Ukrainian Journal of Ecology

Ukrainian Journal of Ecology 2020, 10(2), 249-255, doi: 10.15421/2020_91

RESEARCH ARTICLE *UDC 630.181:581.132:58.087*

Carbon Absorption Ability of Pine Forest Plantations in the Ukrainian Polissya

V.V. Moroz[1], Y.A. Nykytiuk[1], P.A. Nykytiuk[2], M.M. Kliuchevych[1], O.M. Komorna[1]

[1]Zhytomyr National Agroecological University 7, Stary Blvd, Zhytomyr, 10008, Ukraine
[2]State Forest Resources Agency of Ukraine Shota Rustaveli st, 9A, Kyiv, 01601, Ukraine

Author E-mail: vera_moroz@ukr.net

Received: 05.05.2020. Accepted: 05.06.2020

According to the signed climate Paris Agreement, Ukraine is faced with the task to prevent the global average air temperature from rising above 2.0°C in order to avoid an increase in droughts, extinction of certain species of plants and animals, drying up and diseases of tree species, etc. To preserve and increase the number of natural carbon sinks, scientists pay attention in particular to the system of improving forest, soil, and other natural resources management. Among thirty main forest-forming species in Ukraine, Scots pine (*Pinus silvestris* L.) is the predominant tree species. In the Ukrainian Polissya, in particular, its amount is 1686,2 thousand hectares, which is 59,5% of all tree plantations. To establish the carbon absorption capacity of pine plantations of the Ukrainian Polissya we have laid temporary test squares (CCIs) in state-owned enterprises: Volyn Forest Breeding and Seed Center; Volodymyr-Volyn Forestry and Hunting Enterprise; Kovel Forestry; Lyubomlske Forestry; Manevichi Forestry; Specialized Forestry Agricultural Enterprise Rozhyscheagrolis; Turiysk Forestry, Baraniv Forestry; Belokrovichi Forestry; Gorodnitsky Forestry; Emilchinskoye Forestry; Zhytomyr Forestry; Korostensky Forestry; Malinsky Forestry; People's Specialized Forestry; Novograd-Volyn Experimental Forestry; Ovruch Specialized Forestry; Olevsky Forestry; Slovenian Forestry of APK, Ivankiv Forestry, Polissya Forestry, Teterysh Forestry, Gorodnya Forestry, Dobryansk Forestry, Koryukivske Forestry, Nizhyn Forestry. According to the analysis of the distribution of forest land areas designated for pine plantations in the Ukrainian Polissya, the overwhelming majority is occupied by pine forests of category IV (operational), accounting for 63% of the pine plantations in the Ukrainian Polissya, so their carbon absorption capacity is higher. Climatic changes during 1968-2018 were analyzed and a tendency was found for the average annual air temperature to rise by 2.0oC within the measured regions. It was found that the pine forests of the Ukrainian Polissya annually absorb 70,9 to 71,2 thousand tonnes of carbon from the air, which is approximately 5,8–16,6% of the annual carbon emissions released into the atmosphere, which in turn has a positive environmental impact on the research area.

Keywords: Pine plantations; Phytomass; Forest categories; Conversion factors; Carbon sequestration

Introduction

In recent decades, climate change has led to a number of negative factors, including the extinction of certain species of plants and animals, droughts, complications of cultivation of crops, drying up and diseases of tree species, etc. (Buksha et al., 2008; SolovIy, 2016). Taking into account the factors indicated during the United Nations Climate Change Treaty (COP21), the Paris Agreement was signed in 2015. Of the 197 countries that participated in the signing of the agreement, 176 have ratified it. Ukraine was one of the first countries in the world to approve the agreement at the state level (Parizka ugoda OON, 2014; Analitichniy dokument 2018).

The main objective of the Paris Climate Agreement is to prevent the global average air temperature from rising above 2°C (preferably 1.5°C), similar to the period prior to the Industrial Revolution when humankind began to burn huge amounts of fossil fuels. It refers to the historic period before the 1750s – prior to the beginning of the Industrial Revolution in England, which later spread to other European countries (Pochtovyuk & Pryahina, 2012; Partnerstvo zaradi rinkovoyi gotovnostI v Ukrayini (PMR), 2019).

Keeping global warming at 1.5–2°C requires a rapid reduction of anthropogenic greenhouse gas emissions into the environment and their complete elimination by the second half of the 21st century (Tretyakov et al., 2006).

