Agricultural sciences

Vira MOROZ,
Ph.D. Agricultural Sciences
Polissya National University
ORCID ID: 0000-0002-1457-4641
Ukraine

BIOLOGICAL PRODUCTIVITY OF PINE PLANTATIONS IN POLISSYA

Many scientists have been studying the biological productivity of tree species for a long period of time, depending on the natural and climatic conditions of growth.

The study of the biological productivity of a woody plant should begin with the study of the biometric parameters of the tree, because the growth and development of the plant, in addition to climatic factors, is also influenced by the conditions of growth of tree plantations, relief, altitude, soil type, humidity, temperature, and lighting conditions[1].

Given that in 2016 Ukraine signed the Paris Agreement under the Kyoto Protocol, the state has certain obligations to account for greenhouse gas emissions and reduce them, which is partially solved by green spaces.

Modern scientific research focuses on operational forest plantations, where scientists determine the growth and development of trees, bonitet, stock, growth, phytomass, and biological productivity, but little research is focused on the forests of the protected zone, which is the main achievement of the state.

The importance of forests is global and vital for the entire complex of the Earth's ecological systems, as forest ecosystems are characterized by the highest intensity of biological cycling and have the largest organic mass, the value of which is constantly growing[2]. Forests are accumulators and carriers of energy involved in natural processes and the development of the biosphere. Until recently, it was believed that forests, as exceptionally complex ecosystems, were highly resistant to anthropogenic pressures.

1 Moroz V.V., Nykytiuk Yu.A. Vuhletsepohlynalna zdatnist sosnovykh lisovykh nasadzhen Zhytomyrskoho Polissia // Zroshuvane zemlerobstvo. Mizhvidomchyi tematychnyi naukovyi zbirnyk. Kherson. 2020. Vyp. 73. P. 43–50.

2 Hahoshydze Y.A. Byomassa kron osnovnykh lesoobrazuiushchykh porod Zakavkazia // Lesnoe khoziaistvo. 1980. № 12. P. 45–47.

However, the data accumulated over the past decade has shaken the optimistic concepts of the dynamic resilience of forest ecosystems to the long-term absorption of pollutants. Deforestation and degradation of forest ecosystems is one of the most pressing environmental problems of our time.

Reduction of forest area and decrease in their sustainability depend not only on excessive consumption of forest resources and the degree of environmental pollution, but also on the economic development of the state and the level of cultural development of the population. The main reasons for the long-term deterioration of forests, their degradation and death are considered to be complexes of natural, anthropogenic and socio-economic factors.

The ecological function of forests as an ecological and economic system means the recreational (health) value of forests, protection of soils from erosion, increase in crop yields, regulation of water flow, oxygen production, etc. The ecological role of forests is characterized by great diversity, which is grouped into the following ecological functions: global, environment-forming, environment-protecting, socio-ecological, ecological and relaxation, and special[3].

Reproduction, conservation and protection of forests are essential for increasing forest productivity, improving their useful properties, and meeting the needs of society in forest resources. Reproduction of forests, which is carried out in the form of their restoration and afforestation, is the implementation of forestry and agrotechnical measures in accordance with environmental requirements in order to create new forest plantations.

In accordance with the Rules of forest restoration and afforestation approved by the Cabinet of Ministers of Ukraine on January 16, 1996, forest restoration should ensure:

- rational use of the forest fund;
- improvement of the quality composition of forests, increase of their productivity and biological stability;
- increase of water protection, soil protection, sanitary and hygienic, and other useful properties of forests and protective forest plantations;
- achievement of optimal forest cover by creating new plantations of the most economical and efficient species as soon as possible.

Forests are restored under special programs and projects developed by the state forestry authorities. Enterprises, institutions, and organizations engaged in reforestation and afforestation in urban green areas, railroad, highway,

3 Shchepashchenko D.H., Shvedenko A.Z., Shalaev V.S. Byolohycheskaia produktyvnost y biudzhet uhleroda lystesvennychnykh lesov. Yzd-vo MHU lesa. 2008. 296 p.

canal, and other right-of-way shall develop design and regulatory documents in consultation with the forestry authorities. The basis for sustainable use of forest resources is optimization of society's impact on forest ecosystems, based on scientifically sound principles of creating a unified system of use and reproduction of forest ecosystems[4].

The main principles of efficient use and reproduction of forest resources should be considered:

- taking into account the state of forest resources;
- studying and taking into account the zonation of natural and historical conditions;
- comprehensive study and use of forests;
- comprehensive study of primeval forest ecosystems;
- compliance with laws and rules of forest use;
- application of new developments and technologies;
- reduction of anthropogenic load and emission of pollutants;
- development of forest monitoring systems;
- improvement of the legislative and legal framework;
- increase of environmental education of the population.

The exploitation of forest resources must be coordinated with the system of environmental protection measures to preserve and restore forest plantations, and forest protection, increasing its productivity and biological sustainability should be considered as the primary tasks of forestry. Targeted activities of state and non-governmental organizations and a set of organizational, legal, economic, social, scientific and practical measures will help reduce the rate of forest degradation and rationally use and reproduce forest resources.

Biotic factors are the mutual influence of living organisms. There are groups of phytogenic, zoogenic, and microbial factors. All biotic factors are caused by intraspecific (intra-population) and interspecific (inter-population) interactions. Phytogenic factors are the mutual influence of plants (both direct and indirect). Zoogenic factors – the various impacts of animals (eating, trampling, pollination, seed dispersal, etc.).

Microbial factors – the influence of microorganisms and fungi[5].

The influence of fungi is sometimes distinguished into a separate subgroup of mycogenic factors. Direct phytogenic effects include mechanical contacts

4 Moroz V.V., Nykytiuk Yu.A. Vuhletsepohlynalna zdatnist sosnovykh lisovykh nasadzhen Zhytomyrskoho Polissia // Zroshuvane zemlerobstvo. Mizhvidomchyi tematychnyi naukovyi zbirnyk. Kherson. 2020. Vyp. 73. P. 43–50.

5 Usoltsev V.A. Formyrovanye bankov dannykh o fytomasse lesov. Ekaterynburh: Uro RAN, 1998. 542 p.

between plants, symbiosis, parasitism, physiological and chemical effects. For example, parasitic plants, sucking water, organic and inorganic substances from the body of their host, cause metabolic disorders, growth and developmental delays. Some parasitic fungi (tinder fungi, rust fungi, boletus, etc.) not only suck nutrients from the host, but also poison it with their waste products and transmit various viruses.

Mechanical influence is manifested, for example, in the action of climbing plants: when they twine around the stem of a supporting plant, they not only prevent its growth in thickness, but also strongly squeeze the support, making it difficult for nutrients to move along it, disrupting the development of the plant they are supporting. The direct impact of plants through the release of various physiologically active substances should also be considered a direct impact; this form of impact is called allopathy (from the Greek allelon – mutual, pathos – suffering).

Among such substances, we distinguish between those secreted by higher plants – phytoncides and those secreted by microorganisms – antibiotics. Thanks to phytoncides, plants are not susceptible to certain diseases. Phytoncides and antibiotics, which are harmful to other organisms, perform a protective function in the life of their carriers in the fight against other species. For example, bird cherry leaves emit volatile substances that kill various types of protozoa and repel flies. Microbes very rarely damage the leaves of plants such as pine, poplar, and eucalyptus, as they are able to emit large amounts of volatile substances that are toxic to microorganisms[6].

Thanks to the action of chemicals, many plants not only kill pathogenic microflora, repel leafhoppers and other pests, but also maintain a zone around them that is not occupied by other plants, called a phytogenic field. At the same time, the impact of such plants continues even after their death: the dead remains of these plants, in the process of decomposition by reductants, create a certain biochemical environment that can affect other organisms both favorably and negatively.

These residues in the soil can delay the development of crops and reduce yields. In nature, positive interactions between plants are often observed. This is, for example, the formation of mycorrhiza, which is found in more than 2,000 species of higher plants.

The influence of fauna on the structure and dynamics of forest ecosystems. Birds. They contribute to the dispersal of tree species by spreading seeds and

6 Holubets M.A. ta in. Ekolohichnyi potentsial nazemnykh ekosystem. Lviv: Polli, 2003. 180 s.

fruits. This happens by sticking to their feathers or by eating them and then excreting them in their excrement (seeds of bird cherry, mountain ash, rose hips, honeysuckle, blueberries, cowberries, etc.)[7]. Birds play an important role in the destruction of harmful insects (woodpeckers, songbirds). The negative role of birds is that they consume a significant amount of woody plant fruits. In years of abundant harvests, not all seeds are eaten, but some of them still provide for the emergence of a new generation of forest. In years of low harvests, the seeds are consumed in their entirety.

For example, spruce and pine seeds are eaten by woodpeckers, and oak acorns by jays. Other types of forest damage include the destruction of beneficial bird nests (jay), tree ringing, and destruction of anthills (woodpecker). However, these types of damage are not on a large scale. Animals. Like birds, animals spread seeds and fruits.

Rodents (common and red voles, mice, etc.) loosen the soil to a considerable depth, accelerating soil formation processes. Foxes, badgers, and moles, by digging burrows, provide free access of air and water to deep horizons and thus prevent surface runoff. Under conditions of good moisture, the younger generation of the forest settles on molehills (micro-raises on the soil surface). Wild pigs, searching for acorns, loosen the soil and litter, contributing to the natural regeneration of the oak and intensifying the small biological cycle.

Moose and hares eat the bark of birch, aspen, and linden plants, which leads to inhibition of tree growth or even death. This activity of animals can lead to the appearance of conifers in the plantation. Beavers destroy entire aspen plants, regulating the number of this species and the composition of the stand. Animal waste products and decomposition of their bodies are important for soil fertility. Some birds and animals play a positive role in plant pollination (outside of Ukraine)[8].

