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Planning of rational use of forest resources in Ukraine based on the improvement of ecosystem services

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Abstract. The study of land conservation methods for forest conservation and restoration is important and relevant from the standpoint of balanced use of natural resources and biodiversity conservation. The purpose of the study was to investigate effective strategies for the exploitation of land with self-forested areas to meet the needs of the agricultural sector of the Zolochiv

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District of the Lviv Oblast. In the course of the study, the following methods were used: analysis; geographical method; statistical method; cartographic method; geoinformation method. It is worth noting that for the land plot No. 1 within the Buska territorial community of Lviv Oblast, it was recommended to conserve the land, with its subsequent renaturalisation. According to the results of the analysis, it is shown that in 2011 the processes of independent afforestation of agricultural land within the Busk territorial community were insignificant. In 2023, the situation improved, as the area of afforded land increased significantly. To the soils of the land plot No. 2, which was part of the Brody urban community, it was advisable to use conservation and transformation. In the Zolochiv community, 14.2 hectares of land should be rehabilitated, 27.3 hectares should be transformed into pasture, and 3.5 hectares should be alkalised. The paper suggests the introduction of innovative approaches for integrated planning of the use of forest resources: creation of forest farms, development of forest tourism, creation of special forest stands for air filtration, application of bio-refining technology, etc. The findings can be used by local communities to develop and implement a draft of measures for the comprehensive development plan of the territory of the Lviv Oblast to improve forest ecosystem services

Keywords: inventory; conservation areas; agricultural areas; self-forested land; soil cover; remote sensing

Introduction

Regular studies of methods for analysing the soil cover of land massifs were important for maintaining a favourable condition of land plots with self-seeded forest vegetation within the Lviv Oblast. The problem of the presence of a significant area of unaccounted forests exists because a large amount of forest land (the presence of about 800 thousand hectares has been established) located on state and municipal property lands was not transferred to permanent forest users in time due to the lack of procedures for state registration of forests and forest cadastre (Public report of..., 2023).

The results of the study of the restoration of destroyed forest vegetation in pine plantations of fresh coniferous forest in Zhytomyr Oblast after clear-cutting, which are presented in the paper by H.R. Talakh & V.P. Krasnov (2023), point out the need to introduce comprehensive measures for the restoration of forest crops. According to researchers, artificial reforestation may be a possible way to solve the problem of vegetation destruction and deforestation after continuous logging.

During the study of forests of the state enterprise "Dovzhansk forest enterprise", where the dominant part of the forest fund (more than 80%) was accounted for by beech trees, the paper by V.V. Batryn & V.P. Kichura (2020) provided important methodological approaches to evaluating the effectiveness of various methods for restoring forest stands. In particular, the method of natural restoration of tree species can also be applied on the territory of woodlands within the Lviv Oblast.

The study conducted by O.H. Chaskovskyy & H.H. Hrynyk (2020) analysed changes in forest cover on the territory of the national nature park "Skolivski Beskydy" in the Ukrainian Carpathians. It was revealed that the main losses of forest cover are associated with logging, the vast majority of which occurred at an altitude of more than 1100 m above sea level (A.S.L.). To be able to respond to changes in forest cover in real time, the researchers suggested using data from satellite images of the Sentinel-2 system, since comparative analysis with open data from the Global Forest Watch portal (GFW) showed that these images were characterised by good spatial and temporal resolution.

The study by V. Fesyuk *et al.* (2023) was devoted to the assessment of the state of forest cover and its changes in the Volyn Oblast. In the Manevychi administrative district, the highest rates of forest losses (deforestation) were recorded – 27.6 thousand hectares. Researchers have proposed to solve the issue of rational use and protection of forests through the introduction of forest monitoring measures using remote sensing of the Earth methods and reforestation, in particular natural renewal.

Based on the results of a study of forest cover losses in Ukraine, which are described by N. Stoiko *et al.* (2023), the need to implement measures for the protection and restoration of forests in Ukraine were identified. According to researchers, a possible way to solve the problem of forest loss may be the introduction of a programme of independent afforestation, in particular, on agricultural land that is not fertile, degraded, or unproductive.

The study by Yu. Zaitsev *et al.* (2003) considered the main indicators of soil fertility based on the results of an agrochemical survey of agricultural land in the Lviv Oblast. It was found that in terms of the acidity of the soil solution, the vast majority of land had a neutral reaction of the soil solution (pH value 7), but the largest area in the region was found under medium-quality soils.

O. Dorosh & I.O. Zastulka (2022) investigated effective strategies and methods for regulating self-afforestation on agricultural land within territorial communities. The scientific approaches proposed in the researchers to solve the problem of excessive self-afforestation were based on the prevention of exceeding the forest cover by more than 50% and the predominance of forest land areas by more than twice over agricultural land.

Insufficient attention has been paid to the development of measures for the conservation of degraded and unproductive agricultural land from a technical, economic and environmental standpoint. The purpose of the study was to develop practical proposals for the exploitation of agricultural land with self-afforested and unaccounted forests in modern conditions of land relations development.

