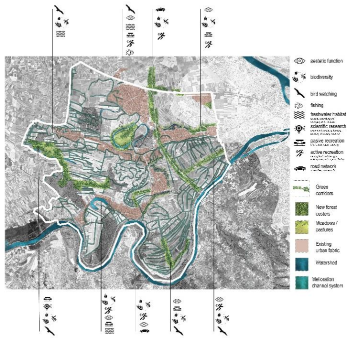

Landscape approach to Forest landscape restoration (FLR): Case study of Surčin minicipality

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Abstract

“Planning at the landscape scale” is the new paradigm of spatial development which embraces the management, protection, and restoration of the landscape character distinguished through “landscape approach” which differs from traditional sectoral and project-based approaches.

The institutionalization of “the planning at the landscape scale” has shown an upward trajectory since the Republic of Serbia ratified the European Landscape Convention (ELC). The ELC aims to promote the institutionalization of landscape planning, management, and protection across all landscapes, whether urban, rural, or natural. The landscape planning approach integrates the principles of landscape ecology, principles of landscape aesthetics, and transdisciplinary research. This approach is solution-oriented, aiming to preserve, restore, and enhance the landscape’s character – the distinctive structure and image of the landscape. It achieves this through the “conservation and development of landscape patterns (mosaic), considering land use, the relationship between built and open spaces, and the distinct qualities of the buildings." (Spatial Plan of the Republic of Serbia, 2035).

As one of the novel tools that can effectively support the achievement of national-level spatial planning objectives, the development of the Forest Landscape Restoration (FLR) methodology holds the potential for incorporating the following goals and principles related to landscape planning, protection, and sustainable utilization:

- Integrating the landscape approach (emphasizing the value of landscape character) into the forestry planning and management system;

- Forestry development aligned with the recognized values of the landscape character (quality objectives, landscape capacity, and sensitivity);

- Urban landscape restoration, preservation, and enhancement of the characteristic structure and image of landscapes through; a) establishing urban spatial order and preserving remnant elements of the rural landscape (reforestation and afforestation within agroforestry areas, peri-urban mosaics complexes, surface watercourses) in suburban areas; d) preserving space for green infrastructure development, as a measure of the city's adaptation to climate change, and creating a network of green and public spaces that connect the natural and cultural values of urban settlements.

In this paper, we present the Surčin Forest Landscape Restoration Plan case study, demonstrating landscape character assessment (LCA) as a research method. This method evaluates the sensitivity of landscape character, addressing both resource and visual aspects. The methodological approach seeks to address the critical questions of “what”, "where" and "how" in the context of establishing new forest areas within the broader landscape framework of the forest restoration plan. By providing a strategic and spatially informed approach, it ensures that the restoration efforts are not only ecologically sound but also optimally positioned to enhance the resilience, biodiversity, landscape diversity, and connectivity of forest ecosystems, as well as to improve the cultural ecosystem services of the Municipality of Surčin.

Keywords

Forest landscape restoration (FLR); Landscape planning; Landscape approach; Landscape character assessment; Forest

Contents

1 Introduction

The European Landscape Convention (ELC) makes a revolution in thinking about landscape. In defining the landscape approach, ELC moved away from the idea of identifying or designating specific exceptional ‘land’, as UNESCO does (2023), but understood it more in terms of all ‘territory’. This pioneering approach to landscape quality provides a holistic view of the landscape that has grown out of contemporary thinking on sustainability and understanding of the human condition related to ecological processes, culture, and nature, and as such it is an important precedent with considerable potential global significance (Selman 2006, 2010, Roe 2008, Roe et al., 2008). In heuristic terms, planning at the landscape scale is solving scientific problems and tasks based on: the concept of *landscape as a whole*, *transdisciplinarity* in the research approach, and *landscape character as a new value* in the planning, protection, and management systems but also in an integral interpretation of the knowledge about landscape (Vasiljević 2018, 2020).

Since 2000 when the European Council put a convention for assignment, 40 European countries ratified the convention (CoE 2000). The ELC sets out general and specific measures at the national and international level that countries should undertake. In terms of general measures, in addition to recognizing the importance and role of landscapes and establishing relevant policies aimed at landscape protection, management, and planning through the adoption of specific measures, countries must implement procedures to enhance public and stakeholder participation in the development and execution of landscape policies. Furthermore, they must ensure procedures for landscape identification and assessment throughout their territory, considering the particular landscape values assigned by the interested parties and the population concerned (CoE 2000).

Ratification of the ELC in 2011 (Off. Gazette of the RS, no. 4/2011) created a more favourable context for Serbian planners to apply the holistic approach of landscape conceptualization which has been implemented in The Spatial Plan of the Republic of Serbia (SPRS) for the period from 2010 to 2020 and from 2021-2035. Legislative measures for the implementation of the third national planning document (SPRS 2021-2035) foresee the development of landscape character assessment, as a methodology for identification of the landscape character, its protection, and management at the regional and local levels through sectoral planning (forestry, agricultural, transportation system, infrastructure, tourism, etc.). The role of forestry planning and management is among the most important in this process.

The World Conservation Union and the World-Wide Fund for Nature have been promoting a “forest landscape restoration” (FLR), since 1999, to provide a complementary framework to sustainable forest management and the ecosystem approach to ecological restoration, combining forest restoration and reconstruction activities at the site level with meeting environmental, social, and economic needs at the landscape and ecological level.

A term was defined by a group of experts in 2000 as “a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes”. However, today, the term FLR has evolved and is interpreted in diverse ways, partly reflecting the variety of environmental and social issues worldwide, including those associated with land degradation and climate change" (Mansourian 2005; Mansourian et al. 2017; Stanturf et al. 2017). The Forest Landscape Restoration (FLR) approach is conceptualized through: A focus on landscape; Maintaining and enhancing natural ecosystems within landscapes; Engaging stakeholders and supporting participatory governance; Tailor to the local context using a variety of approaches; Restore multiple functions for multiple benefits; Manage adaptively to enhance the resilience of the landscape and its stakeholders over the medium and long-term (UNFCCC 2003; Besseau et al. 2018). Based on reflection on developments in FLR, Mansourian et al. (2017) argue that significant *gaps persist in implementing FLR at the landscape scale* and in an *interdisciplinary manner* as well as in promoting the role of restoration in climate change responses and improving *methodologies for measuring long term impacts* and their application.

Forest landscape restoration (FLR) aims to return forests to a landscape in a way that meets both human needs and ecological priorities and *to achieve a landscape containing valuable forests*, rather than returning forest cover across an entire landscape (Mansourian et al. 2005; Lamb 2014). FLR plan aims *to identify strategic areas for new forest design*, reforestation, and afforestation, with particular emphasis on the artificial establishment of trees. In the case of *afforestation*, this involves the introduction of tree cover in landscapes where forests have not previously existed (for a period of at least 50 years), while *reforestation* is defined as the direct human-induced conversion of non-forested land to forested land on land that was forested but that has been converted to non-forested land, thereby fostering new ecosystems and contributing to long-term ecological restoration and sustainability (Mansourian et al. 2005, UNFCCC 2003). A key aspect of this process lies in identifying areas for restoration by transdisciplinary addressing the fundamental questions of “*what” should be restored, for “whom” the restoration efforts are intended, and “why” such restoration is necessary*. There is no proposed methodology for the FLR planning process, but it’s spatial, functional, and contextual complexity is evident.

