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Land Use Changes and Their Impact on the Value of Ecosystem Services in the Model Region

Jarmila Makovníková[1], Stanislav Kološta[2], Boris Pálka[1]

[1]National Agricultural and Food Centre/Soil Science and Conservation Research Institute Bratislava, Regional Station Banská Bystrica, Banská Bystrica, Slovakia
[2]Faculty of Economics, Matej Bel University in Banská Bystrica, Banská Bystrica, Slovakia
Email: jarmila.makovnikova@nppc.sk

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Abstract

The quantification and evaluation of ecosystem services represent key drivers for the sustainable development of human activities, particularly within the framework of natural capital management. This study aims to assess the effects of land use change on both the non-monetary and monetary values of ecosystem services through the application of a matrix-based evaluation approach. In the Brezno District, the total ecosystem service score exhibited only a marginal decline of 0.99% over the observed 20-year period. Nevertheless, when expressed in monetary terms, this reduction corresponds to a loss of €4,715,502. Changes in land use most notably influence the potential for provisioning and regulating ecosystem services.

Keywords

Ecosystem Services, Matrix Approach, Land Use

1. Introduction

The concept of ecosystem services plays a critical role in informing decisions regarding the allocation of nature-derived resources. It facilitates the exploration of alternative strategies aimed at achieving diverse objectives, including both monetary and non-monetary outcomes, improvements in quality of life, and the preservation of nature for its intrinsic value. Ecosystems that deliver such services are collectively referred to as natural capital (Costanza, 2008; Burkhard et al., 2014; Birkhofer et al., 2015). Human interventions and land management practices can profoundly influence ecosystem functionality. It is therefore essential to apply an understanding of interrelationships among ecosystem services to foster synergies, particularly in the context of multifunctional land use systems (Bodnaruk et al., 2017). Unlike systems optimized for the delivery of a single or limited number of services, multifunctional landscapes are distinguished by their capacity to simultaneously support a wide range of ecosystem services within a single spatial unit (Stürck & Verburg, 2017). Land use and management changes represent key drivers of biophysical transformations in agroecosystems, particularly through processes of intensification and homogenization. As the structural heterogeneity of landscapes is positively correlated with ecosystem multifunctionality, such simplification often results in a decline in the value of ecosystem services. Human activities thus impact the structure and functioning of ecosystems in diverse ways—positive, neutral, or negative, which are directly reflected in ecosystem service valuation. Strategic and ecologically sound interventions, especially in degraded areas, can contribute to ecosystem restoration and consequently enhance the provision and value of individual ecosystem services. Moreover, the overall value of a nation's ecosystem services is influenced not only by ecological factors but also by governance structures—particularly the distribution of access to and control over natural resources among different land users (Pacheco & Sanches Fernandes, 2016).

Within the agriculturally utilized areas of the Slovak Republic, the most significant changes are observed in the categories of arable land and grasslands, with a continuing trend of decreasing arable land and expanding grassland areas. The decline in arable land is primarily attributed to increasing pressure on soils, including land sealing, soil degradation, abandonment of agricultural practices, and subsequent natural succession, leading to grassland development or conversion into forest stands (Makovníková et al., 2017; Izakovičová, 2022). This loss of agricultural land occurs despite legislative measures intended to safeguard the land fund. The Constitution of the Slovak Republic affirms that "agricultural and forest land, as non-renewable natural resources, enjoys special protection from the state and society".

The aim of the paper is to evaluate the impact of land type changes on the non-monetary and monetary value of ecosystem services using a matrix evaluation system on the example of a Brezno model region during the 20-year period 2002-2022.

2. Materials and Methods

2.1. Model Region

The Brezno District, covering an area of 1265 km^2, is the largest administrative district in Slovakia (**Figure 1**). Its territory is geographically defined by the southern slopes of the Low Tatras mountain range to the north, the Poľana massif and the Veporské Hills to the south, and the Horehronské Valley in the central part. From the east, the Spiš-Gemer Karst partially extends into the region. Most of the district lies at elevations exceeding 600 meters above sea level (88.6% of the area), with the lowest point situated at 406 meters above sea level. This topography contributes to the predominance of a cold climate across most of the district (86.9% of the area). The distribution of individual ecosystem types is presented in **Table 1**.

Statistical processing and evaluation of the results were carried out in STATGRAPHICS CENTURION XVI. program.

