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LANDSCAPE STRUCTURE AS A MORPHOLOGICAL FRAMEWORK OF SPA SETTLEMENTS IN VOJVODINA'S PANNONIAN BASIN – A COMPARATIVE STUDY

ABSTRACT

The spatial formation of spa settlements in Vojvodina, within the broader context of the Pannonian Basin, reveals a strong yet underexplored relationship between natural landscape conditions and urban morphology. This paper centres on three spa landscapes: Rusanda, Kanjiža and Stari Slankamen – each embedded within a specific environmental setting defined by landform morphology, microclimate and vegetation - providing a framework for this analysis. Using a landscape-driven morphological approach, the study analyses the spatial configuration of each settlement in relation to its surrounding landscape. The aim is to reveal the diversity and specificity of landscape structures within this seemingly uniform lowland territory through a qualitative reading of three spatial models, rather than to construct a comprehensive typology. In doing so, this research highlights the internal landscape variability of the Pannonian Basin, a fragile, layered and ecologically complex system, and addresses the underrepresentation of landscape structure as a morphological agent in architectural and urban discourse. Spa settlements, more than other urban forms, sustain a direct, enduring spatial and functional dialogue with the natural systems that support them, exposing the extent to which landscape structure not only informs their morphology, but actively shapes their spatial logic and identity.

Anja Ljujić

University of Belgrade – Faculty of Architecture

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COMPARATIVE ANALYSIS

1. INTRODUCTION

A word on spa settlements - and landscapes as well

Spa settlements are more than healing springs; they are spatial phenomena in which natural resources, human activity, and cultural practices converge, shaping distinctive landscapes and settlement forms that reflect the dynamic interplay between nature and society. Historically, spas developed as sites of health and recreation, gradually taking on social, cultural, and economic roles, while their environmental setting dictated the possibilities and limits of their spatial and architectural organisation. While hydrological, geological, and tourism-focused studies have extensively documented these areas (Laškov, 1982), their spatial morphology, the ways in which built form responds to landscape structure, remains largely unexplored. In Serbia, spatial planning first formally acknowledged spa settlements in the 1996 Spatial Plan, recognising natural healing factors, location, and transport connections (Stevanović, 2009), yet typological and morphological definitions remain inconsistent.

From a spatial perspective, spa settlements emerge in diverse contexts, alongside settlements, in valleys, clearings, or other specific landscapes, yet always anchored by springs as defining starting points. Their architecture and urban layout create platforms that allow people to access and experience nature, making built structures integral to human-environment interaction. In this sense, spas are a tangible expression of the intersection between human activity and the natural landscape. As an anthropogenic landscape element, a spa settlement can be understood as a spatial and ecological organism that evolves from the landscape in which it is embedded. They become a lens through which the relationship between landscape structure and built form can be read, revealing how architecture mediates human access to nature and how landscape, in turn, structures human space.

The central question of this research is how the spatial morphology of spa settlements reflects and responds to the landscape structure in which they are embedded. Within this framework, three interconnected hypotheses are proposed. First, landscape structure actively conditions the spatial identity and internal organisation of spa settlements, shaping their form, hierarchy, and spatial relationships. Second, the morphology of spa settlements represents a specific mode of interpreting and adapting to the landscape: through their

spatial form and organisation, spa settlements articulate the relationship between natural systems and human intervention, functioning as an interface between the two. Third, even within a seemingly homogeneous ecosystem, subtle variations in landscape structures are expected to generate distinct morphological expressions, revealing how local environmental conditions translate into different spatial and architectural patterns. This framework bridges the gap between landscape and morphological studies in architectural and urban discourse, highlighting the spa settlement as a spatial mediator between natural environment and built form.

The aim of the research is threefold: to identify representative landscape structures within the Pannonian Basin, to analyse the morphology of selected spas in relation to these structures, and to interpret how differences in landscape conditions manifest in spatial form. Through this comparative, qualitative landscape-driven morphological approach, the study situates spa settlements within their environmental context, interpreting them as spatial expressions of landscape logic.

The relevance of this approach lies in repositioning the spa within contemporary architectural and planning discourse. Understanding spas through their landscape structures opens a new perspective on sustainable planning - one that reads spatial form as a record of ecological processes and cultural adaptation. By doing so, it aligns with the principles of the European Landscape Convention (Council of Europe, 2000), which defines landscape as the result of the interaction between natural and human factors. In this sense, the study contributes to the ongoing dialogue on how landscapes are perceived, interpreted, and planned, not as static entities, but as living structures that continuously shape and are shaped by human activity.

Building on this, the study transitions to a conceptual framework connecting landscape structure and morphology, situating their position and interpretation within the research. The spatial context is first defined and explored, aiming to characterise its structure and convey its image. Landscape structures within this broader ecosystem are identified using three structural criteria to capture their spatial logic and diversity. These landscapes, treated as distinctive cases, are then illustrated, highlighting the spa settlements embedded within them. The morphology of these spas is analysed in relation to their landscapes, showing how spatial form, hierarchy, and organisation respond to natural structures. Finally, the two analytical levels converge in a comparative approach, revealing the relationships and dynamics between landscape structures and spa settlement morphology.

2. CONCEPTUALISING LANDSCAPE STRUCTURE AND MORPHOLOGY

Landscape, as a concept, is complex and multidimensional, shared across disciplines such as geography, ecology, and architecture, and interpreted through visual, ecological, and territorial perspectives. Contemporary theoretical discourse, by contrast, increasingly understands landscape as a relational and processual construct, produced through the ongoing interaction of natural and constructed elements (Corner, 1999; Spirn, 1998; Waldheim, 2006). In this research, the notion of landscape structure is introduced to emphasise this systemic dimension from a spatial perspective. Following the principles of landscape ecology (Forman & Godron, 1986), this notion refers to the arrangement and interrelation of natural elements: landforms, water systems, soils, and vegetation, forming a coherent spatial matrix. This perspective enables the natural component of landscape to be understood as an active spatial system rather than a passive setting, conditioning patterns of occupation, movement, and use. Within spa settlements, where natural healing resources are inseparable from spatial organisation, such a structural reading of landscape becomes particularly relevant.

