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THE ASSESSMENT OF NATURAL CAPITAL OF BIODIVERSITY FOR POLLINATORS

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The assessment of natural capital for pollinators in Slovakia

The aim of this paper is to assess the natural capital of biodiversity through the identification of suitable habitats for pollinators at a national level. Various indicators were used for the assessment of appropriate habitats for pollinators, including current land use data, habitat distribution, and indicators reflecting the management of farmland and positive drivers for the protection of natural capital. Other supporting and stress phenomena that influence the pollination potential were assessed and taken into account when evaluating the real natural capital of habitats for pollinators. The final assessment of overall natural capital for pollinators is significantly impacted by various barriers and stress phenomena (approximately 56% of the area of Slovakia). Very good or adequate conditions were mapped for approximately 40% of the area of Slovakia. Unsuitable conditions of habitat for pollinators were recorded in 28% of the country's area. The unfavourable status of habitats with low natural capital for pollination can be changed or mitigated mainly by strengthening green infrastructure networks accompanied by the restoration of degraded habitats, which can be created with the support of various funding opportunities.

Key words: pollinators, habitat assessment, indicators, policy, legislation, Slovakia

INTRODUCTION

Biodiversity loss and the decline of bee populations and other insect pollinators are results of the transformation of agriculture in the last half-century (Batáry et al. 2020). A number of natural and semi-natural habitats deteriorated due to the transformation of traditional small-scale agricultural mosaics into large-block fields in order to increase production (Bezák and Mitchley 2014, Kanianska et al. 2014 and Jepsen et al. 2015). Remnants of semi-natural or human-conditioned habitats such as field margins, hedgerows, field edges and paths, headlands, fence lines, and nearby uncultivated patches of land are important refuges for many pollinators, especially in areas of intensive farming, and provide multiple ecosystem services. In 2016, the IPBES report was published (IPBES 2016) and, among others, highlighted that both wild and managed pollinators are essential pollinators. Pollinators are a source of multiple benefits for people beyond food provisioning. Pollination of plants by bees as well as other insects has a significant and irreplaceable impact on ecosystem dynamics and thus supports multiple provisioning services, including the maintenance of biodiversity and having an impact on crop production (Mederly et al. 2020). Animal pollinators play an essential role in producing numerous plant species (e. g., Willmer 2011), and approximately 85% of the angiosperm plant species (Ollerton et al. 2011) depend on animal pollination, including about 75% of globally important crops, fruit, and seed production, and more than 80% of temper-

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ate wild plants (Potts et al. 2016). Many crops, such as some fruits, nuts, oilseeds, cereals, and vegetables, would not be able to produce any yield without animal pollination. Managed and wild pollinators often cohabit in both managed and natural ecosystems, while the insects perform a major pollination service. Arthropods are responsible for pollinating the majority of food and fuel crops worldwide. Wild pollinators include wild bees (Apis), wasps (Hymenoptera), bumblebees (Bombus), flies (Diptera), butterflies and moths (Lepidoptera), birds (Apodiformes), beetles, and bugs (Coleoptera and Hemiptera). Genera Osmia, Megachile, Melipona, and Trigona are also managed commercially to some extent, either for pollination services or honey production. Other groups of insects probably also play an important role; however, this contribution has not been well researched so far. Wild pollinators are essential for pollinating wild plants and may provide a buffer that protects agriculture from bee population declines. Moths (Lepidoptera) are most likely not essential to crop pollination. However, according to research, they are abundant flower visitors capable of pollinating a range of non-crop plants that are essential for maintaining biodiversity in these ecosystems (Hahn and Brühl 2016). Flower-visiting flies are abundant in both rural and urban agricultural settings and, in some cases, may pollinate plants avoided by bees. However, global declines in insect populations threaten the delivery of pollination services in both managed and natural ecosystems. The western honeybee, Apis mellifera, is the most widely managed pollinator species. However, it was verified that honeybees could only partially replace the contributions of diverse wild insect assemblages to pollinating a broad range of crops (Garibaldi et al. 2013).

Suitable habitats for pollinators

The study of wildlife-friendly farming has been promoted as a means to achieve environmentally sustainable increases in crop yields by enhancing ecosystem functions, including pollination, that regulate and support production. The study over a 5-year crop rotation demonstrated that ecological wildlife-friendly management is compatible with, and can even increase, crop yields (Pywell et al. 2015).

Maintenance and restoration of hedgerows and other vegetation features at field borders is therefore essential for harbouring pollinators (Nicholls and Altieri 2013), and more attention is also paid to the greening of farmland in the European Common Agricultural Policy (CAP). The CAP post-2023 has a new ‘‘Green Architecture,’’ including the new ‘‘Eco-scheme’’ instrument, but for effective CAP implementation and elimination of risks in the CAP’s ability to reverse the loss of farmland biodiversity, it still requires better design, closer monitoring, greater transparency, and better engagement with farmers (Pe’er et al. 2022).

In Slovakia, mountain and sub-mountainous areas, together with grasslands, have the highest capacity to provide suitable habitats for pollinators due to a significant proportion of natural and semi-natural habitats and the presence of melliferous species (Mederly and Černecký 2020). The mosaics with orchards, sub-mountainous hay meadows, and flowering meadows are recognised as favourable for pollinators. The higher biodiversity there promotes ecosystem functioning and contributes to the maintenance of ecological stability. Semi-natural and natural habitats with favourable conservation status are more important for pollinators, as an indicator of biodiversity. The abundance and species diversity of pollinators and the intensity of pollination decrease with distance from natural or near-natural habitats, while an important effect is the fragmentation and/or continual size of natural and semi-natural habitats. The highest demand for pollination is in lowland areas dominated by agricultural production. Due to the significant intensification of the agricultural landscape resulting in large mono-functional intensive agricultural plots, these areas are the most threatened in terms of pollinator survival.