Materials and Methods

In conducting the study, research methods were used to analyse agricultural land with self-seeding forests, the use of which was established by regulatory documents: Land Code of Ukraine (2024), Law of Ukraine No. 858-IV “On Land Management” (2003), Law of Ukraine No. 2321-IX “On Amendments to Certain Legislative Acts of Ukraine on Forest Conservation” (2022), Resolution of the Cabinet of Ministers of Ukraine No. 476 “On Approval of the Procedure for Conducting Land Inventory and Cancellation of Certain Resolutions of the Cabinet of Ministers of Ukraine” (2019), Resolution of the Cabinet of Ministers of Ukraine No. 1051 “On Approval of the Procedure for Maintaining the State Land Cadastre” (2012).

The study used the analysis for investigating agricultural land with self-afforestation. Geographical method was used for analysing the distribution of woodlands in space. Statistical method considered changes in the size of woodlands. Cartographic method was used for visualising self-forested areas. Geoinformation method for describing the geospatial location of objects and processes related to the self-afforestation of agricultural land. The research was conducted during 2022-2023 on the territory of the Zolochiv District of the Lviv Oblast. Zolochiv District united 7 territorial communities. The soils of the district were mainly sod-podzolic soils and chernozems.

The object of the land inventory was the territory where agricultural land and certain land plots with self-seeded forest vegetation are located. Land area No. 1. The plots were located between the villages of Zastavye, Yosypivka, Kuty on the territory of the Busk urban community. Agricultural land was located in the natural area of Small Polissia and the forest-steppe zone (south-eastern part of the community's land use). The plots had a total area of 218.7 hectares and were used for haymaking, pasture, and arable land. Form of ownership – state property transferred to the communal ownership of a territorial community, private property.

Land area No. 2. It was located near the village of Biliavtsi within the Brody territorial community. The location of agricultural land plots is determined within Small Polissia (central part of the community's land use). The land plots had a total area of 48.2 hectares, the land was used for pasture, and the ownership was communal property of the community.

Land area No. 3. It was represented by arable land near the village of Bilyi Kamin within the Zolochiv territorial community. The plot was located in the forest-steppe zone (northern part of the community's land use). The plots had a total area of 45 hectares. 19 plots were examined. The purpose of the land plot – arable land, and the form of ownership – private property in the form of land shares. During the study, the Convention on Biological Diversity (1992) and Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973) standards were observed.

Results

The territory of Ukraine has a small forest cover, but despite this, it ranks 9th in Europe in terms of forest area and ranks 6th in terms of wood reserves (Fig. 1). Notably, forest areas of the steppe zone have the lowest forest value.

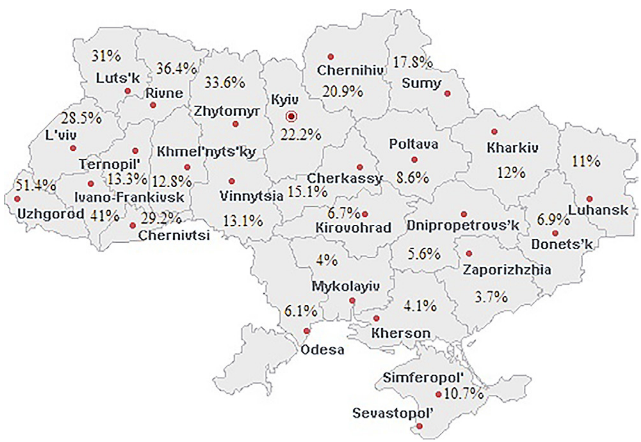

Figure 1. Forest cover of administrative regions of Ukraine
Source: developed by the authors based on data from the official website of the State Forest Resources Agency of Ukraine (General characteristics of..., 2024)

Forest cover varied from 3.7% in the Zaporizhzhia Oblast to 51.4% in the Zakarpattia Oblast (Announcement on the..., 2020). According to the areas with the smallest forest area size, Zaporizhzhia (3.7%), Mykolaiv (4%), and Kherson Oblasts (4.1%) belong to them. Half of the Woodlands in Ukraine (about 56%) were created artificially. About 0.8 million hectares of Ukrainian forests are classified as a reserve and are in a disordered state due to unauthorised logging, forest fires, plant diseases, and soil pests (State Forest Management..., 2020).

One of the objectives of the sustainable development programme of Ukraine until 2030 provides for the expansion of forest cover in the country from 15.9% to 20% (Sustainable Development Goals..., 2024). Since 2021, Ukraine has continued the process of conducting a national forest inventory. The main purpose of such an inventory was to ensure proper management of forest funds, control their use, and protect natural ecosystems. For the period 2021-2023, a survey of 4,135 thousand inventory sites was conducted (Public report of..., 2023).