To address local and global environmental problems, the Paris agreement provides for the active use of trade of quotas for pollutant emissions. A "quota" is a permit or an emission certificate for one tonne of CO_2 equivalent over a specified period of time and may be transmitted in accordance with the agreed-upon measures. Emissions trading is a market-based tool for reducing greenhouse gas emissions (Pochtovyuk & Pryahina, 2012; Analitichniy dokument 2018). The average cost of one greenhouse gas emission quota is $ 18, assuming the possibility of selling the difference between carbon emissions and carbon sequestration, Ukraine would have significant gains from the implementation of the quotas. In view of the above, the Ministry of Energy and Environmental Protection of Ukraine considers ways of introducing an emissions trading system for greenhouse gases (Partnerstvo zaradi rinkovoyi gotovnostI v Ukrayini (PMR), 2019).

The UN Climate Change Conference in Paris (2015) addressed the role of forests in combating climate change. The importance of forests is based on the UN Framework Program, approved in 2013 – REDD + (Emission reductions from deforestation and forest degradation) (SolovIy, 2016). Therefore, scientists are particularly paying attention to preserving existing and increasing natural carbon sinks through the improved forest and other plantations and soil management.

Materials and Methods

Collection of research material was conducted at state-owned enterprises, in which we have laid temporary test squares (CCIs) 2016–2019 y.: Volyn Forest Breeding and Seed Center; Volodymyr-Volyn Forestry and Hunting Enterprise; Kovel Forestry; Lyubomlske Forestry; Manevichi Forestry; Specialized Forestry Agricultural Enterprise Rozhyscheagrolis; Turiysk Forestry, Baraniv Forestry; Belokrovichi Forestry; Gorodnitsky Forestry; Emilchinskoye Forestry; Zhytomyr Forestry; Korostensky Forestry; Malinsky Forestry; People's Specialized Forestry; Novograd-Volyn Experimental Forestry; Ovruch Specialized Forestry; Olevsky Forestry; SLOVENIAN FORESTRY OF APK, Ivankiv Forestry, Polissya Forestry, Teterysh Forestry, Gorodnya Forestry, Dobryansk Forestry, Koryukivske Forestry, Nizhyn Forestry.

Our research has focused on the selection of research material in I – IV categories pine plantations of different ages in Polissya forests. Temporary test areas were laid in pine plantations according to SOU 02.02-37-476: 2006 "Forested test areas. Method of emplacement." The total number of test areas is 300.

Phytomass of wood and bark in an absolute dry state was determined by their volume, according to reference tables (Shvidenko et al., 1987; Kashpor & Strochinskiy, 2013), and multiplied by the average basic density (Poluboyarinov, 1976; Borovikov & Ugolev, 1989):

$$m = V \times \rho_{base} \qquad (1)$$

where m is phytomass of the component, kg; V is volume of the component, m^3; ρbase is base density, kg/m^3.

To establish the phytomass of the pine bark we used the equation suggested by (Atkin & Atkina, 1999; Alekseev et al., 2006):

$$m_{crown} = 8{,}379 + 0{,}087 \times m_{trunk} \qquad (2)$$

where mcrown is phytomass of the crown, kg; mtrunk is phytomass of the trunk, kg.

The total phytomass of the tree was determined by the sum of the individual phytofractions of the tree (bark, wood, crown) (Klevtsov et al., 2018). Carbon stocks in tree stands were established on the basis of stock data of pine trunks using the conversion-volumetric coefficients representing the ratio of phytomass of individual fractions to the stock of wood and age-dependent trees (Lakida, 2002; Lovinska, 2018). Using Microsoft Excel Data Analysis ToolPak, we performed mathematical modeling according to the method of A.I. Kobzar, A.I. Gerasimovich, Y.I. Matveeva (Gerasimovich & Matveeva. 1978; Kobzar. 2006).

Results and Discussion

Under the circumstances of climate change, research on the carbon budget of forests, both at the state and regional levels, is a task of decisive action for scientists. The fulfillment of Ukraine's international commitments (preparation of national reporting, creation of greenhouse gas inventories, determination of priority areas of action, etc.) requires appropriate information and analytical support. Climate change research requires consideration of the global carbon cycle and the contribution of forests to this cycle, which in turn leads to the study of individual elements of forest bioproductivity.

Through modeling of the productivity of forest plantations and assessing their carbon absorption capacity, the course of processes in forest ecosystems can be determined via environmental monitoring with the goal of sustainable forest management.

Particularly in science, a number of domestic scientists (Shvidenko et al., 1987; Lakida, 2002, Kashpor & Strochinskiy, 2013) et al., have developed ways and methods of estimating the biological productivity of forest plantations.

