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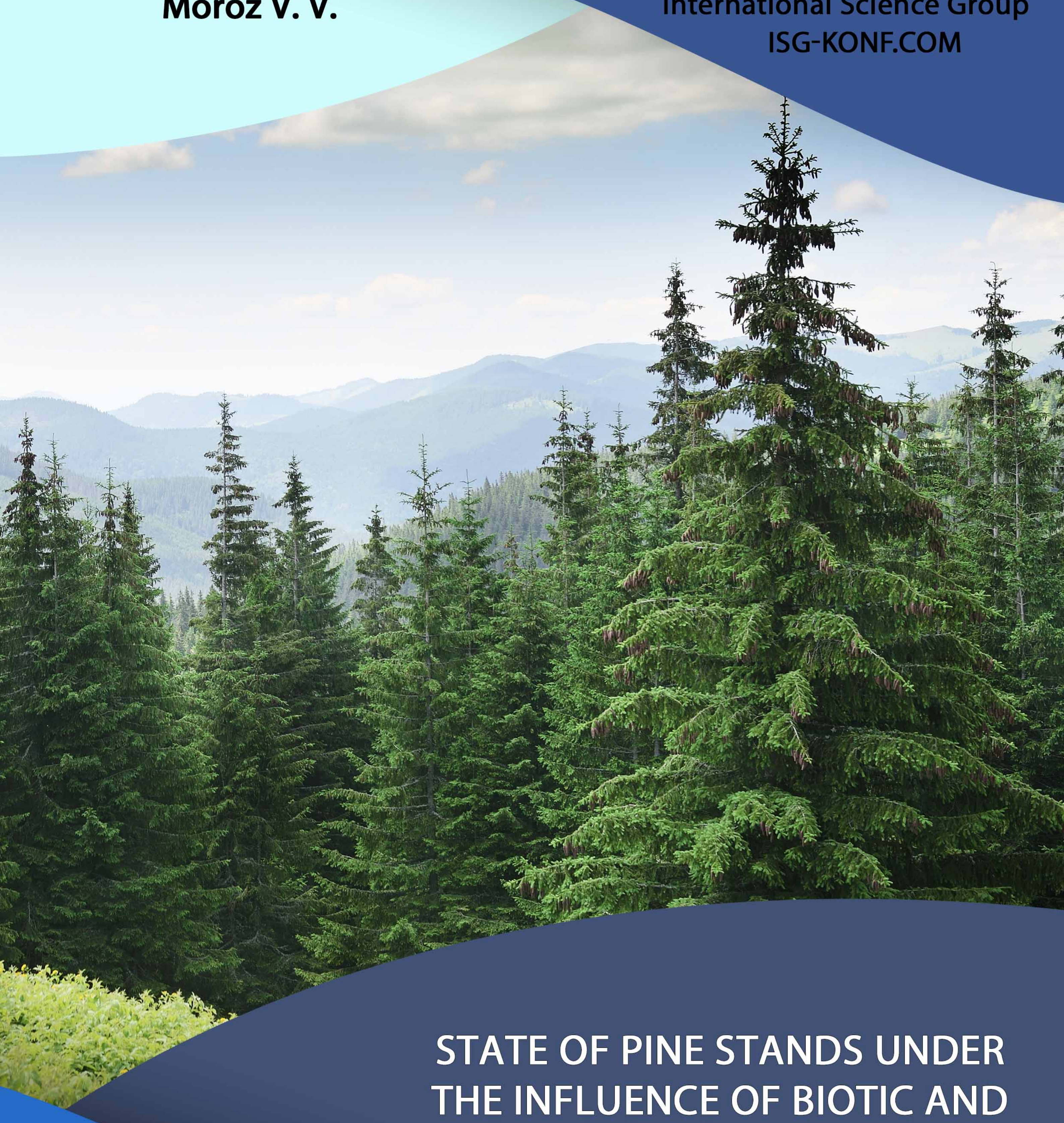

STATE OF PINE STANDS UNDER THE INFLUENCE OF BIOTIC AND ABIOTIC FACTORS IN ZHYTOMYR POLISSYA

ISBN 979-8-89292-741-3
DOI 10.46299/979-8-89292-741-3

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Monograph

2023

UDC 630

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Moroz V. V. State of pine stands under the influence of biotic and abiotic factors in Zhytomyr Polissya. Monograph. – Primedia eLaunch, Boston, USA, 2023. – 108 p.

Library of Congress Cataloging-in-Publication Data

ISBN – 979-8-89292-741-3
DOI – 10.46299/979-8-89292-741-3

UDC 630

ISBN – 979-8-89292-741-3

ABSTRACT

The monograph describes the ecological and biological features of forestry, presents both well-known and newest materials on biological and ecological features and functions of forest biocenoses. The main critical structural components that are negatively affected by climate change are presented.

The ways of forest regeneration, growth and formation, dynamic indicators of forest ecosystems, protection of forest ecosystems under the influence of pests and diseases, as well as ecological and regulatory functions of forest plantations are considered.

The materials of the monograph can be used by students of forestry specialties, teachers, graduate students, scientists, and forestry workers.

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INTRODUCTION

In recent years, due to natural and climatic changes, namely an increase in the average annual air temperature, a decrease in relative humidity, and a decrease in the groundwater level, forest plantations have been weakened and as a result, affected by entomopest and fluorosis, which leads to their weakening and drying out[1].

Every year, the State Agency of Forest Resources of Ukraine reports on the death of forest plantations in its annual reports, and this figure is growing every year. Sanitary felling of forests has also become more frequent in recent years.

According to the forecasts of a number of scientists, rising temperatures lead to a shift in the latitudinal boundaries of climatic zones, so forest productivity has been declining more and more recently. Such changes directly affect the sustainability of tree species[2].

Climate change is often associated with greenhouse gas emissions into the environment, as well as with the cyclical nature of solar activity. In periods when solar activity increases, there is an increase in the number of phytopests, phytodiseases, and as a result, the number of dead plantations[3].

There are also changes in the hydrothermal regimes of the territory, and in years of severe drought, the death of forest plantations increases.

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[1] Iakovliev Ye. O. Ekoloho-heolohichni faktory vplyvu ruinivnykh povenei ta pavodkiv v Ukraini. Vplyv ruinivnykh povenei, pavodkiv, nebezpechnykh heolohichnykh protsesiv na funktsionuvannia inzhenernykh merezh ta bezpeku zhyttiediialnosti : materialy Piatoi naukovo-praktychnoi konferentsii (23-27 liutoho 2009 r., m. Yaremche). K. : NPTs «EKOLOHIIa NAUKA TEKhNIKA», 2009. S. 15-17.

[2] Stoiko S.M. Potentsiini ekolohichni naslidky hlobalnoho poteplinnia klimatu v lisovykh formatsiiakh Ukrainskykh Karpat. Naukovyi visnyk UkrDLTU: zb. nauk.-tekhn. prats. Ser.: Hlobalni zminy klimatu zahroza liudstvu ta mekhanizmy vidvernennia. Lviv : RVV NLTU Ukrainy. 2009. Vyp. 19.15. S. 214-224.

[3] Buksha Y.F. Izmenenye klymata y lesnoe khoziaistvo Ukrayny. Naukovi pratsi Lisivnychoi akademii nauk Ukrainy : zb. nauk. prats. Lviv : RVV NLTU Ukrainy. 2009. Vyp. 7. S. 11-14.

In recent years, forestry workers have been faced with the task of creating sustainable forest plantations by selecting tree species that can withstand environmental stress, as well as increasing the area under forest crops[4].

The predominant forest-forming tree species in Polissia is Pinus sylvestris L., and the area of forest land covered with forest vegetation under pine plantations is about 75%[5]. Pine forests perform extremely important diverse ecological functions and are characterized by a high level of economic importance. The dynamics of pest outbreaks is not stable: in some years, an increase in damaged areas can be observed due to the impact of sickly gnawing insects, in other years, outbreaks of stem pests. According to many scientific studies, a variety of phytodiseases and pests appear and spread in monocultures. Since scots pine is the predominant tree species in Zhytomyr Polissia, forest crops have been created mainly vegetatively for many years, so due to climate change, pine plantations are weakening and, as a result, entomopests are increasing[6]. The increase in the area under pine crops on old arable lands also affects the sanitary condition of plantations, and as a result, it reduces the intensity of tree growth and deteriorates the quality characteristics of wood.

According to numerous results of studies conducted in different regions, reducing the level of entomofauna damage can only be achieved by applying appropriate forestry and silvicultural measures aimed at creating appropriate environmental conditions that will increase the level of sustainability of pine plantations or in a less environmentally friendly way with the option of using insecticides in the largest pest breeding areas. However, all of the above measures are currently insufficiently studied and scientifically substantiated.

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[4] Bardina O. O. Mizhnarodne normatyvne zabezpechennia vyrishennia problem zminy klimatu. Naukovi zapysky Instytutu zakonodavstva Verkhovnoi Rady Ukrainy. 2013 № 5. S. 131–137.URL: http://nbuv.gov.ua/UJRN/Nzizvru_2013_5_28.

[5] Bahniuk V., Polishchuk V. Pryrodni roslynni resursy Polissia: suchasnyi stan i perspektyvy. Visnyk Kyivskoho natsionalnoho universytetu imeni Tarasa Shevchenka. Kyiv: Vydavnycho-polihrafichnyi tsentr Kyivskyi universytet, 2011. Vyp. 29. S. 4–12.

[6] Dolia M. M., Yushchenko L. P., Varchenko T. P. Osoblyvosti zastosuvannia suchasnykh biolohichnykh zasobiv zakhystu silskohospodarskykh kultur vid shkidnykiv u Lisostepu i Polissi Ukrainy. Silskohospodarska mikrobiolohiia. 2018. Vyp. 27. S. 60–66.

Despite the intensity and level of pine plantation pests in Zhytomyr Polissia, there are still many questions about their specific biological characteristics, seasonal development dynamics, density and level of damage[7].

The study of these issues will create an opportunity for more effective implementation of preventive measures against the spread and growth of insect foci and timely effective protection of pine plantations from them. This will be aimed at increasing the level of forest sustainability and restoring their respective ecological functions.

The pine forests of Zhytomyr Polissia perform important and diverse ecological functions and are characterized by a high level of economic importance. Pest outbreaks observed in recent years have caused significant damage to pine stands and devalued industrial timber[8].

Ukrainian scientists are monitoring the dynamics of pest spread, making forecasts, assessing the situation and causes of outbreaks.

The exact causes of pest outbreaks have not been determined, but many publications name possible causes, such as early spring, mild winters, an increase in average annual air temperature, solar activity, vegetative reproduction of forests, growing crops on old arable land, creating monocultures, etc.

In addition to studying the number and outbreaks of forest phytophages, the issue of means and methods of combating them is also relevant. Every year, chemical companies create a variety of pesticides to combat pests and diseases, but it should be noted that such drugs can cause significant damage to forest vegetation and wildlife[9]. Therefore, a significant number of state forestry enterprises prefer to use biological

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[7] Zvedenyi proekt orhanizatsii i rozvytku lisovoho hospodarstva Zhytomyrskoho OULMH. Irpin: Vyd-vo Ukr. lisovporiad. pid-vo, 2009. 300 s.

[8] Zborovska O. V. Ekolohichnyi stan i produktyvnist lisovykh nasadzhen sosny zvychainoi u svizhykh borakh i suborakh Zhytomyrskoho Polissia. Visnyk natsionalnoho universytetu vodnoho hospodarstva ta pryrodokorystuvannia. Ser.: Silskohospodarski nauky. 2013. Vypusk 2 (62). S. 198–207.

[9] Omarov A. E. Suchasnyi stan ekolohichnoi bezpeky v Ukraini. Visnyk Natsionalnoho universytetu tsyvilnoho zakhystu Ukrainy. Seriia : Derzhavne upravlinnia. 2017. Vyp. 2. S. 156-164. Rezhym dostupu: http://nbuv.gov.ua/UJRN/VNUCZUDU_2017_2_24

products. Biological products cause less environmental damage, but there is a need to improve their effectiveness.

Reducing the level of entomofauna damage is possible by applying appropriate forestry and silvicultural measures aimed at increasing the level of sustainability of pine plantations[10]. This includes the implementation of preventive protection methods, timely use of protective equipment, and selection of tree species taking into account hydro-edaphic conditions.

In any case, a detailed study of the problem of the emergence and spread of phytopests, as well as methods and ways to combat them, is quite relevant and requires detailed study.

[10] Mieshkova V. L., Mieshkova T. S., Sokolova I. M., Cherniavska O. M. Terminy diahnostyky poshkodzhennia derev komakhamy u prohrami monitorynhu stanu lisiv.: Tezy naukovoi konf., prysviachenoi pamiati chlena-korespondenta NAN Ukrainy, d.b.n., prof. V. H. Dolina «Zahalna i prykladna entomolohiia v Ukraini» (Lviv, 15–19 serpnia 2005 r.). Lviv, 2005. S. 150–152.

THE IMPACT OF CLIMATE CHANGE ON PINE STANDS IN ZHYTOMYR POLISSYA

Climate change is one of the greatest threats to humanity with far-reaching impacts on society, the environment and the economy. Climate change affects all regions of the world and all segments of the population[11]. However, today, without adaptation measures, climate change could reduce the global level of forestry by up to 30% by 2050[12].

A further temperature increase of 1.5°C will only increase the intensity and frequency of most natural hazards. Over the past decade, greenhouse gas emissions have been increasing by 1.5% per year, with a brief period of stabilization in 2014-2016[13]. At present, there are no signs of peak greenhouse gas emissions with the development options in the next few years, and the annual option to postpone the peak determination means that larger-scale and faster decisions on their level of reduction will be required in the near future[14].

According to the World Meteorological Organization, the period 2016-2021 was the warmest period on record globally, with an average temperature increase of 1.1°C compared to pre-industrial levels and 0.2°C compared to the previous five-year period.

The most vulnerable to climate change today are agriculture, forestry, and water management, and in general both anthropogenic and natural ecosystems.

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[11] Moroz V.V., Nykytiuk Yu.A. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Zhytomyrskoho Polissia cherez zahybel sosnovykh nasadzhen. Mizhvidomchyi tematychnyi naukovyi zbirnyk «Melioratsiia i vodne hospodarstvo». Kherson. 2020. №1. S.112-121.

[12] Moroz V.V., Nykytiuk Yu.A., Vorobel M.I. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Volynskoho Polissia cherez zahybel sosnovykh lisiv. The scientific heritage. 2020. №46. Vyp. 2 (46). S.21-27.

[13] Moroz V.V., Nykytiuk Yu.A. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Chernihivskoho Polissia cherez zahybel sosnovykh nasadzhen. Journal of science. Lyon. 2020. №6. T. 1. S.3-10.

[14] Martyniuk V. S., Temuriants N. A., Vladymyrskyi B. M. U pryrody net plokhoi pohody: kosmycheskaia pohoda v nashei zhyzny. K.: Yzdatel V. S. Martyniuk, 2008. 212 s.

Climate change manifestations are critical for forestry, as they change important optimal indicators for the full functioning of forest ecosystems[15]. For example, the increase in summer extreme temperatures poses an irreversible threat of extinction of dominant species and the emergence of new (including invasive) species, which affects not only the species composition of living organisms, but also the reduction of forest areas[16]. Numerous studies have made the following unfavorable predictions for the main forest-forming species: for European spruce, there will be a further active shrinkage of areas with suitable conditions, meaning that there will be virtually no optimal conditions for its growth in Ukraine, and for scots pine, conditions that are optimal for pine growth can be preserved only in the west and in a small area in the north, which will be the main reason for the significant deterioration of pine plantations in Ukraine[17].

Increased temperatures, especially in winter, cause climate mitigation and active expansion of the habitat of certain pests, such as the pine beetle, which, even under current conditions, is the main cause of massive death of pine plantations and pathogens of woody plants that already pose a significant threat to forest plantations.

Changes in the regime, intensity, and frequency of precipitation are another negative factor affecting forest plantations, which causes deterioration in the sanitary condition of forest ecosystems, weakening and large-scale drying of trees, and increased fire hazard[18].

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[15] Mieshkova V. L. Vplyv hlobalnykh zmin klimatu na poshyrennia oseredkiv masovoho rozmnozhennia komakh-khvoielystohryziv. Problemy ekolohii lisiv i lisokorystuvannia na Polissi Ukrainy. Vyp. 5 (11). Zhytomyr: Volyn, 2005. S. 62–65.

[16] Moroz V.V., Nykytiuk Yu.A. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Zhytomyrskoho Polissia cherez zahybel sosnovykh nasadzhen. Mizhvidomchyi tematychnyi naukovyi zbirnyk «Melioratsiia i vodne hospodarstvo». Kherson. 2020. №1. S.112-121.

[17] Omarov A. E. Suchasnyi stan ekolohichnoi bezpeky v Ukraini. Visnyk Natsionalnoho universytetu tsyvilnoho zakhystu Ukrainy. Seriia : Derzhavne upravlinnia. 2017. Vyp. 2. S. 156-164. Rezhym dostupu: http://nbuv.gov.ua/UJRN/VNUCZUDU_2017_2_24

[18] Semenova Y. H. Otsenka zasushlyvykh uslovyi na Ukrayne v kontse XX – v nachale XXI stoletyia. Vestnyk Baltyiskoho federalnoho unyversyteta ym. Kanta. 2014. Vyp 2. S. 20-29.

In general, according to the State Forestry Agency, the area of drying out of tree plantations due to pests and diseases increased from 203 thousand hectares in 2010 to 454 thousand hectares in 2021. The need to preserve and enhance the level of sustainability of forest plantations is due to another important factor - trees are the cheapest and most active factor and accumulator for the selection and retention of CO_2, which is manifested in the form of phytomass of living plants (the value of the "net" annual photosynthesis of organic matter ranges from 7.8 to 21.5 t/ha, of which 26-44% of the products of the photosynthesis process are subsequently converted into wood).

