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Methodological approaches in the study of agroecosystems' biodiversity

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In agroecosystems, the structure and dynamics of taxonomic and functional biodiversity differs significantly from the local intact identical standard types of ecosystems and depends on the type and duration of management, the degree of environmental friendliness of the applied technologies. Agroecosystems significantly affect the biodiversity of the surrounding areas. To harmonize its preservation in agricultural landscapes with the aim of optimizing agriculture, it is necessary to improve the methods of its research. It is established that the choice of methodological bases (principles, criteria and methods) of biodiversity research depends on the purpose and hierarchical level of ecosystem analysis, scale of the researched question, as each group of living organisms selected according to a certain principle has its peculiarities, identification and characterization of which requires appropriate methods, necessary knowledge, special equipment and other resources of scientific research. It is advisable to apply a systematic approach, biotic and / or ecological criteria and indices for assessing / analyzing the diversity of biota, the ratio and characteristics of its ecological groups, indicator capacity of species, multifunctional relationships (within and between taxa and their environment) and other ecological indicators describing the state of integrity of the agroecosystem, its functional diversity and dynamics. Gradient analysis by changing the values of determining factors is appropriate for zoning the distribution in space of different levels of agroecosystem transformation and its biodiversity. Retrospective analysis makes it possible to identify the causes, characterize the dynamics of changes in biodiversity in the past and future and justify the directions of its conservation.

Key words: diversity of living organisms, agriculture, research methods, ecosystem, connections, ecological factors.

Problem statement and analysis of recent research. Biodiversity is the totality of all life forms in all its manifestations, i.e. the diversity of species with their set of genes, their interactions in communities with other species and interactions between communities, the diversity of their functions and relationships, and ecosystems [1–4]. For people, biodiversity has economic, recreational, cultural, environmental and other values [1, 2]. Therefore, it is an important component of a number of basic action plans of the UN and its international institutions, their environmental policies and programs (IUCN, UNESCO, WWF, GEF) to implement the tasks of sustainable nature management, including in the agricultural sector (Rio-92; Sofia, 1995; Nagoya, 2010). International projects related to biodiversity and ecosystem services are being implemented – TEEB, ESMERALDA, IPBES, ORERAs, BDTF SEE. Ukraine is actively participating in international cooperation on these issues, ratifying the basic principles of the relationship to biotic and landscape diversity.

Biodiversity is considered at the genetic, species and ecosystem levels. Genetic diversity describes the total number of genetic characteristics that occur in a population or species. All the genetic diversity of species, consisting of all genotypes of populations, is united in the concept of the gene pool of the planet [1, 5]. The set of gene pools and genotypes of all populations and individuals that are part of the ecosystems of a particular area, Golubets calls a genoplast [6, 7].

Species diversity covers all species of living organisms. The more species in the biocenosis, the richer and more stable it is. Species diversity of biocenoses depends on the diversity of habitats and ecological niches in which different ecological groups of species and their adaptations are formed. Species and coenotic diversity of biota are closely related to the conservation of certain types of natural or semi-natural habitats [8]. Of particular importance are relict and endemic species, as well as rare and endangered species, which are included in the relevant lists of international conventions, the Red Book of Ukraine and other lists of regional and local levels. According to the IUCN Red List [9], there are about 37,400 endangered species in the world.

The diversity of communities and ecosystems includes phyto-, zoo-, microbiocenosis, as well as their biotopes. In addition, ecosystems have different sizes – micro-, meso-, macro-dimensions. The more different ecological systems exist in a given area, the less likely it is to disturb the balance in nature, and the more valuable this area for humans [10]. All components of the ecosystem support its functioning, sustainability and direction of succession development. The existence of biota significantly depends on environmental conditions (ecotope), while the biota of a particular ecosystem affects the direction and intensity/speed of its development. The current fragmentation of landscapes by anthropogenically transformed areas, changes in the habitats of flora and fauna causes significant difficulties for their migration, which leads to the extinction of some species and a sharp reduction in others [11]. Ecosystems that contain communities, species or habitats listed in the Green Book of Ukraine, in international conventions, agreements (in particular, Bern, Bonn, Washington (CITES), etc.) are especially valued [8].