Therefore, the landscape character assessment (LCA) as a research method for Surčin Forest Landscape Restoration Plan is proposed here. The main objective is to explore concrete landscape assessment methods derived from the main ELC principles of “planning, protection, and management at the landscape scale”. The research seeks to achieve the following objectives:

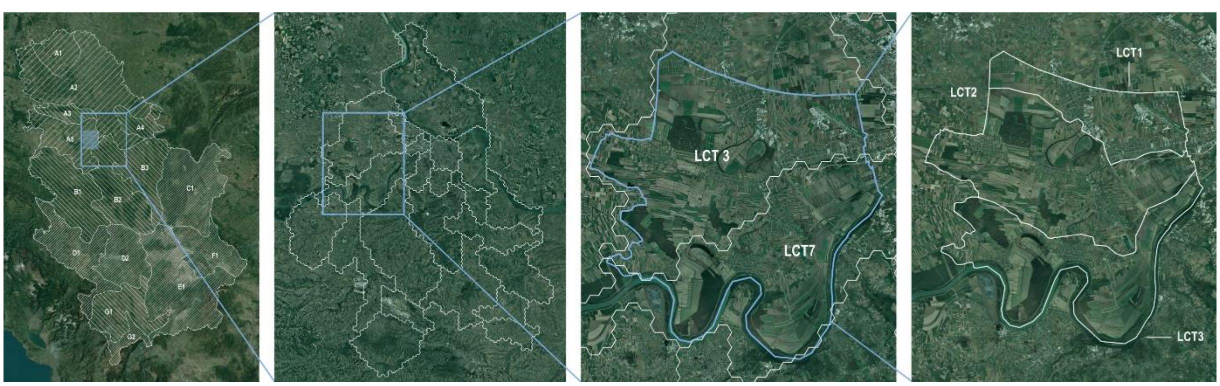
- To explore the Landscape character assessment as a methodological approach for understanding, assessing, and evaluating landscapes, as introduced by the European Landscape Convention (ELC), and its applicability in implementing Forest Landscape Restoration (FLR).
- To identify the most suitable indicators and metric parameters for assessing and quantifying landscape quality and sensitivity, particularly in relation to monitoring and measuring the long-term impacts of forest restoration.

2 Materials and methods

2.1 Research area and data

The Municipality of Surčin is strategically located within the Belgrade Metropolitan area (Figure 1b, Figure 1c), one of the 17 urban municipalities that form the City of Belgrade and includes 9 Local Communities which are territorially organized in 7 cadastral municipalities: Bečmen, Boljevci, Dobanovci, Jakovo, Petrovčić, Progar, and Sučin.

The study area, as defined by the Spatial Plan of the Municipality of Surčin, covers 20,660 hectares (Official Gazette of the City of Belgrade, no. 10/2012).



a. Landscape character types at the National level
b. Landscape character types at the Regional level
c. Landscape character types at the Regional level of the Surčin Municipality
d. Landscape character types at the Local level of the Surčin Municipality

Figure 1. Landscape Typology of the Republic of Serbia.

Located within the Sava-Kolubara zone, Surčin holds significant importance in the City of Belgrade and encompasses fertile soils that contribute to agricultural productivity. Additionally, the municipality serves as a “vital node” in regional and national transportation networks, intersected by key traffic routes, including the International E-road network’s North-South European route E75 and the West-East European route E70.

Following the methodology of Landscape Character Assessment, the diversity of landscape structure, function, meaning, composition and configuration of the territory of Serbia is represented by 15 distinct landscape character types (SPRS 2021-2035). Surčin is part of the Posavina Landscape character type, characterized by a lowland of larger rivers, featuring a mix of homogeneous and heterogeneous agricultural areas, as well as linear and compact settlements (Figure 1a).

Based on the Regional Landscape Typology from *The Atlas of Landscape Character Types of Belgrade* (2020), Surčin covers two of the 22 distinct landscape character types within the Belgrade Metropolitan Area (Figure 1b and 1c): (a) LCT3 – the alluvial landscape of Posavina, and (b) LCT7 – the marshland of the Srem Plain.

2.2 Research methodology

The landscape analysis and assessment for the Municipality of Surčin follow a multi-stage process that integrates three key phases: identification of landscape character types, and the analysis and assessment of landscape sensitivity (Figure 2).

This comprehensive approach to landscape sensitivity evaluation allows a detailed understanding of landscape quality, biodiversity sensitivity, and visual sensitivity. Practical techniques for landscape assessment are grounded in GIS techniques. Landscape metrics were used to quantitatively describe landscape structure on the landscape and class level (Prastacos et al. 2017; Ramos and Silva 2019; McGarigal et al. 1995). The metrics parameters assess and evaluate spatiotemporal changes within the landscape (McGarigal et al. 1995; Mitrović et al. 2023; Elmi, et al. 2022). In this study, landscape metrics parameters are applied to evaluate the landscape quality indicators *coherence, complexity, naturalness,* and *openness* (Ćorović et al. 2024; Mitrović et al. 2023; Vasiljević et al. 2022; Gavrilović et al. 2017), and landscape biodiversity indicators such as *heterogeneity*, *land use intensity*, *connectivity*, and *resilience* (Bergamini et al. 2013; Walz and Stein 2014; Botequilha-Leitão et al. 2006).

Landscape structure analyses were performed on the land cover medium in vector form as a result of remote sensing with a spatial resolution of 10 m (CLC, Urban Atlas). The subject base has 10 classes of CLC and for the needs of the project, it is interpreted through the principles of landscape ecology, i.e. through the spatial models that enable the landscape structure analysis through - *patch-corridor-matrix*. Data for the analysis were sourced from the Urban Atlas (2018), which provides metadata for urban land use (Copernicus 2023; https://land.copernicus.eu/en/products/urban-atlas/urban-atlas-2018, accessed on 22nd of May 2023). The assessments are based on the shape, size, distribution, and edge characteristics of landscape elements. These calculations were performed using the Spatial Analyst extension in ArcMap, enabling a comprehensive analysis of landscape patches across all urban land use classes.

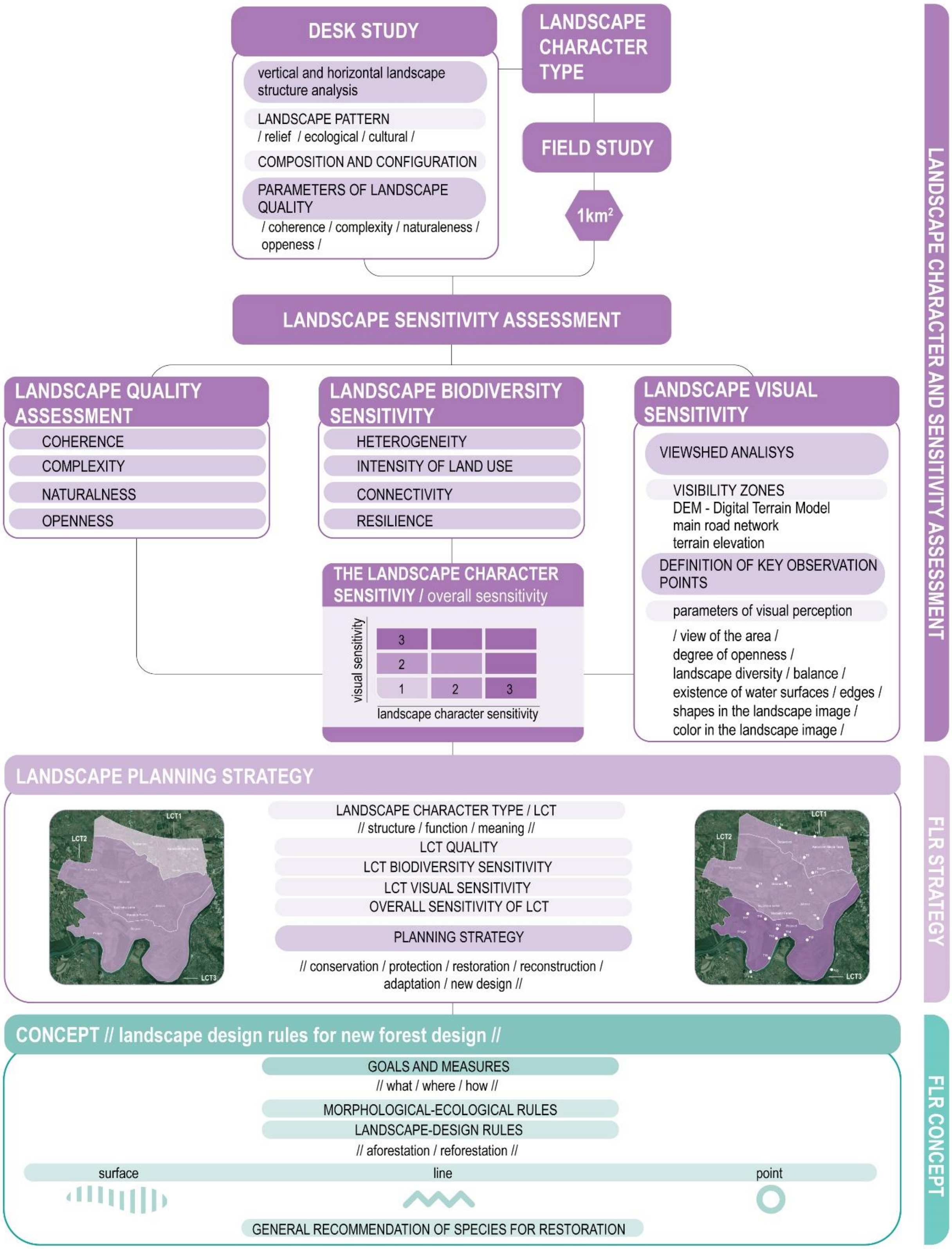
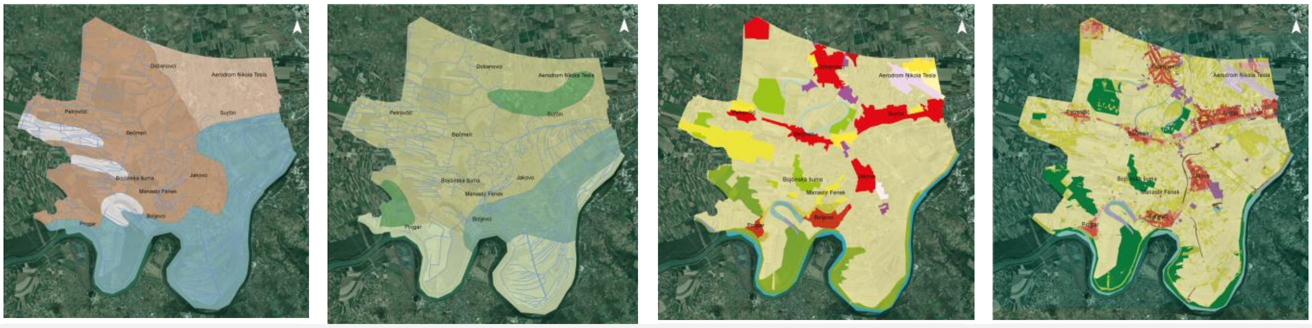


