LANDSCAPE VULNERABILITY ASSESSMENT IN THE DYJE RIVER BASIN

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Abstract
The primary objective was to assess the area's susceptibility to degradation defined as the loss of its ability to perform ecosystem functions and services. This was achieved using the ESAI+ (Environmental Sensitivity Assessment Index) which integrates environmental and socio-economic indicators to identify potential risks well in advance. The method provides a comprehensive assessment of the state of territory and its susceptibility to degradation based on evaluation of 16 parameters grouped into four thematic components. For practical use, the resulting index of degradation risk is categorized into eight classes. This method is followed by an analysis of the functionality of the landscape and its resilience in climate change conditions. Based on the inter-comparison of categories across the selected territorial units, the most at-risk areas were identified, highlighting where mitigation and adaptation measures should be prioritized. The assessment was carried out at the habitat level in the detail of a regular square grid with a 100x100m grid spacing.

Key words: degradation, landscape, spatial analysis, GIS

Introduction

Human well-being depends on the environment; however, increasing land-use intensity heightens anthropogenic pressure, leading to ecological challenges. Identifying specific thresholds is essential to preventing the onset of land degradation processes.

Since the beginning of the 21st century, environmental quality has become unsustainable in the long term due to escalating land-use pressures. Land degradation typically results from a complex interplay between environmental processes and anthropogenic influences (Wilson & Juntti, 2005). Human activities contributing to land degradation are often exacerbated by natural conditions and further intensified by climate change and biodiversity loss (UNCCD, 1994). At a global scale, factors such as climate change, economic development, landscape transformation, and population pressure drive soil and landscape deterioration, leading to land degradation (Geist & Lambin, 2004). Additionally, urbanization and industrial expansion further contribute to this process (Oliveira et al., 2018). Vulnerability to degradation varies depending on environmental conditions, even under similar land-use patterns (Darradi et al., 2012; Van der Werf and Petit, 2002). Factors such as topography, soil properties, climate, and geology play a crucial role in determining the susceptibility of agricultural landscapes to degradation (Nowak & Schneider, 2016).

Materials and methods

Study area

The Dyje River basin is a third-order river basin in Central Europe, and a sub-basin of the Morava River, collecting water to Dyje river either directly or via its tributaries. It covers western, south-western, and central-western Moravia, along with adjacent parts of Lower Austria and, to a lesser extent, Bohemia. The largest city within the basin is Brno. The highest point in the basin is Javořice (837 m. a. s. l.), the lowest point is the mouth of the Dyje River into the Morava River, 148 m above sea level. The basin has a general south-eastward slope.

Methods

For land degradation risk assessment, the ESAI (Environmental Sensitivity Assessment Index) was used. The method is based on the combination of 16 parameters grouped into four thematic components (quality of climate, soil, vegetation and management). From these parameters, an index of the area's susceptibility to degradation is first calculated for each thematic component and then aggregated into an overall index which is classified into eight categories. A detailed description of the methodology can be found in Pechanec et al. (2021).

The next step involves analysing i) landscape functionality using a look-up table assessment of three key functions essential for regulatory ecosystem services: evapotranspiration, carbon storage and habitat provision, ii) landscape resilience to climate change based on assessment of “resilience preconditions”, including species diversity, habitat heterogeneity and connectivity, and iii) assessment of climate change risk based on historical, current and predicted climatic data. The assessment was carried out at the habitat level in the detail of a regular square grid with a 100x100m grid spacing. The calculation of values consists of several steps, including assigning values to segments, computing the area-weighted average for each square, normalizing data on a 1-2 scale (climate change risk, CCR), and calculating geometric averages for ecological functions (EF) and resilience preconditions (RP). The results of each assessment are divided into three categories. The matrix table with all combinations of value categories in the assessed parameters (CCR, EF, RP) was proposed, based on which the types and urgency of mitigation and adaptation measures are assigned and visualized on a map.

Results

Firstly, the ESAI value for each landscape segment was calculated and then categorized into 8 categories of degradation risk. A basic overview of the different categories and their values (average over the whole area) is shown in Table 1. Their spatial distribution is shown on Fig.1.

Tab. 1: ESAI categories and their average values in the Dyje river basin

Category	Area (ha)	Area (%)	ESAI average	ESAI STD
N - unaffected area	5434,09	0,52	1,145	0,022
P - potentially vulnerable	31635,72	3,04	1,2	0,014
F1 - weakly vulnerable area	66062,81	6,34	1,242	0,011
F2 - slightly vulnerable area	138542,88	13,3	1,291	0,017
F3 - highly vulnerable area	101340,3	9,73	1,345	0,014
C1 - weakly critically endangered area	74460,66	7,15	1,39	0,012
C2 - slightly critically endangered area	402929,61	38,69	1,468	0,034
C3 - critically endangered area	221001,46	21,23	1,577	0,042
Total / Average	*1041407,53*	*100*	*1,33*	*0,02*

The most represented category is C2 - a slightly critically endangered area, which occurs in 39% of the study area. The critically endangered areas (C3) cover cca 21% of the area, mainly lowlands, where densely urbanized or intensively managed land dominates, for example areas including Brno and adjacent agricultural land. The most endangered areas are related to two main factors: drier and warmer climatic conditions and intensive agriculture.
regulatory capability of the landscape is impaired.