Animals consume a significant amount of seeds and fruits, which is especially important for forest regeneration in years of poor harvest. For example, even in years of abundant fruiting, squirrels consume about 40% of spruce seeds. When there is a shortage of seeds and fruits, birds and animals migrate or switch to other food (buds, shoots). Large animals (moose, deer, wild pigs, bears) cause significant damage to the forest[9].

7 Danylyn Y.M. Opredelenye nadzemnoi fytomassy drevostoev po aerofotosnymkam // Lesnoe khoziaistvo. 1993. № 1. P. 35–36.

8 Lakyda P. I. ta in. Normatyvy otsinky komponentiv nadzemnoi fitomasy derevostaniv holovnykh lisotvirnykh porid Ukrainy. Korsun-Shevchenkivskyi : FOP Havryshenko V.M., 2013. 457 p.

9 Lovynska V.M. Nadzemna fitomasa stovburiv Pinus sylvestris L. u derevostanakh pivnichnoho stepu Ukrainy // Naukovyi visnyk NLTU Ukrainy. 2018, T. 28, № 8. P. 79–82.

Deer and elk break the undergrowth (oak, ash, and sharp-leaved maple) and undergrowth, while bears break the tops of trees when they climb them. In forest cultures, moose eat the bark of oak, aspen, pine, and even spruce. Gnawed trees are doomed to die. By damaging young specimens of valuable species, moose can change the species composition of the plantation (oak to linden or maple, pine to birch). Large animals make trails in the forest and build dens, which leads to soil compaction or destruction (poorly durable soils).

Beaver dams on small watercourses can change the hydrological regime of adjacent forest areas, which manifests itself in excessive moisture or even flooding of forest plantations. In this case, trees may die due to their soaking. Mouse-like rodents eat away at the bark of young trees from the root collar to a height of 20-30 cm, and up to 1 m on snow cover[10].

Young pine and spruce plantations are particularly affected. Insects are involved in pollination of woody plant flowers, increasing the heterogeneity of the population. Some insect pests can cause significant damage to the forest when they reproduce in large numbers (silkworm). Invertebrates (earthworms, beetles, mites, ants, etc.) decompose litter, loosen the soil, improving aeration, infiltration, mixing organic matter with the mineral part of the soil, and enrich the soil with their mass when they die. Interestingly, earthworms produce up to 25 tons of excrement per hectare. Soil invertebrates do about 80% of the work of utilizing and transforming dead soil matter.

Pastures in the forest. Livestock grazing in the forest is a fairly common phenomenon. In order to reduce its environmental damage to forest ecosystems, it is necessary to scientifically regulate this process.

The negative consequences of unregulated livestock grazing are as follows – destruction of litter and lower tiers of vegetation[11];

- soil compaction, which reduces its porosity and the intensity of tree growth;
- deterioration of root systems, especially on shallow soils, as well as soil biota;
- increase in surface runoff and erosion processes;
- deepened trails formed by regular livestock passage lead to linear erosion, and on waterlogged soils – to waterlogging;
- impact on the species composition and forest formation processes as a result of livestock eating buds and shoots in spring, destroying undergrowth, gnawing the bark of valuable species;

10 Lovynska V.M. Nadzemna fitomasa stovburiv Pinus sylvestris L. u derevostanakh pivnichnoho stepu Ukrainy // Naukovyi visnyk NLTU Ukrainy. 2018, t. 28, № 8. P. 79–82.

11 Onuchyn A.A., Borysov A.N. Opyt taksatsyy fytomassy sosnovykh drevostoev // Lesovedenye. 1984. № 6. P. 66–71.

– increased development of cereals (especially pikegrass in dry conditions, sedge in moist conditions) and vegetative reproduction of aspen;
– replacement of valuable conifers with softwoods;
– lowering of the upper forest boundary in the mountains.

Scientifically based regulation of livestock grazing in the forest can be outlined by the following provisions[12]:

– prohibition of grazing in nature reserves, forest parks, forest areas of scientific or historical significance; in natural monuments);
– in young growth and on the territory of forest crops until the threat of eating the tops disappears (i.e., until a certain age);
– in areas of various types intended to produce young forest generation (forest plantations, clearings and other non-forested areas where measures are taken to promote natural forest regeneration);
– on steep slopes and in areas where erosion processes can potentially develop;
– pasture areas should be fenced, especially for goat grazing;
– do not drive livestock on waterlogged soils in spring, as such trails deepen and fill with water;
– do not graze livestock in forest areas with valuable food and medicinal plants;
– it is recommended to allocate forest areas with soft-leaved species, or with coniferous species or mixed with rich grass cover for pastures.

To prevent the degradation of forest ecosystems and pastures, it is necessary to comply with the maximum load standards, taking into account not only the number but also the breed composition of livestock per unit area. In addition, it is necessary to take into account the duration of grazing on the same site during the growing season and over a number of years. For example, horses require at least 3.3 hectares per head, cows – 2.5, goats – 3.0, and sheep – 0.5 hectares.

The ecological capacity will differ for different types of forest. Such areas should be given a "rest" if necessary. In general, you should take care of the condition of pastures and take measures to optimize it (applying mineral fertilizers, draining, sowing grasses).

The importance and use of biotic factors in forestry A significant part of forest diseases and damage is associated with biotic factors. Among them are diseases caused by fungi or bacteria, damage by insects, mammals, etc. Some diseases have become global in nature and have been the subject of special attention of international scientific organizations in recent decades.

12 Miakushko V.K. Pervynna biolohichna produktyvnist sosnovykh lisiv Ukrainskoho Polissia // Ukrainian botanic zhurnal. 1972. T. 29. № 3. P. 328–339.

For example, root sponge disease (Fomes apposus Fr., Heterobasidion annosum) is widespread in the forests of Europe, North America, Asia, and Australia. This species is an economically important pathogen of about 200 different species of coniferous and deciduous species from 31 genera. The fungus affects species such as fir, maple, larch, apple, pine, spruce, poplar, pear, oak, sequoia and hemlock; but is most commonly found on nongerminous species. This problem has been the subject of special consideration at several international JUFRO conferences.

JUFRO (International Union of Forest Research Organizations) is the oldest international organization in forest science – the International Union of Forest Research Organizations. The idea of its creation was put forward in 1890 in Vienna at the Congress on Agriculture and Forestry; the union was officially approved in Eberswald (Germany) in 1892. JUFRO conferences are held regularly at intervals of 4-5 years, in particular, the last one was held in Salt Lake City (USA).

Ukraine is represented in this organization by the Ukrainian Research Institute of Forestry and Agroforestry named after Georgii Vysotskyi. Symbiotic and antagonistic phenomena play a significant role in the life of the forest, which can be used to improve its health and increase productivity. For example, mycorrhiza is currently being actively studied in the context of its impact on forest productivity.

For example, E.S. Lisovyi found that with an increase in the stage of recreational digression and the degree of powdery mildew damage, the density of mycorrhiza decreases, which prevents the restoration of undergrowth and thereby contributes to the destruction of oak forests under the influence of the whole complex of negative factors. It is especially necessary to study and use biotic factors as antagonists. An important direction in the development of biological methods of controlling forest pathogens is the use of antagonistic fungi that suppress the development of pathogens or cause their death. It has been established that fungi of the genus Trichoderma, which live in the soil, are antagonists of some diseases of tree species.

For example, T. lignorum inhibits the development of pathogens and root sponges. The saprophytic fungus Peniophora gigantea can also be used to control root sponge. The biological method of root sponge control has a significant advantage over other methods of protection. It involves localization of the infectious origin of H. annosum by artificially colonizing stumps with saprotrophic microorganisms, primarily axylotrophic fungi, competing with the root sponge for wood as a food substrate. The preparation is based on a spore suspension of P. gigantea[13].

It is also promising to use such fungi antagonists of the root sponge as Hirschioporus abietinus and Fomitopsis pinicola for stump treatment. These types of saprotrophic fungi develop rapidly in the wood of stumps and prevent or limit the development of root sponges[14]. Of great practical interest is the use of mycorrhizal fungi and rhizosphere organisms (bacteria, fungi, actinomycetes) characterized by high antagonistic activity against pathogenic fungi. Biological methods of controlling forest diseases and pests include measures to attract insectivorous birds, protect and increase the number of anthills, breeding parasitic insects and predators that destroy insect pests, creating appropriate biological products, as well as the autocidal method, which consists in breeding and distributing sterile individuals that, when copulated, leave females sterile. The use of the biological method means regulating the number of harmful living organisms with beneficial ones. Natural enemies: parasites, predators and pathogens are able to keep the population of their host (victim) at a lower level than it would be in their absence.

The biological method of plant protection against pests has a long history. The literature provides examples of the use of beneficial insects in citrus plantations in ancient China and date groves in the medieval Middle East.

The first known literary source describing the activities of parasitic insects was the work of Ulysses Aldrovandi (Italian naturalist of the 16th century) "De Animalibus Insectis", published in 1602. Thus, one of the first supporters of biological methods of forest protection in our country was D.V. Pomerantsev (30s of the twentieth century). He found that birds of one species alone, the great tit, successfully suppressed the silkworm outbreak. The observations were conducted in the Velykoanadolsk forestry. By January, the great tits had destroyed more than half of the 150,000 lacewing nests: 36 to 74% of the pests, although there were relatively few tits in the patch[15].