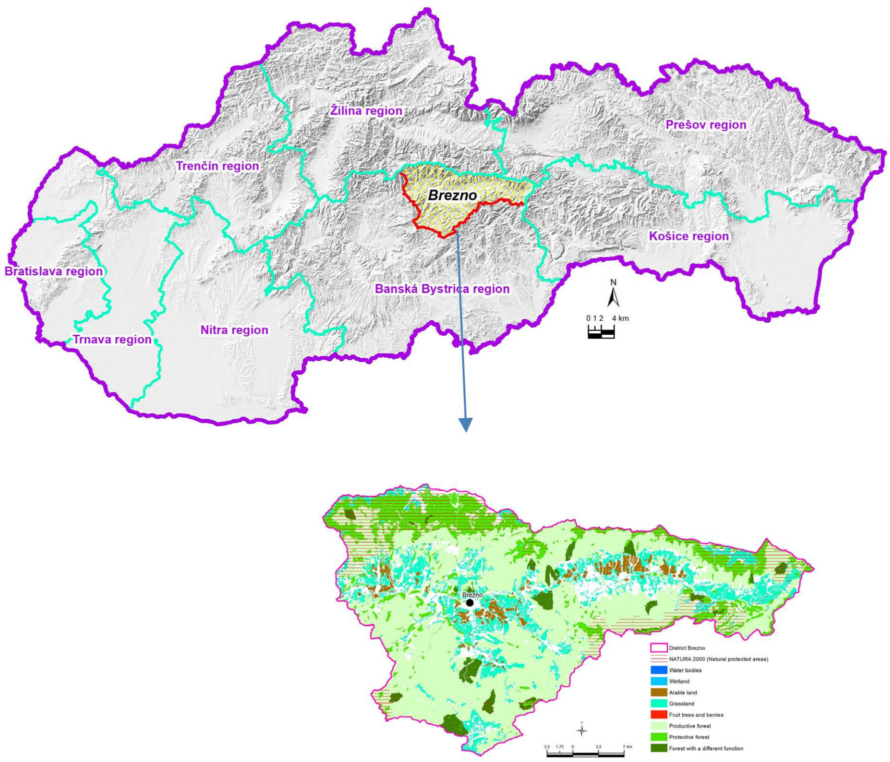

Figure 1. Geographical localization of the Brezno model region within Slovakia.

Table 1. Ecosystem areas (land use in the Brezno model region in ha).

Ecosystem	Year 2002	Year 2012	Year 2022
Arable land	4114	3938	3951
Grassland	29,853	29,583	27,384
Vineyards	0	0	0
Fruit trees and berries	9	7	7
Agro-forestry areas: fast-growing woody plants	0	0	0
Water bodies	401	474	499
Wetlands	3.2	3	3
Natural protected areas	31,528	31,528	31,528
Productive forest	55,140	55,400	56,516
Total area	121,048	120,933	119,888

2.2. Assessment of ESS by the Matrix System

The non-monetary assessment of ecosystem services was conducted using a matrix-based approach, which is considered an effective tool in landscape planning and nature conservation at both regional and national scales (Müller et al., 2020). The evaluation was based on the matrices developed by Burkhard et al. (2014), Müller et al. (2020), and Černecký et al. (2020). In cases where the ecosystem service values proposed by Müller et al. (2020)—expressed on a 0 - 100 scale, were unavailable, the matrix from Burkhard et al. (2014) was used as a substitute, with its original values converted to the same 0 - 100 scale. **Figures 2-4** present the final adjusted matrix values for evaluating the three primary categories of ecosystem services (Makovníková et al., 2022). These matrices provide a generally applicable framework for assessing ecosystem resources across various regions or countries.

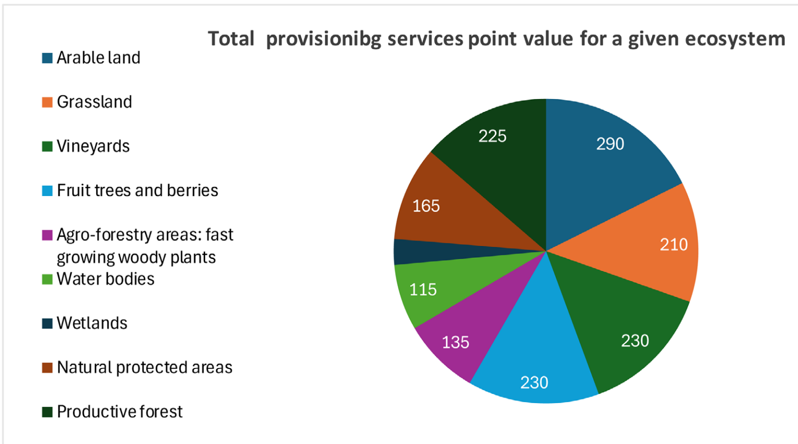

Figure 2. Provisioning ecosystem services point values in the Brezno model region (production of crops, biomass for energy purposes, cattle grazing, timber production, game hunting, fodder for cattle and animals).