In the next step, the functionality of the landscape was assessed based on the performance of three ecosystem functions; their lower performance indicates a higher risk of landscape vulnerability, as the self-regulatory capability of the landscape is impaired. The results correspond to the typical agricultural landscape, with extremely low performance of habitat provision reflecting the impact of intensive agricultural practices, which limit biodiversity and reduce habitat availability for various species. Carbon storage is also rather low in most areas (except for forests), which aligns with the dominance of agricultural land, which generally contributes to lower long-term carbon retention. Evapotranspiration is performed at the average level in most areas.
In the third step, landscape resilience was assessed, as it is crucial for maintaining ecological stability under climate change conditions. The results are summarized in Tab. 2. The overall resilience, based on indicators of resilience preconditions, is generally moderate. However, nearly 13% of the area exhibits low resilience, indicating limited self-regulation and adaptive capacity, making it highly vulnerable to habitat deterioration under changing climate conditions.

Finally, individual vulnerability indicators and their combinations were evaluated to determine the urgency and types of mitigation and adaptation measures. Tab. 3 presents the proportion of the area assigned to different measure types and urgency levels. More than 58% of the Dyje River Basin requires interventions to enhance ecosystem functions and resilience. Urgent action is needed in over 8% of the area, particularly in the northern and central regions, where vulnerability is highest. To mitigate future environmental risks, recommended strategies include reforestation, biodiversity support, and sustainable land-use planning.

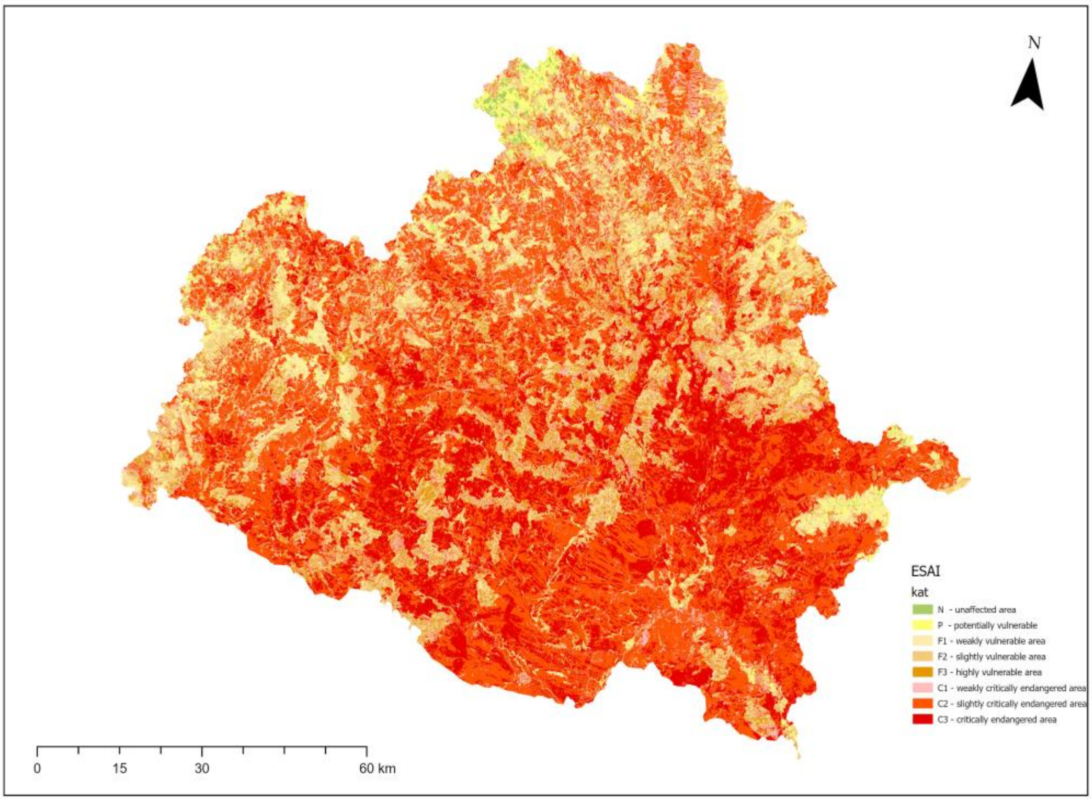

Fig. 1: Final ESAI index.