On the initiative of D.V. Pomerantsev, many nesting boxes were hung, which gave good results. At the stage of development of biological methods, the following main directions are distinguished:

1) conservation of entomophages (predatory and parasitic arthropods) living in forest communities;

13 Kofman H.B. Rost i forma derevev. Novosybyrsk: Nauka, 1986. P. 93–161.

14 Danylyn Y.M. Opredelenye nadzemnoi fytomassy drevostoev po aerofotosnymkam // Lesnoe khoziaistvo. 1993. № 1. P. 35–36.

2) introduction of entomophages into forest communities;
3) intra-areal relocation of entomophages;
4) application of the classical biological method (introduction and acclimatization of entomophages);
5) use of entomophages by colonization or flooding;
6) use of ants;
7) use of vertebrates;
8) use of entomopathogens (viruses, fungi, bacteria, protozoa, nematodes).

Conservation of entomophages. In undisturbed forest ecosystems, a significant proportion of invertebrate populations are at a low level that is not harmful to humans, thanks to the activities of their many natural enemies. But this equilibrium can be easily disturbed. Long-term drought or, conversely, prolonged flooding, fires, and massive tree falls as a result of hurricanes upset the established balance.

The anthropogenic factor also destabilizes forest ecosystems. This is facilitated by intensive agricultural production on lands adjacent to forests, disorderly large-scale logging, industrial emissions, land reclamation, and the replacement of stable, complex natural communities with monocultures.

All these factors disrupt the natural habitat of entomophagous insects. They gain advantages, the density of their populations grows rapidly, and outbreaks of mass reproduction occur. Such a trend, with a simultaneous reduction in the species composition and density of entomophage populations, is precisely the prerequisite for the use of the biological method.

Involvement of entomophages[16]. Synthetic kairomones have recently been produced; research has begun on their practical use to attract beneficial insects and mites to habitats that are to be protected from pests.

For now, food baits are more accessible for this purpose. Spraying the plantations with an aqueous solution of protein hydrolyzate of fodder yeast and cane sugar attracts ladybugs and syrphids. As a result of the treatments, the number of these most active aphid exterminators increases significantly. Such treatments are recommended several times per season. Syrphids, lacewings and ladybugs can be attracted not only by yeast extracts[17].

They willingly flock to areas that are sprayed with artificial honeydew (in addition to sucrose, aqueous solutions of any other carbohydrates are also suitable for this purpose)[18]. At the same time, predators flock to the treated areas to

18 Moroz V.V., Nykytiuk Yu.A. Vuhletsepohlynalna zdatnist sosnovykh lisovykh nasadzhen Chernihivskoho Polissia // Visnyk Poltavskoi derzhavnoi ahrarnoi akademii. 2020. №1. P. 90–99.

lay eggs. Their number grows so much that in the treated areas they completely suppress aphids and small lepidopterans.

Unfortunately, the high cost of this technique does not allow it to be used on large areas. But in the most valuable plantations, crops or nurseries, it may be quite acceptable and will allow you to refuse chemical treatments against sucking and a number of leaf-eating pests. Many species of parasites and predators gather on and near flowering plants, attracted by nectar and pollen.

This reaction of beneficial insects is the basis of the most popular method of attracting them. To this end, whole plots or clumps of honey plants are artificially created by sowing them in the aisles or leaving them on forest edges and clearings. At the same time, they try to ensure that flowering plants remain in the biocenosis throughout the period when they are threatened by pests. For this purpose, so-called nectar-bearing conveyors are created.

There are many recommendations in the domestic and foreign literature on how to create such “conveyors”. In each zone, for each specific purpose, a different approach should be chosen. Intra-areal relocation of entomophages is their massive transfer from places where they prevail to places where they are absent or rare. It happens that within the pest’s range there are separate populations of the pest in which this or that entomophage is absent. In such cases, beneficial arthropods are relocated here from a region where they are abundant.

For example, a comparative study of the parasites of a number of forest pests in the UK and Central Europe showed that their parasite complexes were 2–3 times richer on the continent. The enrichment of the “British entomofauna” by relocating the entomophages of the same pests that are absent here (within their common range) gave a tangible result and was recognized as a promising area of forest protection. In France, a forest protection technique based on the transfer of parasite-infested pests from dying foci to places where their numbers, on the contrary, were increasing was tested[19].

Entomologists did not limit themselves to collecting infected pests in the patch, but also bred entomophages artificially and then released them where their density was still low. The use of the classical biomethod Increasingly, introduced entomophages are used against forest pests. This measure is used mainly against adventive (foreign) forest pests and is called the classical biomethod.

19 Danylyn Y.M. Opredelenye nadzemnoi fytomassy drevostoev po aerofotosnymkam // Lesnoe khoziaistvo. 1993. № 1. P. 35–36.

A typical program for the application of this method includes the following steps[20]:

- identification of the target species and its place of origin;
- consideration of all information about the pest and its natural enemies;
- search for natural enemies;
- assessment of their effectiveness as regulators of the pest population at the place of origin;
- study of the biology of the most effective natural enemies;
- introduction of natural enemies and, if necessary, their mass breeding;
- quarantine treatment of the introducer, study of food specificity at the place of intended release;
- release of natural enemies.

The use of entomophages by colonization. In this case, they are released into the biocenosis inhabited by the pest. The method is divided into seasonal colonization and "flooding". During the seasonal colonization of entomophages, the calculation is made on their independent settlement and further beneficial activity of both directly released individuals and individuals of daughter generations.

The "flood" method is designed for the direct effect of the release of entomophages (in the latter case, the entomophage is commonly called a "living insecticide"). Since this method is rather expensive, it is advisable to use it in the most valuable forest plantations (nurseries, forest crops, forest parks, forest belts). There is a need for preliminary mass breeding of native or introduced entomophages. Parasitic species are best suited for these purposes, as they can be bred on cheap alternative feed.

One of the first entomophages for which a successful breeding methodology was developed was the oviparasitic Trichogramma. The trichogramma, which can infect the eggs of many harmful insects, is bred on grain moth eggs in biofactories specially created for this purpose.

The resulting oviparasites are introduced into the cenosis, where they infest the eggs of the moth. Use of ants in forestry. To provide their numerous offspring with protein food, ants actively hunt a wide variety of invertebrates throughout the brood rearing period.

As entomophages, ants exhibit the so-called "food reactivity" (the ability to switch to prey species that are abundant at a particular time). Thanks to this property, ants have become effective defenders of the forest from many dangerous leaf-eating pests.

20 Lakyda P.I. Fitomasa lisiv Ukrainy: monohrafiia. Ternopil: Zbruch, 2002. 256 p.

With the mass reproduction of a pest, ants almost completely switch to feeding on it. To protect the forest from pests, a high density of ants is required.

Therefore, the main effect as entomophages is provided by the Formica rufa group and the red-breasted sand ant F. imitans, whose settlements can include millions and tens of millions of individuals.

Methods of using forest ants to protect the forest from pests include their protection and resettlement in potential centers of mass reproduction of needle- and leaf-eating insects by transferring layers from queen anthills found in plantations during the inventory.

The following goals can be pursued with artificial relocation of ants[21]:

1) removal of anthills from clearcuts and flooded areas to save them from further destruction;
2) donation of overpopulated complexes to enhance their growth and prevent stagnation;
3) facilitating the recolonization of previously lost territories by ants after the cessation of environmental factors (including anthropogenic ones) that are harmful to ants;
4) relocation of forest pests to existing forest pest centers;
5) planting of plantations to increase their biological stability and improve growth conditions.

There are two fundamentally different ways to relocate ants: relocating the entire ant hive and taking a certain part of the family as a breeding ground. The first method means eliminating the nest in its original place and moving it to a new area of the forest, which is done in the spring.

The second method has several options for donation adapted to different phenological periods (during the period when pupae of winged individuals are in the nest, after winged individuals leave the anthill, etc.) Such work should be carried out only with the involvement of appropriate specialists. Use of birds and other vertebrates.

Protection and attraction of birds are aimed at increasing the biological stability of plantations and are preventive in nature. The use of birds is unlikely to make a difference in eliminating large forest pest infestations, as the growth of bird numbers is much slower when insect populations are high.

The idea of involving beneficial birds in plant protection originally arose from the purely practical considerations of farmers due to the ability of a number of

21 Lovynska V.M. Lokalna shchilnist komponentiv fitomasy stovbura sosny zvychainoi (Pinus sylvestris L.) Pivnichnoho Stepu Ukrainy // Visnyk ahrarnoi nauk Prychornomoria. 2018. Vyp. 3. P. 73–78.

species to exterminate pests of gardens and orchards. To do this, farmers made and hung birdhouses.

Improvements in forestry practices led to the idea of attracting insectivorous birds with the help of artificial nesting boxes to exterminate forest pests. Birds nesting in hollows were attracted to the steppe forests as early as the late nineteenth century.

Starlings, titmice and other insectivorous birds were protected in parks and gardens and nesting conditions were created for them. The life support of the forest bird population primarily depends on the degree of preservation of the natural habitat.

Management activities carried out in the forest should be based on knowledge of the biological and ecological characteristics of birds, namely:

– to create convenient nesting sites, hollow trees are left, undergrowth is preserved, and artificial nests are hung during forest maintenance and sanitary felling;
– for birds that nest openly on the ground, branches of undergrowth and shrubs are cut to make them branch more, hedges, shrubby edges and dense groups of shrubs are planted. Thorny plants (rose hips, olive, hawthorn, blackthorn, white acacia), as well as Tatar honeysuckle, red and black elderberry are the most effective;
– in winter and early spring, when birds lack food, it is possible to organize their feeding to prevent death and attract them to certain areas of the forest with a high density of pests.