Morphology provides a complementary analytical lens for interpreting spatial form and organisation. Rooted in the study of settlement structure and evolution, morphological research has traditionally focused on the internal composition of the built environment - plots, streets, buildings, and their hierarchical relationships, as articulated by Muratori and later developed within the Italian and British schools of urban morphology (Cataldi, Maffei & Vaccaro, 2002; Conzen, 1960). Morphological analysis reads spatial form as a material record of social, cultural, and functional processes, revealing the internal logic through which settlements are structured and transformed over time (Moudon, 1997).

While both landscape studies and morphological studies address spatial structure, they have often developed along parallel trajectories. Landscape is frequently treated as an external condition, while morphology focuses on the autonomous organisation of built form. This conceptual separation obscures the ways in which spatial form emerges through continuous interaction between environmental structure and human intervention. As emphasised by Conzen (1960) and Moudon (1997), the natural setting, spatial layout, and functional organisation together constitute an integrated system. Building on this understanding, morphology is here extended beyond the internal structure of the built environment to include its relationship with landscape structure.

Within this framework, spa settlements are approached as particularly revealing spatial configurations, in which landscape structure functions as an operative rather than a representational element. Water, vegetation, microclimate, and terrain directly condition both function and form, making spa settlements an appropriate field for examining how landscape structure informs spatial organisation and morphological differentiation. By positioning landscape structure and morphology as interdependent analytical categories, this study establishes a conceptual foundation for the methodological approach that follows. Accordingly, the research proceeds through a layered spatial reading, moving from the characterisation of broader landscape structures toward the analysis of spa settlements as specific morphological configurations embedded within them, enabling a comparative interpretation of their spatial logic across multiple scales.

3. METHODS AND MATERIALS

3.1 Methodological framework

The research adopts a qualitative and interpretative methodological approach, grounded in the principles of landscape and urban morphology, prioritising a spatial reading of spa settlements as expressions of their environmental context. The approach is structured in two main analytical phases. The first defines and illustrates the landscape structures of the Pannonian Basin through a set of criteria, while the second examines the morphology of spa settlements within these landscape frameworks. Together, these phases form a coherent methodological sequence, from contextual positioning to morphological interpretation, enabling a comparative analysis of how landscape structure informs the spatial structure of spa settlements.

This approach builds upon theoretical foundations established in landscape ecology (Forman & Godron, 1986), geomorphological process theory (Ritter et al., 1995), and the tradition of urban morphology (Conzen, 1960; Moudon, 1997). Recent contributions further refine the interface between territory, landscape and urban form, exploring the reciprocal relation of territorial structure and urban morphology (Neglia, 2024). The integration of these domains allows the morphology of spa settlements to be interpreted as a hybrid system, shaped simultaneously by natural structure and human intervention.

The first phase of analysis addresses the landscape structure of the Pannonian Basin, within which Vojvodina’s spa settlements are located. Grounded in the fact that the spatial structure of the Pannonian Basin has

already been clearly defined through geomorphological and hydrogeological research (Filipović, 2003; Marković, 1973), this study acknowledges and builds on them, using that established knowledge, using it as a spatial reference framework. The aim is to approach them interpretatively, illustrating the landscape diversity through three analytical criteria: relief, microclimate, and vegetation. This landscape characterisation, derived from landscape ecology and environmental geography, serves to construct a comparative framework for the selected spa landscapes, translating them into operative categories for the subsequent morphological analysis of spa settlements. Relief provides the physical foundation and defines the morphological boundaries of the landscape, microclimate reflects the atmospheric and hydrological processes that influence local ecological conditions, and vegetation acts as both an indicator and an active component of landscape structure. By applying these consistent criteria, the analysis captures the spatial logic of each landscape and its capacity to shape specific environmental and morphological conditions. This interpretative basis serves to verify and contextualise the selection of three case studies: Rusanda, Kanjiža, and Stari Slankamen, each representing a distinct landscape within the lowland ecosystem of the Pannonian Basin.

Building upon the landscape framework established in the first phase, the second analytical stage focuses on the morphological structure of the selected spa settlements, and is conducted through three interpretative levels, where the relationship between landscape structure and spa morphology becomes legible at different spatial scales. Each case study is approached through its spatial definition, understood not only as an administrative or protected area, but as a material and functional entity embedded within its landscape context. Where available, the boundaries of the spa were determined according to the officially determined spa settlement area, recognising its spatial structure through the defined core and protective zones. This provided analytical consistency and allowed for comparability across cases. In the case of Stari Slankamen, where such documentation was absent, the spatial extent was reconstructed on the basis of the physical and functional components directly related to the spa: the spring, the park, therapeutic and accommodation facilities, and their immediate setting, as identified from available maps and plans.

To operationalise this analytical framework, the study is structured through three interrelated levels of interpretation, each addressing a different scale of spatial organisation and relation to the landscape. Morphological interpretation across these levels is guided by fundamental aspects of spatial form: position, size and form (Đokić, 2004), which are examined relationally across scales in relation to landscape structure:

I - *Territorial and Spatial Context*

The first level examines the position of each spa within its wider settlement and landscape system, its territorial reach, and relation to the surrounding settlement, infrastructure, and protective zones. This establishes the spa's spatial logic and hierarchy, clarifying how it occupies and structures its immediate environment.

II - *Structure and Morphology*

The second level addresses the internal organisation of the spa complex. It focuses on the distribution of functional zones, the arrangement and typology of buildings, and the hierarchy of open and built spaces. The spa is interpreted as an integrated spatial composition shaped by both functional and morphological principles.

III - *Relation to Landscape Structure*

The third level explores the interaction between the spa and its natural setting, the integration of topography, water, and vegetation into spatial form. Here, the landscape acts as an active determinant, guiding spatial organisation and defining the identity of the spa.

2.2 Materials

To support this analysis, a comprehensive body of primary and secondary sources was examined, including spatial municipal plans, general and detailed regulation plans, and local municipal development strategies which define the spatial and functional framework of the spa settlements. It also incorporates studies of areas with exceptional natural features, as well as development plans and strategies for spa development that outline current conditions and provide insight into the morphogenetic processes that occurred. Complementing these official sources are expert studies, previous research, and relevant literature documents, including monographs and scientific articles on spa morphology and the Pannonian Basin.

