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Strategies and challenges of artificial forest reproduction in the forest-steppe zone: Experience of the Korsun-Shevchenkivskyi forest enterprise branch

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Abstract. One of the key problems that arise in the reproduction of forests in the paradigm of sustainable development of the forest industry is the volume of reforestation, which requires its correlation. This problem requires attention, since effective afforestation and reforestation determine the stability of the ecosystem and the importance of forest resources for the conservation of biodiversity in the forest sector. The purpose of the study is to investigate the features of artificial forest reproduction in the conditions of the forest-steppe climatic and geographical zone. The methodological basis for organising observations included field survey of planting material plots,

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monitoring the state of crops on the area, conducting analytical substantiation of progressive experience, and evaluating the final results obtained. The study was conducted in the Korsun-Shevchenkivskyi forest enterprise branch of the state enterprise "Forests of Ukraine". The dynamics of annual volumes of artificial forest reproduction, considering the predominant tree species during 2012-2021, is presented. Additionally, the advantages and disadvantages of transplanting of main and related species in the presented forest conditions were analysed. During this period, there is a fluctuation in the volume of artificial forest reproduction in the forest districts under study. With regard to the transplanting of main and related species, it is worth noting its advantages in ensuring biodiversity and rapid forest regeneration. However, there are disadvantages, such as the possibility of losing genetic diversity and considering local conditions for effective seating. As a result, the study helped to determine the trends and features of forest reproduction in these forest districts, and to note the advantages and disadvantages of transplanting of the main and related breeds in various forest-growing conditions. The enterprise is actively implementing measures for forest reproduction, focusing on intensive planting of forest crops. This is achieved by placing plantations in areas that have been subjected to continuous sanitary and reforestation logging. One of the key tasks of the enterprise is to ensure high productivity of forest crops in the region. For this purpose, significant amounts of reforestation work are carried out, including systematic soil preparation and careful selection of optimal species for specific conditions. Considering the recommendations of forest management, an integrated approach to reforestation is reflected, which ensures sustainable and productive ecosystems in the region. The developed strategies can serve as an important tool for introducing innovations in the field of forestry

Keywords: forest conditions; transplanting; forest crops; reforestation; productivity of forest crops

Introduction

The issue of restoring forest resources, in particular their expansion to increase the share of forest cover in Ukraine, closely correlates with significant tree felling, the impact of planetary climate changes, shifting groundwater levels, floods that provoke natural and other disasters. Therefore, it is logical that in modern conditions, the restoration, preservation and reproduction of forests is considered by the world establishment as a guarantee of an environmentally stable future of humanity. The implementation of the model of sustainable development of the forest industry can be successful only if the main problems inherent in Ukrainian reforestation and afforestation are solved. The key tasks are to overcome these problems and ensure the systematic reproduction of forests in sufficient volumes, which is a necessity today. Among the key problems in forest reproduction in the paradigm of sustainable development of the industrial sector, a small share of afforestation and reforestation at the proper level is singled out. Insufficient afforestation makes it difficult to maintain forest cover at the required scientifically proven level in certain regions of the country. High-quality reforestation, in particular artificial, even with sufficient regulatory measures, it is not possible to guarantee the reproduction of full-fledged forest cenoses, in particular, the creation of ecosystems with high biological resistance, which are as close as possible in composition and shape to natural stands.

The search for new ways of a balanced ecological and economic approach in forestry in the context of sustainable development is highlighted in the studies by O. Furdychko *et*

al. (2021a; 2021b), that present a multi-factor model for predicting the state of forest ecosystem recovery by 2035. The researchers point to the fact that the social aspect of the balance of forest fund use in Ukraine is determined by the impact of forestry on the local population. Ensuring social responsibility in forestry involves balanced access to forest resources for local communities, providing jobs and community participation in forest management decisions. An important aspect is the preservation of traditional forest use and the promotion of rural development through effective forest management. M. Sobkowiak *et al*. (2020) reviewed the implementation of government programmes for biodiversity conservation and the importance of climate change for forest management decision-making. The researchers focused on exploring the relationship between conservation strategies and climate change adaptation strategies, providing important insights into how these two aspects interact in shaping effective forest management. The results of their study point to the need to integrate biodiversity and climate change adaptation strategies to create more integrated and sustainable forest management.

