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Multi-Criteria Evaluation of Recreational Potential in Post-Industrial Landscapes: A Case Study of the Prydniprovsk Region

Iryna Merylova

Department of Architectural Design and Urban Planning, Ukrainian State University of Science and Technologies, REI 'Prydniprovska State Academy of Civil Engineering and Architecture', Ukraine

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Abstract This article explores methodological approaches and specific methods for addressing the scientific challenge of spatial planning organization of recreational areas in the Prydniprovsk region of Ukraine. The study aims to provide a systematic foundation for the investigation and understanding of spatial planning phenomena; to develop a structured framework for landscape and recreational zoning of the region's territory; to establish a toolkit for integrating interdisciplinary approaches; to facilitate comparative studies through standardized methods of data collection and analysis, enabling the identification of trends and regularities in various contexts; and to lay the groundwork for generating practical recommendations. As a result of the analysis of both quantitative and qualitative indicators of recreational resources, the specific characteristics of the region's recreational assets were identified, revealing their overall deficiency. The article presents a detailed application of cartographic methods based on geographic information systems (GIS) and multi-criteria evaluation according to defined categories. This approach enabled the structuring of the Prydniprovsk region's landscape-recreational, historical-cultural, and socio-economic resources within the framework of their recreational and tourism potential. Consequently, areas with the highest composite index values were identified and designated as having the greatest potential for the development of recreational and tourism functions. These zones serve as core recreational districts in the formation of a regional tourism and recreation network. By applying area-based parameters to the selected territories, the study developed a clear taxonomy for establishing a hierarchical spatial model of "region–district–zone." Moreover, the research contributed to the construction of a conceptual model for the regional recreation system and identified potential areas of urban planning conflict between recreational development and existing settlement structures.

Keywords Landscape-Recreational Zoning, Regional Planning, GIS-Based Spatial Analysis, Urban Regeneration, Cultural Landscape Transformation, Recreational Land Suitability Mapping, Revitalization of Industrial Regions

1. Introduction

In many scientific disciplines, territory serves as a fundamental subject of study due to its complexity and its critical role in shaping scenarios of human activity and interaction. Territorial research encompasses socio-economic dynamics, environmental impacts, cultural

and historical contexts, governance policies, and - most relevant to this study - the planning organization of space.

The objects of spatial planning include territorial socio-economic systems at various hierarchical levels: global, regional, subregional, and local [1]. Modeling territorial organization requires the preliminary delineation of the study area's boundaries. For this purpose, the present paper applies a method aimed at identifying objectively existing regions and their boundaries - namely, the zoning method.

In this study, the term "zoning" is understood both as a scientific method of analysis and as a product of its application, represented by synthetic cartographic outputs that reflect the integral characteristics of regions on maps by delineating the boundaries of the territories to which these characteristics pertain [2].

As a component of the regional planning process, territorial zoning involves dividing an area into homogeneous zones (regions) for the purpose of rational use of natural, socio-economic, and cultural resources, as well as for the optimal development and governance of these territories. The zoning process includes the following key aspects: territorial analysis, classification, planning, and utilization aimed at achieving balanced development, effective management, and control. Despite existing studies on recreational planning, the regional-scale spatial evaluation of post-industrial territories remains understudied. This paper addresses that gap by offering a multi-criteria model specifically applied to the Prydniprovsk region.

The aim of this study was to establish a recreational-tourism taxonomy for the Prydniprovsk region, to organise the identified areas according to the spatial logic and functional hierarchy of recreational planning, and to characterise the recreational profiles of the resulting taxa.

The research was undertaken from 2021 to 2025 and is oriented towards developing a scenario for the region's rehabilitative territorial development. The projected timeframe for implementing the recreation and tourism strategy is 2025–2035, contingent on regional stabilisation and post-war policy priorities. Consequently, this research fulfils a preliminary analytical role, laying the scientific groundwork for future spatial decisions.