Figure 2. Methodological framework for Forest landscape restoration.

2.2.1 Landscape character and sensitivity assessment

The *landscape character assessment* is based on systematically examining both vertical and horizontal landscape structures. This process begins with an exploration of *relief patterns* (Digital Elevation Model, hypsometric and geomorphic characteristics of landscape development), followed by *ecological patterns* (natural and potential vegetation) and *cultural patterns* (land cover and land use pattern) (Figure 3).



a. Relief pattern	b. Ecological pattern	c. Cultural pattern Corine Land Cover	d. Cultural pattern – Urban Atlas

Figure 3. Landscape Pattern Analysis of Surčin Municipality.

The previous exploration resulted in the designation and identification of landscape character types (LCTs), focusing on structural, functional, and visual landscape elements, and described by *parameters of composition and configuration*. This approach highlights the distinct qualities of each LCTs, designated by indicators such as *coherence, complexity, naturalness,* and *openness* (Gavrilović et al. 2017; Ćorović et al. 2024, The Atlas of Landscape Character Types of Belgrade 2020).

Following the identification of LCTs, *the landscape sensitivity assessment* is conducted by encompassing three main aspects: *landscape quality assessment*, *landscape biodiversity sensitivity*, and *landscape visual sensitivity* (Gavrilović et al. 2017; Mitorović et al. 2023; Ćorović et al. 2024; Bergamini et al. 2013; McGarigal et al. 1995; Vasiljević et al. 2022; Botequilha-Leitão et al. 2006), (Figure 4 and Figure 5).

- The *Landscape quality assessment* is based on the interpretation of indicators that reflect the landscape's ecological functions and aesthetic values. The assessment focuses on four indicators: Coherence (SDI, PSSD) Complexity (PD, SEI, AWMPFD), Naturalness (H – hemeroby index), and Openness (MPAR, CA) (Ćorović et al. 2024; Mitorović et al. 2023; Vasiljević et al 2022; Gavrilović et al. 2017; Botequilha-Leitão et al. 2006), (Figure 4).
- *Landscape biodiversity sensitivity* of each identified landscape character type is evaluated using specific indicators, including *heterogeneity*, *land use intensity*, *connectivity*, and *resilience.* These indicators are derived from the guidelines defined in the UNU-IAS *Policy Report Indicators of Resilience in Socio-ecological Production Landscapes* from the United Nations University Institute of Advanced Studies (UNU-IAS Policy Report, 2013). They provide insight into the ecological health and biodiversity of the landscape, contributing to the overall assessment of landscape quality. The assessment focuses on

four key indicators: Heterogeneity (SDI, SEI), Intensity of Land Use (NP, H, TLA), Connectivity (ED, MPE), and Resiliency (TLA, ED, NP) (Figure 4). They are quantified using specific landscape metrics, allowing for a detailed understanding of the biodiversity and ecological stability of the region.

- *The Landscape visual sensitivity* was appraised based on the indicators (the *view of the area*, *openness*, *landscape diversity*, *balance*, the presence of water surfaces, *edges*, *shapes in the landscape image*, and the *colour of the landscape*) outlined in Figure 6. Field photography was conducted from predefined key observation points to capture the visual characteristics of the landscape (Figure 5). The photographs collected during the site visits were subsequently evaluated (Figure 7). (See supplementary Material 2: Landscape Visual Assessment).