Map interpretation and comparative reading of these materials provide the methodological basis for tracing territory, spatial structures, functional zones, and landscape relations at multiple scales. In this regard, the study proceeds through a progressive reduction of scale, tracing how landscape conditions inform spatial structures from the territorial to the architectural level. Spa settlements thus emerge as morphological reflections of the landscapes that sustain them, at once therapeutic systems and heritage landscapes shaped by the instrumentalisation of natural resources and spatial structures.

4. THE PANONIAN BASIN - A MORPHOSTRUCTURAL COMPONENT OF VOJVODINA

The complex geotectonic structure of Serbia includes several morphotectonic units, among which the Pannonian Basin forms a distinctive and geologically autonomous depression in the northern part of the country (Stanković, 2009). Originating from the subsidence and rifting of the former Pannonian landmass, the basin was shaped by marine transgressions of the Tethys Ocean, which led to the formation of the Pannonian Sea, and subsequently the Pannonian Lake (Kazmer, 1990). As the waters gradually retreated, thick sedimentary layers of sand, clay, and loess were deposited, forming the present-day lowland landscape of Vojvodina. The basin is bounded by the Carpathians to the northeast, the Dinarides to the southwest, and the Alps to the west, a geomorphological frame that defines both its physical and ecological distinctiveness.

Water, as one of the fundamental natural resources, underlies the long tradition of spa culture in Serbia. More than 300 natural occurrences of mineral and thermal waters have been identified across the country, and when including exploratory and exploitation boreholes, the number exceeds one thousand (Filipović, 2003). The spatial distribution of these springs reflects complex geological, structural, and hydrogeological conditions. Based on these criteria, Serbia was divided into hydrogeological regions, with the Pannonian Basin region representing a distinct unit. This region largely coincides with the territory of Vojvodina and extends into parts of Hungary and Romania, where occurrences of mineral, thermal, and thermo-mineral waters, both naturally outflowing and artificially extracted, are numerous and diverse. Parallel to this hydrogeological regionalisation, the classification of spa zones within Serbia identified nine main spa regions: the Šumadija, West Morava, Kopaonik-Jastrebac, Novi Pazar-Priboj, South Morava, Carpatho-Balkan, Kolubara-Podrinje, Vojvodina, and Kosovo-Metohija zones (Marković, 1973). The Vojvodina spa zone, relevant for this research, thus provides both a spatial and conceptual framework for the analysis of spa landscapes in the Pannonian Basin. Within it, three regional subunits, Srem, Bačka, and Banat, encompass several historically and functionally recognised spa centres such as Slankamen and Vrdnik in Srem, Kanjiža and Junaković in Bačka, and Rusanda and Torda in Banat (Marković, 1973).

Vojvodina lies on thick sequences of Neogene and Quaternary sediments, composed predominantly of sand, clay, loess, and gravel, containing multi-layered aquifers (Marinković, Papić, Dragišić, & Andrijašević, 2016). These permeable strata enable the circulation and accumulation of groundwater,

creating favourable conditions for thermal and mineral water deposits. The geothermal springs and saline flats of Banat, the alluvial terraces of Bačka, and the slopes of Fruška Gora in Srem represent three principal morpho-structural types of the region's spa landscapes. The saline ecosystems of Banat, such as those around Rusanda, are of particular ecological and morphological relevance. These fragile systems illustrate the interplay between geology, hydrology, and vegetation in shaping the spatial and visual identity of spa landscapes. In contrast, Banja Slankamen, located on the slopes of Fruška Gora, represents a transitional morphology, a spa integrated into a hilly rural context with natural springs emerging along the loess terraces of the Danube valley. Banja Kanjiža, on the other hand, reflects the hydrogeological character of the northern Bačka plain, where deep artesian wells extract thermal waters from confined aquifers beneath the loess cover. Together, these three sites encapsulate the spatial variability and environmental typology of the Vojvodina spa landscape.

The Pannonian Basin in Serbia represents the lowest geomorphological section of the basin system and a distinctive lowland ecosystem. Its relief, shaped by long sedimentary and fluvial processes, provides a uniform but ecologically complex environment in which micro-landscapes emerge as unique spatial and ecological entities. These micro-landscapes - saline flats, loess plateaus, wetland margins, and gentle slopes- manifest the diversity of a seemingly homogeneous plain. The landscape structure in this context becomes the key to understanding spatial variation: the continuous sequence of landscape 'scenes' reflects the mosaic of the basin's ecological and morphological diversity. In contrast to the mountainous spa complexes of central and southern Serbia, where dramatic topography defines the architectural and urban morphology of spa settlements, the lowland landscape of Vojvodina introduces a different morphogenetic logic. Here, water bodies, lakes, rivers, and canals, vegetation patterns, forests, grasslands, wetlands, and the interplay of soil and microclimate form the principal shaping forces of spa settlements. The subtlety of relief requires that morphology be understood through horizontal spatial relationships, the alignment of built form, water systems, and vegetation in a continuous landscape matrix (Ćalić, Milošević, Gaudenyi, Štrbac, & Milivojević, 2012).

Figure 1. Illustrative map of the Pannonian basin, Source: Author

This understanding of the landscape–driven morphological approach should also be viewed within the broader framework of the spatial and cultural logic of Vojvodina, whose landscape has been shaped by a complex network of historical, hydrological, and agrarian structures. Urban development in Vojvodina, including spa settlements, has largely been determined by the geomorphological characteristics of the Pannonian Basin and the rational systems of planned construction that have evolved since the eighteenth century (Stevanović, 2009). These patterns produced a characteristic morphology, an orthogonal street grid, a clearly defined central area, and peripheral zones often connected to natural resources (Krunić, 2012). Within such spatial and organisational models, Vojvodina's spas emerged as a distinct type of settlement

that inherited the fundamental characteristics of the regional urban pattern but transformed them through the relationship with natural springs, parks, and recreational landscapes. The interaction between the planned urban grid and the naturally conditioned spa location forms the basis for understanding the morphology of spa landscapes in the regional context. Spatial patterns of Vojvodina's settlements reflect a rational and functional approach to space, yet also demonstrate adaptability to local landscape conditions, which is considered a crucial aspect for analysing spa territories as specific landscape units.