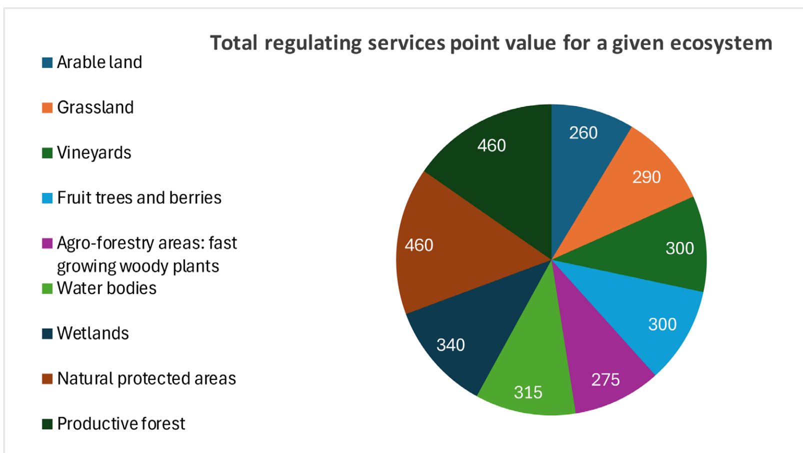

Figure 3. Regulating ecosystem services point values in the Brezno model region (local climate regulation, global climate regulation, air quality regulation, water regulation, erosion regulation, nutrient regulation, filtration/immobilization of risk elements, pollination, biodiversity protection).

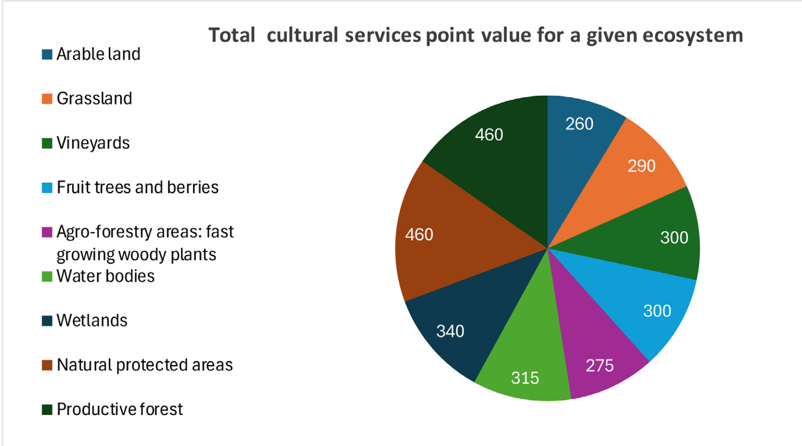

Figure 4. Cultural ecosystem services point value in the Brezno model region (recreation and tourism, knowledge system, cultural heritage, regional significance, natural heritage).

The total ecosystem services (ESS) score for a given region was calculated according to the method proposed by Vihervaara et al. (2012), using the following formula: $\text{CBH ES} = \sum(\text{BHe} \times \text{Pe})$, where BHe represents the index score indicating the potential of a specific ecosystem to provide a given service, and Pe denotes the area of the corresponding ecosystem within the model region.

To estimate the monetary value of natural capital associated with ecosystem service provision, the value transfer method was employed (Liu et al., 2010; Wilson & Hoehn, 2006; Burkhard & Maes, 2017; Černecký et al., 2020; Kološta et al., 2023). This approach enables the conversion of ecosystem service point scores into corresponding economic values. A comprehensive meta-analysis by Frélichová et al. (2014) synthesized relevant published valuations of ecosystem services across Europe, providing average monetary values expressed in euros per hectare per year.

