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CLIMATOSTABILIZING VALUE OF OAK SHELTERBELTS IN UKRAINIAN POLISSYA

Management of forest plantations involves not only the use of forest products, but also the preservation of their productivity, enhancement of ecological functions, and improvement of recreational and aesthetic values[1]. Forest plantations are a reliable stabilizer of the environment in agricultural landscapes, able to deposit carbon from the atmosphere in their phytomass for a long time and generate oxygen, which partially prevents global climate change.

Currently, much attention is focused on improving methods of accounting and studying the ecological functions of massive forest plantations, but little attention is paid to shelterbelts, in particular oak forests, which are an integral element of the agricultural landscape structure[2]. Assessment of the climatostabilizing functions of oak shelterbelts in Ukrainian Polissya will improve the accounting system for these plantations and establish their functional and ecological role.

Thus, the issue of accounting for greenhouse gas absorption, assessment of oxygen-creating capacity and energy efficiency of growth of oak shelterbelts in Ukrainian Polissya is quite an urgent task and needs to be studied using modern forestry and taxation methods.

The 2015 Paris Agreement establishes a framework for limiting global warming to well below 2°C, preferably to 1.5°C (degrees Celsius), compared to pre-industrial levels. To achieve this global temperature limit, countries aim to reduce the growth of greenhouse gas emissions as quickly as possible and then reduce them rapidly based on the best available science and economic and social feasibility[3].

The effects of climate change are already clearly visible in rising air temperatures, melting glaciers and shrinking polar ice caps, rising sea levels, increased desertification, and extreme weather events such as heat waves,

1 Alexiuk, I.L., Lakida, P.I., Terentyev, A.Y. (2013). Peculiarities of changes in taxonomic indicators of pine stands of natural origin in Polissya of Ukraine depending on their composition. Scientific Bulletin: National University of Life and Environmental Sciences of Ukraine. Series: Forestry and ornamental gardening, 187 (2), 9–15.

2 Bertash, B.M., Galukha, V.L., Mykytyn, T.M. (2011). All about biomass. P.: Rivne Center for Marketing Research. 36.

3 Buksha, I.F., Butrym, O.V., Pasternak, V.P. (2008). Inventory of greenhouse gases in the land use and forestry sector. KH.: KHNAU. 232 .

droughts, floods and storms. Climate change is not globally uniform and affects some regions more than others.

In recent years, the average annual temperature in Zhytomyr Polissya has increased by 2.5°C, according to the Ukrainian Hydrometeorological Center.

Such temperature changes have led to the drainage of water bodies in Polissia, a decrease in the groundwater level, drying out of coniferous tree species and weakening of deciduous trees[4]. Climate change affects the soil regime, increasing biological activity in the soil, resulting in mineralization and decomposition of humus, which has a direct impact on increasing carbon emissions from the soil. Such changes are unfavorable given that soils have a carbon reserve that is 2 times greater than the atmosphere and 3 times greater than plants, so an increase in temperature has irreversible global changes[5].

The second important indicator in assessing climate change is precipitation, whose formation and precipitation are the result of complex macro-circulation processes that determine heat and moisture exchange in the atmosphere. According to the analysis, the average annual precipitation in Zhytomyr Polissia increased by 2 mm over the period 1961–2022.

Increasing air temperature also leads to an increase in precipitation, which in turn leads to an increase in evaporation and the number of floods. In addition, an increase in humidity affects the rate of reproduction of phytopathogens and fungal diseases of plants[6].

Given that over the past 100 years, the global air temperature has increased by 1°C, and in Ukraine by 1.4°C, there is a need to take all necessary measures to improve climate change.

Environmental significance of shelterbelt forestry. Protective forest plantations are an effective long-term means of combating soil erosion and a universal environmental stabilizer[7]. The ecological role of forest belts in agricultural landscapes is manifested in counteracting dry winds, neutralizing the harmful effects of deflation to a certain extent by reducing wind speed and water consumption for transpiration and physical evaporation, increasing air humidity and lowering the temperature in the inter-belt fields, protecting fields from ruderal invasions, and preserving and improving soil fertility.

