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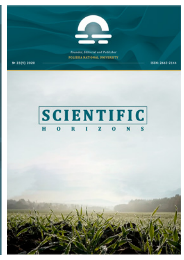

Assessment of the impact of the "Green Country" programme on carbon neutrality and long-term CO_2 absorption forecasts

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Abstract. The aim of the study was to determine the potential of the Green Country programme for CO_2 sequestration and its capacity to ensure the achievement of climate neutrality in Ukraine by 2035. A complex of spatio-temporal modelling, analysis of official statistical data from the State Forest Agency and geospatial assessment of natural zones using age-based absorption indicators was applied. Time intervals of 10, 20, 60 and 80 years were used to assess sequestration dynamics, alongside planting density standards and species composition of the stands. It was established that within the Green Country programme, as of the first half of 2025, 719.9 million trees had been planted, which made it possible to forecast an annual absorption of approximately 7.12 thousand tonnes of CO_2. The analysis demonstrated the dominance of coniferous stands (51.4%), which provided the highest productivity during the vegetation period of 0-20 years. Significant regional differentiation was identified: the highest sequestration rates were recorded in Polissia and Forest-Steppe, while steppe and eastern regions showed minimal values due to climatic constraints and the impact of military actions. The developed predictive model showed that over 80 years the plantations would be able to accumulate 376.3 million tonnes of CO_2, with 35.6 million tonnes absorbed over ten years and 142.5 million tonnes over twenty years. It was determined that if the current pace of forest restoration were maintained, the target of 75.6 million tonnes of CO_2-equivalents per year, set by the state strategy, would be exceeded by 2 million tonnes. The practical value of the research lay in the possibility of using the results by governmental bodies, environmental institutions and digital monitoring systems for afforestation planning and the formation of Ukraine's climate policy

Keywords: carbon sequestration; spatio-temporal modelling; age structure of forests; climate policy; forest ecosystems; environmental management

INTRODUCTION

The achievement of carbon neutrality was considered a key component of contemporary climate policy and served as a priority for most states within the framework of the Paris Agreement and the European Green Deal. Forest ecosystems were regarded as one of the most significant natural mechanisms of carbon

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sequestration, ensuring the absorption and accumulation of CO_2 in biomass and soils. Afforestation programmes implemented at national and regional levels were increasingly viewed not only as ecological measures but also as strategic instruments of state climate policy, capable of shaping a long-term balance of greenhouse gases. However, the actual effectiveness of such programmes depended on regional characteristics, the environmental condition of territories, the selection of tree species, the quality of forest management and the capacity of plantations to retain carbon in the long term.

The analysis of scientific publications demonstrated a growing interest in assessing the carbon potential of forests and identifying optimal strategies for their restoration. In the study by I. Ménard *et al.* (2022), a multi-model approach was applied to evaluate different afforestation scenarios, and it was proven that the choice of tree species and forest management strategies had a more substantial impact on carbon sequestration than climate scenarios. Similar conclusions were obtained in the work of A. Repo *et al.* (2024), where it was established that adaptive forest management strategies could lead to short-term reductions in carbon stocks, while still preserving potential for its accumulation in the long term. In the research conducted by M. Wolicka-Posiadała and A. Kaliszewski (2024), it was emphasised that the implementation of afforestation policy in the EU faced difficulties caused by the absence of a unified methodology for evaluating results and the fragmentation of sectoral strategies. Attention was also drawn to the conflict between environmental and economic priorities, which reinforced the need for integrated approaches to forest management.

For countries with high ecosystem vulnerability, the prioritised use of territories with maximum ecological potential acquired particular relevance. In the work of Fahrudin *et al.* (2024), the application of remote sensing data analysis was proposed for the spatial identification of areas ensuring the highest effectiveness of afforestation in terms of CO_2 absorption, biodiversity support and resilience to fires. The study by Z. Xu *et al.* (2025) also indicated the potential of optimisation models that considered climatic, economic and silvicultural factors when planning tree rotations; however, the authors stressed the difficulties of adapting such models to actual state policies and legal frameworks of different countries. Similar methodological limitations were identified in the work of K. Dsouza *et al.* (2025), where it was emphasised that most carbon sequestration models failed to account for the dynamics of soil organic carbon, seasonal fluctuations and the impact of anthropogenic factors.

In the context of Ukrainian research, active scientific interest was likewise observed in the potential of forest plantations for carbon sequestration and climate adaptation. The analysis of scientific sources demonstrated a gradual formation of a national approach to assessing the carbon balance of forest ecosystems and developing models for forecasting their absorption capacity. In the study by R. Feshchenko and A. Bilous (2022), the structure of carbon deposited in forest biomass was examined using the case of the 'Feofania' nature park, and the importance of employing local models for estimating the carbon reserve of protected territories was substantiated. In the research conducted by I.V. Gruzinska and T.P. Fedoniuk (2025), factors influencing the carbon balance of forest stands were assessed, with emphasis placed on climatic parameters and afforestation indicators, and the application of quantitative models was proposed for identifying zones with the highest sequestration productivity. In the work of V. Pasternak *et al.* (2021), monitoring data from the Forest-Steppe of Eastern Ukraine were analysed, and regional differences in carbon content were determined depending on the age and type of plantations. Additionally, in the study by V. Moroz *et al.* (2020), the absorption potential of pine forest cultures in Polissia was substantiated, and the necessity of considering the spatial distribution of plantations when forming environmental policy was highlighted. The totality of these findings indicated the growing relevance of the problem of CO_2 sequestration in Ukraine and confirmed the need to establish a national system of spatio-temporal modelling, which determined the foundation of the present study.