According to the GFW website, in Ukraine, as of 2000, natural forests occupied 11.1 million hectares (18% of the area) (Ukraine Interactive Forest..., 2024). However, from 2001 to 2022, Ukraine lost 1.2 million hectares of forest cover, including 48 thousand hectares (0.43%) of natural forests lost in 2022 (Fig. 2).

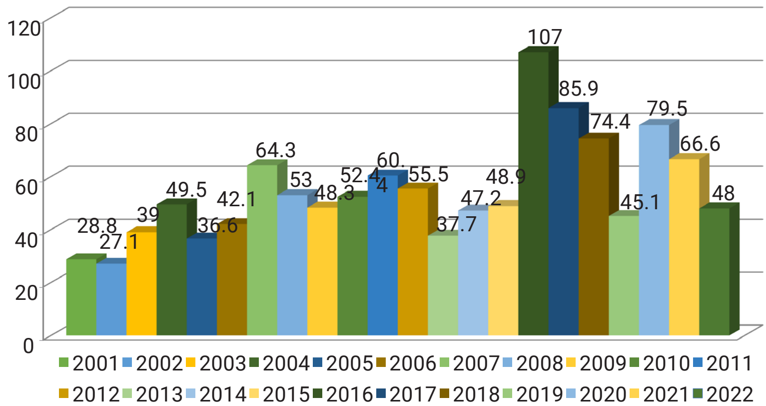

Figure 2. Data on tree cover losses in Ukraine from 2001 to 2022, thousand hectares
Source: developed by the authors based on GFW data (Ukraine Interactive Forest..., 2024)

From 2000 to 2022, there was an 11% decrease in forest cover. For the period 2001-2012, the growth of tree cover amounted to 353 thousand hectares, while losses – 557 thousand hectares (Ukraine Interactive Forest..., 2024). The main factors causing a decrease in forest cover from 2001 to 2022 include illegal felling of trees, negligent forest management, changes in the use of land plots for construction and agriculture.

The state statistics service of Ukraine published data that the area of forest reproduction in 2022 was 36.9 thousand hectares (33.2 thousand hectares less than in 2010), including by planting and sowing – 26.5 thousand hectares (29.6 thousand hectares less than in 2010), as a result of natural renewal – 10.4 thousand hectares (3.6 thousand hectares less than in 2010) (Environment of Ukraine..., 2023).

According to official data of the State Forest Resources Agency of Ukraine (State Forestry Agency) in 2023, the area of plots with forest vegetation of the forest fund of Ukraine amounted to 9.6 million hectares. Positive changes in forest reproduction were identified, according to which in 2023, compared to 2022, they increased by 3.1 thousand hectares (9.7%) (Public report of..., 2023). As of 2022, as part of the implementation of the Green Country programme, enterprises of the State Forestry Agency planted 174.8 million trees on an area of 16,890.8 hectares, while 5,691.47 thousand trees per hectare were planted in Lviv Oblast (Green country, 2021).

According to the GFW website, in 2000, natural forest covered 743,000 hectares (34% of the area) in Lviv and Lviv Oblast. From 2001 to 2022, 79.6 thousand hectares of forest cover were lost in the city and region, including 1.92 thousand hectares (0.26%) of natural forests were lost in 2022. From 2000 to 2022, the forest cover of the region decreased by 11% (Ukraine Interactive Forest..., 2024). Notably, in Ukraine and the Lviv Oblast, the level of forest losses exceeded the volume of their restoration. It is also worth noting the tendency to increase the area of forests in a natural way due to self-afforestation, including on agricultural land.

According to the legislation of Ukraine, degraded and unproductive land is subject to conservation. Land conservation measures include rehabilitation, transformation, and renaturalisation. The possibility of introducing each conservation area is considered on the example of three massifs of agricultural land in the Zolochiv District of the Lviv Oblast. When using remote sensing data, an analysis of the state of soil cover of agricultural land with self-seeded forest vegetation and unoccupied areas in the Zolochiv District was carried out. Figure 3 shows the privately owned land plots of area No. 1 with self-seeded forest vegetation within the Busk territorial community of Lviv Oblast.

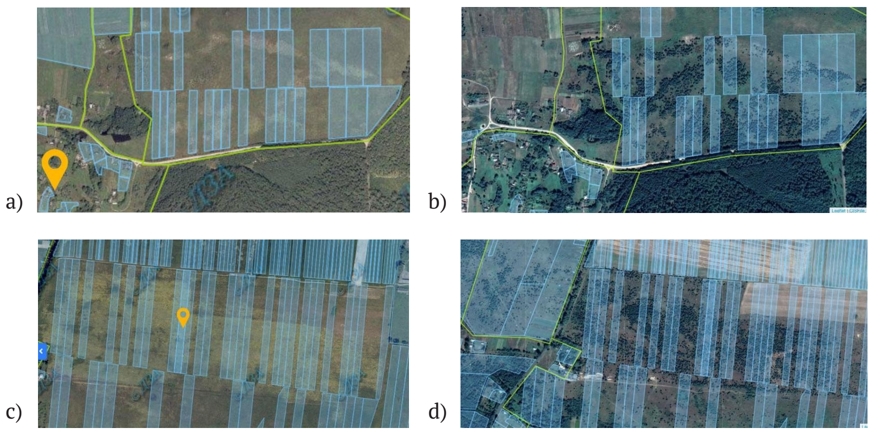

Figure 3. Private land plots with self-seeded forest vegetation within the Busk territorial community of Lviv Oblast