A number of researchers pay considerable attention to the problems of natural renewal of oak forests during logging of the main use in protective and recreational forests. I.S. Neyko *et al*. (2022) found that the main objectives of afforestation and reforestation in the future are to increase forest area by restoring natural ecosystems and preserving existing forests. To do this, it is necessary to take measures for forest planting, creating new tree stands, and ensuring proper care at all stages of development. An important task is to introduce modern methods of forestry aimed at preserving natural resources and balanced use of forest biogeocenoses.

In the study by R. Hazarika *et al*. (2021), reforestation is seen from the perspective of species introduction as a way to increase forest cover, in particular, through genetic diversity of forests and national legislation on trade and use of forest reproductive material (FRM) are key aspects of forest management and adaptation to climate change in European countries.

Changes in forest cover are a major factor in local climate change around the world, as they affect both albedo and evapotranspiration (ET). Deforestation and afforestation are expected to have opposite effects on surface albedo and ET rates, and thus have different effects on Earth's surface temperature (Prevedello *et al*., 2019).

The process of implementing large-scale afforestation projects should consider global changes in circulation and their impact on the remote climate. R. Portmann *et al*. (2022) analysed national datasets for tree species *Picea abies, Pinus sylvestris, P. pinaster, Fagus sylvatica, Fraxinus excelsior, Quercus robur, Q. rubra, and Q. Petraea*. Given the large number of species under consideration, it is important to note that the impacts of afforestation and deforestation on climate are complex and depend on specific ecosystems and geographical conditions. Understanding these processes is key to effective forest management and maintaining climate sustainability on a global scale.

S. Jansen *et al*. (2019) discussed the estimated genetic impact of transferred FRM (forest reproductive material) on local tree populations, reviewed legislation and documentation processes for their compliance. The study by S. Jansen *et al*. (2019) examined in detail the putative genetic effects of transferred FRM (forest reproductive material) on local tree populations. The researchers covered not only scientific information, but also considered important aspects of the legislative environment and documentation processes to ensure that the use of FRM meets the requirements of laws and regulations. An important element of the study was the investigation of the influence of transferred forest reproductive material on the genetic structure of local tree populations. The

researchers identified which aspects of genetic diversity can be changed or improved by implementing FRM, and considered possible impacts on ecosystems and the cost of biodiversity. In the context of reviewing legislation and documentation processes, the researchers determined what rules and requirements should be considered when using transported FRM. This is important for ensuring long-term sustainability and effective management of forest resources, and for ensuring compliance with the health and development of local tree ecosystems.

The purpose of the study was to investigate the characteristic features of artificial forest reproduction in the climatic and geographical region of the forest-steppe.

The objective of the study was to characterise the dynamics of annual volumes of artificial forest reproduction in the Korsun-Shevchenkivskyi forest enterprise by the predominant tree species; to highlight the advantages and disadvantages of transplanting of the main and related species in the specified forest conditions.

Materials and Methods

The study was conducted during 2012-2021 on the territory of Vyhraiv, Kvitky, Kumeiky, Korsun, Tahancha, and Yasnozirya forestry sections (Korsun-Shevchenkivskyi forest enterprise branch, Cherkasy Oblast, Ukraine). The paper used a variety of resources and methodologies for a comprehensive analysis of the research subject. The theoretical approach involved analysing, synthesising, deducing, inducing, comparing, concretising, and generalising scientific sources related to the contextual problem. Additionally, the study of regulatory documents (project of the forestry development organisation) (Ukrainian State Design Forestry Production Association, n.d.) related to the object of research was conducted. The empirical method included such methodological foundations as the organisation of observations (field survey of planting material plots, monitoring of the state of crops on the area), the of analytical substantiation of progressive experience, the assessment of the final results, and the description of the structure of the subject matter. For objective data collection and their subsequent analysis to obtain comprehensive information on the state of the forest ecosystems, empirical research tools were used (collection of actual data, generalisation, systematisation, in particular, forestry and ecological ones – when studying the typological characteristics of forest plantations; generalisation – to record the general features of a certain set of objects and to make a transition from the individual to the general, that is, to generalise the results of research; by visual assessment of seedlings on the plantation, description of the research object). Methods of detection, including field mapping, and interpretation, including functional and analytical methods, were also used to study the structure of the vegetation cover. To analyse the current stages of growing forest crops and investigate the features of phytocenoses of pine forests of the Korsun-Shevchenkivskyi forest enterprise branch, early office analysis was carried out. Based on the forest management documentation of the enterprise, it was determined that the most characteristic site is located on the territory of the Korsun-Shevchenkivskyi forest enterprise, and this served as the basis for determining the study areas. The research was conducted in compliance with the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973) and the Convention on Biological Diversity (1992).