2.3. Geospatial Datasets Used for Specifying the Distribution of Individual Ecosystems

The layer of land cover LPIS (Land Parcel Identification System), the layer of the ecosystem category Corine Land Cover (dataset https://land.copernicus.eu/pan-european/corine-land-cover/clc2018), and the geodatabase NFC (National Forest Center) were used for specifying the distribution of individual ecosystems. The LPIS is an identification system for agricultural areas based on digital orthophoto maps and changes in accordance with the current state of land use. The LPIS geodatabase also contains a register of natural protected areas. The LPIS and the NFC geodatabase are updated according to the actual use of agricultural and forest areas.

3. Results and Discussion

Changes in land use most significantly impact the potential of arable lands and grasslands to provide provisioning and regulatory ecosystem services (see **Table 2**).

These effects can be positive, such as when arable land is converted to grassland, or negative, as in the case of grasslands being ploughed for cultivation. Historically, agricultural production was more closely integrated with natural ecosystem processes, including nutrient cycling, pollination, and natural pest regulation. However, these functions have increasingly been replaced by agrochemicals, fertilizers, pesticides, and mechanization (Frélichová & Fanta, 2015). Presently, intensive agricultural practices adversely affect the delivery of regulatory ecosystem services. Optimization of agricultural ecosystems for maximum yield often entails structural simplification, characterized by expansive monoculture fields, which triggers a cascade of detrimental impacts on biodiversity, natural pest control, water retention, and carbon sequestration (Zhang et al., 2007; Flynn et al., 2009; Frank et al., 2012).

Table 2. Impact of land use changes on the value of ESS in the Brezno model region.

Conversion	A	B	C	D	E
Provisioning ecosystem services					
Production of crops	−80	−85	−10	−5	−5
Biomass for energy purposes	−40	0	−80	40	−40
Cattle grazing	85	0	35	−85	−80
breeding Wood production	0	0	35	0	85
Game hunting	0	10	40	10	80
Fishing fodder for cattle and animals	−45	−80	−80	−35	−25
Regulating ecosystem services					
Local climate regulation	0	0	−10	0	50
Global climate regulation	50	50	10	0	20
Air quality regulation	0	0	10	0	70
Water regulation	10	40	−10	30	30
Erosion regulation	60	60	0	0	0
Nutrient regulation	−10	40	10	50	50
Filtration/immobilization of risk elements	50	40	20	−10	−10
Pollination	50	60	50	10	−10
Biodiversity protection	20	10	20	−10	−10
Cultural ecosystem services					
Recreation and tourism	0	10	10	10	40
Aesthetic values	0	0	0	0	30
Knowledge system	0	20	20	20	30

Continued

Cultural heritage	0	−15	0	−15	20
Regional significance	0	0	0	0	30
Natural heritage	30	0	10	−30	20

Explanations: A—arable land to grassland, B—arable land to grow fast-growing woody plants, C—arable land to orchards, vineyards, D—grassland to grow fast-growing woody plants, E—grassland to forest.

Arable land ecosystems hold irreplaceable significance, particularly within the category of provisioning ecosystem services. The most pronounced decline in ecosystem service value within this group occurs when arable land is converted to fast-growing woody plants; however, the current ecosystem service assessment matrix does not differentiate based on arable land quality. The utilization of lower-quality or contaminated arable land for cultivating fast-growing wood species is notably important for the energy sector (Porvaz et al., 2009). The establishment of fast-growing trees on agricultural lands (Dominati et al., 2010) contributes to greenhouse gas mitigation through carbon sequestration, thereby enhancing regulatory ecosystem services such as climate regulation, pollutant filtration, water regime stabilization, biodiversity conservation, and prevention of land abandonment on less productive sites (Burkhard et al., 2009). Consequently, the conversion of arable land to fast-growing woody plants results in a positive shift in regulatory ecosystem service values. Conversely, the conversion of grasslands to fast-growing woody plants leads to a reduction in services related to grazing, livestock breeding, and fodder production. The production of free-range livestock is intrinsically linked to grassland ecosystems, though this service is less affected by mowing practices (Kanianska et al., 2016), which are also vital for maintaining rare ecosystems in Slovakia (Černecký et al., 2020). Grazing and livestock provisioning are directly connected to fodder availability. Afforestation of less productive grasslands may yield a positive increase in ecosystem service value; however, this comes at the cost of a loss of agriculturally productive land. Forest ecosystems represent the most structurally complex and highly organized phytocenoses (Vološčuk et al., 2011). Nonetheless, excessive timber production or exploitation of other forest products can generate negative externalities for society, such as biodiversity loss, degradation of water quality and quantity, and elevated carbon emissions (Báliková et al., 2021).

