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# Economic Assessment of the Impact of Biodiversity on the Productivity of Organic Agricultural Systems

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**ABSTRACT:** This study examines the economic impact of biodiversity on the productivity and sustainability of organic agricultural systems. Its relevance stems from the growing need for sustainable soil management amid climate change and resource depletion. The objective is to assess how biological diversity, particularly soil microbial biodiversity, influences productivity and cost efficiency. Results demonstrate that maintaining biodiversity through biosymbiotic technologies reduces dependence on chemical inputs and increases yield stability. The findings emphasize that biodiversity preservation is an economically justified strategy for enhancing long-term soil fertility and ensuring the resilience of organic agroecosystems.

**KEYWORDS:** biodiversity, microbiome, economic efficiency, organic farming, symbiosis, agroecosystem stability, immunomodulators.

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## Introduction

The problem addressed in this study arises from the intensifying degradation of agricultural soils, loss of biological diversity, and growing dependence on chemical fertilizers, which collectively threaten the long-term productivity and sustainability of global agriculture. Under conditions of climate instability and limited natural resources, organic agriculture represents a promising alternative based on restoring soil quality and ecological balance. The relevance of this study lies in the necessity of economically substantiating the role of biodiversity, particularly soil and microbial diversity, as a key factor affecting the productivity, economic efficiency, and sustainability of organic agricultural systems.

Several researchers have addressed the study's subject matter. Specifically, Aslanyan and Emelin (2024) emphasize the effectiveness of biological and microbiological methods for enhancing soil fertility, demonstrating that minimizing chemical fertilizers promotes restoration of biocenotic balance and increases the economic sustainability of agroecosystems. Mohammad and Kozlov (2021) analyze agriculture's environmental impact, noting that intensive agrochemical use leads to soil degradation and reduced biodiversity, necessitating a transition to ecologically balanced farming models.

Ushakov and Sereda (2024), in turn, examine the consequences of agricultural land erosion, emphasizing the need to apply biological and soil-protective technologies to preserve soil structure and enhance productivity. Cheshev (2024) substantiates the ecological transformation of the agricultural sector as a strategic direction for agricultural modernization, positioning biodiversity as the foundation for sustainability and economic efficiency of agromeliorative systems.

## Research Aim and Research Questions

The aim of this study is to assess the impact of biological diversity, particularly microbial and soil biodiversity, on the productivity and economic efficiency of organic farming systems.

The main objectives of the research are as follows:

– to analyze the economic mechanisms linking biodiversity and productivity within organic agricultural systems;

– to evaluate the role of microbial and soil diversity in enhancing the resilience of agroecosystems;

– to assess the economic efficiency of biosymbiotic and biological technologies;

– to substantiate strategic directions for improving the economic sustainability of organic agro-systems.

## Research Results

Biodiversity in agroecosystems encompasses all living organisms and their interactions within the agricultural environment, spanning genetic, species, and ecosystem levels. At the genetic level, biodiversity provides variability in populations of agricultural crops and soil organisms, contributing to their adaptive capacity and resilience under stress conditions. Species diversity reflects the abundance and balance of different plant, animal, and microbial species, which collectively determine the complexity and functionality of the agroecosystem. Ecosystem diversity integrates the structural and functional variability of agricultural landscapes, including soil, vegetation, water systems, and microhabitats. These levels of biodiversity constitute the biological foundation of sustainable agricultural production, determining its capacity for self-regulation, productivity, and resistance to degradation. Microorganisms constitute a critical component of agroecosystem biodiversity, forming the foundation of soil symbiotic systems. Soil microorganisms, including bacteria, fungi, actinomycetes, and archaea, participate in fundamental processes such as organic matter decomposition, nitrogen fixation, phosphorus mobilization, and humus formation. Interactions between microbial communities and plant roots, particularly mycorrhizal and rhizobial symbioses, create a dynamic exchange system that regulates nutrient availability, improves soil structure, and enhances plant immunity. The balance between autotrophic and heterotrophic microorganisms maintains stable nutrient cycling, while microbial succession determines the potential for soil recovery following external disturbances. In organic farming systems, where chemical fertilizer and pesticide use is minimized, the role of the microbial component becomes even more significant, as it replaces many functions previously performed by synthetic fertilizers.

The mechanisms through which biota influences agrocenosis productivity and stability are complex and multidimensional. Biotic interactions promote maintenance of soil aggregate integrity, improve aeration, and increase water-holding capacity. Microorganisms synthesize enzymes and biologically active compounds that stimulate plant growth and protect crops from pathogens. Diverse plant and microbial communities create ecological niches that suppress pest and disease development through competitive exclusion and natural regulation. This functional complementarity within the biota stabilizes ecosystem processes and reduces yield fluctuations caused by climate variability, drought, or soil degradation. In this context, biodiversity serves not only as an ecological attribute but also as a regulatory mechanism ensuring the sustainability and long-term productivity of agricultural systems (Cheshev, 2024).