Positioning spa settlements within the broader spatial framework of Vojvodina thus allows their morphological structure to be interpreted not merely as a result of functional organisation or planning tradition, but as an expression of the region's distinctive landscape identity. This confirms that the analysis of spa morphology must integrate the regional spatial pattern, as it determines the ways in which the built environment and natural elements interact and are perceived as a unified landscape entity.

5. LANDSCAPE CHARACTERISATION

Within the seemingly uniform lowlands of the Pannonian Basin, Vojvodina encompasses a diverse range of landscapes, reflecting a complex spatial and ecological structure. Although the region is broadly defined by flat terrain, it is composed of loess plateaus, sandy plains, alluvial lowlands, and isolated hilly areas, each contributing to the distinctiveness of local environmental conditions. The division of Vojvodina into Banat, Bačka, and Srem highlights three principal landscape segments, which serve as representative units for understanding the variety of natural settings in which spa settlements have historically developed. These landscapes are further distinguished by soils, groundwater regimes, saline surfaces, vegetation communities, and microclimatic conditions, all of which influence the spatial distribution of flora and fauna and the ecological sensitivity of the region. Vojvodina hosts a network of natural parks, reserves and protected areas, reflecting the ecological importance and vulnerability of its landscapes. In this context, the characterisation of these landscapes in this study is based on three central aspects: relief, microclimate, and vegetation - providing a layered understanding of each region. By illustrating these features, the analysis conveys the structural and ecological diversity of Vojvodina's landscapes, providing a clear spatial context for a subsequent comprehensive assessment of the relationship between these landscape structures and spa settlement morphology.

The Banat landscape represents the flattest segment of the Pannonian Basin, characterised by minimal elevation differences and a gently articulated microrelief. The terrain is predominantly flat, with elevations generally ranging between 76 and 77 m above sea level, locally rising to approximately 82 m along loess terraces (Obradović, 2005). This area marks the contact zone between the alluvial plains of the Tisa and Danube rivers and the adjacent loess formations, resulting in subtle surface undulations rather than pronounced landforms. Although visually understated, this microtopography plays a decisive role in hydrological processes, enabling the retention of surface and groundwater within shallow depressions and thus providing the geomorphological basis for the development of saline soils, salt flats, and saline lakes. Banat encompasses nearly two-thirds of all saline and alkaline soils in Vojvodina, making it the core area of this landscape type within the Pannonian Basin (Miljković, 1965). Historically, the region was subject to repeated flooding associated with the wider Carpathian Basin, particularly through the dynamics of the Tisa and Danube river systems. Subsequent drainage and desiccation processes led to salt accumulation and soil alkalisation, especially within low-lying depressions. Variations in microrelief and groundwater depth produce spatially heterogeneous salinity patterns, resulting in fragmented yet clearly legible saline landscapes. Many saline lakes represent remnants of abandoned river meanders or shallow lacustrine depressions in which salts accumulated following water withdrawal (Miljković, 1965).

FIGURE 2. The saline-steppe landscape of Banat Source: Stojanovic (2016), Wikimedia Commons (CC BY-SA 4.0)

In the Middle Banat, saline landscapes spatially overlap with Pannonian steppe formations, forming a distinctive saline-steppe mosaic. Salt-affected depressions are closely juxtaposed with slightly elevated steppe surfaces, creating a fine-grained spatial pattern typical of this part of the Pannonian Basin. The regional climate is moderately continental, with cold winters and very warm summers. High summer evaporation frequently exceeds precipitation, intensifying salinisation processes (Gavrilov et al., 2020). The openness of the plain exposes the landscape to strong prevailing winds, while localised woodland belts and linear vegetation structures create microclimatic enclaves with reduced thermal extremes. Saline and alkaline soils support specific halophytic and steppe plant communities that contrast sharply with the surrounding agricultural landscape (Zeremski et al., 2021). Vegetation adapted to elevated salt concentrations forms distinctive assemblages, including saline grasslands and halophytic meadows, which appear as isolated or semi-continuous natural enclaves within the intensively cultivated lowland. These plant communities are important ecological indicators of saline environments and often include endemic or relict species characteristic of the Pannonian Basin. The resulting mosaic of vegetation types contributes significantly to the spatial heterogeneity, visual identity, and ecological specificity of the Banat saline-steppe landscape.

Along the course of the Tisa River, a landscape that geographically belongs to the Bačka region unfolds. It is predominantly a flat lowland area in northern Vojvodina, characterised by gentle elevation changes and subtle relief differences. Loess plateaus rise slightly above the surrounding floodplain, creating terraces and slopes that influence soil conditions and local topography. Along the river, natural backwaters and alluvial terraces form minor micro-relief features, providing spatial variety within the otherwise flat plain (Marković & Pavlović, 1995). These formations mark the interface between the river corridor and the broader lowland landscape.

Microclimatic conditions are shaped by the interaction of the river and open terrain. Tisa River contributes to localised humidity, forming cooler and more humid micro-zones along its banks and floodplains, especially during summer. Open plains allow unobstructed air circulation, which increases thermal amplitude compared to areas with vegetative cover. Tree belts along river channels and wetlands create small, sheltered microenvironments that moderate temperature extremes and retain moisture. The regional climate is moderately continental, with cold winters and warm to hot summers, and relatively low precipitation that often limits water availability (Radulović et al., 2021). Vegetation reflects this interplay of relief and climate. Floodplain forests

and marshes develop along the river and its side channels, with species adapted to periodic inundation and wet soils. On higher loess terraces and plateaus, steppe-like grasslands merge with cultivated areas, forming a landscape of natural and semi-natural vegetation. Steppe-like vegetation persists on higher loess terraces and drier areas, where well-drained soils and open exposure favour drought-tolerant grasses and herbaceous species (Jakovljević et al., 2020). Salt-tolerant and halophytic plant communities appear in localised depressions, contributing to the ecological diversity of the lowland. The spatial pattern of open grasslands, riverside wetlands, and scattered tree belts emphasises the diverse yet coherent character of the Bačka lowlands.

FIGURE 3. Source: Ivanavpopov (2023), Wikimedia Commons (CC BY-SA 4.0).

