

Trade-Offs and Synergie Effects of Regulating Ecosystem Services along an Climatic Gradient in Slovakia

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Abstract

This study aims to assess the synergies and trade-offs of regulating ecosystem services. Ecosystem services are non-linearly interconnected and changes in one service can positively or negatively affect another. We evaluated ecosystem services based on biophysical indicators using an expert scoring system that determines the corresponding soil functions and is part of the existing databases available in Slovakia. This methodological combination enabled us to provide unique mapping and assessment of ecosystem services within Slovakia. Correlation analysis between individual regulating ecosystem services and climate regions, slope, texture, and altitude confirm the statistically significant influence of climate and slope in all agricultural land, arable land, and grassland ecosystems. Statistically significant synergistic effects were established between the regulation of the water regime and the regulation of soil erosion within each climate region, apart from the very warm climate region. Only in a very warm climate region was potential of regulating ecosystem services mutually beneficial for soil erosion control and soil cleaning potential (immobilization of inorganic pollutants).

Keywords

Agroecosystem Services, Climatic Zone, Mapping, Trade-Offs, Synergies

1. Introduction

Soil is a basic production factor. More than 60% of the Earth's total land surface is cultivated. Approximately 60% of this is agricultural land use (agroecosys-

tems). Agroecosystems contribute to human well-being in many complex ways at multiple scales of space and time (Costanza et al., 2017). The ecosystem services (ES) of agricultural land, linked to natural capital, is divided by Dominati et al. (2010) into three main groups, namely provisioning, regulating and cultural services. Due to the complexity of ES interactions, an in-depth understanding of them is needed to reduce unintended trade-offs and improve synergies to realize multifunctionality of territories (Costanza et al., 2017; Shen et al., 2021). As the benefits that ES provide to people underpin socio-economic development, ES are important in linking the natural ecosystem and the socio-economic system. At the same time, the level of supply of ES is influenced by a range of socio-economic and ecological factors, leading to spatial and temporal differentiation of both ES and their interactions (Luo et al., 2019). Currently, ES research is increasingly exploring the factors influencing the interaction between ES in socio-ecological systems to help understand and optimize objective trade-off relationships that can sustainably improve human well-being (Torralba et al., 2018). For these reasons, there is a need for good evidence and methodologies that evaluate from a wide range of ES in relation to the type of human activities and the pedo-geographic conditions in which these activities are carried out. ES assessments in EU countries are one of main objectives of Biodiversity strategy 2030, as human activities are also one of the most important factors affecting the healthy functioning of ecosystems. It is important that people apply knowledge of the relationships between services to promote synergies in the context of multifunctional land use (Grêt-Regamey et al., 2017). In terrestrial ecosystems, the majority of ES come precisely from soil functions to a greater or lesser extent dependent on interactions between organisms, organic and mineral soil fractions (Kibblewhite et al., 2007).

The ecosystem approach is now an essential strategy for integrated land management, water resources and biota management, as it is an approach that promotes the conservation and sustainable use of ecosystems (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). The ES provided by the soil, agroecosystem service (soil ecosystem services) is a subset of ES related to the soil, directly and quantifiably controlled, or provided by the soil and its chemical, physical and biological properties, processes, and functions. ES can be evaluated using soil functions and indicators that directly or indirectly determine these functions (Bujnovský et al., 2011; Burkhard et al., 2014; Makovníková et al., 2017). In agroecosystems, regulation of water regime (water storage), control of soil erosion (erosion control), climate regulation (carbon reserves in the soil) and filtration of pollutants (cleaning potential) are main regulation ES (Dominati, 2013).

ES trade-offs can be considered as one of the most important current sustainability issues (Schaafsma et al., 2021; Aryal et al., 2022), and together with ES synergies are essential for better multi-functional ecosystem management (Le et al., 2023). There are little results in the literature (Zhang et al., 2022; Dai &

Wang, 2024) on the evaluation of trade-offs between regulating ecosystem services and environmental parameters at the regional level with its subsequent connection to the climatic regions. This type of research is absent within Slovakia. Studies in this area are often focused only on a certain ecosystem, most often on protected areas and national parks (Považan et al., 2015). The aim of this study was to assess synergy and trade-offs of between agroecosystem services on at national level along the climatic gradient in the Slovak Republic.

2. Material and Method

2.1. The Regulating ES Assessment

Potential of regulation of water regime—was based on the value of retention water capacity recalculated to soil water storage in context with the soil depth. Values were categorized into five groups: 1) very low potential (<135 mm), 2) low potential (135 - 175 mm), 3) medium potential (175 - 215 mm), 4) high potential (216 - 275 mm), 5) very high potential (>275 mm).