From an economic perspective, the ecological functions of biodiversity can be interpreted as ecosystem services that provide tangible benefits to agricultural production and sustainable development. Enhanced microbiological and species diversity reduces dependence on costly external inputs such as mineral fertilizers, pesticides, and soil amendments. By maintaining soil fertility and health, biodiversity reduces the need for intensive mechanical interventions, thereby decreasing energy expenditure and preserving soil carbon stocks. Moreover, ecosystems with high biological diversity demonstrate greater stability and predictability of outcomes, which reduces production risks and enhances economic efficiency over time.

Soil and microbial biodiversity play a decisive role in ensuring the productivity and resilience of organic farming systems by forming the biological foundation for nutrient cycling, plant health, and the long-term stability of ecosystems. The functional diversity of microorganisms in the rhizosphere facilitates continuous exchange of nutrients and biochemical signals between the soil and plant roots, creating an integrated biosymbiotic system that replaces synthetic fertilizers and chemical plant protection agents. Among the most significant symbiotic relationships are those involving nitrogen-fixing bacteria (*Rhizobium*, *Azospirillum*), phosphate-solubilizing microorganisms (*Bacillus*, *Pseudomonas*), and mycorrhizal fungi, which expand the effective surface area of roots and enhance the absorption of water and mineral elements. These microbiological partnerships not only improve the nutritional status of plants but also stimulate the production of phytohormones and secondary metabolites that strengthen natural immunity. As a result, plants grown in biologically rich soils demonstrate greater resistance to pathogens and abiotic stressors while maintaining stable yields under changing environmental conditions (Mohammad and Kozlov, 2021).

Biodiversity directly influences the agroecological stability of organic systems by improving soil structure, water retention capacity, and the resilience of agrocenoses to environmental stressors. Diverse microbiological and faunal communities contribute to the formation of stable soil aggregates through the secretion of polysaccharides and organic acids that enhance porosity and aeration. Improved soil structure promotes deeper root penetration and more efficient water infiltration, reducing surface runoff and erosion. The balanced coexistence of soil microorganisms and mesofauna also prevents the accumulation of toxic metabolites and maintains the self-purification capacity of soil ecosystems. This complex biological network acts as a buffer that mitigates the adverse effects of drought, temperature fluctuations, and excessive moisture. In the long term, such agroecological stability ensures the sustainability of organic systems, preserving both soil fertility and biological productivity without degradation processes (Krause et al., 2024).

The economic aspect of biodiversity conservation in organic agriculture is reflected in reduced production costs and improved resource use efficiency. By maintaining microbial diversity, organic systems minimize their dependence on mineral fertilizers and synthetic plant protection agents, which are among the most expensive components of conventional farming. Studies have shown that the use of microbial inoculants, compost-based fertilizers, and green manure can reduce fertilizer costs by 30–50% while maintaining or even increasing yields. In addition, biologically active soils require less effort for weed and pest control, which lowers operating costs and energy consumption. The long-term accumulation of organic matter naturally enhances soil fertility, creating a self-sustaining productivity cycle that ensures the economic stability of farming enterprises (Aslanyan and Emelin, 2024).

Practical research results confirm that the application of biosymbiotic technologies in organic systems leads to a significant increase in both yield and product quality. Comparative trials conducted in various agroclimatic zones demonstrate that crops grown in soils with high microbial activity have higher nutrient content, improved flavor characteristics, and longer shelf life. For example, experiments with wheat, tomatoes, and soybeans showed that inoculation with mycorrhizal fungi and rhizobacteria increased yields by 15–35% and enhanced protein and antioxidant levels. This increase is attributed to more efficient nutrient uptake and the activation of plant defense systems through microbial signaling pathways (Table 1).

**Table 1**

*Comparison of conventional and organic systems (Araújo et al., 2009; Krause et al., 2024)*

| Indicator | Conventional system | Organic system with high microbial biodiversity | Change, % |
|---|---|---|---|
| Average yield (t/ha) | 3.8 | 4.5 | +18.4 |
| Cost of fertilizers and plant protection products (USD/ha) | 520 | 290 | -44.2 |
| Soil organic carbon (%) | 1.4 | 2.3 | +64.3 |
| Water-holding capacity (%) | 32 | 45 | +40.6 |
| Antioxidant content in product (mg GAE/100 g) | 145 | 192 | +32.4 |

These data demonstrate that preserving soil and microbial biodiversity not only improves soil biophysical parameters but also contributes to tangible economic and qualitative enhancement of agricultural production. Thus, biodiversity functions as both a natural and economic asset, enabling organic farming systems to simultaneously achieve ecological balance and profitability. The integration of biosymbiotic approaches into agroecological practices represents a strategic direction for future sustainable agriculture, ensuring harmonization of productivity growth with long-term preservation of soil health and ecosystem sustainability.