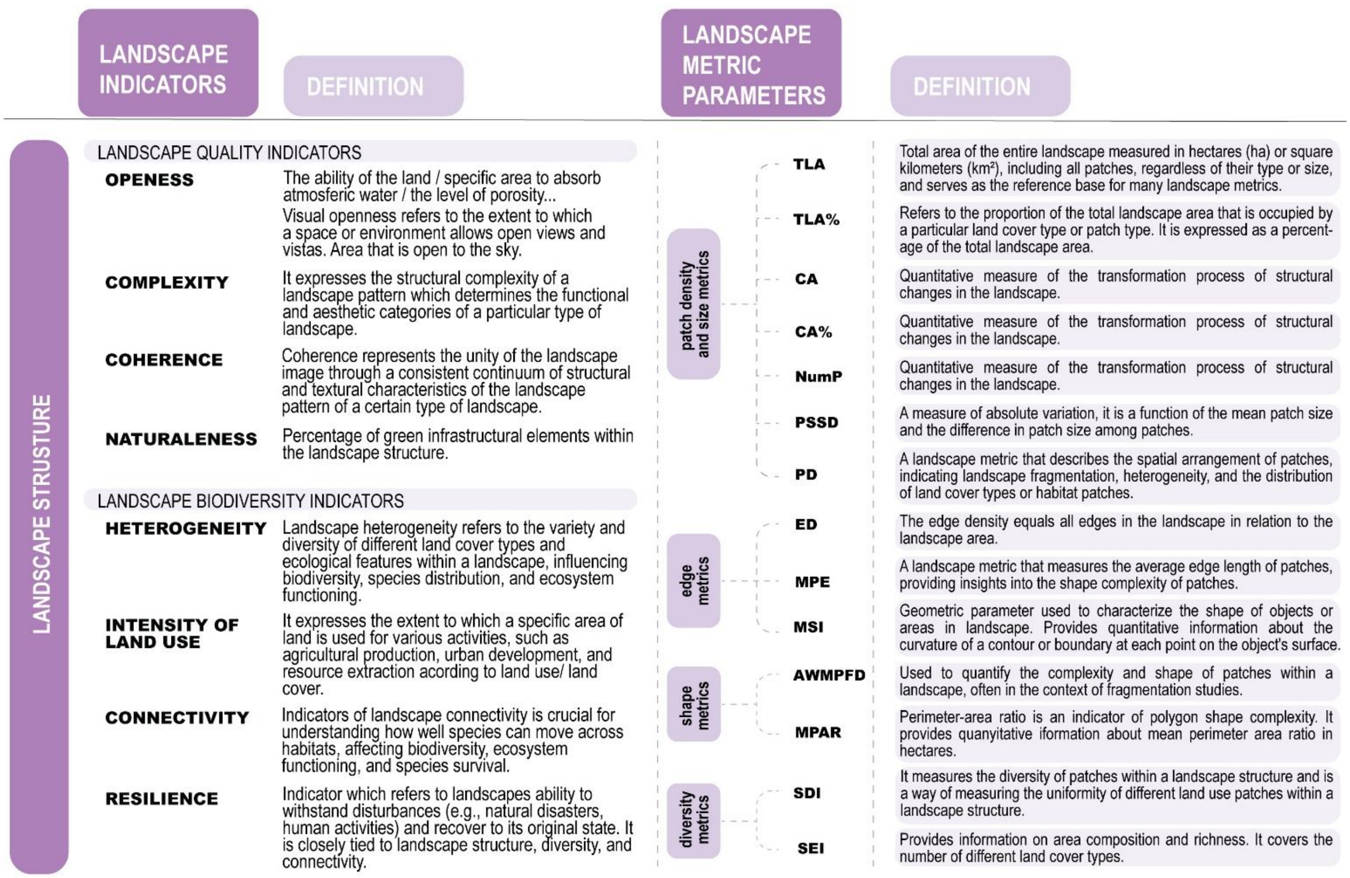


Figure 4. Landscape quality and landscape biodiversity assessment: landscape indicators and parameters.

The overall sensitivity is rated on the three-level scale and ranges from low-medium-high, indicating the level of sensitivity of each landscape type (Figure 2).

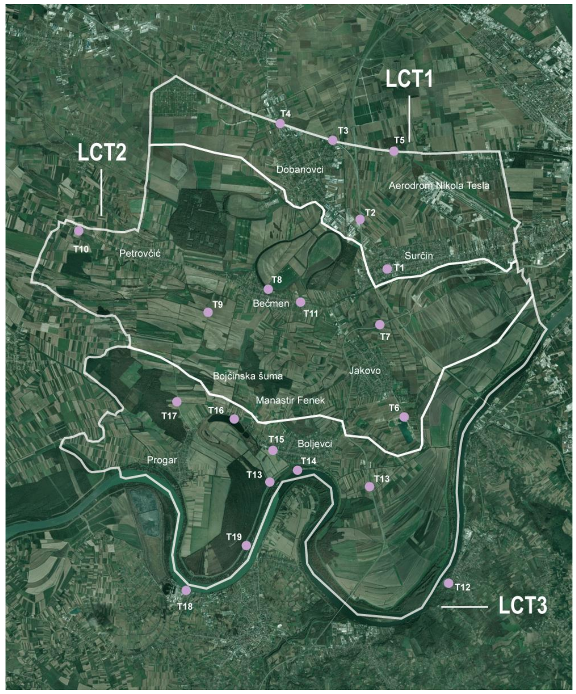


Figure 5. Pre-defined key observation points for field photography.

Landscape character type		LCT 1 - Intensive agriculture on the loess plain of the Surčin settlement			
Landscape character elements		Linear form of fragmented shelterbelts, geometric form of agricultural fields, local roads…			
Study area	Surčin	Point number	T3	Toponym	Dubanovci

1	View of the area	3	2	1
2	Degree of openness	3	2	1
3	Landscape diversity	3	2	1
4	Balance	3	2	1
5	Existance of water surfaces (EVS)	3	2	1
6	Edges	3	2	1
7	Shapes in the landscape image	3	2	1
8	Color in the landscape image	3	2	1
SUM VALUE OF VISUAL SENSITIVITY		2 (18)		

Figure 6. Landscape visual evaluation table.

Figure 7. Photographs collected during the site visits.

2.2.2 Landscape planning strategy

Interpreting the overall sensitivity of each landscape character type (LCT) (including its quality, biodiversity, and visual value) provides valuable insights into the structure, function, and significance of the landscape, highlighting the importance of character and condition in defining landscape health and distinctiveness. After assessing the landscape condition, the landscape planning strategy has to be recommended: *conservation, protection, restoration, reconstruction, adaptation,* and *new design* (Vasiljević 2020 according to Warnock and Brown 1998; Wood and Handley 2001) (Figure 2).

2.2.3 Concept for Forest landscape restoration

The concept development outlines the *goals and measures* for Forest Landscape Restoration (FLR) of Surčin Municipality, specifying *"where"*, *"what"*, and *"how"* to plan future interventions. The primary objective of the concept is to enhance the landscape's ecological and aesthetic qualities. Based on the sensitivity of each landscape character type, specific landscape design guidelines are proposed, incorporating both *morphological-ecological* and *landscape-design rules*. These guidelines introduce key landscape elements for future restoration efforts. Previous assessments provide further recommendations for *forest restoration and afforestation*, supported by field observations and analysis of native and invasive vegetation within Surčin Municipality (Figure 2).

The *general recommendation of species* for restoration is based on prior research, with particular attention given to the main species and their requirements to the territory of the Municipality of Surčin. The focus was on identifying tree and shrub species suitable for the new forest design - afforestation and reforestation.

Additionally, socio-economic and cost-benefit analysis, as an essential component of any spatial development plan, has been conducted to evaluate the broader impact of the proposed landscape goals and measures regarding new forest design. This analysis ensures that the recommended activities and interventions are both ecologically viable and economically feasible.

3 Results

3.1 Landscape character and sensitivity assessment

Identifying the local landscape character at the Municipality of Surčin, recommended by the Spatial Plan of the Republic of Serbia and the Master Plan of the City of Belgrade, begins with national and regional landscape typology (Figure 1a, Figure 1b).

The landscape of the Surčin Municipality is represented by three distinct Landscape Character Types (LCTs) each exhibiting unique composition and configuration of the landscape structure, characteristics revealed through landscape quality assessment (Figure 8) (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 1).

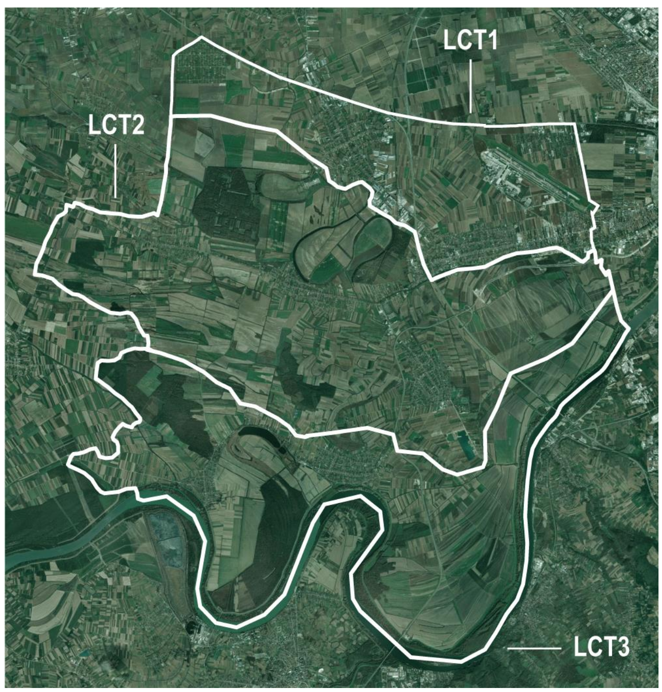


Figure 8. The Landscape character types (LCTs) of Surčin Municipality: a) Intensive agriculture on the loess plain of the Surčin settlement (LCT 1); b) Intensive agriculture with elements of remnant forests "in block" on eluvial and fluvial relief in the settlements of Jakovo and Bečmen (LCT 2); c) Intensive agriculture with elements of remnant forests "in block" on the alluvial plain of the Sava river bank (LCT 3).

a) ***Intensive agriculture on the loess plain of the Surčin settlement*** **(LCT1)** displays a landscape structure with low naturalness represented by the hemeroby index value of 5.49, a simple landscape structure with low coherence (SDI 1.16, SEI 0.60), and moderate complexity (AWMPFD = 9.31). Although openness is categorized as medium (MPAR 283.39, CA 3712.97ha), this makes this landscape type moderately sensitive to change due to limited natural diversity and dominance of agricultural practices, which reduces its resilience and ecological stability (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 2).