Note: 01.01 plots for commercial agricultural production, private property, land-pasture: a, c) copy from the public cadastral map of Ukraine (orthophotoplane 2011); b), d) copy from the GISFILE geoportal (space image of Google Satelite 2023)

Source: compiled by the authors

According to the results of the analysis, it was revealed that the self-afforestation of plots within the Busk territorial community occurred mainly on natural forage lands. There is no development of livestock farming in these areas, which is probably why the study sites were not used. These land plots were privately owned, outside the settlement and near existing Woodlands.

Based on the results of visual comparative analysis of figures 1a, 1b and 2a, 2b, it is noticeable that in 2011 the processes of independent afforestation of agricultural land on the studied plots were insignificant (Statistical Yearbook of…, 2017). However, after a twelve-year period of time, a large area of agricultural land was covered with forests. On the territory covered with forests, the presence of private land plots with an area of 0.7 to 1.5 hectares was noted.

According to the state land cadastre, these land plots are intended "for commercial agricultural production". On the ground there are ravines with slopes of 3-5°, which, with intensive agricultural use, can cause erosion. Information on the soil cover of the land areas of the plots under study is shown in Figure 4.

Figure 4. Ground cover of the land area No. 1 with self-seeded forest vegetation within the Buska urban community of Lviv Oblast

Note: with the code of the agricultural production group of soils – 158. Copy from the GISFILE Geoportal (2023 Google Satelite satellite image)

Source: compiled by the authors

Analysing the data on the soil cover of the area under study, it should be noted that the soil conditions represented by low-fertile swamp soils, meadow-swamp soils are vulnerable to flooding and erosion. Meadow-swamp soils were characterised by low productivity due to limited oxygen access to plant roots, high acidity and insufficient supply of nutrients, insufficiently deep underground water, flooding in the spring, autumn, and summer. Most often, such soils were used for natural forage land, and drained massifs – partially for arable land or vegetable growing. To solve the problems of low fertility, insufficient moisture supply and uneven distribution of nutrients on drained soils, various types of fertilisers should be applied, such as organic, manganese and copper microfertilisers, as well as potash and phosphorous fertilisers (Litvinova *et al.*, 2023). Marsh soils can be used for growing agricultural and vegetable plant species, provided that proper reclamation, fertilisation, and selection of agricultural crops capable of growing in conditions of waterlogging and cooling of the soil are observed. In the future, a swamp can be created on them as a valuable land for the ecosystem.

On the swampy soils of the land mass under study, it is advisable to carry out land conservation with their subsequent renaturalisation. For anthropogenically flooded soils of the automorphic range, land conservation should be applied by means of their alkalisation for a period of 10 to 20 years. Data on the soil cover of the land area No. 2 of the studied areas are shown in Figure 5.

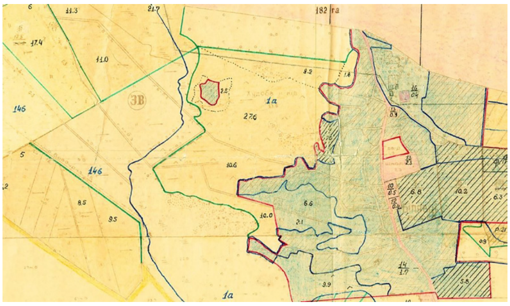

Figure 5. Ground cover of the land area no. 2 within the Brody urban community of Lviv Oblast

Note: with the code of the agricultural production group of soils – 1a

Source: compiled by the authors

The analysis identified land not covered with forest vegetation (non-forested areas) within the Brody urban community. Analysis of soil cover data of the land area No. 2 showed that these areas are represented by hidden sod-podzolic sandy soils on water-glacial deposits. These soils should be allocated for conservation and transformation, namely, subjected to the afforestation process. The land area is located near forest lands, so under such conditions, afforestation will unite existing woodlands, which is very important for maintaining biological diversity, in particular, migration of forest fauna. Using these areas with unproductive soils, the territorial boundaries of a locality can be expanded. However, the studied area near the village of Biliavtsi cannot be recommended as an attractive area for settlement, since the land mass is located at a fairly large distance from the city of Brody. Scheme of soil cover of land plots No. 3 is shown in Figure 6.