2. Materials and Methods

The relief of the Prydniprovsk region is undulating lowland with absolute elevations of roughly 100-200 m above sea level. The territory lies within Ukraine's steppe zone and is dissected by river valleys, gullies, and ravines. Forest patches occur along these landforms, predominantly of artificial origin. The region includes the Prydniprovsk Regional Recreation System, characterized by aquatic-steppe landscapes with isolated floodplain forests and meadows. Its recreational profile is defined by tourism and health-oriented uses and by angling and fishing activities. The system formed within the floodplains of the Dnipro River and is classified as an extrazonal zoogeographic district of a large-river valley [3]. The region's spatial framework exhibits a radial-ring configuration centered on the city of Dnipro, shaped by the channels of the Dnipro, Samara, Oril, and Inhulets rivers and by a suite of factors including the distribution of mineral resources, the regional settlement system, and the transport-engineering infrastructure that emerged from the area's historical development trajectories.

The industrial complex of the Prydniprovsk region is represented by metallurgy, mining, and machine-building, including the rocket and space sectors. A strong resource base and developed infrastructure have led to clusters of enterprises with large territorial and production scales. The principal industrial centers are Dnipro, Kryvyi Rih, Kamianske, Kropyvnytskyi, Nikopol, and Pavlohrad. Many facilities were established during the intensive industrialization of the 1880s-1930s, now hold protected status, and possess high historical and cultural value. Given sectoral stagnation, limited modernization, declining production efficiency, and, above all, the optimization of municipal functional-planning structures, these enterprises are progressively losing their original production functions and can become key attractors for industrial tourism [4].

The conceptual foundation of the methodology employed in this study takes into account the impact of land use patterns and ecological factors on the spatial and planning organization of the regional recreational system. It also considers the influence of industrialization and urbanization, which shape the cultural landscape and the socio-economic dynamics of the Prydniprovsk region in the context of its industrial development, the spatial structure of industrial zones, and the urban development models of the region's cities [5, 6].

The literature analysis conducted in this research is based on the Systematic Literature Review (SLR) method [7]. The systematic literature review is a scientific approach to analyzing sources that begins with a clearly defined review question, identifies all relevant studies, evaluates their quality, and synthesizes their results using a transparent and structured methodology [8, 9]. A key feature of applying the SLR was the ability to combine findings obtained from multiple studies - regardless of their theoretical or methodological frameworks - that address the research topic. This approach was used to assess the reliability of findings and to summarize evidence for practical application [10, 11].

An analysis of scientific, technical, and regulatory literature has shown that the territorial zoning approach holds significant values for both the global political and scientific communities. On May 20, 1983, in Torremolinos, Spain, the European Charter of Regional/Spatial Planning was adopted during the 6th European Conference of

Ministers responsible for Spatial/Regional Planning (CEMAT) under the Council of Europe. This document, a milestone in European spatial development policy, laid the groundwork for the development of the Guiding Principles for Sustainable Spatial Development of the European Continent [12, 13].

The Charter is not merely a system of taxonomic classifications governed by specific rules, as suggested by its title and content; it also establishes concrete approaches to spatial planning, recognizing it as a fundamental policy area. It promotes the integration of various planning approaches at local, regional, national, and transnational levels, encouraging inter-territorial cooperation and network creation to foster development. Although the Torremolinos Charter is not legally binding, it serves as a guiding framework for spatial planning practices across European countries, advancing a holistic model that takes into account social, economic, and environmental dimensions of sustainable territorial development.

- Territorial planning and land use issues have concerned researchers since at least the 17th century, finding expression in diverse models of urban ecosystems, including:
- Utopian urban visions by Tommaso Campanella (The City of the Sun, 17th century), Charles Fourier (The New World of Industrial Societies, 19th century), and Ebenezer Howard (Garden City, 1898);
- Theories of territorial and socio-economic organization by Johann Heinrich von Thünen (The Isolated State, 19th century), Alfred Weber (Theory of Industrial Location, 20th century), Walter Christaller (Central Place Theory, 1933), and August Lösch (Theory of Economic Space, 1940);
- Urban spatial structure models by Ernest Burgess (Concentric Zone Model, 1925), Homer Hoyt (Sector Model, 1939), and Chauncy Harris and Edward Ullman (Multiple Nuclei Model, 1945);
- Urban form theory by Kevin Lynch (The Image of the City, 1960).

