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Challenges and opportunities for utilizing ecosystem services in the sustainable management of agroecosystems

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Abstract

Different agricultural practices and farming systems influence biodiversity and the ecosystem services in two fundamental and opposing directions. Some practices lead to a decline in biodiversity, thereby reducing the associated benefits, while others contribute to maintaining or enhancing biodiversity and increasing ecosystem services. Today, ecosystem services are increasingly threatened by human activities, as anthropogenic impacts have greatly diminished the self-regulation capacity of agroecosystems. In agroecosystems, biodiversity is often reduced or modified and pest management practices, particularly those relying heavily on pesticides, can have a substantial negative impact on both biodiversity and ecosystem services. This presents one of the greatest challenges of our time: developing sustainable agricultural production systems capable of meeting the growing demand for food while simultaneously preserving biodiversity and protecting the environment. This study examines farmers' awareness of ecosystem services and their attitudes toward the broader integration of these services into pest management strategies. It identifies the key challenges to the wider adoption of ecosystem services in agroecosystems and proposes potential incentives and measures to encourage their uptake by farmers.

Keywords: Ecosystem services, pest control, biological control, agroecology, biodiversity, sustainable agriculture.

INTRODUCTION

Reducing the use of pesticides and replacing them with alternative control measures such as biological control or agroecological methods is of paramount importance for preserving the environment and biodiversity. The direct and indirect contributions of ecosystems to human well-being are defined as ecosystem services by the EU Biodiversity Strategy (EU, 2020). The System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA) uses three broadly agreed categories of ecosystem services - provisioning services representing the contributions to benefits that are extracted or harvested from ecosystems; regulating and maintenance services resulting from the ability of ecosystems to regulate biological processes and to influence climate, hydrological and biochemical cycles, and cultural services related to ecosystems whose existence and functioning contributes to a range of cultural benefits, such as improved health, recreation or cultural rituals (BISE, 2023). Regulating ecosystem services, particularly in the form of biological pest control, are increasingly being adopted in modern agriculture. Maintaining optimal agrobiodiversity is the key to effectively utilizing ecosystem services (FAO, 2019).

The use of predators and parasitoids has gained prominence due to the growing desire of farmers to overcome resistance in many pest

species and achieve sustainable pest management with reduced or no reliance on chemical crop protection products (Ilieva & Karova, 2023). Additionally, there is increasing demand for pesticide-free produce and heightened awareness among consumers and producers regarding environmental protection and biodiversity conservation (Gross & Gundermann, 2016, Ilieva & Karova, 2023a).

Biological pest control plays an important role in various agricultural systems, including integrated, organic, and biodynamic farming. It involves the use of living organisms called bioagents to suppress pest populations, diseases, or weeds, minimizing their damage (DeBach & Rosen, 1991). The bioagents are natural enemies of the pests and include predators, parasitoids, pathogens, or competitors. Biological control includes three main approaches: classical control through introducing a natural enemy from pest's native range, augmentative control by releasing additional natural enemies to boost population levels, conservation control through enhancing habitats to support existing natural enemies (Waage & Greathead, 1988; Huffaker, ed. 2012; van Lenteren, 2012; Heimpel & Mills, 2017). Biological control is a core principle of Integrated Pest Management (IPM), required under Directive 2009/128/EC. IPM emphasizes using biological and cultural methods as first-line strategies and chemical interventions only as a last resort (Stenberg, 2017).

Organic farming, as a production system, strives to establish sustainable ecosystems by enhancing soil fertility, promoting biodiversity, and minimizing synthetic inputs (Karova, 2011). For these reasons, it is among the most suitable approaches for managing agroecosystem services.

This highlights that preserving agrobiodiversity yields not only environmental but also social and economic benefits, underscoring the need for its promotion and support.

The aim of the study is to assess the extent to which farmers are familiar with ecosystem services and to identify the key challenges and opportunities for their broader implementation in environmentally sustainable crop protection.