The southern landscape in Srem, along the Danube, represents a distinctive segment of Vojvodina, shaped by the intersection of the Pannonian lowland, the Danube, and the foothills of Fruška Gora. At the southern edge of the plain, the otherwise flat terrain acquires local variations due to the river corridor and the isolated relief of Fruška Gora. The landscape's relief is defined by a sequence of river islands - adas, alluvial plains, and terraces formed through long-term sediment deposition and water-level fluctuations (Tomić et al., 2020). A notable feature is the loess profile, consisting of wind-deposited sediments up to 800,000 years old, creating terraces and gentle slopes descending toward the Danube (Vasiljević et al., 2011). These formations produce a clear transition between the alluvial plain and Fruška Gora's foothills, where the terrain gradually rises, with increasing gradients and micro-relief closer to the mountain.

Microclimatic conditions are shaped by the Danube and the relief. The river increases local humidity and creates microclimatic zones along its banks, islands, and loess terraces, particularly in summer. Open lowland areas allow free air circulation and pronounced thermal amplitudes, while Fruška Gora's forested slopes moderate temperatures, retain moisture, and influence wind

patterns, producing contrasts between northern and southern exposures (Lazić, Savić, Tomić, 2006). Vegetation reflects this relief and climate. Fruška Gora features a heterogeneous forest-shrub mosaic dominated by oak, hornbeam, and mixed forests, while lower zones include meadows and open areas (DEIMS-SDR, 2025). Along the Danube and its islands, fluvial vegetation adapts to periodic flooding. Loess terraces and slopes with fertile soils support diverse plant communities and historically cultivated landscapes, such as vineyards and orchards. Overall, southern Srem forms a layered landscape structure where relief, microclimate, and vegetation intersect, creating a visually and ecologically distinct environment.

FIGURE 4. Source: Jankovic Faza Dragan (2012), Wikimedia Commons (CC BY-SA 3.0).

6. SPATIAL AND MORPHOLOGICAL ANALYSIS OF SPA SETTLEMENTS

6.1 Banja Rusanda

Banja Rusanda is a specialised rehabilitation spa located in the central Banat region, on the northern shore of Lake Rusanda, in the settlement of Melenci within the Zrenjanin municipality. It lies in the fertile Pannonian Basin at a low elevation of 82 m above sea level. The spa is particularly significant in the Serbian and Vojvodina spa system, as it is the only active therapeutic facility in Banat. Banja Rusanda was established in 1878 and has a long tradition of therapeutic use based on the medicinal properties of mineral peloids - mud from Lake Rusanda, considered among the most healing in the country. Lake Rusanda is a remnant of the former extensive Pannonian Sea; its bottom is covered with predominantly inorganic mud, and its water is saline and alkaline, resembling seawater. Lake functions as the primary balneological resource, together with a borehole of thermo-mineral water located in the immediate vicinity of the spa core (Obradović, 2005)

I - Territorial and Spatial Context

Banja Rusanda is situated on the northern shore of Lake Rusanda, at the western edge of the settlement of Melenci, within the central Banat landscape. Spatially, the spa occupies a transitional zone between the built fabric of the settlement and the open saline lowland, forming a clearly legible interface between urbanised and natural space. Its position reflects the broader geomorphological setting of Banat, characterised by the contact between the alluvial plain of the former Tisa river system (76–77 m a.s.l.) and slightly elevated loess terraces, on which the spa complex is located at approximately 82 m a.s.l. This subtle elevation difference provides comparatively better drainage conditions and has historically defined the location of both the settlement and the spa. The spa is well connected to the regional network via the main road linking Zrenjanin (17 km) with Kikinda (39 km), as well as to Pančevo and Belgrade (approximately 90 km to the south). The Pančevo–Zrenjanin–Kikinda railway line passes through Melenci, while the Danube–Tisa–Danube (DTD) canal runs through the wider cadastral area, reinforcing the role of the settlement within the hydro-engineered landscape of Banat. Despite this infrastructural connectivity, the spa itself remains spatially distinct from traffic corridors, embedded within a continuous green and open landscape structure.

Lake Rusanda, located immediately south of the spa complex, is a shallow saline lake with a surface area of approximately 4 km² and depths ranging between 0.5 and 1.5 m. It represents an abandoned meander of the former Tisa River, within which saline and alkaline conditions developed due to long-term water retention, evaporation, and sedimentation processes. The lake and its surrounding saline depressions form the core natural framework of the spa's territory. A second former meander, Lake Ostrovo, located about 4 km north of Melenci, further confirms the dominance of fluvial relics and engineered hydrological systems in shaping the wider landscape context.

It is encompassed by spatial planning documents addressing the saline landscapes of central Banat, including the protected natural areas of Okanj Bara and the Slatine srednjeg Banata, while Lake Rusanda itself has been designated as a nature park. These overlapping regimes of protection establish clear constraints on land use, construction intensity, and spatial expansion, reinforcing the preservation of open saline surfaces, water bodies, and natural vegetation. As a result, the territorial context of Banja Rusanda is defined not only by its physical position but also by a multi-layered system of environmental regulation that directly conditions its spatial form and limits its morphological transformation.

FIGURE 5. Analytical map of Banja Rusanda - Spatial and morphological analysis, Source: Author

II - Structure and Morphology

The internal structure of Banja Rusanda is characterised by a dispersed, pavilion-based layout embedded within a large landscaped park. The spa complex occupies an extensive, open spatial unit at the northwestern edge of Melenci, clearly separated from dense residential development. Its morphology reflects a low-density, horizontal organisation, with built volumes distributed across a cultivated green matrix rather than concentrated into a compact core. The central functional nucleus of the spa is formed by several primary buildings positioned closest to Lake Rusanda, establishing a direct spatial relationship with the primary natural resource. Secondary pavilion structures

complement these central volumes arranged laterally and toward the rear of the complex, creating a loose hierarchical composition. The pavilion typology, combined with modest building heights and fragmented footprints, produces a porous spatial structure in which open spaces, paths, and vegetation play an organising role equal to that of the buildings themselves. Circulation within the spa is organised through a network of internal pedestrian paths that connect the pavilions and central facilities, forming a clearly defined internal system largely independent from the surrounding settlement. Access to the complex is oriented from the landward side, through landscaped green areas, reinforcing the perception of the spa as an inward-oriented spatial entity. The absence of dominant axial compositions or monumental built forms further emphasises the primacy of the park as the core spatial framework.