METHODS AND STUDY AREA

The natural capital assessment of suitable habitats for pollinators is prepared on a national level. Slovakia has a small but very diverse landscape. The Slovak Republic had 5,426,857 inhabitants as of March 31, 2023. The total area is 49,034 km^2. The population density reaches a value of 111 inhabitants per km^2. Out of the total number of 2,927 municipalities, 2,749 are of rural character. The use of the land is dominated by agricultural land (48.4%) and forest (41.4%). Built-up areas cover approximately 5% of the area of Slovakia.

A total of 120 potential representative geosystems were identified in Slovakia (REPGES: homogeneous landscape units created on the basis of the synthesis of potential vegetation and abiotic conditions) – Miklós et al. (2006) – Fig. 1. These are landscape units that would have developed in the landscape if humans had not intervened. During historical development, man has significantly influenced the structure of the REPGES, which has been manifested mostly by an expansion of man into originally forest ecosystems, resulting in their deforestation and subsequent transformation into agricultural land, especially arable land. At the time of collectivization under socialism, there was a massive intensification of agriculture with typical deforestation and ploughing of the land, which led to the creation of a mono-functional, intensively farmed agricultural landscape. The collectivization period during the communist regime was characterized by the confiscation of the property of private farmers and by the establishment of cooperatives, which resulted in the decline of small-scale production and in the concentration of production in large industrial plants (Bański 2017 and Izakovičová et al. 2022).

Intensification of agriculture and urbanisation together with industrialization has also played an important role in changing the natural structure of REPGES, the negative impacts of which have been not only human expansion into natural ecosystems, but also the production of pollutants, dust, radiation, etc. It has also affected the natural evolution of many ecosystems. This has resulted in threats to and changes in the ecological conditions of natural ecosystems.

According to Bezák et al. (2010), the mountainous landscape is the most prevalent type of terrain in Slovakia. The Pannonian Basin spreads to the south, and the Carpathians form a vast arch towards the north. The highlands and mountains make up around 53.0% of the total area of Slovakia. The huge Carpathians mountain range is made up of numerous mountains and intermontane basins.

The origin and types of geologic substrate that make up the various mountain groupings make them distinct from one another. Gerlachovský štít (2,655 m above sea level) is the highest peak in Slovakia. Due to the arrangement of the mountain ranges, the basin scenery is broken into multiple sections rather than forming a continuous area. This type of landscape has the highest density of settlements and makes up about 18.3% of Slovakia's total area. With a 28.7% area, the lowlands extend to the southwest, south, and east. They are a part of the Pannonian Basin, a vast depression. The Danubian Lowland is the largest and most fertile. The Bodrog river's level at Streda nad Bodrogom (94 metres above sea level) is the lowest point. Slovakia's geographical conditions have contributed to a wide range of animal and plant species. More than 11,000 plant species and about 29,000 animal species have been described on its territory (Lieskovská and Lényiová 2023).

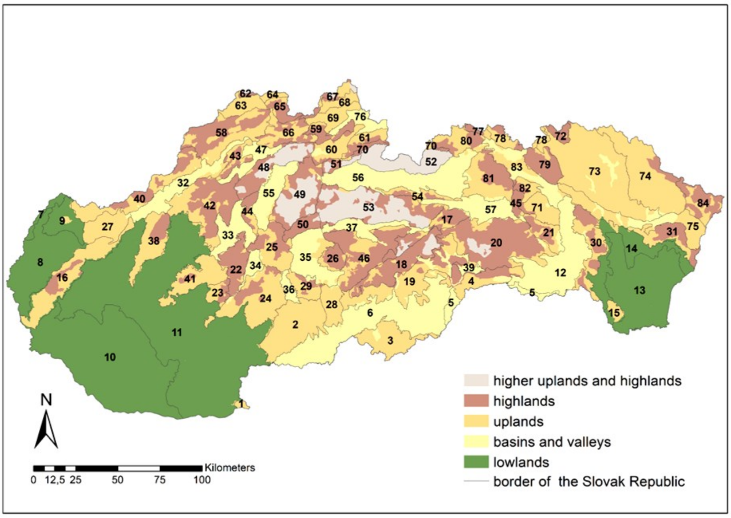

Fig. 1. The study area of Slovakia with main landscape macro-types and geomorphologic units (Source: Miklós et al. 2006)