Today, ornithologists have developed many different options for bird nesting sites according to their biological properties. At the same time, a good result of forest protection measures to attract birds is considered to be the occupancy of at least 85% of artificial nesting sites. It is very important to educate the public about the beneficial activities of birds, to prevent their complete destruction and destruction of nests; to be careful when carrying out any forestry activities in the forest to maximize the preservation of convenient nesting sites and bird nests themselves.

Mammals also bring great benefits by destroying forest pests. Protection of animals includes limiting hunting for the most useful predators and protecting insectivores (hedgehog, mole, shrew, badger; bats, which often roost in large colonies in old hollow trees). To attract bats, artificial nests (hollows) made of one-meter-long aspen fragments or board houses are arranged. Some reptiles (e.g., lizards) and almost all amphibians (amphibians) are of great benefit, as they exterminate a huge number of different forest insects. Frogs, toads, and real frogs are very useful and also need to be protected.

Biodiversity of flora and fauna in Ukraine. In addition to its intrinsic value, biodiversity ensures the functioning of ecosystems, including the circulation and purification of natural water, soil conservation and climate stability; it provides the population with food, medicines, and raw materials for industry, and creates a safe environment for life and health.

Ukraine's biodiversity includes more than 72 thousand species of flora, microbiota and fauna. The flora and microbiota includes more than 27 thousand species, including 15 thousand fungi and slime molds, 5 thousand algae, 1.2 thousand lichens, 800 mosses, and 5.1 thousand vascular plants, including the most important cultivated species.

The fauna includes more than 45 thousand species, including: insects – 35 thousand, arthropods without insects – 3.4 thousand, worms – 3.2 thousand; vertebrates are represented by fish and roundworms (170 species and sub-species), amphibians (17 species), reptiles (21 species), birds (about 400 species), mammals (108 species)[22].

According to experts, one third of the species, mostly fungi and arthropods, have not yet been described. The first edition of the Red Data Book of Ukraine included 151 species of higher plants and 85 species of animals. The second, current edition of the Red Data Book of Ukraine (fauna – 1994, flora – 1996) includes 541 species of plants and fungi and 382 species of animals.

The significant increase (4.5 times) in the number of rare and endangered plants and animals is due to the growing anthropogenic pressure on natural ecosystems and indicates a continuing trend towards the loss of the living component of nature and is becoming a threat to national security.

Let us consider the main reasons for the decline in biodiversity in our country.

1. Destruction of natural habitats of animals and plant growth areas occurs as a result of land plowing, deforestation, drainage or watering of territories, industrial, residential and suburban construction, etc. There has been a catastrophic decline in the area of wetlands, steppe ecosystems, and natural forest ecosystems, which are the basis for biodiversity conservation. Thus, agricultural land occupies 71.3% of Ukraine's territory.

Agricultural land (69.2%) is represented by 53.8% of arable land, and only 9.6% (in %) are pastures, 4.4% are hayfields, 1.5% are perennial plantations, and

22 Onuchyn A.A., Borysov A.N. Opyt taksatsyy fytomassy sosnovykh drevostoev // Lesovedenye. 1984. № 6. P. 66–71.

0.7% are fallow land. The condition of agricultural land continues to deteriorate, including its soil cover, which has largely lost its inherent self-regulating properties. Over the past 35–40 years, the humus content in Ukrainian soils has decreased by 0.3–0.4% (compared to 5% at the beginning of the twentieth century) and is now 3.1%, which significantly affects fertility.

Today, there are 3.4 million hectares of drained land in Ukraine that used to function as wetland ecosystems. Only 957.1 thousand hectares of open wetlands remain. The loss of natural wetlands from their former area is about 80%. The total area of forest land is 10.4 million hectares or 17.3% of the country's territory, of which 9.4 million hectares are covered with forest vegetation. Natural forest ecosystems cover an area of 5.1 million hectares, and artificially created forest ecosystems – 4.3 million hectares[23].

Ukraine is considered a steppe state, as the steppe zone occupies 34% of its territory. Natural steppe ecosystems have become rare nowadays, covering about 1% of the country's area. They have been preserved only as small, small-scale remnants that are constantly degrading in the midst of agricultural land, industrial and commercial agglomerations.

2. Fragmentation of animal and plant habitats, landscapes, and ecosystems occurs as a result of the division of integral ecosystems during the construction of a network of transport communications (roads, highways), pipelines, reservoirs and related irrigation facilities (dams, dams, pumping stations), etc.

Ukraine's favorable transport and geographical location between Central and Eastern Europe has helped turn it into an important transport corridor of international importance. Ukraine ranks among the top countries in Europe in terms of transitivity. This fact intensifies the processes of transformation of Ukraine's transport system in order to integrate it into the European network, i.e., to include it in the projects of international transport corridors being formed in Central and Eastern Europe, as well as between Europe and Asia. This poses potentially significant threats to biodiversity, disrupts animal migration routes and ecosystem integrity[24].

3. The degradation of natural habitats is mainly due to environmental pollution, which leads to the inclusion of pollutants in the biogeochemical chains of plants and animals and their chronic intoxication. Significant contamination of water bodies with nutrients is observed as a result of imperfect technological processes in agricultural production and industry.

23 Lovynska V.M. Nadzemna fitomasa stovburiv Pinus sylvestris L. u derevostanakh pivnichnoho stepu Ukrainy. Naukovyi visnyk NLTU Ukrainy. 2018, T. 28, № 8. P. 79–82.

24 Lakyda P.I. Fitomasa lisiv Ukrainy: monohrafiia. Ternopil: Zbruch, 2002. 256 p.

The content of zinc, manganese, iron, nickel, copper, and cobalt in water bodies in the Polissya, Forest-Steppe, and Steppe regions exceeds the standard values by 2 to 12 times. As a result of the Chornobyl disaster, about 4 million hectares of forests have been contaminated with radionuclides, of which 157 thousand hectares are unsuitable for economic use, and another 1.5 million hectares are unsuitable for the use of non-wood food and medicinal resources. Due to significant pollution of water bodies, various diseases in commercial fish species are increasingly being recorded.

Pollution affects the growth, fatness, and commercial value of fish. As a result of toxicosis, fish suffer from systemic immunodeficiency, venous thrombosis, pigment metabolism disorders, anemia, egg dystrophy, etc. The incidence of tumors in fish is increasing, and almost all organs and tissues are affected.

4. Ecologically unbalanced and exhausting use of species, their populations and plant communities is caused by inefficient forestry, hunting and fishing. There is a steady downward trend in the number of major game species. For example, the number of elk decreased from 14,250 in 1990 to 4,510 in 2005, and the number of bison, a priority species of rare mammals in Europe, dropped from 664 in 1992 to 313 in 2005. In general, over the last 11 years the number of ungulates has decreased by 77.3 thousand (30%), and the number of ducks, geese, and partridges has decreased among birds.

As a result of predatory fishing, the number of sturgeons continues to decline: in the Sea of Azov, the volume of sturgeon catches in 1992 amounted to 144 tons, and since 2001, sturgeon fishing has been allowed only for research purposes.

5. The spread of alien species that may adversely affect ecosystems, native species, or human health into natural ecosystems causes a significant imbalance in biocenoses. The mnemiopsis comb, a planktonic organism of the Ctenophora type that was first discovered in the Black Sea in 1982, led to the undermining of the fish food base, a catastrophic decrease in plankton mass, and an almost tenfold decrease in fish catch. In the 1980s, there was a massive degradation of the Azov hamsa and tulka stocks. In turn, the spread of rapana since the 1950s has led to massive destruction of oyster and mussel stocks in the Black and Azov Seas.

6. The spread of diseases, pests and parasites among species of natural flora and fauna is a growing concern for experts.

There is a tendency for the rapid spread of viral infections in the biocenoses of Ukraine, and for flora and fauna to be affected by viruses. A number of new pathogens have been identified that have not been previously identified in Ukraine.

The research and development of new technologies in the field of genetic engineering, and the transboundary movement of living modified organisms are not properly controlled. One of the sources of fish morbidity is parasites that have entered Ukrainian water bodies together with alien species.

7. The low level of environmental qualifications and environmental awareness at all levels of modern Ukrainian society in terms of biodiversity conservation indicates the lack of measures to develop environmental education and awareness, professional development and public consciousness regarding the natural environment. There is still no unified comprehensive approach to public education and training in the field of biodiversity conservation, including the use of international experience.

The system of professional development of wildlife decision makers is not effective enough. Most programs related to raising public awareness of biodiversity conservation and sustainable use are fragmented and have limited public awareness, especially in the regions. Further development and implementation is also required to promote knowledge among the general public about the legal framework for the conservation and use of biodiversity in the country, ways and methods of preserving natural ecosystems and their components. More information on measures to conserve biodiversity in Ukraine can be found in the text of the National Program for the Conservation of Biodiversity of Ukraine for 2007–2025.

Biological productivity of pine. Assessment of biological productivity involves determining the products formed in the process of photosynthesis per unit area in the aboveground phytomass (in our case).

The first step is to determine the phytomass. To determine the phytomass of pine, we used the mathematical equations of power regression proposed by P.I. Lakyda[25]: «Standards for estimating the components of aboveground phytomass of stands of the main forest-forming species of Ukraine» (2013) for natural pine stands.