4 Didukh, Y.P. (2009). Ecological aspects of global climate change: causes, consequences, actions. Bulletin of the National Academy of Sciences of Ukraine, 2, 34–44.

5 Gitarskiy, M.L. (2017). Carbon flux from deadwood in the southern taiga forests of the Valdai Upland. Ekologiya, 6, 447–453. https://doi.org/10.7868/S0367059717060063

6 Golubets, M.A. (2000). Ecosystemology. Lviv. 316.

7 Ivanov, A.V. (2018). Carbon emission from the surface of deadwood in the cedar forests of the Southern Primorye. Ekologiya, 4, 275–281. https://doi.org/10.7868/S0367059718040042

Numerous studies have shown that forest belts affect the temperature of the surface air layer, reducing it in summer and increasing it in winter by 1–6°C, increasing air humidity by 2–3 and sometimes by 10–12 %, reducing physical evaporation from the soil surface by 30–40 %and from plants by 20 %, and transpiration by 14 %.

In the works of V.O. Bodrov, V.I. Koptev, O.I. Pylypenko, A.P. Stadnyk, G.B. Gladun, V.Y. Yuhnovsky, and others. The theoretical foundations and practical and analytical material on the ecological and functional role of shelterbelts are presented[8].

Shelterbelt afforestation involves improving soil and climatic conditions for growing crops and protecting soils from erosion in steppe and forest-steppe regions.

The system of shelterbelts has numerous potential benefits for land use, including protection of crops and pastures from dry winds, protection of farm animals from winds, provision of habitat for wildlife and birds, prevention of soil salinization and erosion, preservation of soil moisture, creation of natural barriers to the spread of weeds, pests, pathogens, etc.

Forest belts contribute to high and sustainable yields even in years with unfavorable weather and climate conditions[9]. In the case of long-term forest strips (30–50 years or more) in the Black Earth Steppe, the integrated soil improvement is about 25 %, and crop yields on field lands increase by 10–20 %. Under the influence of forest belts, the efficiency of agrotechnical measures, including no-till tillage with the preservation of stubble, is significantly increased.

Protective forestry affects the efficiency of the agro-industrial complex. Under the protection of shelterbelts, crop yields increase by 20 %, grain yields increase by 20 – 40 % on average, vegetable yields increase by 45–60 %, and grass seedlings increase by 2 times. In addition, the productivity of pastures increases by up to 25 %; which ensures an increase in dairy production by up to 12 %.

In his research, V.I. Koptev found that with an increase in field protection strips to 3 %, their agroclimatic impact contributes to an increase in yield: 4.6 c/ha (32.8 %) for grain crops, 3.3 c/ha (40.4 %) for sunflower, and 48 c/ha (64.7 %) for corn for silage[10].

8 Kasatkin, A.C., Zhanabaeva, A.S., Akimov, R.Y. (2015). Above-ground phytomass and qualimetry of some tree species of southern Sitote Alinia. Eco-potential, 1 (9), 41–50.

9 Kashpor, S.M., Strochynskyi, A.A. (2013.) Forestry reference book. K.: Vinnichenko Publishing House. 496.

10 Krasnov, V.P., Shelest, Z.M., Davydov, I.V. (2012). Phytoecology with the basics of forestry. Study guide for higher educational institutions. Sumy. 415.

With a difference in forest cover of 1.5 %, differences in yields are on average 29.8 %for winter wheat, 37.1 %for barley, and 27.2 %for oats.

Millions of hectares of arable land in Ukraine are protected by shelterbelts (1 hectare of shelterbelt protects 20-30 hectares of arable land), which increases the efficiency of these lands and reduces the cost of crop production. The increase in yields for every 0.5 %of arable land afforestation ranges from 0.75 to 3.5 %.

The impact of forest belts on crop yields is closely related to their age and height. The higher the height and age, the higher the absolute and relative yields. The effectiveness of mineral and organic fertilizers increases under the influence of forest belts, and they are a permanent factor in improving environmental conditions in the fields.

