

DOI: <https://doi.org/10.34069/AI/2022.55.07.27>

How to Cite:

Shvets, O. (2022). Variety and action of soil microorganisms in diverse Ukraine climatic zones. *Amazonia Investiga*, 11(55), 256-264. <https://doi.org/10.34069/AI/2022.55.07.27>

## Variety and action of soil microorganisms in diverse Ukraine climatic zones

### Diversidad y actividad de los microorganismos del suelo en diferentes zonas climáticas de Ucrania

Received: July 2, 2022

Accepted: August 28, 2022

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#### Abstract

The study aims to summarize the important results of the long-term studies of soil microorganisms: structure, interaction, functioning, activity, and diversity in the main types of soils in different natural and climatic zones of Ukraine.

Methods for the study are the generalization and analysis of literary sources and scientific papers, and materials, as well as our own research. The initial information for the assay's calculations, matheanalysis were the resokution of many year discovering of soil microorganisms in the period 2005-2021.

The researches have shown a powerful action and diversity of soil microorganisms of the ecosystems. The Chernozem of the Steppe zone was characterized by a more stable and balanced structure of microbiocenosis, processes of mineralization-immobilization, decomposition of organic matter, and humus accumulation than the sod-podzolic, forest soils of Polesie.

Studies of soil microbiome showed a direct correlation between natural conditions and soil treatment methods and the activity of microbiocenoses, a decrease in the biodiversity of bacterial groups through the use of plowing. The increase in the proportion of micellar organisms occurred with the prolonged application of mineral fertilizers.

**Keywords:** ecosystem, microbiome, biodiversity, soil microorganisms, microbiocenosis.

#### Resumen

El objetivo del estudio es resumir los resultados importantes de los estudios a largo plazo de los microorganismos del suelo: estructura, interacción, funcionamiento, actividad y diversidad en los principales tipos de suelos en diferentes zonas naturales y climáticas de Ucrania. Los métodos para el estudio son la generalización y el análisis de fuentes literarias y documentos científicos, materiales, así como nuestra propia investigación. Los datos iniciales para el análisis, los cálculos y el análisis matemático fueron los resultados de los estudios plurianuales de los microorganismos del suelo en el período 2005-2021.

Los resultados del estudio mostraron una alta actividad y diversidad de los microorganismos del suelo de los ecosistemas. El Chernozem de la zona esteparia se caracterizaba por una estructura más estable y equilibrada de la microbiocenosis, de los procesos de mineralización-inmovilización, de la descomposición de la materia orgánica y de la acumulación de humus, que los suelos forestales de Polesie.

Los estudios del microbioma del suelo mostraron una correlación directa entre las condiciones naturales y los métodos de tratamiento del suelo y la actividad de las microbiocenosis, una disminución de la biodiversidad de los grupos bacterianos por el uso del arado. El aumento de la proporción de organismos micelares se produjo con la aplicación prolongada de fertilizantes minerales.

**Palabras clave:** ecosistema, microbioma, biodiversidad, microorganismos del suelo, microbiocenosis.

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## Introduction

Soil is an important component of the ecosystem for the development and activity of many species of microbiocenoses. The quality of soil depends directly on the diversity of the species composition of the microbiome as well as its activity. Soil microorganisms take part in all stages of humus formation, from the decomposition of plant residues to the creation of simple humic acid compounds and their gradual transformation directly into soil humus. Microbiota are also involved in the processes of humus degradation and renewal of soil structure. The biological activity of soils in turn determines their ecological condition and fertility.

At the present stage of development of agrotechnologies more and more increased attention is being given to study of the potential of soil's microbiome. Active microbial structures carry out various processes of decomposition of organic matter, the transformation of elements, as well as the processing of nutrients required for crop development. Depending on the zone of climat, also soil sort in the convert environment, significant changes can occur in the construction and variety of the ground's microorganisms because of the using certain agronomic impacts.

Despite the rather urgent topic of research, there is still no clear understanding of the mechanism of interaction of soil microbes with the environment, other organisms, as well as with the impact on their development of specific soil treatment methods.

Generalization of a scientific research study of soil microbiota functioning, its structure, interaction, activity, and diversity creates a research basis for understanding the interaction of ecosystems, which are made possible by a clear consideration of the role of soil microbes.