The equation for determining the trunk phytomass is as follows[26]:

$$Ph_{tr} = 2{,}288 \times d^{-0{,}162} \times h^{1{,}592} \times p^{1{,}018}$$

$$Ph_{st} = 1{,}844 \times d^{-0{,}144} \times h^{1{,}624} \times p^{1{,}017}$$

$$Ph_{b} = Ph_{tr} - Ph_{st}$$

where Ph_{tr} – trunk phytomass in the bark, t/ha;

Ph_{st} – phytomass of trunk wood, t/ha;

25 Lakyda P.I. Fitomasa lisiv Ukrainy: monohrafiia. Ternopil: Zbruch, 2002. 256 p.

26 Moroz V.V., Nykytiuk Yu.A. Vuhletsepohlynalna zdatnist sosnovykh lisovykh nasadzhen Volynskoho Polissia. Naukovi horyzonty. 2020. № 01 (86). P. 61–70.

Ph_b – phytomass of trunk bark, t/ha;

d – diameter, cm;

h – height, m;

P – completeness of planting.

Equation for determining the phytomass of the crown[27]:

$$Ph_n = 2{,}625 \times d^{-0{,}0013} \times h^{0{,}138} \times p^{0{,}722}$$
$$Ph_{br} = 3{,}056 \times d^{0{,}675} \times h^{-0{,}355} \times p^{0{,}434}$$
$$Ph_{sr} = Ph_n - Ph_{br}$$
$$Ph_{wq} = 3{,}380 \times d^{0{,}080} \times h^{0{,}109} \times p^{0{,}697}$$

where Ph_n – needles phytomass, t/ha;

Ph_{br} – phytomass of branches, t/ha;

Ph_{cr} – crown phytomass, t/ha;

Ph_{wg} – phytomass of woody greenery, t/ha;

d – diameter, cm;

h – height, m;

P – completeness of planting.

With age, woody plants undergo changes in size, morphological and anatomical structure, i.e. certain quantitative and qualitative changes that characterize their growth and development. Growth consists in the reproduction and accumulation of cells, which leads to an increase in the size of various structural elements of trees (shoots, branches, trunks, roots, etc.), resulting in an increase in their volume and mass.

Thus, the concept of «growth» reflects quantitative changes of an irreversible nature. The growth of tree species is characterized by such an indicator as growth. In particular, one of the main criteria for assessing the growth rate of tree species is the current height growth during the growing season. In addition, certain qualitative changes occur in the plant organism that characterize the development of the organism. In biology, the individual development of a plant organism from a zygote (or vegetative embryo) to natural death is called ontogeny.

During ontogenesis, the hereditary information of the organism (genotype) is realized in specific environmental conditions, resulting in the formation of a phenotype – a set of all the characteristics and properties of an individual organism. In addition, the development of an organism is also determined by environmental conditions. Thus, individual development of plants is a gradual qualitative change of irreversible nature in the structure and functional activity

27 Kobzar A.Y. Prykladnaia matematycheskaia statystyka. Dlia ynzhenerov y nauchnykh rabotnykov. M: FYZMATLYT, 2006. 816 p.

of plants and their parts in the process of ontogenesis. The term «development» also includes age-related changes. In addition to growth and development, the body undergoes processes of accumulation and transformation of substances and energy, which are reversible[28].

Growth and development are inseparable and are one of the main properties of a plant organism. Woody plants have two developmental cycles: a general large cycle covering development from seed formation to natural death, and a small annual cycle covering the annual development of shoots from apical buds (growth points) to the formation of new apical buds. The growth of woody plants is largely determined by abiotic environmental factors: light, temperature, moisture, soil minerals, photo- and thermoperiodicity.

Height growth. Tree species differ significantly in their growth rate, which is why they are conditionally divided into two groups: fast-growing and slow-growing. Fast-growing tree species are those that are characterized by intensive growth in the first half of life and reach their maximum height by the age of 30-50. In the following stages, growth in height slows down or stops completely. Slow-growing species grow much more slowly in the first half of their life and reach their maximum height by 80-120 years.

Their growth is long and stops gradually. Tree species of the first group have an early culmination of growth (in height – in 10–20 years, in stock – in 25–50 years), and in the second group, the culmination periods are delayed by 10-30 years. The growth rate of tree species depends on their biological properties, habitat conditions (climatic, edaphic), origin (seed or vegetative), interaction between neighboring trees, age, etc.

According to this indicator, a number of tree species have been formed, in which they are arranged in descending order: poplar, white acacia, larch, birch, black alder, elm, pine, ash, black walnut, maple, hornbeam, oak, beech, spruce, fir, yew. As a rule, light-loving tree species have a higher growth rate compared to shade-tolerant ones. In optimal climatic and edaphic conditions, tree species are characterized by the best growth and reach the highest bonita classes.

Trees of shoot origin tend to grow faster in the first 15–30 years than those of seed origin. However, their growth slows down more quickly, and by the age of 30–40 years, trees of seed origin are ahead of those of the shoots. The same tree species grows faster in a forest than in an open space. There is a close connection between the density of a stand and its growth and productivity. Insufficient den-

28 Moroz V.V., Nykytiuk Yu.A. Vuhletsepohlynalna zdatnist sosnovykh lisovykh nasadzhen Chernihivskoho Polissia. Visnyk Poltavskoi derzhavnoi ahrarnoi akademii. 2020. № 1. P. 90–99.

sity before the young trees close, as well as excessive density after the crowns and root systems close, inhibits growth.

In overdense plantations, where there is strong mutual oppression of trees, growth is delayed. Growth in diameter depends on the rhythmicity of hormonal processes in the cambium, which is determined by photo- and thermoperiodicity. The cambium functions throughout the life of woody plants, and its activity cycles annually.

During the growing season, trees form various wood elements that form the so-called annual rings. In the process of cambium cell division, xylem (wood) cells are deposited towards the middle and phloem (bast) cells towards the outside of the trunk. Within the annual ring, there is early wood of light color, which is formed in the first half of the growing season, and late wood of darker color, which is formed in the final stage of the growing season. In deciduous species, diameter growth begins in early May and lasts until the end of August. In conifers, it begins somewhat later – from mid-May, but lasts longer – until mid-September.

In general, diameter growth takes longer than height growth and depends on the weather conditions of the current year. The maximum growth of larch, Douglas-fir, and pine in Central Europe is recorded in June, spruce in early July, and oak in late July.

The development of a forest stand is a transition from one qualitative state to another as a result of quantitative changes. From the beginning to the end, stands go through a number of age stages. Trees, like other living organisms, emerge from germ cells, develop, age, and eventually die. The lifespan of species populations is much longer – centuries and millennia. In communities of woody plants, new individuals are born and old ones die simultaneously.

It is identified six phases of development for stands with 20-year age classes[29]:

1) young growth of the first class before crown closure and after closure – the formation of a "thicket" (the state of "thicket" is very important for shade-tolerant species such as beech, fir, spruce, in which it is difficult to achieve timely clearing of knots);
2) old growth of the second class of age, which is characterized by the maximum number of small and medium branches and leaves, the culmination of growth in height, intensive differentiation, tree fall and natural thinning of stands;

29 Danylyn Y.M. Opredelenye nadzemnoi fytomassy drevostoev po aerofotosnymkam // Lesnoe khoziaistvo. 1993. № 1. P. 35–36.

3) medieval forest of class III (height growth culminates, decreases in light-loving species, photosynthesis intensity decreases);
4) maturing forest of class IV (height growth slows down, differentiation stops, diameter growth is characteristic);
5) mature forest of V and VI classes (inhibition of growth in height and weakening in diameter);
6) overstock forest of VII class of age and older (age of decay of plantations due to aging and death).

Professor Gorshenin M.M. identified six stages (phases) of plantation development in ontogeny, which are repeated at a new level in each generation of phylogeny[30]:

1. Individual growth of self-seeding or forest crops until closure.
2. Forest formation, the period of complete closure of crowns, which is characteristic of natural young growth of high density ("thicket").
3. Intensive growth in height and accumulation of needle mass of trees, formation of trunks, crowns and the second tier (girders), as well as undergrowth on more fertile soils; formation of the forest environment, and in some species – the beginning of fruiting.
4. Ripening of the forest, which is accompanied by inhibition of growth in height or its complete cessation in light-loving species and slowing down in shade-tolerant species, increased growth in diameter, and good fruiting.
5. Forest maturity, characterized by continued growth in diameter, and intensive fruiting in shade-tolerant species.
6. Forest aging, which is accompanied by the disorder of the first tier of the stand, the beginning of dry treetops, diseases and tree death, thinning of stands, negative growth of plantations in general.

On the example of single-aged stands, S.V. Belov identified five stages of stand development, not taking into account the latent period in the state of seeds:

1. Seedlings – individuals up to one year old.
2. Youth, which includes three phases: individual growth until the closure of crowns or roots of trees; closure; the phase of growth in the closed state until the fruiting stage.

For coniferous species, the juvenile stage lasts from 2 to 35 years, for softwoods – from 2 to 25 years.

3. Maturity – the age of mass fruiting of stands: for conifers it ranges from 36–40 to 70–80 years, for softwoods – 26–40 (50) years.

30 Lakyda P. I. ta in. Normatyvy otsinky komponentiv nadzemnoi fitomasy derevostaniv holovnykh lisotvirnykh porid Ukrainy. Korsun-Shevchenkivskyi : FOP Havryshenko V.M., 2013. 457 p.

4. Maturity is the age of decreased fruiting, significant slowdown in tree height and diameter growth, and suitability for harvesting for main use.
5. Old age and decay (death) of stands – begins when the decline is equal to the annual growth of wood, and then exceeds it.

There comes an age when there is no increase in the stock of the stand, and then its gradual decrease begins, up to the complete death of the trees of the main generation. This stage of plantation life lasts for many years and depends on the biological age of the tree species. For example, the age of old age and decline of pine and spruce stands is approximately 140–240 years, beech – 180–300 years, and birch and aspen – 81–140 years. Of particular scientific interest is the study of the phases of development of natural anthropogenically undisturbed forests, the so-called virgin forests.