MATERIALS AND METHODS

Within the framework of Project No. BG06RDNP001-16.001-0025 *"Sustainable Development of Ecosystems through the Implementation of Monitoring Methods and Biological Control"*, Contract: RD 50–44/21.12.2020, Sub measure 16.1 *"Support for the Formation and Functioning of Operational Groups within EIP"*, under Measure 16 *"Cooperation"*(BG06RDNP001-16.001) of the Rural Development Program 2014–2020, with the beneficiary *"Innovations for Sustainable Agriculture"* Consortium, a qualitative study was conducted as one of the main activities within the operational group. The study aimed to assess the most commonly applied plant protection approaches, the level of awareness among farmers regarding ecosystem services and their role as a tool for pest control, and to identify the challenges and barriers to the broader adoption of ecosystem services in plant protection strategies. To achieve this, a questionnaire was developed, and interviews were conducted with participants. Through a series of workshops held with the participants, suitable approaches and measures were jointly identified, including applicable eco-schemes and interventions that could contribute to promoting the use of regulatory ecosystem services. Farm sizes ranged from 2 to 5 hectares, all located in the Plovdiv region. Smallholders with diverse crop systems were selected to reflect typical regional practices. The cultivated crops included outdoor vegetable crops, greenhouse vegetables, orchards, and cereals.

RESULTS AND DISCUSSION

The results from the survey and interviews with the members of the operational group indicate that the most widely used plant protection methods include chemical control and preventive measures.

Farmers often rely on commercially available pesticide products for rapid and effective pest suppression and because of their cost-effectiveness and ease of use, despite being aware of their potential negative impacts on the environment and biodiversity. They commonly apply plant protection products (PPPs) registered for trade and use in the Republic of Bulgaria in compliance with the Plant Protection Act, Good Plant Protection Practices, and the conditions under which the PPPs are registered. When conducting chemical plant protection measures, farmers are required to maintain a Plant Protection and Fertilization Record Book in accordance with Articles 115a and 142, paragraph 3 of the Plant Protection Act. The record book includes detailed entries on the occurrence, development, density, or level of pest infestation, specifying the date, phenological phase, pest/disease, surveyed area, infested area, degree of infestation, pest development stage, and density. For chemical treatments, it records the dates, target pests, applied PPPs (chemical, biological agents, adjuvants, etc.), trade names, application dose (g/ml/ha; %), treated areas, application method, quarantine period, earliest harvest date, or manual processing of the crop as well as the name, surname, and certificate number (under Article 83 of the Plant Protection Act) of the person responsible for the treatment. The record books are regularly reviewed and certified by phytosanitary inspectors from the Bulgarian Food Safety Agency (BFSA). Compliance with regulatory requirements for recording pesticide use ensures accountability but reinforces reliance on chemical solutions over alternative methods.

At EU level the Regulation (UE) No 1107/2009 governs the approval of active substances and products for plant protection. Although the Regulation primarily applies to synthetic chemicals, it includes microbial pesticides, defined as "biological agents composed of microorganisms, including bacteria, fungi, viruses, and protozoa". The EU promotes the use of bioagents in IPM under the Sustainable Use of Pesticides Directive (2009/128/EC). To encourage a transition to sustainable practices, regulatory frameworks could be adjusted to incentivize the adoption of ecosystem-based approaches. For instance, streamlining the certification and registration processes for bioagents and other biological control products would lower barriers to entry for farmers. Additionally, introducing subsidies or tax breaks for producers who prioritize eco-friendly pest management strategies could offset the initial costs of transitioning away from chemical inputs. Regulatory adjustments could also include simplified approval for innovative practices and tools, increased transparency in labeling to highlight eco-friendly products, and requirements for integrating biological controls as part of integrated pest management (IPM) programs. These changes, coupled with enhanced technical support and awareness campaigns, would create a more favorable environment for adopting alternatives while reducing reliance on traditional chemical pesticides.

The preventive measures and agronomic practices applied within the group vary depending on the crops and whether they are cultivated in greenhouses or in open fields. Common measures include: thorough removal of old crops and destruction of plant residues and infested leaves, fumigation of structures by burning sulfur, weed management within and around greenhouses, monitoring and eliminating pest host weeds, disinfection of tools and greenhouse structures, installation of mesh screens with hole diameters not exceeding 0.5 mm at greenhouse entrances, use of healthy

and pest-free seedlings, verified by shaking the seedlings over a white sheet or using a white glove to detect pests, maintaining optimal growth conditions for crops, crop rotation, intercropping and spatial isolation to disrupt pest cycles, balanced fertilization and proper plant nutrition, soil health maintenance to reduce pest pressure, mechanical removal of adult pests. Regular field inspections and early interventions are emphasized to prevent severe infestations.

While farmers recognize the importance of these practices, they often prioritize yield over ecosystem-based approaches. Although less common, some farmers implement measures to enhance biodiversity, such as preserving hedgerows, establishing flower strips, reducing pesticide application rates to protect beneficial species. The use of natural enemies such as predatory insects, parasitoids and entomopathogenic fungi is limited mainly to the greenhouses due to their controlled environment but gaining interest also in open field. Practices such as pest population monitoring and targeted treatments are also increasingly being adopted. Although ecosystem services and biological control play a crucial role in the sustainable protection of plant health, farmers face several challenges in the broader integration into plant protection programs (Tab. 1).