## Research Focus

Many scientific works are devoted to the study of the processes of functioning of microbial diversity of soils, but studies of microbial resources of soils in Ukraine are quite rare.

That is why rigorous and exhaustives crutiny of the fundamental regularities of organization microorganisms groupings, functional action which depend on the natural, climatic zone, also the applied agrotechnical methods of soil treatment, as well as the degree of land pollution due to anthropogenic impact, especially in the

context of Ukraine, as one of the largest suppliers of agricultural products.

## Research Aim and Research Questions

Study aim – generalization of significant outcomes of prolonged studies ground microorganisms: formation, interplay, activity, multiformity in the basic soil's sort in any kind native and Ukrainian climatic zones.

To achieve the goal, the following tasks were defined:

- analysis of modern scientific studies of soil microbiota functioning, its structure, interaction, activity, and diversity;
- analysis of the calculated results of long-term soil's analysis of microorganisms in stady field of assays of the National Academy of Agrarian Sciences of Ukraine (2005-2021);
- assessment of the variety and action of ground microorganisms in various native and Ukrainian climatic zones: Steppe, Forest-steppe, Polesie;
- formation of conclusions on the interaction of soil microbes with the environment, with other organisms, as well as with the influence of specific tillage methods on their development.

## Literature Review

Soils are the natural physical covering of the earth's surface and the unique foundation of all terrestrial ecosystems, capable of producing the resources necessary for the development of all alive microorganisms. Soil biome are involved in many biogeochemical processes and are responsible for the mineralization of organic matter, the cycle of elements, synthesis of proteins and nucleic acids, and conversion of forms of nitrogen, phosphorus, other nutrients, making them available to vegetation (Furtak & Gajda, 2018). The most active component of the soil biocenosis are microorganisms (bacteria, archaea, fungi, etc.), whose main role in soil ecosystems. Condition of the soil environment, in addition to soil activity, is related to the diversity of soil microorganism (Fazekašová & Fazekaš, 2019). The presence, diversity, and activity of microorganisms depends on the chemical composition, moisture, pH, and soil structure. The vital action of soil microorganisms affects the processes of biomass decomposition, biodegradation of impurities, which will support

soil structure, the cycle of nutrients and nutrients that become available to plants and animals (Demyanyuk et al., 2020). Microbiological aspects of soil fertility are extremely important traits, but they are often underestimated or neglected altogether. Some symbiotic microorganisms have a lead positive effect on crop productivity by increasing the bioavailability of nutrients. Baliuk et al., (2017) cite three sources of fertility associated with microbial activity: mineralization of organic residues; involvement in the biological cycle of chemical elements from minerals; and biological nitrogen fixation. It is well known that an important function that occurs due to soil microorganisms is the degradation of organic matter into simpler molecules. Thus, up to 90% of degradation processes are carried out by bacteria and fungi (Głodowska & Wozniak, 2019). Microbial communities play a main role in the nitrogen cycle, mediate nitrogen fixation, influence the processes of denitrification and nitrification of soil (Aislabie et al., 2013). Ukraine has very favorable conditions for agricultural production, so more than 68% of its territory is occupied by agricultural land, which is several times higher than in developed countries of the world. Therefore, particularly negative ecological effects such as soil depletion and changes in microbial diversity and microbiome structures are created, proving the study (Symochko, 2020). Scientific papers by Chen et al., (2020) and Ukrainian researchers Alyokhin et al., (2020) on soil microorganisms show that cultivation, fertilization, and pest control have a significant impact on the physical and chemical parameters of soils and, as a consequence, on the functioning of soil microbiota. Changes in the direction of biogeochemical cycles of biophilic elements, the content, and composition of organic solutions, soil density structure, air and irrigation regime etc., lead to changes in the number, action and diversity, activity of soil microorganisms. Reduced activity or death of soil microbiota reduces the availability of nutrients in the soil. Therefore, an assessment of soil diversity and microbial activity is critical to determining the application of tillage technology (Balanovska et al., 2021). Agro-technology used in tillage can affect soil microbiocenosis directly or indirectly through changes in physicochemical parameters of microclimate and carbon release, reorganization of microbial group composition, and functional activity, as evidenced by studies (Auffret et al., 2016, Qamar et al., 2018). Crowther et al., 2019). Structure of the soil microbiome, activity, and microbe community diversity are sensitive indicators of soil property.