The main effects of climate change on forest plantations are as follows[19]:

1. the areas of growth of tree species will be changed due to the change in the boundaries of natural and climatic zones, but, unfortunately, in some cases, some productive tree species will disappear altogether;

2. changes in the modes, types, intensity and frequency of various damaging factors (insects, diseases, fires) will negatively affect the areas of forest ecosystems;

3. irreversible changes in the balance of nutrients will occur;

4. there will be negative changes in the indicators of stability and vitality of forest plantations, the level of productivity of forest woody and non-woody plants;

5. the level of efficiency of ecological functioning of forests, their impact on biogeochemical cycles, biodiversity, and reduction of carbon storage will decrease. Under this scenario of rapid growth of negative changes, forests will turn from carbon storage into emission sources;

6. changes in the reproductive cycles of forest plantations, the dynamics of successions, and changes in the ecological and social functions of forest ecosystems

7. decrease in biodiversity, especially stenotopic and endemic species.

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[19] Stoiko S.M. Potentsiini ekolohichni naslidky hlobalnoho poteplinnia klimatu v lisovykh formatsiiakh Ukrainskykh Karpat. Naukovyi visnyk UkrDLTU: zb. nauk.-tekhn. prats. Ser.: Hlobalni zminy klimatu zahroza liudstvu ta mekhanizmy vidvernennia. Lviv : RVV NLTU Ukrainy. 2009. Vyp. 19.15. S. 214-224.

Vulnerability of Ukrainian forests to climate change

At the level of international importance, forests and forestry are an important component of climate policy, which is further implemented in international agreements that currently include fundamental principles in the processes of human development, such documents are[20]: The United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, the Paris Agreement, etc. According to the Intergovernmental Panel on Climate Change (IPCC), about 21% of the total greenhouse gas (GHG) emissions are associated with active land use and forestry (LULUCF) processes: conversion of forestry land to other land use options, loss of forest biomass, which may be further accompanied by processes of carbon removal accumulated in forest ecosystems and a decrease in the level of carbon dioxide absorption capacity due to a decrease in the area of forests[21].

At the same time, greenhouse gases are absorbed in the general forestry sector, and under conditions of rational land and forest management in this sector, it is possible to ensure significant volumes of carbon sequestration by forest ecosystems[22]. According to the National Greenhouse Gas Inventory of Ukraine, forest ecosystems are net sinks of greenhouse gases, with an average of 54.4 million tons of CO2 per year in 2018-2021. In Ukraine, the general forestry sector is the only sector of the economy where greenhouse gases are absorbed in volumes that exceed the volume of other sectoral emissions[23].

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[20] Omarov A. E. Suchasnyi stan ekolohichnoi bezpeky v Ukraini. Visnyk Natsionalnoho universytetu tsyvilnoho zakhystu Ukrainy. Seriia : Derzhavne upravlinnia. 2017. Vyp. 2. S. 156-164. Rezhym dostupu: http://nbuv.gov.ua/UJRN/VNUCZUDU_2017_2_24

[21] Didukh Ya. Ekolohichni aspekty hlobalnykh zmin klimatu: prychyny, naslidky, dii. Visnyk Natsionalnoi akademii nauk Ukrainy. 2009. № 2. S. 34-44. URL: http://nbuv.gov.ua/UJRN/vnanu_2009_2_12

[22] Holovetskyi M. P. Formuvannia vysokoproduktyvnykh i biolohichno stiikykh shtuchnykh nasadzhen sosny u svizhykh borakh pivnochi Kyivskoho Polissia: Avtoref. dys. na zdobuttia nauk. stup. kand. s.-h. nauk. Kh., 2003. 91 s.

[23] Shvydenko A.Z., Buksha I.F., Krakovska S.V.Urazlyvist lisiv Ukrainy do zminy klimatu: monohrafiia. Kyiv : Nika-Tsentr, 2018. 184 s.

Improvement of the general forestry sector is the main factor that ensures the growth of greenhouse gas absorption and increase in the volume of carbon accumulation[24]. According to the IPCC forecast, in the second half of the twenty-first century, Ukraine may experience significant warming and an increase in the level of arid climate conditions (Fig. 1)[25].

The calculation and forecasting of the effects of further climate change on forest ecosystems is carried out by scientists of the UkrRFI together with the International Institute of Applied Systems Analysis and the Ukrainian Hydrometeorological Institute for 3 main climate factors by categories of satisfactory environmental conditions, which makes it possible to assess the level of viability of tree species in forest ecosystems.

It has been established that humidity is the most limiting climatic factor in the growth of Scots pine. According to preliminary forecasts, the period of 2080 – 2100 will be characterized by a significant decrease in the zone for optimal growth of pine species.

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[24] Hamaiunova S. H., Novak L. V., Davydenko K. V., Mieshkova V. L. Vplyv umov utrymannia sosnovoho shovkopriada v laboratorii na znachennia osnovnykh populiatsiinykh pokaznykiv. Lisivnytstvo i ahrolisomelioratsiia. 2000. Vyp. 97. Kh.: RVP «Oryhinal», 2000. S. 105–111.

[25] Buksha Y.F. Yzmenenye klymata y lesnoe khoziaistvo Ukrayny. Naukovi pratsi Lisivnychoi akademii nauk Ukrainy : zb. nauk. prats. Lviv : RVV NLTU Ukrainy. 2009. Vyp. 7. S. 11-14.

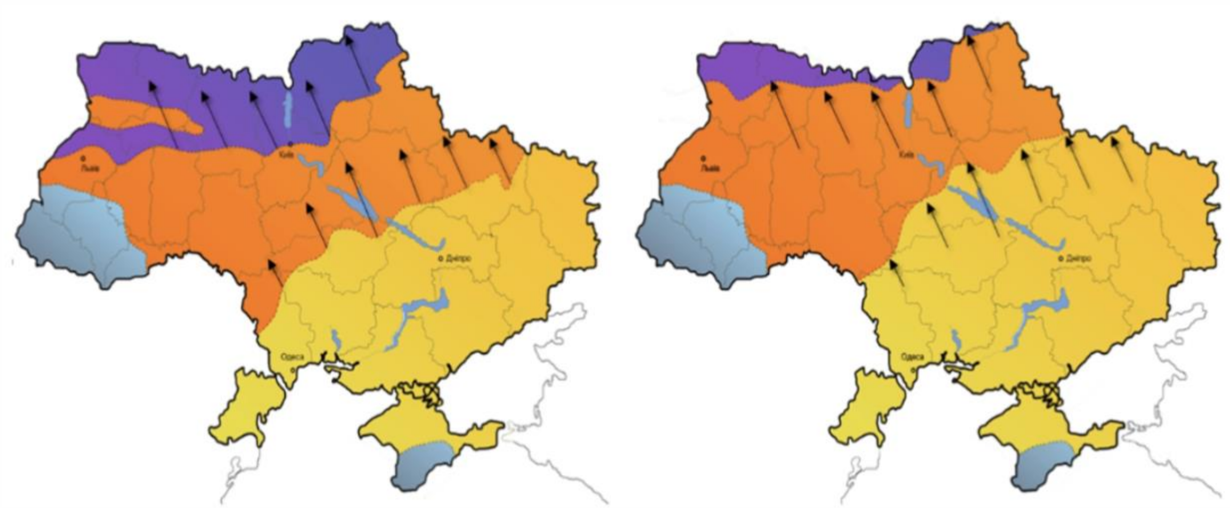

Fig. 1. Forecast of the process of reduction of mixed forest area in the north of Ukraine under the influence of critical temperature increase

As a result of the processes accompanied by climate change, by the end of the twenty-first century, significant areas with characteristic unfavorable conditions for the growth of pine tree species and changes in the main zonal vegetation types are expected to appear[26].

In the variants of territories with unfavorable climatic conditions there will be a significant decrease in the level of productivity of forest-forming tree species, the process of gradual loss of reproductive capacity and natural regeneration, disruption of seasonal development and ontogeny, a decrease in the level of resistance of tree species to pests and diseases, and an increase in the percentage of fire probability (Fig. 2).

[26] Bahniuk V., Polishchuk V. Pryrodni roslynni resursy Polissia: suchasnyi stan i perspektyvy. Visnyk Kyivskoho natsionalnoho universytetu imeni Tarasa Shevchenka. Kyiv: Vydavnycho-polihrafichnyi tsentr Kyivskyi universytet, 2011. Vyp. 29. S. 4–12.

Fig. 2. Forest fires, one of the consequences of global temperature rise

The lower level of changes[27] in the areas favorable for active growth and development of forest ecosystems, which are determined for the growth conditions of Scots pine, is due, on the one hand, to expected climate change and ecological and physiological properties of pine forest species that determine the level of their sensitivity to climate change (Fig. 3).

The projected changes in climate indicators within the current and expected values are generally less dangerous than manifestations of climate variability and the frequency of extreme situations, such as heat waves and active extreme droughts[28].

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[27] Lakyda P.I. Buksha I.F., Pasternak V.P. Zmenshennia ryzyku hlobalnoi zminy klimatu shliakhom deponuvannia vuhletsiu pry lisorozvedenni ta lisovidnovlenni v Ukraini. Naukovyi visnyk NAU : zb. nauk. prats. Ser.: Lisivnytstvo. K. : Vyd-vo NAU 2004. № 79. S. 212 217.

[28] Mieshkova V. L. Vplyv hlobalnykh zmin klimatu na poshyrennia oseredkiv masovoho rozmnozhennia komakh-khvoielystohryziv. Problemy ekolohii lisiv i lisokorystuvannia na Polissi Ukrainy. Vyp. 5 (11). Zhytomyr: Volyn, 2005. S. 62–65.

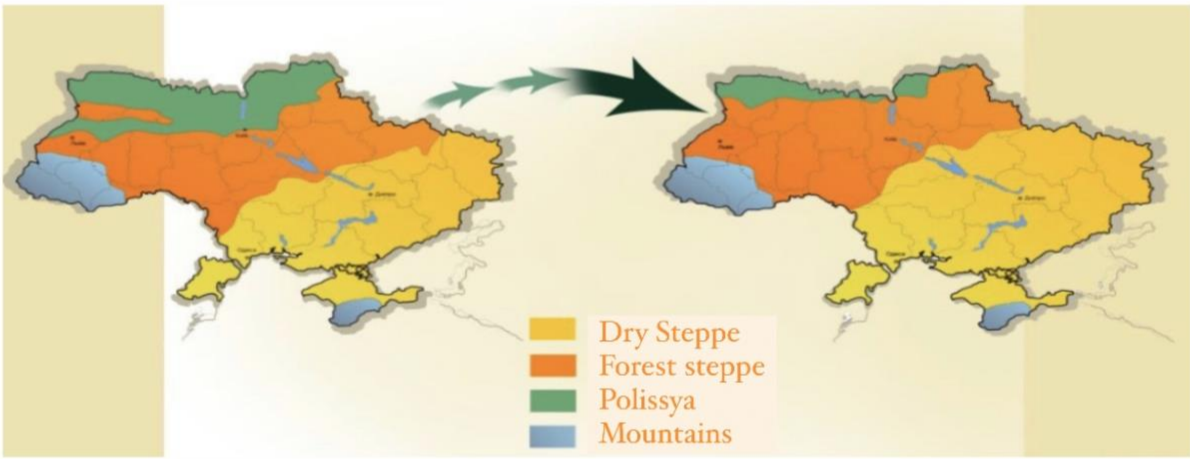

Fig. 3. Change of climate zones in Ukraine (2019 - 2060)

In general, the impact of climate change indicators on the territory of Ukraine can be manifested in various ways[29]:

1) geographical and landscape changes in areas suitable and used for growing certain types of tree species (change in the boundaries of natural climatic zones, disappearance of important forest-forming species or emergence of microorganisms and plants that are not typical for the area)

2) change in the level of vulnerability of forest ecosystems - an option to increase or decrease the level of sustainability, vital processes and forest productivity;

3) manifestation of water or heat stress conditions, especially during the period of extreme climate change impacts;

4) change in ecosystem functions (especially important impact on the quantity of high-quality timber production);

5) processes of increasing or decreasing the volume of plant nutrient cycles;

6) changes in the reproductive cycle of tree species, patterns of succession changes, changes in ecological and social features (especially the impact on the recreational value of ecosystems);

[29] Lakyda P.I. Buksha I.F., Pasternak V.P. Zmenshennia ryzyku hlobalnoi zminy klimatu shliakhom deponuvannia vuhletsiu pry lisorozvedenni ta lisovidnovlenni v Ukraini. Naukovyi visnyk NAU : zb. nauk. prats. Ser.: Lisivnytstvo. K. : Vyd-vo NAU 2004. № 79. S. 212 217.

7) changes in the hydrological regime, etc.

The classical principles of forest management, which are aimed at the processes of creating and forming high productivity forest plantations, preserving and protecting forest ecosystems, are also important for the process of addressing key issues of mitigating the conditions and intensity of climate change. The current regulatory and legislative framework in Ukraine does not describe any special forestry measures to prevent or adapt forest ecosystems to climate change[30].

However, according to the results of scientific research conducted in recent years, the main forestry areas for preventing and facilitating adaptation processes to climate change have been formed[31]. The main areas of forestry activities aimed at preventing the negative processes of climate change are increasing the level of greenhouse gas absorption through further afforestation, sustainable active forestry and reducing deforestation[32]. Given the characteristics of Ukraine's conditions, the imbalance of the land use structure, excessive plowing of the territory, and low level of high-quality forest cover, the priority areas for preventing climate change processes can be identified in the following areas:

1. Optimization of the land use structure, increase in the area of forest plantations, forest belts with options for different purposes, and strengthening of cross-sectoral indicators. The main measures are aimed at reducing the level of arable land in land use, increasing the main areas of land covered with forest woody vegetation, rational planting of forests and special agroforestry tree plantations that create an ecological framework for all agricultural landscapes, taking into account the forest and forest reclamation component in agricultural policy[33].

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[30] Zherebtsov H. A., Kovalenko V. A., Molodыkh S. Y., Kyrychenko K. E. Vlyianye solnechnoi aktyvnosty na temperaturu troposfery y poverkhnosty okeana. Yrkutsk: Yzvestyia Orenburhskoho hosudarstvennoho ahrarnoho unyversyteta. 2013. T.6. №1. S. 61-79.

[31] Buksha Y.F. Yzmenenye klymata y lesnoe khoziaistvo Ukrayny. Naukovi pratsi Lisivnychoi akademii nauk Ukrainy : zb. nauk. prats. Lviv : RVV NLTU Ukrainy. 2009. Vyp. 7. S. 11-14.

[32] Buksha I. F., Pasternak V. P. Inventaryzatsiia ta monitorynh parnykovykh haziv u lisovomu hospodarstvi. Kh.: KhNAU, 2005. 125 s.

[33] Buksha I. Status-kvo zakhodiv shchodo zapobihannia ta adaptatsii do zminy klimatu v lisovomu hospodarstvi Ukrainy ta propozytsii shchodo implementatsii Stratehii z adaptatsii do zminy klimatu

In this option, the main measures are the processes of timely restoration of forest ecosystems (reforestation processes), processes of active high-quality afforestation, high-quality landscaping through tree plantations in settlements, restoration of existing field protection forest strips and all options for agroforestry plantations.

2. Development and implementation of the state program for forestry development, which will take into account the priorities of climate change indicators and low-carbon development.

The national forestry development program should take into account all the development needs of the country and characterize the priorities for further components, such as[34]:

- a set of national and regional forestry policy frameworks with defined goals and ways to achieve them, with options for assigning responsibilities, linkages to land use and climate change policy sectors; legislation, i.e., the creation of laws that will allow for the implementation of the policy and regulatory visions;

- institutions - societies that will develop and make decisions and their implementation in forest administrative bodies, public organizations, professional associations and non-governmental organizations, research and educational institutions;

- information, communication and research on inventory and monitoring of forest ecosystems, forest resource information system, collection, exchange and dissemination of reliable information on forest tree species, including the impact of climate change and vulnerability;

- research on biophysical, social and political aspects of forests and climate change; annual reporting to national and international organizations at various levels;

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silskoho, lisovoho, myslyvskoho ta rybnoho hospodarstv Ukrainy do 2030 roku Elektronnyi resurs. URL: https://mepr.gov.ua/files/docs/Zmina_klimaty/2020/APD%202019%20Climate%20change%20adaptation%20in%20forestry_UA.pdf

[34] Stoiko S.M. Potentsiini ekolohichni naslidky hlobalnoho poteplinnia klimatu v lisovykh formatsiiakh Ukrainskykh Karpat. Naukovyi visnyk UkrDLTU: zb. nauk.-tekhn. prats. Ser.: Hlobalni zminy klimatu zahroza liudstvu ta mekhanizmy vidvernennia. Lviv : RVV NLTU Ukrainy. 2009. Vyp. 19.15. S. 214-224.

- communication and outreach activities for public organizations; competence; financial support mechanisms (all types of possible mechanisms used for effective financing in forestry with mechanisms for attracting and managing financial resources for forestry);

- mechanisms from regulatory authorities.

Priority measures for climate change adaptation

The main task of adaptation for forestry is to increase greenhouse gas absorption through afforestation, sustainable forest management, reduce deforestation and increase the resilience of forest ecosystems[35].

The main priorities in this area[36] are:

increasing the area of forests, forest belts and green spaces, optimizing the structure of land use, strengthening cross-sectoral links;

restoring and modernizing the forest inventory and monitoring program (ground and remote monitoring);

promoting sustainable forest management and forest use; applying incentive mechanisms (forest certification, financial incentives, etc.);

implementing best practices, including adaptive forest management (Climate Smart Forestry);

close-to-nature forestry.

Of particular importance is ensuring the financial sustainability of the state's forestry support, including attracting financial support from international institutions.

For example, the European Union has spent about €8.2 billion on financial support for sustainable forestry for the period from 2014 to 2020[37].

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[35] Buksha I. F., Pasternak V. P. Inventaryzatsiia ta monitorynh parnykovykh haziv u lisovomu hospodarstvi. Kh.: KhNAU, 2005. 125 s.

[36] Didukh Ya. Ekolohichni aspekty hlobalnykh zmin klimatu: prychyny, naslidky, dii. Visnyk Natsionalnoi akademii nauk Ukrainy. 2009. № 2. S. 34-44. URL: http://nbuv.gov.ua/UJRN/vnanu_2009_2_12

There is a need for educational work aimed at raising awareness and knowledge of climate change issues in forestry; initiating a dialogue on forestry policy; and creating a positive image of forestry as a basis for stabilizing the environment in the world in general and in Ukraine in particular[38].