Therefore, the aim of the research was to assess the impact of the President's Green Country programme on achieving carbon neutrality in Ukraine and to model long-term CO_2 sequestration scenarios by forest ecosystems.

MATERIALS AND METHODS

The methodological approach of the study was based on a combination of statistical analysis, quantitative modelling and spatio-temporal assessment aimed at determining the potential of Ukraine's forest plantations for CO_2 sequestration within the framework of the President's Green Country programme and the achievement of the national goal of carbon neutrality. Official data from the State Forest Agency of Ukraine (State Forest Resources Agency of Ukraine, n.d.) and the President's Green Country Programme (President's Green Country Programme, n.d.) were used, covering the period from the second half of 2021 to the first half of 2025. To ensure the representativeness of the analysis, preliminary systematisation of information was carried out by regions, species composition of plantations, natural zones and the dynamics of annual tree planting. The official statistical data did not contain direct CO_2 sequestration indicators, which necessitated the development of an independent forecasting model that accounted for the specificity of Ukrainian forests, their age structure and the normative planting density.

The calculation part of the study was based on adapted CO_2 absorption coefficients defined in the work of B. Bernal *et al.* (2018), which served as an internationally recognised benchmark for assessing the climate-regulating function of forest ecosystems. According to the provided parameters, broadleaf species in a temperate humid climate ensured the absorption of 21.1 tonnes of CO_2 per hectare per year, whereas coniferous species absorbed 11.6 tonnes of CO_2. The inclusion of these indicators enabled a standardised comparison of regions and the identification of dominant species that formed the primary contribution to the carbon balance. The highest level of sequestration occurred within the age interval of 0-20 years, corresponding to the phase of most intensive biomass growth. This temporal range was therefore determined as the baseline for assessing the effectiveness of the Green Country programme, while subsequent calculations covered 60 and 80 years – the periods of mid-age development and wood maturity, reflecting long-term perspectives of carbon absorption.

To determine potential plantation areas, a normative planting density of 1500 seedlings per hectare was applied, in accordance with the requirements of DSTU 8119:2015 (2017) and the Resolution of the Cabinet of Ministers of Ukraine No. 303 (2007). The planting standards took into account the type of forest-growing conditions, the dominant species and the economic purpose of cultivation, and their use made it possible to construct both implemented and projected plantation structures. The annual volume of CO_2 absorption was calculated using the following formula:

$$C = A \times D \times R, \tag{1}$$

where C represented the volume of CO_2 absorption (tonnes per year), A denoted the area of forest plantations (ha), D corresponded to the normative planting density (seedlings per ha), and R was the absorption coefficient derived from tabulated values.

The obtained data made it possible to determine not only the overall absorption potential but also the regional differences in CO_2 sequestration depending on species composition and natural zone. The constructed model also included spatio-temporal differentiation of the data. For this purpose, a cartographic analysis was carried out, within which forests were classified according to the main natural zones of Ukraine: the Carpathians, Polissia, Forest-Steppe and Steppe. Within each zone, dominant species, regeneration density and age structure of plantations were identified, which enabled the delineation of areas with the highest sequestration potential. The temporal dimension made it possible to assess the evolution of carbon absorption over 10-, 20-, 60- and 80-year intervals, which allowed the modelling results to be linked to the strategic aim of increasing greenhouse gas absorption to 75.6 million tonnes of CO_2-equivalent per year, as defined in the State Forest Management Strategy of Ukraine until 2035. This approach formed an analytical basis for the quantitative assessment of the feasibility of achieving this goal and allowed the degree of correspondence between regulatory benchmarks and the actual state of forest restoration to be determined.

The methodological approach was aligned with contemporary priorities of climate and forest policy in the European Union. In particular, the EU Biodiversity Strategy for 2030 (European Commission, 2020) defined the relevance of considering forests not only as CO_2 sinks but also as providers of biodiversity and ecosystem services. Provisions of the New EU Forest Strategy for 2030 (European Commission, 2021) formed the basis for the inclusion of age structure, species composition and spatial differentiation, all of which were integrated into the CO_2 sequestration forecasting model. The spatial component of the methodology was reinforced by the principles of digital monitoring implemented on the MapMyTree platform (European Environment Agency, n.d.), confirming the feasibility of applying a similar approach to establish a national system for spatial analysis of forest restoration in Ukraine.

RESULTS AND DISCUSSION

In light of the global challenges associated with climate change, Ukraine, as a European country, actively integrated climate and environmental priorities into its state policy. An important component of this process was the development of comprehensive programmes for the restoration and preservation of forests, since forest ecosystems served as key natural carbon sinks while simultaneously playing a critical role in maintaining biodiversity. In response to the need to combine climatic, environmental and economic aspects of development, large-scale initiatives in the field of forestry were launched in Ukraine. In the context of climate commitments, the Energy Strategy of Ukraine until 2050 (Resolution of the Cabinet of Ministers of Ukraine No. 373-p) should be highlighted first, as it established the goal of achieving carbon neutrality. Within its provisions, the land use and forestry sector was designated as one of the key compensators of residual greenhouse gas emissions. The tasks formulated in the energy policy reinforced initiatives aimed at increasing forest cover and ensuring sustainable forest management, making them a crucial element of the national decarbonisation strategy.