Changes in microbial activity and reduction in individual microbiota species can affect plant vegetation and yield, and this has been noted in scientific papers (Yang et al., 2018; Wakelin, 2018; Liu et al., 2020). For example, scientists Nannipieri et al., (2020) and Jezierska-Tys et al. (2020) in their works noted the soil's skill to execute its acts directly relies on the biological activity of soils, the reduction in any group of microbiota species affects the overall processes in the soil. The stability of the structure of soil microorganisms is important for the activity of processes in grounds. A change in any soil function decreases its value, ability and quality to provide agroecosystem fertility (Jacoby et al., 2017; Looby & Martin, 2020). Soil fertility management has been studied by Meliani et al. (2011), Bertola et al. (2021), Cusumano et al. (2022). Their works have proven that fertility control is the management of the microbiological processes that occur in it. Unfortunately, there have been few studies by van der Bom et al. (2018), Martin et al. (2019), Weng et al. (2021) quantifying useful relationships between microbial diversity and soil and plant activity and quality, and ecosystem resilience. The soil microbiome of Ukraine has been studied by a small number of scientists such as Demyanyuk et al., (2020), as well as Tsyuk et al., (2018), Illienko et al., (2021). Patyka et al., (2019) and a group of scientists studied the functioning of microorganisms in the Steppe of Ukraine. Their scientific papers indicate that ecosystem functioning is mainly regulated by soil microbial dynamics. Therefore, it is necessary to generalize the results of studies of soil microbiome and detailed full tests of the main regularities of formation of microorganisms groupings and their functional action based on agrarian methods and factors.

### Methodology

The study was based on the analysis of literary sources and scientific papers and materials, as well as our own research. The initial data for the analysis, calculations, and mathematical analysis were the results of many year researching of soil microbiome in the study field of assays of the National Academy of Agrarian Sciences of Ukraine (2005-2021).

The following research methods were used: analytical, abstract-logical, monographic, expert.

### Results and Discussion

From north-west to south-east Ukraine soils can be divided into three large aggregations in

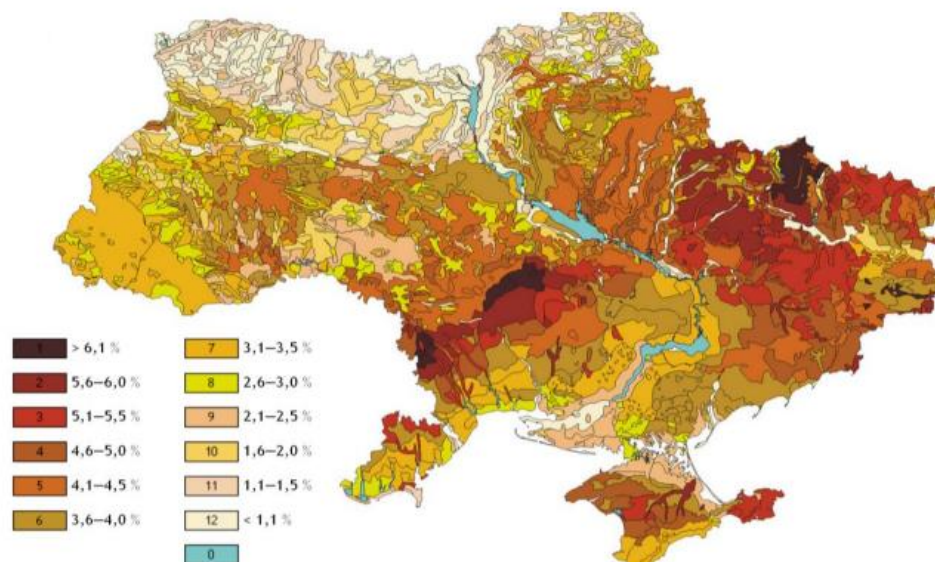
different natural-climatic zones: a Polesie - sandy podzolized soils, the central of Ukraine includes of black very rich harvest chernozems, Steppe – brown forest and saline grounds.