According to Whittaker's classification of biodiversity, alpha, beta and gamma diversity are distinguished. The fewer common species in communities or at different points of the gradient, the higher the beta diversity. Delta diversity is the change in species diversity between landscapes, mainly along large climatic and physical-geographical gradients [12–15].

Biodiversity is a guarantee of sustainability of both individual ecosystems and the biosphere as a whole [16]. The more the structure of biodiversity of a certain ecosystem corresponds to the potential and diversity of ecological niches of a given ecotope, the more stable this ecosystem is. This system of mechanisms for maintaining balance is formed during the evolution of ecosystems; it is multidimensional and dynamic. However, as a result of long-term human use of nature, this formed correspondence of "biocenosis-ecotope" of natural (indigenous) types of ecosystems is significantly violated. Therefore, to maintain their sustainability, productivity and sustainable development until the target resource (yield or ecosystem service/function) a person must contribute the necessary energy in the form of various care systems for cultural (target) species, communities and/or their protection, etc. In this sense, agroecosystems deserve special attention, as they are a typical example of replacing natural ecosystems with cultural agrocenoses from bred new varieties/species, and therefore are unstable, subsidized ecosystems. In contrast to natural ecosystems, agrosystems are characterized by low closedness of the cycle of substances, constant extraction of organic anthropogenic energy from the outside, short trophic chains, strong soil erosion, insignificant biological diversity, and as a consequence – instability [17], loss of homeostasis and unbalancing the existing links between the components of the agroecosystem [18]. In addition, the traditionally complete concentration of farmers on the crop, its harvest causes their lack of attention to other species of biota, which do not have a significant impact on the productivity of this agroecosystem (the yield of this crop).

Intensification of agriculture remains one of the main causes of biodiversity loss and ecosystem degradation not only in Ukraine but in Europe in general [10, 19]. Excessive or untimely application of agrochemicals, non-compliance with storage requirements, systematic use of high doses of mineral fertilizers lead to contamination of soils, reservoirs and other components of the environment, to violation of homeostasis and simplification/change of the ecosystem biodiversity structure [1, 10, 20–23].

Over the long period of the paradigm of intensive agriculture due to the use of pesticides for agricultural plants protection, the chemistry of the natural environment of agricultural and adjacent landscapes and even remote areas, as well as the structure and dynamics of their biodiversity significantly changed. Modern agrolandscapes have an anthropogenically transformed mosaic structure, where field protective and other forest belts, other phytocenoses not involved in management are elements of the ecological network. They provide some restoration of biota, animal migration, serve as habitat for certain species of wildlife [16, 10]. Rich biodiversity in agricultural ecosystems contributes to the sustainability and productivity of agriculture [19]. However, the transformation of natural complexes into artificial cultivation of crops, change of plantations, use of pesticides, soil degradation lead to the filling of new ecological

niches with other types of biota. New species are formed, populations of certain resistant species (including pests) grow, and species more sensitive to anthropogenic interference, on the contrary, reduce their numbers [25–28]. Many species have disappeared at all or are on this border and need protection. And the biota diversity of agrolandscapes has acquired specific features that are significantly different from the local standart (undisturbed) identical types of ecosystems. It depends on: the type and duration of management, the technologies used, the degree of their environmental friendliness (or the degree of compliance with current environmental regulations).

The part of biodiversity that depends on agriculture or is under its influence is considered to be agrobiodiversity – the diversity of wild species associated with agricultural ecosystems and the diversity of economically feasible, domesticated animals, plants [1, 29, 30], other biota, that supports the most important functions of agroecosystems. The condition for creating an effective agroecosystem is the maintenance of a stable and controlled agrobiocenosis. To do this, agroecosystems additionally receive extraneous energy from machine fuel, organic and mineral fertilizers, seeds, human and animal labor. The bioproduction process in them is supported by man so as not only to obtain but also to extract the maximum valuable in economic terms biomass [30]. Stable, cost-effective and environmentally friendly development of agroecosystems depends on the success of the combination of ecological component (approach to the natural ecosystem), economic (profit) and social (level of consciousness [16]).