Furthermore, at the end of 2021, the Cabinet of Ministers of Ukraine adopted the State Forest Management Strategy of Ukraine until 2035 (hereinafter – the Strategy). This was the first strategic document in the forestry sector that accounted for environmental and biodiversity-related components alongside economic ones. The Order of the Cabinet of Ministers of Ukraine No. 1777-r (2021) outlined five development priorities: efficient forest management, ensuring ecological stability, securing a substantial contribution of forests to economic development, recreation and an open society, research and education. For the effective implementation of the Strategy, the Green Country presidential programme was introduced in 2021 under the Decree of the President of Ukraine No. 228/2021 (2021) within the framework of the environmental initiative Large-Scale Afforestation of Ukraine. The programme envisaged an increase of forested areas by 1 million hectares through the planting of 1 billion tree seedlings.

The Green Country programme held significance not only for achieving climate goals but also for supporting the development of rural areas, improving the environmental situation in the country and ensuring ecosystem services. It also formed part of Ukraine's commitments within international climate agreements and aimed to reduce the impact of CO_2 emissions by expanding forested areas. According to data from the State Forest Resources Agency of Ukraine (n.d.) (hereinafter – the Agency), as of the first half of 2025, approximately 719.9 million trees had been planted under the Green Country presidential programme. These were predominantly young trees aged between one and three years (Fig. 1).

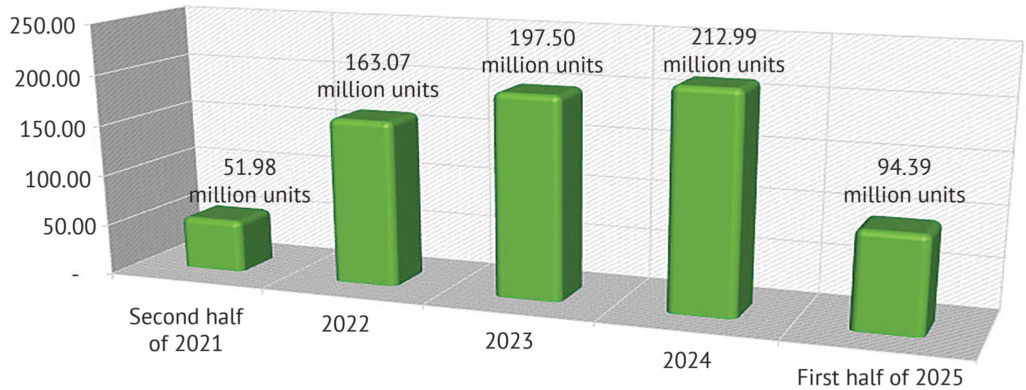

Figure 1*. Number of trees planted under the President's Green Country programme, 2021-2025*
Source: *compiled by the authors based on State Forest Resources Agency of Ukraine (n.d.)*

The analysis of the dynamics of tree planting in 2021-2025, illustrated in Figure 1, indicated a gradual increase in the scale of forest restoration in Ukraine. In the second half of 2021, 51.98 million seedlings were planted, serving as a starting point for further expansion of indicators. By 2022, a substantial increase in planting volumes was observed, reaching 163.07 million units, which exceeded the previous period by more than threefold. This trend continued in subsequent years: in 2023 the planting volume reached 197.50 million, and in 2024 it rose to 212.99 million seedlings. This demonstrated a stable intensification of tree planting within the programme. In the first half of 2025, 94.39 million trees had already been planted, allowing for the forecast of surpassing previous annual figures by the end of the year. The presented data reflected steady growth in the implementation pace of the President's Green Country programme. The dynamics of planting volumes pointed to the formation of a positive trajectory necessary for achieving the state's long-term climate and environmental objectives.

To assess the impact of the President's Green Country programme on carbon neutrality, maps were developed by regions of Ukraine based on the Agency's data, illustrating in Figures 2 and 3 the number of trees planted as of the first half of 2025, differentiated by coniferous and broadleaf species.

The analysis of the aggregated data indicated that within the implementation of the President's Green Country programme in 2021-2025, coniferous species dominated over broadleaf species. The total number of trees planted amounted to approximately 720 million seedlings, of which 473.6 million (65.8 per cent) were coniferous species, while 246.4 million (34.2 per cent) were broadleaf. This proportion corresponded to the established practice of forest restoration focused on fast-growing coniferous species, which effectively stabilised soils and performed a climate-regulating function. The regional analysis showed that the Carpathian region (Zakarpattia, Ivano-Frankivsk and Chernivtsi oblasts) demonstrated some of the lowest overall indicators of programme implementation compared with other forested areas in Ukraine. In these regions, between 1.8 and 4.6 million trees were planted annually on average, whereas in forest-steppe and Polissia regions (Zhytomyr, Rivne and Kyiv oblasts), annual volumes reached tens of millions. This was due to the predominance of selective sanitary felling and the high rate of natural forest regeneration, which did not require additional artificial afforestation.

