Review

Possibilities for Increasing Biodiversity of Natural Ecosystems and Agroecosystems

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The presented study addresses the issue of biodiversity, which is a fundamental element of all ecosystems. Since the reduction or loss occurs as a result of many factors, such as habitat degradation, rapidly increasing environmental pollution, worsening climate crisis, monoculture cultivation, urbanisation, and the expansion of non-native species, among others, which have serious consequences for the existence of life on Earth. For this reason, biodiversity protection is necessary, as any change threatens the existing flora, fauna, habitats and the entire society, since all of these factors lead to a deterioration in the functioning of not only natural ecosystems, but also agro-ecosystems. Especially in agricultural landscapes, it is necessary to solve the above problem with measures that would support wild organisms. One of the measures is modern biobelts, which serve to slow down or stop the reduction of biodiversity, as they address the agro-environmental-climatic aspect. The present vegetation of biobelts improves the trophic supply and increases the spatial and temporal availability of food sources for the present organisms. On the other hand, biobelts pose a risk of enriching the soil seed bank with weeds, which may later be manifested in increased weeding of cultivated crops, and the proliferation of pests also appears to be a problem. Another highly effective measure in providing multiple ecosystem services, ensuring water regulation and quality, pest and disease control, while supporting biodiversity, long-term productivity and soil quality, is the use of agroforestry. The results show that increasing diversity in natural ecosystems and agroecosystems through planned measures represents an important strategy, which leads to improved biodiversity and ecosystem services.

Keywords: agriculture, agricultural landscape, agroecosystems, biodiversity, biobelts, ecosystems

1 Introduction

1.1 The Importance of Biodiversity

The global intensification of agriculture, population explosion, industrialisation, and the ongoing impacts of climate change are among the primary drivers of biodiversity degradation, with consequent disruptions to ecosystem functions and services. Biodiversity structure serves as a reliable indicator of the degree of anthropogenic pressure exerted on natural environments (Udawatta et al., 2019). The decline, or complete loss, of biodiversity appears as a critical issue, predominantly resulting from human activities, which has adverse effects on other trophic levels within ecosystems (Lomba et al., 2022; Thomine et al., 2022; Wyckhuys et al., 2018; Marshall et al., 2003). Agricultural landscape represents a fundamental tension between two sides: on one side is the conservation of living organisms and on the other is the necessity to protect crops from harmful organisms (Hanusová et al., 2022). The European cultural landscape has been shaped by the historical tradition of small-scale and extensive farming practices, which resulted in the creation of a mosaic and diverse agricultural landscape. The second half of the 20th century brought an intensification of farming systems and extensive transformation of agricultural landscapes across Europe (Stoate et al., 2009). According to Tryjanowski et al. (2011), the level of agricultural

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intensification typical for Western Europe is clearly higher compared to Central and Eastern Europe. Furdychko & Tymochko (2020) state that throughout Europe, agricultural intensification remains one of the leading causes of biodiversity loss and ecosystem degradation. The excessive application of agrochemicals, failure to comply with storage requirements, and the systematic use of high doses of mineral fertilisers contribute to the contamination of soil, water, and other components of the environment disruption of homeostasis, and alteration of the biodiversity structure of ecosystems. According to Marada et al. (2019), agricultural intensification has significantly increased the size of individual land parcels, leading to a decline not only in the diversity of cultivated crops but also in the species richness of both flora and fauna. These changes have resulted in a significant decrease in biodiversity and an overall homogenization of the open agricultural landscape.

Agriculture profoundly affects soil biodiversity through farming practices while simultaneously benefiting from the services provided by soil ecosystems. Management systems and the diversity of habitat types can influence the capacity of soil organisms that deliver essential ecosystem services (Wolfrum et al., 2014). Global biodiversity is changing at an unprecedented and alarming rate, leading to the unsustainable exploitation of the Earth's biological diversity (Shibu, 2012). These trends are expected to continue, as the human population is projected to reach 9.5 billion by 2050. Climate change, ocean acidification, and other anthropogenic and environmental pressures are contributing to the further decline of flora, fauna, habitats, and consequently, biodiversity. Agricultural intensification and deforestation are among the primary drivers of biodiversity loss and the degradation of ecosystem functions, while the global economy remains heavily dependent on natural resources (Udawatta et al., 2019). Biodiversity has always been regarded as a fundamental prerequisite for the provision and maintenance of ecosystem services. Species present within a given community often exert varying effects on different ecosystem services. Early studies demonstrated that communities rich in species deliver enhanced ecosystem functions and services, both in natural ecosystems and in agroecosystems (Butterfield et al., 2016). Theoretical ecological knowledge indicates that biodiversity exerts a positive and stabilising influence on the delivery of ecosystem services. The effects of increasing the diversity of cultivated species or crop varieties within agroecosystems remain the subject of ongoing research (Beillouin et al., 2021).