At the same time, most contemporary studies tend to overlook the regional level of territorial planning, focusing instead on the analysis of cities, their structures, sociological dimensions, and sustainability issues [14-17]. This focus is driven by the greater reliability of data within smaller spatial units, stronger practical applicability, and, most importantly, the more dynamic development of urban areas in the context of post-war urbanization and subsequent globalization.

In Ukrainian urban planning theory and practice, a landmark document in the field of territorial planning is the General Scheme of Territorial Planning of Ukraine, developed by the Dipromisto Institute in 2002 and later formalized as a national law [18, 19]. This document established key priorities for the spatial development of the country, including systems such as settlements, tourism, protected areas, recreational and health zones, among others [20, 21].

Research on landscape-recreational zoning has revealed its inherently interdisciplinary nature, involving the integration of approaches and principles from various domains, including geography, ecology, urban planning, and landscape architecture [22]. Among the most commonly used methodological approaches for analyzing the impact of industrial-urban development processes on areas with landscape-recreational functions are:

- Cartographic analysis and geographic information systems (GIS), which enable spatial analysis, map overlay, and proximity evaluation;
- Multi-criteria analysis (MCA), applied to assess landscape characteristics in relation to recreational potential, environmental conditions, and socio-economic factors [23].

A review of existing sources revealed that the boundaries of the Prydniprovsk region are not officially defined in Ukrainian legislation or regulatory acts. Consequently, the regional zoning approaches vary significantly depending on the discipline - whether regional planning or recreational geography. Therefore, a crucial stage in this study was the delineation of the spatial boundaries of the research area. This process is described in detail in the author's previous publication, Revitalizing Industrial Territories in Ukraine: Spatial Model of the Tourism Cluster in the Prydniprovsk Region [4], where the boundaries were determined through a cartographic method based on the analysis of key regional characteristics.

Once the spatial boundaries were defined, the study employed a methodology grounded in the use of Geographic Information Systems (GIS). GIS tools enabled the integration of diverse types of spatial data - including land use, topography, infrastructure, environmental conditions, and socio-economic factors - facilitating the analysis of spatial relationships, patterns, and trends across the Prydniprovsk region. As a result, areas suitable for recreational development were identified based on factors such as proximity to settlements, accessibility, natural and cultural-historical assets, and environmental considerations [24, 25].

The analysis of sources made it possible to identify key examples of territorial zoning. This study placed primary emphasis on recreational and historical-cultural aspects, after which, using the cartographic method and based on zoning schemes, the boundaries of the Prydniprovsk region were determined.

3. Results

3.1. Functional Zoning of the Prydniprovsk Region

The study applies a landscape-recreational regionalization approach as a systemic framework, based

on the functional zoning of the Prydniprovsk region. This approach, traditionally used in urban and regional planning, serves to classify and organize land use and economic activity within a defined territory. It involves an assessment of the current landscape functions, an evaluation of the region's potential for recreational development, and the delineation of zones that optimize land use while preserving ecological integrity [26, 27].

Figure 1 is based on data from the dynamic land cover map for the period 2015–2019. The graphic material presents a land cover classification scheme according to functional characteristics and may reflect areas with heterogeneous vegetation cover [28]. The analysis of land cover using this scheme enables the identification of the recreational landscape types within the region: green zones are predominantly located along ravines, gullies, and river valleys, resulting in a distinctly linear spatial structure. The properties of the region's recreational resources - particularly their extensive linear distribution - impose specific characteristics on the regional recreational system: they complicate the formation of compact recreational zones but facilitate the development of recreational routes and corridors.

The applied cartographic analysis method involves the collection and functional analysis of data based on the physical characteristics of the territory (climate, topography, vegetation, water resources), demographic indicators of the population, primary land use types, forms of recreational activities, recreational sites, and their usage patterns [29, 30]. The provided scheme visually demonstrates the level of agricultural land use in the region. The analysis of the graphical materials, considering the significant presence of linear recreational territories, revealed the dispersion and fragmentation of natural complexes and ecological corridors, which hinders the free movement of species, reduces the ecological stability of the area, and decreases its biodiversity [3, 31, 32].