Forest nurseries are an integral part of the forestry process of the Korsun-Shevchenkivskyi forest enterprise branch. In particular, the Kumeiky forestry established a sowing department and a decorative nursery of a temporary forest nursery, where 1-2-year-old Scots pine seedlings and 2-year-old European spruce seedlings grow (Fig. 1). In the temporary nursery of the Kvitky forestry, annual seedlings of common oak and northern red oak were grown (Fig. 2, 3).

Figure 1. General view of the temporary nursery of the Kumeiky forestry
Source: photo by O. Zabrodotskyi, I. Chemerys

Figure 2. General view of the temporary nursery of the Kvitky forestry section
Note: general view of forest crops with a predominant tree species of common oak established in spring 2022
Source: photo by O. Zabrodotskyi, I. Chemerys

Figure 3. General view of forest crops after mechanised care in the row spacing of forest crops by MTZ-82 tractor (Belarus), combined with Kanzas-170 (Ukraine)
Note: the photo shows 4-year-old cultures of common oak, Kvitky forestry
Source: photo by O. Zabrodotskyi, I. Chemerys

This strategic decision was aimed at improving the sustainability and productivity of forest ecosystems in the region. The period of transition of forest crops to land covered with forest vegetation was determined for about 6-7 years, depending on the main species. Soil preparation included furrowing with an MTZ-82 tractor (Minsk Tractor Works, Belarus) using a PKL-70 combined forest plough (SPETSLISMASH LLC, Ukraine). This process took place in September-November for spring planting and in August for autumn planting. 2-3 weeks before planting forest crops, deep nonmouldboard cultivation of the soil was carried out, while nitrogen fertilisers were applied at the rate of 70 kg/ha of ammonium nitrate. For these works, the MTZ-82 tractor (Minsk Tractor Works, Belarus) was used in combination with RN-60.80 tractor-mounted ripper (LLC SPETSLISMASH, Ukraine). In the areas where the cover of madrones and other cereal plants was found, herbicides with contact action from the glyphosphate group, such as Clinic, Roundup, Felix, and Uragan-Forte, were applied. The dosage was 3-7 litres per 1 hectare of active substance. To carry out these activities, an MTZ-82 tractor (Minsk Tractor Works, Belarus) with an ON-400 mounted sprayer was used by spraying the drug on the leaf surface during the growing season and vegetation height of 20 cm or above. Planting of crops was carried out using Kolesov's planting iron. Annual seedlings of Scots pine, common oak, northern red oak, black walnut, and black locust tree, obtained from their own nurseries, were used for planting. In the areas where multi-age May beetle larvae were recorded, material with a root system treated with Prestige or Aktara preparations was used during planting. Forest crops received care for five years according to a specific scheme, which provided for a gradual reduction in the intensity of work: starting with five rows of row spacing and mechanised cultivation using MTZ-82 (Minsk Tractor Works, Belarus) with KLB-1.7 combined forest plough (LLC SPETSLISMASH, Ukraine),

the row spacing was reduced at each subsequent stage. The lines were handled manually throughout the period. In addition, with a mortality of more than 15%, the addition of forest crops with the main species was carried out to maintain the sustainability of the ecosystem and ensure optimal growth. Possible areas for improving forest culture activities at the enterprise include the following aspects: expansion of work aimed at natural renewal, especially in conditions that contribute to this; implementation of furrowing to promote the natural renewal of forest tree species; use of high-quality planting material with improved hereditary properties; use of plants with a closed root system to ensure better survival and development; establishment of a seed bank for storing and using seed material in lean years; effective use of internal reserves to ensure sustainable seed production and reduce dependence on purchases. These areas are aimed at optimising the processes of forest culture activities, preserving biodiversity and ensuring the sustainability of forest ecosystems at the enterprise.