Our scientific research is complemented by modern research (Hrynyk & Zadorozhnyy, 2018; Lovinska 2018; Sytnyk 2019), developments by foreign scientists in the field of forest biodiversity assessment (Shvidenko et al. 1987; Atkin & Atkina, 1999; Schepaschenko et al., 2008; Demakov et al., 2015; Alekseev et al.), and improved by mathematical modeling using the methods of (Gerasimovich & Matveeva. 1978; Kobzar. 2006).

The objective of our research was to develop mathematical dependencies of conversion coefficients to establish the accumulation of phytomass and carbon sequestration by pine forest plantations of the Ukrainian Polissya by age, using methodological approaches of domestic and foreign scientists. Scots pine (*Pinus silvestris* L.), among the thirty main forest-forming species in Ukraine, is the predominant tree species. Scots pines cover 1686,2 thousand hectares in the Ukrainian Polissya, accounting for 59,5% of all tree plantations. The problem of studying carbon pools in forest ecosystems is closely linked to climate change trends. Establishing a distinction between carbon emissions and its accumulation in the phytomass of trees will allow us to reliably predict the state of the environment and fulfill the requirements of the Paris Agreement. Using the data of the Volyn, Zhytomyr, Kyiv, Chernihiv Oblast Hydrometeorological Centers, a detailed analysis of the air temperature over the period 1968–2018 was conducted to find out climatic changes in the measured region (Figure 1).

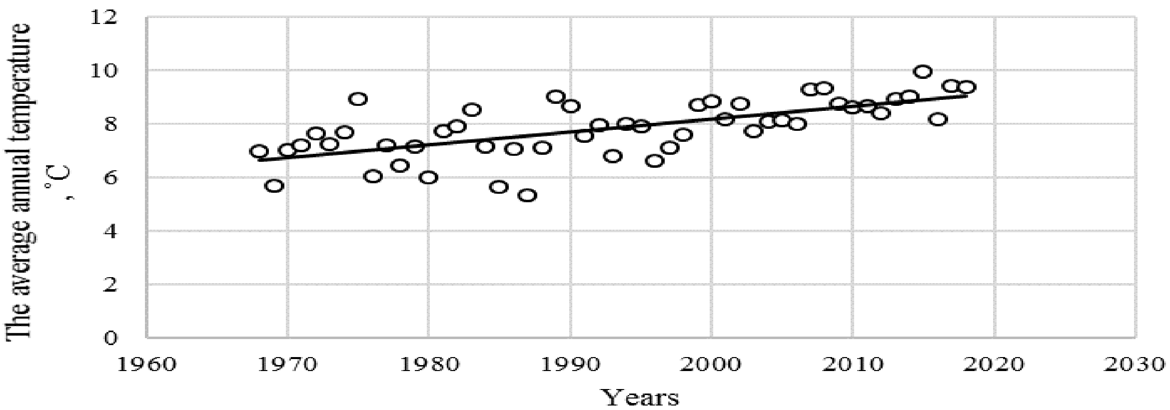

Figure 1. The average annual temperature between the years 1968-2018.

Thus, according to the obtained results of the analysis, we found a tendency for the average annual air temperature in the Ukrainian Polissya to rise by 2.0°C. According to the State Forestry Agency of Ukraine, among the 30 major woodland breeds, Scots pine (*Pinus silvestris* L.) occupies 35% and is one of the most promising carbon sinks of the state (Figure 2).

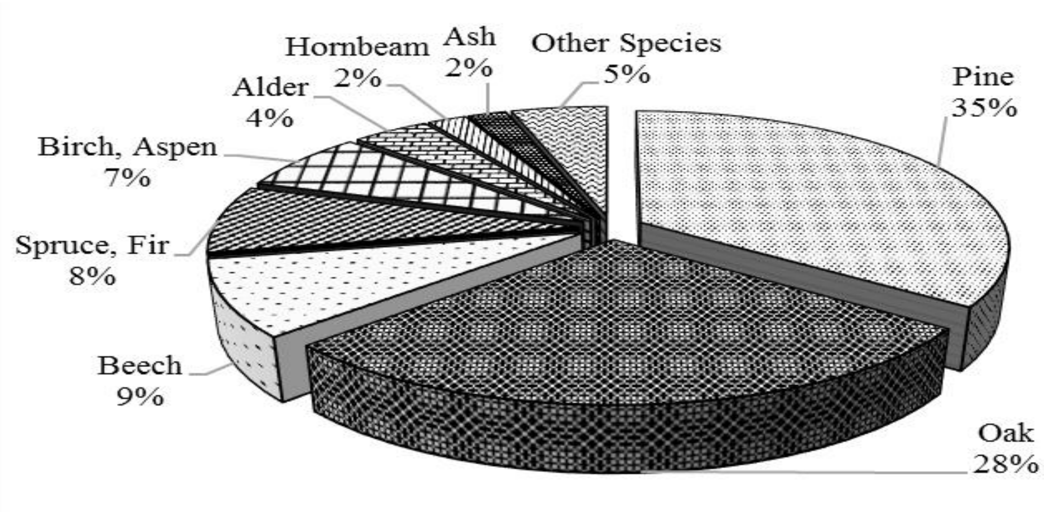

Figure 2. Distribution of forest area of Ukraine by prevailing tree species (according to the State Agency of Forest Resources of Ukraine) (Publichniy zvit Golovi Derzhavnogo agentstva lisovih resursIv Ukrayini za 2017).