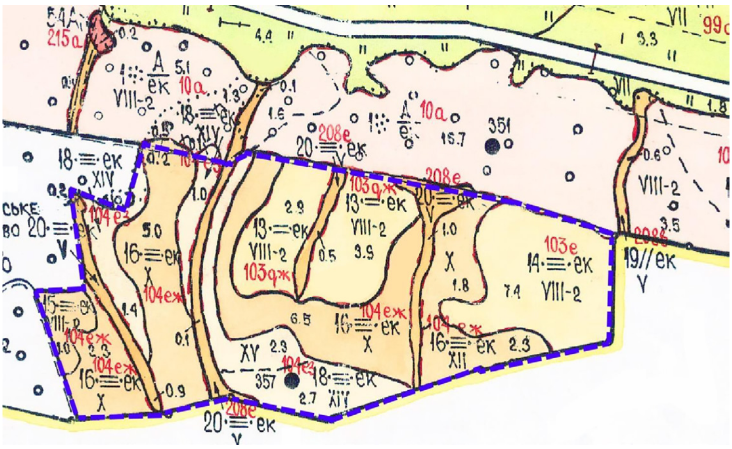

Figure 6. Ground cover of the land area No. 3 within the Zolochiv urban community of Lviv Oblast

Note: with the code of the agricultural production group of soils – 103 dj (sod-carbonate weakly eroded medium-chipped sandy-medium loamy soils on the alluvium of dense carbonate rocks); 103 e (sod-carbonate weakly eroded slightly crushed sand-heavy loamy soils on the alluvium of dense carbonate rocks); 104 ej (sod-carbonate weakly eroded slightly crushed soils with spots of medium eroded soils (30-50%) and sod-carbonate medium eroded medium crushed sand-heavy loamy soils on alluvium of dense carbonate rocks); 104 ez (sod-carbonate underdeveloped strongly crushed soils, sod-carbonate medium eroded medium crushed soils with spots of strongly eroded (30-50%) and sod-carbonate strongly eroded medium crushed sand-heavy loamy soils on the alluvium of dense carbonate rocks); 208 e (sod-carbonate alluvial sandy-heavy loamy soils on the alluvium of dense carbonate rocks)

Source: developed by the authors based on data from the Main Department of StateGeoCadastre in the Lviv Oblast

For the rehabilitation process, ground covers were allocated with codes of agricultural groups 103 dj and 103 e (with a slope steepness of 2-3°), codes 104 ej (with a slope steepness of 3-7°) and 104 ez (with a slope steepness of 7-15°) for transformation into pasture, and code 208 e (with a slope steepness of 0-1°) for alkalinisation.

Thus, within the Zolochiv urban community, 14.2 hectares were subject to rehabilitation, 27.3 hectares were recommended to be transformed into pasture, and 3.5 hectares were to be subjected to the alkalinisation process. Self-afforestation of agricultural land occurred for two reasons: land (arable land), the soil of which is degraded, unproductive and was not used for crops (categories of reserve land or unclaimed land shares (units); land plots for commercial agricultural production, which were not cultivated and were abandoned state (land in private ownership) (Santosa *et al.*, 2024).

The problem of self-seeded forests on agricultural land should be solved at the state level, but the final decisions on the use of such land plots should be made at the local government level when developing comprehensive plans for the spatial development of territorial communities. The global Millennium Ecosystem Assessment report, published in 2005, examines the fundamentals of the concept of ecosystem services (Guide to the…, 2005). Figure 7 shows the three main groups of ecosystem services.

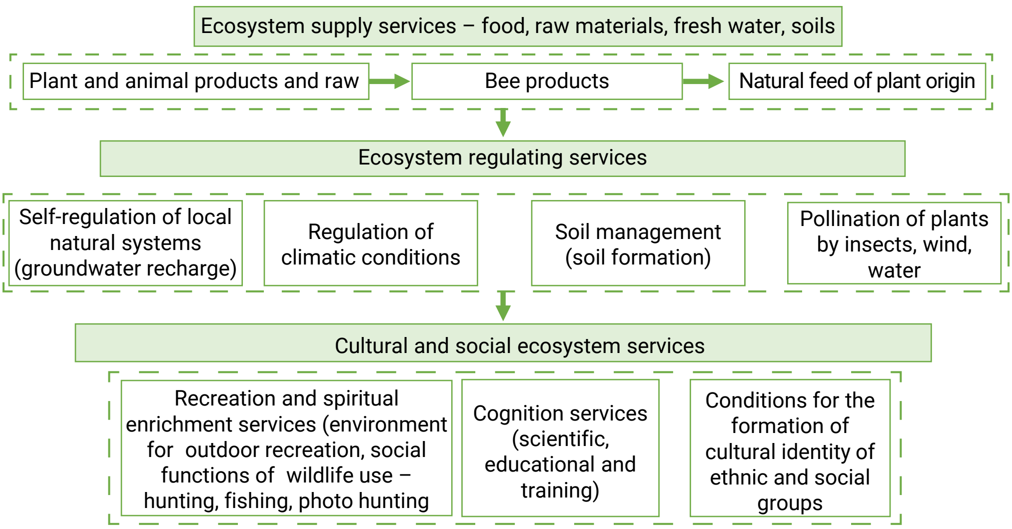

Figure 7. Ecosystem services group
Source: developed by the author based on the TEEB Manual for Cities: Ecosystem Services in Urban Management (2011)