In the Steppe and Forest-steppe zone formed unique fertile soils, 60% of which occupy - chernozems. They are the main means of production in agriculture and forestry and the main source of crop production. Forest steppe is covered with podzolized typical chernozems, which contain up to 9% of humus, and the land structure is well-drained with water and high fertility. In the northern strip of the Steppe - ordinary chernozems (4 - 6 % of humus), and in the middle strip - southern chernozems (3 - 4 % of humus) (National atlas of Ukraine, 2009). The taxonomic construction of the microbiocenoses after analysis showed that the soils give for natural environment, and defined like a sustainable proportion of microbes (streptomycetes, myxomycetes) For common chernozem - 94%: 4.5%: 1.1%, brown forest - 77.0%: 16.1%: 7.0%, gray forest - 82.9%: 15.3%: 1, 8%, sod-podzolic - 77.2%: 20.3%: 2.5%, respectively. Bacteria are usually found in soils rich in organic nutrients, whereas relatively high numbers of saprophytic fungal groupings tend to increase when soil fertility decreases Illienko et al.(2021) The results of Demyanyuk et al. (2020) showed that the impact of agricultural activities on soil microbiota was most pronounced in the brown forest, podzolic, and gray forest soils of Polissia Ukraine. The total pool of soil microorganisms ranged from 7.4 million to 5.4 million CFU/g in natural ecosystems and from 3.7 million to 2.8 million CFU/g of dry soil in transformed ecosystems. Prolonged cultivation

of unfertilized crops resulted in a 2.2-fold to 4.5-fold decrease in the total pool of microorganisms. The composition and number of microorganisms are closely related to the environment of their existence and the depth of the studied soil layer. In the studies of Beznosko et al. (2022), different phytocenoses changed the activity index of soil microorganisms of typical chernozem, which was less manifested in the root-bearing layer of soil (0-5 and 5-20 cm) and was more pronounced in the 20-40 cm layer (Figure 2).

The biogenicity of typical chernozem within the root-containing 0-5 cm layer was 1.5-3.5 times higher than grounds depth in 0-40 cm and was defined by the lowest values in the arable and the highest in the forest belt and fracture. It is predicted that this is due to the activation of soil processes due to grassing and the presence of significant biomass of plant residues in the forest belt. In the 5-20 cm layer, the increase in the number of soil microbiomes was influenced by water-air and temperature regimes in addition to the inflow of plant biomass.

The number of microorganisms in the 20-40 cm layer was 1.5-2.0 times less compared to the 5-20 cm layer, except for the forest belt variant, where the difference is 1.25 times. On depth 0-40 cm soil layer the maximum biofillic was in the line of forest variant, where the indicator arrived 38,9 mln./year and then in descending order - 30,98 mln./year of the virgin soil, 29,8 mln./year of the arable land, 27,1 mln./year of the swidden land, 24,2 mln./year of the mown virgin land. Plowing of virgin lands and additional oxygen supply lead to an increase of microorganisms activation.



**Figure 1.** Humus content of soils of Ukraine (National Atlas of Ukraine, 2009)

Without sufficient organic matter in the form of plant residues and fertilizers, the nutrient medium for the soil microbiome is the decomposition of humus (Kosovska et al., 2022).

The population of soil microorganisms depends not only on the of soil's kind but also on the depth and type of vegetation cover. This is shown by

the results of a study (Meliani et al., 2011). Soil specimens were collected from different levels of ground (5-10, 10-15, and 15-20 cm), they was formed from 30 various sites (randomly) of sod-podzolic soil. The exampls were tasted for pH, chemical composition, and soil structure. The ecological qualities of the researched soil presented in Table 1.