A long-term forecasting model of CO_2 absorption by forest plantations planted in different regions of Ukraine under the President's Green Country programme was developed, taking into account the most productive vegetation period of 0-20 years. An absorption rate of 11.6 was applied for coniferous trees and 21.1 for broadleaf species, according to the data provided in Table 1. For the calculation of the long-term forecasting model of CO_2 sequestration by forest plantations, the number of trees planted within the President's Green Country programme was used based on data from the State Forest Resources Agency of Ukraine (n.d.). According to the data shown in Figure 4, it was established that the forest plantations planted under the President's Green Country programme from the second half of 2021 to the first half of 2025 would accumulate approximately 7.12 thousand tonnes of CO_2 per year.

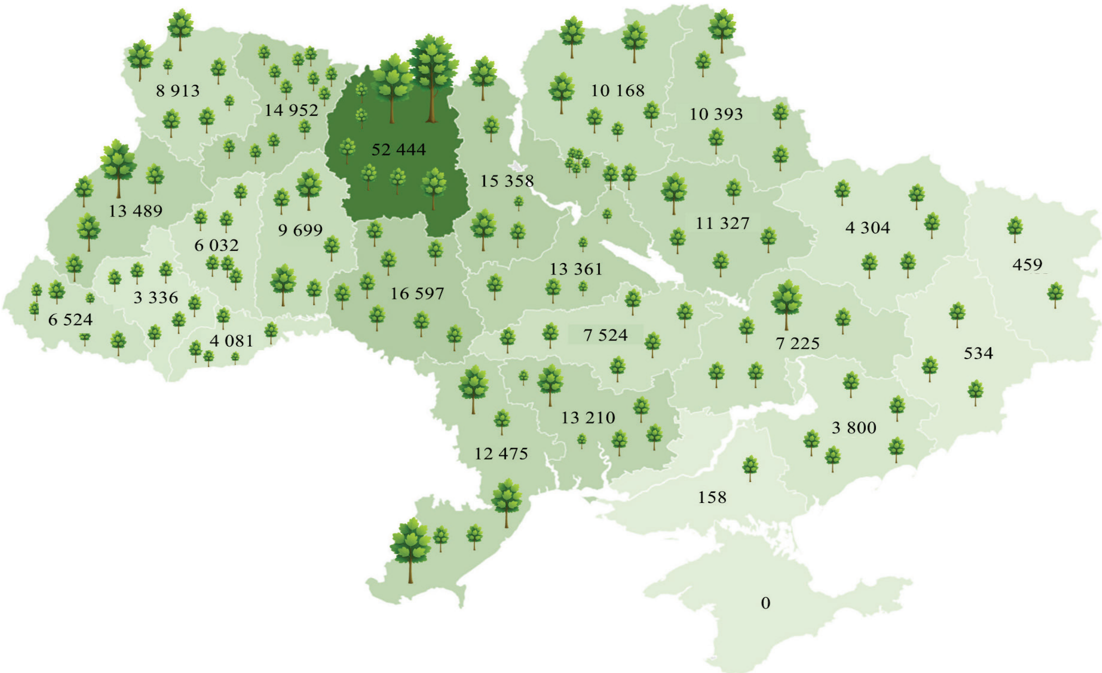

***Figure 2**. Volume of trees planted by species category "broadleaf", 2021-2025*
***Source:** compiled by the authors based on State Forest Resources Agency of Ukraine (n.d.)*

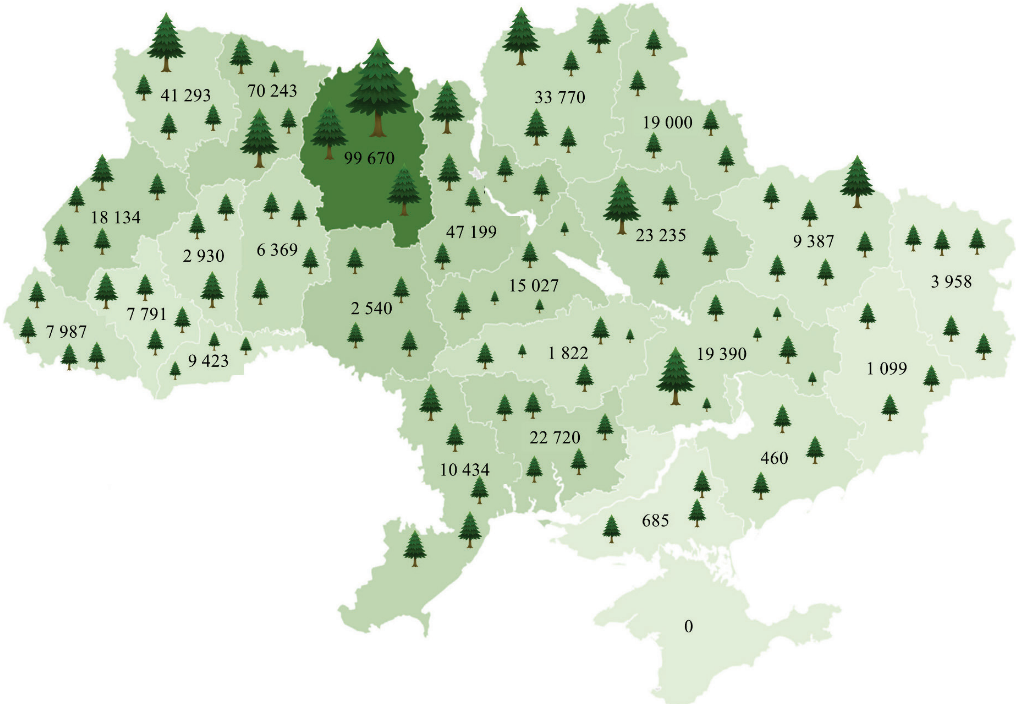

***Figure 3**. Volume of trees planted by species category "coniferous", 2021-2025*
***Source:** compiled by the authors based on State Forest Resources Agency of Ukraine (n.d.)*