Potential of regulation of soil erosion (water erosion)—was derived from maps and databases based on empirical model of the Universal Soil Loss Equation—USLE. The relative ratio of the calculated values of soil loss and acceptable erosion expresses the degree of soil erosion endangerment (SEOP value). Values were categorized into five categories: 1) very low potential (more than 2.60), 2) low potential (2.21 - 2.60), 3) medium potential (1.81 - 2.20), 4) high potential (1.40 - 1.80), 5) very high potential (less than 1.40).

Cleaning potential (immobilization of soil pollutants) of agricultural land ecosystem depends on the actual soil contamination and potential of sensitive soil sorbents to the sorption of risk elements. Due to considerable differences of soil sorbents on arable soils and grassland, as well as differences in the limit values of pollutants in the produced biomass, score evaluation was determined separately for different cultivation. The method is described in detail in our previous article (Makovníková et al., 2017). Values were categorized into five categories as follows: 1) very low potential (more than 6.50 points), 2) low potential (5.51 - 6.50 points), 3) medium potential (4.51 - 5.50 points), 4) high potential (3.50 - 4.50 points), 5) very high potential (lower than 3.50 points).

Climate regulation—within agroecosystems, soil organic matter represents the largest share of total organic carbon. Agroecosystems contribute to climate regulation by sequestration of organic carbon in the soil. Soil organic carbon stock (SOCS) was calculated as a function of soil bulk density (BD, g·cm⁻³) and soil organic matter content (SOC, %) according to the equation (Makovníková et al., 2017):

$$\text{SOCS (depth 0 - 0.30 m) in t}\cdot\text{ha}^{-1} = 10 * (\text{BD (0 - 0.10 m)} * \text{SOC (0 - 10 cm)} + \text{BD (0.10 - 0.20 m)} * \text{SOC (0.10 - 0.20 m)} + \text{BD (0.20 - 0.30 m)} * \text{SOC (0.20 - 0.30 cm)})$$

BD—soil bulk density in g·cm⁻³, SOC—soil organic matter content in %. The categories are as follows: 1) very low potential (lower than 58.00 t C·ha⁻¹), 2) low

potential (58.00 - 62.00 t C·ha⁻¹), 3) medium potential (62.01 - 67.00 t C·ha⁻¹), 4) high potential (67.01 - 72.00 t SOC·ha⁻¹) 5) very high potential (more than 72.00 t SOC·ha⁻¹).

For a comprehensive assessment and mapping the ES, a regular spatial network was done from a combination of agro-ecological indicators (climatic region, slope topography, land cover, soil texture) in accordance with the proposed assessment system:

- 1) Climatic region (categories: moderately cold, moderately warm, warm, and very warm).
- 2) Slope topography (categories: 0° - 2°, 2.1° - 5°, 5.1° - 12° and more than 12°).
- 3) Soil texture (categories: soil particles < 0.01 mm less than 20%, 20% - 45%, more than 45%).
- 4) Land use (arable land, grassland).

For this study, we used a classification of agro-climatic regions provided by the Information Service of the National Agricultural and Food Centre/Soil Science and Conservation Research Institute. For our purpose, the original vector layer with 11 categories were merged into four categories (climatic regions: moderately cold (regions 09, 10), moderately warm (regions 06, 07, 08), warm (regions 03, 04, 05), and very warm (regions 00, 01, 02) (**Figure 1**). The method is described in detail in our previous article [Makovníková et al. \(2022\)](#).

2.2. Data Sources

The cartographic basis for the assessment of ecosystem services was the layer of land cover LPIS (Land Parcel Identification System) and the layer of the ecosystem category Corine Land Cover (CLC), Data from the Digital Soil Map of Slovakia and data of Soil Monitoring of Slovakia ([Kobza et al., 2011, 2014](#); [Kobza, 2018](#)) were used to evaluate soil properties changes.