Legend – geomorphological units: 1. Burda; 2. Krupinská planina; 3. Cerová vrchovina; 4. Slovenský kras; 5. Bodvianska pahorkatina; 6. Juhoslovenská kotlina; 7. Dolnomoravský úval; 8. Borská nížina; 9. Chvojnická pahorkatina; 10. Podunajská rovina; 11. Podunajská pahorkatina; 12. Košická kotlina; 13. Východoslovenská rovina; 14. Východoslovenská pahorkatina; 15. Zemplínske vrchy; 16. Malé Karpaty; 17. Spišsko-gemerský kras; 18. Stolické vrchy; 19. Revúcka vrchovina; 20. Volovské vrchy; 21. Čierna hora; 22. Vtáčnik; 23. Pohronský Inovec; 24. Štiavnické vrchy; 25. Kremnické vrchy; 26. Poľana; 27. Myjavská pahorkatina; 28. Ostrôžky; 29. Javorie; 30. Slanské vrchy; 31. Vihorlatské vrchy; 32. Považské podolie; 33. Hornonitrianska kotlina; 34. Žiarska kotlina; 35. Zvolenská kotlina; 36. Pliešovská kotlina; 37. Horehronské podolie; 38. Považský Inovec; 39. Rožňavská kotlina; 40. Biele Karpaty; 41. Tribeč; 42. Strážovské vrchy; 43. Súľovské vrchy; 44. Žiar; 45. Branisko; 46. Veporské vrchy; 47. Žilinská kotlina; 48. Malá Fatra; 49. Veľká Fatra; 50. Starohorské vrchy; 51. Chočské vrchy; 52. Tatry; 53. Nízke Tatry; 54. Kozie chrbty; 55. Turčianska kotlina; 56. Podtatranská kotlina; 57. Hornádska kotlina; 58. Javorníky; 59. Oravská Magura; 60. Oravská vrchovina; 61. Skorušinské vrchy; 62. Moravsko-sliezske Beskydy; 63. Turzovská vrchovina; 64. Jablunkovské medzihorie; 65. Kysucké Beskydy; 66. Kysucká vrchovina; 67. Oravské Beskydy; 68. Podbeskydská brázda; 69. Podbeskydská vrchovina; 70. Podtatranská brázda; 71. Šarišská vrchovina; 72. Busov; 73. Ondavská vrchovina; 74. Laborecká vrchovina; 75. Beskydské predhorie; 76. Oravská kotlina; 77. Pieniny; 78. Ľubovnianska vrchovina; 79. Čergov; 80. Spišská Magura; 81. Levočské vrchy; 82. Bachureň; 83. Spišsko-šarišské medzihorie; 84. Bukovské vrchy.

Slovakia is an industrial-agricultural country with growing service sector, providing employment to about half the labour force. In terms of industrial production, the automotive industry has an important position. As for as agriculture production, cereals are grown on most arable land.

The aim of this article is to assess the natural capital of biodiversity by identifying suitable habitats for pollinators at a national level based on current land use data, habitat distribution, and the authors' expert knowledge, assessing the value of grazing for pollinators (using bees as an example), and other indicators that contribute to favourable conditions for pollinators. The assessment also takes into account supporting and stress phenomena that influence the pollination potential. The assessment of the current state of conditions for pollinators will also include an overview of the supporting instruments – financial and legislative – that can be the basis for developing proposals to improve conditions for pollination.

THE METHODOLOGICAL APPROACH TO THE ASSESSMENT OF NATURAL CAPITAL FOR POLLINATION

The natural capital for pollinators was assessed at a national level based mainly on spatially expressed biophysical and environmental data. We used available spatial layers and indicators reflecting the current land use and quality of habitats and their functional value for providing suitable habitats for pollinators, as well as indicators reflecting the management of farmland and positive drivers for the protection of natural capital. For this purpose, we used a qualitative expression of the functional capacity for ES (ecosystem services) provision on a 6-point scale: 1 – the best or excellent potential; 2 – good; 3 – adequate; 4 – limited; 5 – severely limited; 6 – unsuitable; or X – indifferent. Eight indicators supporting biodiversity for pollinators were proposed for assessment:

Current land cover (CLC) was used as a baseline for delineation of suitable habitats for pollinators, including elements of green infrastructure, small-scale farmland, orchards, and grassland. The map of CLC was derived from OpenStreetMap and updated on natial level (Esprit Ltd. 2019). Indicators derived from land cover are spatial landscape diversity and ecological stability. Spatial *landscape diversity* influences habitat connectivity, and vice versa, habitat fragmentation presents barriers to animal movement in the landscape. Connected ecosystems provide higher capacity for pollinators, migration barriers and the average size of landscape features influence the capacity and flow of this ecosystem service. The *coefficient of ecological stability* expresses the overall value of individual land cover elements to the surroundings and the ecosystem's ability to maintain a stable species composition without additional energy such as mowing, grazing, and other management (Ružičková 1990). The degree of ecological stability for land cover elements is directly correlated with the degree of naturalness and inversely related to the intensity of human impact on the ecosystem. Natural and semi-natural forests, natural grasslands, wetlands, and peatlands are of great importance in terms of ecological stability, and significance for pollinators. On the contrary, in terms of ecological stability, artificial, man-made elements of the landscape structure, such as built-up and degraded areas, have the lowest potential.

EUNIS habitats were an indicator that was based on expert assessment of the functional value of habitat attractiveness from the perspective of beekeepers for honey bees (an example of pollinators), where we took into account the naturalness of ecosystems and, in particular, the occurrence of natural and semi-natural ecosystems. We used the map of ecosystems in Slovakia (Černecký et al. 2020) as a basis, with assigned values of functional capacity for each ecosystem habitat. Species-rich grasslands are key habitats from the pollinators' point of view. We have also taken into account *habitats of European importance* (EEC 1992) which are natural habitats with specific conservation conditions, and a *simplified assessment of the conservation status of habitats* for the assessment of the quality of the habitats for pollination. Habitats in favourable conservation status provide significantly better conditions for pollinators in comparison to degraded habitats. There are 3 basic categories of assessment of conservation status (FV: favourable; U1: unfavourable inadequate; U2: unfavourable bad). The data set takes into account national monitoring data of habitats of European interest on monitoring plots. Outside of the monitoring plots, in the case of forest habitats affected by logging and calamities, the age of the forest stand was taken into account. For grassland, the level of secondary succession was assessed, and in the case of water habitats, the ecological status of the waters was the baseline.

Ecological farming practises and other agri-environmental-climate measures create favourable conditions for pollinators. These areas have been earmarked based on the support from the Rural Development Programme, including areas with organic farming, support for the protection of semi-natural and natural grassland habitats; protection of the great bustard habitat; protection of the grassland pocket gopher habitat; management of species habitats in areas of European importance (NPPC VUPOP 2023).