According to the State Forest Inventory, as of January 1, 2011, the area of pine forest covered with forest vegetation in the Ukrainian Polissya is 1686,2 thousand hectares, which is 59,5% of the remaining plantations (Figure 3).

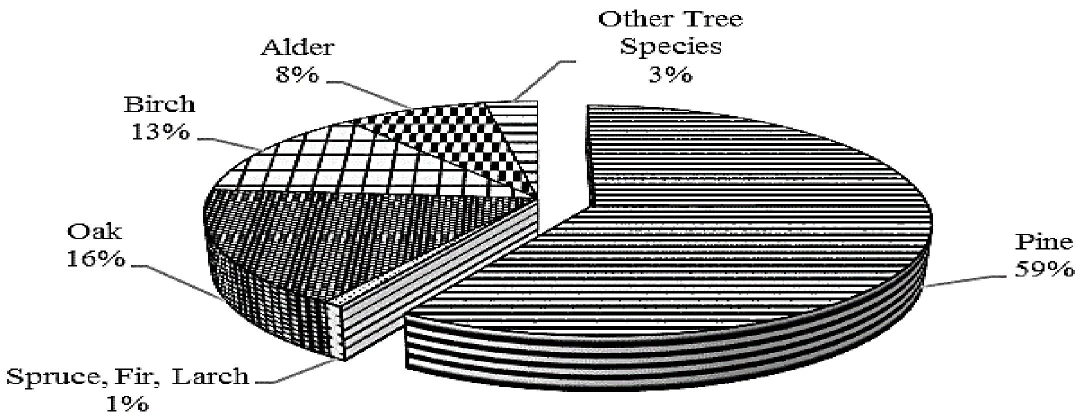

Figure 3. Distribution of the pine forest areas of the Ukrainian Polissya covered by forest vegetation.

Distribution of forest areas under forest plantations by categories in the Ukrainian Polissya indicated that an overwhelming majority is occupied by pine forests of the category IV (operational), their share is 63% (Figure 4).

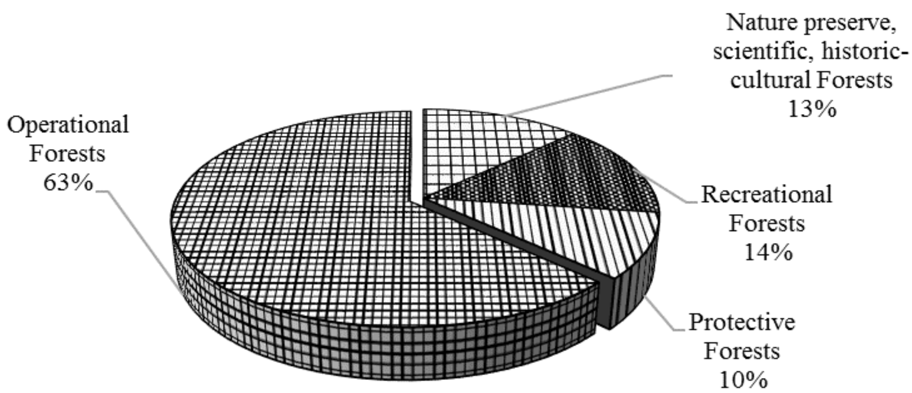

Figure 4. Distribution of pine forest areas of the Ukrainian Polissya by categories.

According to formulas 1 and 2, we established phytomasses of wood, bark, and crowns of pine and constructed the correlation matrix between indicators of aboveground phytomass in an absolute dry state and taxation indicators of wood (diameter and height) (Hrynyk & Zadorozhnyy, 2018). The results of the analysis are presented in Table 1.

Table 1. Correlation matrix of the main taxation indicators of pine stands and aboveground phytomass in an absolute dry state.