According to the research of scientists in Ukraine, the level of air pollution in the system of shelterbelt forest plantations is reduced by 7–35 %, 1 hectare of forest plantations cleans 50–70 tons of air from dust in one year, reducing its concentration by 30–40 %[11].

Protective forest plantations perform health-improving functions. They clean the air from dust and gaseous toxicants, enrich the air environment with oxygen and negatively charged ions, have antimicrobial and sterilizing properties, and influence the carbon cycle in nature, in particular, assimilate and retain its compounds for a long time.

Forest plantations are recognized as effective carbon storage facilities (reserves) that can naturally reduce its concentration in the environment and bind it in wood, bark of tree trunks and branches for a long time, which is important for stabilizing the global climate.

The greenhouse effect plays a significant role in shaping the climate on the planet, depending on the content of gases in the atmosphere: carbon dioxide – 55 %, freons – 24 %, methane – 15 %and nitrogen oxides – 6 %. Anthropogenic activity increases the concentration of greenhouse gases in the air, especially CO_2[12].

According to recent meteorological observations, the average annual temperature in Ukraine is 0.5–1.3°C above normal, and the increase in temperature is associated with an increase in greenhouse gas emissions, especially carbon[13].

11 Lakyda, P.I. (2001). Dynamics of carbon stocks in the forests of Ukraine. Collection of scientific papers «Problems of forest science and silviculture». Gomel. 86–90.

12 Lovynska, V.M. (2018). Aboveground phytomass of Pinus Sylvestris L. trunks in the stands of the northern Steppe of Ukraine. Scientific Bulletin of NLTU of Ukraine, 28(8), 79–82. https://doi.org/10.31521/2313-092X/2018-3(99)-12

13 Moroz, V.V., Nykytyuk, Yu.A. (2020). Carbon absorption ability of pine forest plantations in Volyn Polissya. Scientific horizons, 1(86), 61–70. https://doi.org/10.33249/2663-2144- 2020-86-1-61-70

Forests play a huge role in preventing global climate change, which is associated with an increase in the concentration of greenhouse gases, primarily CO_2, in the Earth's atmosphere. According to the UN Framework Convention on Climate Change adopted in 1992. Framework Convention on Climate Change and the Kyoto Protocol (1997), Ukraine is tasked with annual inventory and control of greenhouse gases in all sectors of the economy, including the forestry sector.

At the end of 2015, the Paris Agreement was signed to replace the Kyoto Protocol, aimed at accelerating the implementation of the UN Framework Convention on Climate Change and was ratified by Ukraine in 2016. This agreement allows for the sale of emission allowances on the international market[14].

Therefore, the creation of a system for accounting for the carbon-absorbing capacity of shelterbelts using modern silvicultural and taxation methods is a very relevant and modern task.

Current state of shelterbelt forest plantations. According to the current legislation of Ukraine, forests are divided into the following categories depending on their functions:

1) forests of nature protection, scientific, historical and cultural purposes;
2) recreational and health forests;
3) protective forests;
4) exploitation forests.

The category of protective forests includes forest areas that perform the function of protecting the environment and engineering facilities from the negative impact of natural and anthropogenic factors, in particular linear type forest plantations – field protection forest belts (FPB), state protective forest belts, forest belts along built-up areas of settlements; forest areas (forest belts) located in the right-of-way of canals, railways and highways; forest areas (forest belts) adjacent to the right-of-way of national roads and separated from the category of operational forests with a width of 250 meters on each side of the road[15].