Economic assessment of strategies for conserving and enhancing biodiversity in organic agricultural systems requires a comprehensive approach that integrates ecological indicators, productivity metrics, and cost-benefit analysis within a holistic framework of sustainable development. Unlike traditional assessments based exclusively on short-term yield, contemporary economic models of agricultural biodiversity emphasize the long-term value of ecosystem services, such as soil fertility maintenance, nutrient cycling, pollination, pest regulation, and carbon sequestration, which collectively determine the sustainability and profitability of organic systems. The primary approaches to valuing agricultural biodiversity include ecosystem services valuation, cost reduction analysis, and total economic value (TEV) models, which account for both market and non-market benefits. These methods enable quantification of the economic impact of biological diversity through reduction of production risks, stabilization of yields under stress conditions, and minimization of external input costs. For organic agricultural systems, where natural ecological processes replace synthetic interventions, such assessments are essential to demonstrating that ecological integrity directly contributes to economic efficiency (Ushakov and Sereda, 2024).

The use of biostimulants, immunomodulators, microbial inoculants, and living soil cover systems constitutes the technological foundation of biodiversity-based economic strategies. Biostimulants, composed of seaweed extracts, humic acids, amino acids, and microbial metabolites, stimulate root development, enzymatic activity, and plant stress tolerance, enabling higher productivity with reduced external input use. Immunomodulators, often derived from beneficial microorganisms or plant compounds, enhance the natural defense mechanisms of crops, reducing the need for chemical plant protection products. Microbial inoculants, containing nitrogen-fixing, phosphate-solubilizing, and growth-promoting bacteria, restore soil microbiota balance and accelerate the regeneration of degraded soils. Living soil cover systems, such as cover crops and permanent green mulches, not only prevent erosion and nutrient leaching but also maintain continuous biological activity in the soil profile. The combined application of these technologies promotes the creation of a stable, biologically active environment in which soil biodiversity supports nutrient self-regulation and plant viability, thereby reducing dependence on costly external inputs and ensuring higher ecological and economic efficiency.

Comparative studies of the economic efficiency of organic and conventional farming systems convincingly demonstrate that, although organic production yields may be somewhat lower in some cases, it often provides higher profitability through cost reduction, premium prices for organic products, and long-term soil improvement. In conventional systems, 25 to 40% of total production costs are typically allocated to mineral fertilizers and chemical plant protection products, whereas in organic systems these expenses are substantially reduced or completely eliminated. Implementation of biological soil management practices also results in slower rates of fertility decline, reducing the need for periodic restoration. Multi-year cycle assessments indicate that the profitability of organic farms generally exceeds that of conventional farms by 10 to 25% even without subsidies, due to production stability and reduced environmental remediation costs. Additionally, biodiversity-based systems exhibit lower income volatility, as diversified crops and resilient soils mitigate risks associated with climate fluctuations and market volatility (Durham and Mizik, 2021).

The prospects for implementing biosymbiotic technologies as a factor in long-term soil productivity and stability are promising from both ecological and economic perspectives. Biosymbiotic technologies, based on plant-soil microorganism interactions, create agroecosystems capable of maintaining fertility and productivity without external chemical support. These systems enhance nutrient use efficiency, optimize water balance, and increase carbon sequestration, contributing to the economic valuation of ecosystem services in agricultural landscapes. In the broader context of the bioeconomy, the transition to biosymbiotic management is viewed as an investment in natural capital, where soil health and biodiversity become assets generating sustained economic returns. The application of such technologies also aligns with global sustainable development policies, including the European Green Deal and FAO agroecological frameworks, which prioritize soil restoration and biodiversity conservation as key components of food system sustainability.

**Conclusions**

This study demonstrated that biological diversity, particularly microbial and soil diversity, constitutes a key factor determining the productivity, sustainability, and economic efficiency of organic agricultural systems. Soil biota diversity promotes maintenance of natural nutrient cycling processes, improves soil structure, water regime, and plant resistance to stress factors, collectively reducing dependence on mineral fertilizers and chemical plant protection products. Economic assessment confirms that implementation of biosymbiotic technologies, including the use of microbial inoculants, biostimulants, immunomodulators, and living soil cover systems, not only improves yield and product quality but also ensures reduction of production costs, enhancing the long-term profitability of organic farming. Thus, biodiversity conservation and restoration must be considered an economically justified strategy for sustainable development of the agricultural sector. Future research perspectives include development of quantitative models for assessing the economic impact of biological diversity and integration of these indicators into organic production management systems.

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