Leibundgut identified the following phases of virgin forest development:

1. optimal phase – a strong, closed stand with a high timber reserve and good average tree life. In the early stages of the optimal phase, the closeness of the upper canopy of the stand is not too high and does not impede the development of the middle tier. In the late stage of the optimal phase, the closeness of the upper canopy is already high.
2. Alterphase – a strong stand with the loss of individual trees and clumps due to their aging. At the early stage of the senescence phase, the stand's stock is maximum, and at the late stage, it is more than half of the maximum stock. Small windows and gaps are formed in the upper canopy as a result of the loss of one or more trees.
3. Zerfallphase – there is a progressive disorder of the stand, and its stock is less than half of the maximum. Large windows and gaps are formed in the upper tier.
4. Verjungungsphase – occurs after the decay phase, accompanied by slow stand disorder and the appearance of dense undergrowth.
5. Plenterwaldphase – the plantation is restored selectively, and high-stage stands are formed.
6. Young forest phase (Jungwaldphase) – after rapid disintegration (destruction) of the plantation, a young forest (young growth, thickets, thickets) is evenly formed from dense natural regeneration.
7. Phase of uniform stand (Phase des gleichformingen starken Stangenholzes und Baumholzes) – a stand is formed from dense young growth. The stock of the stand is growing, the trees of the upper tier are characterized

by intensive growth in height. Subsequently, the optimal phase of virgin forest development gradually occurs.

The duration of the phases of plantation development, as well as the age of natural maturity, cannot be characterized by the same terms for all conditions, because they depend on a number of factors (climatic and soil-hydrological conditions, biological properties of the species, stand density, etc.). A characteristic feature is the change in the requirements of tree species to environmental conditions at different stages and phases of development.

The formation of pure and mixed stands in natural conditions and their territorial location depend on geographical conditions, biological and ecological properties of tree species, environmental factors, and human activities. The main reason for the formation and existence of a sustainable natural virgin stand is the compliance of the bio-ecological properties of a particular tree species with the habitat conditions in which the existence of other tree species is problematic.

The biological essence of the existence of a pure stand is to preserve the species, facilitate its struggle against other species and adverse environmental influences. Pure stands are formed in special, specific soil and climatic conditions that correspond to the ecology of a particular tree species[31].

For example, pure stands of black alder (wet and wet succulents and black alder) grow on alluvial-boggy soils with excessive moisture. Scots pine forms mainly pure stands in unfavorable conditions: on swampy peat soils (wet and wet pine forests), on dry sandy soils (very dry and dry pine forests). In the extreme conditions of the Carpathian highlands at an altitude of 1400–1750 m, continuous thickets of mountain pine (wet and damp mountain pine forests and subforests) are common, the so-called mountain pine crooked forest.

In the same conditions, green alder forms thickets – green alder crooked forest (wet green alder subora). Pure stands have both advantages and disadvantages.

The advantages of pure stands include the following:

1. Specialization of raw materials, i.e. better satisfaction of the needs for certain types of raw materials, for example, spruce or poplar wood for the pulp and paper industry.
2. Expediency of creating pure stands in such soil and climatic conditions where the formation of full-fledged mixed stands is impossible or problematic.
3. Uniformity of trunks cleaning from knots, which helps to improve the quality of wood.

31 Vatkovskyi O.S. Metody opredelenyia fytomassy stvola y krony duba. Lesovedenye. 1968. № 6. P. 58–64.

4. Simplicity of operation of clean stands during clear-cutting.
5. Simplified organization and implementation of forestry mechanization, especially in the case of monocultures. Better opportunities to create cost-effective plantations of fast-growing species. Most of the advantages of pure stands are of a purely organizational and economic nature.

However, they also have significant disadvantages:

1. Mono-dominant stands, especially of coniferous species, usually cause deterioration of forest and vegetation properties of soils due to the formation of coarse humus and increased soil acidity, intensive consumption of nutrients from the same horizons at the same time.
2. They are characterized by reduced resistance to negative abiotic, biotic and anthropogenic factors: windfalls, snowstorms, snowmelt, droughts, entomopest pests, phytodiseases, forest fires, man-made emissions, etc. For example, pure spruce forests artificially created in beech, fir and oak forest types of the Carpathians are intensively damaged by root sponge, stem rot and bark beetles as early as 50–60 years old, and are thinned out by selective sanitary felling, which in turn reduces their resistance to strong winds and leads to massive damage by windbreaks and storms.
3. The possibility of a decrease in demand for wood of this species due to changes in market conditions weakens the economic value of pure stands. The history of European forestry demonstrates the higher silvicultural efficiency of mixed stands. The biological essence of a sustainable mixed community lies in the bio-ecological correspondence of different tree species to specific habitat conditions.

In Ukraine, on the vast majority of its territory suitable for forestry, soil and climatic conditions are favorable for the formation and growth of highly productive mixed stands. The Ukrainian Carpathians have preserved mixed natural plantations with a peculiar age structure, characteristic structure and combination of tree species.

For example, in the belt of beech forests, fir-beech, beech-fir, spruce-fir-beech, and spruce-fir-fir stands are common. These unique plantations, which used to occupy much larger areas, can be used as ecological models in solving the problem of reproduction of indigenous stands. The interaction of tree species in plantations is characterized by dynamism and develops in different ways. Joint growth with pine, birch, and aspen is favorable for spruce at certain stages.

A positive role is played by the admixture of linden, maple, sycamore, cherry, and a small proportion of hornbeam in oak plantations. Thus, the maximum absorption of phosphorus by oak coincides with the highest release of this element by maple. The hornbeam admixture helps to increase the acidity of the soil solution, while intensifying the cycle of nutrients.

This is important on chernozem soils. In hornbeam and oak-hornbeam forests, an admixture of oak, hornbeam, sycamore, linden, sharp-leaved maple, elm, etc. is useful for beech. In spruce-beech stands, fir and beech are characterized by better diameter growth than in pure stands. This improvement in growth is the result of the positive mutual influence of beech and fir in their joint growth. In general, mixed stands are an example of a stable biological community[32].

However, not all species and not at all stages of growth in a mixed stand have favorable conditions. Along with positive interactions, there is intense interspecies competition, which often leads to undesirable forest changes. For example, in oak forests, it is quite common for oak to be replaced by hornbeam and for low-productive and low-value hornbeam forests to form.

Pine is often replaced by softwoods such as birch and aspen[33]. The condition, formation, and productivity of a mixed stand depend on the quantitative ratio of tree species and forest vegetation conditions. A significant admixture of birch in wet pine forests inhibits pine growth, while its share of 20–30% has a positive soil-improving effect. Oak and ash form mixed stands, but their role in shaping the composition differs in different forest vegetation conditions. In dry and wet oak forests, oak is more competitive. Fresh hygrotop conditions are more optimal for ash, so it is able to displace the main species. The advantages of mixed stands include the following[34]:

1. More efficient use of the aboveground and underground environment. Tree species with a shallow root system and species with deep roots use nutrients from all available soil horizons when growing together. In addition, nutrients are used more efficiently due to the consumption of nutrients by different species at different times. The combination of light-loving and shade-tolerant species results in more efficient use of the sun's radiant energy.

2. Improvement of forest and vegetation properties of soils due to the addition of soil-improving species, for example, birch in pine and spruce forests,

32 Lovynska V.M. Nadzemna fitomasa stovburiv Pinus sylvestris L. u derevostanakh pivnichnoho stepu Ukrainy. Naukovyi visnyk NLTU Ukrainy. 2018, T. 28, № 8. P. 79–82.

33 Moroz V.V., Nykytiuk Yu.A. Vuhletsepohlynalna zdatnist sosnovykh lisovykh nasadzhen Volynskoho Polissia // Naukovi horyzonty. 2020. № 01 (86). P.61–70.

34 Onuchyn A.A., Borysov A.N. Opyt taksatsyy fytomassy sosnovykh drevostoev // Lesovedenye. 1984. № 6. P. 66–71.

linden and maple in oak forests, etc. Beech in mixed plantations is valued as an economically valuable, soil-improving and soil-protecting species that promotes the growth of conifers, for example, in beech-fir-spruce stands in the Carpathians.

3. Higher biological resistance to adverse factors: wind, snow, droughts, fires, insect pests and phytopathogens, atmospheric pollution, etc. The wind resistance of a mixed stand is associated with the combined growth of tree species with different rooting depths. The wind resistance of tree species with superficial rooting increases due to the intertwining of roots. This is observed in spruce stands with an admixture of birch. Birch roots cover the spruce roots from above and below, which contributes to mutual reinforcement. The higher resistance of forest stands to entomopests is due to the fact that a certain type of insect often prefers one tree species without damaging others.

4. Mixed stands provide a wider range of different timber products, so the absence or decrease in demand for a single tree species does not cause economic problems that may occur in the case of predominance of pure stands of a currently low-value species. Some specialty woods (resonance, aviation, ski) can also be produced only in mixed stands.

5. Mixed plantations are more conducive to the conservation and reproduction of biodiversity, have a higher aesthetic value, and therefore play a leading role in recreational use.

6. They are characterized by a greater diversity of forest fauna, and therefore are more suitable for hunting management.

7. They better meet the principles of multi-purpose forest use, more effectively performing environmental stabilizing and protective functions. However, mixed stands also have certain disadvantages:

1. The risk of loss of certain economically valuable species, including the main species.

This phenomenon is most typical during the period of intense competition for light and nutrients, i.e. at the stages of young growth and stand formation. Therefore, in many cases, timely intervention of foresters in the process of forming a mixed stand is necessary.