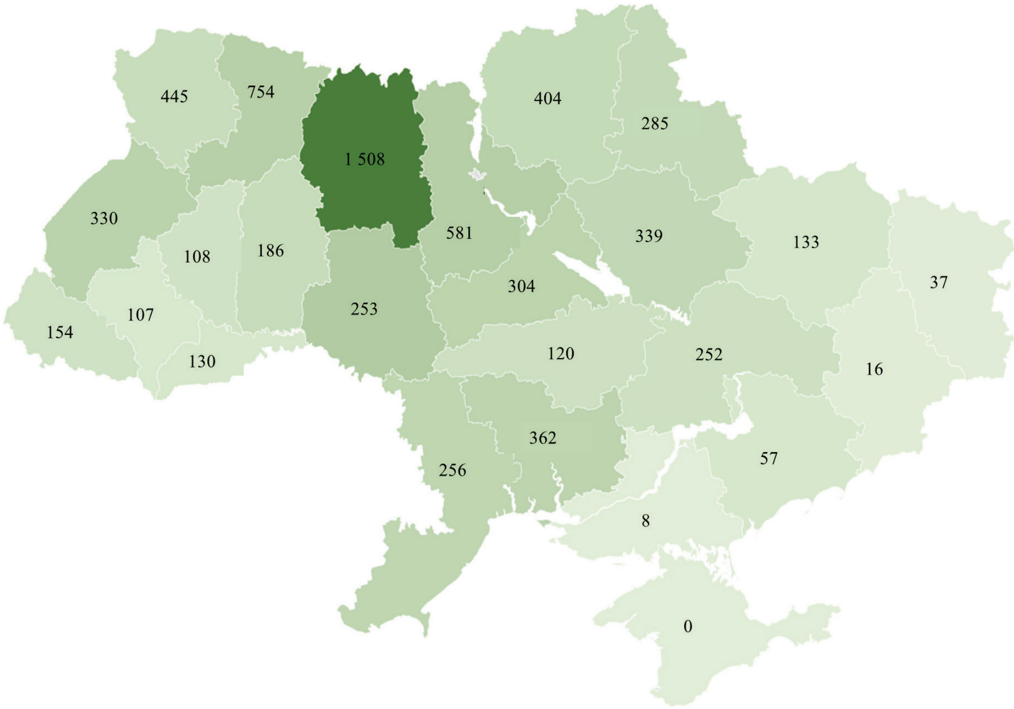

***Figure 4**. Modelled map of CO_2 absorption potential, thousand tonnes per year*
***Source:** compiled by the authors based on State Forest Resources Agency of Ukraine (n.d.)*

This modelling made it possible to determine that the greatest effect of the President's Green Country programme on CO_2 absorption was observed in the following oblasts: Zhytomyr – 1,508 thousand tonnes per year, Rivne – 754 thousand tonnes per year and Kyiv – 581 thousand tonnes per year. The lowest tree planting rates were characteristic of Donetsk, Luhansk, Zaporizhzhia and Kherson oblasts, located within zones of military action, which consequently resulted in low CO_2 absorption indicators. Overall, the spatial distribution of CO_2 absorption by forest plantations within the President's Green Country programme demonstrated substantial regional differentiation. The programme targeted the creation of artificially established forests in regions with limited natural regeneration. It had the strongest effect in Polissia (Zhytomyr, Rivne, Volyn and Chernihiv oblasts) and partly in the Forest-Steppe, providing the main contribution to absorption, whereas steppe and eastern oblasts remained the least effective due both to natural-climatic conditions and the consequences of military actions.

Within the study, modelling of the share of CO_2 absorption by forest plantations planted under the President's Green Country programme was carried out, considering the most productive growth period of 0-20 years across natural zones: the Carpathians (Zakarpattia, Ivano-Frankivsk, Lviv and Chernivtsi oblasts); Forest-Steppe (Vinnytsia, Kyiv, Poltava, Ternopil, Kharkiv, Khmelnytskyi, Cherkasy and Sumy oblasts); Polissia (Volyn, Zhytomyr, Rivne and Chernihiv oblasts); Steppe (Autonomous Republic of Crimea, Dnipropetrovsk, Donetsk, Zaporizhzhia, Kirovohrad, Luhansk, Mykolaiv, Odesa and Kherson oblasts), as well as species types, as shown in Figure 5.