According to the recommendations of the Food and Agriculture Organization of the United Nations (FAO) on the development of climate-smart forestry[39], relevant measures should be based on the concept of "ecosystem adaptation" aimed at improving ecosystem management and providing a wide range of ecosystem services beneficial to society through regulation of local climate conditions, air purification, carbon sequestration, reduction of disaster risks, and provision of clean drinking water[40].

Research methodology. To achieve this goal, the necessary statistical information was collected, which included: data from the Main Department of Statistics of the Zhytomyr Region, indicators of the Ukrainian Hydrometeorological Center and the State Agency of Forest Resources of Ukraine (Form 12-LG) as well as materials provided by the Subbotin Institute of Geophysics of the National Academy of Sciences of Ukraine (NAS of Ukraine)[41].

According to the data obtained from the Ukrainian Hydrometeorological Center, the dynamics of climate change for the period 1961-2020 was analyzed, namely:

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[37] Ieriemieiev V., Yefimov V. Rehionalni aspekty hlobalnoi zminy klimatu. Visnyk NAN Ukrainy. 2003. № 2. S. 14-19.

[38] Khylko M. I. Ekolohichna bezpeka Ukrainy: Navchalnyi posibnyk. K., 2017. 266 s.

[39] Lakyda P.I. Buksha I.F., Pasternak V.P. Zmenshennia ryzyku hlobalnoi zminy klimatu shliakhom deponuvannia vuhletsiu pry lisorozvedenni ta lisovidnovlenni v Ukraini. Naukovyi visnyk NAU : zb. nauk. prats. Ser.: Lisivnytstvo. K. : Vyd-vo NAU 2004. № 79. S. 212 217.

[40] Melnyk P. P. Ekoloho-ekonomichni osnovy upravlinnia pryrodokorystuvanniam v ahroekosystemakh. K: DAI, 2016. 328 s.

[41] Metodychni rekomendatsii shchodo obstezhennia oseredkiv stovburovykh shkidnykiv lisu / V. L. Mieshkova ta in. Kh.: UkrNDILHA, 2011. 27 s.

average annual air temperature, average annual relative humidity, and average annual precipitation[42].

According to the statistical data provided by the State Agency of Forest Resources of Ukraine, the dynamics of entomopest and root sponge occurrence in pine plantations of Zhytomyr Polissya for the period 2009-2020 was analyzed.

According to the materials provided by the Subotin Institute of Geophysics of the National Academy of Sciences of Ukraine, the periods of growth and decline of solar activity (W Number) for the period 2009-2020 were established[43].

The formula of G.T. Selyaninov was used to establish a quantitative indicator of aridity in the study area[44]:

$$MPC = \sum P/0,1 * \sum t_{act>10}$$

where

$\sum P$ – amount of precipitation per month, mm;

$\sum t$ – the sum of the average daily temperature above 10°C.

According to formula if the[45]:

MPC < 0.4, it is a very severe drought;

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[42] Metodychni vkazivky z nahliadu, obliku ta prohnozuvannia poshyrennia shkidnykiv i khvorob lisu dlia rivnynnoi chastyny Ukrainy. Za red. V. L. Mieshkovoi. Kharkiv: TOV Planeta-Print, 2020. 92 s.

[43] Prykhodko M. M. Ekolohichna bezpeka pryrodnykh i antropohenno modyfikovanykh heosystem: monohrafiia. K. : Tsentr ekolohichnoi osvity ta informatsii, 2013. 201 s.

[44] Mieshkova V. L., Bobrov I. O. Balna otsinka prynadnosti nasadzhen Novhorod-Siverskoho Polissia dlia sosnovoho pidkorovoho klopa. Materialy naukovoi konferentsii, prysviachenoi 150-richchiu vid dnia narodzhennia akademika H. M. Vysotskoho, 90-richchiu vid dnia narodzhennia profesora P. S. Pasternaka ta 85-richchiu vid chasu zasnuvannia Ukrainskoho ordena "Znak Poshany" naukovo-doslidnoho instytutu lisovoho hospodarstva ta ahrolisomelioratsii im. H. M. Vysotskoho. Lisivnycha nauka v konteksti staloho rozvytku. (m. Kharkiv, 2-30 veresnia 2015 r.). Kharkiv: UkrNDILHA, 2015. S. 122-123.

[45] Omarov A. E. Suchasnyi stan ekolohichnoi bezpeky v Ukraini. Visnyk Natsionalnoho universytetu tsyvilnoho zakhystu Ukrainy. Seriia : Derzhavne upravlinnia. 2017. Vyp. 2. S. 156-164. Rezhym dostupu: http://nbuv.gov.ua/UJRN/VNUCZUDU_2017_2_24

MPC 0.4-0.5 – severe drought;

MPC 0.6 – 0.7 – moderate drought;

MPC 0.8 – 0.9 – weak drought;

MPC 1.0 – 1.5 – sufficiently humid;

MPC > 1.5 – excessively humid.

The years of drought and humidity in the study region for the period 2009 – 2021 were determined.

One of the main characteristics of solar activity is the power (activity) of sunspot formation (sun flares, sunspots, Zurich number) (Fig. 4), this indicator is called the Wolf number in honor of the Swiss astronomer Rudolf Wolf.

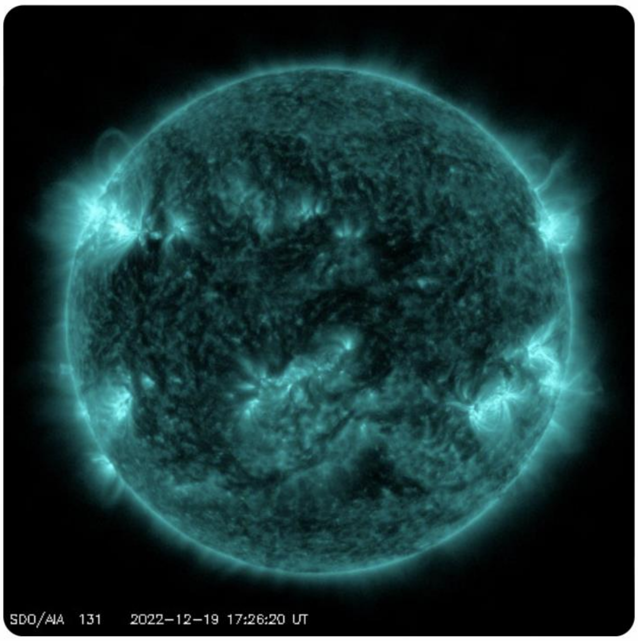

Fig. 4. Solar flares

(source: https://www.spaceweatherlive.com/uk/sonyachna-aktivnist/sonyachni-spalahi.html)

The Wolf number is determined by the formula[46]:

[46] Moroz V.V., Nykytiuk Yu.A. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Zhytomyrskoho Polissia cherez zahybel sosnovykh nasadzhen. Mizhvidomchyi tematychnyi naukovyi zbirnyk «Melioratsiia i vodne hospodarstvo». Kherson. 2020. №1. S.112-121.

$$W = k * (10 * g + f)$$

where

k – coefficient close to 1;

g – the number of sunspot groups;

f – the total number of spots in the groups.

Greenhouse gas emissions cause significant damage to plants, often leading to non-communicable diseases, drying out and death of plantations.

In the course of the statistical analysis, the amount of greenhouse gas (CO_2) emissions into the environment for the period 2009-2021 was analyzed (statistical indicators of the State Statistics Service of Ukraine were used)[47].

We conducted a dispersion statistical analysis based on the theory of probability (in biology, this analysis was first applied in 1912 by R. Fisher, who discovered the law of distribution of the ratio of mean squares (dispersions)).

The analysis was performed using the Microsoft Excel data analysis package.

Assessment of the impact of biotic and abiotic factors on the state of pine forests

Climate change in Zhytomyr Polissia[48]. According to the Ukrainian Hydrometeorological Center, a detailed analysis of changes in air temperature,

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[47] Mieshkova V. L., Bobrov I.O. Prynadnist nasadzhen Novhorod-Siverskoho Polissia dlia poshyrennia oseredkiv sosnovoho pidkorovoho klopa. Fundamentalni ta prykladni doslidzhennia v zoolohii: materialy mizhnarodnoi nauk.-prakt. konf., prysviach. 175-richchiu kafedry zoolohii ta entomolohii im. B. M. Lytvynova KhNAU im. V. V. Dokuchaieva (1840-2015 rr.), (Kharkiv, 21-22 travnia 2015 r.). Kh.: KhNAU, 2015. S. 75-78.

[48] Iavorskyi P. P. Vplyv zmin klimatu na lisovi ekosystemy. Lisove i sadovo-parkove hospodarstvo. 2015. №6. http://journals.nubip.edu.ua/index.php/Lis/article/view/9995.

precipitation, and relative humidity in Zhytomyr Polissia[49] over the period 1961 – 2021 was conducted[50].

In recent years, the average annual air temperature in the study area has increased by 3.0˚C (Fig. 5)[51].

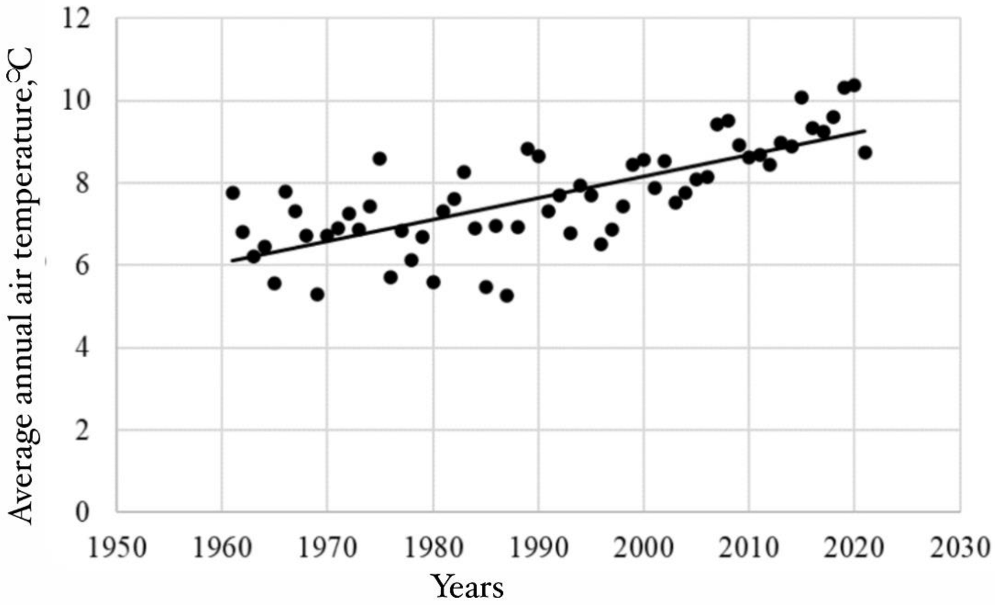

Fig. 5. Changes in the average annual air temperature in Zhytomyr Polissia for the period 1961-2021

[49] Marynych A. M., Syrota N. P. Zhytomyrskoe Polesia. Fyzyko- heohrafycheskoe raionyrovanye Ukraynskoi SSR. K.: Yzd.-vo Kyev, un.-ta, 1968. S. 52–77.

[50] Stykhiini meteorolohichni yavyshcha na terytorii Ukrainy za ostannie dvadtsiatyrichchia (1986-2005) / za red. V.M. Lipynskoho, V.I. Osadchoho, V.M. Babychenka. K.: Vyd-vo "Nika-Tsentr", 2006. 312 s.

[51] Heohrafichne roztashuvannia ta klimatychni umovy. URL: http://ztinvest. gov.ua/ua/pro-region/geografichne-roztashuvannya-ta-klimatichni-umovi

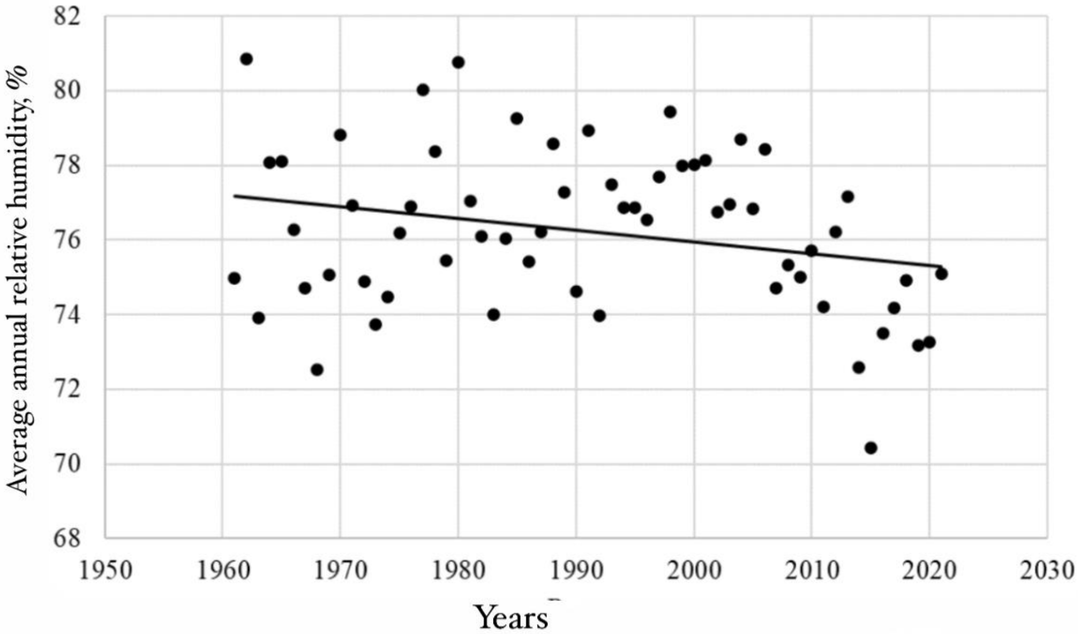

Fig. 6. Average annual relative humidity in Zhytomyr Polissia for the period 1961-2021

This warming has had a direct impact on relative humidity (Fig. 6), with relative humidity decreasing by 2% over the past forty years.

There is also an increase in average annual precipitation by 10 mm (Fig. 7).

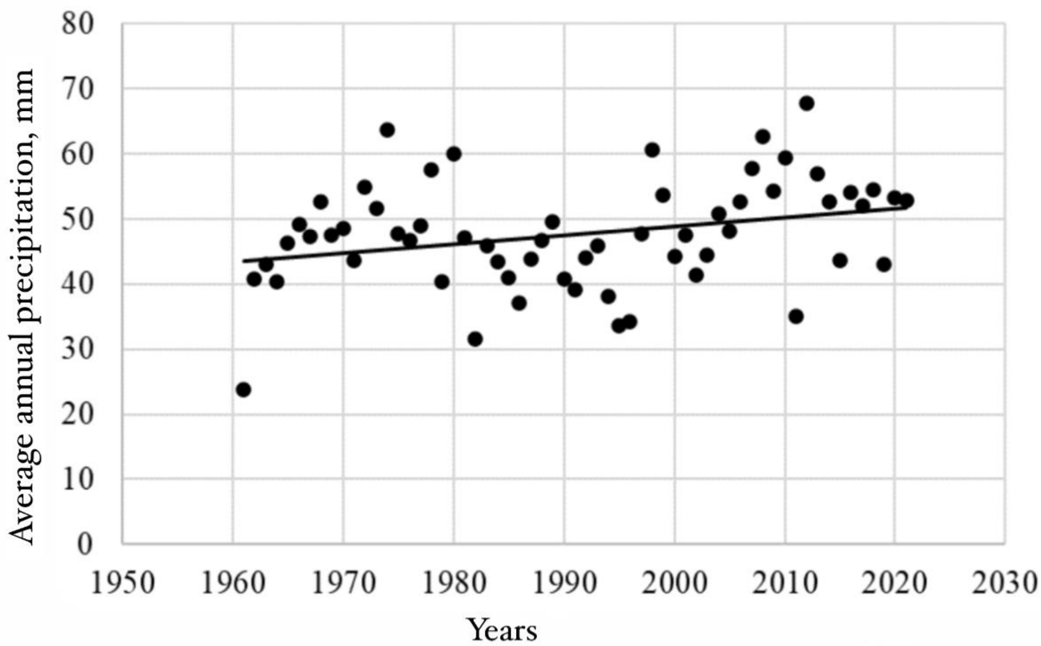

Fig. 7. Average annual precipitation in Zhytomyr Polissya for the period 1961-2021

Thus, the analysis of climate indicators showed significant climate change in the study area, and such climate change in the study area has an impact on biodiversity.

Analysis of the influence of biotic and abiotic factors on the state of pine plantations

Since 2009, the State Agency of Forest Resources of Ukraine has been carefully recording the occurrence of entomopest pests in Ukraine. According to the submitted reports for 2009-2021: "Report on forest protection works", the research analyzed that the pine plantations of Zhytomyr Polissya are most damaging to pine trees: pine scoopers (*Panolis flammea* Denis & Schiffermuller), common pine sawfly (*Diprion pini* L.), red pine sawfly (*Neodiprion sertifer* Geoffroy), pine bark beetle (*Aradus cinnamomeus* Panz), pine silkworm (*Dendrolimus pini* L.), pine moth (*Bupalus piniarius* L.) and other pests (Fig. 8).