According to surveyed farmers plant protection products offer faster, more efficient, and reliable solutions to crop protection problems. Farmers often prefer chemical pesticides because financial support programs, such as subsidies for chemical treatments, are available. However, similar incentives for using bioagents are lacking. Initial costs and investments in bioagents or ecosystem restoration to enhance natural biological control may exceed those of chemical control methods.

In most cases, farmers are unaware of the benefits of ecosystem services and biological control or lack adequate knowledge about their proper application. This generates distrust in the methods and insufficient skills and experience in pest and beneficial species monitoring, which is critical for effective biological control. Many farmers, especially smallholders, lack access to up-to-date scientific research on optimizing crop protection strategies. Moreover, they often cannot invest in the technology and knowledge required to apply these approaches effectively.

Table 1. Challenges and possible solutions for broader integration of ecosystem services into plant protection programs

Challenges	Possible solutions
Dependence on pesticide use	Financial incentives – subsidies and grants
Lack of sufficient knowledge and experience	Market access and premium prices
Insufficient awareness of ecosystem services/biological control	Long-Term contracts and guaranteed markets
Uncertainty and high risk related to climatic conditions	Technical assistance and support
Habitat destruction	Access to resources
Risk of broad-spectrum pesticide use in adjacent areas	Offer farmer-friendly guides and training on bioagents and agroecological practices.
Monoculture farming	Insurance programs and risk reduction
Legislative requirements	Research funding
Lack of financial support	Regulatory incentives
Economic reasons	Environmental management programs
	Demonstration farms
	Peer networks
	Community engagement
	Recognition and awards

Dynamic climatic changes negatively impact the distribution and behavior of both pests and beneficial species, complicating predictions and effective population management. For example, rising temperatures can accelerate the life cycles of pests like aphids, leading to increased population densities and more frequent infestations. Conversely, higher temperatures and changing precipitation patterns may disrupt the synchrony between beneficial species, such as parasitoid wasps, and their pest hosts, reducing the effectiveness of biological control. In regions experiencing prolonged drought, natural habitats for beneficial insects like pollinators and predatory beetles may be diminished, further weakening ecosystem resilience. Additionally, milder winters can allow certain pest species, such as the codling moth, to survive in greater numbers, leading to earlier and more severe outbreaks in the growing season. These shifts highlight the importance of adaptive pest management strategies that account for the changing dynamics of agroecosystems under climate change.

Changes in land use, deforestation, and conversion of semi-natural habitats into arable land reduce the availability of natural shelters and food for beneficial species. The application of non-selective pesticides can lead to the destruction of not only pests but also beneficial species, hindering natural biological control. Cultivation of monocultures over large areas creates favorable conditions for pest proliferation due to an unlimited food source, which challenges the effectiveness of bioagents. There is a lack of clarity in the regulations concerning bioagents, including a specific ordinance for protecting crops from economically significant pests and a list of approved bioagents. Encouraging the adoption of ecosystem-based approaches in agriculture requires incentives that make these practices economically and environmentally attractive. The key drivers according to the farmers include financial and regulatory incentives, technical advice and support, market access and community engagement (Fig.1).

Subsidies and grants provided by governments or agricultural organizations can offset initial costs and risks associated with transitioning to ecosystem-based methods. For instance, eco-schemes and interventions under the CAP Strategic plan for agriculture and rural development 2023-2027 can promote biodiversity and reduce chemical pesticide use. Suitable agricultural systems, eco-schemes, and interventions were identified (Tab. 2).