In Ukraine, biodiversity management is carried out by the Ministry of Environmental Protection and Natural Resources. The main documents dealing with the maintenance of biodiversity of agricultural landscapes are the Law of Ukraine "On Environmental Protection" [31], the Law of Ukraine "On the Ecological Network of Ukraine" [32] and the Order of the Ministry of Agrarian Policy of Ukraine "On Approval of the Concept of Sustainable Development in Ukraine for the period up to 2025 "[33]. One of the principles of environmental protection is to preserve the spatial and species diversity and integrity of natural objects and complexes [31]. Moreover, the protection of both individuals and ecosystems is provided [34]. It is recognized that threats to biodiversity are due to landscape fragmentation and pollution caused by agricultural production [35]. Therefore, the preservation of biological and landscape diversity is one of the priorities of the state environmental policy of Ukraine until 2030 [36]. This is an important component of our country's international cooperation with the EU in the context of the Biodiversity Strategy until 2030 [37]. In the EU, it is planned to reduce the use of pesticides by 2030 and increase the degree of landscape diversity of agricultural land by 10 %. This is expected to increase the resilience of the agricultural sector to climate change, environmental risks and socio-economic shocks. For this, 25 % of EU agricultural land tends to be cultivated using organic technologies. These and other environmental objectives are to some extent reflected in the Sustainable Development Goals of Ukraine for 2015–2030. There are information centers: Internet resource Data Center for Biodiversity of Ukraine [38], Global Biodiversity Information Facility [39].

It should be noted that there is a conflict between human interests, which is manifested in the need to use the area for various purposes, raw materials or food, and natural processes aimed at preserving ecosystems and biodiversity, i.e. between pragmatic technocratic attitude to natural resources and environmental goals [17, 40–42]. In modern agricultural production, economic priorities prevail over environmental ones. In Ukraine, this is evidenced by the high percentage of plowed land (57 % of the country), loss of soil fertility, and violation of scientific crop rotations, the use of intensive technologies, disregard for the basic laws of agriculture and ecology [18].

The transition to artificial phytocenosis with the cultivation of a number of agricultural plants provokes the spread of certain weed species that compete with cultivated plants for water, nutrients and living space, contribute to pests and diseases, complicate tillage, crop care and harvesting [22]. However, weeds are natural components of agrophytocenoses, a kind of indicator of biodiversity. They play a significant role in stabilizing the soil, preserving its moisture and preventing erosion, they are often mycorrhizal, increase the activity of microorganisms, and are a source of nectar and pollen for bees [22, 43]. This encourages ecologists to consider wild plants as an important component of agroecosystems, the protection of the gene pool of which is an essential part of the conservation of biological diversity on Earth [44]. They are certain analogues of phytocenoses at the stages of secondary successions and due to their explicit strategy, complete eradication of weeds from agrophytocenoses is practically impossible and ecologically impractical [22]. From the standpoint of phytocenology, the complete destruction of weeds can lead to the loss of many useful (or potentially useful) species of plants, insects and other organisms, is a threat to biodiversity. These ideas are supported by biodynamic agriculture [45]. In some countries of South America, the

presence of a significant species diversity of weeds contributes to the yield of cultivated plants [46, 47]. In order to reduce the risk of weeds, cultivated plants need to be controlled to minimize their harmfulness. The use of herbicides in crop fields significantly reduces their numbers, while natural phytocenoses bordering the field are experiencing significant expansion of these species [48]. Depletion of species biodiversity creates conditions for penetration of new species into the communities. Such "enrichment" of flora or fauna is not always useful for humans [2]. As for biota, it is considered biological pollution. Invasive species reduce the biodiversity of agrophytocenosis by a gradient of increasing the presence of this species, such as ragweed (*Ambrosia artemisiifolia* L.) due to increased antifungal activity and phytotoxicity [49]. More and more species are on the verge of extinction as a result of their displacement by invasive alien plants [19], especially in those regions where the natural vegetation is quite fragmented [50]. According to the Secretariat of the Convention on Biological Diversity [19], by 2050 the projected growth of international shipping will increase the risk of invasions of alien species by 3–20 times compared to the current level. To some extent, a scientific structure of sown areas on the basis of polyculture provides the preservation of biodiversity in the system of agrobiocenosis [43].