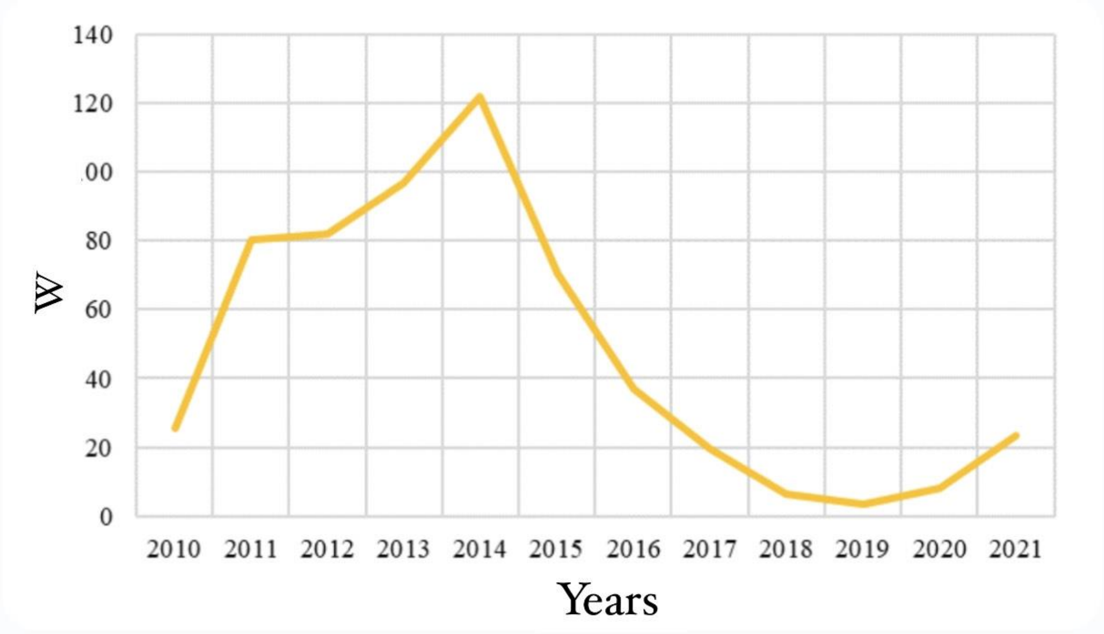

Fig. 8. The value of Wolff's annual average numbers for the period 2010-2021.

According to Fig. 8, the most harmful effect on pine plantations is caused by the needle-gnawing pest - the common pine sawfly (*Diprion pini* L.), its largest centers were observed in 2011-2014 and amounted to 11.1 thousand hectares. Over the past four years, this number has decreased by almost 2 times.

Pine plantations in Zhytomyr Polissya occupy 59% of other tree species, and over the past 12 years, 20% of their area has been damaged by entomopest.

Studying the dynamics of solar activity, the Wolf number (W number) for the period 2009 – 2021, it was found that the highest solar activity was observed in the period 2011 – 2014, starting from 2014 – 2019, there was a decrease in solar activity, and from 2020, the solar activity began to increase.

Analyzing the dynamics of the number of W (Fig. 8) and the area of damaged trees by entomopests, a certain pattern was observed: during the period of increasing solar activity in 2011-2014, the number of damaged pine plantations also increased, and in the years of decreasing solar activity, the opposite is true.

The same situation is observed when analyzing the impact of the root sponge Heterobasidion annosum (Fr.) Bref. on pine plantations.

In 2011 – 2015, the area of plantations damaged by the root sponge was much larger than in other years, which coincided with the sun's activity during this period. Using the formula of G.T. Selyaninov, the change in climate humidity in the conditions of Zhytomyr Polissya for the period 2009-2021 was determined. According to the results of calculations of the hydrothermal coefficient, the years of mild drought were 2009, 2016, 2017; moderate drought – 2015; sufficient moisture – 2010 – 2012, 2014, 2018 – 2021; excessive moisture – 2013. If we compare the sun's activity with changes in humidity[52], we do not observe a pattern.

To find out whether there is a relationship between the W-number and CO_2 emissions into the environment, we analyzed carbon dioxide emissions into the environment for the period 2009 – 2021. In order to find out whether there is an

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[52] Mieshkova V. L., Bobrov I. O. Balna otsinka prynadnosti nasadzhen Novhorod-Siverskoho Polissia dlia sosnovoho pidkorovoho klopa. Materialy naukovoi konferentsii, prysviachenoi 150-richchiu vid dnia narodzhennia akademika H. M. Vysotskoho, 90-richchiu vid dnia narodzhennia profesora P. S. Pasternaka ta 85-richchiu vid chasu zasnuvannia Ukrainskoho ordena "Znak Poshany" naukovo-doslidnoho instytutu lisovoho hospodarstva ta ahrolisomelioratsii im. H. M. Vysotskoho. Lisivnycha nauka v konteksti staloho rozvytku. (m. Kharkiv, 2-30 veresnia 2015 r.). Kharkiv: UkrNDILHA, 2015. S. 122-123.

influence of one indicator on another, we used an analysis of variance between the impact of solar activity[53] and the area of occurrence of entomopest pests, root sponge, Selianinov MPC, average annual air temperature, average annual relative humidity, as well as the impact of CO_2 emissions[54] on the number W.

The results of the analysis are presented in Tables 1 – 8 .

In the tables, with analysis of variance: the first column "Source of Variation" contains the name of the variance;

"SS" is the sum of squared deviations;

"df" is the degree of freedom;

"MS" is the mean square (MS=SS/df);

"F" is the actual criterion (calculated value of Fisher's criterion);

"F-value" is the distribution (calculated value of minimum significance);

"P-value" is the probability that the variance reproduced by the equation is equal to the variance of the residuals.

Table 1.

One-factor analysis of variance between W number and the presence of pest infestations

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
W	13	580,2	44,6	1632,4
Area of trees damaged by entomopest pests, thousand hectares	13	96,6	7,4	13,7

[53] Zherebtsov H. A., Kovalenko V. A., Molodыkh S. Y., Kyrychenko K. E. Vlyianye solnechnoi aktyvnosty na temperaturu troposfery y poverkhnosty okeana. Yrkutsk: Yzvestyia Orenburhskoho hosudarstvennoho ahrarnoho unyversyteta. 2013. T.6. №1. S. 61-79.

[54] Ieriemieiev V., Yefimov V. Rehionalni aspekty hlobalnoi zminy klimatu. Visnyk NAN Ukrainy. 2003. № 2. S. 14-19.

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	8996,3	1	8996,3	10,9	0,003	4,26
Inside the groups	19753,8	24	823,07			
Together	28750,1	25				

Let's compare the value of Fisher's criterion (F-actual) with the critical one (F-distribution):

$$Factual > Fdistribution = 4.26.$$

Thus, we can conclude that the number W affects the presence of pest foci.

Table 2.

One-factor analysis of variance between W number and the presence of root sponge cells

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
W	13	580,2	44,6	1632,4
Area of trees damaged by presence of root sponge cells, thousand hectares	13	174,8	13,4	1,84

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	6321,6	1	6321,6	7,74	0,0104	4,26
Inside the groups	19610,8	24	817,12			
Together	25932,4	25				

According to the data obtained, Factual > Fdistribution = 4.26, so it can be argued that the number W affects the presence of root sponge cells.

According to the analysis of variance, Factual > Fdistribution = 4.26, which means that the number W affects the average annual air temperature.

Table 3.

One-factor analysis of variance between the W number and the average annual air temperature, °C

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
W	13	580,2	44,6	1632,4
Average annual air temperature, °C	13	237,6	18,3	0,329

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	4514,2	1	4514,2	5,53	0,027	4,26
Inside the groups	19592,7	24	816,36			
Together	24106,9	25				

Since the calculated value of the Fisher's criterion is greater than the calculated value of the minimum significance (Factual < Fdistribution), we can conclude that solar activity has no effect on the average annual relative humidity in Zhytomyr region.

Table 4.

One-factor analysis of variance between the W number and the average annual relative humidity, %

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
W	13	580,19	44,6	1632,4
Average annual relative humidity, %	13	836,88	64,4	276,6

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	2534,2	1	2534,2	2,66	0,116	4,26
Inside the groups	22908,0	24	954,5			
Together	25442,2	25				

Table 5.

One-factor analysis of variance between W and average annual precipitation, mm

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
W	13	580,19	44,6	1632,4
Average annual precipitation, mm	13	668,84	51,4	69,4

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	302,3	1	302,3	0,355	0,557	4,26
Inside the groups	20421,1	24	850,9			
Together	20723,4	25				

According to the analysis, it can be noted that W has no effect on the average annual precipitation Factual < Fdistribution.

Table 6.

One-factor analysis of variance between the W number and the hydrothermal coefficient of Selyaninov G.T.

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
W	13	580,2	44,6	1632,4
Hydrothermal coefficient of G.T. Selyaninov	13	15,0	1,2	0,1

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	12285,8	1	12285,8	15,1	0,0007	4,2597
Inside the groups	19589,9	24	816,2			
Together	31875,8	25				

According to the analysis of variance, Factual > Fdistribution = 4.26, so the number W affects the hydrothermal coefficient of G.T. Selyaninov.

Table 7.

One-factor analysis of variance between CO_2 emissions and the number W

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
CO_2 emissions	13	15,3	1,2	0,204
W	13	580,19	44,6	1632,4

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	12273,1	1	12273,1	15,0	0,0007	4,2597
Inside the groups	19591,2	24	816,3005			
Together	31864,3	25				

According to the analysis of variance, Factual > Fdistribution = 4.26, we can conclude that CO2 emissions affect the sun's activity.

Table 8.

One-factor analysis of variance between average annual air temperature and area of entomopest infestations, thousand hectares

RESULTS

Groups	*Account*	*Amount*	*Average*	*Dispersion*
Average annual air temperature, °C	13	237,6	18,3	0,330
Area of entomopest infestations, thousand hectares	13	96,6	7,4	13,7

ANALYSIS OF VARIANCE

Source of variation	*SS*	*df*	*MS*	*F*	*P-value*	*F-distribution*
Between groups	765,2	1	765,2	108,7	2E-10	4,26
Inside the groups	168,9	24	7,04			
Together	934,1	25				

According to the results of the dispersion analysis, Factual > Fdistribution, therefore, it can be concluded that the average annual air temperature affects the occurrence of areas with entomopest pests.

Thus, according to the dispersion analysis, it can be concluded that the number W directly affects the occurrence of pest foci, root sponge, average annual air temperature, the G.T. Selyaninov hydrothermal coefficient, and has no effect on average annual relative humidity and average annual precipitation.

Carbon dioxide emissions affect solar activity, and the average annual air temperature affects the occurrence of pest foci.

The obtained results of the analysis fully coincide with the statements of scientists[55] O. L. Chizhevsky, P. Faraone, V. S. Martyniuk, N. A. Temuryants, B. M. Vladimirsky, G. O. Zherebtsov, V. A. Kovalenko, S. I. Molodykh, K. E. Kirichenko, P. P. Melnyk, V. B. Chernyshov and others[56], who in their scientific works emphasized the influence of solar activity[57] on the dynamics of phytodiseases, entomopests, the relationship between air temperature[58] and CO2 emissions[59], etc.

In recent years, sanitary felling has increased significantly as a result of forest damage caused by pathogenic diseases.

If the stock of plantations subject to sanitary felling in the period 1997 – 2020 averaged 593.7 thousand m3, then in the period 2003 – 2009 sanitary felling increased by 47%, and from 2010 – 2020 it increased 3.2 times.

Since pine plantations predominate in Zhytomyr Polissia, accounting for 59%, they naturally become the main "victim" of pests and phytodiseases.

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[55] Zherebtsov H. A., Kovalenko V. A., Molodыkh S. Y., Kyrychenko K. E. Vlyianye solnechnoi aktyvnosty na temperaturu troposfery y poverkhnosty okeana. Yrkutsk: Yzvestyia Orenburhskoho hosudarstvennoho ahrarnoho unyversyteta. 2013. T.6. №1. S. 61-79.

[56] Druhe natsionalne povidomlennia Ukrainy z pytan zminy klimatu. K. : Vyd-vo "Interpres", LTD, 2006. 80 s.

[57] Moroz V. V., Nykytiuk U. A. The effects of solar activity, moisture supply, and carbon dioxide on Ukrainian forest plantation death. Danish scientific journal. 2020. №34. Vol. 2. P.8-14.

[58] Moroz V.V., Nykytiuk Yu.A., Vorobel M.I. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Volynskoho Polissia cherez zahybel sosnovykh lisiv. The scientific heritage. 2020. №46. Vyp. 2 (46). S.21-27.

[59] Moroz V.V., Nykytiuk Yu.A. Znyzhennia vuhletsepohlynalnoi zdatnosti derevostaniv Zhytomyrskoho Polissia cherez zahybel sosnovykh nasadzhen. Mizhvidomchyi tematychnyi naukovyi zbirnyk «Melioratsiia i vodne hospodarstvo». Kherson. 2020. №1. S.112-121.

Restoration of forests by the Zhytomyr Regional Forestry and Hunting Department

The main goal of forestry development in Zhytomyr region is the restoration and reproduction of forests. To ensure timely reforestation, the Zhytomyr Regional Forestry and Hunting Range Administration (FRHA) is committed to timely reforestation of logging areas.

Every year, the Zhytomyr FRHA approves "Action Plans" that provide for spring silvicultural companies. In addition, the possibility of increasing the volume of forest crops is considered annually. For this purpose, valuable sowing and planting material is grown at state-owned enterprises. When choosing the material, preference is given to hereditary and genetic properties. Seeds are harvested in a timely manner, and the system of their storage is improved so that the plant does not lose its sowing qualities. Selected high-quality seeds are tested for germination and then sown in forest nurseries.

The farm's employees take care of the seedlings at a high technological level.

When planting seedlings on forestry plots, forestry workers are tasked with producing a highly productive and biologically sustainable forest.

The state forestry enterprises of the Zhytomyr FRHA have a permanent forest seed base with an area of 4276.2 hectares, which includes:

- plantations of plus trees with an area of 111.6 hectares;
- permanent forest seed plots with the area of 1151.2 hectares;
- genetic reserves covering an area of 2917.4 hectares;
- timber and seed plantations with an area of 96.0 hectares.

The company has 170 units of forest nurseries with a total area of 100 hectares, and it is in these nurseries that harvested seeds from the forest seed base facilities are sown, where 35.2 tons of seeds from tree species are harvested, which is 51% of the total amount of seeds.

Seed sowing and creation of forest crops are carried out in accordance with the approved "Project".

In 2022, the state enterprise, which annually increases the volume of the forestry company, grew 40.9 million cuttings and seedlings. This amount is quite sufficient to restore logging sites, as well as to sell products to various farms.

For reforestation of logging sites and forest plantations, 600,000 seedlings were grown. The seedlings are grown using peat tablets, which accelerates the growth process and simplifies the care technology.

In addition to the main forest-forming tree species, ornamental plants for sale are grown on the 22.5-hectare school grounds. The ornamental planting material is dominated by various decorative forms, spruce, fir, barberry, thuja, juniper, magnolia, holly mahonia, willow, including Matsudana willow, forsythia, spirea, lilacs, hydrangeas, cotoneaster, buddleia, hibiscus and other types of trees and shrubs.

The main base for collecting seeds and cuttings is 290 plus trees. Plus trees are defined by their biological stability and promising genetic material. Seeds are collected from these trees and then planted in forest nurseries. Cuttings of plus trees are also subject to propagation.

In addition to growing their own planting material, the state-owned enterprises of the Zhytomyr Regional Forestry and Hunting Range Administration purchase seeds from other farms. For example, last year, 58.8 thousand kg of acorns and 1.89 thousand kg of conifers were purchased.

Every year, state-owned enterprises of the Zhytomyr Regional Forestry and Hunting Range Administration increase the area of forest reproduction in Zhytomyr region. The graph shows that from 2020 to 2022, the area of forest reproduction increased by 30%.

Given the influence of biotic and abiotic factors on the state of pine plantations, forest restoration should be considered as a necessary measure of environmental protection.

Conclusions. It is analyzed that certain climatic changes have been taking place in the conditions of Zhytomyr Polissya over the past forty years, namely: an increase in the average annual air temperature by 3.0˚C, a decrease in the average annual relative humidity by 3%, an increase in the average annual precipitation by 2 mm.

It was found that the most harmful effect on pine plantations of Zhytomyr Polissya is caused by: pine scoopers (Panolis flammea Denis & Schiffermuller), common pine sawfly (Diprion pini L.), red pine sawfly (Neodiprion sertifer Geoffroy), pine bark beetle (Aradus cinnamomeus Panz), pine silkworm (Dendrolimus pini L.), pine moth (Bupalus piniarius L.), and among phytodiseases, Heterobasidion annosum (Fr.) Bref causes significant damage.

A comprehensive analysis of various indicators for the period 2010-2020 confirmed the statements of scientists about the impact of the Wolf number and carbon dioxide emissions on the spread of entomopests and phytodiseases in pine plantations in Zhytomyr Polissya. It was found that the increase and decrease in solar activity directly affects the growth and decrease in the number of entomopests and phytodiseases, respectively.

It is analyzed that in recent years, as a result of damage to pine plantations by phytopathogens and pests, sanitary felling has increased by almost 320% (or 3.2 times) in recent years.

In order to improve the current state of forests, Zhytomyr FRHA takes all necessary measures to restore forests. A permanent forest seed base with an area of 4276.2 hectares, 170 units of forest nurseries with a total area of 100 hectares were created, 40.9 million cuttings and seedlings were grown in 2022, a base for collecting seeds and cuttings from plus trees was created, and the area of forest reproduction in Zhytomyr region is increasing every year.

THE INFLUENCE OF ENTOMOFAUNA ON THE STATE OF PINE PLANTATIONS IN ZHYTOMYR POLISSYA

Currently, a significant number of research results are devoted to the effectiveness of diagnosing the sanitary condition of forest plantations, including the characterization of the species composition of the entomofauna, their development, the degree of damage to forest plantations, and measures to combat them[60].

Climate change[61] has led to a weakening of pine plantations and, as a result, an increase in the population of entomopest pests that have a harmful effect and cause the death of plantations[62]. Succession changes also result in certain changes in the species composition of the plant world, which also affects the structure, development and functioning of entomocomplexes.

Entomofauna is one of the sensitive indicators of hydro-edaphic conditions[63]. The increase in the population of entomofauna depends on the type of forest, the type of soil conditions, the bonita, the stability of tree plantations, and the moisture supply of the territory. Insect communities of different ecosystem layers depend on their habitat and are directly or indirectly affected by various anthropogenic factors.

Insects are an extremely diverse group of animals in terms of size, feeding method, spatial location, level of connection in different soil types, and other properties that form a rather complex system called the "geobiological complex."

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[60] Anfinikov M. O., Lisovskyi A. V., Spektor M. R. Shkidnyky i khvoroby lisu ta borotba z nymy. Kyiv: Urozhai. 1973. 12 s.

[61] Babichenko V. M. Nikolaieva N. V., Hushchyna L. M. Zminy temperatury povitria na terytorii Ukrainy naprykintsi XX ta na pochatku XXI stolittia. Ukrainskyi heohrafichnyi zhurnal. K.: Akademperiodyka, 2007. № 4 C. 3-12.