Mainly in agriculture, biodiversity loss presents a particularly pressing issue, that is frequently discussed, as the sector exerts considerable pressure on biological diversity. Consequently, agriculture is facing increasing demands to become more sustainable and to minimise its impact on biodiversity decline. There is a need to develop production systems that harness the benefits of biodiversity in relation to ecosystem services. In this context, one of the significant challenges is to understand, monitor, and manage soil biodiversity and its functions, such as maintaining soil fertility, soil structure, and water infiltration (Wolfrum et al., 2014). As previously noted, biodiversity loss represents one of the most significant challenges we face. According to Hanusová et al. (2022), responses to the declining biodiversity of agricultural landscapes include various measures aimed at supporting the presence of wild organisms and their associated ecosystem services.

1.2 Biobelts, their Functions and Importance

In connection with the above, one of the greatest challenges that our civilsation must face is the reduction of biodiversity, landscape diversity and climate change, which come to the fore in the creation and protection of a sustainable agricultural landscape. It is necessary, especially in farming areas, to address this issue through measures that primarily support wild organisms. One such tool, promoted within the framework of the agri-environment-climate measures of the Common Agricultural Policy, is the establishment of modern biobelts, According to Petlušová & Petluš (2022), these biobelts shelter wildlife, provide food sources, enhance biodiversity within the landscape, and protect sloping farmland from soil erosion. The implementation of biobelts has a particularly positive impact in Slovakia, where the landscape is characterised by large, intensively cultivated arable fields.

Biobelts represent a measure aimed at slowing down or halting the reduction of biodiversity, serving not only as shelter for wild animal species but also as a rich food source during the period from the harvest of main crops until winter. Within agricultural landscapes, biobelts support biodiversity and protect the soil from erosion on sloping terrain. The dominant plant species recorded in biobelts during the research were *Avena sativa, Panicum miliaceum, Brassica oleracea* var. *acephala, Fagopyrum esculentum, Phacelia tanacetifolia*, and *Pisum arvense*. Weeds were also present in the biobelts, the most frequent were *Chenopodium album, Amaranthus retroflexus, Setaria verticillata, Cirsium arvense, Equisetum arvense*, and others. The results demonstrated that the risks associated with establishing of biobelts in terms of weed occurrence were negligible. Any potential spread of weeds from biobelts into adjacent arable land was not confirmed (Hanusová et al., 2022). In Slovakia, we know of 2 types of biobelts: nectar-bearing and forage. The differences are presented in Table 1 (Petlušová & Petluš, 2022).

A significant proportion of entomophilous plant species serve as a food source for the present insects. The results provide evidence that pollinators are shared not only among flowering crops, but also between flowering crops and existing weeds. It can be stated that weeds along field margins, whether flowering or non-flowering, constitute potential resources for improving pollination services in agricultural landscapes. This corresponds with other studies that emphasize the role of arable weeds as essential resources for wild pollinators (Ouvrard & Jacquemart, 2018). The primary goal of biobelts, which represent multifunctional field margins, is unequivocally the enhancement of biodiversity, the support of bee colonies and other pollinators, and the creation of suitable conditions for bird nesting as well as the protection of small animals in fields. Biobelts represent an innovative element in agricultural policy: however, their implementation into practice always requires awareness of current legislation. Specific regulations apply to their establishment. A condition within the Slovak legislation is that the minimum width of a biobelts must be 12 m, with 22 m being the recommended width. The composition of a biobelts may include mixtures of clover and grass, grass and herbs, pollinator-specific seed mixes, or herbal mixtures. Biobelts should be established on fields by April 30. They may be mown no more than twice a year, with the first mowing taking place no earlier than June 23 and the second mowing occurring at least two months after the first (Petlušová & Petluš, 2022). According to ornithologists, biobelts in fields have come to life. Over the last 50 years, once common farmland bird species have become threatened. In cooperation with farmers, ornithologists monitored 40 biobelts and 40 control sites located in the middle of fields without biobelts from April to July. Twice as many birds were recorded in biobelts compared to control sites, and threatened species returned in 7.5 times higher numbers. Farmers welcome this higher biodiversity in the fields. However, they also point out that the easier spread of weeds within biobelts. Additional concerns include an excessively increased population of *Microtus arvalis* and unwanted disturbances caused by quad bikers and hunters. Species observed included *Otis tarda, Lanius collurio, Circus aeruginosus, Ciconia ciconia, Chloris chloris, Saxicola rubetra, Sylvia communis*, and *Serinus serinus*. The most encouraging finding for ornithologists was the return of *Perdix perdix*. As no pesticides were applied in the biobelts, the chicks, whose diet in the first weeks consists primarily of insects, were able to find sufficient food (Kubisová, 2023). A demonstrable decline has been observed in various ground-nesting bird species, such as *Perdix perdix, Vanellus vanellus*, and *Crex crex* (Cukor et al., 2019; Traba & Morales, 2019). Among other wild animal species that respond negatively to changes in agricultural landscapes is *Lepus europaeus*. The intensification of agriculture and homogenization of the landscape significantly affect the size of its home range, which is one of the key factors influencing the survival of this species in modern agricultural