Indicators	**Age, years**	**Stand Density**	**Average diameter, cm**	**Average height, m**	**Volume of the trunk in the bark, m^3**	**Phytomass of wood, kg**	**Phytomass of bark, kg**	**Phytomass of crown, kg**
Age, years	1,00	–	–	–	–	–	–	–
Stand Density	-0,118	1,00	–	–	–	–	–	–
Bonity	0,898	-0,101	–	–	–	–	–	–
Average height, m	0,825	-0,061	1,00	–	–	–	–	–
Average diameter, cm	0,877	-0,089	0,900	1,00	–	–	–	–
Volume of the trunk in the bark, m	0,877	-0,089	0,960	1,00	1,00	–	–	–
Phytomass of wood, kg	0,875	-0,090	0,960	0,999	1,00	1,00	–	–
Phytomass of bark, kg	0,877	-0,089	0,960	1,00	0,999	0,999	1,00	–
Phytomass of crown, kg	1,00	1,00	0,960	1,00	1,00	1,00	0,999	1,00

The obtained correlation matrix indicates a close relationship (0.810–0.999) between all indicators in the table except stand density and bonity.

The statistical analysis showed homogenous average diameter and height, but not for other indicators. We found a moderate distribution in terms of age and average diameter, left asymmetric distribution for average height, and right absolute dry state asymmetric distribution for the rest. The excess factor indicated a flat-top distribution by all indicators except for stand density (Table 2).

Table 2. Basic statistical characteristics of biometric indicators and components of aboveground phytomass of pine trees in an absolute dry state.

Indicators	**Age, years**	**Stand Density**	**Average diameter, cm**	**Average height, m**	**Volume of the trunk in the bark, m^3**	**Phytomass of wood, kg**	**Phytomass of bark, kg**	**Phytomass of crown, kg**
Xmean (arithmetic mean)	73,5	0,728	28,1	22,1	0,776	294,6	24,6	36,2
Cv (standard error)	1,66	0,019	0,531	0,328	0,033	12,5	0,988	1,17
σ (standard deviation)	28,6	0,324	9,16	5,66	0,565	215,6	17,1	20,2
D (sample variance)	818,0	0,105	83,9	32,0	0,319	46503,2	290,9	409,8
E (kurtosis)	-0,430	237,5	-0,278	0,137	0,902	0,892	0,978	0,899
A (asymmetry coefficient)	0,426	14,5	0,075	-0,722	1,03	1,03	1,02	1,03
V (coefficient of variation),%	38,9	44,5	32,6	25,6	72,7	73,2	69,3	56,0
min (minimum)	8,0	0,200	2,0	3,0	0,014	4,91	0,706	8,87
max (maximum)	151,0	6,0	52,0	32,0	2,88	1095,1	88,6	111,4

To find mathematical models for the relationship of pine planting conversion factors, we used the following function:

$$R_{cc} = f(A, B, Sd, Sp) \qquad (3),$$

where Rcc is the corresponding conversion factor for each tree phytofraction; A, B, Sd, Sp are age, bonity, stand density, stock of planting in the bark (Demakov et al., 2015; Sytnyk 2019).

We used the ratio between the mass fraction of phytomass and the stem stock of the stand in the bark as the dependent variable, w: $R_{cc} = \frac{M_{pf}}{M}$ (4).

where Rcc is the conversion coefficient, Mpf is the mass of the phytomass fraction in an absolute dry state, t/ha, M is the stock stand in the bark, m^3/ha.
To obtain the empirical equations Rcc, we used the indicators of the temporary test areas on which the phytomass was established by equations 1 and 2.

In the course of mathematical modeling we obtained the equations shown in Figures 5–7.

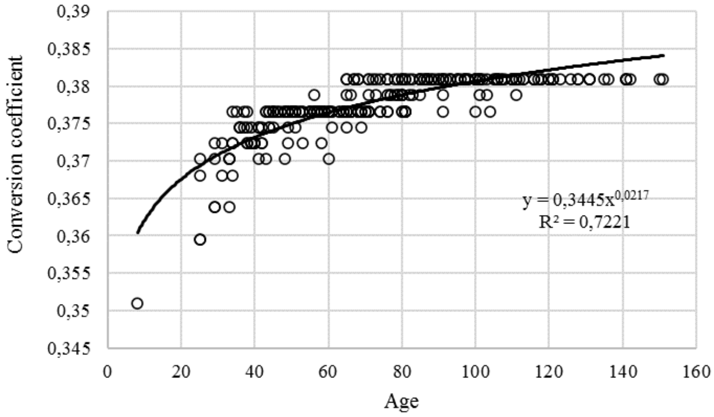

Figure 5. The dependence of wood conversion factor on tree age.

The obtained mathematical dependence has an adequately high coefficient of determination, R_2=0,72, which allows for further use.