Climate regulation operates at both global and local scales. Natural forest and wetland ecosystems play a crucial role in maintaining atmospheric conditions conducive to life on Earth, thereby regulating the global climate (Maes et al., 2014; Nedkov et al., 2018). In the context of climate change, which increases the frequency and intensity of extreme weather events such as flash floods, effective water regulation within landscapes has become increasingly critical. Flood risk is particularly elevated in areas characterized by steep terrain and a lack of woody vegetation. Forest ecosystems and wetlands that function as natural water retention systems are essential for flood mitigation. Additionally, forests and permanent grasslands—including woodlands and linear tree stands—serve as key components in modulating precipitation dynamics and surface runoff regimes.

The highest capacity for ensuring the regulatory service of supporting biodiversity is in mountain and foothill areas, together with grasslands, because a significant part of them is also part of the network of protected areas. Higher biodiversity supports the functioning of the ecosystem and contributes to maintaining ecological stability. Forests also have the highest point values in relation to the examined categories of cultural ecosystem services, such as recreation and tourism, aesthetic values, regional importance, natural heritage, knowledge base, and cultural heritage. Protected areas have a significant impact on the value of the natural capital of the European Union, especially in the provision of regulatory and cultural services (Černecký et al., 2020). The total changes in the value of the three groups of ecosystem services under land use change (non-monetary) (points/ha/year) in the Brezno model region are shown in **Table 2** and **Figure 5**, while monetary changes are shown in **Figure 6**.

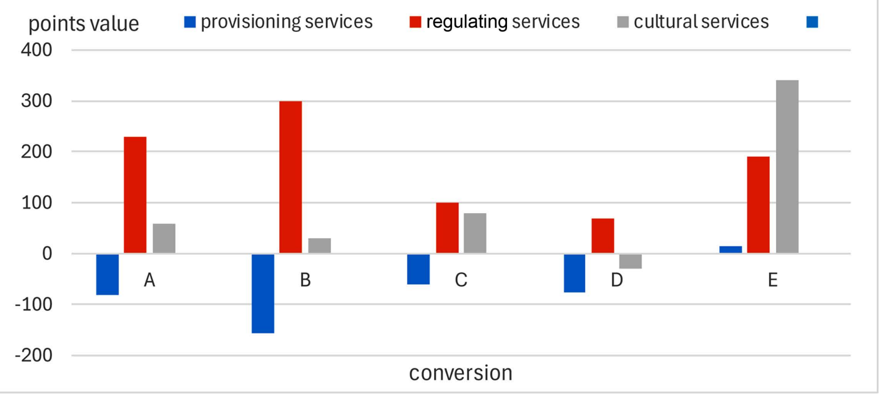

Figure 5. Impact of land use changes on the value of ESS groups (non-monetary) in the Brezno model region.

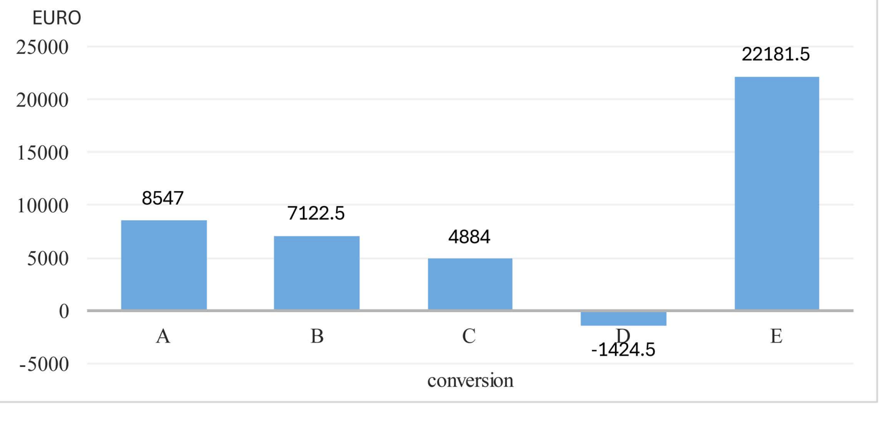

Figure 6. Impact of land use changes on the value of ESS (monetary) in the Brezno model region.