2. The threat of the spread of certain phytodiseases. For example, aspen admixture is often undesirable for pine because of the risk of infection with the fungus Melampsora pinitorqua, which causes a disease known as pine spindle beetle.
3. The danger of damage to the crown of spruce and pine by birch is a phenomenon that is typical for mixed stands of these species.

4. Complication of operation, more complex technique of creation and cultivation of forest crops compared to pure plantations. The spatial structure of forest communities includes two types: vertical and horizontal.

The vertical structure of plantations is reflected in the tiering. Separate tiers are distinguished in stands if trees of the same or different species differ significantly in height. Trees are often arranged in two tiers: the first is of light-loving species (pine), the second is of more shade-tolerant species (oak). Stands are divided into one-tier, two-tier, and three-tier.

Plantations that have two or more tiers are called multi-tiered or complex, while single-tiered ones are called simple. The tier with the largest stock is called the main tier, and the others are called secondary tiers. Mostly complex stands are mixed in terms of species composition, while simple stands are mostly pure.

However, in mono-dominant stands of different ages, several tiers can also be formed. In this case, the upper tier contains trees of the older generation, and the lower tiers contain younger individuals. A multi-tiered structure is typical for mixed stands with light and shade-tolerant species. The dominant tier is formed by light-loving species (pine, larch, birch), and the lower tiers are represented mainly by shade-tolerant species, while some trees can reach the upper tier.

The predominance of shade-tolerant species in the upper tier prevents the development of lower tiers of light-loving species. In complex plantations of shade-tolerant species, such as beech trees, the subordinate tiers also include shade-tolerant species that can grow and develop in conditions of light deficit (hornbeam, fir, sycamore, sharp-leaved maple, linden)[35].

The number of tiers and their nature are closely related to natural and geographical conditions. With the improvement of climatic and edaphic conditions, the vertical structure of stands becomes more complex along with the species composition. The tiering of forest communities has biological, ecological, and economic significance. The biological essence lies in the more complete use of aboveground and underground space by woody plants.

Natural selection is manifested in the settlement of tiers. The stock of phytomass and its spatial distribution are related to the tiering. In a complex plantation, there are multifaceted interrelationships: between individuals of the same and different tree species of the same tier and different tiers, the influence of the upper tiers on the lower ones and vice versa. These interrelationships imply competitive interspecific and intraspecific relationships, as well as positive mutual influences.

35 Churakov B.P., Maniakyna E.V. Deponyrovanye uhleroda raznovozrastnymy kulturamy sosny // Ulianovskyi medyko-byolohycheskyi zhurnal. № 1, 2012. P. 125–129.

Woody vegetation layers transform the forest ecological environment, affecting the microclimate, soil, CO_2 content, etc[36]. The lower tiers utilize part of the solar energy transmitted by the upper forest canopy and, in turn, prevent it from reaching the soil surface. They also intercept part of the precipitation, affecting its distribution. The division into tiers is also of economic importance[37]. The trees that form the individual tiers differ in size and are used for harvesting different types of timber.

Trees of the first tier are used for sawmill, plywood, sleeper ridge, construction logs and other rough grades. Trees of the lower tiers with smaller diameters produce a higher yield of smaller business grades: mining risers, balances, poles, etc. Each of the allocated tiers should have a more or less significant stock. If a particular tier has a small stock, in which specialized forestry measures are not economically feasible, it is not allocated. A secondary layer is allocated if its stock is at least 30 m3-ha^{-1} .

The lower tiers influence the formation of the trunks of the main tree species, creating side shading for them, promote growth in height and clear them of knots. Oak is especially in need of side shading. Shrubs and some tree species that form the lower tiers and surround oak trunks are called “fur coat”. There is an expression among foresters: “an oak grows well in a fur coat, but with its head open,” i.e. with side, not top, shading. Thus, the growth of oak in complex plantations has both biological and economic meaning. The advantages and disadvantages of simple and complex plantations are in many ways similar to those of pure and mixed plantations. Taking into account the composition of the stand, foresters must find the optimal parameters of the plantation structure in accordance with the natural capabilities and economic needs.

In the life of a forest there are two opposite and, at the same time, interrelated biological processes that affect the formation of a certain age structure of the stand: the process of tree mortality and the process of emergence and formation of new generations of trees through natural renewal. There are two main types of stand age structure: single-age and multi-age. The age structure of stands is related to their origin and formation.

Same-age stands are often formed as a result of artificial reforestation, after forest fires or clear-cutting carried out in the seed year. Natural anthropogenically undisturbed forests, the so-called virgin forests, are most often represented by

36 Moroz V.V. et al. Carbon Absorption Ability of Pine Forest Plantations in the Ukrainian Polissya // Ukrainian Journal of Ecology. 2020. №10(2). P. 249–255.

37 Utkyn A.Y. Opredelenye zapasov uhleroda nasazhdenyi na probnykh ploshchadiakh: sravnenye allometrycheskoho y konversyonnoho-объemnoho metodov // Lesovedenye. 1997. № 5. P. 51–65.

multi-age stands[38]. Depending on the type of age structure, certain patterns of taxonomic structure are observed in the stands: distribution of the number of trees by diameter, height structure, canopy closure, etc.

Based on the study of cedar forests, based on the variability of age, diameter and height of trees, I identified three management groups of stands by age structure: conditionally single-aged, conditionally mixed-aged and mixed-aged.

In the study of the structure of beech virgin forests of the Uholsko-Shyrokoluzhanskyi massif in the Carpathian Biosphere Reserve, three types of distribution of the number of trees by thickness levels were identified:

- decreasing (multi-age stands) – the number of trees in medium thickness levels does not exceed 10% of the number of trees in the 8 cm thickness level;
- transitional (conditionally multi-age stands) – this number is 10–30%, respectively;
- uniform (conditionally single-age stands) – more than 30%.

Dyrenkov S.O. proposed a different methodological approach. The division of stands into conditionally different-aged, relatively different-aged and absolutely different-aged is based on the distribution of the total stock by 40-year age classes, or so-called generations. Gusev I.I. determined the type of age structure of spruce forests in the European North by the coefficient of age variation, which is correlated with the indicators of taxonomic structure.

When the coefficient of age variation is up to 12–14%, stands are classified as single-aged (conditionally single-aged); more than 14% are conditionally multi-aged, which have a natural single-peaked curve of tree distribution by age and do not differ in taxonomic structure from single-aged stands.

Multi-age stands are those that differ significantly in their classification and age structure from the previous types, and the coefficients of age variation exceed 14%. Bitsyn L.V. identified the following types of age structure of beech forests in the North Caucasus: single-aged, relatively old-aged, and cyclic-aged. Beech stands with age fluctuations not exceeding 40–60 years are considered to be of the same age. In his opinion, this type of age structure is characteristic of forests that are affected by economic activity.

Relatively old-growth stands are characterized by a significant amplitude of age fluctuations (200 years), however, the main stock of stem wood is concentrated in two or three age classes. For cyclic-aged stands, the amplitude of age fluctuations is more than 200 years.

38 Lakyda P.I. Fitomasa lisiv Ukrainy: monohrafiia. Ternopil: Zbruch, 2002. 256 p.

Another authors identified the following types of age structure of plantations[39]:

1) absolute single-age;
2) relatively (conditionally) single-age;
3) multi-age – with a characteristic representation of trees of different ages and a pronounced vertical closure of the canopy;
4) step-aged stands (step-aged – with single-aged trees within a tier; step-aged – with multi-age within a tier);
5) cyclic-aged.

The age differences of trees that have reached a significant age are smoothed out, and therefore the age structure itself changes its character. For example, a stand of trees aged from 1 to 50 years is a multi-age stand. However, the same stand, having reached the age of 200–250 years, with the same difference in tree age, will practically be closer to single-aged.

In physiological terms, 200–250-years-old trees are much more similar than 1- and 50-year-old trees. Age structure is a dynamic category that manifests itself in various forms, including transitional ones. The species composition has a significant impact on the formation of the age structure of plantations. Thus, in mixed stands, tree species often have different ages. In this case, different options are possible.

For example, an older single-age generation of one species in the first tier and a younger single-age or multi-age generation of another species in the second tier. After a while, tree species from the lower tiers can also enter the dominant layer, which complicates the age structure of this layer and the stand as a whole.

Biological monitoring of forests. In Ukraine, the need to conduct forest monitoring is stipulated by the following laws and governmental decisions: Law of Ukraine "On Environmental Protection" (1991), Article 22; Law of Ukraine "On Flora" (1999), Article 39; Forest Code of Ukraine (2006), Article 55. Resolution of the Cabinet of Ministers of Ukraine of March 30, 1998, № 391 approved the "Regulation on the State Environmental Monitoring System", according to which the State Committee of Forestry and Range Administration is responsible for monitoring forests in Ukraine.

In accordance with the Law of Ukraine of 21.09.2000, № 1989 III "On the National Program for the Formation of the National Ecological Network of Ukraine for 2000–2015", it is envisaged to conduct environmental monitoring within this network, which will be based on forests, since all areas of forests, forest belts and shrubs are included in the national ecological network of Ukraine[40].

39 Lovynska V.M. Lokalna shchilnist komponentiv fitomasy stovbura sosny zvychainoi (Pinus sylvestris L.) Pivnichnoho Stepu Ukrainy // Visnyk ahrarnoi nauk Prychornomoria. 2018. Vyp. 3. P. 73–78.