Results and Discussion

The technological process of creating forest crops is a complex of agrotechnical, silvicultural, sanitary and protective and other techniques aimed at growing forest crops with the help of machines, materials, mechanisms, as well as organising their implementation. Agrotechnical methods of planting forest crops are determined by various factors, such as the nature of the terrain, the type of forest conditions, and the category of forest-cultivated area. Silvicultural techniques are determined by the orientation of plantation in accordance with its intended purpose. Biological methods include the use of pest control products. Sanitary protection techniques include the implementation of sanitary selective logging and other measures to improve the condition of forest stands. The Korsun-Shevchenkivskyi forest enterprise branch has improved and implemented agricultural techniques for growing planting material in forest nurseries in forest-steppe conditions. This technology must be considered and followed at all stages of the production process. Conventional methods of sowing in beds have been replaced by new approaches that involve the use of longitudinal rows and strips. This decision is substantiated by studying the optimal parameters for seedling placement, growth, and development. Seeding rates, optimal sowing depth, timing and structure of crops were established. The efficiency of using fertilisers in the corresponding geographical areas of Ukraine, to ensure optimal plant nutrition and increase yields, was considered. All these measures are aimed at improving the quality and quantity of planting material obtained, and optimising agricultural processes in forestry (Debryniuk, 2013).

The existing nurseries on the enterprise almost completely meet the needs for planting material. The sowing department uses breeding material collected from family and clone plantations, and from permanent and temporary forest seed plots. Based on the average annual production volumes of forest crops, the required volume in planting material is calculated, which corresponds to 95.1 thousand seedlings. This indicator is considered to determine the area of the sowing and nursery departments. In the sowing sector of the nursery, the following species are grown: Scots pine *(Pinus sylvestris* L.), common oak *(Quercus robur* L.)*,* black walnut *Juglans nigra* L.), northern red oak *(Quercus rubra L.)* (Table 1).

Table 1. Dynamics of annual volumes of artificial forest reproduction in the Korsun-Shevchenkivskyi forest enterprise branch by predominant tree species during 2012-2021

Year of establishment	Planting and sowing forest								
	incl. by predominant tree species								Total, ha
	Scots pine		Common oak		Black walnut		Northern red oak		
	ha	%	ha	%	ha	%	ha	%	
2012	75	61.9	21.1	17.4	11.2	9.2	13.8	11.4	121.1
2013	115.6	82.5	16.9	12.1	5.6	4	2	1.4	140.1
2014	102.6	79.7	21.6	16.8	4.5	3.5	-	-	128.7
2015	136	85.3	13.4	8.4	10.1	6.3	-	-	159.5
2016	141.2	81.7	18	10.4	13.6	7.9	-	-	172.8
2017	140.3	86.3	15.6	9.6	6.6	4.1	-	-	162.5
2018	75.5	72.9	25.4	24.5	-	-	2.6	2.5	103.5
2019	57.3	64.6	30.9	34.8	0.5	0.6	-	-	88.7
2020	63.8	63.4	35.8	35.6	1.1	1.1	-	-	100.7
2021	43.5	50.3	36.4	42.1	6.6	7.6	-	-	86.5
Total	950.8	75.2	235.1	18.6	59.8	4.7	18.4	1.5	1,264.1
Average for 10 years	95.1	75.2	23.5	18.6	6.0	4.7	1.8	1.5	126.4

Note: includes the volumes of reproduction of Vyhraiv, Kvitky, Kumeiky, Korsun, Tahancha, and Yasnozirya forestry sections
Source: developed by the authors based on the Ukrainian State Design Forestry Production Association (n.d.)

Forest transplanting has its advantages, in particular, the possibility of planting already grown plants on forest-cultivated areas that can immediately compete with grass vegetation. However, planting seedlings or saplings is often used to establish forest cultures, as this simplifies the care process and ensures a certain level of plant safety. Among the disadvantages of transplanting, there are significant costs associated with the cultivation of planting material, namely: the creation, maintenance, selection, and transportation of seedlings, and the payment of wages to employees.

In the context of this forest enterprise, three main methods of artificial reproduction of forest crops are defined: sowing, planting, and a combination of both previous methods. In the future, it is planned to recreate forest ecosystems by artificial plantings on the edges of logging sites within the forest fund of enterprise on a total area of 638.6 hectares, while natural restoration was planned on a total area of 225.3 hectares. Forestry has actually completed work on an area of 2,493.1 hectares, including 655.3 hectares of natural regeneration. There are no protective forest plantations on lands unsuitable for agricultural production, which are not included in the area of the forestry enterprise due to the lack of regulatory and economic documents confirming the right to permanent use of land (Table 2).