From a morphological perspective, the spa does not rely on relief articulation or built density to define its structure. Instead, spatial order is achieved through the distribution of built volumes within a continuous green field, supported by high and low vegetation layers. The flat terrain and lack of pronounced topographical features result in a morphology that is predominantly horizontal and visually open, with long sightlines and gradual transitions between built and unbuilt areas. This configuration establishes the spa as a spatially extensive but formally restrained ensemble, whose structure is inseparable from its landscaped setting.

III – Relation to landscape structure

Banja Rusanda is spatially positioned at the contact zone between the alluvial plain of the Tisa River and a slightly elevated loess terrace, which provides a stable and well-drained base for development while maintaining immediate proximity to Lake Rusanda as the primary natural resource. This minimal but decisive elevation difference structures the relationship between the spa complex and the surrounding saline landscape, allowing the built fabric to remain outside the most sensitive depressions associated with saline soils and fluctuating water levels.

The lake functions as a dominant organising element, not through direct construction along the shoreline, but through orientation, distance, and spatial sequencing. The main pavilions are arranged predominantly parallel to the lake, forming a linear frontage that visually addresses the water while maintaining a green buffer zone between the buildings and the shoreline. Pedestrian access to the lake is enabled through landscaped open spaces and designated paths, including docks, ensuring controlled contact rather than continuous occupation of the waterfront.

Given the absence of pronounced relief, vegetation plays a critical structuring role. The park and forest belt surrounding the spa were established as a protective and spatially formative layer, mitigating wind exposure and thermal extremes typical of the open Pannonian Basin. Vegetation thus replaces topography as the primary means of spatial articulation, defining movement, enclosure, and visual continuity. While the broader saline-steppe landscape remains largely beyond direct visual reach, the spa maintains a clear and consistent relationship with the lake, integrating the therapeutic landscape into its internal spatial logic without disrupting the ecological integrity of the surrounding saline environment.

6.2 Banja Kanjiža

Banja Kanjiža is located in the northern Bačka region of Vojvodina, on the fertile Pannonian Basin along the Tisa River, within Kanjiža municipality, at an elevation of 86m above sea level. It has operated as an independent balenological centre since 1976, while being established during the 19th century. The spa primarily exploits three artesian horizons, accessed through hydrogeological boreholes, which provide the thermo-mineral water used for therapeutic purposes, while this infrastructure also supports local communal and urban energy use (Stanković, 2009).

I - Territorial and Spatial Context

Banja Kanjiža is located on the southeastern periphery of the settlement of Kanjiža, in the northern Bačka region, on the flat alluvial plain of the Tisa River at 86 m a.s.l. The spa occupies a transitional zone between the built urban fabric and open lowland terrain, maintaining accessibility to the settlement while remaining closely integrated with surrounding natural and semi-natural areas. Its territorial logic reflects the lowland spa typology of Vojvodina, where complexes are established at settlement margins, balancing infrastructural access and environmental integration.

The wider territorial context of the spa is strongly defined by hydrological and ecological structures. Although the compact spa core is relatively limited in size, the functional territory of Banja Kanjiža extends far beyond its immediate built area through a dispersed system of hydrogeological boreholes and their associated sanitary protection zones. One of the key water sources used for balneological purposes is located within the, ecologically significant, area of outstanding landscape features Kanjiški jaraši which contains habitats of nationally protected species. In addition, the territory of the municipality includes two internationally significant ecological corridors, the Tisa and

the Kereš, which intersect with zones relevant to the spa's water resources. These overlapping natural and regulatory structures impose spatial constraints, shaping a territorial framework where land-use, vegetation, and construction intensity are regulated to preserve water quality and ecological continuity.

II - Structure and Morphology

The spa core exhibits a compact, centralised morphology. The primary spa and accommodation building concentrates the main therapeutic and lodging functions, while several smaller structures, including historically protected buildings, complement the ensemble. Unlike pavilion-based spa types, Kanjiža's morphology is characterised by aggregation rather than dispersion, forming a coherent complex oriented toward the adjacent Narodni Park.

The park functions as an integral spatial element, mediating between the built core and the surrounding landscape. Its pedestrian paths, tree-lined areas, and open spaces establish continuity with the wider lowland terrain, while allowing gradual spatial transitions from the urban settlement to natural areas. Original spa structures are directly integrated with the park, while newer buildings extend the core southeastward, creating a coherent ensemble that respects both urban adjacency and environmental integration. The horizontal and low-rise character of the complex maintains openness and visual permeability, aligning morphology with the flat, open context of the Bačka plain.

III – Relation to landscape structure

Banja Kanjiža's spa core is positioned on the southeastern periphery of the settlement, oriented toward the Narodni Park, which functions as the primary spatial framework connecting the built environment to the surrounding lowland landscape. The compact arrangement of buildings establishes a controlled interface between the urban fabric and open terrain, while the park mediates spatial continuity and provides a soft transition to the broader Pannonian Basin. The spa's functional territory extends well beyond the built core, encompassing dispersed hydrogeological boreholes, sanitary protection zones, and associated infrastructural elements. Some of these zones reach up to the Tisa River embankment upstream and include point-like features scattered across the municipality, overlapping with ecologically protected areas. This distribution illustrates a spatial logic in which the therapeutic landscape integrates with regulatory and ecological frameworks, ensuring water protection and ecological continuity without necessitating dense or visually dominant construction.

Vegetation and park elements play a central morphogenetic role in structuring space. Tree-lined pathways, open recreational areas, and green buffers articulate movement and enclosure, compensating for the flat and visually homogeneous terrain. The resulting morphology is horizontal and moderately permeable, with the spa's built volume subordinated to the ecological and hydrological logic of the surrounding landscape. Consequently, Banja Kanjiža demonstrates a spatial configuration in which morphology is largely shaped by lowland fluvial and regulatory constraints, rather than by topographical relief or monumental form.