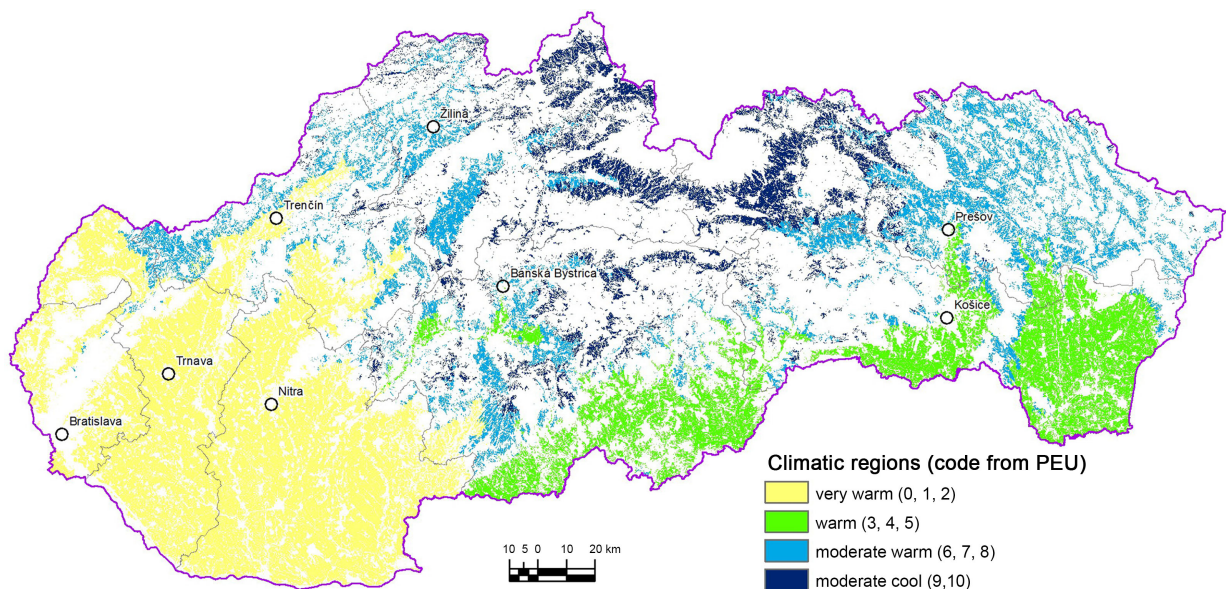
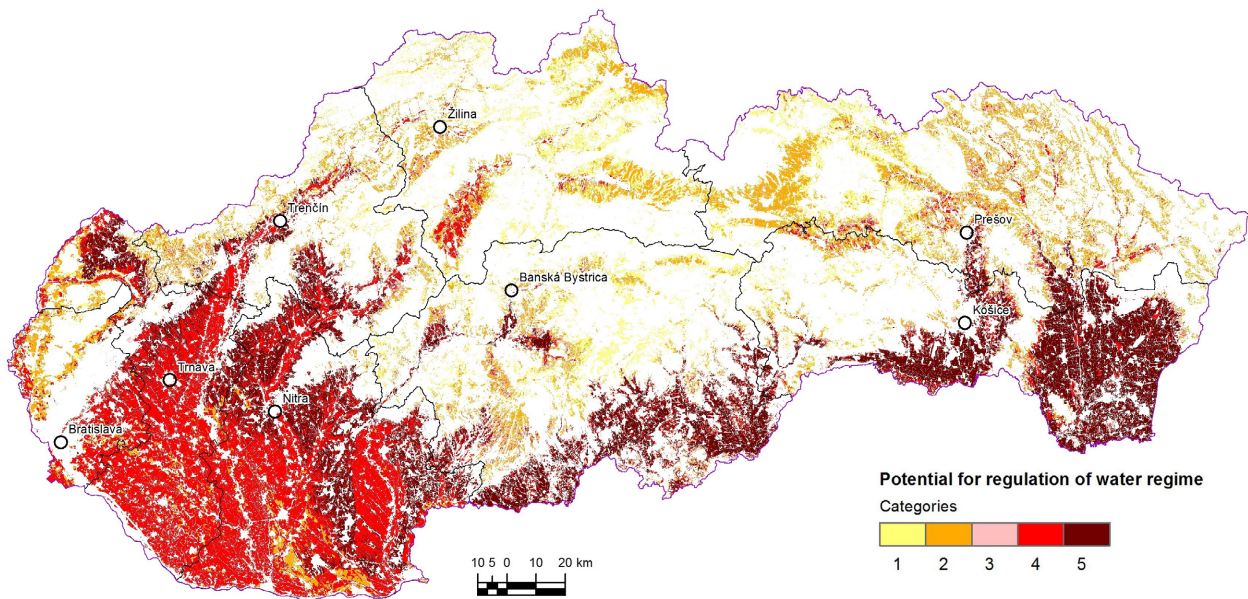