Table 1. Implementation of the main types of forest restoration work in 2014-2023

Main types of work	Total, ha	Average annual implementation in ha	
		2014-2023	in the year preceding the current forest management
1. Reproduction of forests, total, incl.	2,493.1	249.3	255.1
◈ forest sowing	-	-	-
◈ forest planting	2,493.1	249.3	255.1
2. Reforestation:	2,360.5	236.0	235.0
◈ incl. reconstruction of plantations	-	-	-
3. Afforestation:	132.6	13.3	20.1
◈ in clearings, wastelands,	132.6	13.3	20.1
◈ on unsuitable land of other land users	-	-	-
4. Natural renewal	655.3	65.3	55.8
5. Creation of protective forest stands on the lands of other users	-	-	-
◈ including shelterbelts	-	-	-
6. Sowing seeds of tree and shrub species in nurseries	21	2.1	2.1
7. Planting of seedlings of tree and shrub species in nurseries	10.0	1.0	1.0

Source: developed by the authors based on the Ukrainian State Design Forestry Production Association (n.d.)

Forest management measures related to reforestation methods, selection of the main species, soil preparation under 84% mechanisation conditions, and types of forest crops are carried out at the proper level at the enterprise. However, it is necessary to introduce additional techniques for creating forest crops for such species as northern red oak, European spruce, European larch, common ash, black walnut, and black alder in the forest fund of the forestry enterprise on an area of 156.7 hectares or 16.5%. This will improve and enrich the diversity of species in the created forest plantations, which also corresponds to the types of growing conditions of these tree species. Forest crops are planted using two methods: 70% of the area is planted manually, and 30% using mechanised means. During 2012-2021, ten treatments of forest crops was carried out. In total, during this period of time, an area of 3,901.6 hectares was cultivated, which is 106% of the planned volume. The mechanised approach to crop care is 8.7%. The system of measures aimed at forest crops in recent years has covered the use of a chemical method on a total area of 76.0 hectares. In 2012, Uragan-Forte (active ingredient: glyphosate) was used in forest crops of Scots pine on an area of 17.2 hectares. The main species were added to forest crops when the mortality was 15% or more. On average, additional measures were implemented annually on a total area of 205 hectares. The number of plantings and mixing schemes of forest crops correspond to the technological schemes that were designed as part of forest management. The timing of the transfer of forest crops to forest vegetation is carried out in accordance with the established regulatory documents (Fuchylo & Kyrylko, 2022; Kychylyuk *et al.*, 2022).

Forestry enterprise facilitated the natural renewal, in particular, by fertilising the soil with minerals on an area of 305.3 hectares on plots during logging of the main use. However, the implementation of these events did not always lead to the desired result. The transfer of forest plots to those covered with forest

vegetation after the implementation of measures to promote natural renewal in the forestry enterprise did not take place.

The production site designed reconstruction of low-value and low-top plantings on an area of 34.3 hectares, including continuous reconstructive logging on 34.3 hectares. The next step is to create forest plantations of common oak on the same area. Practical restoration was carried out on an area of 33.0 hectares of black locust trees. It is important to note that the implementation of this economic measure did not significantly improve the species composition and expected changes in the derived stands. It was planned to carry out natural renewal on an area of 225.3 hectares, of which 200.2 hectares were provided in cutting areas of audit design.

Natural recovery was observed with the participation of black locust tree and black alder in open forest areas and cutting areas devoid of forest vegetation on a total area of 402.3 hectares. In particular, black locust tree successfully populated the slopes of various exposures, while black alder prevailed in conditions with high humidity levels. These natural processes gave positive results and did not cause changes in the main species, given the specific natural conditions. The satisfactory condition of forest crops of the 1st and 2nd quality class in unclosed forest areas is 83.1%, while in areas converted to forest grasses, this class is only 62.4%. It is important to note that no unsatisfactory forest crops were found, which indicates the effectiveness of silvicultural work in the enterprise. This was achieved due to the timely implementation of measures to restore plantings on logging sites of the main use and sanitary logging of valuable forest-forming species. Care at a sufficient level with the necessary agrotechnical techniques also plays an important role in ensuring the stable condition of forest crops.

The forestry enterprise needed an average of 5,285.0 kg of seeds to perform reforestation operations over the past two years. Seed collection was carried out from isolated trees with the best condition, located in parks, forest strips and on permanent seed plots. The total amount of seeds harvested over the past two years is 4,324.0 kg, of which 33.5% were collected on permanent seed plots for common oak. It is also important to note that some of the seeds were imported from other districts of the region (Table 3). The forestry enterprise has created a permanent forest seed base for the purpose of growing high-quality planting material with valuable hereditary properties (Table 4).