**Table 1.**

*Ecological characteristics of the soil under study (Meliani et al., 2011)*

Soil type	Sampling depth, cm	Plant	Ground temperature, °C	Average annual precipitation, mm
Chernozem	495 m for all samples	Vicia spp. (C1-C2-C3)	16,50	46,00
		Triticum spp. (C4-C5-C6)		
		Lens spp. (C7-C8-C9)		
Grey forest	710 m 695 m 670 m	Pinus spp. (C10-C11-C12)	16,00	19,00
		Asphodelus spp. (C13-C14-C15)		
		Tamarix spp. (C16-C17-C18)		
Sod-podzolic	710 m 695 m 670 m	Triticum spp. (C19-C20-C21)	19,00	25,00
		Cirsium spp. (C22-C23-C24)		
		Hordium spp. (C25-C26-C27)		

Soil types influenced the activity of microorganisms in ground. The maximum fungal was noted Triticum spp. density, rhizosphere (1.35x10<sup>9</sup> CFU/g) at the depth (0-5 cm), and the minimum for Vicia spp., rhizosphere (1.8x10<sup>9</sup> CFU/g) (10-20 cm). Actinomycetes showed a maximum of 1.98x10<sup>10</sup> CFU/g in Triticum spp.,

rhizosphere (5-10 cm), and a minimum of 1.8x10<sup>9</sup> CFU/g in Vicia spp., rhizosphere (10-20 cm). Studies by Bertola et al. (2021), and Cusumano et al. (2022) also confirm that the diversity and abundance of soil microorganisms can be strongly influenced by some abiotic and biotic factors, such as the type of agriculture.

Mil. in 1 g a.s.o.

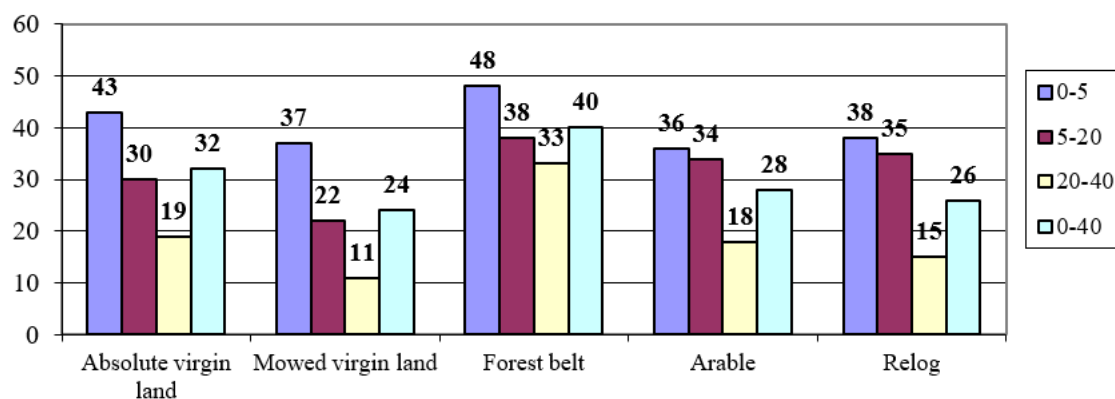


Fig. 2. Numbers of the microbiota of typical chernozems in different agrocenoses

Table 2.

Numbers of microorganisms in the area contaminated by radiation (Illienko et al., 2021).

Pollution dose rate, $\mu\text{G}/\text{year}$	Organisms assimilating organic N, mln/y	Organisms assimilating mineral N, mln/y	The number of microorganisms, ths./y
0,2	$3,754 \pm ,192$	$2,155 \pm 0,145$	$935,5 \pm 25$
1	$6,550 \pm 0,435$	$1,002 \pm 0,102$	$285,1 \pm 15$
1,57	$2,115 \pm 0,285$	$7,855 \pm 0,525$	$2215 \pm 195$

Table 2 shows outcome results of the number of microorganisms in the contaminated area. The result of sowing on the contaminated soil showed the highest number of colonies of microorganisms, points with an index of 1.57  $\mu\text{G}/\text{h}$  (the highest level of contamination with radionuclides) about 2215 thousand / g are highlighted. On the radioactively contaminated soils in the points with a higher level of contamination with radionuclides decrease of the content of humus substances in the soil was observed, which was combined with the increase of activity and increase of the number of soil microorganisms.

The depth of transformation and aeration of the soil major affects to activity of the soil microbiome. Inputs of organic fertilizer provide a positive influence on the establishment of micro-populations. As deep of ground increases, organic solutions, aeration content reductions as microbial community decreases. It shows that the soil's upper layer is productive for microbial population because a favorable terms is created for their development.