Ecosystem services are benefits that people receive from ecosystems that can be tangible, such as food, building materials, water, or intangible, such as climate regulation, air and water purification, flood management, and recreational opportunities (Lipińska *et al.*, 2023b). Lviv Regional Department of Forestry and Hunting (RDFH) is located in Lviv. The total area of Lviv RDFH is 478.021 ha, including 431.8 ha covered with forest vegetation, of which 213.42 ha are used for forest crops. Air pollution data was measured at post No. 1 Rava-Ruska of the Lviv Regional Centre for Hydrometeorology. Table 1 shows the cost of forest ecosystem services.

Table 1. Assessment of the cost of forest ecosystem services

Ecosystem service	Amount	Unit price, UAH	Service cost, UAH/ha
Carbon dioxide assimilation, t/ha	5.04	420	2,117
Oxygen production, m^3/ha	350	110	38,500
Assimilation of pollutants, in particular:			
Sulphur dioxide (SO_2), mg/m^3	0.003	8,273.63	25
Nitrogen dioxide (NO_2), mg/m^3	0.03	2,574.43	77
Dust (suspended matter), t/ha	100	369.52 92.37	36,952
Total			77,671

Source: developed by the authors based on Environmental tax rates in 2022 (2022), Regional report on the state of the NPS (2023)

The total annual growth of wood reserves in the Lviv Oblast was 5.6 m^3/ha. The study assumes that the specific gravity of wood is about 0.5 t/m^3 (this may vary depending on the type of forest and tree species.) Then the growth of wood in tonnes per hectare will be equal to 5.6 m^3/ha * 0.5 t/m^3 = 2.8 t/ha. Assuming that each tonne of wood absorbs about 1.8 tonnes of CO_2 (carbon dioxide) during its lifetime, then the assimilation capacity of the forest in tonnes of carbon dioxide per hectare will be 2.8 t/ha * 1.8 t CO_2/t of wood will be equal to 5.04 t of CO_2/ha. Therefore, the calculation of the amount of carbon dioxide absorbed determines the assimilation capacity of the forest at 5.04 t/ha. At the current rate of UAH 420 per tonne, the price of the assimilation service was UAH 2,117 per hectare.

In the forests of the Lviv Oblast, the annual release, minus oxygen respiration, was estimated at 350 m^3/ha. Considering that the cost of industrial oxygen production is UAH 110 per m^3, the cost of the service was UAH 38,500 per hectare. On average, 1 ha of forest per year retained up to 100 tonnes of dust per year. Subject to the fee rate for 1 tonne of suspended matter emissions of UAH 369.52 per tonne, the price of the dust absorption service was UAH 36,952 per hectare. The calculation of the total value of regulating ecosystem services of the forest was UAH 77,671 per hectare.

The strategy of sustainable, scientifically based use of forest resources consists of plans and innovative approaches aimed at preserving and effectively using forest ecosystems, considering their sustainability and productivity for the long term. The introduction and application of innovative approaches for integrated planning of forest resources is proposed: creation of forest farms – the process of growing forest for the purpose of obtaining wood, improving the ecological state of the territory, preserving biodiversity and other ecosystem services; development of forest tourism – the process of promoting tourists to visit forest areas for rest, recreation, healthcare, and training (may include various activities such as hiking, cycling, camping, wildlife observation, excursions with educational purposes, photographing natural landscapes, etc.); the use of forest resources waste for the creation of biomass and biofuel production allows for more efficient use of woodlands, which can contribute to their economic sustainability and conservation; the creation of special forest stands for efficient air filtration and carbon reduction (oak, maple, fir, pine, and birch have a high capacity in carbon removal and air filtration); the use of modern drones to monitor forest ecosystems and control the use of forest resources; the use of artificial intelligence (AI) can be extremely useful for improving the efficiency of forest resources management and ensuring their sustainable development; the use of bio-refineries for processing forest resources when using all components of the stand (bark, leaves).

Discussion

Analysing the results of the study, it can be concluded that it is necessary to pay special attention to the implementation of integrated measures for the management of forest resources and land areas aimed at preserving environmental sustainability and maintaining the biodiversity of the region. The study by N. Reid *et al.* (2023), using examples of reforestation and forest rehabilitation in temperate regions, showed that the effectiveness of forest restoration depended on factors such as local climatic conditions and available financial resources. Ukraine could benefit from the experience of growing exotic plants mentioned N. Reid *et al.* (2023), such as the silver fern (*Punga* (*Cyathea dealbata*)), which grows in shade and humidity, and "New Zealand Christmas tree" (*Pohutukawa* (*Metrosideros excelsa*)) with red flowers blooming in winter. In addition, a native New Zealand plant known as rivea or "New Zealand violet", which has bright flowers and large leaves, can adapt to temperate climates.