For animals of most species, the best lands are those that are most similar to natural indigenous ecosystems, provided that there is no factor of concern and the threat of direct destruction of organisms [51]. Therefore, agroecosystems should be formed as close as possible to natural analogues, taking into account the current climate change or other conditions [52, 53]. Organic farming provides significant prospects for preserving biodiversity and improving the ecological safety of products [16, 19, 54, 55]. Increasing the productivity of modern agricultural is impossible without the formation of sustainable agroecosystems and the wider use of innovative agricultural technologies based on ecological principles [18]. Farms with a greater variety of crops are always more economically and environmentally stable.

In general, there is still no accepted systematic approach to the selection of best methods for studying the biodiversity of agroecosystems. It should be recognized that most of the "white spots", unresolved issues still exist on the implementation of the principles of ecologically and economically balanced use of the biotic component of agroecosystems. In particular, the ecological potential of "beneficial" organisms is still insufficiently taken into account in the integrated management not only of plant protection (with activation of biological methods), but also in general in the strategy of transition to sustainable agricultural development, which should ensure the systematic harmonization of interests – social, economic and environmental (especially – norms of ecological safety and nature protection) [42, 55]. This is probably due to the long-term dominance of applied research goals in solving agricultural problems, the difficulties of transition from intensive and conventional management principles to environmentally friendly methods, as well as the frequent change of plant crops in certain areas due to crop rotation and other reasons. It is still unclear what ecological role functional agrobiodiversity plays in the agroecosystem, what and under what conditions it is able to provide expected agroecosystem services, etc. [56, 57]. It is difficult to assess biodiversity in agroecosystems, as it is necessary to take into account the type of agroecosystem (field, garden, farm, greenhouse), changes in space and time, biota structure and features of its constituent species, respond to anthropogenic negative impacts, micro- , mesoclimate, which is formed in different subsystems, changes in the habitat of species by phenological phases and more.

The aim of the research is to generalize the tested methods of biodiversity research, to justify their choice for use in agroecosystems, taking into account the identified methodological problems.

Material and methods of research are theoretical methods of system and comparative analysis, interdisciplinary, ecosystem approaches.

Research results and discussion. It is advisable to start the analysis with the levels of the hierarchy of the living organization. *Genetic diversity* is necessary for any species to maintain reproductive activity, resistance to disease, the ability to adapt to changing conditions. Genetic variability can be manifested both at the level of the species and at the level of varieties or local populations. To identify genetic differences between individuals, populations and species there are methods: studying the sequence of nucleotides in DNA, RNA; determining the sequence of aminoacids in proteins; immunological and electrophoretic comparisons of proteins and others [1]. To maintain diversity in agroecosystems, an *in situ* approach is used, comparing the results with identical natural standart systems (as a control) or with *ex situ* (gene banks). To preserve agrobiodiversity, genetic banks of agricultural crops have been established, in particular the National Center for Plant Genetic Resources of the Institute of Plant Breeding named after Yuriev (Kharkiv, Ukraine). These methodological approaches allow using modern experimental approaches, such as methods of plant biotechnology [5, 40, 58].

Species diversity is characterized by species richness and species evenness [59]. It is well known that the main object of biodiversity is the population of living organisms. As the population structure of most species is insufficiently studied, at the present stage florists and faunists assess biodiversity mainly at the species level. All species in agrolandscapes are of some importance for the stable functioning of agroecosystems and the maintenance of their balance. However, the difficulty of determining the diversity of living organisms and their role in the agroecosystem is the constant change of animals groups (insects, birds, rodents), plants (vegetative reproduction of perennials), fungi and microorganisms (spread of diseases at a certain stage of development) depending on vegetation. Therefore, it is desirable to assess biodiversity in the dynamics, taking into account the peculiarities of distribution and activity of each species. Changes in plant phenophase, weather conditions, and the presence of predators/prey determine the quantitative and qualitative change in the species composition of biota. In addition, as a result of crop rotation, systemic links between the phytocenosis subsystem of a particular crop and the soil subsystem, especially its biotic component, are often interrupted and mostly re-formed annually. To some extent, this restructuring is likely to affect the links between the subsystems of all levels of the hierarchy in the agroecosystem, in general – its structural and functional organization. Currently, there are proven methods for studying species diversity in the field of biology.