Traditional agricultural landscapes created by small-scale agriculture mosaics with the presence of typical agrarian landforms (terraces, baulks, and stone walls) are generally associated with a relatively high species richness of plants and animals, and create suitable nesting and food conditions for pollinators. They represent high-nature-value farmland type 2, farmland dominated by traditional mosaics of cultivated land and small-scale features (Šatalová et al. 2021).

Nature protection: levels of protection (1–5), where 1 is the lowest level of legislative protection and 5 represents a non-intervention regime, where natural processes are maintained without human intervention (ŠOP SR 2023). The higher the level of protection, the better the potential for suitable habitats for pollinator evolution in different life stages. More than three-fourths (76.6%) of the area of Slovakia is in the 1st level of protection, and 2.5% is in the 4th and 5th levels.

Natural forest capital: consist of protective forests in which ecological functions are of primary importance (17.2%), special purpose forests (10.7%) in which social and cultural functions prevail, and production forests (72.1).

We used a coordinated approach of determination set of eight indicators x_i and their weighting coefficients v_{xi} to express the relative ability of the landscape to provide conditions for pollinators (Tab. 1), according to the formula

$$PotXi = \sum fxi*vxi.$$

The weighting coefficients were determined according to the order of importance of the indicator for the activity, from 1 to 5, by project expert team, who provide the weights. The final ranking values were converted to v_{xi} values ranging from 1 – 0.2 .

Various barriers and stress phenomena, which are significant limiting factors for pollinators, can limit the ecosystem's ability to provide conditions for pollinators. The most significant limiting factors include land use change (taking over natural ecosystems for development, increasing the anthropization of the area), intensive agricultural practises (large block plots, monocultures, high pesticide use, and intensive tillage), environmental pollution, including light pollution (production of contaminants, contamination of environmental compartments), expansion of invasive non-native species, and climate change. Under stress factors, we assessed – primary stressors that create physical barriers to pollinators. The increase in anthropization of the territory is associated with the occurrence of invasive species, which threaten biodiversity through their expansion and displacement of native species; on the other hand they are significant for pollinators (e.g. Robinia pseudo-accacia, Amorpha fruticosa, Helianthus tuberosus). We have taken into account occurrence of invasive species as a limiting determinant to biodiversity. Secondary stressors are the concomitant phenomena of human activities (production of exhalates, light effects, soil degradation, radiation, etc.) that significantly affect the change in the ecological conditions of pollinators and their habitats.

Tab. 1. Indicators used to model natural capital supporting biodiversity for pollinators

Basic indicators	Data source	Weighting coefficient
Current Land Cover (naturalness of landscape elements)	vector layer in 1:10 000 scale, converted to raster (cell size 10×10 m) with assigned values for each category Source: Esprit Ltd. (2019)	0.8
Habitats in terms of biodiversity and attractiveness to pollinators	map of ecosystems in Slovakia (Černecký et al. 2020) raster layer with cell size 10×10 m with assigned values for each category	1,0
Surviving traditional agricultural landscape	Areas with traditional agricultural landscapes (Špulerová et al. 2011) – vector layer converted to raster (cell size 10×10 m) with assigned values for each category	0.8
Ecological stability coefficien	Miklós et al. (2019) vector layer derived from CLC	0.2
Types of agricultural crops – arable land, permanent crops, grassland habitat	Agricultural crops according Land Parcel Identification System (Source: https://portal.vupop.sk/portal/apps/webappviewer/index.html?id=32beed691b01498d9ebe11bf8f9b7b04) – vector layer	0.7-1.0
Categories of protected forests	Forest areas (Source: National Forest Centre (NFC 2019) – vector layer converted to raster (cell size 10×10 m) with assigned values for each category	0.8
Ecological farming	Areas of ecological farming practises or other agri-environmental-climate measures (Source: Rural Development Programme, Agricultural Paying Agency (APA 2022) - vector layer converted to raster (cell size 10×10 m)	0.7
Categories of national protected areas – degree of nature protection	Protected areas (Source: ŠOP SR 2023) vector layer converted to raster (cell size 10×10 m)	0.8

For the assessment of limiting indicators for pollination we assessed indicators as follows: Type of environmental burden (probable, real, remedied); Air pollution zones based on the degree of pollution; Degrees of ecological and chemical status of surface water bodies; Categories of soil contamination; Degrees of vegetation damage; Levels of area threats by water erosion; Levels of area threats by wind erosion; Threats by landslides; Road traffic load coefficient; and Rail transport load coefficient.

In terms of limits and constraints threatening biodiversity, we assessed limits on a 3-degree scale: 0 – no limits; 1 – limited; 2 – excluded; and N – not rated. If at least one indicator excluded the conditions for pollinators, the overall assessment for the target area was unsuitable for providing suitable habitat for pollinators.

To assess the real landscape capacity to provide conditions for pollinators, a computational algorithm was developed based on the landscape potential to provide conditions for pollinators and limits from stress phenomena. The limiting drivers multiplied the summed potential for pollination. In the presence of any limiting driver number of degree 2 (the "excluded" category), the site has zero potential for pollinators. In the case of the limited conditions (occurrence of the 'limited' category), this constraint has been marked on the resulting map of the real potential for pollination.

AN OVERVIEW OF CURRENT POLICY FOR POLLINATORS

The analysis of the supporting instruments – financial and legislative – was also a partial task of our assessment, as it can be the basis for developing proposals that can help improve conditions for pollinators. Legislative instruments were evaluated in the form of an analysis of legal norms related to pollinators at the European and national levels. Financial instruments were evaluated on the basis of document analysis, where we focused on the evaluation of operational programmes and grant schemes from the point of view of supporting activities aimed at the protection of pollinators and their habitats.