Despite the fact that the national program for the formation of the national ecological network of Ukraine and the State Target Program «Forests of Ukraine»

14 Moroz, V.V., Nykytyuk, Yu.A. (2020). Carbon absorption ability of pine forest plantations in Zhytomyr Polissya. Irrigated agriculture. Interdepartmental thematic scientific collection, 73, 43–50. https://doi.org/10.32848/0135-2369.2020.73.13

15 Moroz, V.V., Nykytyuk, Yu.A. (2020). Carbon absorption ability of pine forest plantations in Chernihiv Polissya. Bulletin of the Poltava State Agrarian Academy, 1, 90–99. https://doi.org/10.31210/visnyk2020.01.10

for 2000–2015 provided for the creation of 174 thousand hectares of shelterbelts, in reality, the area of shelterbelts is decreasing annually, which is a cause for concern among experts. The program «Forests of Ukraine» for 2016–2020 left out the system of field protection plantations. Over the past 10 years, the number of protected forests has been created as much as in just one year in the 1980s. Compared to 1990, the number of FPBs has decreased by 90 %, and such changes have a negative impact on the ecological value of the IBA[16].

According to official statistics, there are currently about 446 thousand hectares of shelterbelts in Ukraine. The largest areas under linear shelterbelts are located in Zaporizhzhia (51.9 thousand hectares), Odesa (50 thousand hectares), and Dnipro (42.5 thousand hectares) regions.

According to various authors, the optimal forest cover for Ukraine should be 19–22 %, including 37 %in Polissia (actual 26.1 %), 17 %in the Forest-Steppe (13 %), 8 %in the Steppe (3.5 %), and 50–53 % in the Carpathians (40.2 %).

Currently, shelterbelts in Ukraine are in a state of disrepair, which makes it impossible for them to fulfill their protective functions. As a result of the land reform, land shares have become private property of peasants, and the BFBs actually located on them belong to the state (state property). Due to the territorial indivisibility of the property object and the insecurity of the state component (the PFLs remained unprotected), private property almost completely absorbed state property. Another legal conflict is that shelterbelt forests are potentially agricultural land, but they are not agricultural land[17].

The average area under protective forest plantations is about 40 thousand hectares, of which 15 %are field protection forest plantations.

In the field protection strips that have not been transferred to the ownership and permanent use (about 318 thousand hectares), protection, care and reproduction are not carried out. The absence of sanitary and felling operations has provoked the growth of root and seed growth, and the number of pests (rodents) has increased dramatically. As a result of thinning of plantations by unauthorized logging, the processes of sodding and soil compaction develop, and overgrown and shrubby vegetation appears. Often, forest strips become breeding grounds for weeds, places for grazing and garbage dumps, and suffer from fires during stubble burning (Figures 1, 2).

16 Moroz, V.V., Stasiuk, N.M., Fedoniuk, T.P. (2021). Peculiarities of Growth, Development and Climate Stabilization Value of Spruce Plantations in the Ukrainian Carpathians. Scientific Bulletin of UNFU, 5, 36–41. https://doi.org/10.36930/40310505

17 Moroz, V.V., Stasiuk, N.M., Tymoshenko, L.M.. (2021). Features of growth, development and climate stabilizing of fir plantations in the Ukrainian Carpathians. Balanced nature management, 3, 68–77. https://doi.org/10.33730/2310-4678.3.2021.247139

Figure 1. Unauthorized felling of shelterbelts

Figure 2. Lack of forestry care for forest strips

In addition, forest belts that are not properly maintained lose their ecological functions.

In recent years, the creation and restoration of protected forest belts in Ukraine has been absent.

The only measure to address this situation is the regulatory framework governing the creation of linear-type protective forest plantations (which include shelterbelts) and forest management.

In Polissia, shelterbelts created with a predominance of oak trees are of various shapes – strips, ribbons, stakes, areas in massifs, on slopes and ravine and gully tracts. They differ in habitat conditions, agricultural techniques, initial and subsequent composition, age, generation, structure, density and interaction of tiers, forestry and protective reclamation status, forest environment, grass cover, litter features, biogeocenotic formation and stability.

The surviving shelterbelts are of medium age, usually of rows, with a mixed composition of oak, ash, pear, other tree species and shrubs. Pure oak forest belts are rare, with a width of up to 20 meters, including edges. Row strips usually have 7–9 rows of trees with a row spacing of about 1.5 m. Young strips are more often 5-row with row spacing of up to 3 m, the inner rows consist of oak in rows or holes, and the outer rows consist of maples, linden, sometimes with oak.