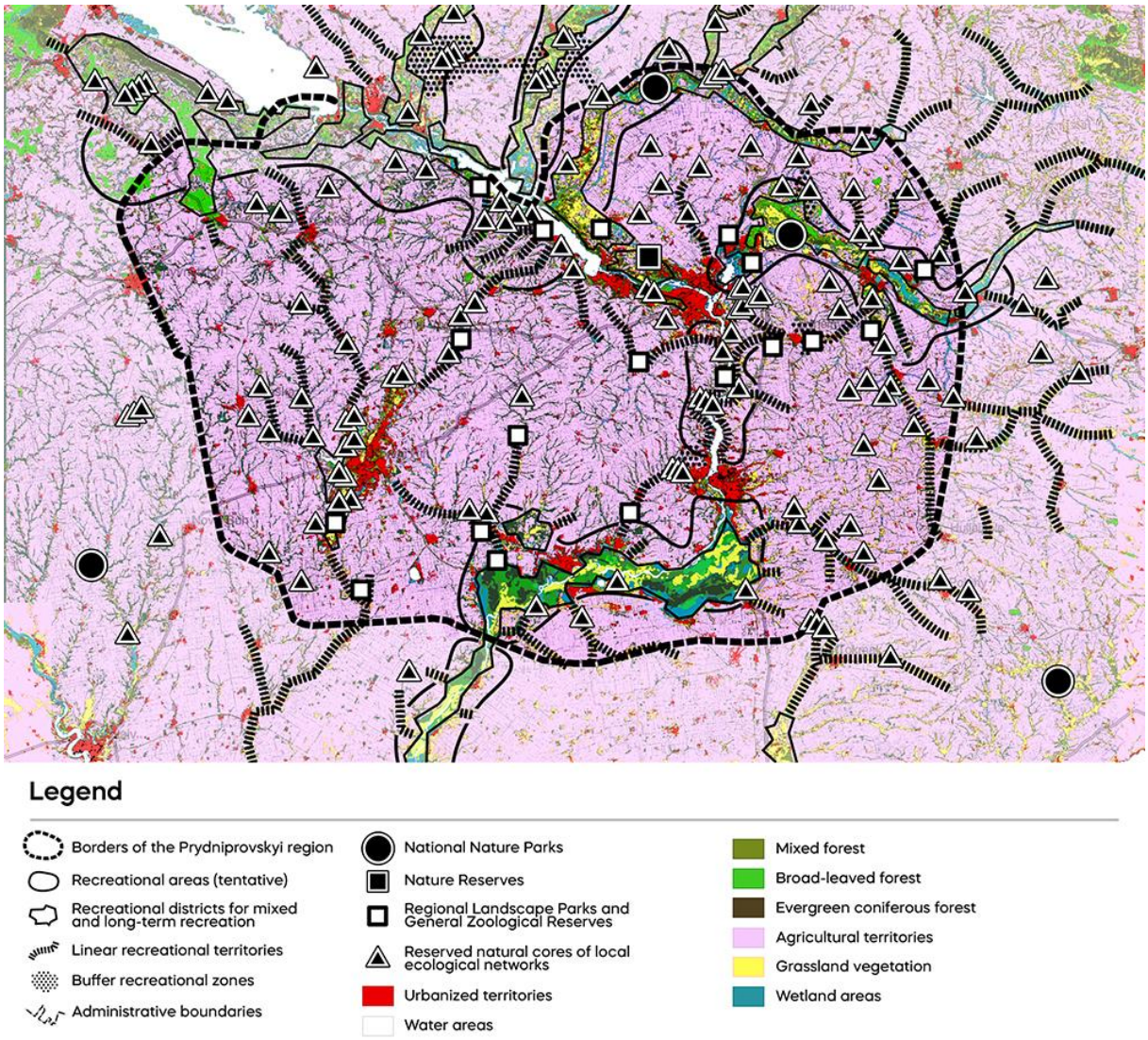


Figure 1. Current state of functional zoning in the Prydniprovsk region. Functional land use complexes

The processing of the collected materials led to conclusions regarding the ecological functions of the landscape: the filtration of water from the large Dnipro River occurs through its floodplains, but is complicated by the regulation of the riverbed, which affects the river's hydrological regime; rainfall filtration takes place through its initial runoff into ravines and gullies, followed by redirection to smaller rivers in the Dnipro basin; soil stability is determined by the terrain's characteristics, but requires specific local measures for the slopes of river valleys, ravines, and gullies, which are mostly carried out using phytostabilization methods.