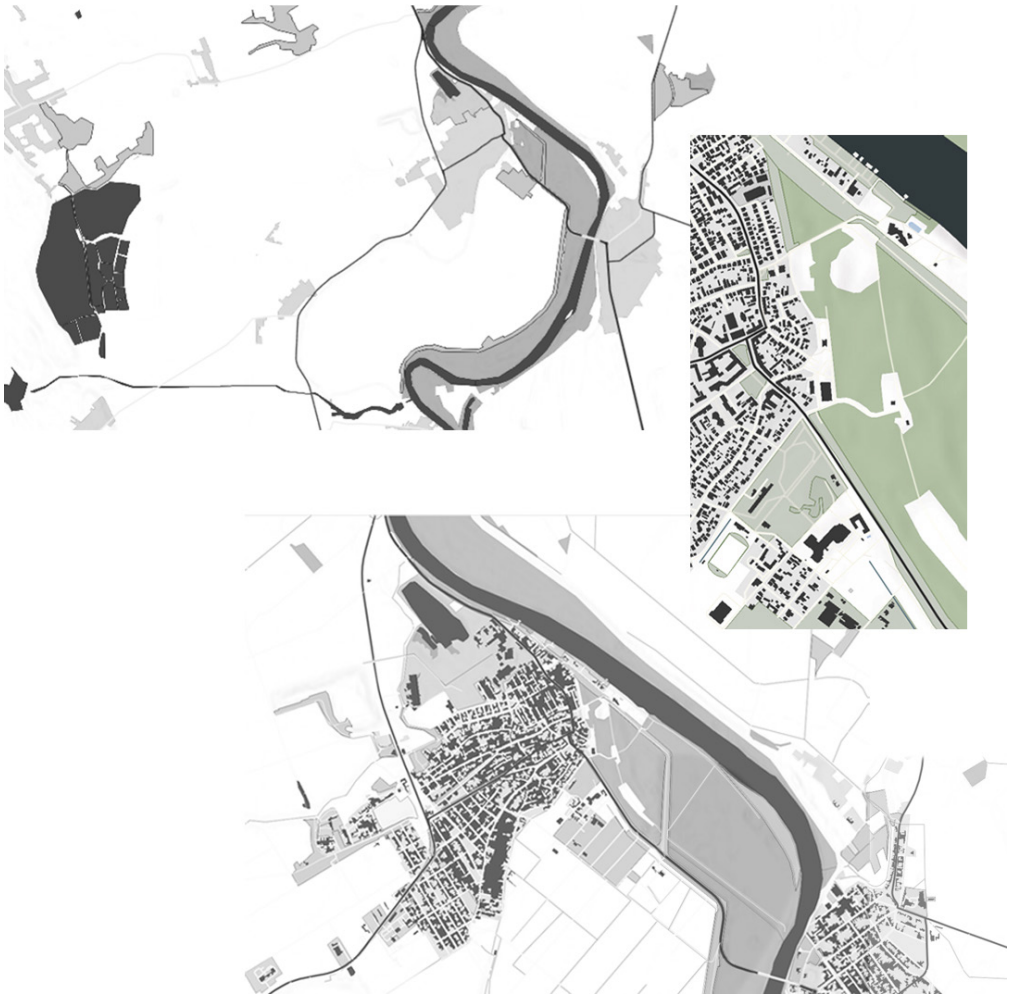

FIGURE 6. Analytical map of Banja Kanjiza - Spatial and morphological analysis.
Source: Author

6.3 Banja Stari Slankamen

Stari Slankamen is the oldest spa in Vojvodina and one of the earliest natural healing sites in Serbia. It is located at the easternmost edge of Fruška Gora, on the right bank of the Danube, where mineral springs emerge beneath the loess escarpment at an elevation of approximately 80 m above sea level. The spa is situated within the rural landscape of Stari Slankamen, combining natural hydrogeological features with the historic character of the village. The modern spa was established in 1906, building upon a long tradition of using the local mineral springs for therapeutic purposes. The therapeutic use of saline mineral water in this area dates back to the Ottoman period, when a bathing site existed at the springs, later followed by water extraction from shallow wells. These springs emerge naturally through artesian processes, providing saline and relatively warm water suitable for health and wellness treatments.

I - Territorial and Spatial Context

Stari Slankamen is positioned in southeastern Srem, Vojvodina, 55 km from Belgrade and in close proximity to Novi Sad. The historic and cultural town of Sremski Karlovci lies 20 km upstream, offering cultural and spiritual landmarks such as the oldest Serbian library and seminary, baroque architecture, churches, and museums. The spa is integrated into a broader landscape shaped by the Danube and Tisa rivers, which define the hydrological and ecological corridors of the region. Several riverine islands (adas) and protected riverbanks form part of the ecologically sensitive zones near the spa. The area is also adjacent to Fruška Gora National Park, with forested slopes contributing to biodiversity, recreation, and microclimatic regulation. The location has been identified in regional nautical tourism development plans as a primary site for marinas along the Danube, reflecting its strategic position at the confluence of major river corridors and its accessibility from surrounding urban centres.

II - Structure and Morphology

The settlement of Stari Slankamen is organised into two main spatial and functional units: the upper part, consisting of the historic residential core with the church, houses, and central square dating from the 9th century, and the lower part, occupied by the spa and medical complex, which extends along the riverbank. The spa complex includes the early 20th-century bathhouse, now functioning as a specialised hospital, patient pavilions arranged in a pavilion-type layout oriented toward the river, an outpatient facility for daytime therapies, accommodation units, rehabilitation spaces for hydrotherapy and physiotherapy, and supporting amenities. This arrangement allows patients

and visitors to combine treatment with leisure within a carefully structured environment. The spa core is subtly nestled within the settlement, not directly accessible from the main roads connecting larger towns. A park and green corridors along the river organise the space between buildings, while the main hospital building has been modernised in the early 21st century. The approach road connects the upper residential area with the spa, reinforcing the vertical hierarchy imposed by the relief. The spatial organisation emphasises the relationship between the settlement, the spa, and the river, highlighting the artesian spring as a defining element of both structure and experience.