The landscape functional matrix is composed of agricultural land, which covers 60% (3009.18 ha), spreading across a flat loess terrace and featuring cultivated land under crop rotation. Urban areas settlements Surčin and Dobanovci, contribute 27% (1461.0ha) of the landscape structure. The patch density (PD = 0.0026) highlights a sparse and simplified landscape composition, dominated by a functional and structural matrix of agricultural land. The landscape's configuration is largely determined by geometric features such as melioration channels, roads, the settlement of Surčin, and the airport 'Nikola Tesla' (159.0ha), adding to the overall simplicity of the landscape structure.

In future spatial development and landscape maintenance, increasing the level of landscape heterogeneity should be a primary goal by enhancing naturalness, coherence, and complexity.

b) ***Intensive agriculture with elements of remnant forests "in block" on eluvial and fluvial relief in the settlements of Jakovo and Bečmen*** **(LCT2)**, shows *high landscape quality* due to its well-structured and complex landscape, despite a relatively low naturalness (H = 4.26). This landscape type is distinguished by its high coherence in structure (SDI = 1.36, PSSD = 836.46) driven by the integration of remnant forest patches within the agricultural matrix, and shows high complexity (AWMPFD = 12.95, PD = 0.0033). It also exhibits high openness (MPAR = 152.85, CA = 6,977.91), reflecting the dominance of extensive agricultural practices on the alluvial plains and terraces (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 2).

The matrix of agricultural land dominates (5,867ha / 57%) while remnant deciduous forests "in the block" occupy 20% of the LCT area (1,666 ha). Although the forests are unevenly distributed, their presence contributes to the landscape's complexity and coherence. The landscape configuration is characterized by rural settlements, a rectilinear street network, and narrow houses along straight roads, reflecting the typical urban-rural character of settlements in Srem. This configuration has persisted since the mid-18th century when the Habsburg monarchy established the urban regulations that connected individual settlements via the main street. The landscape configuration is defined by the morphology of the flat terrain, which is geometrically shaped by the rural settlements drainage system, with an agricultural mosaic of medium-granulation structure.

In future spatial development, the preservation and improvement of forest elements should be prioritized to maintain the landscape high quality. Strengthening the connectivity between these remnant forest patches will also help sustain the ecological and visual integrity of the landscape.

c) ***Intensive agriculture with elements of remnant forests "in block" on the alluvial plain of the Sava river bank*** **(LCT3)**, features high complexity (AWMPFD = 12.76) but low coherence (SDI 1.04), making it particularly sensitive to changes. Despite the existing natural elements, this type of landscape has a less organized structure, indicated by low SDI (1.04) and PD

(0.0020). However, the remnant forest patches along the Sava Riverbank, like the Crni lug and Bojčinska forests enhance the landscape resilience. This makes a highly sensitive landscape to change due to higher natural diversity and higher complexity (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 2).

The landscape composition features a dominant matrix of agricultural elements covering 72% (9,389.29ha), spreading across alluvial plains and river terraces. Natural elements such as alluvial forests and water bodies (pond "Bara Živača", canals: Progarska jarčina, and Boljevac), are relatively small in extent but important for the landscape's complexity, and their presence adds ecological value. Other significant elements include pastures and small settlements like Progar and Boljevci.

The landscape configuration, although geometrical in its agricultural matrix, is organically shaped by natural features such as alluvial forests, river channels, and water bodies (e.g., "Bara Živača" and Progarska jarčina), which contribute to its high complexity.

In the future management strategies should focus on improving the coherence and connectivity of these natural features/elements to ensure greater landscape stability and quality.

These assessments highlight the need for targeted management strategies to enhance natural elements and improve landscape resilience, particularly in areas with lower coherence and naturalness. LCT1 requires efforts to increase landscape heterogeneity and complexity, LCT2 demands the preservation, connectivity, and coherence of remnant forests, while LCT3 needs better organization and integration of natural elements to improve coherence and overall landscape quality.

The *Landscape Biodiversity Assessment* provided a detailed understanding of the landscape type's biodiversity and ecological stability (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 3).

- *Intensive agriculture on the loess plain of the Surčin settlement* (LCT1): exhibits moderate heterogeneity (SDI = 1.16, SEI = 0.60), but low biodiversity due to concentrated land use (intensity of Land Use NP = 14, TLA = 5333.47ha) and low connectivity (ED = 34.67 km/ha, MPE = 13,207.87 km), and resilience (NP = 14) (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 3). The concentrated land use reduces ecological stability highlighting the need for strategies to enhance landscape resilience.
- *Intensive agriculture with elements of remnant forests "in block" on eluvial and fluvial relief in the settlements of Jakovo and Bečmen* (LCT2): demonstrates a slightly higher diversity (SDI = 1.36, SEI = 1.36, NP = 33) and land use intensity (NP = 33, TLA = 9862.04), with medium resilience (NP = 33, ED = 38.98km), and low but improved connectivity (ED = 38.98km, NP = 33) (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 3) A more resilient and diverse landscape, where the presence of the remnant forests and varied land use patterns contribute to its ecological stability.
- *Intensive agriculture with elements of remnant forests "in block" on the alluvial plain of the Sava river bank* (LCT3): shows the least diverse landscape (SDI = 1.04, SEI = 0,45), with moderate land use intensity (NP

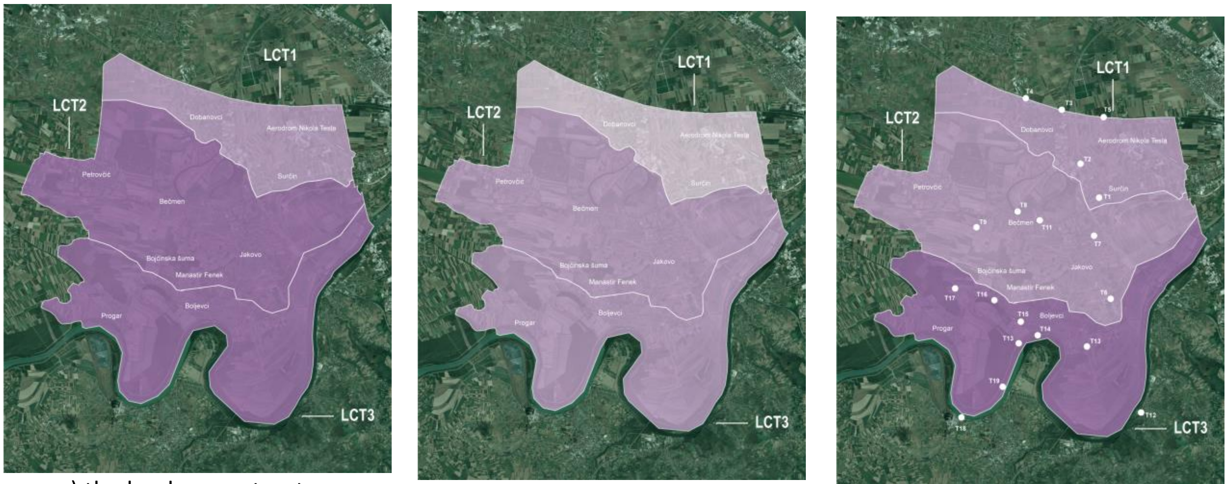
= 26, TLA = 12958.82ha), but with well-connected (ED = 27.30km/ha, MPE = 19,608.71 km) landscape elements and medium resilience (NP = 26) (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 3). The balanced but less complex structure suggests a stable but vulnerable landscape that would benefit from increased homogeneity and diversity.

