has a constant effect on the stability of crops. The survival of crops worsens with each passing year. Among the trial plots, the most successful survival rate – 91.1% – was in Scots pine plantations planted in the spring of 2020 in trial plot No. 1. On the other hand, the least was in the 2019 plantations on FR5 – 84.2%.

The successful establishment and initial growth of forest crops largely depends on two factors: the depth at which the seedlings are planted in the soil and the location of their roots. The greatest decrease in seedling survival occurs during the first year after planting. Analysis of dead seedlings showed that the main causes of death of seedlings with a bare root system are dehydration, which accounts for 27.7% of cases, and predation by wild animals.

In the trial plots of forest crops, we measured their condition, paying special attention to the height of the shoots (or the length of the axial shoot) and the length of the lateral shoots. These measurements serve as a tax indicator, which is believed to be very characteristic of the overall condition of the crop. After analyzing the data, we found that the main reasons for the poor condition of the crops are as follows: 14.1% of the crops had roots covered with sand during planting, 10.2% suffered from bending of the roots during planting, 8.2% had insufficient root pressure. taproot, and 5.9% were affected by other factors. These findings highlight the importance of proper planting techniques and rootstock care to ensure the viability and growth of forest crops. In addition, in Scots pine crops, stand growth over the previous year was assessed and the number of needles per 5 cm of vertical branch was recorded.

Table 4. Statistical indicators of the length of axial (central) and lateral shoots of Scots pine in forest crops, cm

No. In Order	Year of creation	Sprout	Maximum valueue	Minimum value	Average value	CV, %
1	2023	Axial	25,2	8,1	14,9±0,26	23,5
		Side	7,8	3,7	5,60±0,68	32,1
2	2022	Axial	72,8	25,6	40,5±0,45	66,4
		Side	25,0	6,9	8,6±0,31	36,2
3	2021	Axial	95,1	33,2	70,1±0,17	54,2
		Side	33,7	12,3	18,6±0,47	38,9
4	2020	Axial	100,0	40,2	95,6±0,23	49,3
		Side	40,1	13,2	23,6±0,42	18,9
5	2019	Axial	195,0	78,5	155±0,65	73,5
		Side	56,2	32,1	45,2±0,45	23,5

Scots pine trees in the 2023 harvest ranged in height from 8.1 to 25.2 cm with an average height of 14.9 cm. In addition, lateral shoots had an average length of 5.6 cm. It is worth noting that the coefficient of variation is higher for lateral shoot length compared to seedling height (Table 4).

In 2022, new two-year crops were established, demonstrating a height range from 25.6 cm to 72.8 cm. The average recorded height was 40.5 ± 0.45 cm. In these crops, lateral shoots of pine varied in length from 6.9 cm to 25.0 cm. The average length of these shoots was 8.6 ± 0.31 cm. It should be noted that the coefficient of variation of height exceeded the coefficient of variation of lateral shoot length.

In experimental area No. 3, pine crops had a height range from 33.2 cm to 95.1 cm with an average height of 70.1±0.17 cm. In addition, lateral shoots had an average length of 18.6±0.47 cm.

For 4-year-old crops, the typical length of the main shoot (PP4) is 95.6±0.23 cm, and lateral shoots are about 23.6±0.42 cm. It is worth noting that the coefficient of variation is higher for crop height and reaches 49.3%.

In the 2019 plants, pine trees had a height range from 78.5 to 195 cm with an average measurement of 155±0.65 cm. Lateral shoots had a length of 32.1 to 56.2 cm with an average value of 45.2±0.45 cm.

In almost all test plots, except for PP1, the coefficient of variation of the height of axial shoots is higher than that of lateral ones. This indicates that the length of axial shoots in forest crops has a wider range of variation and is more responsive to environmental changes. It is this parameter that allows us to more fully reflect the state of cultivated forest crops.

The natural growth of Scots pine directly correlates with the age of the stands. By selecting the studied samples from comparable conditions, we can establish consistent patterns of height fluctuations over time (see Table 5).

Table 5. Statistical indicators of growth of tree species in forest crops in height over the last year, cm

Indicators	TA 1	TA 2	TA 2	TA 3	TA 4
Maximum valueue	9	40	65	50	80
Minimum value	3	9	15	20	30
Average value	5,9±0,22	20,4±0,36	35,9±0,71	41,0±0,11	54,1±0,01
Coefficient of variation, %	22,1	36,4	26,2	17,8	22,2
Accuracy of the experiment, %	3,7±0,45	2,0±0,45	2,5±0,12	2,8±0,32	2,5±0,21

The analysis showed that the correlation between height and planting by year can be accurately represented by a power function (Y2=0.99), with the equation in = 14.9x1.4102.. The most significant increase occurred between the fourth and fifth years.

Over time, since the establishment of pine plantations, the annual height increase showed a tendency to increase in the experimental plots.

It is noteworthy that the experimental plot No. 4 showed a larger annual increase, while the experimental plot No. 1 showed the smallest. It is worth noting that the experiment conducted in PP1 demonstrated the highest level of accuracy (3.7±0.45), while 11112 gave the lowest (2.0±0.45). The coefficients of variation of growth increment had relatively low values (from 17.8% to 36.4%), indicating a consistent trend within each trial area (corresponding to a certain age of the stands).

Conclusions

As a result of a thorough analysis of the practice of reforestation and the technology of creating forest crops used in the economy, as well as the study of the growth and condition of crops on the forestry trial areas, it was established that 81.7% of the reforested area of reforestation areas is intended for forest crops, and the remaining 18.3% is for natural regeneration. The majority of the created plantations belong to the second quality class - 54% of the total.

Forestry deserves praise for timely and high-quality reforestation, which contributes to the sustainable and efficient use of forest resources.

In the Nedryhaylivka forestry, traditional planting technology is used, which involves the early preparation of furrows and strips. Mechanized soil preparation is carried out with a combined forest plow (PKL-70) attached to an MTZ-82 tractor, creating furrows 15-20 cm deep with an interval of 2.5 and 3 m. The actual planting of the forest is carried out manually using a Kolesov sword.

The results of the study show that forest crops in all five experimental plots demonstrated excellent survival and preservation rates, ranging from 84.2% to 91.1%. This exceptional level of survival can be explained by careful adherence to optimal timing and advanced technologies in the creation of these forest crops.

In almost all trial plots, except for PP1, the coefficient of variation of the height of axial shoots is higher than that of lateral ones. This indicates that the length of axial shoots in forest crops has a wider range of variation and is more responsive to environmental changes. It is this parameter that allows us to more fully reflect the state of the forest crops being grown.

The natural growth of Scots pine directly depends on the age of the stands, in particular in terms of height. Extensive research has shown that

the most accurate reflection of the relationship between years of growth and growth occurs through the use of a power function.

The height growth of pine stands in the experimental plots showed a positive correlation with the length of time since their creation. In the experimental plot No. 4, a greater annual growth was observed, and in the experimental plot No. 1 - the smallest.

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