The GIS mapping method enabled the assessment of the potential for different types of recreational activities based on the physical and ecological attributes of the landscape. Conditional recreational areas of the region were identified, along with areas suitable for the establishment of mixed-use and long-term recreational zones [33, 34].

The creation of suitability maps for land use and recreational activities within the region, based on GIS mapping and the overlay of ecological, social, and recreational data, allowed for the identification of potential conflict zones and areas with the highest recreational potential:

- Conservation zones: Areas with high ecological value where human activity is restricted to protect biodiversity and ecosystem functions;
- Recreational zones: Areas designated for recreational activities, which can be divided into high- and low-intensity use zones;
- Mixed-use zones: Areas that, alongside recreational activities, support a combination of different types of land use;
- Buffer zones: Transitional areas that mitigate conflicts between different zones.

In the context of territorial zoning within the region, considering the nature of its industrial and urban development, identifying potential conflict zones is crucial, especially between active production areas and those hosting recreational resources. The results of the analysis are reflected in Figure 2, where zones exhibiting conflicting functions are marked. Such zones require the resolution of land use specifics and the creation of specialized buffer zones to mitigate conflicts [35].

The issue of potential land-use conflicts between recreational development and urban-industrial utilization is particularly relevant for the Prydniprovsk region, which possesses significant subsoil reserves - most notably in the areas of Kryvyi Rih, Pavlohrad, Nikopol, and Marhanets. These territories contain substantial deposits of mineral resources that have historically shaped the economic profile of the region.

In this study, several of the proposed recreational zones are located within or adjacent to areas that are currently, or were previously, used for industrial activities. This overlap of functions creates potential spatial and functional tensions between competing land uses - namely, between ecological tourism and public access on the one hand, and ongoing or future industrial operations on the other.

To address this challenge, the study adopts the concepts of buffer zones and multifunctional land use (multifunctional zoning), grounded in international best practices of post-industrial landscape planning. Examples from Germany (the Emscher Landscape Park in the Ruhr area; the Leipzig New Lake District), Poland (the Silesian Industrial Monuments Route), and the Czech Republic (the research programme Industrial Topography) illustrate how former or partially active industrial territories can be transformed into hybrid landscapes that support both heritage-based tourism and industrial-economic activity under strict environmental controls [36, 37, 38].