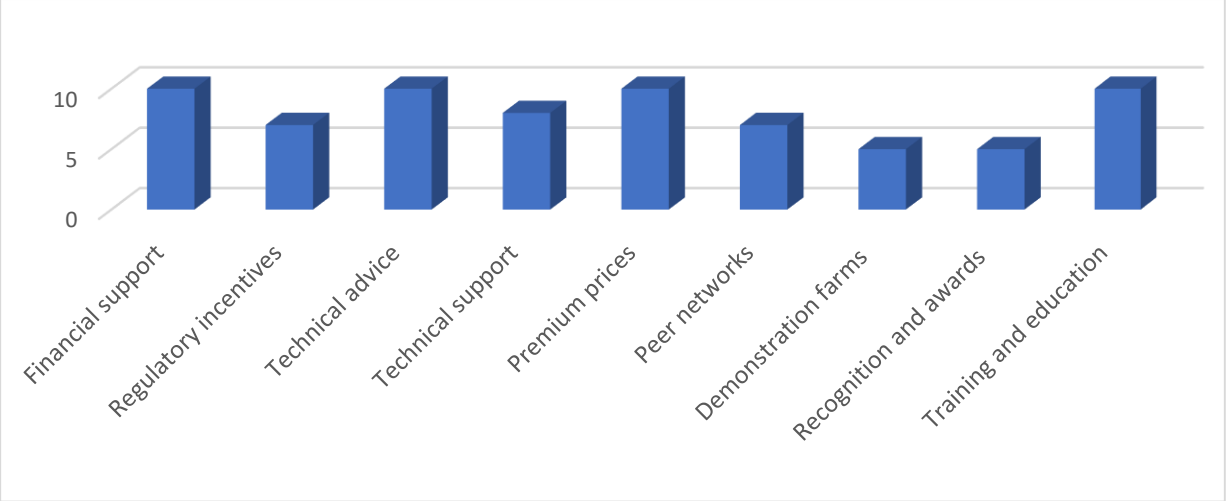

Figure 1. Possible solutions for broader integration of ecosystem services into plant protection programs.

Table 2. Agricultural systems, eco-schemes and interventions aimed at promotion of biodiversity and reduced pesticide use

Agricultural systems	Eco-schemes	Interventions
Organic farming Biodynamic farming IPM Agroforestry	Eco-scheme for maintaining and enhancing biodiversity and ecological infrastructure (ECO-BREI); Eco-scheme for reducing pesticide use (ECO-NIP); Eco-scheme for ecological maintenance of permanent crops (ECO-TN); Eco-scheme for diversification of cultivated crops (ECO-ROC)	Organic Crop Production Support for Cultivating Varieties Resistant to Climatic Conditions through Integrated Production Practices Encouragement of Reduced Use of Plant Protection Products and Fertilizers via End-Product Control

Systems like organic farming, biodynamic farming, IPM, and agroforestry present opportunities for diversifying farms and enhancing ecosystem services.

Organic farming is the most widely recognized sustainable practice among farmers in Bulgaria. It was initiated in 1987 with the establishment of the Agroecological Center at the Agricultural University of Plovdiv (formerly Higher Institute of Agriculture). Numerous research and dissemination projects have contributed to the accumulation of knowledge and experience, enabling organic farming to evolve into a priority sector in agriculture today. A significant challenge is posed by the European Commission's Farm to Fork strategy, which targets at least 25% of the EU's agricultural land under organic farming by 2030 to encourage the development of organic farming areas. Despite the recorded growth of organic farmland by 182% between 2012 and 2022, according to Eurostat, Bulgaria remains among the lowest-ranking EU countries, with organic land accounting for only 2% as of 2022.

The implementation of European legislation, the operation of a stable and reliable control and certification system, increased market opportunities driven by growing demand for healthy food, and, not least, financial support, are factors that foster the development of organic farming.

Although recognized as the oldest system of sustainable agriculture, biodynamic farming remains significantly less known and practiced in Bulgaria, with only one certified farm to date. A prerequisite for biodynamic certification is that farms must already be certified under organic farming standards, indicating a strong foundation for the broader adoption of biodynamic practices. However, even non-organic farmers express interest in applying biodynamic methods, albeit informally.

At the EU level, Directive 2009/128/EC introduced the concept of integrated pest management (IPM) to achieve the sustainable use of plant protection products (PPPs). The general principles of IPM are outlined in Annex III of the Directive and have been mandatory since 2014, meaning that farmers now have nearly a decade of experience in their implementation.

The general principles of integrated pest management (IPM) form the foundation of crop protection strategies. Farmers who adopt and implement specific IPM principles can also officially register for integrated production, gaining a competitive advantage in the market.

Integrating forestry with agriculture through agroforestry systems offers excellent opportunities for farm diversification, increased agro-biodiversity, and enhanced stability of agroecosystems. Financial incentives and eco-

schemes, such as those promoting biodiversity, reduced pesticide use, and crop diversification align with these systems to offer both economic and environmental benefits.