40 Klimat Ukrainy / za red. V.M. Lipinskoho, V.A. Diachuka, V.M. Babichenko. K.: Vydavnytstvo RAIeVSKOHO, 2003. 343 p.

Forest monitoring is included in the priority areas of implementation of the State Program "Forests of Ukraine" for 2002–2015. The Cabinet of Ministers of Ukraine approved the concept of the State Program for Environmental Monitoring by its Decree № 992-r dated December 31, 2004, which stipulates the need for forest monitoring.

According to this decree, state, regional and sectoral monitoring programs should be developed, including relevant forest monitoring programs.

Monitoring is mandatory in accordance with the international agreements signed by Ukraine within the framework of the pan-European process of sustainable forest management (resolutions of the Strasbourg (S1), Helsinki (NO) and Lisbon (L2) Ministerial Conferences on the Protection of European Forests) and international conventions ratified by the Verkhovna Rada of Ukraine – the Convention on Large-scale Transboundary Air Pollution, the UN Convention on Biological Diversity, and the UN Framework Convention on Climate Change[41].

Monitoring is carried out on a regular basis in almost all European countries, and its results define a number of agreed pan-European criteria for sustainable forest management. In 2003, Ukraine signed Resolution of the Ministerial Conference on the Protection of Europe's Forests, which requires forest monitoring to be conducted on a long-term and regular basis using methods harmonized at the pan-European level (the Forests ISR). In 2004, the Verkhovna Rada ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Law of Ukraine № 1430-IV of February 4, 2004). According to international obligations, national inventories of greenhouse gas emissions and removals, including those in forests, must be conducted annually.

Therefore, it is necessary to develop a sectoral forest monitoring program to ensure that complete, objective and timely information on the state of forests is obtained and to provide information support in making management decisions in the field of forest protection, restoration and sustainable use. The Forest Monitoring Program of the State Committee of Forest Resources of Ukraine for the period 2006–2010 was developed on the basis of the State Program "Forests of Ukraine 2002–2015" and is coordinated with the draft State Program for Environmental Monitoring of Ukraine (2005).

Prerequisites and objectives of forest health monitoring. The purpose of biological monitoring is to determine changes in the regional distribution and

41 Kyotskyi protokol. Ystoryia razvytyia, tsely y pryntsypy. Proekty sovmestnoho osushchestvlenyia v Ukrayne: sbornyk ynformatsyonno-metodycheskykh materyalov / pod. red. S.V. Tretiakova. Donetsk: OOO «UKRDRUK», 2006. 184 p.

intensity of changes in forest resilience and sustainability[42]. To determine the sanitary condition of forests, in accordance with the requirements of the ISR-ESE, an assessment of the degree of defoliation and certain morphological indicators of tree crowns, which are localized on permanent test surfaces (PTS) in stands mainly more than 20 years old, is used.

Biological monitoring of forests is one of the main sources of information on the sanitary condition of forests. Its results are collected in a certain defined order in time and space, which allows for a comprehensive analysis that makes it possible to highlight various cognitive aspects.

Forest monitoring is a system for assessing the forest environment and the sanitary condition of stands based on permanent or periodic research and measurement of certain indicators in permanent test areas.

Biological monitoring includes the following components:

- crown condition assessment program (crown defoliation);
- entomological monitoring;
- biodiversity monitoring;
- phytopathological monitoring;
- assessment of scots pine seed viability;
- soil properties assessment;
- program for assessment of the chemical state of the assimilation apparatus;
- air pollution assessment.
- The main objectives of forest monitoring are:
- determining territorial differences in the sanitary condition of forests;
- studying changes in the sanitary condition of forests over time;
- assessing the level of heterogeneity and diversity of the aboveground forest cover;
- analyzing the cause-and-effect relationships between the sanitary condition of forests and biotic and abiotic environmental factors;
- developing short-term forecasts of changes in the sanitary condition of forests.

Monitoring tasks include:

- sending information to the administrative units of the State Forests on the state of forests in order to make optimal decisions on planning and implementation of economic activities;

42 Lovynska V.M. Nadzemna fitomasa stovburiv Pinus sylvestris L. u derevostanakh pivnichnoho stepu Ukrainy // Naukovyi visnyk NLTU Ukrainy. 2018, T. 28, № 8. P. 79–82.

- collecting the necessary information for the formation of forest policy and environmental policy of the state;
- support and assistance in fulfilling international obligations under the Convention on Long-range Transboundary Movement of Pollution, the Convention on Biological Diversity and resolutions of the Strasbourg and Helsinki Pan-European Ministerial Conferences held in.

Objectives of phytopathological monitoring. The task of phytopathological monitoring is to identify and determine the possibility of a threat from fungi to the normal sanitary condition of forests. During the research, work is carried out to identify species of pathogenic and saprotrophic fungi in stands of various tree species, determine the degree of their threat and assess possible damage. Based on the analysis of the annually updated database, conclusions are drawn on the types and quantity of both pathogenic and saprotrophic fungi, and the level of threat to the stands and their general sanitary condition is assessed.

Role of fungi in the forest environment/ When conducting biological and ecological monitoring of forests, it is important to study the role of fungi in the forest ecosystem. Fungi are one of the most significant factors in the cycle of matter and energy change – they participate in the decomposition of dead organic matter and modify metabolic processes in living matter in the case of parasitism or symbioses (mycorrhizae). It is these last two factors that make fungi play an important role in the forest environment.

In the case of diseases caused by fungi, entire stands are often threatened with destruction, while in the case of mycorrhiza, fungi contribute to the rapid development of plants. In the case of pathogens in the roots of pine trees, negative changes occur in the growth and development of the whole tree – the number, length and weight of shoots and needles decrease.

Among the large number of infectious diseases caused by fungi, the main ones in determining the sanitary condition of forests are crown and root diseases. In contrast, fungi that settle in the trunk are less important from an economic point of view. The role of pathogenic fungi as a factor that initiates and participates in the process of forest diseases is significant. The presence and type of mycorrhizae also affects the condition of trees. Their main function is to increase the absorption surface of the root system, which results in better supply of water and mineral compounds dissolved in it. Mycorrhizae are also important from the point of view of phytopathology.

On the one hand, the presence of mycorrhizae determines the type of susceptibility of a tree to the possibility of infection by fungi, and on the other hand, it often prevents the plant from being infected by pathogenic fungi. This protection can consist of[43]:

- limiting the release of compounds through the roots that stimulate the development of pathogens;
- creating a physical or biological barrier to the penetration of infectious organs (hyphae, mycelium);
- releasing antibiotics;
- promoting the emergence of protective rhizosphere communities.

The main tasks of inventory (monitoring) works are to record the state of a given object in a possible acceptable way in a specified time using certain defined indicators.

Methodological principles of monitoring[44]. The test plots for phytopathological monitoring are located in the network of permanent test plots (PTP) for biological monitoring of forests. The research and measurements are carried out with a 5-year cycle. They consist of 4 circular test sites (central and 3 satellite or satellite) with an area of 0.0025 hectares each, of which the central site (number 1) is located in the middle of the PPP.

The radius of each site is 8.0 m, and the centers of each of the satellite sites are equidistant from the center of the central site by a distance of 36.6 m in the direction of 360° (site 2), 120° (site 3) and 240° (site 4)[45]. If the site is completely part of a certain type of forest or land, its area is determined as "1", if a path or stream passes through the site – "1/2", if the site is inaccessible for research (road, water body, cliff, etc.) – "0". Defoliation, tree damage by pests and the degree of fungal infestation of stumps are assessed on the monitoring surfaces.

In addition, the position of objects (trees, stumps) on the territory of the sites is measured using polar coordinates (distance to the object from the center of the site and azimuth of the direction to the object). The obtained data is grouped into the appropriate levels: Surface level:

- PPP number Test site level: "address" of the area – association, enterprise, forestry, quarter and allotment;
- land category (forest or land that has been abandoned for agricultural cultivation);

43 Lovynska V.M. Nadzemna fitomasa stovburiv Pinus sylvestris L. u derevostanakh pivnichnoho stepu Ukrainy // Naukovyi visnyk NLTU Ukrainy. 2018, T. 28, № 8. P. 79–82.

44 Ysaev A.S., Korovyn H.N., Utkyn A.Y. Otsenka zapasov y hodychnoho deponyrovanyia uhleroda v fytomasse lesnykh ekosystemakh // Lesovedenye. 1993. № 6. P. 3–10.

45 Onuchyn A.A., Borysov A.N. Opyt taksatsyy fytomassy sosnovykh drevostoev // Lesovedenye. 1984. № 6. P. 66–71.

– management activities and information on the presence of certain natural phenomena (burning, harvesting, soil preparation for natural regeneration, etc.);
– age of the stand;
– symptoms of pine shoot dieback diseases (applies exclusively to pine stands or with significant pine participation);
– number of branches lying on the ground;
– degree of infection of lying branches with fungi involved in the process of shoot dieback;
– identification data of the taxation;
– date of inspection.
– Level of the object on the site: tree:
– species;
– diameter;
– number from the biological monitoring plan (if available);
– Kraft class;
– damage: type, location and intensity;
– position on the site (azimuth and distance from the middle of the site);

stump:

– type of tree from which it originated;
– age after felling (I – 1–2 years, II – 3–5 years, III – 6 years or more);
– degree of decomposition (1 – strong, 2 – medium, 3 – weak);
– fungal infestation;
– position on the site (azimuth and distance from the middle of the site).

The surface identification data (PPP number, bypass, quarter and allotment) and the land category, stand age and habitat type are determined based on maps and information received from the forestry. Information on the site category, economic activities and characteristics of natural phenomena that occurred on the site, information on symptoms of shoot dieback diseases based on the site surface assessment, condition of trees and stumps are determined directly during field surveys.

DOI: 10.51587/9798-9866-95983-2023-015-5-40