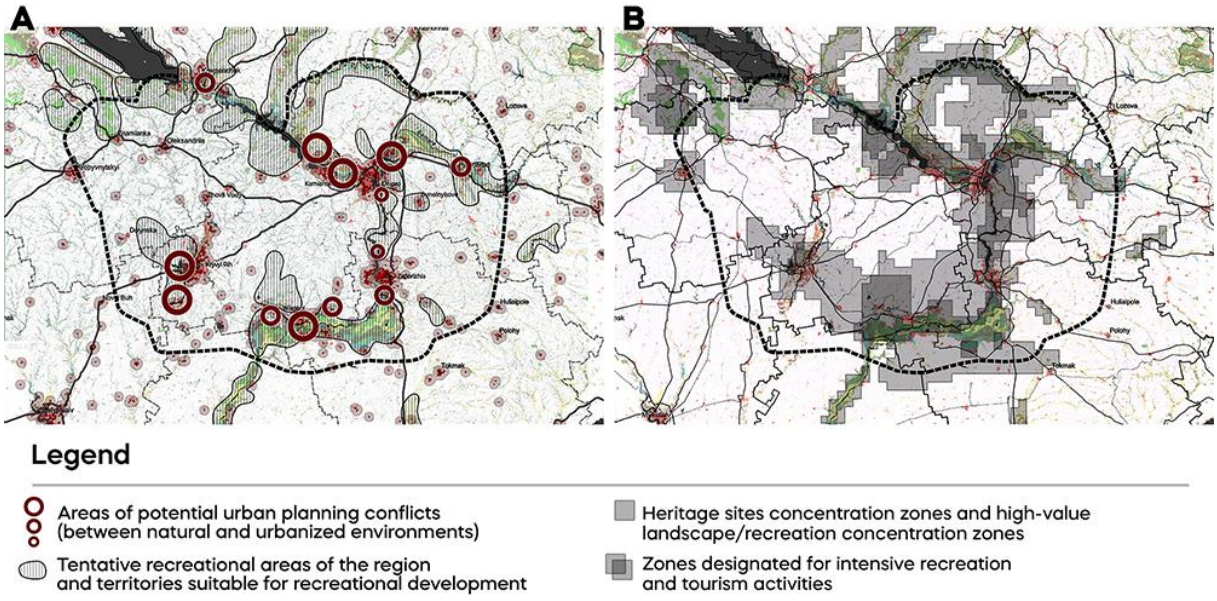


Figure 2. Part A – Urban development conflict scheme. Part B - High-intensity recreation/tourism scheme

Accordingly, the planning model proposed in this paper avoids a simplistic dichotomy between preservation and exploitation. Instead, it advocates for context-sensitive zoning, whereby the intensity and type of recreational use are adapted to local geological, ecological, and economic realities. The study promotes flexible, multi-layered planning approaches for the Prydniprovsk region that enable strategic decision-making in areas of overlapping interests, with the dual aim of minimizing land-use conflicts and ensuring sustainable regional development.

3.2. Multi-Criteria Evaluation (MCE) of the Prydniprovsk Region

The assessment of territorial suitability for recreational and tourism activities was conducted using Multi-Criteria Evaluation (MCE). Criteria were developed for various recreational scenarios (e.g., hiking, camping, fishing), categorized into three main groups [39]:

- Environmental criteria (natural features, attractive landscapes, visual appeal, biodiversity and presence of protected species, ecological sensitivity);
- Social criteria (accessibility, infrastructure availability, safety, cultural and historical significance);
- Economic criteria (economic feasibility, land-use compatibility, visitor demand).

A joint MCE of landscape values was developed by specialists from the Institute of Environmental Science and Technology (Autonomous University of Barcelona, Spain) together with experts from the Interdisciplinary Centre for Mountain Research (University of Lausanne, Switzerland), in collaboration with the Catalan Government Firefighters and with the support of the Pau Costa Foundation. Their methodology informed the compilation of Table 1 [40, 41].

Table 1 presents scores to various landscape elements based on their importance within five categories: biodiversity, socio-economic activity, heritage, leisure, and public values. These scores are relative within each category, meaning there is no direct correlation between scores across different categories [40, 42, 43]. The next stage involved evaluating the territory of the Prydniprovsk region based on scores assigned to selected categories [44].

Each landscape element was assessed within five thematic categories: biodiversity, cultural heritage, socio-economic activity, leisure, and public values. A score from 1 to 5 was assigned to each element, where 5 corresponded to the highest relative value within its category. For example, nationally protected cultural heritage sites were assigned a score of 5, while areas with low public accessibility or limited recreational potential were given lower scores (1–2). These values reflect the relative significance of each element in shaping the recreational landscape of the region.

For the Biodiversity category, statistical analysis was conducted using data from the Nature Reserve Fund, as well as the Green Book of Ukraine and the Red Book of Ukraine - official regional and national registers of animal, plant, and fungal species whose habitats require special land-use regimes. The Heritage category was evaluated using databases of historical and architectural monuments, tangible and intangible heritage sites. The Socio-economic activity category was assessed using data from the Atlas of the Administrative-Territorial Structure of Ukraine and reports of the State Statistics Service of Ukraine on economic activity. The Leisure category was informed by materials from the State Agency for Tourism Development of Ukraine (SATD) and the open-source Strava Global Heatmap. Finally, public value was assessed using an expert-based evaluation method.