The landscape biodiversity across these three LCTs shows varying levels of heterogeneity, intensity of land use, connectivity, and resilience. LCT2, with its higher structural diversity and greater number of patches, demonstrates the highest potential for recovery and ecological stability. In contrast, LCT1, characterized by lower biodiversity and connectivity, presents the greatest vulnerability to disturbances. LCT3, while having the largest total area, shows a balanced but less diverse landscape structure. Overall, the findings highlight the importance of enhancing connectivity and diversity to improve landscape resilience and biodiversity across these agricultural regions.

The *Visual sensitivity assessment* of each LCT provided a comprehensive understanding of the landscape's visual characteristics and key design elements (See supplementary Material 2: Landscape Visual Assessment Table 1).

- *Intensive Agriculture on the Loess Plain of the Surčin Settlement* (LCT 1) has medium visual landscape character sensitivity with open views and a predominantly geometric landscape configuration where the landscape visual character is defined by geometric form of agricultural fields, urban settlements Surčin and Dobanovci, local roads with industrial and commercial objects. Shapes of landscape elements are mainly geometric, creating weak connections through the landscape (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 4).
- *Intensive agriculture with elements of remnant forests on eluvial and fluvial relief in the settlements of Jakovo and Bečmen* (LCT 2) has medium visual landscape character sensitivity and is characterized by open views. The landscape's visual character is defined by vertical forms of lowland forest and church bell towers, and picturesque settlements of Petrovčić, Jakovo, and Bečmen. The visual integration of these elements creates a harmoniously integrated but dynamic landscape (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 4).
- *Intensive agriculture with elements of remnant forests on the alluvial plain of the Sava riverbank* (LCT 3) has high visual landscape character sensitivity that is defined by the main visual landscape elements such as geometric agricultural fields with organic forms of deciduous forest remnants, canals, local road, and linear settlements. The open views and strong visual connections of natural elements contribute to a landscape that is both visually complex and ecologically significant (See supplementary Material 1: Landscape quality and landscape biodiversity assessment, Table 4).

Overall Sensitivity of the Landscape Character of the Surčin Municipality highlights the balance between human activities and natural elements across different landscape character types (Figure 9).



a) the landscape structure sensitivity

b) landscape biodiversity assessment

c) the landscape visual assessment

Figure 9. Landscape Character Sensitivity Level.

The varying levels of landscape structure sensitivity, biodiversity, and visual character reflect the impact of agricultural practices and urban development on the region's ecological and aesthetic qualities. To enhance landscape resilience and sustainability, future spatial planning and management should prioritize the preservation and restoration of natural elements, increase landscape heterogeneity, and improve connectivity across these agricultural regions.

Intensive agriculture on the loess plain of the Surčin settlement has medium sensitivity in landscape character and low landscape biodiversity. The influence of human activities reduced natural complexity resulting in low levels of complexity and naturalness, connectivity, and resilience. The degree of landscape vulnerability is seen through the configuration elements that contribute to landscape connectivity and resilience (ED = 34.67). Future efforts should focus on increasing heterogeneity and diversity of the landscape character (SDI = 1.6 and AWMPFD = 1.29).

Intensive agriculture with elements of remnant forests on eluvial and fluvial relief in the settlements of Jakovo and Bečmen shows high landscape character sensitivity and medium landscape biodiversity. Human activities altered the natural landscape structure, even though remnants of forest indicate high complexity naturalness and openness. The LCT configuration elements highlight a more complex landscape structure (ED = 38.98). Future spatial development and the management of landscape should be focused on emphasizing heterogeneity and diversity of elements (SDI = 1.36; MPE = 11649; NP = 33).

Intensive agriculture with elements of remnant forests on the alluvial plain of the Sava River bank shows high landscape character sensitivity and medium landscape biodiversity. Human activities modified the natural landscape structure with natural remnants - forests indicating a high level of complexity, naturalness, and openness. The landscape character connectivity is underscored by TE = 25818 km. While landscape heterogeneity and diversity of elements are balanced by SDI = 1.04; MPS = 498; NP = 26. The future spatial development and the management of landscape should be focused on heterogeneity and diversity of elements.

Table 1. Landscape Sensitivity Assessment.

	Coherence	Complexity	Naturalness	Openness	Heterogeneity	Intensity of land use	Connectivity	Resiliency	Parameters of visual perception
	ASSESSMENT OF LANDSCAPE QUALITY				**LANDSCAPE BIODIVERSITY SENSITIVITY**				**LANDSCAPE VISUAL SENSITIVITY**
	SDI / PSSD	PD/SEI/ AWMPFD	H	CA / MPAR	SDI / SEI / NP / TLA	H / TLA / TLA% / NP	ED / NP / MPE/	NP / TLA / ED	SUM VALUE OF VISUAL SENSITIVITY OF LCT
LCT1	MEDIUM	LOW	LOW	MEDIUM	MEDIUM	LOW	LOW	LOW	12
SUM VALUE	MEDIUM				**LOW**				**MEDIUM**
LCT2	HIGH	HIGH	LOW	HIGH	MEDIUM	MEDIUM	LOW	MEDIUM	12
SUM VALUE	**HIGH**				**MEDIUM**				**MEDIUM**
LCT3	LOW	HIGH	MED	LOW	MEDIUM	MEDIUM	HIGH	MEDIUM	22
SUM VALUE	HIGH				**MEDIUM**				**HIGH**

3.2 Landscape planning strategy

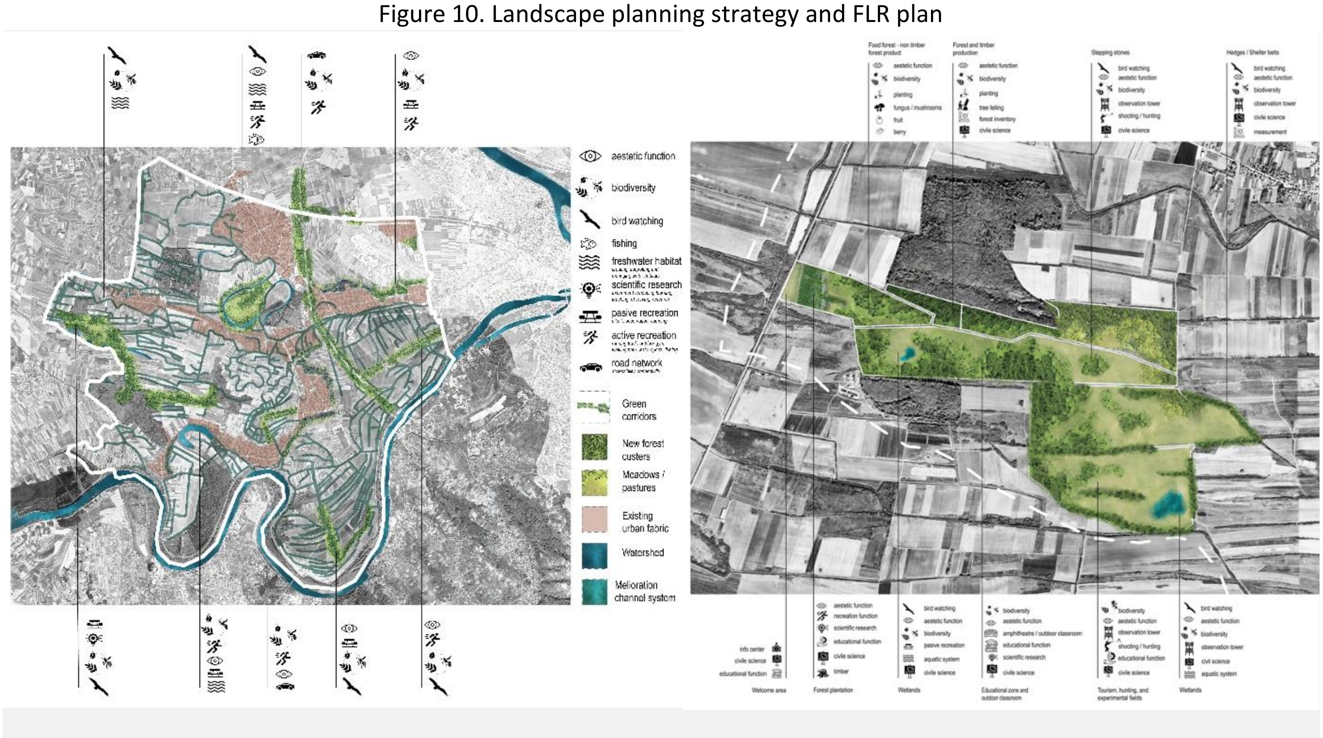
The *landscape planning strategy* of Surčin Municipality are aligned with national and regional Belgrade's spatial planning regulations, focusing on establishing urban spatial order and preserving remnant elements of the rural landscape, represented by forests, agroforestry areas, and surface natural watercourses. It emphasizes the development of green infrastructure as a climate adaptation strategy, promoting the connectivity of green and public spaces. The goal is to create multifunctional areas, such as blue-green corridors, integrating bicycle paths and pedestrian routes that combine nature, recreation, education, and cultural and historical heritage.