In addition, the current state of shelterbelts has been negatively affected by violations of recommendations on the selection of plantation species and agricultural practices. There is no data on the types and scope of work to correct existing stands, improve their efficiency or replace them.

The vast majority of oak plantations are formed by the natural forest environment, without forestry intervention. Often, stands have different age composition, which significantly reduces their protective functions. The low effectiveness of field protection oak plantations is also due to the fact that in forest belts, common oak occupies less than 50 %of the total number of trees. In many plantations, oak is in the second tier and is suppressed by other species.

The largest area under shelterbelt plantations in the Ukrainian Polissya zone is occupied by Kyiv oblast (11.5 thousand hectares) and Chernihiv oblast (10.3 thousand hectares).

If we compare the area of forest vegetation covered by shelterbelts in 1996 and 2011, we can conclude that in 2011 the area under linear plantations increased in Volyn region by 68.4 %, in Chernihiv region by 13.1 %, and decreased in Zhytomyr region by 29.0 %, in Kyiv region by 3.8 %.

According to the State Forest Cadastre, the largest area under oak shelterbelts in Ukrainian Polissia is occupied by linear plantations in Chernihiv Oblast – 6.8 thousand hectares.

The Polissia zone is characterized by sod-podzolic soils (strong, weak, and medium podzolic). This type of soil conditions was formed under pine and mixed forest plantations, although it is sometimes found under deciduous tree species.

The humus content ranges from 0.6–1.0 %, characterized as low and very low; on sandy and clay-sandy soils, the humus content is up to 1.5–2.0 %.

The most common soils of Ukrainian Polissya are soddy-medium podzolic soils.

When planning the experiment, we used a scientific research methodology based on the collection of the material under study, its statistical processing using arithmetic averages, and methods of analysis and synthesis.

The field collection of material included taxation of model trees and processing of experimental material. Desk-based processing of the collected empirical data was carried out using systematization, forestry and taxation methods, mathematical modeling of biometric parameters, modeling of dependencies between taxation values and phytomass indicators of model trees in the plantation.

Selective methods were used to characterize the population by its parts. According to the data of several model trees, the set of all trees in the test area was characterized, and according to the data of a number of test areas, the set of homogeneous plantations was characterized.

Materials and methods of the study: during the field research of tree accounting, an altimeter IU1M, an aluminum peace plug Haglof (Sweden) were used. A multifunctional device FLO 89000 (Poland) and a GM 1030 luxmeter were used to establish the microclimate at the experimental sites.

A detailed analysis of biometric indicators was carried out on 84 test plots. The established trial plots ranged from 0.045 to 0.24 hectares, with tree diameters ranging from 14.0–36.3 cm, heights of 14.0–26.0 m, tree ages ranging from 25 to 71 years, and plantation bonuses of classes Ia, I, II, and III. The soil cover under the tree plantations is represented by typical and podzolized black soil, dark gray podzolized and gray forest soils, and sod-podzolic soils.

In most of the temporary test plots, the soil acidity was pH 7.0 (neutral). The air temperature under the strips was 2°C lower than in the field, and the soil temperature was 8°C lower than in the field. Soil moisture in the strip was identical to that in the field. Illumination in the strip was 2 times lower than in the field.

Oak field protection plantations in the research area are represented by three age categories: maturing 60–71 years, middle-aged – 35–40 years.

The work on the establishment of trial plots was carried out in the places of forest belts, which typically reflect the structure and design of the plantation. The trial plots were established in the following order: delimitation of the territory, tying and installation of poles; determination of the composition of the plantation, structure and other taxation and forest reclamation indicators with recording in the trial plot map; list of trees and shrubs (undergrowth); determination of tree height using a height meter (eclimeter); determination of the stock and volume of wood.