In the integration phase, no additional weighting scheme was applied to the cumulative scores. Instead, an equal-weighting approach was adopted, ensuring that each thematic dimension contributed equally to the composite index. This method allowed for a balanced synthesis of ecological, cultural, and socio-economic factors, avoiding overrepresentation of any single criterion in the final spatial analysis.

The multi-criteria evaluation allowed for the identification of valuable landscape components, which were classified into three dimensions: forms, relationships, and practices. Forms refer to the physical and measurable aspects of the landscape, including natural elements (e.g., topography, vegetation, water bodies) and anthropogenic features (e.g., agricultural fields, bridges, roads). Relationships encompass interactions within human-human systems, human-landscape dynamics, and ecological processes within the landscape [45]. Practices include both human activities and ecosystem processes.

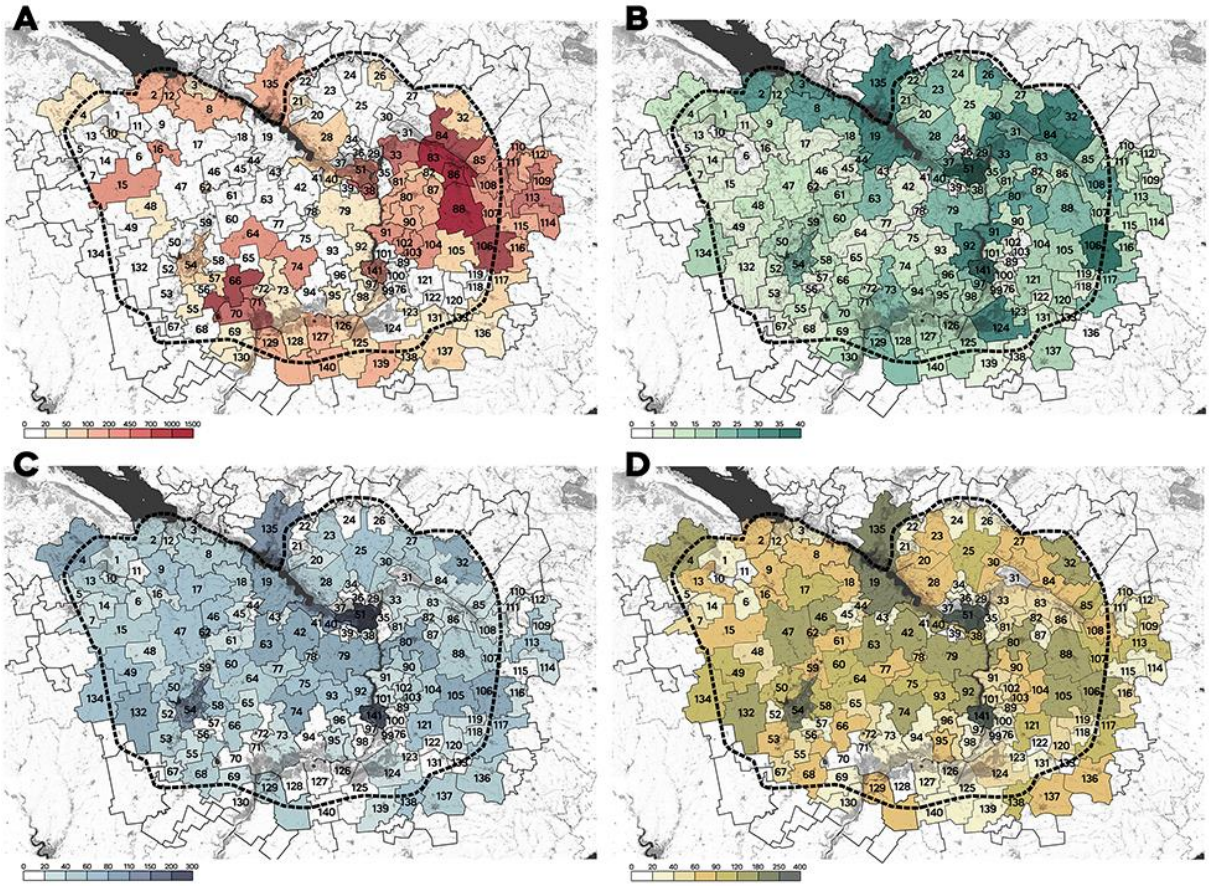
The application of mapping within the multi-criteria evaluation (MCE) enabled the visualization of results on a map. Accordingly, Figure 3 presents the graphical representation of each category separately, as well as an integrated scheme combining all categories. The image illustrates which areas receive the highest scores in specific categories relevant to tourism and recreational activity - where the most significant natural resources affecting biodiversity are located, and where the highest concentration of historical and cultural landmarks can be found.