Table 3. Dynamics of forest seed harvesting volumes in the state enterprise Korsun-Shevchenkivskyi forest enterprise during 2012-2021

Tree species	Harvested seeds per year, kg									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Common oak	1,300	1,500	1,700	3,763	3,040	565	3,130	3,390	3,700	6,450
Northern red oak	958	1,060	920	400	2,690	2,432	1,300	980	1,600	1,600
Black walnut	2,500	3,099	2,840	2,480	3,110	2,870	1,933	2,108	1,906	2,920
Common walnut	–	–	–	–	–	108	62	60	58	120
Scots pine	160	150	179	111	100	129	70	51.5	59.3	43.1
Other	20	20	15	10	10	10	–	28.5	26.5	13
Total	4,938	5,829	5,654	6,764	8,950	6,114	6,495	6,618	7,350	11,146
From them for PSP	–	500	300	–	500	–	–	500	1900	500

Note: PSP –permanent seed plantation
Source: developed by the authors based on the Ukrainian State Design Forestry Production Association (n.d.)

Table 3. Availability of planting material according to the balance (2013-2022)

Balance for spring, year	Standard seedlings and rooted cuttings, thousand units					
	availability according to the autumn inventory	used in autumn for planting, supplementing, and selling	availability as of January 1 of the reporting year	need for everything	balance	
					excess	shortage
2022	684.7	184	500.7	445.7	55	–
2021	725.2	114.4	610.8	608.4	2.4	–
2020	1,001.6	–	1,001.6	903.3	98.3	–
2019	1,187	229	958	816.9	151	9.9
2018	1,177	312	865	815	50	–
2017	1,264	250	1,014	977	69	32
2016	1,777	290	1,487	1,541.2	–	54.2
2015	1,221	138	1,083	1,102	–	19
2014	1,098.9	171	927.9	950.7	0.2	23
2013	2,010.6	184.6	1,826	1,526.8	355	55.8

Source: developed by the authors based on the Ukrainian State Design Forestry Production Association (n.d.)

From the presented statistical results (Table 3) it can be seen that the dynamics of the volume of harvesting of forest seeds increased significantly in 2021, increasing from 111% to 500% compared to 2012. However, the volume of pine seed harvesting in 2021 decreased by 27% compared to 2012.

At the enterprise, there are nurseries with a total area of 4.6 hectares, of which 1.0 hectares are intended for temporary use. The productive area of nurseries is 4.5 hectares, and the average annual number of seedlings grown over the past two years is 379.5 thousand units. Of this total number: 11.6 thousand units of Scots pine; 5.2 thousand units of Crimean pine; 9.2 thousand units of European spruce; 0.5 thousand units of larch; 2.7 thousand units of northern white cedar; 4.5 thousand units of juniper; 0.3 thousand units of other species; 96.7 thousand units of common oak; 0.6 thousand units of Norway maple; 22.9 thousand units of small-leaved linden; 190.8 thousand units of black locust tree; 5.8 thousand other tree species; 28.7 thousand units of shrub species.

The forestry uses two greenhouses with an area of 447 m^2 to grow planting material. An average of 43.15 thousand plant cuttings with a well-developed root system are grown in these greenhouses annually, which are then used for decorative purposes. In particular, this applies to seedlings of common box, European spruce, northern white cedar, Scots pine, common juniper, and common ninebark. Currently, the existing nurseries in the forestry enterprise fully produce the necessary amount of planting material, and therefore, their further expansion is not planned. Planting material that is grown in forest nurseries finds its application to improve the condition of forest crops and landscaping the territories where the forestry enterprise is located.

The forest fund of Ukraine corresponds to an area of 10.4 million hectares, which nowadays has a significant predominance of artificial plantations – forest crops – over natural formations.

V.M. Maurer (2012) noted that the state of provision of planting material for reforestation in Ukraine now requires attention and analysis. One of the key problems is the lack of availability and variety of planting material for the restoration of forest areas. It is necessary to address the issue of providing high-quality and adapted seedlings of the main tree species that play an important role in reforestation. In addition, it is important to improve planting technologies

and introduce new methods to improve the efficiency and sustainability of reforestation. The development and implementation of national strategies and programmes aimed at improving the supply of planting material are identified as priority tasks for the conservation and restoration of forest cover in Ukraine (Hensiruk, 2002).