Table 1 Differences between nectar-bearing and forage biobelts

	Nectary	Fodder
Time of establish ment	no later than mid-June, preferably earlier due to possible lack of precipitation	no later than mid-June, preferably earlier due to possible lack of precipitation
Duration	2–3 years	1 year
Composition	mandatory types: legumes, minimum 4 types- *Trifolium pratense*, *Melilotus albus*, *Anthyllis vulneraria*, *Onobrychis viciifolia*, *Vicia sativa*, *Medicago sativa*, *Securigera varia*	mandatory types: spring cereal (oats, barley, wheat), *Panicum miliaceum*, *Fagopyrum esculentum*, *Brassica oleracea*
	minimum 2 types – *Sinapis alba*, *Phacelia tanacetifolia*, *Fagopyrum esculentum*, *Helianthus annuus*, herbs	optional species: *Helianthus annuus*, *Lupinus albus*, *Phalaris canariensis*, *Phacelia tanacetifolia*, *Linum usitatissimum*, *Pisum sativum* or *Pisum sativum* subsp. *arvense*, *Vicia faba*
	minimum 1 type – *Carum carvi*, *Daucus carota*, *Malva sylvestris*, *Verbascum densiflorum*	
Care and treatment	from July to mid-September, mowing and removal of biomass – weeding is prevented and flowering of sown species is supported, mowing is carried out in a mosaic or alternating pattern – availability of food and pollen, after 2–3 years, incorporation and sowing of a new mixture	from mid-June to the end of March without intervention – overwintering of various animal species; from April to mid-June, incorporation and sowing of a new mixture is possible

According to Vejvodová (2016)

landscapes (Šálek et al., 2023; Schai-Braun et al., 2020; Pavliska et al., 2018; Schai-Braun & Hackländer, 2014).

From an agro-environmental and climatic perspective, it can be clearly stated that biobelts increase the species diversity of vegetation in agricultural landscapes. The vegetation in biobelts subsequently improves trophic resources and increases the spatial and temporal availability of food for other present organisms. However, biobelts also pose a risk of enriching the soil seed bank with weeds, which may later result in higher weed infestation in cultivated crops. They can also serve as a source of diaspores to adjacent plots. Therefore, appropriate combinations of plant species in biobelts can ensure greater crop competitiveness and thus lower weed occurrence. The conditions for establishing biobelts remain a challenge for further research. Vegetation within biobelts is a welcome asset for maintaining and supporting biodiversity in intensively used agricultural landscapes. The risks associated with biobelts for agricultural production must be financially compensated. Such compensation is crucial in alleviating farmers' concerns and reluctance to adopt agro-environmental and climate measures (Hanusová et al., 2022).

In the Czech Republic, biobelts also represent special agro-environmental measures. The well-known species *Perdix perdix* reflects the diversity of the agricultural landscape through its presence. A significant decline in its population was recorded between 2014 and 2017, with the number of pairs decreasing to between 8,000 and 16,000. *Perdix perdix* is a sedentary species with a migration range of no more than 10 km, preferring unmanaged vegetative habitats. Since 2004, farmers and hunters have been utilising a special agro-environmental measure in the form of biobelts. Their role is to increase the availability of food for wildlife species on agricultural land. Creating suitable habitats through subsidy systems is currently the most appropriate and promising method to support the population of *Perdix perdix* in the Czech agricultural landscape (Šálek & Zámečník, 2020).

The second notable fact is that *Microtus arvalis* caused enormous damage to Slovak farmers in 2024. The overpopulated vole can pose a significant threat to Slovak agriculture. The most affected crops were rapeseed, barley, winter and spring wheat, and now also corn (News, 2025).