[62] Buksha I. Status-kvo zakhodiv shchodo zapobihannia ta adaptatsii do zminy klimatu v lisovomu hospodarstvi Ukrainy ta propozytsii shchodo implementatsii Stratehii z adaptatsii do zminy klimatu silskoho, lisovoho, myslyvskoho ta rybnoho hospodarstv Ukrainy do 2030 roku Elektronnyi resurs. URL: https://mepr.gov.ua/files/docs/Zmina_klimaty/2020/APD%202019%20Climate%20change%20adaptation%20in%20forestry_UA.pdf

[63] Bardina O. O. Mizhnarodne normatyvne zabezpechennia vyrishennia problem zminy klimatu. Naukovi zapysky Instytutu zakonodavstva Verkhovnoi Rady Ukrainy. 2013 № 5. S. 131–137.URL: http://nbuv.gov.ua/UJRN/Nzizvru_2013_5_28.

The biggest difference between soil invertebrates is that their trophic relationships are rather unstable and less obligatory than those of the entomofauna of the aboveground layers of the biogeocenosis[64]. Almost all species and groups of soil layer insects have a very complex and variable trophic structure.

Stem insects often cause damage to living healthy trees, thereby worsening the biological productivity of forests and reducing the cost of the business part of the tree. In the process of additional feeding, hard-winged insects destroy the main central bud and gnaw the shoot, which causes the replacement of the terminal shoot and provokes a defect in the trunk part of the tree in the process of further development.

The level of physiological harmfulness of stem insects is manifested by the fact that they weaken viable trees in the process of additional nutrition and subsequently contribute to the infection of plantations with pathogens of various diseases. Stem pests are able to live and reproduce in different ranges of temperature and humidity. Soil and climatic conditions (temperature, precipitation, humidity, lighting, wind direction and intensity, and soil types) affect the properties of the insect population, such as fertility, mortality rate, age structure, sex structure, and migration rate.

The most common coniferous forest-forming tree species in Zhytomyr Polissia is Pinus sylvestris L. This species is characterized by a rapid growth rate and is quite resistant to a wide range of soil conditions and variable humidity levels. Pine is capable of forming clean forest stands even on extremely poor soil types (sandy and limestone), where other tree species do not grow[65].

On the territory of Polissia (according to V. K. Myakushko), two main groups of subformations are distinguished in the formations of Scots pine (Pinus sylvestris L.): pure pine plantations (forests: dry, wet, fresh, damp) and broadleaf pine (forests: oak-

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[64] Beletskyi E. N., Stankevych S. V. Polytsyklychnost, synkhronnost y nelyneinost populiatsyonnoi dynamyky nasekomykh y problemy prohnozyrovanyia: Monohrafyia. Vena: Premier Publishing s.r.o.Vienna, 2018. 138 s.

[65] Valenta V. T. Entomokompleksy khvoinykh porod Lytvy y pryntsypy razrabotky systemy lesozashchytnykh meropryiatyi. Vylnius, 2012. 302 s.

pine and hornbeam-oak-pine), which are characterized by different environmental conditions and have the appropriate species composition of insect communities.

The study of entomocomplexes of forest ecosystems in Polissia has a long history, but the level of research remains insufficient[66].

For a considerable period of time, all studies were aimed at a detailed study of the species structure of micro- and mesoarthropods.

According to studies conducted in different parts of the world, in the first years of development, loblolly pine is most affected by insects and various pathogens more than by abiotic factors. At the stage of establishment of a young forest, the primary damage to the roots, bark of the trunk and branches, buds, shoots and needles of the plantation is caused by insects.

Distribution and biological features of pine bark beetle (Aradus cinnamomeus Panz.)

The bark beetle is widespread in almost all young pine plantations, but the centers of its massive reproduction are dry forests and subboreal forests in thinned pine crops.

Adult bugs are 3.5-5.0 mm long and have a color very similar to the color of pine bark and live most of the time under the scales of the tree bark (Fig. 9)[67]. The main property of this species is the presence of a special mouthparts of the spiny-sucking type, which, when used to suck sap from tree tissues, makes it 2 times longer than its body length.

A significant level of damage to pine trees is caused by pests at the larval and adult stages. The full cycle of larval to adult transformation takes five molts, and the

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[66] Hamaiunova S. H., Novak L. V., Davydenko K. V., Mieshkova V. L. Vplyv umov utrymannia sosnovoho shovkopriada v laboratorii na znachennia osnovnykh populiatsiinykh pokaznykiv. Lisivnytstvo i ahrolisomelioratsiia. 2000. Vyp. 97. Kh.: RVP «Oryhinal», 2000. S. 105–111.

[67] Holovetskyi M. P. Formuvannia vysokoproduktyvnykh i biolohichno stiikykh shtuchnykh nasadzhen sosny u svizhykh borakh pivnochi Kyivskoho Polissia: Avtoref. dys. na zdobuttia nauk. stup. kand. s.-h. nauk. Kh., 2003. 91 s.

development period of larvae of each age lasts 28-30 days. Mostly larvae of the fourth instar overwinter, which in the spring after molting turn into larvae of the fifth instar, and then in 27-32 days (depending on air temperature) turn into adults.

Fig. 9. Aradus cinnamomeus Panz

The adult pine beetle is represented by males and females, which are short-winged and long-winged. Only long-winged females are capable of colonizing new plantation territories, their share in populations being only 6 – 10%.

Larvae and adults resume feeding in the spring under the bark of trees, under conditions of stable air temperature above 5ºC. Depending on the level of forest floor warming, the period of pests' ascent to tree trunks lasts several weeks, from 1 – 2 weeks for adults and 3 – 5 weeks for larvae, due to differences in their spatial distribution in wintering areas.

After feeding, adults immediately begin mating. Most often this happens in mid- or late April, but in some years even at the end of March.

The process of egg laying occurs 6 – 10 days after mating, and each clutch contains 16 – 28 eggs in cracks, under bark scales and on the surface of the trunk in the period from April to mid-June. For eggs to develop, the optimum temperature is between 10 and 35°C and humidity is at least 55%. The larvae start feeding 7 – 9 days after hatching (June – July). Larvae and adults of the pine bark beetle can overwinter both in the forest floor around trunks and under the bark of trees, depending on the climatic conditions of the region, forest and vegetation characteristics and species composition of plantations.

This type of pest stops feeding only when stable subzero temperatures occur, but the activity of individuals resumes during the day after night frosts.

The bugs feed on the tissues of pine trees that are 5 – 20 years old, which causes changes in tree tissues (brown spots are formed) and "wound" parenchyma appears, which prevents the flow of water from the roots to the crown (Fig. 10).

Fig. 10. Apical drying of a pine in the event of a violation of the nutrition of tree tissues

At the same time, irreversible changes in the appearance of the crown begin, and the needles lose their luster, become smaller, change color, and eventually turn yellow. As a result, growth decreases and trees with dry tops are formed.

Distribution of the pine bark beetle depending on the types of forest conditions, age and species composition of stands

According to scientists, the pine bark beetle can be found in almost all types of forest conditions.

The pest is a light-loving species, so the initial population of plantations depends on their density: at a plantation density of 0.1 – 0.3, the occurrence of this species reaches 85 – 90 individuals/dm2, at a density of 0.4 – 62 individuals/dm2, at a density of 0.5 – 0.6 – up to 150 – 250 individuals/dm2.

However, in Polissia, the pine bark beetle was found in 16 – 25-year-old crops with a density of 0.6 – 0.7 in dry forests and suburbs.

The researchers believe that the intensity of the pine bark beetle's damage depends not only on the climatic conditions of the region, but also on the age of the tree plantations, as this species begins to actively colonize pine plantations at the age of 5 – 7 years, when scales are already forming on the bark of trees. The level and intensity of pine bark beetle infestation increases with the age of the plantations, and the pest centers are permanent and can last for 24 – 26 years.

Along with the age factor, the intensity of the growth of the number of bark beetles in coniferous plantations is also affected by the species composition.

The introduction of hardwoods into coniferous plantations, the presence of dense undergrowth and herbaceous vegetation in plantations negatively affects harmful insects due to changes in humidity, lighting, and heat.

Harmfulness of the pine bark beetle

The harmfulness of the pine bark beetle largely depends on the condition of the tree plantations it infests. There is a significant amount of research on the infestation of healthy trees by the pine beetle, followed by their significant weakening and death.

The harmful properties of the pine bark beetle activity actively begin when the trees reach the age of 5 – 7 years. The first signs of the pest's "attack" are easy to detect visually, they appear as small whitish spots – these are the places where the insect's suction tube enters. Such spots are especially noticeable on young trees. Over time, the spots gradually darken, turn yellow, and finally become brown. With a significant number of pests, the spots cover most of the trunk surface and eventually overgrow with "wound" parenchyma, which occurs as a result of prolonged feeding of the pine beetle.

The process of tissue resinization begins as a result of the death of epithelial cells lining the resin passages, and cavities filled with resin form under the bark. The bark cracks, the resin flows out, first in the form of droplets, then ulcers form, from which the resin flows constantly.

After the appearance of this symptom, the appearance of the tree crown changes: gradually luster is lost and becomes light in color. With a significant number of pests in younger trees, resin flow is more intense, and the sap covers most of the trunk surface. The further process of tree damage by the pest causes a decrease in growth, a decrease in the length of needles and, as a result, the death of plantations.

The harmful activity of the subcarpal bug in pine plantations is manifested primarily in the negative impact on the moisture conducting system of trees. Damaged tissues block the core rays and reduce the possibility of using the tree's reserve moisture reserves, which are stored in the deeper layers of the plant.

Internal resinous ulcers, which suck away the surrounding wood, further disrupt the tree's moisture conducting system. Plantations in which pine beetle infestations have developed are also extremely susceptible to fungal diseases.

Research methodology. Field studies were conducted in the forest fund of the state specialized forestry enterprise (SFE) "Ovruch Specialized Forestry" (SE "Ovruch SFE") located in Zhytomyr Polissya in the territory of Ovruch district in the northeastern part of Narodytsia administrative district, according to the current zoning.

For the purpose of the analysis, 12 test plots were established in the forestries of the special forestry: Pishchanytsia, Pryluky, Sitovets, Berezhestvo, Vystavytske, Hladkovytsia, Ignatpillya, Ovruch, Vystavytske, and Zhurben forestries.

The trees were recorded on the CCI using an IU1M height meter (measuring the height of a tree), a Swedish peaceful aluminum Haglof fork (measuring the diameter of a tree at a height of 1.3 m). The TPP was established in accordance with SOU 02.02-37-476:2006 "Forest management trial areas. Method of establishment".

The number of pine bark beetle was estimated on trees growing on 5 10×10 m plots, established along the edges and in the central part of the 100×100 m trial area.

On 50 trees of each trial area (10 experimental trees at each site), where the peculiarities of seasonal development of the pine bark beetle were studied, its accounting was carried out every 2 weeks. The pine bark beetle was counted according to the "sticky tape" method proposed by S.V. Nazarenko, using standard industrial sticky tape for agricultural purposes to catch winged insects at a height of 0.7 – 1.7 m from the ground surface (Fig. 11), as well as by completely counting the bark beetle individuals under the bark scales.

Fig. 11. Use of sticky tape in the experiment

In addition, 5 Barber traps (Fig. 12) (25 in total) were placed at each test site to catch insects moving on the soil surface[68]. The traps were placed at ground level as close to the tree trunks as possible. Every two weeks, the traps were collected to further assess the presence of the pest under study and new ones were set.

Temporary trial plots were established in plantations with a predominance of Scots pine in the composition of the plantation from 70% to 100%.

[68] Dolia M. M., Yushchenko L. P., Varchenko T. P. Osoblyvosti zastosuvannia suchasnykh biolohichnykh zasobiv zakhystu silskohospodarskykh kultur vid shkidnykiv u Lisostepu i Polissi Ukrainy. Silskohospodarska mikrobiolohiia. 2018. Vyp. 27. S. 60–66.

Before laying out the trial plots, we studied the materials of the SE "Ovruch Forestry" on the detection of pine bark beetle (Aradus cinnamomeus Panz) pest centers.

Fig. 12. Barber's trap

The trial plots were planted in 16 – 25-year-old crops in dry boreal and suburban forests under native conditions:

A2 (fresh forest);

A3 (wet forest);

B2 (fresh subir);

B3 (wet subir).

Only the intensity of the pine beetle infestation was determined; the infestation of trees with other pests was not assessed.

Assessment of the sanitary condition on the trial plots was carried out by categories (according to the Resolution of the Cabinet of Ministers of Ukraine

(CMU) "On Approval of Sanitary Rules in the Forests of Ukraine" of July 27, 1995, № 555):

I – no signs of weakening;

II – weakened;

III – very weakened;

IV – dying;

V – fresh deadwood;

VI – old deadwood".

Location and area of the research object. The State Enterprise "Ovruch Specialized Forestry" has a territory of 50 km from east to west and 80 km from north to south (Table 9).

Table 9

Administrative and organizational structure of the special forestry enterprise

Names of forestries, locations of offices	Administrative districts, cities of regional subordination	Area, hectares
Borutynske	Ovrutskyi	8964,0
Vystupovytske c.	-/-	13531,5
Sytovetske	-/-	8718,2
Zhurbenske	Narodytskyi	4440,7
		714,2
Together		5154,9
Koptivshchynske	Ovrutskyi	4517,7
TOTAL for special forestry		40886,3
including by administrative	Ovrutskyi	40172,1

Names of forestries, locations of offices	Administrative districts, cities of regional subordination	Area, hectares
districts:		
	Narodytskyi	714,2

SE "Ovrutske SFE" was organized in 2006 according to the order of the State Committee of Forestry and Hunting № 2 dated 12.01.2006 and № 3 dated 19.01.2006 of the Zhytomyr Regional Forestry and Hunting Range Administration by reorganizing the state enterprise "Ovrutsko-Narodytske SFE", from which two state enterprises "Narodytske SFE" and "Ovrutske SFE" were separated.

The state enterprise includes: Borutynske forestry with an area of 9023 hectares, Vystavytske forestry with an area of 13551 hectares, Sitovets forestry with an area of 8691 hectares, Zhurbenske forestry with an area of 5125 hectares and Koptivshchyna forestry with an area of 4656 hectares.

At the time of the forest management, the area of the special forestry was 41045 hectares.

The first forest management of the forests that are part of the SFE was carried out in 1939 according to the first category of forest management.

Subsequent forestry surveys were conducted in 1947, 1956, 1967, 1977, 1987, and 1997. The archives have not preserved the materials of these works.

Since 1997, continuous forest management has been carried out on the entire territory of the forests that were transferred to the special forestry after the reorganization[69]. The reorganization consisted of annual field forestry and taxation works on the areas covered by economic activity and on forest areas affected by

[69] Zborovska O. V. Ekolohichnyi stan i produktyvnist lisovykh nasadzhen sosny zvychainoi u svizhykh borakh i suborakh Zhytomyrskoho Polissia. Visnyk natsionalnoho universytetu vodnoho hospodarstva ta pryrodokorystuvannia. Ser.: Silskohospodarski nauky. 2013. Vypusk 2 (62). S. 198–207.Zvedena vidomist po inventaryzatsii oseredkiv shkidlyvykh komakh ta khvorob lisu po Kharkivskomu oblasnomu upravlinniu lisovoho ta myslyvskoho hospodarstvastanom na 01.01.2020 roku. https://kharkivlis.gov.ua/ohorona-i-zahist-lisu/.

natural disasters. All available changes were made to the existing inventory and mapping database.

When carrying out forest management activities, proper control is exercised over the quality of all necessary forest management activities[70]. The time and place of their implementation are determined, and sets of accounting and reporting documentation are maintained and later provided, which were drawn up in accordance with the work performed during the continuous forest management[71].

The previous forest management was carried out in 2008 by a comprehensive forest management expedition. The works were carried out in accordance with the requirements of the forest management instructions according to the first category.

The current forest management was conducted by the Comprehensive Forest Management Expedition in 2018 in accordance with the requirements of the current forest management instructions, and in accordance with the decision of the first forest management meeting, as well as according to the technical meeting with the results of the field work (Table 10).

Forest management is carried out by the method of age classes, productivity and composition of stands, felling method, etc.

Table 10.

Main indicators of forest management

Indicators	Units of measurement	Volumes
1. Forest management area	hectares	40886,3
including the use of orthophotomaps	hectares	40886,3

[70] Zvit z otsinky vplyvu na dovkillia planovoi diialnosti zi spetsialnoho vykorystannia lisovykh resursiv. 2019. 555 s. URL: http://eia.menr.gov.ua/uploads/documents/4069/reports/fca5bfea73791d5d83ea93850392411f.pdf.

[71] Didukh Ya.P. Yakymy budut nashi lisy? Ukrainskyi botanichnyi zhurnal : nauk. zhurnal NAN Ukrainy, Instytut botaniky im. M.H. Kholodnoho NAN Ukrainy. 2010. T. 17, № 3. S. 321-343.

Indicators	Units of measurement	Volumes
2. Number of quarters	pcs	455
3. Average area of neighborhoods	hectares	89,9
4. Number of taxonomic allocations	pcs	15614
5. Average area of taxation allotment	hectares	2,6
6. The site of selective taxation methods was laid	pcs	653
7. Sites were laid out to determine the sum of the cross-sectional areas of the stands	pcs	1238
8. Trial areas laid - total	pcs.	12
including for maintenance felling *	pcs	3
9. Number of tablets	pcs	43

The initial primary accounting unit is the taxation allotment, and the economic section is the calculation unit. The entire analysis of calculations is based on the results of the distribution of areas, stocks of plantations, and economic sections by age classes.

Natural and climatic conditions of the research region. According to the forest vegetation zoning, the territory of the SE "Ovruch SFE" belongs to the zone of Zhytomyr Polissya, belongs to the zone of mixed forests.

The region is characterized by a temperate continental climate, so winters are relatively mild, summers are warm, and precipitation is significant. The average annual long-term temperature is 8-9°C.

Negative climatic factors have a certain impact on the growth and development of forest plantations, such as spring frosts, which interfere with the normal growing season, flowering and fruiting of woody plants. In general, the climatic conditions in the region are quite favorable for forestry. Favorable moderate humidity, mild winters, warm summers, insignificant temperature fluctuations, and the absence of drought contribute to the growth and development of the main forest-forming tree species. This is confirmed by the presence of plantations of relatively high bonites in the special forestry: Scots pine – 1.4; Scots oak – 2.0; hanging birch – 1.5; black alder – 1.8.