At the level of communities, selected by biological and ecological features and functional role in the agroecosystem, their spatial location, there is a wide arsenal of methods. The integrity of the ecosystem significantly depends on the links (trophic, foric, topic, fabric and others) between these groups of organisms in the biocenosis. It is known that these issues are much less covered.

Quantitative, comparative and comprehensive assessment of biodiversity is widespread in research. For quantitatively assessment the number of species (or other taxa) for a given sample is used; and biodiversity is characterized at the appropriate level. Menhinick's index, Margalef's index, Berger-Parker dominance index, Shannon-Wiener's index and others are used to calculate diversity [60, 61]. However, they do not allow establishing the dependence of diversity on the functional purpose, productivity and sustainability of ecosystems on the organization of communities of living organisms [60]. Therefore, it is advisable to detail the information to the level of ecological groups, taking into account the limiting factors of the agroecosystem. For example, the distribution for the entomocomplex should be characterized by food specialization (entomophages, phytophages, predators, parasites, and saprophages) [55, 62].

Comparative assessment of biodiversity is based on the study of the dynamics of indicators, which gives an idea about changes in ecosystems, allows you to partially predict their further development [60]. That is why it is desirable to compare agroecosystems that differ in a certain determining factor (or several factors) of impact on biota. Thus, it is possible to identify the effect of new technology or substance, the location of the agroecosystem in the agro-landscape on the diversity of living organisms. Elements of crop technology (selection of predecessor, timing and type of measures, norms of chemicals application, etc.), distance from adjacent ecosystems and their characteristics (forest, field, road, and city), relief, soil and climatic conditions and other factors affect β-diversity. The most informative results are given by a comparative assessment on the gradient of change of determining factors (on the ecotone, ecoprofile, transect). In particular, the structural and functional biodiversity in agroecosystems changes with the abandonment of chemical plant protection products. In organic agriculture, the number of families of plants, insects, and birds is growing, and the ratio of functional groups of organisms is changing [62–64].

Comprehensive assessment (landscape-ecological approach) allows understanding the degree of ecosystem resilience, the level of anthropogenic action and response of the ecosystem to it, the role and place of rare and vulnerable species of plants and animals in this ecosystem, allows approaching the problems of biodiversity conservation [24, 65]. In our opinion, compared to comprehensive (complex) or other approaches, the system approach more adequately reflects the structure and dynamics of biodiversity, as it takes into account the hierarchy of ecosystems, stages of development and life cycles of biota, features of each cluster (group) of living organisms and their contribution to the overall agroecosystem. Systematic, especially synecological analysis of the ecological situation in the agro-landscape allows adequately identify the sources of the main factors influencing agroecosystems and their biodiversity, to characterize the mechanisms and assess the consequences of their action in space and time. In particular, on the ecotone of different ecosystems of the landscape it is possible to detect unidirectional and multidirectional migrations of certain species, features of the dynamics of taxon biodiversity, as well as their ecological functions. This contributes to a deeper understanding of the anthropogenic transformation of the structural and functional

organization of the agro-landscape, assessing the quantity and quality of ecosystem services of certain diversity taxa (food chains, network/diversity of habitats and statios, interspecific relationships, crop pollination, etc.). These data are needed to determine ways to optimize management on the basis of integrated management, harmonization of economic and environmental goals [42, 55, 66].

It is expedient to monitor the state of biodiversity in the following stages: preliminary cameral stage (identification of objects, research areas, expedition routes); reconnaissance – selection of areas/sites for field research (determination of research areas in nature); detailed route (conducting descriptions of certain research areas, selection of material, recording the main indicators of the diversity spread in the research areas); the final stage of the processing (analysis and generalization of the results) [48]. Species composition can be detected by expedition-route method. However, in species diversity it is important to: (i) take into account the regularity of the species presence or life stage in the habitat; (ii) to determine whether it is involved in the metabolism of the ecosystem, as the number of members of the group is limited and not all species living in the region belong to the same group. The elementary mechanisms of the evolution of the biocenosis, the restructuring of existing and the formation of new relationships between species and their functional blocks, the evolution of the community start from this [21]. The relationship between ecosystem state and biodiversity can be explored through biophysical assessment of ecosystem services. Remote sensing data of the Earth make it possible to track changes in the parameters of the natural environment and the state of ecosystems [67].