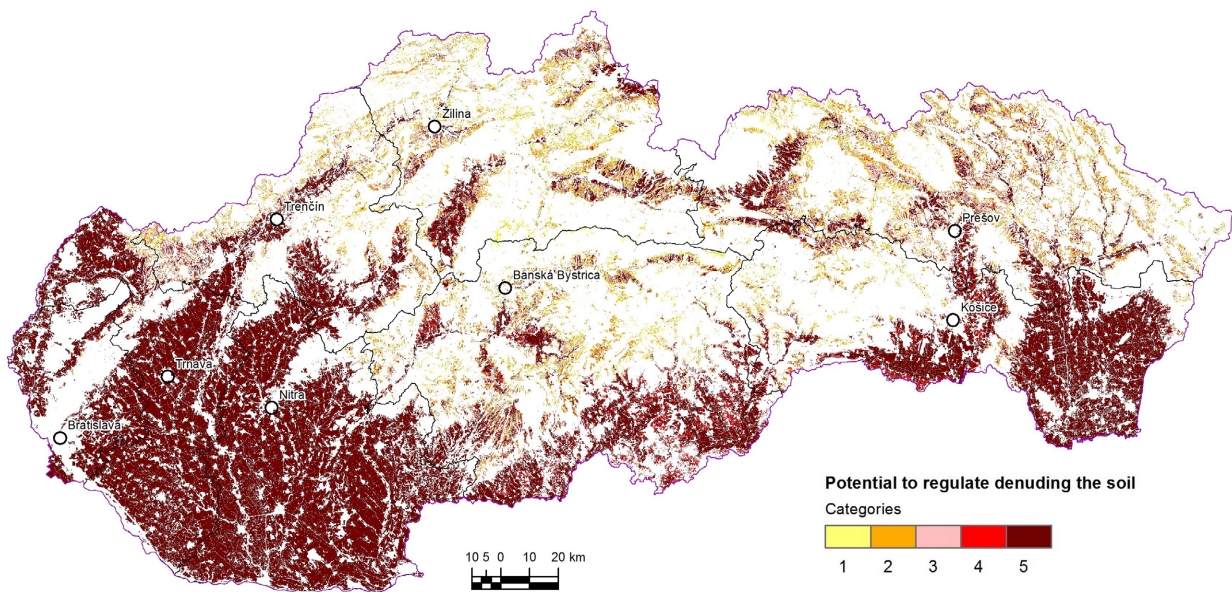
Figure 1. Categories of climatic regions in the Slovak Republic.

3. Results and Discussion

According to Alam et al. (2016), the analysis of synergies and compromises of individual categories of ES is most appropriate by comparing their potential for its performance. **Figure 2** shows the regulatory EC potential of agriculturally used soils of the Slovak Republic. In Slovakia, 27.47% of the area of agricultural ecosystems has very high potential for regulation of water regime (accumulation of water in the soil) (**Figure 2**). Ecosystems with low potential for water storage are on 21.21% of territory and they are located on deep to moderately deep, light soils without skeleton and on moderately heavy, slightly to moderately skeletal soils. The greatest influence on water storage potential in both ecosystems



(a)



(b)