A.N. Nekos & M.Z. Rego (2015) present an approach to identifying high conservation value forests (HCVF). It is determined that the main principles of conservation and reproduction of forest resources aimed at improving the environmentally useful properties of wood are the achievement of environmentally oriented forest management with the study and consideration of forest resources depending on zoning and integrated ecological and economic forest management with environmentally advanced technologies.

Using a high-resolution spatial analysis of global drylands, 448 million hectares suitable for afforestation were identified, and the concentration of forestry in areas with a net cooling effect alone would use up half the area and double the compensation for emissions, report S. Rohatyn *et al*. (2022). This discovery not only highlights the significant opportunities for forest growth in the country, but also highlights the need for strategic planning and priority measures to promote forestry. The application of this approach in forest management can become a key area for a balanced approach to solving problems and setting priorities in the field of providing planting material for forest restoration in Ukraine. In the fight against global climate change, in order to restore biodiversity and increase the income level of local residents around the world, forest planting activities are being accelerated. While afforestation programmes can mitigate not only global climate change itself, but also its adverse effects in the form of drying out, report A. Staal *et al*. (2024). Reforestation in Europe is increasing summer precipitation locally, according to a new analysis of precipitation measurements across the continent. These programmes are becoming a key tool for managing the carbon cycle and conserving water resources, providing a positive impact on biodiversity and the local environment. Effective afforestation is expected to help restore ecosystems and create a sustainable, carbon-neutral environment, which will help counteract climate change and ensure balanced development for local communities. J. Baker (2021) argues that real tree planting levels can mitigate future droughts that are expected due to climate change. Tree planting is defined by the researcher as an effective measure in the fight against droughts, since the forest cover can affect the hydrological cycle and the storage of ground water. Given that trees release less water during the transpiration process in winter than plants in summer, they can affect the reduction of evaporation and, consequently, the storage of moisture in natural ecosystems. The results of this study highlight the importance of careful planning and implementation of tree planting programmes as part of a strategy to adapt to climate change and overcome its negative impacts, in particular, in the form of droughts.

The problems of reforestation and afforestation in the lowland part of Ukraine are given attention in a number of scientific and practical studies, which reveal the features of technological processes for the establishment of forest stands. In particular, O.T. Danchuk (2004) investigated aspects of factors affecting the biological stability of forest biocenoses involving introducers, and possible changes in the genetic structure of populations of native and introduced breeds during reforestation activities. Determining the impact of introduction on biodiversity and interactions between different species, O.T. Danchuk (2004) identified key aspects that determine the sustainability

and long-term sustainability of ecosystems. The study points to the need to consider genetic aspects in reforestation programmes and strategies to preserve natural biodiversity and improve ecosystem sustainability in forest management. V.I. Bilous (2009) made a significant contribution to understanding the features of growing and breeding common oak in the forests of Ukraine. The researcher focused on a detailed investigation of the biological and forest properties of this species, considering intraspecific variability and identifying outcomes that are important for further breeding and management of forest resources. The studies by V.I. Bilous (2009) and Y. Yelisavenko *et al.* (2023) highlight how important it is to consider common oak as a key element of forestry, given its multifaceted characteristics. The results of the study open up new opportunities for optimising the management of this species and developing breeding strategies.

The natural conditions of the region under study create favourable soil and climatic conditions for the successful cultivation of highly productive pine stands, and other valuable tree species. In modern conditions, the production of forest crops must necessarily be aimed at using methods of restoration and afforestation based on the principles of close to nature forestry. This includes the creation and cultivation of biologically sustainable plantings, considering the conservation of natural resources and biodiversity. The enterprise carries out practical complete independent harvesting of seeds, but in case of its insufficiency, purchases are made from neighbouring enterprises. The grown planting material almost all corresponded to standard sizes, which made it suitable for planting on forestry plots. The enterprise performed a significant amount of reforestation work, in particular by increasing the volume of forest crops planted. This was achieved by creating forest crops in areas where continuous sanitary and reforestation logging was carried out. The recommendations of forest management regarding reforestation methods, soil preparation, and rock mixing were mainly considered and implemented by forestry enterprises. The company's task was to ensure high productivity of forest crops in the region. To achieve this goal, significant amounts of reforestation work have been carried out, including soil preparation and selection of optimal rocks. An important aspect was the consideration of fresh hornbeam-oak-pine subor forest types, where an increase in the area of Scots pine and a decrease in common oak were substantiated.