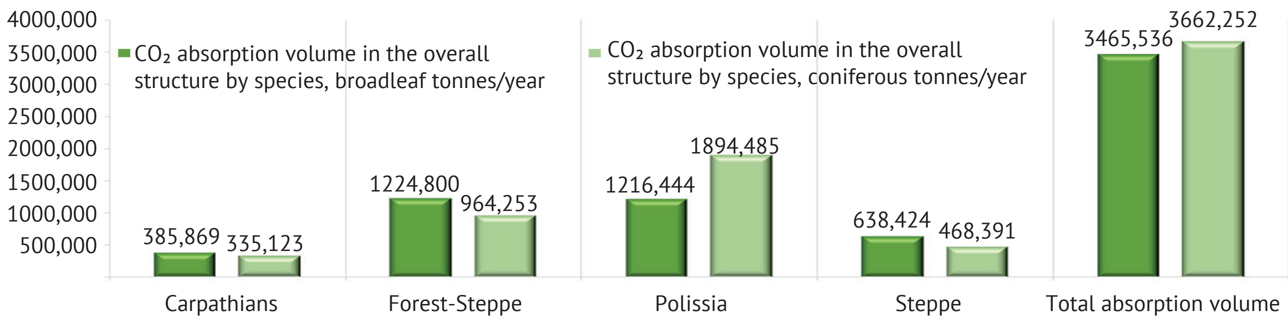

***Figure 5**. Modelling of the share of CO_2 absorption by natural zones and forest plantation types*
***Source:** compiled by the authors*

The analysis of the spatial distribution of CO_2 absorption by natural zones and species indicated that coniferous plantations accounted for 51.4 per cent of total sequestration, while broadleaf species represented 48.6 per cent. The highest CO_2 absorption rates were characteristic of Polissia and the Forest-Steppe, where the combined absorption capacity was greatest due to the substantial proportion of both coniferous and broadleaf species. Conversely, the Carpathians and the Steppe exhibited lower CO_2 absorption rates, which were attributed to the reduced level of tree planting in these regions within the framework of the President's Green Country programme and, accordingly, a much smaller contribution to total CO_2 absorption in the overall structure shown in Figure 5. Hence, the efficiency of carbon fixation varied considerably depending on the natural zone, the quantity and the species composition of forest plantations.

The analysis of CO_2 absorption dynamics over time, presented in Figure 6, showed that trees planted under the President's Green Country programme could absorb 376.3 million tonnes of CO_2 over 80 years. In a ten-year perspective, the volume of carbon absorbed by forest plantations could amount to 35.6 million tonnes of CO_2, creating conditions for a cyclical absorption capacity in the following years. This trend indicated significant growth in the absorption potential of forest plantations during their middle age. In turn, after twenty years the plantations would accumulate approximately 142.5 million tonnes of CO_2, and over sixty years – 342.1 million tonnes of CO_2.

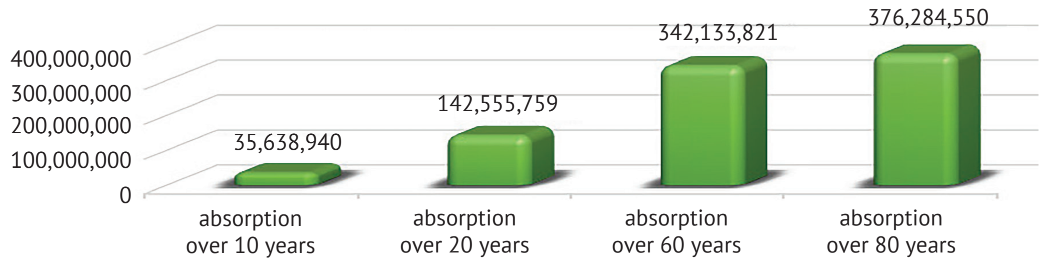

***Figure 6**. Dynamics of CO2 absorption over time: 10, 20, 60 and 80 years*
***Source:** compiled by the authors*

Thus, the efficiency of CO_2 absorption had a pronounced age-related pattern. In particular, the greatest contribution to climate stability was made by middle-aged and mature forests, while young and over-mature plantations demonstrated considerably lower absorption capacity. This indicated the need for a balanced forest management strategy that would combine the regeneration of young plantations with the maintenance of an optimal age structure of forests.

One of the key objectives of the State Forest Management Strategy of Ukraine until 2035 (Order of the Cabinet of Ministers of Ukraine No. 1777-r, 2021) was to enhance the capacity of forests to absorb greenhouse gases, especially carbon dioxide. The Strategy envisaged increasing the absorption level of greenhouse gases by Ukrainian forests to 75.6 million tonnes of CO_2-equivalent per year. However, the Strategy did not specify a baseline level of greenhouse gas absorption by forests in Ukraine. The baseline indicator amounted to approximately 43 million tonnes of CO_2 as of 2025, taking into account the forest area indicators presented in the Report of the Head of the State Forest Resources Agency for 2024 (State Forest Resources Agency of Ukraine, n.d.).

Considering that in a ten-year perspective the carbon absorption volume of forest plantations could reach 35.6 million tonnes of CO_2, as shown in Figure 6, and taking into account the calculated baseline value of approximately 43 million tonnes of CO_2 as of 2025 Ukraine would achieve the target of increasing the level of greenhouse gas absorption by forests to 75.6 million tonnes of CO_2-equivalent per year by 2035, since the estimated absorption volume would amount to 77.6 million tonnes. This indicated a positive dynamic of the impact of the President's Green Country programme on achieving the target of increasing the level of greenhouse gas absorption by forests, as well as the goal of climate neutrality. The analysis of the obtained indicators showed that the projected volume of CO_2 absorption, defined according to the applied methodology, fully ensured the achievement of the strategic targets established by the Strategy and exceeded them by 2 million tonnes. However, the attainment of this result would only be possible if the full number of seedlings envisaged under the President's Green Country programme were actually planted, and if proper agrotechnical and silvicultural maintenance were provided to ensure optimal growth and absorption capacity.