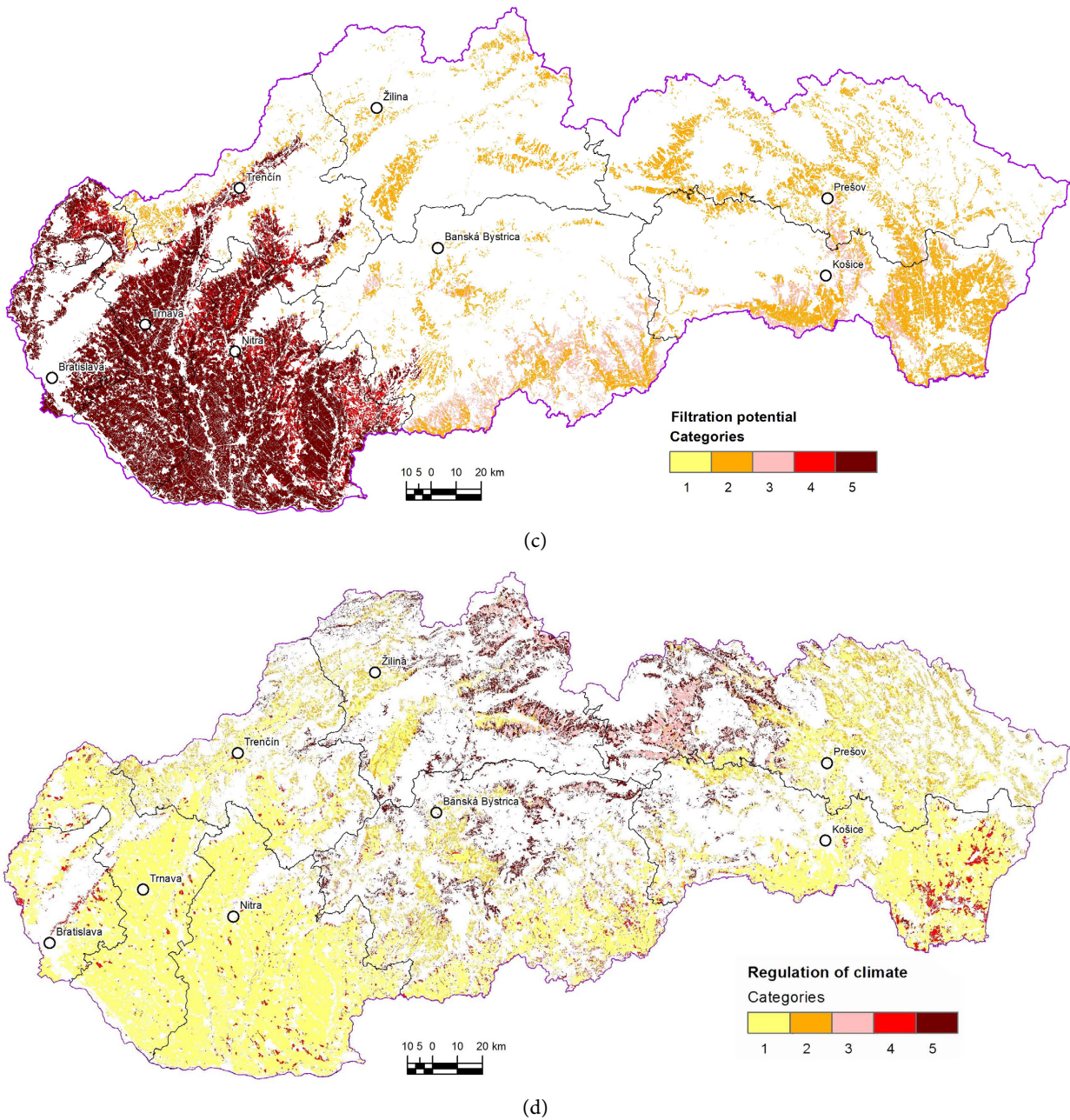


Figure 2. The potential of regulating ecosystem services of agricultural land. (a) Potential of water regulation (water accumulation); (b) Potential of erosion regulation; (c) Filtration potential (immobilization of pollutants); (d) Potential of climate regulation.

has climate, but the impact of soil texture is also significant. Agroecosystems of arable soils have a high to very high potential for regulation of soil erosion, regulation of water erosion (92% out of the total area of arable land). Arable land is located mainly in flat areas where low risk of water erosion occurs (Figure 2). Cleaning potential of ecosystems in agricultural land depends on the potential for contamination and potential of soil sorbents with high affinity to inorganic pollutants. Out of the total agricultural land in Slovakia, 41.67% of ecosystems have very high potential for soil cleaning (immobilization of inorganic pollu-

tants). These are mainly ecosystems of arable land with high carbonate content developed on loess, located in the Danube and the Eastern Slovak Lowlands without any anthropogenic and geochemical depositions (**Figure 2**). Carbon stored in ecosystems is an important indicator of regulating ES potential (Makovníková et al., 2023), which amount depends on land use and land management practices (Skalský et al., 2024). Agroecosystems contribute to climate regulation by organic carbon sequestration in soil. Soil organic carbon content can be used to represent the carbon sequestration and can be used as an indicator of climate regulation potential ES. The results of percentage distribution of various categories of potential of climate regulations are significantly influenced by the ecosystems of arable land due to high share of area of these ecosystems within the total area of agricultural land. Out of the total area of agroecosystems for agricultural land up to 94.83% belong to the category of low potential of climate regulations (**Figure 2**). Ecosystems of arable land located in lowlands are characterized by low potential for climate regulation and low average stocks of soil organic carbon. In higher altitudes, the average organic carbon stocks, and thus the potential of climate regulation is slightly rising (Barančíková et al., 2019).

ES are non-linearly linked and changes in one service can impact the others in positive or negative way (Felipe-Lucia et al., 2014). Spake et al. (2017) defines synergies when multiple services are enhanced simultaneously and trade-offs when the provision of one service is reduced due to increased use of another service. Understanding the mechanisms under ES trade-offs helps to regulate the driving factors aiming at ESs balance development, which is conducive to promoting the efficiency of ecosystem management (Dai and Wang, 2024). To identify associations of agro-ecosystem services with respect to known land use (agricultural land, arable land, or grassland), Spearman's pairwise correlation analysis was used to evaluate relationships between ES (Mouchet et al., 2017). **Table 1** shows correlations between regulating ecosystem services and environmental indicators.