There are inventory (diversity within the biosystem, assessment of the diversity of ecosystems of different scales as a whole, description of certain fauna and communities) and differential diversity (detection and evaluation of spatial changes of the group (diversity trends) along the gradient of ecological conditions) [14, 15]. Tsaryk et al. [25] found that an integrated approach (detection of all the diversity of living things in a given area) can be problematic for a number of reasons – successive changes in groups, imperfections in research methods, significant financial and scientific costs, and so on. Researchers consider a differential approach to be more accepted, which includes several methodological approaches, among them the study of key species – environmental, conservation, economic, social. Konishchuk [40] emphasizes the ecocentric approach to the formation of the geoverse, in contrast to the paradigms of anthropo- and biocentrism, as well as the integrated approach (landscape protection, bio- and geodiversity conservation) in contrast to the differentiated (monitoring of soil, water, air) sanitary and hygienic control, radiation monitoring, etc.).

Spatial trends in biodiversity are studied on different scales: global, regional, local and biogeocenotic. There are two scientific approaches to the study of these issues: individualistic and typological [68]. The first is used in the study of flora and fauna (biota), and the second – biomes, ecosystems and communities. Accordingly, zonal, specific and coenotic fauna are a component of zonal and local biota and communities within the biogeocenosis [12].

Both research and ways to conserve biodiversity are based on different approaches: conservation of nature standards in general; preservation of the dynamics of natural phenomena, processes, changes; conservation of biodiversity in quasi-natural ecosystems (ponds, recreational lakes, regulated meadows, protective forest belts, etc.) [69]. Criteria for determining the value of biodiversity are divided into groups: biotic, social, environmental, economic [1]. By Tailor et al. [70], biodiversity assessment can be based on economic, ecological-economic and biological criteria. The first is a system of cost indicators that characterize the economic results caused by changes in biodiversity. The economic assessment is complicated by the impossibility of covering the whole set of interconnected living organisms in a given area. Physiological, social, economic, ecological functions of biodiversity are most fully characterized by ecological-economic indicators. Biological assessment is specific and most inherent to biodiversity.

Specifics of the microorganism's diversity study. Identification of microorganisms requires special equipment, they are difficult to identify and display in all their completeness [51]. At the same time, using classical methods of soil microbiology, it is possible to take into account no more than 10% of soil microorganisms [20]. The endogenous heterotrophic succession first increases the diversity of soil microorganisms, then the phylogenetic diversity decreases and almost does not change. Regarding exogenous heterotrophic successions, the phylogenetic diversity of microorganisms increases in the middle and late stages [71]. An informative way to study soil microorganisms is to apply a set of molecular methods using molecular-genetic indicators, which can be used to obtain the most complete knowledge about the diversity, condition and activity of microbial communities [72]. Important indicators of the state of soil microbiocenosis are the ratio of the number of certain ecological-trophic groups of microorganisms, which reflect the direction of mi-

crobiological processes. Species diversity of microbial communities is assessed using ecological indices. The ability of an ecosystem to maintain a state of dynamic equilibrium depends on the complexity of multifunctional relationships and species diversity of soil microorganisms [73].

Specifics of the plants' diversity study. It is informative to find out the dynamics of the horizontal and vertical structure of the vegetation of the agrolandscape cover under the influence of certain factors. In modern phytocenology there are two approaches to the classification of vegetation: ecological-phytocenotic (dominant) and ecological-floristic (Brown-Blanke method). In the first one community is considered as a synusia of the phytocenosis (an element of its horizontal structure), named after the dominant species and determined by the same or similar life forms. In the second approach, communities are considered both as components of phytocenoses and as independent objects. The criterion for establishing a community is a group of common species (floral nucleus), which are called diagnostic [74].