RESULTS

The results of the assessment of ecosystem suitability for pollinators are summarised in three maps: a map of natural potential for pollinators (Fig. 2), a map of limiting drivers for pollination (Fig. 3), and, based on their synthesis, a map of real -time ecosystem suitability for pollinators (Fig. 4).

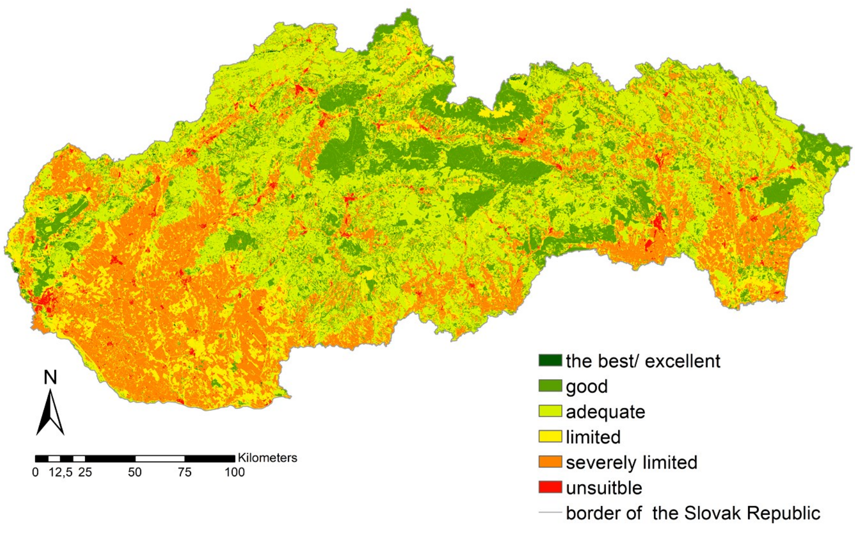

Fig. 2. The potential of natural capital for pollination in Slovakia

The highest natural capital is conditioned by current land use with high ecological stability, which consists of the presence of green infrastructure like small woodland and grassland. The overall potential for pollinators is increased by the presence of natural and semi-natural habitats attractive to pollinators, including species-rich semi-natural meadows, dry heathland, fens, peatlands, and mosaic pasture landscapes with trees. Ecological or traditional extensive farming, the application of agri-environmental climate measures, and the protection of natural resources also positively increase the overall natural capital for pollination. The highest potential was assessed in sub-mountain landscapes with dominant grassland and shrubland habitats.

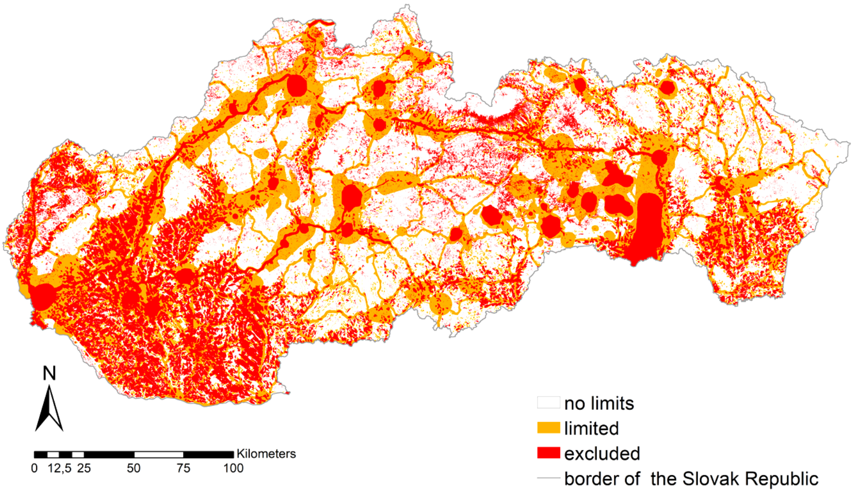

Fig. 3. The spatial distribution of investigated limiting phenomena for pollinators

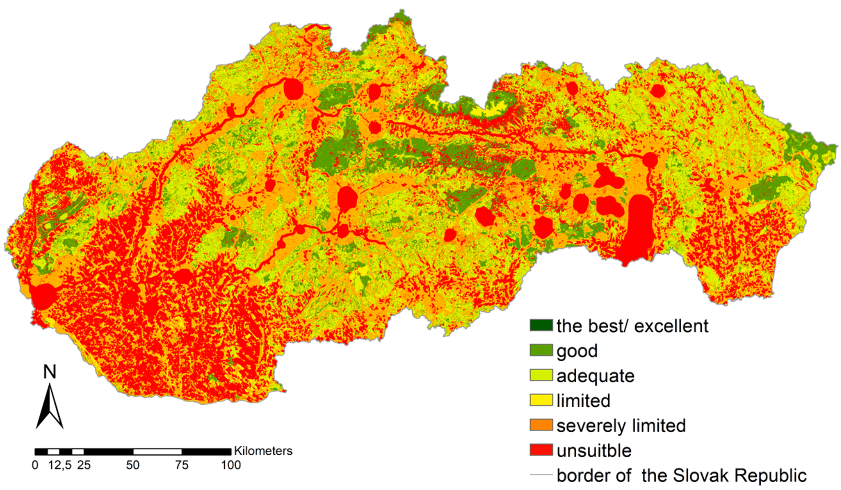

Fig. 4. The total natural capital for pollinators in Slovakia

The largest number of areas affected by limiting factors are located in industrial regions (Bratislava, Košice, Považské podolie basin, Hornádska kotlina basin, Hornonitrianska kotlina basin, Beskydské predhorie foothills, etc.), where a number of secondary stress phenomena related to the production of pollutants accumulate, which subsequently affect the quality of individual environmental components. These contaminated environmental components threaten not only the ecological conditions of individual ecosystems, but also the ecological conditions of the pollinators themselves. A distinct cluster of areas with limiting factors can also be seen in lowland and basin areas of intensively used agricultural areas (the Podunajská rovina plain, Východoslovenská nížina lowland, Záhorská nížina lowland, Popradská kotlina basin, Liptovská kotlina basin, etc.), which, in addition to low spatial stability, are also characterised by a significant burden of secondary drivers resulting from intensive agriculture (intensive chemicalization and mechanisation). The most significant limiting line elements include intensively loaded traffic corridors.