The *landscape planning strategy* for the Municipality of Surčin emphasizes *conservation, protection, restoration, reconstruction,* and *adaptation* to improve landscape health and distinctiveness within the municipality's territory. Valuable insights into the landscape's structure, function, and significance, derived from the overall assessment of landscape sensitivity, have highlighted the importance of achieving landscape goals such as enhancing landscape heterogeneity, diversity, resilience, and naturalness. The landscape design rules for the new forest design for the Municipality of Surčin are essential spatial and functional tools for achieving these goals.

For each location's specific ecosystem and socio-economic goals are outlined with corresponding objectives. The Landscape planning strategy and FLR plan (Figure 10) proposes the improving structural connectivity of existing forests, their expansion, and connection to the broader green infrastructure system, canal network (existing), including roads (city and agricultural roads - existing and planned), and settlement boundaries (residential, commercial, and weekend area).

As one of the prioritized activities in answering the question of *what*, efforts to *increase biodiversity* should focus on establishing new forested areas to link existing forests and restore the degraded Višnjik and Draž forests, contributing to ecological resilience and species diversity. Equally important is *enhancing landscape connectivity* by establishing forests along existing and planned roadways, as well as implementing shelterbelts on arable land, which will *strengthen ecosystem linkages a*nd *reduce habitat fragmentation*. In addition, the reconstruction of irrigation canals is necessary to support more efficient water transport for agricultural irrigation, municipal, industrial, and recreational purposes, *optimizing water resource management*. Furthermore, reconfiguring the urban landscape is essential *to create a recognizable* and *cohesive landscape pattern* that emphasizes the city's identity, shaped by the dynamic interaction of both natural and human factors. These measures jointly aim to foster sustainable development while preserving and enhancing urban landscapes.

Figure 10. Landscape planning strategy and FLR plan



a) Concept of landscape plan and design for The Municipality of Surčin

b) Landscape planning and design rules for forest "Višnjik".

Figure 10. Landscape planning strategy and FLR plan.

3.3 Forest landscape restoration FLR concept

By answering the questions of *where* and *how*, the FLR implementation plan for the Municipality of Surčin outlines detailed restoration measures, that specify actions, locations, responsible parties (stakeholders), and costs associated with the interventions of the new forest design. The main activities of afforestation and reforestation are illustrated in Figure 11. highlighting the main elements of landscape design related to those activities.

Afforestation activities include the establishment of 124.64 hectares of new forests, connecting Draž and Višnjik, and creating educational and recreational zones. Additionally, meadows and pastures will be established on 100 hectares of former agricultural land (Figure 11a). The *landscape design elements* are focused on developing new forests, preserving forest edges and shelterbelts to preserve distinct landscape patterns, increasing forested areas, and enhancing the landscape structure's ecological composition.

Reforestation activities involve the restoration of 90 hectares of degraded forests, particularly enhancing the forest edges of the Višnjik and Draž forests (Figure 11a). This also includes improving the management of existing wetlands and riparian vegetation, specifically over 221.19 hectares of riparian zones and 297.53 hectares of wetlands (see Figure 11b). The landscape design will integrate water management systems to create an environmental framework that supports the municipality's development while considering ecological, social, and cultural factors.

a. reforestation

b. afforestation

c. afforestation

d. afforestation

Figure 11. Elements of landscape design rules – new forest design //afforestation/reforestation//.

By enhancing the water regime, the interventions will facilitate the growth of aquatic and riparian ecosystems, promoting landscape and biodiversity enrichment (see Figure 11b). New forests will be also developed along existing and planned roads, covering 629.54 hectares, and 5km/100ha of new shelterbelts (green belts) will be established on arable land in settlements Dobanovci, Jakovo, Bečmen, and Boljevci (see Figure 11c). The landscape design rules will also include protective forest belts along existing regional roads, particularly along the new municipal road connecting the Sava River Bridge to the “Dobanavačka petlja” interchange, with afforestation plans prioritizing species known for their pollution-absorbing capabilities (see Figure 11c).

Lastly, the urban environment will be reconstructed in settlements Dobanovci, Surčin, Jakovo, Bečmen, Petrovčić, Boljevci, and Progar by establishing a new pocket park or urban park covering 1 hectare (see Figure 11d). The landscape design aims to bring back the elements of settlement identity, foster a strong sense of place, enhance positive interaction and engagement, and provide new recreational and social functions (see Figure 11d).

The recommendation of species for forest restoration is aligned with the ecological pattern analyzed in the initial assessment phase of the framework, where forests in the Surčin area belong to the alluvial-hydrophilic forest type. The importance of enhancing landscape heterogeneity, diversity, resilience, and naturalness demand particular attention that should be given to selecting new plant material from tree species that relic, endemic, rare or endangered in Serbia which are naturally distributed in the Municipality of Surčin (*Ulmus laevis*, *Ulmus minor*, *Populus alba, Pyrus malus* and *Prunus pseudoarmeniaca*). Proposed species are mainly represented in this area and most of them are typical for lowland forests, such as *Quercus robur, Fraxinus angustifolia, Populus alba, Populus nigra, Salix alba, Carpinus betulus, Ulmus laevis, Ulmus minor, Tilia cordata*, wild fruits, and shrubs. The introduced species *Robinia pseudoacacia* and *Morus alba* can be valuable for this area because of bee grazing and wild animal nutrition. Both species are naturalized in Serbia, but higher attention needs to be given to combat the spread of *Robinia pseudoacacia.* Forest tree species are highly heterozygous and most of the total genetic variation can be found within populations (provenances). There is also a significant presence of introduced and invasive species such as *Amorpha fruticosa* marked as potentially the most dangerous invasive tree species in this area, and other species as *Ailanthus altissima washigher*, *Polygonum aviculare*, *Conyza canadensis*, *Cichorium intybus*, *Erigeron annuus*, *Aristolochia clematitis*, *Ambrosia artemisiifolia*, *Asclepias syriaca*, *Phytolacca americana*, *Rubus caesius* and the most common *Symphyotrichum lanceolatum.*

The FLR methodological framework is concluded with *Cost-benefit and Socio-economic* assessment, as an overall evaluation of the FLR plan for the Surčin Municipality. This analysis indicates a negative net present value for business as usual whereas the NPV (Benefits – Costs) = USD -250.558,73. While the FLR intervention shows a positive NPV (Benefits – Costs) = USD 93.226,10. Based on FLR measures given in the implementation plan, the total intervention costs per ha are set at USD 1933. For the FLR intervention, the net present value is positive to some extent. When applying sensitivity analysis, while using intervention costs as a variable, the NPV tends to be negative if intervention costs suppress levels of USD 2.291 per ha, whereas the simulation still provides the conclusion that in most scenarios, the NPV will remain positive.

The FLR *monitoring plan* focuses on outcome indicators aligned with the objectives, supplemented by additional indicators for the landscape character type. Evaluation will occur midway through and after the intervention, assessing progress and impact based on predefined questions. Yet, in addition to the set of indicators derived from the national list of indicators for environmental protection, an additional set of indicators to be monitored at the landscape character type level is developed depending on the restoration activities' success.