J. Kuttippurath & R. Kashyap (2023) analysed changes in India's green cover, in particular, to increase the normalised difference vegetation index (NDVI), leaf area index (LAI) and (SiF) plant photosynthetic activity index. Approaches for assessing changes in India's green cover described by J. Kuttippurath & R. Kashyap (2023) can be useful for analysing the situation in Ukraine. In particular, the use of satellite field monitoring data, such as NDVI, LAI, and SiF indices, can help in assessing crop yield dynamics and studying the photosynthetic activity of the root system of plant crops.

M. Rosa *et al.* (2021) found that despite the relative constancy of indigenous forest cover in the Atlantic Forest of Brazil, there was a constant loss of old indigenous forests, mainly on the plain. Geographical and statistical research methods for analysing changes in the size of woodlands and their distribution in space and geoinformation analysis methods for mapping and determining the dynamics of changes in forest cover in the study area, which were used by M. Rosa *et al.* (2021), can be adapted to the conditions of Ukrainian forests.

A.K. Fernandes *et al.* (2023) reviewed scientific papers that assess the genetic diversity of restored areas in comparison with natural forest. In forest restoration programmes for the conservation of biodiversity in Ukraine, it is advisable to include commercial trees for growing, such as Scots pine (*Pinus sylvestrus*) 'Fastigiata' with a narrow columnar crown, common oak (*Quercus robur* L.), the white fir (*Abies alba*).

Proposal of G. Davidson *et al.* (2024) regarding the inclusion in future research of modern technologies, such as restoration of degraded natural forests in a closed canopy, can be considered justified, since the innovation will contribute to the strategy to combat monkey malaria. This new method of renewal of forest ecosystems can be implemented in Ukraine, but this requires the creation of protective forest zones around renewable woodlands, which may require significant financial resources compared to the renewal of forests in more favourable climatic conditions (Panfilova & Byelov, 2022). One of the necessary steps to restore such forests in Ukraine may be the removal of invasive plant species, which will help prevent the loss of native species (Lipińska *et al.*, 2023a).

S. Stephens *et al.* (2023) investigated the impact of various forest management methods on their recovery after a fire. The study by S. Stephens *et al.* (2023) found that the use of the combined Mech+Fire treatment was the most effective option that provided resistance to forest fires. The proposed forest management approaches, such as Mech, Fire or a combination of them, can also be applied in Ukraine and, in particular, include the removal of dry and diseased trees, selective felling to reduce competition between trees and increase forest recovery.

D. Pragya & P. Jaiswal (2022) proposed the implementation of forest restoration strategies such as rehabilitation, reconstruction, reclamation, and replacement. Compared to reconstruction, reclamation, and replacement of forests in terms of financial cost, forest rehabilitation in Ukraine may be less expensive, since natural restoration does not require human intervention and costs for planting material, but this process takes longer.

D. Evison & S. Wyse (2023) found that the survival rate of planted mountain beech seedlings was 75%, which indicated the effectiveness of forest restoration measures. The project is recommended in the study by D. Evison & S. Wyse, which aims to restore the forest by using the method of planting seedlings and using digital technologies to monitor and investigate the effectiveness of the restoration process, can be successfully implemented in Ukraine. This was due to the fact that the country is actively developing the latest technologies, such as the use of drones and satellite images for monitoring agricultural land (Fedoniuk *et al.*, 2024).

Project to restore ecological functions in degraded natural forests, implemented by H. Qu *et al.* (2024) can only be effectively applied on the southern coast of Crimea, as the peninsula is characterised by a mild subtropical climate favourable for oak and cypress forests that have adapted to prolonged summer droughts. The reason for the territorial restriction is the climatic conditions, according to which the mainland of Ukraine is characterised by a temperate continental climate with cold winters and warm summers, while in China the climate varies from tropical in the south to subtropical and temperate in the north. In the mountainous Crimea, 65% of the area of all forests is occupied by oak forests, beech – 14%, while in the forests of the Ukrainian Carpathians, spruce (41%) and beech (35% of the area is covered) predominate.

K. Lee *et al.* (2023) reviewed the use of the remote sensing method for monitoring, evaluating, and restoring damaged forests. The researchers highlighted an important topic of ecological forest restoration, which is becoming increasingly relevant in the context of the aggravation of the problems of forest destruction and loss of biodiversity in the Lviv Oblast. Recently in the Lviv Oblast, the development of a platform for forest restoration of Ukraine has begun, which will help restore and increase the area of plantings, and calculate the area of self-seeded forests using decoding satellite images.