The final assessment of total natural capital for pollinators is significantly impacted by various barriers and stress phenomena, as 27.9% of the area of Slovakia has unsuitable conditions for pollinators. A significant part of the area (40.0%) represents habitats for pollinators with good or adequate conditions that are situated mostly in highland and mountain landscapes. Limited or severely limited conditions were mapped in approximately 31.5% of the territory of Slovakia, and approximately 28% have unsuitable conditions for pollinators.

OVERVIEW OF MAIN INITIATIVES AT THE GLOBAL, EUROPEAN, AND NATIONAL LEVELS RECOGNISING THE IMPORTANCE OF POLLINATORS AND THE NEED FOR THEIR PROTECTION

The importance of pollinators is being recognised from the global to the local level, and several initiatives are emerging that highlight their role as well as take action to improve their conditions.

According to the IPBES report (IPBES 2016), wild pollinators have declined in occurrence and diversity. The number of managed western honeybee hives has increased globally over the last decades, but the seasonal colony loss in recent years has been high. The production volume of pollinator/dependent crops has grown over the years. However, these crops experienced lower growth and stability than non-pollinator crops.

In response to the IPBES assessment, the Coalition of the Willing on Pollinators was formed in 2017 to establish a learning network. Several countries have already joined this coalition, including Slovakia. The EU Pollinators Initiative was adopted in 2018 to address the decline of wild pollination insects.

The EU Farm to Fork and Biodiversity Strategies from 2020 aim at biodiversity maintenance and tackle the key drivers of biodiversity loss, such as unsustainable use of land, overexploitation of natural resources, pollution, and invasive alien species. Biodiversity protection should also be embedded in economic growth strategies.

One of the aims is also to “bring back pollinators to agricultural land”. The quantitative aims are to transform at least 30% of Europe's lands into protected areas and get back at least 10% of agricultural areas under high-diversity landscape features.

The New Restoration Law of 2022 (EC 2022) proposes to reduce the use and risk of chemical pesticides by 50% by 2030. It aims to reduce the environmental footprint of the EU's food system, protect the health and well-being of citizens and agricultural workers, and help mitigate the economic losses that we are already incurring due to declining soil health and pesticide-induced pollinator loss. To help deliver on the targets while keeping flexibility for national circumstances, the law would require Member States to develop National Restoration Plans in close cooperation with scientists, interested stakeholders, and the public.

In 2023, the alarming decline in wild pollinating insects in Europe pushed for additional actions by the EU Commission and the public. The EU Commission revised "A New Deal for Pollinators." (European commission 2023). It aims at better conservation of species and habitats, supporting more pollinator-friendly farming, mitigating the impact of pesticides, enhancing pollinator habitats in urban areas, and tackling the effects of climate change, invasive alien species, and other threats.

The initiative focuses on improving knowledge and establishing a comprehensive monitoring system, including mapping Key Pollinator Areas by 2025.

A specific necessity to help pollinators is the spatial planning of ecological corridors for pollinators, or "Buzz Lines" that would enable species to move in search of food, shelter, nesting, and breeding sites. The Commission will also support the development of national pollinator strategies. The revised pollinator initiative sets out 2030 and related targets and measures within the framework of these three priorities: improving knowledge about the decline of pollinators, its causes, and its consequences; improving the protection of pollinators and combating the causes of their decline; and mobilisation of society and support of strategic planning and cooperation on all levels

Signed by 1.1 million citizens, the European Commission received the European Citizens' Initiative (ECI): "Save bees and farmers! Towards a bee-friendly agriculture for a healthy environment". The EC acknowledges the importance of the ECI, particularly as the interlinked crises of climate change, pollution, and biodiversity loss create challenges for agriculture and food security (European Union 2023).

The new EU common agricultural policy (CAP) for the period 2023 – 2027 is currently the most significant funding source for nature conservation, biodiversity, and landscape conservation and management (75 – 80%).

The Slovakian National Plan of CAP (MPRV SR 2022) supports environmentally ambitious actions on farms, among others. It helps farmers set aside non-productive areas and sow them with pollinator mixtures or postpone moving. Additionally, beekeeping is supported regarding breeding, protection, and bee health, as well as the production of honey and other bee products. Slovak beekeepers can also apply for pollination subsidies of up to 4 euros per honeybee family.

The support of biodiversity and the building of green infrastructure is also ensured by the Quality of the Environment operational programme within the priority axis. 1 Sustainable use of natural resources through the development of environmental infrastructure (measure 085 Protection and strengthening of biodiversity, nature protection, and green infrastructure, and measure 086 Protection, restoration, and sustainable use of sites of the Natura network) and priority axis 2 Adaptation to the adverse consequences of climate change with a focus on flood protection (MPRV SR 2022).