Assessment of phytobiota of agrocenoses is mainly carried out by indicators: species richness, frequency of occurrence, abundance (according to Whittaker). Taxonomic and typological analyzes of phytobiota of agrocenoses are carried out, which makes it possible to predict changes in it and propose the necessary measures for their control [44]. According to the tiers of vegetation, it is necessary to establish a change in the ratio of ecological groups, biomorphs, ecomorphs and life forms in the phytocenosis. Life forms are determined by the method of Raunkiaer [75], biomorphological structure – by Serebryakov [76], ecomorphic analysis – by the method of Tarasova [77]. Changes in ecological conditions should be detected by the ecological structure of the grass tier, using the appropriate scales [78]. To characterize the condition, indication the factors of impact and forecast the dynamics of the phytocenosis, it is advisible to analyze its structure according to the ecological strategies of plants (competitors (violets, C-strategists), ruderals (experts, R-strategists), stress tolerants (patients, S-strategists)) by method of Ramensky-Grime [79, 80]. The degree of adventization of the grass cover should be determined by Burda [81]. To identify mechanisms for regulating the penetration and spread of unwanted plants, the characteristics of the phytocenosis by ecological valence of species and tolerance index are promising [82].

Weeds in agrophytocenoses are distinguished by botanical grouping (division into springs dicotyledonous, wintering dicotyledonous, perennials dicotyledonous, annuals), other biological groups (annual and biennial – ephemeral, spring late and early, wintering, winter, biennial; perennial – rhizome-root, rhizomatous and so on), by economic use (medicinal, fodder, honey, ornamental, food and others) and by the way of feeding (parasites, semi-parasites, non-parasites). Depending on the place of growth, weeds are divided into groups (segetal, ruderal, meadow and their variations). They are usually determined by quantitative, weight or quantitative-weight methods.

Specifics of the animals' diversity study. The structure of the species, genetic composition of animal complexes, as well as their diversity depends on the dominance of producers [83], the determinants of consortium relations. The consequences of anthropogenic intervention in agroecosystems should be assessed by the ornitho-, entomo-, theriofauna of agro-landscapes. To study the diversity within these groups, the degree of dominance of certain taxa (eudominants, dominants, subdominants, recedents, subrecedents) is determined by the share of species. The most common field methods of studying animals in agroecosystems are trapping (insects, arachnids, and rodents), analysis of pellets (birds), and trap lines (small mammals). The sex and age structure of animal populations, as well as the features and causes of the distribution of species in the area, frequency and number of finds are found out. Set the total number, the proportions of species in the sample, the abundance score are established. In addition, it is advisable to identify species that are subject to protection in accordance with the lists of international conventions, the Red Book of Ukraine, regional and local lists, as well as the share and origin of alien (invasive) species. The diversity of animal groups is determined by the relevant ecological groups.

Mammals, in particular, are classified according to the level of their adaptation to anthropogenic transformation of the environment [84]: anthropophobes, synanthropes (semi-synanthropes, synanthropes, and supersynanthropes), urbophiles (semi-urbophiles, urbophiles, and superurbophiles), and anthropophiles. The distribution of life forms into different groups: terrestrial overground, constant-water (marine), waterfowl, flying, underground – geobionts, digging, burrowing mammals. In entomocomplex, diversity is determined separately by the life forms of insects: geophiles – geobionts and herpetobionts (inhabit the soil and its surface) and phytophiles – hortobionts and dendrobionts (inhabit the grass cover, trees and shrubs) [85]. The diversity of avifauna is characterized by the share of ecological guilds of the community depending on the microstatios occupied by them for the arrangement of the nest.

That is, the methodological emphasis of biodiversity research depends on the goal and hierarchical level of ecosystems analyzes, spatial measurements of the research question, as well as selected criteria for determining the values of biodiversity (biotic, social, environmental or economic). Each group of living groups has its own characteristics, the identification of which requires appropriate methods, necessary knowledge, special equipment or other resources, etc.