The territory of the special forestry belongs to the plains, except for the territory of Koptivshchyna forestry, where there are ravines and hills. In the central part of the special forestry, there is the Slovechansko-Ovruchsky ridge, which is part of the Ukrainian crystalline massif[72]. From the ridge, the terrain slopes down in different directions. The Slovechansko-Ovruchsky ridge is interesting because it is covered with loess and loess-like loams. The continuous cover has a thickness of 1.5 – 25 m, and in some places up to 37 m.

The northern part of the state-owned enterprise has a mountainous terrain with hills and dunes left over from moraine deposits with wide depressions between them[73]. The altitude is 110 to 140 meters above sea level.

The main soil-forming rocks are fluvio-glacial sands and moraines. The mechanical composition is dominated by sandy light loam soils, which are characterized by high moisture permeability[74].

The state enterprise is characterized by sod-podzolic soils (90% of the forested land), peat-podzolic and peat-gley soils located along river valleys and lands located in flat depressions.

Hydro-edaphic conditions are represented by fresh soils.

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[72] Zibtsev S. V., Borsuk O. Okhorona lisiv vid pozhezh u sviti ta v Ukraini – vyklyky XXI storichchia ta perspektyvy rozvytku. Lisove i sadovo-parkove hospodarstvo. 2012. № 1. URL: http://nbuv.gov.ua/UJRN/licgoc_2012_1_7

[73] Zvedenyi proekt orhanizatsii i rozvytku lisovoho hospodarstva Zhytomyrskoho OULMH. Irpin: Vyd-vo Ukr. lisovporiad. pid-vo, 2009. 300 s.

[74] Krasnov V. P., Tkachuk V. I., Orlov O. O. Dovidnyk iz zakhystu lisu /pid red. d. s.-h. n., prof. V. P. Krasnova. K.: Vydavnychyi dim "Ekoinform", 2011. 528 s.

Erosion processes are observed on the forestry's territories, mainly located on the territory of Koptivshchyna forestry. This forestry was artificially reforested many years ago.

The main climatic indicators of the area where the SFE is located are taken from the data of the meteorological station in Ovruch.

Key indicators of forest management, production capacity of special forestry

The economic activities of the special forestry[75] are aimed at protecting forests from fires and other forest disturbances, improving the sanitary condition of plantations, and increasing the productivity and quality of the forest fund[76].

Table 11 shows the average volume of forest use per unit area of forest plots covered with forest vegetation, the degree of utilization of average growth per hectare, and the annual volume of forest crops, indicating an increase in the intensity of forest management.

Table 11.

Main indicators of forest management.

Intensity of management

Name of indicators	Units of measurement	According to the project of the previous forest management	According to the project of the current forestry

[75] Lisova typolohiia v Ukraini: suchasnyi stan, perspektyvy rozvytku: Materialy XI Pohrebniakivskykh chytan (10-12 zhovtnia 2007 r., m. Kharkiv). Kh.: UkrNDILHA, 2007. 254 c.

[76] Lytvyk P. V. Lesnye ekosystemy Polesia Ukrayny: [monohrafyia]. Zhytomyr: Polyssia, 2001. 340 s.

Name of indicators	Units of measurement	According to the project of the previous forest management	According to the project of the current forestry
1. Annual volume of forest use (liquid) – total	ths. m^3	57,3	90,3
including from harvesting for main use	ths. m^3	45,5	65,9
2. Average volume of forest use per 1 hectare of forest area covered with forest vegetation	m^3	1,53	2,39
3. Annual volume of reforestation work:			
– creation of forest crops	hectares	165	214
– promoting natural renewal	hectares	27	–

The technical and transport support of the special forestry is sufficient for the successful implementation of planned tasks.

The degree of provision with vehicles is 95%. The special forestry is 100% provided with production facilities and 75% with housing. The SFE is 100% staffed with permanent employees.

The existing organization of forestry operations in the SFE is carried out by private entrepreneurs under contracts.

The importance of forestry in the economy of the region of location. Environmental protection

Specialized forestry is important from an economic point of view for the study region. First of all, it provides employment for the population, and secondly, it contributes to economic growth by producing valuable economic wood[77]. In terms of environmental protection functions, special forestry contributes to the preservation and enhancement of environmental, protective, sanitary, aesthetic and other useful functions of the forest.

Existing agricultural land belonging to the forest fund is used for the needs of the company's employees, which also contributes to the economic growth of the region. The lands belonging to the specialized forestry are characterized by small areas and have no practical significance in the economy of the area where the special forestry is located.

Livestock grazing is not allowed in the forest fund due to radioactive contamination of the territory.

In the areas with less than 2 Ci/km2 of 137Cs contamination, mushrooms, berries and medicinal raw materials are collected as ancillary forest uses, mainly by local residents for their own needs.

The fauna for hunting in the forests of the special forestry enterprise is represented by such species as wild boar, hare, fox, roe deer, elk and other animals.

In hunting, such hunting is mainly of a sporting nature in accordance with licenses.

In addition to their economic value, the forests of the state-owned enterprise are of great environmental and recreational importance.

Current state of forests

All types of economic activities were aimed at improving the quality and productivity of forests, their conservation and enhancement of protective properties. No negative anthropogenic impact on the environment was observed on the territory of the special forestry.

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[77] Mieshkova V. L. Vplyv hlobalnykh zmin klimatu na poshyrennia oseredkiv masovoho rozmnozhennia komakh-khvoielystohryziv. Problemy ekolohii lisiv i lisokorystuvannia na Polissi Ukrainy. Vyp. 5 (11). Zhytomyr: Volyn, 2005. S. 62–65.

No harmful impacts from industrial and agricultural enterprises, as well as excessive recreational loads and excessive numbers of wild animals in the forests were detected in the area of the SFE and near the adjacent territories, according to the SFE and in the course of field forestry operations.

However, most forest tracts and quarters of the special forestry are classified as contaminated with radionuclides according to the laboratory of radiobioecology of the Polissia Agroforestry Research Institute under the UNECE program.

No forest management measures are planned for contaminated lands with a density of 10.1 Ci/km2 or more.

During the field survey of the forests of the special forestry enterprise, no drying out of plantations due to radionuclide contamination was observed.

The territory of the special forestry is 100% located in the zone of radiation contamination. The area of forests where economic activity is restricted is 7970.8 hectares, including logging areas, felling for general use, maintenance felling (clarification, clearing, thinning, and thinning), and selective sanitary felling.

Since 2007, the SFE has been monitoring first-level forests. Every year, specialists of the special forestry enterprise monitor the state of forests on two monitoring plots (one of which is cut down). The locations of the plots are determined by UkrRFI specialists using specialized software. Calculations are made in accordance with the "Methodological Recommendations for Monitoring the Forests of Ukraine of the First Level". At each site, a number of indicators are determined, the most important of which are crown defoliation, crown deformation, and damage to the trees under study. The collected information is sent to the Forest Monitoring and Certification Laboratory of the UkrRFI to conduct the necessary analysis, assess the current state and systematize the indicators.

In accordance with the requirements of the Convention on Transboundary Air Pollution, the results of the monitoring conducted in all forests of Ukraine are systematized and sent to international institutions. Forest monitoring is an important part of the state system of environmental analysis.

Forest protection measures

During the year, the presence of entomopests and phytodiseases on the farm was monitored.

The results obtained during the audit period are presented in Table 12 Among them, the area of forest plantations damaged by the pine beetle is 35.9 hectares.

In addition, forest management revealed damage to forest plantations from windbreaks on an area of 4.1 hectares, from drying out on an area of 17.8 hectares, damaged by highland fire on 14.9 hectares, lowland fire on 228.1 hectares, and stem rot on 18.6 hectares.

Among the forest diseases, the most widespread are root sponge, oak cross cancer, oak tinder fungus, and false aspen tinder fungus. The forest protection measures planned for the audit period were almost fully implemented by the special forestry enterprise.

Forest pathological survey was conducted on the area of 8100 hectares, 300 soil excavations were made, spraying in greenhouses was carried out on the area of 0.56 hectares, 500 artificial nests were made on the area of 130 hectares, annual monitoring of pests and forest diseases was carried out on the entire area, and 6 forest protection corners were organized.

Table 12

Presence of pests and diseases

Types of pests and diseases	Area of cells, hectares					
	at the beginning of the period	emerged again	liquida-ted	faded	cell balance	
					all	including those requiring control measures

Ips acuminatus		359,6			359,6	359,6
Viscum album L.		0,9			0,9	0,9
Heterobasidion annosum		1,6			1,6	1,6
Fomitopsis betulina	0,7	7,1	0,7		7,1	7,1
Phellinus igniarius	9,9		9,9			
Polyporus squamosus	1,1		1,1			
Phellinus tremulae	1,2	8,9	1,2		8,9	8,9
Heterobasidion annosum	85,1	817,3	585,1		317,3	317,3
Aradus cinnamomeus		35,9			35,9	35,9
Total	**108,3**	**1231,3**	**608,3**		**731,3**	**731,3**

Regular maintenance felling helps to improve the sanitary condition of forest plantations, reducing the area of forests damaged by pests and diseases.

General conclusion on the state of forest protection in the SFE: in general, sanitary and health measures carried out by the SFE in the last audit period had a positive impact on the sanitary condition of plantations.

Dynamics of entomopest distribution in pine plantations of Zhytomyr Polissya

There are different reasons for the death of coniferous plantations in Zhytomyr Polissia, due to phytodiseases and phytopests, due to abiotic and anthropogenic factors

According to the State Agency of Forest Resources, since 2019, there has been a decrease in the area of pine plantations that have died as a result of insect damage. In 2019, this area amounted to 951 hectares, and in 2021, 280 hectares.

Also, a decrease in plantation mortality is observed among forest diseases by 20.0%, as a result of forest fires by 72.6% (except for 2020), while an increase due to adverse weather conditions by 96.7% and for other reasons by 100%.

Evaluating the presence of pest centers of pine plantations in Zhytomyr Polissia for the period 2009-2021 there is a decrease in the damaged areas by the common pine sawfly (Diprion pini L.) by almost 2 times, a decrease in the pine bark beetle (Aradus cinnamomeus Panz) since 2019, but since 2020 there has been an increase in the number of stem pests.

From 2013 to 2021, the pine silkworm (Dendrolimus pini L.) in Zhytomyr region remained unchanged within 956.0-959.0 hectares.

Spread of pine beetle in the State Enterprise "Ovruch Specialized Forestry"

Temporary trial areas (TTAs) were established in forest crops in Pishchanytsia, Pryluky, Sitovets, Berezhestvo, Vystavytske, Hladkovytsia, Ignativka, Ovruch, Zhurben forestries by the State Enterprise Ovruch Specialized Forestry. The total number of trial plots is 12.

The trial plots were established in places where foresters had found pine beetle outbreaks according to preliminary surveys. On the selected temporary trial plots, tree accounting was carried out using a height meter (measuring the height of the tree) and a Haglof peace fork (measuring the diameter of the tree). The trial plots were established in accordance with the Standard of the Organization of Ukraine 02.02-37-476:2006 "Forest management trial plots. Method of establishment".

Plots were established in plantations with a predominance of Scots pine in the composition of the plantation from 70% to 100% in the conditions of A2, A3, B2, B3 habitats, three plots per each type of forest vegetation conditions.

The average age of the trees in the sample plots ranged from 16 to 25 years, with a tree height of 7.2 – 8.5 m and a diameter of 6.9 – 8.8 cm. The sanitary condition of the trees was mainly without signs of weakening (category I), with detected weakening (category II) and very weakened (category III).

On each temporary trial plot, 5 plots of 10×10 m were laid out, laid out along the edges and in the central part of the 100×100 m trial plot. Pine beetle was counted on 50 trees of each plot using "sticky tape" and Barber traps.

The study of the pest population was carried out during the growing season from April to September every two weeks the number of pine beetle caught in the traps was checked and recalculated based on the results of the observation the following conclusion can be made the proportion of pest adults caught in the Barber trap was highest in April and September (in conditions A2 – 10 – 35%, A3 – 12 – 28%, B2 – 15 – 32%, B3 – 11 – 25%), the proportion of adults caught on the "sticky tape" –

from May to August (in conditions A2 – 65 – 90%, A3 – 72 – 88%, B2 – 68 – 85%, B3 – 75 – 89%).

When assessing the proportion of larvae caught in the traps during the season, it was found that the highest number of larvae was observed from July to August.

In particular, the proportion of larvae by type of forest vegetation conditions from July to August was 20 – 90% for conditions A2, 18 – 94% for A3, 15 – 92% for B2, and 19 – 97% for B3.

When assessing the population density of the pine bark beetle on pine crops aged 16 to 25 years, it was found that their highest density was observed in the types of forest vegetation conditions in the fresh bore A2 – 32 units/tree, and the lowest in the wet bore A3 – 20 units/tree.

In the subdivisions of the state enterprise "Ovruch Specialized Forestry", the population density of Aradus cinnamomeus is 31 specimens/tree in B2 conditions, and 22 specimens/tree in B3 conditions.

Means of controlling the pine beetle

Efficiency of biological preparations. In forestry, in order to control the pine bark beetle Aradus cinnamomeus Panzer: Heteroptera, Aradidae), the preparation Engio 247 SC h.p., Syngenta LLC, Switzerland, is used.

The content of the active substance of the preparation is 141 g/l Thiamethoxam with the addition of 106 g/l Lambda-cyhalothrin; the chemical group consists of neonicotinoids and pyrethroids; toxicity class – II. Coniferous seedlings are sprayed with the preparation during the growing season, the consumption rate of the preparation is 0.18 l/ha, the maximum number of treatments is 2 times.

Engio has shown its effectiveness in use; its peculiarity is also the possibility of application even at low temperatures, the range of use of the drug is from +8 to +25 ° C. The product is manufactured using Zeon technology and can be used together with fungicides, herbicides, and growth regulators.

One of the most effective biological products for controlling the pine beetle is the entomopathogenic drug Boverin. The drug is included in the list of authorized drugs in Ukraine and is manufactured by CherkasyBioProtection LLC. The drug is based on an entomopathogenic fungus, the causative agent of white muscadine (Beauveria bassiana Vuill.).

According to the scientific research of Meshkova V.L. and Bobrov I.O. (2018), the effectiveness of the use of the biological preparation Boverin was noted. When it is used in the autumn, the mortality of the pine bark beetle is observed from 63.8 to 100%, regardless of the hydro-edaphic conditions of pine crops growth.

Efficiency of organic and mineral substances use. According to the studies of the above authors, the efficiency of the use of organic and mineral substances was established when applied for 4 consecutive years in the trunk circle under each tree at the rate of ash (in an aqueous solution of 200 g/100 l of water), ammonium nitrate (0.07 kg of active ingredient), birch litter (5 kg to a depth of 5 cm), potash fertilizers (0.06 kg of active ingredient), phosphorus fertilizers (0.05 kg of active ingredient).

This method reduced the population density of pine bark beetle by 92.2% when using ash, 82.8% when using ammonium nitrate, 65.9% when using birch litter, 62.3% when using potash fertilizers, and 61.6 when using phosphorus fertilizers.

Efficiency of chemicals use. In the monograph "Pine bark beetle in plantations of Novgorod-Siverskie Polissia" by Meshkova V.L. and Bobrov I.O. describes the results of insecticide use: Prestige-Chameleon (consumption rate of 0.2 g/l per tree), Bazudin (consumption rate of 2.0 g/l per tree), Fastak (consumption rate of 0.1 g/l per tree), Zolon (consumption rate of 0.3 g/l per tree), consumption rate of 0.2 g/l, Decis (consumption rate of 0.2 g/l per tree), Aktara (consumption rate of 0.5 g/l per tree) on adults and larvae of the pine rootworm.

As a result of the analysis, it was found that Decis (biological effectiveness 68.8%), Zolon and Aktara (biological effectiveness 64.5%) have the best biological effectiveness on pine bark beetle adults.

The result of the chemicals' effect on the larvae of the pine bark beetle indicated the effectiveness of the Prestige-Chameleon preparation (biological efficiency of 84.3%).

The literature often refers to the repeated use of insecticides during the season, but their harmful effects on forest ecosystems should be taken into account.

Conclusions. It is analyzed that since 2019, there has been a decrease in the area of pine plantations that have died as a result of their damage by entomofauna. In 2019, this area amounted to 951 hectares, and in 2021, 280 hectares. There is also a decrease in the death of plantations due to forest diseases by 20.0%, due to forest fires by 72.6% (except for 2020), while an increase due to unfavorable weather conditions by 96.7% and for other reasons by 100%.

Evaluating the presence of pine plantation pests in Zhytomyr Polissia for the period 2009 – 2021, an increase in the damaged areas damaged by the common pine sawfly (Diprion pini L.) was found, since 2019 there has been a decrease in the pine bark beetle (Aradus cinnamomeus Panz), and an increase in the number of various stem pests. From 2013 – 2021, the pine silkworm (Dendrolimus pini L.) infestations in the Zhytomyr region within 957.0 hectares remained unchanged.

In the course of the research, it was found that the proportion of pine bark beetle adults caught in the Barber trap was highest in April and September (in conditions A2 – 10 – 35%, A3 – 12 – 28%, B2 – 15 – 32%, B3 – 11 – 25%), and the proportion of adults caught on the "sticky tape" from May to August (in conditions A2 – 65 – 90%, A3 – 72 – 88%, B2 – 68 – 85%, B3 – 75 – 89%).

The proportion of larvae by type of forest vegetation conditions from July to August was 20 – 90% for conditions A2, 18 – 94% for A3, 15 – 92% for B2, and 19 – 97% for B3.

When assessing the population density of the pine bark beetle in pine crops aged 16 to 25 years, it was found that their highest density was observed in the types of forest vegetation conditions A2 – 32 units/tree, and the lowest in A3 – 20 units/tree. The population density of Aradus cinnamomeus is 31 specimens/tree in B2 and 22 specimens/tree in B3.

The effectiveness of the use of biological products was analyzed. Engio 247 SC hp, Syngenta LLC, Switzerland, when spraying coniferous seedlings during the growing season, the consumption rate of the drug should be 0.18 l/ha, the maximum frequency of treatments – 2 times. Entomopathogenic drug Boverin, when used in the autumn, the mortality rate of the pine bark beetle ranges from 63.8 to 100%.