Apart from CAP, there are several funding sources mainstreaming biodiversity in Slovakia:

– State budget (primary funding): Ministry of the Environment, its subordinate organisations (including National Nature Protection), and Ministry of the Interior of the Slovak Republic (pays compensation for § 61 and § 97 of Act No. 534/2002);

– Environmental Fund, which is a supplementary fund in areas that the EU funds do not cover;

– LIFE 2021 – 2027 (Environment and Climate Action);

– Slovakia Programme 2023 – 2027, Interreg Central Europe, Interreg Danube Region Programme;

– Next Generation Europe: Recovery and Resilience Plan 2021 – 2026, mainly its component about adaptation to climate change;

– Global Europe: an instrument for neighbourhoods, development, and international cooperation;

– Invest Europe, Connecting Europe Facility;

– Horizont Europe (science and research for climate, energy, mobility, food, bioeconomy, natural resources, agriculture, and environment) 2021 – 2027; and

– Other financial resources, like Norwegian funds, the European Social Fund, the Green Educational Fund, the Village Renewal Programme, etc.

DISCUSSION

Agricultural land forms the matrix that is interconnected by remnants and fragmented patches of natural or semi-natural vegetation that have the positive and significant effect on biodiversity of increasing landscape complexity in farmland. Increasing habitat connectivity is critical to stop biodiversity loss and to provide more favourable conditions for animals, including pollinators, in complex landscapes, potentially contributing to sustainable agriculture production, ecosystem resilience, biodiversity conservation, and human well-being (Estrada-Carmona et al. 2022).

In order to manage agricultural landscapes in a way that supports biodiversity, profound structural changes are required worldwide, including increasing landscape complexity through changes in composition, configuration, increasing landscape heterogeneity, and promoting multifunctional agriculture's value at the farm and landscape levels (Angelstam et al. 2021 and Estrada-Carmona et al. 2022). land ownership. The ecological awareness of farmers also plays an important role.

One of the main goals of the Slovak Enviro Strategy 2030 (MŽP SR 2019) for sustainable land management, is to increase the share of cultivated land in organic agricultural production to at least 13.5% of the total area of agricultural land by 2030 (MŽP SR 2019), which was already achieved in 2021. There are a total of 872 entities registered in the database of ecological agricultural production in Slovakia, which manage 249,723 ha of agricultural land (ÚKSÚP 2021). The ambitions of the Commission aim to achieve the European Green Deal target of 25% of agricultural land under organic farming by 2030 (European Commission 2019). The main concern of organic farming is to exclude the use of pesticides and herbicides that pose a threat to pollinators. In Slovakia, during the period of intensive agriculture, high doses of pesticides were applied. While in 1980 the consumption of pesticides was 19,016 t, by 1993 it had decreased to 3,904.5 t, which represented a decrease of 79.5%. From 1993 to the present, the consumption of pesticides has been increasing. Compared to the years 2005 – 2021, there was an increase in the consumption of fungicides, herbicides, and insecticides, while the total consumption of pesticides increased by 42% during the given period. There was also a significant decrease in industrial fertilisers used in agriculture. In the period 1990–2021, the consumption of nitrogen fertilisers decreased by 21.4%, the consumption of phosphorus fertilisers by 75.6%, and potassium fertilisers by 85.0%. (MPRV SR 2022). In 2021, the total consumption of industrial fertilisers was 100.7 kg of pure nutrients per hectare of agricultural land, which was 2.7 kg per hectare less than in the previous year. Between 2005 and 2021, the consumption of industrial fertilisers increased by 55.2% (Lieskovská and Léniová 2023).

Conditions for nature and landscape management are also set out in the Nature and Landscape Conservation Act (Národná rada SR 2002). According to this law, the national protected areas total 22.49% of the area of Slovakia. They are mostly covered by natural or semi-natural habitats more favourable for pollinators. However, the importance of these habitats is more significant in the open agricultural landscape, which occupies 48.4% of the territory of Slovakia, but the proportion of significant landscape features is very low (less than 5%), and the average parcel size (12 ha) significantly exceeds the average size in the EU (3.9 ha) – Gális (2020). Therefore, new interventions in Slovak CAP post-2023 include new eco-schemes and interventions of support for grassing of waterlogged arable land; support for forestry-environmental and climate services and forest protection, support for the establishment of agroforestry systems on agricultural land and for the protection and maintenance of trees in established agroforestry systems, and support for the establishment of linear vegetation features and for the protection and maintenance of trees in established linear vegetation features. Farmers' efforts to sow pollinator mixtures on their fields will be highly influenced by the technical and cost-effective availability of plant species. High diversity landscape features, which can be established within eco-schemes by dividing large block fields or by supporting the planting of linear tree features, can be of particular benefit. Many studies have shown that pollinator abundance and species diversity, as well as pollination intensity, decline with the distance of ecosystems from natural or near-natural habitats (Garibaldi et al. 2011 and Ricketts et al. 2008), as they are existentially dependent to a large extent on habitat options for nesting and sources of flowers that cannot be found among arable land. The challenge still remains how to set up and promote these interventions to make them attractive and familiar to farmers, so that they become actively involved and contribute to improving the conditions of connectivity and biodiversity, eventually also improving conditions for important pollinators. An overview of financial and legislative instruments highlighted the importance of this topic, paying more attention to pollinators and the need to halt the negative trend of pollinator decline, to which various funding opportunities can contribute.

The expert habitat assessment raised the question of how to approach the perception of non-native habitats, such as Robinia plantations, which have high honey-producing potential but threaten native habitats through their invasive behaviour. In addition, the period of pollen and nectar production for some invasive species may be different from the native vegetation. This can lead to disruption of the annual life cycle of some pollinators (e.g. Apis mellifera), especially when it comes to late flowering at a time when some pollinators inevitably need a winter rest without laying pollen and nectar. Mitigating the impacts of these species on local biodiversity is possible through awareness raising and information sharing on plant invasions (Burda and Koniakin 2019). Further discussion brought up beekeepers' preferences for oilseed rape monocultures with high honey production potential, versus natural and semi-natural habitats, which, although providing lower honey yields, are more sustainable. A study from Ireland suggested the appropriate conservation and management of both honeybees and wild pollinators in agricultural areas to ensure the continued provision of pollination services to oilseed rape (Stanley et al. 2013).