4 Discussion

The FLR concept aims to support the achievement of landscape development goals, with the *landscape character assessment* serving as an essential framework for determining *where, what,* and *how* forest design and development should take place

(Figure 10). This approach ensures that spatial, functional, and strategic decisions are informed by an understanding of the landscape's intrinsic qualities and potential, thereby aligning development interventions with broader ecological, cultural, and aesthetic (visual) objectives at different scales.

Landscape Character Assessment (LCA) methods, developed in the UK and France in the early 1990s, have become central to landscape identification and evaluation, serving as one of the key measures for implementing the European Landscape Convention (ELC) (Swanwick 2002; Van Eetvelde and Antrop 2009; Tudor 2019; Bell 2003; Vasiljević 2018, 2020). These landscape approaches aim to encompass various aspects of the landscape in the characterization process. It considers not only geological and ecological elements of landscape patterns and structural variations, but also visual perception, historical context, architectural features, and visual aesthetic values. This method aims to integrate natural and cultural aspects of landscapes at the different levels (national, regional, and local scale), and people's perceptions, whilst forming a *landscape strategy* for spatial planning and development. By integrating these diverse factors, the characterization process offers a comprehensive understanding of the landscape's identity and significance, resulting in the identification of various landscape types and their detailed maps. LCA approaches emphasize a crucial distinction between two stages: the relatively "value-free" process of characterization and the subsequent assessment, which relies on a deep understanding of landscape character (Swanwick 2002; Tudor 2014; Selman 2006; Vasiljević 2018).

For the purpose of designing FLR for the Municipality of Surčin, a deep understanding of landscape character, "tailor to the local context using a variety of approaches" (UNFCCC 2003), continue with a comprehensive approach to landscape sensitivity evaluation. It allows for the detailed quantification of landscape quality, biodiversity sensitivity, and visual sensitivity using landscape metrics. These parameters are applied to evaluate landscape quality indicators such as coherence, complexity, naturalness, and openness, as well as biodiversity indicators like heterogeneity, land use intensity, connectivity, and resilience.

The *landscape strategy*, as a precondition for the FLR and the new forest design in the Municipality of Surčin, is aligned with national planning regulations as well as regional Belgrade's urban landscape regulations. It focuses on preserving remnant forest elements and the development of green infrastructure, promoting the connectivity of green and public spaces, and establishing valuable forests as a climate infrastructure. This approach prioritizes the development of valuable urban landscape forests by creating multifunctional spaces, such as blue-green corridors, bicycle paths, and pedestrian routes that integrate education, culture, and historical heritage, rather than merely 'restoring forest cover across an entire landscape,' as noted by Mansourian (2005) and Lamb (2014).

Mansourian and her colleagues (2017) provide an insightful explanation of Forest Landscape Restoration (FLR) as "the return of forests within a landscape." FLR serves as a tool to align reforestation and afforestation efforts with broader landscape planning goals which aim to preserve and maintain the key features of a landscape, which are significant due to their heritage value, whether from natural formation or human activity, as emphasized by the European Landscape Convention (ELC).

The developed concept for forest landscape restoration of Surčin Municipality, "restore multiple functions for multiple benefits" (UNFCCC 2003) of landscape improving quality, biodiversity, and visual characteristics through key interventions:

- Landscape Quality is improved by enhancing coherence through the connection of natural elements, creating a more unified structure. Complexity is enriched with a blend of diverse natural and cultural features, adding ecological and visual depth, while afforestation boosts naturalness by restoring ecological balance and reducing human-modified areas. Openness is maintained by incorporating open meadows and parks, preserving visual depth and accessibility.
- Landscape biodiversity is improved through increased heterogeneity, by introducing new forests, restoration of wetlands, and establishing shelterbelts, which boost species diversity and increase landscape complexity. Connectivity is strengthened by green corridors that link fragmented habitats, reducing isolation and fostering ecological flow. By expansion of forests and riparian zones improves ecosystem resiliency, allowing better adaptation to environmental changes.
- In terms of visual qualities, the landscape achieves greater continuity with green corridors, shelterbelts, and urban parks, softening rigid geometric patterns and fostering a more organic, engaging environment. Collectively, these measures promote a more sustainable, resilient, and aesthetically pleasing landscape with higher biodiversity and improved ecological function.

By recognizing the inherent value of landscapes, FLR becomes a vital tool for preserving and enhancing landscape character in a manner that is both ecologically and socially sustainable as it is prescribed within the Spatial plan of the Republic of Serbia (2021-2035). The landscape approach to FLR explored in this research builds on the principles of the ELC by adopting a transdisciplinary methodology (Tres et al. 2003). This approach to FLR facilitates spatial development that incorporates a broad spectrum of perspectives linking spatial and urban planning, forestry planning, landscape planning, transportation, agricultural and socio-economic considerations. The flexibility of this methodology allows for an adaptable process that addresses the key questions of "*where*", "*what*", and "*how*" interventions should be planned, *making it more responsive to local landscape needs*.

A key advantage of this landscape-based FLR methodology lies in its ability to assess and measure landscape quality and sensitivity. Landscape quality is indicated by coherence, complexity, naturalness, and openness and quantified with metric parameters (PD, SEI, SDI, MPS, NP, H) which allow for a precise evaluation of landscape structure and landscape capacity, enabling planners to monitor ecological stability, resilience, and the impact of land-use changes, while guiding sustainable restoration and management strategies.

The selected landscape metrics parameters effectively measure changes across indicators, providing valuable insights for forest restoration planners. They assess resilience levels and enable comparative evaluation of planning scenarios, but require careful selection; Some of the key parameters that best support the process of following scenario development and spatial plan implementation include:

- Patch Density (PD): Measures the number of patches in a landscape. Increasing PD by adding natural elements like forests or water bodies enhances heterogeneity.

- Edge Density (ED): Evaluates boundaries between land uses. Adding buffers like hedgerows improves connectivity and biodiversity.
- Shannon Diversity Index (SDI): Enhances heterogeneity through varied land uses, increasing biodiversity and resilience.
- Mean Patch Size (MPS): Tracks average patch size, aiding plans to enlarge natural areas for ecological stability.
- Land Use Intensity (NP, CA, H): Assesses human activity, balancing development with conservation for sustainable land use.

Lastly, *monitoring and evaluation* are essential components of this approach. Following and assessing the development of the proposed scenarios ensures that the FLR efforts remain adaptive and aligned with long-term landscape and ecological strategies.

Furthermore, the landscape approach incorporates a transdisciplinary methodology, which is especially relevant for future research. The adoption of a *Geodesign framework*, together with scenario-based planning for future landscape development (Steinitz 2012; Albert et al. 2015; Campagna et al. 2020; Mitrović et al. 2023), has a potential for innovation in FLR practices. Geodesign allows the integration of insights with stakeholder engagement, promoting social interaction and participation in the planning process. This participatory approach enhances the adaptability of spatial interventions, making them more resilient to future challenges.

5 Conclusion

Even if the FLR originally emerged from the disciplines of conservation biology and landscape ecology, after more than 20 years of gaining popularity it is useful to explore its value within other disciplines such as landscape architecture and landscape planning. A transdisciplinary approach and understanding and organizing ecological, cultural, and visual information about landscape patterns (landscape mosaic) is the purpose of landscape character assessment which we proposed as FLR research methodology. Our assessment shows that it enables detailed local quantification of landscape quality, biodiversity sensitivity, and visual sensitivity, through the use of landscape indicators and appropriate metrics parameters, making it well-suited for monitoring and evaluating the achievement of landscape goals.

The landscape approach to FLR is a flexible and innovative framework for forest restoration and spatial development. By enhancing existing methodologies with the landscape approach, Geodesign framework, and scenario-based planning, we can achieve a transdisciplinary integration of insights that fosters stakeholder engagement and participation in the planning process. It will pose a significant challenge for future research on forest landscape restoration.

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