The results of the study allowed for a comprehensive assessment of the potential of the President's Green Country programme in the context of achieving Ukraine's climate objectives, particularly regarding the strategic task of increasing greenhouse gas absorption to 75.6 million tonnes of CO_2-equivalent by 2035. The obtained findings were explained primarily by the age structure of forest plantations and regional characteristics. In the first 10-20 years (Fig. 6), forest plantations ensured the highest rates of CO_2 absorption due to intensive biomass growth. The greatest effect was concentrated in Polissia and the Forest-Steppe (Zhytomyr, Rivne and Kyiv oblasts), while steppe and eastern regions displayed the lowest values due to military actions and unfavourable climatic conditions (Fig. 5). The spatial distribution by natural zones and species (Fig. 5) confirmed that coniferous trees dominated the absorption structure (51.4 per cent) due to higher biomass density, although the proportion of broadleaf species was only slightly lower (48.6 per cent). In the temporal perspective, the modelling (Fig. 6) demonstrated a clear age dependency: 35.6 million tonnes of CO_2 at 10 years, 142.5 million tonnes at 20 years, 342.1 million tonnes at 60 years and 376.3 million tonnes at 80 years. The greatest contribution was made by middle-aged and mature forests, while young and overmature plantations exhibited significantly lower productivity. This confirmed the necessity of maintaining an optimal age structure of Ukraine's forests.

In turn, the comparison of the obtained research results with the target defined in the Strategy – 75.6 million tonnes of CO_2-equivalent per year – showed that with a baseline level of greenhouse gas absorption by forests in Ukraine of approximately 43 million tonnes in 2025 and the projected increase, the volume would reach 77.6 million tonnes by 2035. Thus, the target would be exceeded by 2 million tonnes. However, this outcome depended on the full implementation of the afforestation volumes envisaged in the President's Green Country programme, as well as proper management of forest plantations and the reduction of risks related to factors such as fires or pests.

As in the study by I. Ménard *et al.* (2022), which analysed the impact of species composition and climate scenarios on afforestation potential in Quebec, the results of the present research also demonstrated that the choice of species for planting and the adopted forest management strategy were crucial for shaping carbon stocks. A key scientific gap was the absence of a universal methodology for assessing the effectiveness of afforestation programmes and state strategies. The presented study partly addressed this issue by combining quantitative forecasting, spatial analysis and regulatory indicators to develop a tool for estimating CO_2 absorption potential. This approach considered not only plantation area but also age structure and species composition, bringing the results closer to real conditions. Moreover, the scenario-based approach, which accounted for different growth rates, forest management types and planting standards, provided flexibility in forecasting and planning, allowing for a balanced assessment of risks and potential benefits of each management decision.

The constructed model of CO_2 sequestration within the Green Country programme demonstrated the uneven potential of Ukrainian regions and highlighted the need to evaluate territorial priorities. A similar conclusion was presented in the work of Fahrudin *et al.* (2024), where it was determined that the highest carbon absorption levels were possible in regions with a balanced combination of climatic and soil characteristics. Based on the obtained results, this pattern was confirmed: the highest sequestration rates were recorded in the natural zones of Polissia and the Forest-Steppe, where the productivity of forest plantations exceeded the national average. A comparable statement was demonstrated in the study by M. Wolicka-Posiadała and A. Kaliszewski (2024), although the authors limited their analysis to strategic documents without developing a temporal model or quantitative forecast of sequestration, which heightened the significance of the current assessment.

A comparable approach was recorded in the study by A. Repo *et al.* (2024), where it was demonstrated that the age of plantations was a key parameter for determining the effectiveness of CO_2 absorption, and the optimal temporal interval was precisely 0-20 years. This was consistent with the approach applied in the model, which accounted for age structure and enabled the formation of a stable predictive trajectory of carbon accumulation. A conceptually similar conclusion was presented in the work of Z. Xu *et al.* (2025), where emphasis was placed on the importance of plantation rotation and the integration of economic and ecological objectives; however, the authors' model was not adapted to the specific conditions of individual countries, whereas the present research established regional parameters using the example of Ukraine.

In the studies most closely related to the present topic, I. Ménard *et al.* (2022) applied a multi-model approach that accounted for climate change, which resonated with the methodological principles of spatial differentiation used in this research. However, the authors did not analyse the relationship between afforestation programmes and CO_2 sequestration, which made it possible to enhance the approach within the framework of the current study. The importance of territorial criteria was also confirmed in the work by M. Fuller *et al.* (2025), where it was noted that the most accurate projections were achieved when ecological and economic indicators were combined within a single model. This corresponded fully with the modelling logic applied in the assessment of the Green Country programme.

At the same time, a number of studies emphasised the limitations of existing models. In the research by K. Dsouza *et al.* (2025), it was stressed that most assessments failed to account for seasonal fluctuations and soil organic carbon, which reduced forecast accuracy. Some of these limitations were addressed in the current model through age-based differentiation, although the introduction of soil carbon parameters required further research. In the study by S. Holzwarth *et al.* (2023), the problem of fragmentation in remote sensing was identified, yet the authors did not propose a mechanism for adaptation to the policy level, whereas the present study suggested using forecasts as an element of state monitoring.