The correlations between environmental indicators (climatic region, soil texture, slope and altitude) and agroecosystem services for agricultural land, arable land and grassland in the Slovak Republic are in **Table 1**. Correlation analysis between individual regulating services and climatic region, slope, texture and altitude confirms the statistically significant influence of climate and slope in agricultural land, arable land and grassland ecosystems. A positive correlation coefficient in the case of climatic region indicates a positive influence of cold climate zone, a negative one, on the other hand, a positive influence of warm climate zone. A positive correlation coefficient in the case of soil texture indicates a positive influence of clay content in soil. A negative correlation coefficient indicates a negative influence of higher slope. Together with the substrate, the climate is one of the main factors that influence the genesis of the soil-forming process. The effect of soil texture on the potential of water accumulation was demonstrated only for arable soils. In the case of arable soils, the influence of climate on the cleaning service is also more significant (**Table 1**) compared to the ecosystem of grasslands, where the effect of altitude is more pronounced.

Table 1. Spearman correlations coefficients between regulating ecosystem services and environmental indicators.

Environmental indicators	Regulating ecosystem services—agricultural land			
	water	erosion	cleaning	climate
Climatic region	−0.54**	−0.35*	−0.72***	0.21ns
Soil texture	0.36*	−0.10ns	0.17ns	−0.12ns
Slope	−0.35*	−0.72***	−0.14ns	−0.11ns
Altitude	−0.22ns	−0.20ns	−0.36*	0.10ns
Environmental indicators	Regulating ecosystem services—arable land			
	water	erosion	cleaning	climate
Climatic region	−0.59**	−0.37*	−0.78***	0.74***
Soil texture	0.46*	−0.10ns	0.10ns	−0.10ns
Slope	−0.34*	−0.73***	−0.10ns	−0.10ns
Altitude	−0.28ns	−0.18ns	−0.39*	0.14ns
Environmental indicators	Regulating ecosystem services—permanent grassland			
	water	erosion	cleaning	climate
Climatic region	−0.53**	−0.34*	−0.66**	0.10ns
Soil texture	0.27ns	−0.10ns	0.23ns	−0.14ns
Slope	−0.42*	−0.74***	−0.10ns	−0.13ns
Altitude	−0.10ns	−0.22	−0.44*	0.14ns

Significance labels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns: non-significant.

Positively correlated agroecosystem services are assumed to be synergistic, while negative correlations infer trade-offs (Felipe-Lucia et al., 2014). The relationship of individual ES and environmental indicators in different climate regions expressed through correlation coefficients is given in Tables 2(a)-(c).

We identified the impact factors of various ES trade-offs in different geomorphic and climate zones. The potential to regulate erosion is increasing with warmer climate in case of arable land as well as permanent grassland. This is related to the occurrence of deep soils in lowland areas, where warm and very warm climatic regions predominate, and the limit for acceptable loss of soil is higher. In case of arable soils, there is a potential for regulation of soil erosion at approximately the same level in moderately cold and moderately warm climatic zone. In terms of human influence factors, the land use is a relatively comprehensive factor, which is a comprehensive reflection of policies, economic trade-offs, ecological engineering (Dai and Wang, 2024).

A synergistic effect was established between the regulation of the water regime and the regulation of soil erosion and soil cleaning (Table 3), and between regulation of soil erosion and soil cleaning for agricultural land. The similar relationships have been established for arable land, supplemented by a synergistic effect between water regulation and soil cleaning service.

Table 2. (a) Spearman correlations coefficients between regulating ecosystem services and environmental indicators in different climatic regions (agricultural land); (b) Spearman correlations coefficients between regulating ecosystem services and environmental indicators in different climatic regions (arable land); (c) Spearman correlations coefficients between regulating ecosystem services in different climatic regions (permanent grassland).

(a)					
Climatic region	Environmental indicators	Regulating ecosystem services—agricultural land			
		water	erosion	cleaning	climate
Very warm	Soil texture	0.66**	−0.30ns	−0.45*	−0.15ns
	Slope	−0.17ns	−0.64**	−0.52**	−0.12ns
	Altitude	−0.41*	0.54**	0.25ns	−0.15ns
Warm	Soil texture	0.41*	−0.23	0.69**	−0.15ns
	Slope	−0.57**	−0.78**	0.35ns	−0.16ns
	Altitude	−0.10ns	−0.14ns	0.17ns	0.18ns
Moderately warm	Soil texture	0.35ns	−0.27ns	0.59**	−0.33ns
	Slope	−0.64**	−0.89***	−0.21ns	−0.37ns
	Altitude	−0.31	−0.27ns	−0.10ns	0.31ns
Moderately cold	Soil texture	0.54**	0.10nsns	0.52*	−0.14ns
	Slope	−0.55**	−0.94***	−0.40ns	−0.10ns
	Altitude		−0.10ns	0.14ns	−0.14ns
(b)					
Climatic region	Environmental indicators	Regulating ecosystem services—arable land			
		water	erosion	cleaning	climate
Very warm	Soil texture	0.81***	−0.27	−0.62*	−0.10
	Slope	−0.10	−0.60*	−0.53*	−0.10
	Altitude	0.11	0.10	−0.10	−0.11
Warm	Soil texture	0.56*	0.18	0.69*	−0.10
	Slope	−0.54*	−0.75**	0.39	−0.10
	Altitude	−0.29	−0.15	−0.10	−0.11
Moderately warm	Soil texture	0.44	0.10	0.71**	−0.10
	Slope	−0.81***	−0.94***	−0.26	−0.10
	Altitude	0.37	0.35	0.23	−0.11
Moderately cold	Soil texture	0.64*	0.10	0.37	−0.23
	Slope	−0.52*	−0.95***	−0.41	−0.10
	Altitude	0.29	−0.14	0.14	−0.25