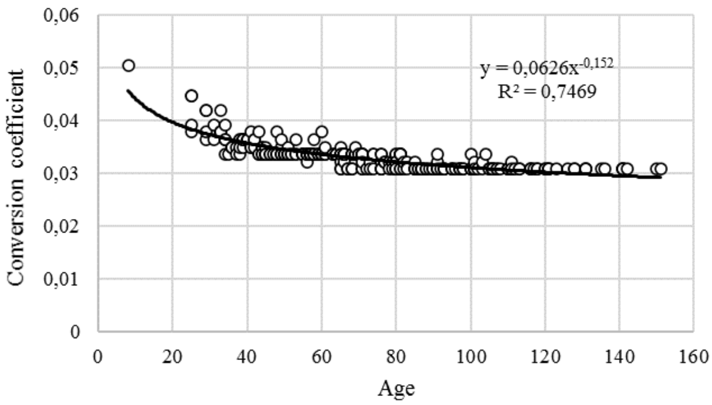

Figure 6. The dependence of bark conversion factor on tree age.

By analyzing the obtained equations of the dependence of bark conversion to tree age, (Figure 6), we can state the significant influence of each factor introduced on the productive trait. The indicators' coefficients of determination explain 75% of the studied traits variability.

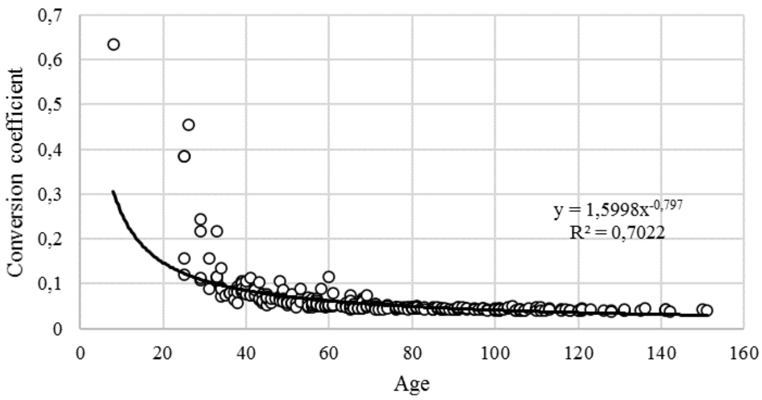

Figure 7. The dependence of crown conversion factor on tree age.

The obtained dependence equation of the crown conversion coefficient and the age of the trees has a value of approximation reliability of 0.702, which characterizes the model of acceptable quality. Using the obtained conversion coefficients of pine plantations (equations 5–6) we determined the carbon stock according to the "Distribution of forested areas covered by forest vegetation by 10-year age periods" (Form No. 5) of the state forest inventory as of January 1, 2011. the last record of plantations) (Figure 8).

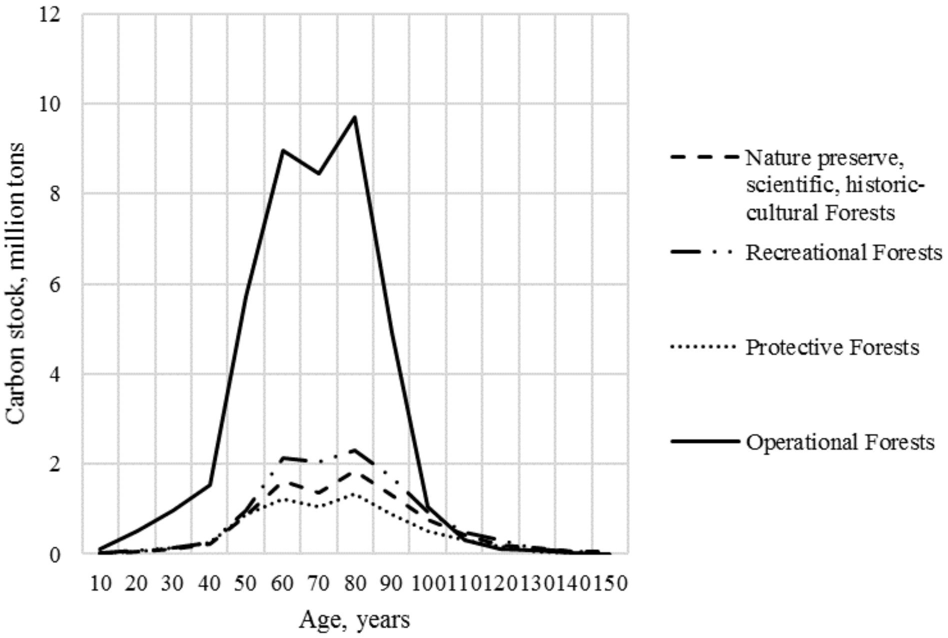

Figure 8. Carbon stock in pine plantations of the Ukrainian Polissya by forest category.