Changes in the value of ecosystem services in the Brezno model region

Changes in land use in the model region over the monitored (2002-2022) period are presented in **Table 3** (in ha) and in **Figure 7** (in % of the model region area).

Table 3. Changes in land use over the monitored period in ha in the Brezno model region.

Ecosystem	Changes in land use over the monitored period in ha		
	2022-2012	2012-2002	2022-2002
Arable land	13	−176	−163
Grassland	−2199	−270	−2469
Vineyards	0	0	0
Fruit trees and berries	0	−2	−2
Water bodies	25	73	98
Wetlands	0	0	0
Natural protected areas	0	0	0
Productive forest	1116	260	1376
Total area (A)	−1045	−115	−1161

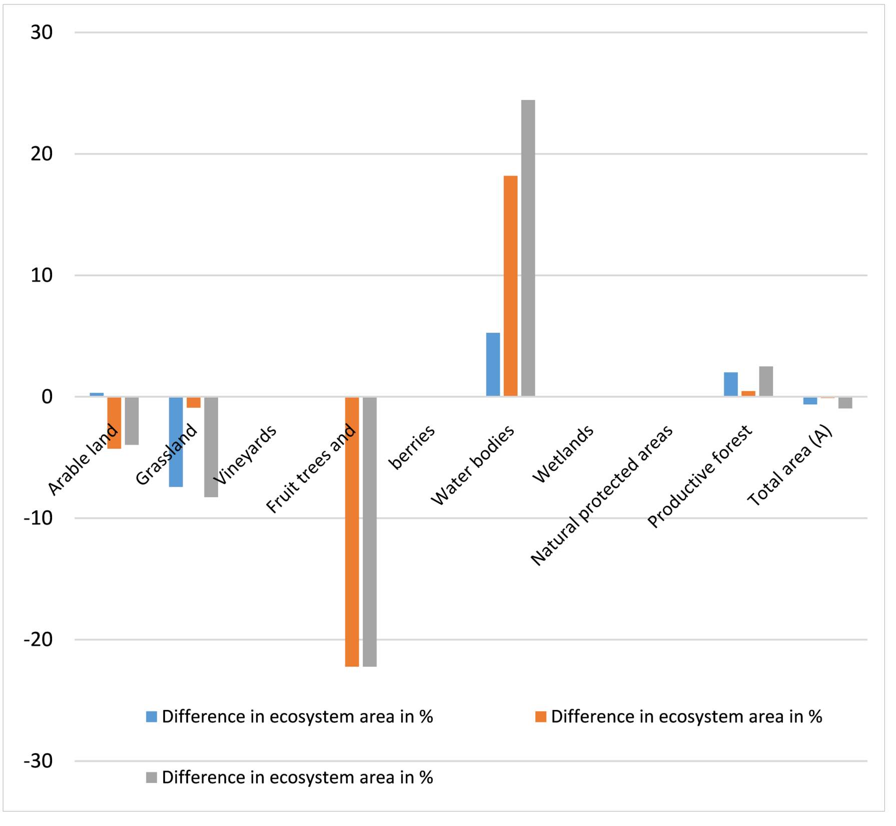

Figure 7. Changes in land use over the monitored 20-year period in % in the Brezno region.

In the comparison of the period from 2002 to 2012, areas of fast-growing woody plants cultivated on arable land for energy purposes were recorded for the first time. The potential of natural capital represented by agricultural land designated for such cultivation was determined in accordance with Act No. 220/2004 Coll. on the protection and use of agricultural land, as well as amendments to Act No. 245/2003 Coll. concerning integrated prevention and control of environmental pollution. Since these changes constitute a 100% increase relative to the baseline year 2002, they are excluded from the overall evaluation of changes in ecosystem areas. Comparing the period from 2012 to 2022, forest land areas in the Brezno region have increased substantially by 1116 hectares. The arable land area experienced a slight increase of 13 hectares. The most pronounced decrease was observed in grasslands, which declined by 2199 hectares. Land use changes have serious impacts on the structure and function of the landscape, therefore significantly affecting ecosystem service values (Wang et al., 2023). How these changes have been reflected in the total value of the ESS in the Brezno region is shown in Table 4.

Table 4. Value of ecosystem services in the Brezno model region.