CONCLUSIONS

While farmers currently rely heavily on chemical control methods for pest management, valuing their rapid and effective results despite awareness of their potential environmental and biodiversity impacts, there is a growing interest in sustainable alternatives. Preventive and agronomic practices, such as crop rotation, mechanical pest removal, and biodiversity conservation, are recognized but often underutilized. Farmers prioritize yield over ecosystem-based practices due to economic pressures, lack of financial support, and insufficient knowledge. The adoption of biological control and the use of natural enemies remain limited, particularly in open-field conditions, though they show promise in controlled environments like greenhouses. Several challenges hinder the adoption of ecosystem services and biological control, including: dependence on chemical pesticides, lack of awareness and experience with ecosystem-based approaches, economic barriers and high initial costs for implementing sustainable methods, uncertainty caused by dynamic climatic changes and habitat destruction, lack of regulatory clarity and specific guidance on bioagents and alternative methods. A significant barrier to sustainable practice adoption is the lack of access to up-to-date scientific research and practical training. Collaboration between scientists, policymakers, and farmers, coupled with demonstration farms and peer networks, can bridge this gap and build trust in ecosystem-based approaches. Incentives such as financial support, subsidies, market access, technical assistance, and insurance programs are key drivers for encouraging sustainable agriculture. The CAP Strategic Plan (2023–2027) offers eco-schemes and interventions to support biodiversity, reduce pesticide use, and foster integrated and organic farming practices. The success of integrating ecosystem services into plant protection requires long-term strategies, including: Regulatory incentives for sustainable practices, Development of markets for sustainably produced products, Community engagement and recognition of sustainable farming efforts. Reassessments at the end of programming periods, such as 2027, will be critical for evaluating progress and refining strategies.

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REFERENCES

Biodiversity Information System for Europe. (2023). Europe's biodiversity: Ecosystems. Retrieved from https://biodiversity.europa.eu/europes-biodiversity/ecosystems

DeBach P, Rosen D. (1991). *Biological control by natural enemies*, 2nd edn. Cambridge University Press, Cambridge.

European Commission. (2020). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions EU Biodiversity Strategy for 202 Bringing nature back into our lives. COM (2020) 380 final.

European Commission. (n.d.). *Farm to Fork Strategy*. Retrieved from https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en

European Union. (2009). *Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for community action to achieve the sustainable use of pesticides*. Official Journal of the European Union. Retrieved from https://eur-lex.europa.eu/eli/dir/2009/128/oj/eng

Eurostat. (n.d.). *Developments in organic farming: Highlights*. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Developments_in_organic_farming#Highlights

Food and Agriculture Organization of the United Nations (FAO). (2019). *The State of the World's Biodiversity for Food and Agriculture*. Retrieved from https://www.fao.org/interactive/state-of-biodiversity-for-food-agriculture/en/

Gross, J., & Gündermann, G. (2016). Principles of IPM in cultivated crops and implementation of innovative strategies for sustainable plant protection. In A. Horowitz & I. Ishaaya (Eds.), *Advances in insect control and resistance management* (pp. 23-44). Springer. https://doi.org/10.1007/978-3-319-31800-4_2

Heimpel, G. E., & Nicholas, J. M. (2017). *Biological control*. Cambridge University Press.

Huffaker, C. B., ed. (2012). *Theory and practice of biological control.* Elsevier.

Ilieva, T. & Karova, A. (2023). Integrated Pest management. In *Proceedings of the International Scientific and Practical Conference Bulgaria of regions 2023. Conference topic '2023 Innovations for Sustainable Regional Development (167-171).* University of Agribusiness and Rural Development, Plovdiv. Bulgaria. Academic Publishing House Talent, Plovdiv ISSN 2815-5262 (on-line).

Ilieva, T. & Karova, A. (2023a). Implementation of methods for monitoring and control of enemies in agriculture. *New Knowledge Journal of Science*, 58-66. ISSN 2376-4598.

Karova A. (2011). Organic agriculture in Bulgaria - current status, prospects and constraints to its Further development. In *Proceedings Climate change: challenges and opportunities in agriculture. AGRISAFE Final Conference* (pp.414-417).

Plant Protection Act (n.d.). Retrieved from https://lex.bg/laws/ldoc/2136270173

CAP SP 2023-2027 for agriculture and rural development. (n.d.). *Interventions*. Retrieved from https://www.sp2023.bg/index.php/en/intervetions

Stenberg, J. A. (2017). A conceptual framework for integrated pest management. *Trends Plant Sci*, 22,759–769. https://doi.org/10.1016/j.tplants.2017.06.010

van Lenteren, J. C. (2012). The state of commercial augmentative biological control: plenty of natural enemies, but a frustrating lack of uptake. *BioControl*, 57, 1–20. https://doi.org/10.1007/s10526-011-9395-1

Waage, J.K. & Greathead, D.J. (1988). Biological control: challenges and opportunities. *Phil. Trans. R. Soc. Lond. B 318*, 111–128. https://doi.org/10.1098/rstb.1988.0001