Conclusions. To study the agroecosystem and their biodiversity, it is advisable to use a systematic approach, as it more accurately and fully reflects the nature, structure and dynamics of the ecosystem. In ecological studies, biotic and/or ecological classes are adequate for biodiversity assessment. The most complete information on biodiversity, status and dynamics can be maintained using complex of methods, diversity indices, data on the ratio of certain ecological groups of biota and their characteristics (number, abundance, occurrence, density, mass, etc.), indicator capacity and other environmental indices. The state of agroecosystem integrity and functional diversity in it should be reflected through multifunctional connections (inside taxa and between them, as well as with the environment). For zoning of different levels of agroecosystem transformation and its biodiversity distribution in space, it is informative to use gradient analysis on change of values of the certain factors. The retrospective provides answers to the reasons and dynamics in the time of the detectioned changes and the basis for forecasting their development taking into account the current situation.

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Методологічні підходи у дослідженні біорізноманіття в агроекосистемах

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В агроекосистемах структура і динаміка таксономічного і функціонального біорізноманіття значно відрізняються від місцевих непорушених ідентичних еталонних типів екосистем та залежать від типу і тривалості господарювання, ступеня екологічності застосованих технологій. Агроекосистеми істотно впливають на біорізноманіття навколишніх територій. Для гармонізації його збереження в агроландшафтах з метою оптимізації сільського господарства необхідне удосконалення методів дослідження. Встановлено, що вибір методологічних основ (принципів, критеріїв і методів) дослідження біорізноманіття залежить від мети та ієрархічного рівня аналізу екосистеми, масштабу досліджуваного питання, оскільки кожна виділена за певним принципом група живих організмів має свої особливості, виявлення і характеристика яких потребує відповідних методів, необхідних знань, спеціального обладнання та інших ресурсів наукового пошуку. Доцільно застосовувати системний підхід, біотичні та/або екологічні критерії й індекси оцінювання/аналізу різноманітності біоти, співвідношення і характеристики її екологічних груп, індикаторної здатності видів, поліфункціональних зв'язків (всередині таксонів та між ними, а також з їх середовищем) та інші екологічні показники, що описують стан цілісності агроекосистеми, її функціонального різноманіття і динаміки. Градієнтний аналіз за зміною значень визначальних чинників доцільний для зонування розподілу у просторі різних рівнів трансформації агроекосистеми та її біорізноманіття. Ретроспективний аналіз дає змогу виявити причини, охарактеризувати динаміку змін біорізноманіття у минулому і майбутньому та обґрунтувати напрями його збереження.

Ключові слова: різноманіття живих організмів, сільське господарство, методи дослідження, екосистема, зв'язки, екологічні чинники.

Методологические подходы в исследовании биоразнообразия в агроэкосистемах

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В агроэкосистемах структура и динамика таксономического и функционального биоразнообразия значительно отличаются от местных ненарушенных идентичных эталонных типов экосистем и зависят от типа и продолжительности хозяйствования, степени экологичности применяемых технологий. Агроэкосистемы существенно влияют на биоразнообразие окружающих территорий. Для гармонизации его сохранения в агроландшафтах с целью оптимизации сельского хозяйства необходимо усовершенствование методов исследования. Установлено, что выбор методологических основ (принципов, критериев и методов) исследования биоразнообразия зависит от цели и иерархического уровня анализа экосистемы, масштаба изучаемого вопроса, поскольку каждая выделенная по определенному принципу группа живых организмов имеет свои особенности, выявление и характеристика которых требует соответствующих методов, необходимых знаний, специального оборудования и других ресурсов научного поиска. Целесообразно применять системный подход, биотические и/или экологические критерии и индексы оценки/анализа разнообразия биоты, соотношение и характеристики ее экологических групп, индикаторной способности видов, полифункциональных связей (внутри таксонов и между ними, а также с их средой) и другие экологические показатели, описывающие состояние целостности агроэкосистемы, ее функционального разнообразия и динамики. Градиентный анализ по изменениям значений определяющих факторов целесообразен для зонирования распределения в пространстве различных уровней трансформации агроэкосистемы и ее биоразнообразия. Ретроспективный анализ позволяет выявить причины, охарактеризовать динамику изменений биоразнообразия в прошлом и будущем и обосновать направления его сохранения.

Ключевые слова: многообразие живых организмов, сельское хозяйство, методы исследования, экосистема, связи, экологические факторы.

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