Another highly effective measure that provides multiple ecosystem services, including regulation of water quality, pest and disease control, while also supporting biodiversity, long-term productivity, and soil quality, is agroforestry. Results emphasise that increasing the diversity of crop species or crop varieties in agroecosystems represents a very promising strategy for more sustainable soil management, leading to higher yields, improved biodiversity, and enhanced ecosystem services. Some crop diversification strategies are more effective in supporting key ecosystem services (Beillouin et al., 2021). All components of ecosystems support their smooth functioning, sustainability, and the direction of successional development. Environmental factors condition the presence of biota, while the biota of a specific ecosystem influences the direction and intensity of its development. Landscape fragmentation caused by anthropogenically transformed areas and changes in the habitats of flora and fauna poses problems for species migration, which subsequently leads to the extinction or decline of particular species, resulting in a reduction in biodiversity (Lavrov & Grabovska, 2021). The transformation of agriculture associated with landscape homogenization primarily manifests in the decline of invertebrate populations, while wild vertebrate species, especially ungulates, respond to these changes with population increases (Marada et al., 2023; Marshall et al., 2023). In agroecosystems, the structure and dynamics of taxonomic and functional biodiversity differ from those in intact ecosystems and depend on the type and duration of management, as well as the environmental sustainability of the applied technologies. Agroecosystems have a significant influence on the biodiversity of surrounding areas. It is advisable to use methods and apply a systematic approach, including biotic and ecological criteria and indices to analyse biota diversity, the ratio and characteristics of its ecological groups, multifunctional relationships, and other ecological indicators describing the integrity, functional diversity, and dynamics of the agroecosystem (Lavrov & Grabovska, 2021).

Studies have confirmed that elements such as semi-natural vegetation, grass strips, hedgerows, and biobelts provide suitable conditions for various taxa and support ecosystem biodiversity (Šálek et al., 2018; Otieno et al., 2022; Tarjuelo et al., 2020). Galloway et al. (2021) researched the role of agricultural intensity by comparing traditional versus commercial conventional agriculture, cover crops, surrounding landscape, and their interaction in supporting arthropod diversity. They hypothesised that lower intensity agricultural systems (traditional and cover crops) would have the highest arthropod species diversity due to lower pesticide application and better resource availability. However, higher biodiversity was observed in cover crops and the surrounding landscape within conventional maize fields because traditional agricultural systems already support high biodiversity. Within traditional agriculture, the authors found a significantly higher number of species, evenness, and abundance compared to conventional agriculture (Gaigher & Samways, 2010).

Arthropod populations are declining globally (Cardoso et al., 2020), with land transformation due to agriculture and direct agricultural impacts being the main drivers of these declines (Sánchez-Bayo & Wyckhuys, 2019). In reality, traditional agriculture has a particularly low impact because it uses few agrochemicals. Conventional agriculture employs numerous agrotechnical interventions and applies pesticides. This creates a stark contrast between the two agricultural systems, which is evident in the arthropod communities, which are typical inhabitants of ecosystems and agroecosystems (Botha et al., 2018). Natural systems, compared to agroecosystems, perform numerous functions, all of which can be positively or negatively influenced by biodiversity and may either enhance or inhibit the provision of other functions. Extrapolating positive results from one function to infer the role of biodiversity in complex systems ignores the interactions between functions. Addressing this requires considering how biodiversity simultaneously affects the number of ecosystem functions present in nature, a concept defined as ecosystem multifunctionality (Lefcheck et al., 2015).

Remarkable consistency was found across four different trophic groups (producers, herbivores, detritivores, and predators) and in both aquatic and terrestrial ecosystems. Analyses suggest that average species loss indeed impacts the functioning of a wide range of organisms and ecosystems. Still, the extent of these effects ultimately depends on the identity of the species that go extinct (Cardinale et al., 2006).

In natural ecosystems, both aboveground and belowground biodiversity play a significant role in supporting many ecosystem functions and services simultaneously. Global surveys show that soil biodiversity can influence the multifunctionality of natural environments. The extent to which the biodiversity of various soil organisms is associated with multiple dimensions of ecosystem functioning remains unknown (Delgado-Baquerizo et al., 2020). The findings of Fan et al. (2023) provide evidence that soil multidiversity positively correlated with the number of functions. In contrast, plant diversity shows no significant correlations with the function of the studied ecosystem. Bacteria, fungi, and protists generally support a high number of ecological functions, while the diversity of larger soil invertebrates is essential in supporting ecological functions.