The comparison of the obtained results with contemporary geospatial approaches demonstrated the necessity of moving from linear calculations of CO_2 absorption to a systemic assessment of the spatial suitability of territories. In the study by T. Burke *et al.* (2021), it was proven that achieving national climate targets was only possible when regional land-use structure, soil potential, fragmentation effects and land availability for afforestation were taken into account. The results presented in this research confirmed this position, as the established differentiation of Ukraine's natural zones indicated varying degrees of readiness for CO_2 sequestration. In the works of M. Castro-Magnani *et al.* (2021) and F. Aggestam and A. Giurca (2021), the necessity of combining remote sensing with econometric models to determine the socio-economic value of carbon absorption was emphasised. This approach correlated with the identified patterns in the present study, which indicated the importance of forest restoration for rural development, the formation of local ecosystem services and the enhancement of climate resilience in regions that experienced the greatest anthropogenic and military pressure. Both sources confirmed the relevance of using spatial and economic differentiation as a basis for establishing policy priorities in forest management and CO_2 sequestration.

Thus, the comparative analysis demonstrated that the results of the current research aligned with international trends while supplementing existing approaches through the implementation of spatio-temporal assessment of sequestration and integration with state policy. This evidenced the potential of the model for application in the formulation of afforestation priorities, resource planning and the creation of an environmental monitoring system, which could form the foundation for digital forest management in Ukraine.

CONCLUSIONS

The synthesis of the research findings confirmed the substantial potential of Ukraine's forest plantations to achieve the target sequestration level of 75.6 million tonnes of CO_2-equivalent by 2035. It was established that the most productive vegetation interval was the period from 0 to 20 years, during which broadleaf plantations were capable of absorbing on average up to 21.1 tonnes of CO_2 per hectare per year, while coniferous species absorbed approximately 11.6 tonnes of CO_2 per hectare. Provided that the planting norm of 1500 seedlings per hectare was maintained, the total projected sequestration volume could reach 23-28 million tonnes of CO_2 within the first two decades of the programme's implementation. The spatial analysis revealed a clear regional differentiation: more than 60 per cent of the potential absorption was concentrated in the Polissia and Forest-Steppe zones, while steppe territories were characterised by lower values due to limited forest-growing conditions and elevated levels of climatic stress.

The results of modelling age-related dynamics indicated the feasibility of phased forecasting of CO_2 absorption: the first 10-20 years of vegetation provided the maximum effect, whereas the intervals of 60 and 80 years formed the basis of a long-term ecological reserve and could be used to assess the overall contribution of forest restoration to the national carbon balance. It was identified that the application of mixed plantations, in comparison with uniform structures, enabled an increase in sequestration efficiency by 12-18 per cent, and the use of digital monitoring tools laid the foundation for the development of a national system for precise accounting of CO_2 absorption. Additionally, a socio-economic effect was recorded, involving the potential to increase productive employment in rural communities by 8-10 per cent, as well as the prospect of restoring more than 200 thousand hectares of degraded land.

The obtained data confirmed the relevance of integrating forest restoration into climate and regional policy as a systemic instrument of environmental stabilisation, local economic development and the formation of a resilient natural environment. Prospects for further research were associated with improving modelling algorithms, applying machine learning for the assessment of carbon flows and creating an integrated GIS platform for monitoring CO_2 sequestration at the national level.

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CONFLICT OF INTEREST

There is no conflict of interest with regard to this study, including financial, personal, authorship or other conflicts that could influence the study and its results presented in this article.

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Оцінка впливу програми «Зелена країна» на вуглецеву нейтральність та довгострокові прогнози поглинання CO_2

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Анотація. Метою дослідження було визначити потенціал програми «Зелена країна» щодо секвестрації CO_2 та її здатність забезпечити досягнення кліматичної нейтральності України до 2035 року. У роботі застосовано комплекс просторово-часового моделювання, аналіз офіційних статистичних даних Держлісагентства та геопросторову оцінку природних зон із використанням вікових показників абсорбції. Для оцінки динаміки секвестрації використано часові інтервали 10, 20, 60 та 80 років, а також нормативи густоти висадки й видовий склад насаджень. Було встановлено, що в межах програми «Зелена країна» станом на I півріччя 2025 року висаджено 719,9 млн дерев, що дозволяє прогнозувати щорічне поглинання близько 7,12 тис. тонн CO_2. Здійснений аналіз показав домінування хвойних насаджень (51,4%), що забезпечують найвищу продуктивність у період вегетації 0–20 років. Виявлено значну регіональну диференціацію: найбільші показники секвестрації зафіксовано у Поліссі та Лісостепу, тоді як степові та східні регіони демонструють мінімальні значення через кліматичні обмеження та вплив воєнних дій. Створена прогностична модель засвідчила, що за 80 років насадження зможуть акумулювати 376,3 млн тонн CO_2, при цьому у десятирічний період буде поглинуто 35,6 млн тонн, а через двадцять років – 142,5 млн тонн. Було визначено, що при збереженні поточних темпів лісовідновлення ціль у 75,6 млн тонн CO_2-еквівалентів на рік, визначена державною стратегією, буде перевиконана на 2 млн тонн. Практична цінність дослідження полягає в можливості використання результатів державними органами, екологічними установами та системами цифрового моніторингу для планування заліснення та формування кліматичної політики України

Ключові слова: секвестрація вуглецю; просторово-часове моделювання; вікова структура лісів; кліматична політика; лісові екосистеми; екологічне управління