The effectiveness of the use of organic and mineral substances, when applied for 4 consecutive years in the trunk circle under each tree at the rate of ash (in aqueous solution it is 200 g per 100 liters of water), ammonium nitrate (0.07 kg of active ingredient), birch litter (5 kg to a depth of 5 cm), potash fertilizers (0.06 kg of active ingredient), phosphorus fertilizers (0.05 kg of active ingredient). With this method of use, the population density of the pine bark beetle decreases by 92.2% when using ash, 82.8% – ammonium nitrate, 65.9% – birch litter, 62.3% – potash fertilizers, 61.6 – when using phosphorus fertilizers.

Among insecticides, Decis (biological effectiveness 68.8%), Zolon and Aktara (biological effectiveness 64.5%) have the best biological effectiveness on pine beetle adults.

The preparation Prestige-Chameleon (biological effectiveness 84.3%) is effective on the larvae of the pine beetle.

ECOLOGICAL PECULIARITIES OF DISTRIBUTION AND HARMFULNESS OF ENTOMOPESTS

Main tasks of forest protection

Damage and infestation of forests by harmful insects and diseases causes great damage to the state's forestry in the form of losses of current wood growth, drying out and degradation of stands, and a decrease in their environmental, water protection and agroforestry functions[78]. For example, when pine trees are heavily eaten by needles, they experience growth losses that are 6 times the average annual current growth, and normal tree functioning can only be restored in 10 – 15 years.

Forests in the area of massive pest outbreaks are particularly affected.

In order to prevent damage, state-owned enterprises are forced to carry out forest protection work on large areas every year[79]. The average annual area of pine needle and leaf pest outbreaks requiring control measures can be 100 – 150 thousand hectares, but the maximum in some years is 184 and 285 thousand hectares, respectively.

Due to the changes in the forest ecological condition in forest plantations over the past 15 – 20 years, forest protection workers have faced a number of new phenomena.

Mainly, independent outbreaks of mass reproduction are observed among forest insects that were previously small in number and did not have much economic importance, nowadays we can observe the massive spread of pine silkworm, pine sawflies, pine bark beetle, treetop bark beetle, etc.

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[78] Mieshkova V. L., Baidyk H. V. Suchasni yevropeiski tendentsii doslidzhen z lisovoi entomolohii. Visnyk Kharkivskoho natsionalnoho ahrarnoho universytetu (Seriia "Fitopatolohiia ta entomolohiia"). 2015. № 1-2. S. 103-111.

[79] Mieshkova V. L., Turenko V. P., Baidyk H. V. Adventyvni shkidlyvi orhanizmy v lisakh Ukrainy. Visnyk Kharkivskoho natsionalnoho ahrarnoho universytetu (Seriia "Fitopatolohiia ta entomolohiia"). 2014. № 1−2. S. 112–121.

To combat pests, modern methods of plantation protection are being developed using biological products and new insecticides that are environmentally acceptable and more or less dangerous for both humans and animals[80]. Entomopathogenic microbial preparations that do not affect the forest biocenosis and do not pollute the environment have also become more widely used[81]. Low-volume spraying technologies and new spraying equipment have been developed, which makes it possible to treat large areas of pest breeding grounds in a short time. Methods using forestry techniques to limit pest reproduction have been proposed.

The main tasks of forestry authorities are to protect forests from harmful insects and diseases[82]. This includes:

- ✓ ensuring the implementation of sanitary rules when conducting forest exploitation, forestry, sanitary and health and other preventive measures to prevent the massive emergence and spread of harmful insects and diseases in forests, forest crops and nurseries;
- ✓ organizing and conducting surveillance and forest pathological surveys for timely detection of damage and other signs of unfavorable condition of forests, forest crops and nursery crops, as well as emergence of forest pests and diseases;
- ✓ measures to combat forest pests and diseases, ensuring timely elimination or localization of emerging foci based on the data of forest pathological surveys and forest management materials.

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80 Omarov A. E. Suchasnyi stan ekolohichnoi bezpeky v Ukraini. Visnyk Natsionalnoho universytetu tsyvilnoho zakhystu Ukrainy. Seriia : Derzhavne upravlinnia. 2017. Vyp. 2. S. 156-164. Rezhym dostupu: http://nbuv.gov.ua/UJRN/VNUCZUDU_2017_2_24

81 Tkach V. P., Bondaruk H. V. Suchasnyi stan i perspektyvy rozvytku haluzevoi lisivnychoi nauky. Lisivnytstvo i ahrolisomelioratsiia. 2002. Vyp. 101. S. 3–8.

82 Prykhodko M. M. Ekolohichna bezpeka pryrodnykh i antropohenno modyfikovanykh heosystem: monohrafiia. K. : Tsentr ekolohichnoi osvity ta informatsii, 2013. 201 s.

Range of Dendrolimus pini L. populations in pine plantations

The pine silkworm pest Dendrolimus pini L.[83], whose main consumer base is the needles of pine forest plantations, is of considerable economic importance. Outbreaks of this pest have been repeatedly observed in Western Europe.

Outbreaks have also been observed in Central and Eastern Europe.

If outbreaks of the phytophage occur over large geographical areas and remain uncontrolled, this leads to the death of trees due to complete defoliation of the needles.

Over the past 150 years, Ukraine has seen outbreaks of mass reproduction of the pine silkworm more than 20 times[84].

In addition, there are periodic outbreaks in the forests of the Polissia region, and their numbers have been unchanged and maintained at a high level for many years.

The first significant outbreak of the pine silkworm in Polissya was observed in 1997 – 1998. In 1997, the wintering stock of silkworms was found on an area of about 4 thousand hectares[85].

Despite the high efficiency of the protective measures, the main pine silkworm centers were not destroyed as a result of the treatments[86]. One of the reasons is that

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83 Karpovych M. S. Tekhnolohichni osoblyvosti biolohichnoho zakhystu sosnovykh nasadzhen vid sosnovoho shovkopriada (Dendrolimus pini L.). Karantyn ta intehrovanyi zakhyst roslyn. Perspektyvy rozvytku v KhKhI stolitti: Mizhnarodna naukovo-praktychna konferentsiia vchenykh, aspirantiv i studentiv, prysviachena 90-richchiu z dnia narodzhennia profesora Y. T. Pokoziia: m. Kyiv, 19–20 lystopada 2015 roku: tezy dopovidi. K., 2015. S. 234–236.

84 Karpovych M. S., Drozda V. F. Ekolohichni osoblyvosti sosnovoho shovkopriada (Dendrolimus pini L.). Poshyrennia ta shkidlyvist. Lisivnycha nauka v konteksti staloho rozvytku: Mizhnarodna naukovo-praktychna konferentsiia, prysviachena 150-richchiu vid dnia narodzhennia akademika H. M. Vysotskoho, 90-richchiu vid dnia narodzhennia profesora P. S. Pasternaka: m. Kharkiv, 29–30 veresnia 2015 roku: tezy dopovidi. Kh., 2015. S. 104–106.

85 Karpovych M. S., Drozda V. F. Osoblyvosti biolohii, ekolohii sosnovoho shovkopriada (Dendrolimus pini Linnaeus, 1758) u sosnovykh nasadzhenniakh Polissia. Tavriiskyi naukovyi visnyk. Seriia: Silskohospodarski nauky. 2020. Vyp. 111. S. 265–272.

86 Kavun E. M. Heohrafo-ekolohichni aspekty poshyrennia stovburovykh shkidnykiv khvoinykh porid derev v mezhakh Zhytomyrskoi ta Vinnytskoi oblastei ta yikh dynamika. Silske hospodarstvo ta lisivnytstvo. Ekolohiia ta okhorona navkolyshnoho seredovyshcha. 2017. № 6 (Tom 2) S. 120–128.

the treatments were carried out with a delay, in particular, against caterpillars of 4 – 5 instars, while according to the standards they should be carried out during the development of caterpillars of 2 – 3 instars.

From 1999 to 2004, the number of the pest was maintained at an insignificant level. Thus, in 2003, single caterpillars were found in most forestry enterprises of Zhytomyr region.

It is known that high numbers of pine silkworms that occurred during outbreaks sometimes persisted for 7 – 8 years, however, during the period of mass reproduction of this pest in 1997 – 1998, over the past 30 years, a decline in the number of silkworms was observed already in the third year.

In 2017 – 2018, the outbreak of the pest's reproduction was naturally attenuated by the mechanism of inter-population and intra-population regulation of its numbers. However, under favorable conditions of wintering and massive spring emergence of caterpillars, the existing stock of the pest is sufficient to cause damage to pine plantations on an area of more than 3.3 thousand hectares in Polissya.

The mass reproduction of the phytophage has decreased after extermination control measures, but the presence of the pest is noticeable in all plantations of Polissya and requires intensive forest pathological surveillance.

Features of the biology of the pine silkworm

According to the classification, the pine silkworm belongs to the class Insecta → subclass Pterygota → infraclass Neoptera → order Holometabola → order Lepidoptera → superfamily Lasiocampoidea → family Lasiocampidae → subfamily Pinarinae → genus Dendrolimus → species Dendrolimus pini L., 1758 (Fig. 13)[87].

[87] Karpovych M. S., Drozda V. F. Biolohichni osoblyvosti sosnovoho shovkopriada (Dendrolimus pini L.) v sosnovykh nasadzhenniakh Zhytomyrshchyny. Priorytetni napriamy rozvytku nauky: XXVIII mizhnarodna naukovo-praktychna internet-konferentsiia, m. Vinnytsia, 18 bereznia 2019 roku: tezy dopovidi. Vinnytsia, 2019. S. 46–49.

Fig. 13. Dendrolimus pini L.

Pine silkworm caterpillars feed on all species of plants of the Pine family (Pinoideae): Scots pine (Pinus sylvestris L.), Rumelian pine (P. pecue Griseb.), Crimean pine (Pinus nigra ssp. pallasiana), Weymouth pine (P. strobus L.), black pine (P. nigra Arnold), Banksea pine (P. banksiana Lamb.), etc.

Fig. 14. Caterpillars Dendrolimus pini L.

According to the proposed classification, the pine silkworm belongs to Group 2, which is characterized by overwintering in the caterpillar stage under the forest floor[88].

Caterpillars[89] emerge from wintering at different ages, from the second to the seventh instar. Individuals overwintering at the third or fourth instar pupate (Fig. 15) in June on branches and trunks. Inside the cocoon is a large pupa with a rounded top, from which butterflies emerge in 20 – 25 days.

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[88] Karpovych M. S., Drozda V. F. Poshyrennia sosnovoho shovkopriada (Dendrolimus pini L.) v sosnovykh nasadzhenniakh Ukrainy. Litni naukovi zibrannia – 2020: XLVIII Mizhnarodnoi naukovo-praktychnoi internet-konferentsiia, m.Ternopil, 30 chervnia 2020 r.: tezy dopovidi. Ternopil, 2020. S. 64–68.

[89] Karpovych M. S., Drozda V. F. Tekhnolohichni osoblyvosti biolohichnoho zakhystu sosnovykh nasadzhen vid sosnovoho shovkopriada (Dendrolimus pini L.) v lisakh Cherkashchyny. Visnyk Kharkivskoho natsionalnoho universytetu im. V.V. Dokuchaieva. Ser.: Fitopatolohiia taentomolohiia. 2019. № 1–2. S. 56–64.

Fig. 15. Chrysalis Dendrolimus pini L.

The seasonal development of the pine silkworm includes periods of caterpillars emerging from hibernation, feeding before pupation, development of pupae, eggs, and the period from the birth of caterpillars to the cessation of feeding in the fall[90].

The generation is one-year, but under certain climatic conditions it can be delayed for up to two years due to the secondary overwintering of caterpillars. Researchers from different regions have reported a two-year cycle of pine silkworm populations under favorable conditions.

A generation of the phytophage can develop within 1 – 2 and even three years. The number of caterpillar ages can vary from 5 to 8, mostly 6; in years of outbreak crisis – 5.

Caterpillars that have overwintered in the second instar may not have time to complete their development, and then they slow down as the day length increases or go into summer diapause and go for a second wintering in the sixth or seventh instar.

[90] Karpovych M.S., Drozda V. F. Rol entomofahiv u populiatsii sosnovoho shovkopriada (Dendrolimus pini L.) v sosnovykh nasadzhenniakh Cherkashchyny. Visnyk Kharkivskoho natsionalnoho universytetu im. V.V. Dokuchaieva. Ser.: Fitopatolohiia ta entomolohiia.. 2018. № 1–2. S. 57–62.

Thus, the temperature regime in June determines how the pine silkworm will develop: in one or two years.

In any case, pine silkworm caterpillars feed more actively at higher temperatures in the first half of summer and increase their biomass accordingly. Larger pupae are formed from more developed caterpillars, and then females with a high level of fertility.

The pine silkworm caterpillar feeds on last year's needles in spring and the current year's needles in summer, and it also likes the buds of young shoots, especially in years of mass reproduction of caterpillars.

Eating needles causes trees to weaken, branches to dry out, and contributes to their further infestation by bark beetles, woodworms, and bullfrogs.

Using the method of phenological curves and thermal resources, it was found that the development of pine silkworm pupae accelerates with increasing temperature, but the period varies between 15 – 20 days. Similarly to pupation, butterfly moths' summer is confined to mid-summer and ends in late July.

The massive moth summer is observed in June-July and lasts 30 – 40 days. At dusk, as well as at night, the flight and movement activity of the pest adults begins.

In the middle of the day, the adult pest sits motionless on tree trunks and branches. Females that develop in a two-year development cycle can travel up to 40 km during the egg-laying period. Individuals that develop on a one-year cycle, with a full supply of eggs, usually do not fly and are found in pine forests on sandy soils.

Males are ready to mate, which lasts up to 10 hours a day after emergence. Reproduction is bisexual. Males live for 10 – 15 days, females – up to 20 days.

Females mate after emerging from pupae and lay eggs in a few hours. At this stage, the insects are inactive.

Females usually lay their eggs on the bark in groups of 50 – 60 in mature stands at a height of 2 – 3 m; in young trees - on branches, needles and bark in the crown in groups and singly and less often on trunks at a height of 2 – 3 m from the ground.

Freshly laid eggs are light green, then turn gray, with a green dot at one end. In the egg stage, the embryonic development of insects takes place, lasting 16 – 20 days, at a temperature of +16 – 18 °C.

With the onset of the first frost, which usually occurs in mid-October, the caterpillars stop feeding, descend from the crowns of trees into the litter or moss cover on the soil surface and hide at a shallow depth of 7 cm in the forest floor, where they spend the winter near the trunks.

An adult caterpillar eats up to 60 needles per day, from 600 to 1000 needles during its development, which is 25 to 36 g of needles.

Influence of environmental factors on phytophage development

The environment is of particular importance for the development and reproduction of the pine silkworm. All environmental factors interact with each other and act on insects not in isolation, but as a whole, just as insects affect the entire environment.

Environmental factors are divided into four categories: abiotic, biotic, hydroedaphic and anthropogenic.

The pine silkworm is a light-, heat-, and drought-resistant species, belonging to the group of needleworms of the summer-spring phenological complex.

In humid conditions, caterpillars die from fungal pathogens during wintering, even in forests. The spread of diseases is facilitated by humidity exceeding 80%. Windy and rainy weather has a negative impact, directly interfering with nutrition or disrupting the function of digestive enzymes. A decrease in relative humidity to 30% is not particularly harmful to the survival of the silkworm.

The age composition of caterpillars migrating for wintering depends on temperature fluctuations in late summer and early fall. In years with warm autumns, caterpillars have time to reach a greater age and have a high probability of completing development in one year. If the proportion of younger caterpillars prevails during wintering, generation lasts two years.

The caterpillars begin to climb into the crown and sap flow in trees after the soil thaws, which occurs gradually and not simultaneously in different parts of the plantations. At higher air temperatures, soil thawing is faster, and the caterpillars rise into the crown in a shorter time.

Given that sap flow begins on average after a steady transition of air temperature through +5°C and the beginning of the active vegetation of pine coincides with the date of a steady transition of temperature above +10°C, it can be assumed that the time interval between these indicators is the period of ascent of pine silkworm caterpillars into the crown.

Abiotic factors contribute to the development of the population, when most of the phytophages migrate to winter at an older age, and this occurs at higher temperatures.

In the course of evolution, geographical and ecological populations of the pine silkworm have adapted to the timing of seasonal plant development, which determines not only the rate of development of individuals but also changes in the water and nutrient content of needles. As the temperature drops at the end of the season, the moisture content of the needles decreases, which serves as an additional signal for the caterpillars to descend for wintering. This happens after a steady drop in air temperature below +10°C. The end of the caterpillars' descent for wintering coincides with the date of a steady drop in air temperature below +5°C.

Thus, the term of cessation of caterpillar feeding and the onset of diapause is determined by the photoperiod, but the calendar date of this event depends on the latitude and longitude of the area. At the same time, caterpillars enter diapause almost simultaneously, regardless of the length of egg laying and age composition.

General characteristics of the research object. Research methodology

The object of the research was the state enterprise "Korostyshiv Forestry" (SE "Korostyshiv Forestry"), which was founded in 1936.

The state-owned enterprise is located in the southeastern region in Andrushivka, Korostyshiv, and Radomyshl districts.

The total area of the enterprise is 24810 hectares, of which forest land covered with forest vegetation is 21486 hectares. The company includes five forestries: Dubovetske, Ivnytske, Korostyshivske, Kropyvnyanske, and Smolivske forestries.

The state-owned enterprise owns the Bobrovo Marsh, Galove Marsh, Ivnytskyi Park, and Lily of the Valley nature reserve fund.

The company annually harvests more than 100 thousand m3 of wood, of which about 30% is processed by the company in its own processing shops. About 300 hectares of forests are reforested annually.

The forestry has established greenhouse facilities to grow planting material (seedlings).

The company's main activities are focused on harvesting timber and wood products, forest conservation and protection, hunting, forestry, indoor seedling cultivation, harvesting non-wood forest products, creating plantations on old arable lands, increasing forest productivity and biological sustainability, and collecting and harvesting seeds of the main forest-forming tree species.

The region's climate is characterized by mild winters and warm, humid summers. The moderately continental climate in most regions depends on various factors: solar radiation, hydrological regime, soil type, relief, wetlands, and forest vegetation type, which influence the formation of local microclimatic differences. The average annual temperature is +6...+7°C. The average temperature in July is +17...+19°C, and in January: -6°C. Significant frosts occur from January to February and reach -30°C, with an absolute maximum of +35...+40°C.