Conclusions

The Korsun-Shevchenkivskyi forest enterprise branch effectively implements agrotechnical techniques for organising production activities in forestry. The enterprise considers the topography, type of forest conditions, and category of forest area when creating forest plantations. Forestry measures include the establishment of plantations in accordance with their intended purpose, the use of pest control products, and sanitary protection measures. Agricultural techniques for cultivating planting material in forest nurseries were introduced, and bedding methods were replaced. Analysis and rationing of seed sowing was carried out based on geographical conditions. The reforestation programme planned to reforest 638.6 ha, while the enterprise actually implemented the programme on 2,493.1 ha.

Forest management activities include felling, selection of main species, and soil preparation with a high level of mechanisation. Deviations from the project were recorded for some species, which contributed to their diversity. Planting of forest crops was carried out manually and technically. 10 treatments were carried out, which is 106% of the planned amount.

The use of machinery during maintenance was 8.7%. Chemical treatment was carried out on 76.0 ha. Promotion of natural forest regeneration through soil mineralisation on 305.3 ha has not always been successful. Forest nurseries are almost completely provided with planting material using breeding material.

The disadvantages of transplanting are the cost of growing planting material. Planting can take place in a variety of ways, including seedlings and saplings, which can affect the amount of care required.

Further research will focus on finding effective methods for managing forest resources to ensure their sustainability and use in an environmentally balanced way, and developing strategies for preserving soil cover and water resources in the forest-steppe zone.

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Conflict of Interest

None.

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Стратегії та виклики штучного відтворення лісів в умовах лісостепової зони: досвід філії «Корсунь-Шевченківське лісове господарство»

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Анотація. Серед ключових проблем, що виникають у відтворенні лісів у парадигмі сталого розвитку лісової галузі, варто відзначити обсяг лісовідновлення, який потребує його кореляції. Зазначена проблема вимагає уваги, оскільки ефективне лісорозведення та лісовідновлення визначають стабільність екосистеми та важливість лісових ресурсів для збереження біорізноманіття лісового сектору. Метою роботи є детальне вивчення особливостей штучного відтворення лісів в умовах Лісостепової кліматo-географічної зони. Методологічні засади організації спостережень включали польове обстеження ділянок садивного матеріалу, нагляд за станом посівів на площі, здійснення аналітичного обґрунтування прогресивного досвіду, оцінка одержаних кінцевих підсумків. Дослідження проходило в філії «Корсунь-Шевченківське лісове господарство» ДП «Ліси України». Представлено динаміку щорічних обсягів штучного відтворення лісів з урахуванням переважаючих деревних видів протягом 2012-2021 років. Додатково, проведено аналіз переваг і недоліків використання розсадництва головних та супутніх порід в представлених лісорослинних умовах. В зазначений період спостерігається коливання обсягів штучного відтворення лісів у розглянутих лісництвах. Щодо розсадництва головних та супутніх порід, слід відзначити його переваги у забезпеченні біорізноманіття та швидкого відновлення лісів. Однак існують недоліки, такі як можливість втрати генетичної різноманітності та врахування місцевих умов для ефективного розсадження. У підсумку, дослідження дозволило визначити тенденції та особливості відтворення лісів у

вказаних лісництвах, а також відзначити переваги та недоліки розсадництва головних та супутніх порід у різних лісорослинних умовах. Господарство активно впроваджує заходи з відтворення лісів, зосереджуючись на інтенсивному збільшенні обсягів посадок лісових культур. Це досягається завдяки розміщенню насаджень на територіях, які піддавались суцільним санітарним та лісовідновним рубкам. Одним з ключових завдань господарства є забезпечення високої продуктивності лісових культур в регіоні. Для цього виконуються значні обсяги робіт з лісовідновлення, включаючи систематичну підготовку ґрунту та ретельний вибір оптимальних порід для конкретних умов. Враховуючи рекомендації лісовпорядкування, відображено комплексний підхід до лісовідновлення, який забезпечує стійкі та продуктивні екосистеми в регіоні. Розроблені стратегії можуть слугувати важливим інструментом для впровадження інновацій у сферу лісового господарювання

Ключові слова: лісорослинні умови; розсадництво; лісові культури; лісовідновлення; продуктивність лісових культур