Studies by Patyka et al. (2019) checked that on soil layer in depth 0-40 cm, the maximum bioactivity was characterized by the forest belt variant, where the index obtained 39.8 million CFU/h, due to the input of a major total of plants remains, followed in descending: absolute virgin soil (31.0

million CFU/h), arable (29.5 million CFU/h), overgrowth (26.2 million CFU/h), mowed virgin (23.1 million CFU/h).

Analisis of biological and also molecular components of eubacterial community of steppe and steppe chernozems showed a major superiority of untreatment bacterial variety in the "absolute virgin land" variant (up to 68%) compared to the "arable land" variant (up to 17%).

Researching of diversity of prokaryotic complex of chernozems revealed a reduce in the biological variety of bacterial groups when plowing was applied.

The modern agrarian soil treatment uses chemical fertilizer, which limits the use of organic one. As a result – soil microbes are malnourished, and their rise stops, which in turn leads to an imbalance of environment, deterioration of its structure and soil richness. To restore the balance of the microbiocenosis, it's needed to assure the introduction of organic compounds into the ground, loosen the soil mass, ensure optimal soil moisture, reduce the impact of heavy agricultural machinery, reduce the use of chemicals in land treatment, and use natural sources of manure. These measures are aimed at balancing and restoring a high population, diversity, with soil's microbiome mobility.

## Conclusion

Soils of natural ecosystems of Ukraine are describe by a elevated microorganisms contant with well-balanced organization and big species variety. Also ukrainian soils are well done transformation and mineralization of organic substance.

The taxonomic structure of microbiocenosis has shown that soils of the natural ecosystems of Ukraine are defined like a sustainable proportion of microbes (streptomycetes, myxomycetes). For the common chernozem - 94%: 4.5% brown forest - 77.0%: forest soil (grey) - 83.1%: 15.25% sod-podzolic - 77.2%: 20.3%. Ukrainian chernozem was characterized by high stability and phylogenetic diversity of soil microbial biogeny of typical chernozem within the 0-5 cm layer is 1.5-3.5 times higher than in the 0-40 cm layer. The considerable influence of agricultural activity on soil microbe is tested in soils with lower content of microbial substance. The high level of microbial diversity and the complex structure of relationships give more opposition, resistance of the microorganisms in soil to negative conditions caused by human-induced influences.

Types of soils of Ukraine influenced the activity of microorganisms from the ground. The biggest solidity of fungi was noted in *Triticum* spp. – ( $1.35 \times 10^9$  CFU/g) at the depth (0-5 cm), and the lowest - in *Vicia* spp., ( $1.79 \times 10^9$  CFU/g), at the depth (10-20 cm). Actinomycetes was the highest  $1.98 \times 10^{10}$  CFU/g in *Triticum* spp. at the depth (5-10 cm) and the lowest of  $1.8 \times 10^9$  CFU/g in *Vicia* spp., at the depth (10-20 cm).

Most of the territories of Ukraine are under the influence of anthropogenic factors from intensive land cultivation, cattle breeding, hay stocks, etc. On average in the soil layer (0-40 cm) the maximum bioactivity was in the test from the forest line - index obtained 39.8 mln CFU/h, which is connected with the ingress of the considerable quantity of the plant remains, further in the downward line of descent.

The result of sowing on the contaminated soil of Polesye showed the most colonies of microorganisms at 1.57  $\mu\text{g/h}$ , about 2215 thousand CFU/h. On radioactively contaminated soils we observed a reduction in the repletion of humus substances in the ground, which was combined with an increase in the activities and abundance of microbiome.

Consequently, regardless of the climatic zone of Ukraine and soil type, important alterations in the formation, difference of the soil microorganisms were detect in the transformed ecosystem as a result of agricultural measures.

Due to changes in climatic conditions, aggressive farming methods, use of chemical fertilizers and pest control agents, soil contamination with heavy metals and radiation, losses of organic matter, and changes in the natural micro biodiversity occur. All of these factors affect soil microbes, so the interpretation of field data from scientific studies of soil properties becomes more difficult, especially when several factors are involved that affect association of microorganisms. Onward discovering is require to confirm the complex action of these factors.

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