The size of the sample depended on the number of measured trees by the diameter of the main species of the first tier. The width of the sample depended on the width of the forest belt, which was measured in three ways: by edges (the width of the forest belt is limited to the extreme rows) – in1, by rows (standard or design width) is set taking into account the row spacing (half a row on each side) – in2, by projections of the crowns of the fringe rows – in3. The length of the sample for plantations up to 20 years old is approximately 100 m, and for plantations over 20 years old – 200 m. The composition of the plantation was determined by the share of tree species stocks and expressed by a formula containing coefficients (integers, each unit of which corresponds to 10 %of the share of a particular tree species in the total stock). Tree species with a stock of up to 5 %of the total stock of the stand were represented in the composition formula with a «+» sign. When determining the age group (young, middle-aged, ripening, mature, and overstayed), we used assortment tables. The nature of crown placement in the plantation is used to determine the closeness of the plantation by eye.

The study of phytomass in field protection plantations was carried out by combining empirical (observation, experiment) and theoretical (analysis, synthesis, mathematical modeling) methods. The basis for such experimental studies are the taxonomic developments of A. A. Strochynskyi and A. Z. Shvydenko, which are supplemented by special biometric techniques depending on the object of study.

The research was based on the methodology of P. I. Lakida, which was modified to the object of research. This methodology is widely used in Ukraine, it combines the study of biological productivity of forest plantations with taxation and biometric methods.

Based on the data obtained, correlations between the main taxonomic indicators and phytomass fractions were established.

According to the obtained correlation coefficients, there is a close relationship between phytomass fractions and height and diameter, while the relationship between age and phytomass is above average.

According to the statistical analysis, the sample is homogeneous in terms of height, diameter and age of the plantation. Moderate asymmetry is observed in the phytomass of wood and bark, as well as in the height and age of trees. The asymmetry is leftward in diameter and age.

The results of the analysis allow for further analysis and construction of regression equations between the fractional phytomass of a tree (crown, bark, wood) and biometric indicators (height, diameter).

To obtain power-law dependencies of phytomass on tree diameter and height, all indicators were prologarithmized, and equations were searched using the Microsoft Excel analysis package.

It can be concluded that in forest belts with the same diameter and height, common oak in the Polissia zone accumulates 9 %more carbon in wood and 13 %more in bark than in the Forest-Steppe zone. And in the Forest-Steppe zone, 3 %more carbon is accumulated in the crown of the tree.

On the established test plots, the vast majority of shelterbelts are represented by medieval and maturing oak plantations, and the amount of accumulated phytomass by individual tree fractions was determined using the obtained mathematical models.

The average age of the middle-aged oak linear plantations on the test plots is 37 years, the diameter of such plantations is 19.3 cm and the height is 14.7 m, the average age of the matured plantations is 65 years, the diameter is 23.8 cm and the height is 16.7 m, the total phytomass of such a tree is 157.7 kg for a middle-aged tree and 275.9 kg for a matured tree.

According to the data of the main statistical departments in Volyn, Zhytomyr, Chernihiv, and Kyiv regions, the amount of CO_2 emissions into the atmosphere for the period 2006–2021 was analyzed. According to the obtained data, the amount of carbon emissions is decreasing annually: if in 2008 this amount was within 4.2 million tons, in 2021 it decreased by 64.3 %.

CONCLUSIONS. It has been analyzed that in the study region for the period 1961–2022, there is an increase in the average annual air temperature by 2.5˚C and an increase in precipitation by 2 mm.

It has been determined that the phytomass of common oak wood increases with an increase in tree diameter by 1.94 %and height by 1.0 %, bark phytomass with an increase in diameter by 1.62 %and height by 1.0 %, crown phytomass increases with an increase in tree fullness by 3.24 %and height by 0.3 %.

It has been established that the total phytomass of oak in linear plantations is 157.7 kg for a middle-aged tree and 275.9 kg for a mature tree.

It was found that in forest belts with the same diameter and height, common oak in the Polissia zone accumulates 9 %more carbon in wood and 13 %more in the bark than in the Forest-Steppe zone. And in the Forest-Steppe zone, 3 %more carbon is accumulated in the crown of the tree.

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