Value of ecosystem services (points)	Ecosystem services			
	Provisioning	Regulating	Cultural	ESS (complet)
Year 2022	24,873,780	145,693,617	49,629,233	220,196,639
Year 2012	25,077,825	145,666,222	49,742,328	220,486,384
Year 2002	25,119,139	145,468,967	49,724,393	220,312,499
Changes in the value of ecosystem services				
Between 2022 and 2012 (points)	−204045	27,395	−113095	−289745
Between 2022 and 2012 (in %)	−0.82	0.02	−0.23	−0.13
Between 2012 and 2002 (points)	−41305	197,255	17,935	173,885
Between 2012 and 2002 (in %)	−0.16	0.14	0.04	0.08
Between 2022 and 2002 (points)	−245359	224650	−95160	−115860
Between 2022 and 2002 (in %)	−0.99	0.15	−0.19	−0.05

Over the monitored 20-year period, the Brezno District experienced only a marginal decrease in the total ecosystem services (ESS) point value, amounting to −0.99%. However, when translated into monetary terms, this corresponds to a loss of approximately €4,715,502. The most significant negative changes in ESS value across both decade-long intervals were observed within the provisioning ecosystem services category, primarily driven by reductions in arable land and grasslands during the 2002-2012 period. Although a substantial decline in grasslands occurred between 2012 and 2022, this was partially offset by an increase in production forests, resulting in a relatively small decrease of 0.82% in the value of provisioning ESS. Additionally, an overall negative trend is evident due to ecosystem loss linked to urban expansion and the conversion of arable land and grasslands into built-up areas around towns and villages.

According to the concept of sustainable intensification, the European Union mandates that efforts to increase agricultural production must prioritize the preservation of soil health and multifunctionality, thereby ensuring the long-term sustainability of agroecosystem potential to deliver a full range of ecosystem services (Garnett & Godfray, 2012). To optimize the ecosystem service (ESS) value of agriculturally used lands, it is crucial to maintain both productive and marginal arable lands, preserve grassland areas considering their provisioning and regulatory functions, and utilize lower-productivity agricultural lands for cultivating fast-growing trees. Furthermore, effective soil erosion control measures should be implemented on erosion-prone soils, informed by detailed assessments of erosion intensity and spatial distribution. Supporting ecological land management practices and regenerative agriculture can significantly enhance the provision of both productive and regulatory ecosystem services. Additionally, improving opportunities for cultural ecosystem service utilization in the region is essential.

4. Conclusion

The assessment of ecosystem services represents key objectives of both the renewed Biodiversity Strategy of the Slovak Republic and the EU Biodiversity Strategy 2030. Ecosystem accounts allow us to track the state of ecosystem assets over time, thus indicating changes in their state. This can help public policymakers distinguish ecosystem assets and services showing the most significant changes and identify policy priorities. Using a modified matrix approach, we evaluated and subsequently valued changes in ecosystem services within the Brezno model region. Changes in land use most significantly impact ecosystem services value. The most significant negative changes in the ESS value in the Brezno model region over 10-year intervals were observed in the ecosystem services providing services category, mainly due to the reduction in arable land and grasslands. In Slovakia, the trend of decreasing arable land area and increasing grassland area has been persistent for a long time. The decrease in arable land area occurs due to pressures on the land, primarily sealing (building up arable land), arable land degradation, as well as the abandonment of arable land and its subsequent grassing or overgrowth and transfer to forest area.

The matrix method, however, carries inherent uncertainties stemming from expert judgment, modeling techniques and data inputs, ecosystem and landscape dynamics, subjective and political factors, limited regional knowledge, technical constraints, and other challenges. The emphasis on specific regional conditions further complicates the generalization of results. The robustness of the matrix system also lies in the fact that it does not take into account the quality of agriculturally used arable lands, which are of equal value in this assessment. The level of uncertainty in the regional or local assessment scale can be reduced by confronting the values in the matrix used with the values obtained based on a questionnaire survey of preferences and evaluation of individual ES in local conditions. The matrix system is suitable when the availability of data sources is limited. Nevertheless, despite these limitations, the matrix approach remains a valuable tool for sustainable landscape management and holds potential for further refinement, particularly to enhance the practical application of the ecosystem services framework. Its advantage is also the connection of non-monetary and monetary evaluation through the "transfer value" method. Monetary expression is an important tool for raising awareness of the importance of ecosystems and biodiversity in the formulation of public policies. Our findings contribute regionally relevant insights into ecosystem service assessment, considering local context and data availability.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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