Our assessment showed biodiversity is essential for pollinators. The most suitable habitats for pollinators with good or adequate conditions are situated mostly in highland and mountain landscapes. Some beekeepers using the agrarian southwest of Slovakia and the more forested north of Slovakia at the same time report lower honey production in the north. Our assessment focuses on the health of pollinators and not on the production of single-species kinds of honey. Although monocultures ensure a short-term abundant output of nectar, they bloom only temporarily and do not provide suitable year-round conditions for the survival of pollinators. In addition, in the case of monocultures, chemical treatment of plants is often applied, which reduces the occurrence of other plant and animal species and can also have negative consequences for the health of pollinators, therefore we include the large-block fields and intensive farming as a barrier for pollinators.

Other indirect factors also support the protection of pollinators. Measures to help pollinators must be based on sound scientific knowledge. Since 2018, significant progress has been made in gathering actionable knowledge to protect pollinators, but there are still significant gaps in this knowledge. Further efforts are needed to establish a reliable pollinator monitoring system, carry out critical assessments and spatial analyses, and support targeted research and innovation activities (European Commission 2023). In addition, the main threats should also be monitored: stress phenomena, both primary and secondary, causing pollinator decline (Izakovičová 2000). Effective pollinator conservation requires the effective cooperation of all relevant actors, including scientists, policymakers, citizens, and farmers.

CONCLUSION

The importance of pollinators is undisputed. In terms of landscape research and the benefits that pollinators provide to society, it is important to investigate the environmental factors that create the potential for suitable habitat for pollinators. The assessment of the natural capital of the ecosystem as a suitable habitat for pollinators included the characteristics of the current landscape structure, the quality of the habitats, as well as activities related to the conservation and management of the landscape and natural resources. We selected indicators reflecting habitat quality that support better living conditions for pollinators. The list of indicators is not exhaustive and can be extended by indicators reflecting the conditions for movement of pollinators, e.g. terrain, aspect, soils, solar radiation, or conditions reflecting the production characteristics, including climate, weather conditions, etc.

The assessment of the real potential also took into account the constraints and barriers that exclude or limit the exploitation of this potential, including the barrier effect of the primary stress drivers (area occupied by natural ecosystems) or the negative impact of secondary stress drivers spatially expressed in terms of air pollution, water contamination, soil contamination, damage to vegetation, etc. Pollinators and their habitats are currently seriously threatened by human activities, mainly related to the use of pesticides, the cultivation of large parcels of monocultures, and the impact of climate change.

The natural conditions of Slovakia provide suitable conditions for pollinators, including beekeeping. There are extensive forests, which are the original home of bees and form a quality bee pasture. The largest group consisted of habitats with adequate conditions for pollination (point 3 of the 6-point scale, or 32.7% of the area of Slovakia).

The unfavourable status of habitats with low natural capital for pollination can be changed or mitigated mainly by strengthening green infrastructure networks, which can be created with the support of the RDP, or Operational Programme Environmental Quality, and other financial mechanisms.

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HODNOTENIE PRÍRODNÉHO KAPITÁLU BIODIVERSITY PRE OPEĽOVAČE NA SLOVENSKU

Krajina je tvorená súborom ekosystémov, ktoré pre spoločnosť ponúkajú rôzne ekosystémové služby. Všetky tieto služby poskytované jednotlivými typmi ekosystémov reprezentujú prírodný kapitál, ktorý je k dispozícii pre rozvoj ľudskej spoločnosti.

Cieľom príspevku je posúdiť prírodný kapitál biodiverzity pre opeľovače prostredníctvom identifikácie vhodných biotopov pre opeľovače na národnej úrovni. Na hodnotenie vhodných biotopov pre opeľovače sa použili rôzne ukazovatele. Za základné ukazovatele sme zvolili súčasnú krajinnú pokrývku, ktorá sa použila ako základ na vymedzenie vhodných biotopov pre opeľovače, a typy habitatu, ktoré boli hodnotené na základe významnosti z hľadiska opeľovačov. Taktiež boli hodnotené podporné faktory (faktory podporujúce výskyt a prežitie opeľovačov – ekologické formy hospodárenia, ochrana prírody a prírodných zdrojov, ktoré podporujú šetrnejšie formy obhospodarovania), ako aj negatívne faktory, ktoré vo vzťahu k opeľovačom vystupujú ako stresové faktory (kontaminácia zložiek životného prostredia, fyzikálna degradácia prírodných zdrojov a bariérny efekt). Na základe syntézy bola urobená klasifikácia prírodného potenciálu biotopov pre opeľovače na národnej úrovni. Veľmi dobré alebo vyhovujúce podmienky pre opeľovače boli zmapované na približne 40 % rozlohy Slovenska. Nevhodné podmienky biotopu pre opeľovače boli zaznamenané na 28 % rozlohy Slovenska.

Nepriaznivý stav biotopov s nízkym prírodným kapitálom na opeľovanie je možné zmeniť alebo zmierniť najmä posilnením sietí zelenej infraštruktúry, obnovou degradovaných biotopov, ktoré je možné vytvárať s podporou rôznych možností financovania. Príspevok predstavuje aj súbor grantových schém na medzinárodnej i národnej úrovni, ktoré je možné na tento cieľ využiť.

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