Continued

		(c)			
Climatic region	Environmental indicators	Regulating ecosystem services—permanent grassland			
		water	erosion	cleaning	climate
Very warm	Soil texture	0.55*	-0.35	-0.37	-0.41
	Slope	-0.32	-0.72**	-0.57*	-0.31
	Altitude	0.41	-0.18	-0.52*	0.10
Warm	Soil texture	0.25	-0.30	0.73*	-0.43
	Slope	-0.72***	-0.89***	0.34	-0.50
	Altitude	0.10	-0.49	0.78**	-0.53*
Moderately warm	Soil texture	0.39	-0.10	0.59*	-0.56*
	Slope	-0.68*	-0.92	-0.28	-0.53*
	Altitude	-0.10	0.10	-0.27	-0.26
Moderately cold	Soil texture	0.43	0.10	0.69*	-0.40
	Slope	-0.63*	-0.97***	-0.50	-0.29
	Altitude	0.35	0.45	0.10	0.10

Significance labels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns: non-significant.

Table 3. Spearman correlations coefficients between individual regulating ecosystem services.

Agricultural land		Regulating services			
		water	erosion	cleaning	climate
Regulating services	water	-			
	erosion	0.54***	-		
	cleaning	0.30*	0.33*	-	
	climate	-0.26ns	-0.20ns	-0.10	-
Arable land		Regulating services			
		water	erosion	cleaning	climate
Regulating services	water	-			
	erosion	0.54***	-		
	cleaning	0.36**	0.31*	-	
	climate	-0.47***	-0.21ns	-0.34*	-
Permanent grassland		Regulating services			
		water	erosion	cleaning	climate
Regulating services	water	-			
	erosion	0.52***	-		
	cleaning	0.28ns	0.34*	-	
	climate	0.10ns	0.13ns	0.19ns	-

Significance labels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns: non-significant.

Between the regulation of the water regime and the regulation of soil erosion within each climatic regions, statistically significant synergistic effects are determined (**Table 4(a)**), except for the very warm climatic region. Only in very warm climatic region, the potential of soil erosion regulation service and the potential of soil cleaning (immobilization of inorganic pollutants) are also mutually beneficial.

The synergistic effect between water regulation and erosion regulation was confirmed in two climatic regions, namely in moderately warm and moderately cold, both for arable land and for permanent grassland (**Table 4(b)**, **Table 4(c)**). In the case of arable soils, we established a synergistic effect between soil cleaning and erosion regulation in two climatic regions, namely in a very warm and a warm climatic region. In synergy, the cooperation of individual components occurs, and the resulting effect is a higher potential of individual services (Spake et al., 2017; Felipe-Lucia et al., 2014).

Table 4. (a) Spearman correlations coefficients between individual regulating ecosystem services in different climatic regions—agricultural land; (b) Spearman correlations coefficients between individual regulating ecosystem services in different climatic regions—arable land; (c) Spearman correlations coefficients between individual regulating ecosystem services in different climatic regions—permanent grassland.

		(a)			
Climatic region	Environmental indicators	Regulating ecosystem services—agricultural land			
		water	erosion	cleaning	climate
Very warm	water	-			
	erosion	0.10ns	-		
	cleaning	-0.23ns	0.44**	-	
	climate	-0.33ns	-0.20ns	-0.14ns	-
Warm	water	-			
	erosion	0.61***	-		
	cleaning	0.25ns	-0.38ns	-	
	climate	-0.27ns	-0.20ns	-0.10ns	-
Moderately warm	water	-			
	erosion	0.74***	-		
	cleaning	0.35ns	0.21ns	-	
	climate	-0.17ns	-0.10ns	0.15ns	-
Moderately cold	water	-			
	erosion	0.59**	-		
	cleaning	0.20ns	0.34ns	-	
	climate	-0.17ns	-0.10ns	0.32ns	-