According to the results of the analysis, we established that the overwhelming majority of the Ukrainian Polissya are forest plantations of the category IV (operational forests), so their carbon absorption capacity is higher. Among the operating forests, plantations between the ages of 60 and 80 years have the greatest carbon accumulation capacity (8.96–9.69 million tons).
According to data from the Main Department of Statistics of the region, stationary and mobile sources of pollution are the largest pollutants of carbon dioxide emissions (Table 3). Based on the conversion factors obtained, taking into account the age changes of pine plantations of different categories of forests of the Ukrainian Polissya and their stock, we established the annual carbon sequestration since 2008 (Table 3).

Table 3. Comparative data of anthropogenic carbon emissions and its sequestration by pine forests of the Ukrainian Polissya.

Years	Amount of sequestrated carbon by year, million tons	Total annual carbon sequestration, million tones	Annual carbon emissions into the atmosphere	The difference between emissions and carbon sequestration per year
2006	70,9	–	–	–
2007	70,9	0,01	15,0	15,0
2008	70,9	0,01	16,6	16,6
2009	70,9	0,02	15,5	15,5
2010	70,9	0,02	16,2	16,2
2011	71,0	0,02	15,2	15,2
2012	71,0	0,03	15,7	15,7
2013	71,0	0,03	14,1	14,1
2014	71,0	0,03	12,7	12,7
2015	71,1	0,03	10,6	10,6
2016	71,1	0,04	7,9	7,9
2017	71,2	0,04	5,8	5,8
2018	71,2	0,04	7,1	7,1

*Since 2004 – by road, rail transport; since 2007 – by road, rail transport and industrial equipment.

Annually, the pine forests of the Ukrainian Polissya absorb from 70.9–71.2 thousand tons of carbon from the air, reducing the annual emissions of carbon dioxide by 5.8–16.6%.

Conclusion

Climatic changes during 1968–2018 were analyzed and a tendency was found for the average annual air temperature to rise by 2.0 oC within the measured regions. Based on the obtained empirical equations, we established that pine forests at the age of 60–80 years in the Ukrainian Polissya, accumulate 8,96–9,69 million tons of carbon in their phytomass. Annually, the pine forests of the Ukrainian Polissya absorb from 70.9–71.2 thousand tons of carbon from the air, reducing the annual emissions of carbon dioxide by 5.8–16.6%.