The period with average daily temperatures above 0° lasts 240 – 260 days. The duration of the frost-free period is 150 – 170 days. Sum of active temperatures: 2390 – 2520°C. Snow cover thickness: 20 – 30 cm. The number of days per year with snow cover reaches 100. The region receives 550 – 600 mm of precipitation per year, most of it in summer. The maximum precipitation occurs in the summer months: June, July, August (40 – 45% of the annual precipitation). From April to October, the region receives 400 mm of precipitation, and from November to March – 140 – 200 mm. In summer, there are quite frequent showers and thunderstorms. Snow cover in most parts of the region is uniform (10 – 30 cm) and lasts 95 – 110 days, but is unstable due to frequent thaws. The catchment area is 15100 km², with 10981 km² within the region.

Forest pathological assessment of the State Enterprise "Korostyshiv Forestry"

The main causes of damage to the surveyed pine trees are the activities of a complex of stem pests, the species composition of which includes: the apex bark beetle (Ips acuminatus), the six-tooth bark beetle (Ips sexdentatus), larvae (including the small pine larvae (Blastophagus minor) and the large pine larvae (Blastophagus piniperda)). Among leaf-eaters is the pine silkworm (Dendrolimus pini L.).

Plantations with Scots pine as the main forest-forming species are characterized by the development and spread of the forests against the background of ecological and climatic factors (uneven rainfall, early beginning of the growing season of previous years, summer heat, etc.) The drying of pine stands to a weak, medium and strong degree - single and group - occurs as a result of the foci of the apex bark beetle, to a lesser extent the pine small bark beetle and the six-tooth bark beetle. Mostly, the drying of pine plantations ranges from a weak degree (5%) to a strong degree (15%).

Drying out is observed in the areas of last year's felling, where there are "windows", in plantations with insufficient or uneven fullness, near roads. The nature of drying out is simultaneous, among the dead trees, trees of V and VI categories of sanitary condition prevail (characterized by partial bark fall, trees damaged by stem pests, needles, branches of the second and third orders are absent). In the SE "Korostyshivske Forestry", we observe mainly the apical type of drying of Scots pine, the needles turn from light green to yellow. Gradually, the needles fall off and the crowns of the trees become openwork.

In the plantations, single and group drying of pine trees is observed due to their damage by the blue pine beetle. In trees affected by the pest, the needles of the vast majority of such trees are red, a small number of trees have yellowish-green needles, or the needles have partially fallen off. The bark on such trees peels off, sooty fungi develop on the wood, which gives the trunk surface a black color. In such trees, drying occurs from the bottom to the top. Pine needles and buds are also eaten by the pine silkworm, which causes weakening of the trees.

The internal tissues of the trunks, in places where the larval passages of the above-mentioned stem pests are distributed, are characterized by the presence of "blue", such "blue" is inherent in the spread of ophiostomal fungi. A variety of pathogens and entomopests usually inhabit weakened trees, which creates the main threat to plantations.

Research methodology. Prior to the establishment of the trial plots, the materials of the State Enterprise "Korostyshiv Forestry" were studied to identify the pine silkworm (Dendrolimus pini L.).

Temporary trial plots (TPP) were established in plantations with a predominance of Scots pine in the composition of the plantation from 80% to 100%.

Trial plots were established in accordance with SOC 02.02-37-476:2006 "Forest management trial plots. Method of establishment" in plantations with pine silkworms. The sanitary condition of the plantations was studied on the trial plots in accordance with the Resolution of the Cabinet of Ministers of Ukraine (CMU) "On Approval of Sanitary Rules in the Forests of Ukraine" of July 27, 1995, № 555.

Biometric indicators of trees (height, diameter) were determined on the trial plots using an altimeter and a Swedish peace fork.

Fig. 16. Use of sticky tape in the experiment

Experimental plots were created on the temporary trial plots, the size of the experimental plot was 100×100 m. On the experimental plots, 5 plots of 10×10 m were divided using the envelope method (along the edges of the plot and in the middle). In each plot, 10 trees were selected for research, and the total number of trees in the experimental plot was 50.

The number of pine silkworm caterpillars was counted using the "sticky tape" method proposed by S. V. Nazarenko. Sticky tape was glued to trees at a height of 1.3 m from the ground.

In addition, 5 Barber traps (25 in total) were laid at each test site to catch caterpillars in the spring, which moved on the soil surface. The traps were placed at ground level as close to the tree trunks as possible. Every two weeks, the traps were collected for further assessment of the presence of the pest under study and new ones were set up.

According to the research program, we studied the peculiarities of the seasonal distribution of pine silkworm caterpillars; the population of trees with other pests was not assessed.

The count was carried out by counting the number of caterpillars caught in a wood trap – "sticky tape" and Barber's trap. The number of live and dead specimens was counted.

Dynamics of phytopest spread in pine plantations of Zhytomyr Polissya

An analysis of the materials of the State Agency of Forest Resources on the death of pine forests for the period 2019 – 2021 showed that in recent years there has been a decrease in the area of pine plantations that have died as a result of pests. In 2019, this area amounted to 951 hectares, and in 2021 it decreased by more than three times.

In addition, the area of dead plantations due to phytodiseases decreased by almost 20.0%. Significant loss of forest plantations was observed in 2020 as a result of forest fires, with almost 570.0 hectares of forests lost. In 2021, the largest amount of forest loss was due to unfavorable weather conditions – 1554 hectares.

The assessment of pest outbreaks in pine plantations in Zhytomyr Polissia for the period 2019-2021 indicated a significant increase in stem pest outbreaks.

Over the three-year period, there has been a decrease in the damaged areas by the common pine sawfly (Diprion pini L.), while in 2019 the area of the centers was 5470 hectares, in 2021 it was only 3 hectares, and the pine cortex bug (Aradus cinnamomeus Panz) decreased almost 2 times. The situation with the detected areas of pine silkworm (Dendrolimus pini L.) remained unchanged at 956 hectares.

According to the statistical analysis for the period of 2019 – 2021, the pine silkworm phytophage inhabited 6% of the forest fund of Zhytomyr Polissya.

The largest percentage of phytopests in Zhytomyr Polissya is accounted for by stem pests and amounts to 72%.

Spread of the pine silkworm in the State Enterprise "Korostyshivske Forestry"

According to the forest pathology survey, the area of damaged plantations in the state enterprise amounted to 425.9 hectares, of which 12.0 hectares were damaged by the pine silkworm.

Temporary trial areas were established in the forestries of the state enterprise, namely: Dubovets, Korostyshiv, Kropyvnia, and Smolivske forestries. The soil type on the trial plots is sod-podzolic. Forest vegetation conditions are C2, B2, B3. The total number of sample plots is 7, all plantations are high-boned 1, 1a, 1b.

The trial plots were established in places where pine silkworm infestations had been identified by foresters in previous surveys. Temporary trial plots were established in areas dominated by Scots pine, where the tree species accounted for 80% – 100% of the stand. The age of the pine trees in the plots ranged from 56 – 101 years, the average diameter from 26.3 – 40.3 cm, and the average height from 24.6 – 27.9 m.

The sanitary condition of the trees was determined on the test plots, mainly the condition of the plantations belonged to 2 categories: II – weakened, III – very weakened.

In the phytophagous foci, observations were made of the pest pressing with adhesive tape and a Barber trap.

Adhesive tape 15 – 17 cm wide was glued around the perimeter of the tree at a height of 1.3 m. The experimental trees were numbered and recorded in a logbook, caterpillars were recorded every 2 weeks, adhesive tapes were renewed, and Barber traps were left at the observation sites. The number of insects and their viability were determined separately when they got on the adhesive tape and separately in the Barber trap. The results of the research are presented in Table 13.

Table 13.

Distribution of the pine silkworm on trees

Number of the test area	Ecological niche of the caterpillar	Caterpillars found, specimens/ 10 trees	Live pests detected, pcs./10 trees	Dead pests detected, units/ 10 trees	Defoliation of needles
1.	Barrel (adhesive tape)	321	234	87	there is a threat of harm
	Soil (Barber's trap)	193	121	71	-
2.	Barrel (adhesive tape)	152	111	41	negligible
	Soil (Barber's trap)	93	58	34	-
3.	Barrel (adhesive tape)	306	223	83	there is a threat of harm
	Soil (Barber's trap)	190	120	70	-
4.	Barrel (adhesive tape)	337	246	91	there is a threat of harm
	Soil (Barber's trap)	219	138	81	-
5.	Barrel (adhesive tape)	181	132	49	negligible
	Soil (Barber's trap)	112	71	42	-
6.	Barrel (adhesive tape)	133	97	36	negligible
	Soil (Barber's trap)	84	53	31	-
7.	Barrel (adhesive tape)	145	106	39	negligible

Number of the test area	Ecological niche of the caterpillar	Caterpillars found, specimens/ 10 trees	Live pests detected, pcs./10 trees	Dead pests detected, units/ 10 trees	Defoliation of needles
	Soil (Barber's trap)	90	57	33	-

Studies on population dynamics were conducted from May to September.

In the course of the research, it was noted that the largest number of Barber's trap entrapments is observed in May, when the caterpillar leaves the wintering place and moves along the soil to the tree trunk, as well as at the end of the growing season in September, when the phytophagous pest leaves for wintering.

In addition, the pest causes significant damage to pure pine plantations, as well as plantations where the age of the pine tree is 80 years and older.

According to the observations, it was noted that the pine silkworm caterpillar eats from 650 to 750 needles per season.

Protection measures for pine plantations

The system of protection of pine plantations should include:

- application of biological protection of scots pine from pine silkworm;
- use of biological preparations;
- use of healthy planting material;
- creation of forest cultures;
- carrying out the necessary felling, sanitary and continuous felling;
- preservation of undergrowth;
- cultivation of planting material;

- application of fertilizers (lupinization);
- reconstruction of plantations.

In the forestry enterprises of Zhytomyr Polissya, the following preparations are used to control the pine silkworm in Table 14.

Table 14.

Pesticides used by forestry enterprises for pine silkworm control

Drug name, active substance and its content, registrant, manufacturer	Application rates (g, kg, l/ha)	Method, processing time, limitations
Lightning, KE (alpha-cypermethrin, 100 g/l), Perezens Technology LLC, Ukraine, manufactured by Tale Exports Limited, India	0,075-0,12	It is used in case of massive pest infestation: the event is carried out with the help of aircraft (AN-2, KA-26, etc.), the working fluid rate is 25 liters per unit area. With the help of aerosol generators, the rate of working fluid is 0.1-1.5 liters per 1 hectare (water or diesel fuel is used to prepare the working fluid).
Dimilin, s.p. (diflubenzuron, 250 g/kg), manufactured by Crompton (Universal Chemical) Registrations Limited, UK, the state of the manufacturer	0,1	Spraying during the growing season

Drug name, active substance and its content, registrant, manufacturer	Application rates (g, kg, l/ha)	Method, processing time, limitations
Fastak, KE (alpha-cypermethrin, 100 g/l), manufactured by BASF Agro B.V., Switzerland	0,01	In case of ground spraying, it is prohibited to graze lactating cattle for 5 days (fattening and young animals and haymaking), entering work – 1 day, rest of people – 4 days after treatment

In the scientific work of Karpovych M.S., methods of controlling the pine silkworm are proposed:

- biological method - using biological preparations - "Boverin", "Metarizin";
- chemical method - the drug "Zolon".

The cost and effectiveness of the proposed technology for protecting pine plantations from the pine silkworm are presented in Table 15.

Table 15.

Cost of the proposed technology for protection of pine plantations from pine silkworm on an area of 1 ha

Method of protection	Measure and technological features of the product	Cost (biomaterials + labor costs), UAH	Cost of the event, UAH	Technology efficiency, %

Method of protection	Measure and technological features of the product	Cost (biomaterials + labor costs), UAH	Cost of the event, UAH	Technology efficiency, %
The biological method	Spray plant residues and the soil surface of the stamp rings, d 1.8-2.0 m, with a 5.0% aqueous solution of Boverin (norm 5 kg per 1 ha).	450,0+150,0	600,0	54,8 (on the 10th day)
	Spray plant residues and the soil surface of the stem rings, d 1.8-2.0 m, with a 5.0% aqueous solution of Metarizin (5 kg per 1 ha).	450,0+150,0	600,0	72,5 (on the 10th day)
	Biological technology, total	–	2133,8	
Chemical method	"Zolon, c.e. ("Fozalon", rate 350 g per 1 liter), the rate of consumption of the drug is 1.5-3.0 liters per 1 ha.	2745,0+400,0	3145,0	81,7
	Chemical standard,	–	3145,0	-

Method of protection	Measure and technological features of the product	Cost (biomaterials + labor costs), UAH	Cost of the event, UAH	Technology efficiency, %
	total			

According to the data in the table, the chemical preparation "Zolon" has the highest efficiency in the fight against the pine silkworm (81.7%), and among biological preparations – the preparation "Metarizin". The author of the technology notes that the biological effectiveness of the preparation increases by 20% on the 30th day of its use.

Basic requirements for the use of chemicals in forestry

Organization of aviation operations in forestry. Aviation activities are subject to mandatory approval by the Ministry of Environmental Protection and Natural Resources of Ukraine, the Ministry of Health and other authorities. Only chemicals that have passed state registration may be used for spraying.

Employees involved in working with chemicals must have all available documents: a medical certificate of health, a work order for aviation work or work with pesticides.

When carrying out work with the help of aviation, a number of preparatory works are carried out, including: insurance of employees involved in spraying forests with chemicals using aviation; recruitment and training of employees, including both technical personnel and pilots; selection of sites for takeoff and landing of aircraft; all equipment and machinery must be in proper (working) condition; chemicals must be closed before unloading and loading onto the aircraft; employees must have special equipment etc.

The customer's application for work must be legally formalized in the form of a contract, which is the basis for conducting aviation work.

A landing site is selected for the runway and undergoes the necessary registration process.

Aircraft must have all the necessary documents and a certificate issued by the State Aviation Administration, as well as a license to perform forest protection work.

Flights are allowed if the aircraft is registered in the register of civil aircraft in Ukraine.

The management of the state-owned enterprise must properly organize the work of employees involved in aerial chemical work. This includes: a schedule and working hours, an agreed work schedule, a staffed aircraft crew, and a planned aircraft maintenance schedule. A crew rest schedule should also be provided.

The place and time of work shall be agreed with the customer.

Prior to the start of aviation chemical operations, the public and agricultural workers shall be informed in advance of the planned work in order to avoid creating a hazard.

In case of failure to comply with the warning, which led to the death of domestic animals, plants, bees, poisoning of the population, or pollution of a water body, the crew commander informs his management about the incident with further investigation of the case.

If the crew is poisoned by pesticides or agrochemicals, the crew commander shall notify the management of the situation, and the management shall take all necessary measures to provide first aid until the ambulance arrives.

All employees who work with pesticides are required to undergo an annual mandatory medical examination, and the responsibility for failure to do so lies with the company's management.

Use of preparations using ground-based equipment. When working with pesticides and agricultural chemicals, climatic conditions should be taken into account. The weather should not be rainy, not too windy. At the beginning of work, check the wind direction, spraying should be carried out in the opposite direction of the wind. The employee who will be spraying must be fully protected by protective clothing - face, hands, body. During the work, avoid contact with the respiratory system. Spraying should be carried out as far as possible from livestock farms, apiaries, residential areas, recreation areas, playgrounds, and water bodies. The sanitary gap zone should be 500 m for fan spraying and 300 m for herbiciding and hose sprinkling.

When using modern aerosol generators of controlled dispersion, follow the prescribed instructions that come with the equipment.

Application of pesticides to the soil. Pesticides used in soil treatment have a variety of forms, they can be solutions, powders, granules, gases.

Pesticides are applied using fumigators, applicators, etc. When applying granular pesticides to the soil, it is forbidden to use carcass seeding devices.

Also, granular pesticides based on mineral fertilizers may not be produced manually on the territories of forestry enterprises.

Granular forms of the drug of the first class of toxicity are allowed to be used only for the treatment of crops that have a long growing season. When applying granular forms, modern technological treatments are used to reduce the harmful effects on the environment.

Conclusions. An analysis of the death of pine forests for the period 2019 – 2021 was carried out, and a decrease in lost plantations due to the impact of phytopests was found in 2021 to be 3 times less than in 2019. The area of dead plantations due to phytopathic diseases also decreased by almost 20.0%. In 2021, most of the forests died as a result of unfavorable weather conditions – 1554 hectares.

The assessment of pest outbreaks in pine plantations in Zhytomyr Polissia for the period 2019-2021 indicated a significant increase in stem pest outbreaks.

It was analyzed that over the three-year period, the number of damaged areas by the common pine sawfly (Diprion pini L.) decreased, while in 2019 the area of the cells was 5470 ha, in 2021 it was only 3 ha, and the pine bark beetle (Aradus cinnamomeus Panz) decreased almost 2 times. The area of the pest Dendrolimus pini L. remained unchanged at 956 hectares.

According to the statistical analysis for the period of 2019 – 2021, the pine silkworm phytophage inhabits 6% of the forest fund of Zhytomyr Polissya.

It was found that in the SE "Korostyshiv Forestry", the area of damaged pine plantations by the pine silkworm is 12.0 hectares, and in the areas where the pest was detected, the sanitary condition of the plantations belongs to categories II and III.

According to the research, it was noted that the number of pine silkworm caterpillars on pine trees during the growing season is about 58%, and the proportion of caterpillars on the soil surface is about 42%.

It has been found that the pest causes significant damage to pure pine plantations, as well as plantations where the age of the pine tree is 80 years and older.

It is proposed to use biological preparations to control pine silkworm caterpillars.

In the course of the research, it was noted that the majority of caterpillars were caught on sticky tape (about 58%) and in Barber's trap (about 42%).

It was found that the pest causes significant damage to pure pine plantations, as well as plantations where the age of the pine tree is 80 years and older.

According to the observations, it was noted that pine silkworm caterpillars eat from 650 to 750 needles per season.

The activity of biological and chemical preparations in the fight against the pine silkworm, and the expediency of using the preparations "Boverin" and "Metarizin" were analyzed according to the literature.

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