The study by M. Heenatigala & G. Duh (2022) was conducted to identify the most effective forest restoration strategies in Sri Lanka, particularly, in the context of increasing forest cover to 30% by the end of 2025. Agreeing with the scientific theses of M. Heenatigala & G. Duh (2022), it can be noted that increasing forest cover is important for preserving biodiversity and reducing greenhouse gas emissions. However, it is also important to consider the potential negative consequences of such actions, in particular, possible disruption of the ecological balance and loss of natural ecosystems (Kotykova, 2022).

To map China's potential forest cover, X. Jiang *et al.* (2022) developed a random forest regression model to assess potential forest recovery zones and their impact on carbon uptake. This innovative model, proposed by X. Jiang *et al.* (2022), is successfully used in Ukraine in the field of ecology for predicting climate change, analysing environmental indicators and assessing the risk to ecosystems.

Thus, this section conducted a literature review and considered studies on such aspects as the impact of land use changes on biodiversity, forest management methods after fires, the impact of climate change on forest restoration, the effectiveness of various forest restoration strategies, the use of remote sensing for forest monitoring, and geospatial analysis to assess forest restoration in specific regions.

Conclusions

As a result of the study, it was found that the total area of woodlands in Ukraine in 2022 amounted to 36.9 thousand hectares, while in 2023, compared to 2022, they increased by 3.1 thousand hectares (or 9.7%). According to GFW data, during the period from 2001 to 2022 in Lviv and the Lviv Oblast, the total volume of forest cover losses amounted to 79.6 thousand hectares, including 1.92 thousand hectares of natural forests in 2022, which led to a decrease in the forest cover of the region by 11% for the period from 2000 to 2022. According to the calculation, the total cost of forest ecosystem services was UAH 77,671 per hectare.

Scientifically based areas of land conservation in the form of rehabilitation, transformation, and renaturalisation were important measures for preserving the natural environment and maintaining the ecological sustainability of the region.

The strategy of sustainable use of forest resources included an inventory of forests to determine the amount of wood that can be cut down without harming the ecosystem, and the development of forest management plans considering the conservation of biodiversity and the restoration of forest ecosystems. The main principles of this strategy included the following activities: development and implementation of a comprehensive forest management system that considers the needs of the ecosystem, society, and economy; preservation and restoration of the diversity of species, ecosystems, and genetic resources in forests; minimisation of the impact of human activities on forest ecosystems to preserve their value and stability; involvement of all stakeholders in the forest management process, including public organisations, local governments, industrial representatives, etc; constant monitoring of the state of forest ecosystems and assessment of the impact of human activities on them, to make adjustments to the management strategy; application of the latest technologies, innovative methods, and scientific research for improving the efficiency of forest management.

Consequently, the introduction of the proposed latest technologies will contribute to the creation of sustainable and efficient management on land with self-seeded forest stands, ensuring a balanced development of community territories, considering environmental and economic aspects.

The areas of further research in the areas of rehabilitation, renaturalisation, and transformation can be a detailed analysis of the impact of these measures on the preservation of soil cover, restoration of biodiversity, and the study of the relationship between measures for the conservation of land masses and changes in climatic conditions and the hydrological cycle.

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Conflict of Interest

None.

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Планування раціонального використання лісових ресурсів в Україні на основі поліпшення екосистемних послуг

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Анотація. Дослідження способів консервації земель для збереження та відновлення лісових масивів є важливим і актуальним з погляду збалансованого користування природними ресурсами та збереження біорізноманіття. Метою дослідження є вивчення ефективних стратегій експлуатації земельних угідь із самозалісненими ділянками для забезпечення потреб аграрного сектору Золочівського району Львівської області. В ході дослідження застосовувались методи: метод аналізу; географічний метод; статистичний метод; картографічний метод; геоінформаційний метод. Варто відзначити, що для земельної ділянки масиву No. 1 у межах Буської територіальної громади Львівської області було рекомендовано проведення консервації земель, з подальшою їх ренатуралізацією. Згідно результатів аналізу показано, що в 2011 році процеси самостійного залісення сільськогосподарських угідь у межах Буської територіальної громади були малозначними. В 2023 році ситуація покращилась, оскільки площа залісених земельних угідь значно збільшилась. До ґрунтів земельного масиву No. 2, що знаходився у складі Бродівської міської громади, було доцільним застосування консервації-трансформації. В Золочівській громаді на ділянці No. 3 необхідно відвести 14,2 гектарів під реабілітацію, 27,3 гектарів трансформувати у пасовище та 3,5 гектарів залужити. В роботі запропоноване впровадження інноваційних підходів для комплексного планування використання лісових ресурсів: створення лісових ферм, розвиток лісового туризму, створення спеціальних лісових насаджень для фільтрації повітря, застосування технології біорафінерії та інше. Результати дослідження можуть бути використані місцевими громадами для розробки та впровадження проекту заходів комплексного плану розвитку території Львівського регіону з метою покращення екосистемних послуг лісу

Ключові слова: інвентаризація; напрями консервації; сільськогосподарські масиви; самозалісені землі; грунтовий покрив; дистанційне зондування