Tab. 2: Categories landscape resilience in the Dyje river basin

Category of resilience	Area (%)
low	12,72
middle	84,33
high	2,95

Tab. 3: Priority category (urgency) to implement mitigation or adaptation action and type of measure needed in the Dyje river basin

Priority	Type of measure	Area (%)
---	Area without urgent problems	1,19
low	Support of ecosystem functions and resilience	2,42
low	Support of resilience	6,21
low	Support of ecosystem functions and resilience	8,65
medium	Support of ecosystem functions	6,78
medium	Support of ecosystem functions and resilience	50,06
medium	Support of resilience	11,25
high	Support of resilience	5,08
high	Support of ecosystem functions and resilience	8,36

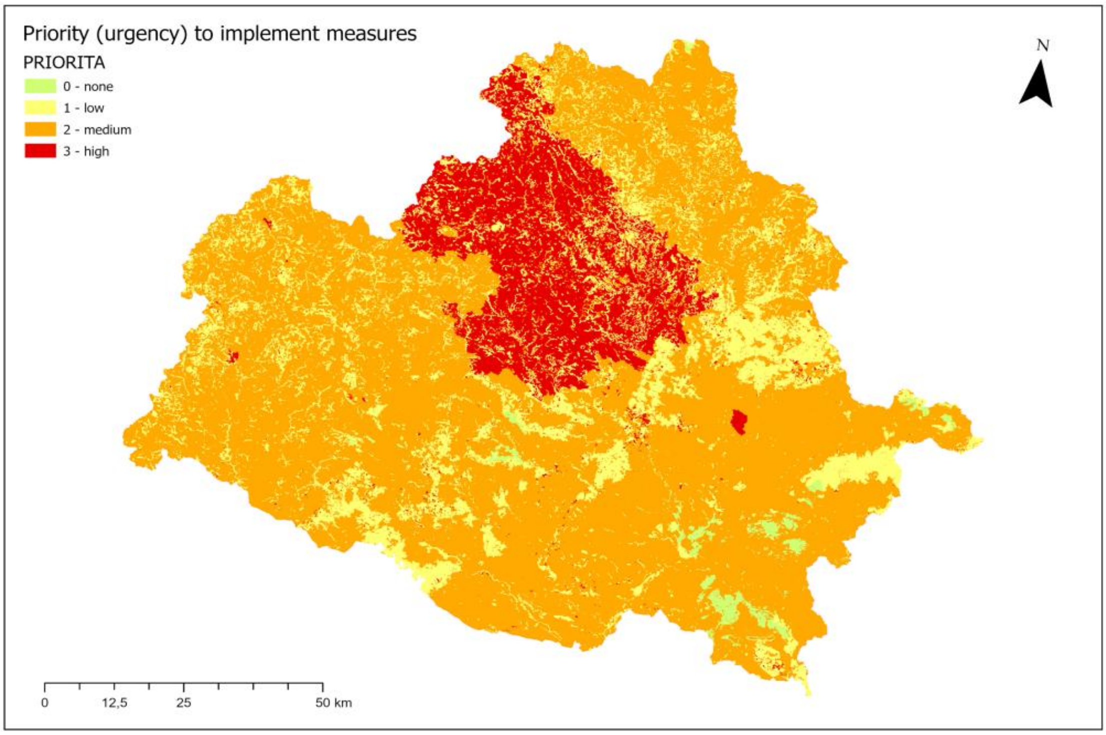

Fig. 2: Spatial distribution of priority categories to implement mitigation or adaptation

Discussion

The ESAI methodological approach quantifies the interactions of various factors over time (e.g., climatic conditions, land-use change, and land-cover change) that contribute to land degradation. Environmentally sensitive areas are often characterized by unsustainable environmental and socioeconomic conditions (Basso et al., 2012). The accuracy of the ESAI is directly dependent on the quality of the source data. However, obtaining all data at the same level of accuracy was challenging, particularly for variables such as precipitation and temperature. Another limitation was the inconsistent availability of data across Czechia, requiring the integration of multiple sources, such as forestry and agricultural datasets for soil quality assessment (Jakubínský et al., 2019). Additionally, inaccuracies in indicator values arose when different methods were used to reclassify or convert absolute values into sensitivity values. In most cases, expert judgment was required to fine-tune the final scale of individual ESAI values. The practical application of individual assessment results was proposed by combining value categories—land degradation, ecosystem functions, resilience preconditions, and climate change risk—to determine the urgency and appropriate type of mitigation and adaptation measures and localize them in a map. The map of proposed measures in the Dyje River basin highlights a significant portion of the area where intervention is recommended. However, it is important to note that the study area primarily consists of regions highly susceptible to degradation, characterized by the warm and dry climate, high exposure to climate change, intensive agricultural use, and dense settlement.

Conclusion

This approach, termed ESAI+, serves as a comprehensive system for assessing degradation risk, landscape functionality, and resilience preconditions critical for landscape stability under changing climate conditions. The proposed method provides a structured framework for restoration-focused mitigation and adaptation strategies, offering practical applications for landscape planning and the development of adaptation measures.

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Souhrn
Představený přístup s názvem ESAI+ slouží jako souhrnný systém pro hodnocení rizika degradace, funkčnosti krajiny a předpokladů resilience, jež jsou nezbytné pro udržení stability krajiny v podmínkách klimatické změny. Navrhovaná metoda poskytuje strukturovaný rámec pro návrhy typů adaptačních a mitigačních opatření, nabízející praktickou aplikaci výstupů vědeckých analýz pro krajinné plánování a návrh adaptačních strategií.

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