FIGURE 7. Analytical map of Banja Stari Slankamen - Spatial and morphological analysis, Source: Author

III – Relation to landscape structure

The Stari Slankamen spa complex occupies a spatial niche in the eastern and lower part of the settlement, developing along the slope in accordance with the relief. Positioned on the steep right bank of the Danube, the artesian mineral springs at the riverside have determined both the development and the linear morphology of the spa. The spa's position on the steep Danube terrace, close to the confluence with the Tisa River, establishes its primary spatial and visual axis, integrating the watercourses into the overall organisation. The surrounding landscape includes forested complexes on the Fruška Gora slopes, natural vegetation belts changing with slope and aspect, and protected areas such as the Fruška Gora National Park and river islands under environmental protection. The proximity to the Danube and Tisa, together with terraced relief and vegetation, creates a distinct microclimate characterised by moderated temperature fluctuations, increased humidity along the riverbank, and local wind patterns shaped by the river.

The spa's morphology, elongated along the river, interacts with this landscape structure, combining natural and recreational spaces. Green corridors and the park mediate between built structures and the river, while the vertical hierarchy emphasises visual connections between the upper settlement, the spa complex, and the surrounding water and relief features. This integration of natural springs, rivers, relief, and vegetation defines the spa's spatial logic and reinforces its role as a landscape-based therapeutic environment.

7. COMPARATIVE ANALYSIS AND DISCUSSION

Although Rusanda, Kanjiža, and Stari Slankamen are all situated within the Pannonian Basin, each occupies a distinct landscape context that shapes its spatial morphology and relationship to the environment. Srem, where Stari Slankamen is located, combines the influence of rivers with upland relief, generating varied microclimates, forest-meadow mosaics, and floodplain dynamics. Banat, the context for Rusanda, features saline depressions interspersed with steppe-like terrain, where soil salinity and high summer evaporation dictate vegetation patterns and open landscape character. Northern Bačka, home to Kanjiža, is largely flat, with deep artesian systems underlying the surface, simplified hydrology, and floodplain vegetation along major river corridors. Despite these differences, all three regions reveal layered interactions among landforms, water, and vegetation communities, providing a comparative framework for exploring how landscape conditions inform spa settlement morphology.

The nature of the spa water source directly informs the spatial positioning and organisation of each settlement. At Rusanda, the saline lake functions as an extended hydrological and ecological anchor, with the spa complex adapting to a closed, self-contained ecosystem. In Kanjiža, the deep artesian wells offer flexibility in surface placement, allowing the spa to integrate with the surrounding settlement without being constrained by topography. By contrast, Stari Slankamen is closely tied to artesian springs emerging on loess terraces, with sloping terrain towards the Danube directly influencing the linear arrangement of buildings, the vertical hierarchy of spaces, and the relationship between settlement and riverfront. These variations demonstrate how water source characteristics, together with topography, establish distinct spatial frameworks that guide the morphology of spa settlements.

Access and connectivity further shape the scale and form of each spa. Kanjiža benefits from proximity to larger urban centres, with infrastructure enabling integration with surrounding settlements, while the linear, terraced form of Stari Slankamen constrains circulation and centralises functions along a descending slope. Rusanda's enclosed landscape creates an internally coherent spatial order, with buildings oriented around the water body, enhancing the perception of a contained therapeutic environment. In each case, transport links, corridor positioning, and access to natural features influence the organisation of functional zones, hierarchy of open spaces, and visitor experience, demonstrating that landscape and human infrastructure operate jointly to structure spa settlements. Climatic factors act as additional

determinants. The location of Stari Slankamen along the Danube and Tisa rivers modifies the local microclimate, with moderated temperature ranges, increased humidity near water bodies, and wind patterns shaped by relief and river corridors. Rusanda's saline depressions create distinct thermal and evaporative conditions, reinforcing its closed ecosystem character. Kanjiža, with its artesian wells and flat terrain, allows for the exploitation of microclimatic conditions in spa programming without significant topographical constraints. These differences illustrate how climate interacts with hydrology and relief to influence both the siting of spas and their functional and spatial organisation, aligning with the hypothesis that local environmental conditions generate distinct morphological expressions.

The three case studies collectively demonstrate that landscape structure actively conditions the spatial identity and internal organisation of spa settlements, supporting the research's first hypothesis. Morphology, in turn, interprets and adapts to these conditions, articulating the interface between natural systems and human intervention. Each spa settlement functions as a mediator between landscape and architecture, translating relief, hydrology, vegetation, and microclimate into spatial form, functional zoning, and visual hierarchy. Subtle differences in environmental context, even within the seemingly homogeneous Pannonian lowlands, produce discernible variations in spatial arrangement, building orientation, and integration with the surrounding landscape, confirming the third hypothesis regarding the influence of localised conditions.

FIGURE 8. Comparative view of spa settlements, Source: Author

By integrating comparative insights across relief, water, vegetation, access, and microclimate, the analysis confirms that spa settlements cannot be understood solely as architectural artefacts; they are spatially and ecologically embedded systems. This study highlights how natural resources, topography, and hydrological characteristics inform spatial hierarchy, functional zoning, and human experience, while also accounting for cultural and infrastructural factors that mediate landscape interaction. The findings demonstrate that spa morphology is both a response to and a reflection of landscape logic, supporting sustainable planning approaches that consider ecological processes, heritage, and human use as intertwined determinants of spatial form.

8. CONCLUSIONS

In conclusion, this study demonstrates that spa settlements are inseparable from their landscape context, where natural structure operates as a generative framework rather than a deterministic background. By examining Rusanda, Kanjiža, and Stari Slankamen, this research demonstrates that landscape structure shapes the range of possible spatial configurations, guiding the positioning, hierarchy, and organisation of built form while allowing for human agency and adaptation. The research confirms that differences in relief, hydrology, vegetation, and microclimate produce distinctive morphological expressions, highlighting how local environmental conditions inform spatial identity. In addressing the research hypotheses and objectives, the study illustrates that spa morphology reflects a layered interaction between natural systems and human intervention, revealing the settlement as a spatial mediator between ecological and cultural processes. The broader contribution lies in demonstrating the analytical and conceptual value of landscape structure for architectural and urban studies: understanding pre-existing natural frameworks allows designers and planners to interpret, integrate, and enhance spatial form in ways that respect both ecological processes and cultural heritage. This study attempts to provide a methodological framework applicable to various architectural typologies and landscape contexts, offering a methodological approach for linking landscape structure with morphology, informing sustainable planning, and expanding architectural and urban discourse on the interrelation between nature and built space.

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