References

Agreement of the UN. Agreement. International Document of 12.12.2015. Kyiv. 2014. Rezhim dostupu: http://zakon2.rada.gov.ua/laws/show/995_l61. (in Ukrainian).
Alekseev, I. A. Kurnenkova, I. P., Cheshuin, A. N., Berdinskikh, S. Y., Stepanova, T. V., Vakhrushev, K. V., & Kotok, O. N. (2006). A method for determining the aboveground biomass of forest stands: Patent of the Russian Federation for the inventive method. № 2272402 S2; patentoobladatel Mariyskiy gosudarstvannyiy tehnicheskiy universitet; zayavl. 25.03.2004; opubl. 27.03.2006. 9, 6. (in Russian).
Analitichniy dokument. (2018). The European emissions trading system and prospects for the introduction of emissions trading in Ukraine. Ekspertno-doradchiy tsentr «Pravova analItika». Veresen. (in Ukrainian).
Atkin A. S., & Atkina L. I. (1999). The method and dynamics of organic matter in forest communities. Izd. UGLTA. Ekaterinburg. (in Russian).
Borovikov, A. M. & Ugolev, B. N. (1989). Handbook on wood. Handbook. Moskva: Lesn. prom-st. (in Russian).
Buksha, I. F., Butrim, O. V. & Pasternak, V. P. (2008). Inventarizatsaya greenhouse gas sector of land use that lisovoe economy [monograph]. Harkiv: HNAU. (in Ukrainian).
Churokov B. P. & Manyakina, E. V. (2012). Carbon sequestration pine cultures of different ages. Ulyanovskiy mediko-biologicheskiy zhurnal, 1, 125–129. (in Russian).
Danilov, D. A., Belyaeva, N. V. & Gryaz'kin, A. V. (2018). Features of Yield and ComModity Composition of Pine and Spruce Modal Coniferous Stands for the Age of Mature Stands. Lesnoy zhurnal, 2, 40–48. doi: 10.17238/issn0536-1036.2018.2.40. (in Russian).
Demakov, Yu. P., Puryaev, A. S., Chernyih, V. L. & Chernyih, L. V. (2015). Using allometric relationships for evaluation of various trees phytomass fractions and their dynamics simulation. Vestnik Povolzhskogo gosudarstvennogo tehnologicheskogo universiteta, 2 (26), 19–36. (in Russian).
Gerasimovich, A. I. & Matveeva, Ya. I. (1978). Math statistics. Minsk: «Vyisheyshaya shkola». (in Belorussia).
Hrynyk, H. H. & Zadorozhnyy, A. I. (2018). Some Models of Dynamics of Above-Ground Phytomass of Spruce Trees Depending on their Assessment Indices in the Prevailing Forest Types of Polonynsky Range of the Ukrainian Carpathians. Scientific Bulletin of UNFU, 28(2), 9–19. https://doi.org/10.15421/40280201. (in Ukrainian).
Kashpor, S. M. & Strochinskiy, A. A. (2013). Lisotaksatsiynyy Directory. Kiyiv: Vid. dim «Vinnichenko». (in Ukrainian).
Kischenko, I. T. (2019). Formation of Picea abies (L.) Karst. Trunk Wood. in Different Taiga Zone Communities. Lesn. Zhurn, 1, 32–39. (Izv. vyissh. ucheb. zavedeniy). doi: 10.17238/issn0536-1036.2019.1.32. (in Russian).
Klevtsov, D. N., Tyukavina, O. N. & Adayi, G. M. (2018). Bioenergy Potential of Aerial Phytomass of Scots pine in the Middle Taiga Forest Region. Lesnoy zhurnal, 4, 49–55. doi: 10.17238/issn0536-1036.2018.4.49. (in Russian).
Kobzar, A. I. (2006). Applied Mathematical Statistics. For engineers and scientists. Moskva: FIZMATLIT. (in Russian).
Lakida, P. I. (2002). Forest biomass Ukraine [monograph]. Ternopil: Zbruch. (in Ukrainian).
Lovinska, V. M. (2018). Above-ground biomass trunks Pinus sylvestris L. stands in the northern steppes of Ukraine. Naukoviy vIsnik NLTU Ukrayini, t. 28(8), 79–82. https://doi.org/10.15421/40280816/. (in Ukrainian).
Lovinska, V. M. (2018). Lokalna schilnist komponentIv fItomasi stovbura sosni zvichaynoyi (Pinus sylvestris L.) Pivnichnogo Stepu Ukrayini. Visnik agrarnoyi nauk Prichornomor’ya, 3, 73–78. doi :10.31521/2313-092X/2018-3(99)-12. (in Ukrainian).
Partnerstvo zaradi rinkovoyi gotovnostI v Ukrayini (PMR). (2019). Proposals for the development of carbon pricing instrument in Ukraine: Report on modeling. Cerpen. (in Ukrainian).
Pochtovyuk, A. B. & Pryahina, E. A. (2012). Emissions trading as one of the Kyoto Protocol. Problemyi sovremennoy ekonomiki, 3 (43), 300–304. (in Russian).
Poluboyarinov, O. I. (1976). Wood density. Moskva: Lesn. prom-st. (in Russian).
Schepaschenko, D. G., Shvidenko, A. Z. & Shalaev, V. S. (2008). Biological productivity and carbon budget of the larch forests of the North-East of Russia: Monograph. Moskva: GOU VPO MGUL. (in Russian).
Shvidenko, A. Z., Strochinskiy, A. A., Savich, Yu. N. & Kashpor, S. N. (1987). Regulatory and reference materials for the forest inventory in Ukraine and Moldova. Kiev: Urozhay. (in Ukrainian).
SolovIy, I. (2016). Evaluation of international practices and procedures / regulations on the concept of payment for ecosystem services in the forestry sector. ENPI EAST FLEG II. September. European Union. (in Ukrainian).
Sytnyk, S. A. (2019). Modeling of the trunk phytomass components of black locust stands in Northern Steppe of Ukraine. Scientific Bulletin of UNFU, 29(3), 48–51. https://doi.org/10.15421/40290310. (in Ukrainian).
The public report of the chairman of the State Agency of forest resources of Ukraine for 2017. (2017). Kiyiv. (in Ukrainian).
Tretyakov, S. V. (Ed.). (2006). Kyoto Protocol. The history of development, goals and principles. Sovmesnogo projects implementation in Ukraine: [collection of informational materials]. Donetsk: OOO «UKRDRUK». (in Ukrainian).

Citation:
Moroz, V.V., Nykytiuk, Y.A., Nykytiuk, P.A., Kliuchevych, M.M., Komorna, O.M. (2020). Carbon Absorption Ability of Pine Forest Plantations in the Ukrainian Polissya. *Ukrainian Journal of Ecology, 10* (2), 249-255.