Continued

		(b)			
Climatic region	Environmental indicators	Regulating ecosystem services—arable land			
		water	erosion	cleaning	climate
Very warm	water	-			
	erosion	-0.14	-		
	cleaning	-0.62*	0.53*	-	
	climate	-0.10	0.12	-0.12	-
Warm	water	-			
	erosion	0.47	-		
	cleaning	0.31	0.51*	-	
	climate	0.10	0.14	-0.10	-
Moderately warm	water	-			
	erosion	0.80**	-		
	cleaning	0.45	0.18	-	
	climate	0.23	0.14	-0.14	-
Moderately cold	water	-			
	erosion	0.51*	-		
	cleaning	0.28	0.45	-	
	climate	0.22	0.17	-0.17	
		(c)			
Climatic region	Environmental indicators	Regulating ecosystem services—permanent grassland			
		water	erosion	cleaning	climate
Very warm	water	-			
	erosion	0.10	-		
	cleaning	0.10	0.36	-	
	climate	0.17	0.10	0.41	-
Warm	water	-			
	erosion	0.69*	-		
	cleaning	0.23	-0.36	-	
	climate	0.24	0.27	-0.32	-
Moderately warm	water	-			
	erosion	0.68*	-		
	cleaning	0.56*	0.30	-	
	climate	0.15	0.17	0.10	-
Moderately cold	water	-			
	erosion	0.72**	-		
	cleaning	0.39	0.45	-	-
	climate	0.20	0.12	0.10	

Significance labels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, ns: non-significant.

Compromises in the management of the arable soil ecosystem are necessary to ensure the regulation of the water regime and to preserve the potential of soil cleaning in a very warm climate region. In connection with climate change and warming, it will be necessary to pay more attention to the accumulation of water and its retention in the country in this region. A warm, dry, lowland region has a higher potential for regulating the water regime, cleaning potential as well as regulating of soil erosion than a moderately warm to moderately cold region. These results are consistent with the position of soil, its properties, processes, and functions in the concept of ES (Bujnovský et al., 2011; Kanianska et al., 2016). In warm, dry, lowland regions, agroecosystems are developed on Chernozems, Mollic Fluvisols, Fluvisols, Cutanic Luvisols on soils with optimal parameters for the filtration of pollutants, and water accumulation. Ecosystems of arable soils in colder regions have a higher potential for climate regulation.

Mutual correlations and comparison of the potential make it possible to optimize the management of a specific monitored site depending on its location and natural conditions.

4. Conclusion

Applying the concept of agroecosystem services can help to show the effects of land use, climate conditions as well as human interventions through qualitative and quantitative analysis of trade-offs between different ecosystem services and support the development of more sustainable site-specific land use strategies. Ecosystem services are non-linearly interconnected and changes in one service can positively or negatively affect another. This study allows us to link the analysis of land use and differences in synergies and trade-offs of agroecosystem services in different climate regions. The evaluation of agroecosystem services linked to spatial visualization enables the management of agroecosystems to be optimized, thereby promoting synergies between the functioning of the ecosystem and the social dynamics of the region. This study indicates that climate has the most significant impact on agroecosystem services. Mutual correlations and comparison of the potential of agroecosystem services allow to optimize the management of a specific monitored site depending on its location and natural conditions and thus support the synergy between the functioning of ecosystems and the social dynamics of the given territory. Based on our results, we can conclude that regulatory measures aimed at regulating the water regime in the soil will also support the regulation of erosion in certain climatic regions. A higher slope of agricultural land is risky for the accumulation of water in the soil and the regulation of erosion, and in a very warm climate region also for the immobilization of pollutants (cleaning). The management of agroecosystems should always be oriented towards optimizing the provision of ecosystem services and of current needs within the framework of the sustainable use of agroecosystems.

Our approach, which combines different landscape parameters into one consolidated scale, it emphasizes the importance of landscape parameters for the

provision of agroecosystem services, and its strength is the agroecosystem services database at the same spatial scale. Our results showed the possibility of using these types of national data for the trade-offs analysis of agricultural land in Slovakia along the gradients of climatic regions, land cover, soil texture and soil slope, thereby effectively expanding the interpretive potential of our results towards sub-national estimates of agroecosystem services potential. Therefore, we assume that our study contributes to the research gap on spatial distributions of agroecosystem services at an adequate level of detail necessary for any practical solution leading to accurate planning of sustainable agricultural land management.

According to the definition of sustainable intensification, the EU requires that even with measures to increase the primary production of agriculturally used soils, emphasis is taken on preserving the multifunctionality of the soil and, thus, on the sustainability of the agroecosystem's potential to provide regulating ecosystem services as well. Therefore, decision-support tools for evaluating and tracking soil resources in the context of agroecosystem services should be the subjects of future research.

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Conflicts of Interest

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

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