An essential part of biocenoses is the zooedaphon, whose presence or absence reflects the pressure on natural ecosystems or agroecosystems. Changes in the structure of epigeic groups reflect shifts in the ecological state of ecosystems and respond to the environmental pressures that affect them. Intensification of soil cultivation, excessive application of herbicides and pesticides, improper agrotechnics, large-scale monoculture fields are factors that contribute to biodiversity reduction. Epigeic communities play a crucial role in many ecosystem services, including decomposing organic matter, facilitating the cycling of biogenic elements, and transforming and degrading substances in the soil. Therefore, their presence in the soil is indispensable. Spatial modelling revealed the connection between present epigeic groups (Araneae, Hymenoptera, Coleoptera, Collembola, etc.) and the ecosystem services performed, also confirming their bioindication capabilities (Langraf et al., 2021a).

The dispersion of epigeic groups is mainly influenced by the type of cultivated crops and environmental variables (soil pH, soil moisture, light conditions, and soil fertility). A significant influence of epigeic animals related to cultivated crops was confirmed. Their distribution was affected by soil moisture, pH, and light. The present Coleoptera species showed a strong correlation with light conditions. The abundance of individuals increased with increasing values of potassium, phosphorus, nitrogen, moisture, and light intensity. The optimal soil pH was neutral (Langraf et al., 2021b). Current evidence shows that intensive agriculture has reached its limits. In pest control, questions often arise about sustainability, especially the harmful effects of massive pesticide application (Bourguet & Guillemaud, 2016; Sheahan et al., 2017), leading to biodiversity disruption, mainly among populations of entomofauna (Hallmann et al., 2017; Sánchez-Bayo & Wyckhuys, 2019) and ornithofauna (Chamberlain & Fuller, 2000; Hallmann et al., 2014). Researchers increasingly point out risks and consequences of intensive agriculture on human health as well (Hedlund et al., 2020; Robinson et al., 2020; Sheahan et al., 2017). This is a turning point that must bring change among farmers. To add more weight to this statement, humanity is not only polluting the planet and threatening its health, but this is also linked to economic losses. This system cannot be sustainable. Therefore, the findings of Ivanič Porhajašová et al. (2025) confirm that various measures are solutions to declining biodiversity in agricultural landscapes. However, one of the modern solutions is biobelts, which clearly support biodiversity. Their importance lies not only in the natural greening of ecosystems, but as ecological areas, from which the entire biosystem benefits. Biobelts fulfill many primarily positive functions within agroecosystems. In 2022, using pitfall traps in biobelts, the authors obtained during their 1st and 2nd years after establishment, up to 19 taxonomic groups with dominant representation of Coleoptera, Collembola, Acarina, Formicoidae, Opilionida, and Araneida. From the perspective of biodiversity support, less represented groups such as Heteroptera, Diplopoda, Chilopoda, Dermaptera, Lumbricidae, and others are also important, as these ecological areas are designated for target animal groups that fulfil their ecosystem services.

2 Conclusions

In conclusion, global biodiversity is changing at an unprecedented and alarming rate, resulting in the unsustainable use of the Earth's biodiversity. Agricultural intensification, population growth, industrialisation, and ongoing climate change are factors that significantly contribute to the degradation of biodiversity, with subsequent impacts on ecosystem functions and services. Biodiversity reduction represents a significant problem, especially in the field of agriculture. As a result, we face enormous pressure on agriculture to be even more sustainable and minimise its negative impact on biodiversity. The opportunity is to develop modern production systems that exploit the benefits of biodiversity in conjunction with ecosystem services. Studies confirm that features such as biobelts, semi-natural vegetation, grassland belts, hedgerows and many others serve to support biodiversity in natural ecosystems and agro-ecosystems. Therefore, it is necessary to understand, monitor and manage the biodiversity of all environmental components and their functions in this context, so as not to disrupt homeostasis and alter the structure of ecosystem biodiversity.

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Conflict of Interest

The authors of the submitted text declare that they have no conflicts of interest or other relationships that would influence the work on this article.

Author Contributions

Jana Ivanič Porhajašová: conceptualization, data curation, resources, supervision, validation, visualization, writing – original draft, writing – review and editing; Mária Babošová: conceptualization, supervision, validation, visualization, writing – original draft, writing – review and editing; Eva Mlyneková: conceptualization, writing – original draft, writing – review and editing

AI and AI-assisted Technologies use Declaration

The authors of the contribution declare that no artificial intelligence was used in its processing.

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