The composite map (Figure 3F) was generated by integrating the five thematic layers (Figures 3A–E) using a standardized raster overlay method. Each layer was first normalized to a unified 1–5 scale to ensure compatibility. The integration was performed using an equal-weighted summation in the GIS environment, where all layers contributed equally to the final spatial index.

The resulting map visualizes territories with the highest cumulative recreational value across ecological, cultural, and socio-economic criteria. This synthesis highlights the multifunctional potential of specific zones.

Table 1. Scores Assigned to Each Identified Landscape Element

Score	Biodiversity	Heritage	Socio-Economic Activity	Leisure	Public Values
5	-	Nationally recognized cultural heritage monuments protected by law	-	Highly visited locations Tourist routes	-
4	Elements of high and very high conservation interest	Locally recognized cultural heritage sites protected by law	-	-	-
3	Technically prioritized habitats Potential habitats for protected species	Potential cultural heritage sites	-	Public areas	-
2	-	-	Urban centers and households	Private lands with open access	Highly valued locations
1	Monumental trees Open spaces: harvest meadows, arable land, cleared forests, pastures	Residential buildings Agricultural infrastructure of heritage interest Tourist-related buildings and structures Other heritage-related elements (e.g., springs, cemeteries, archaeological sites) Historical resource extraction sites (e.g., mines, lime kilns)	Campsites, recreation areas, and restaurants Arable land and pastures Managed forest areas Resource extraction sites Industrial zones	Private lands with restricted access	Valuable places



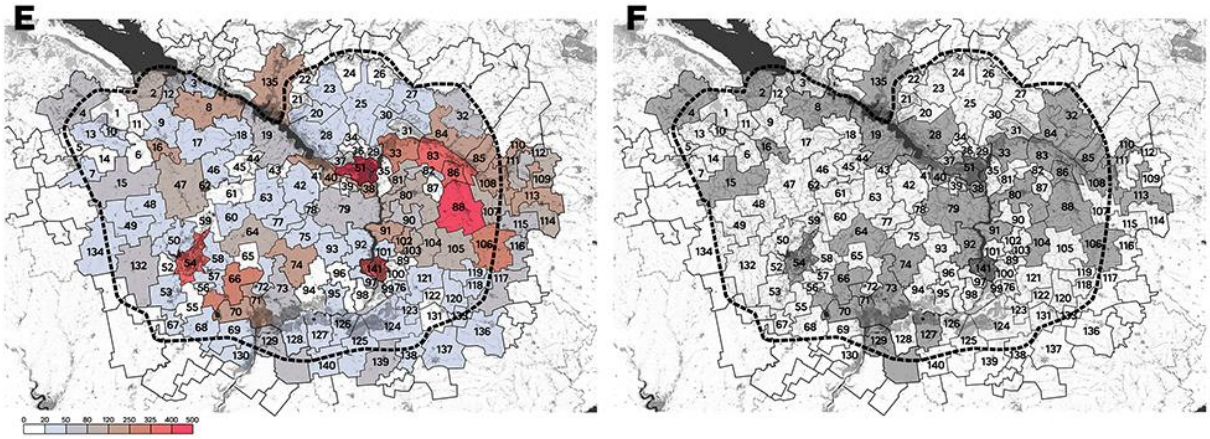


Figure 3. Part A – Cultural heritage; Part B – Biodiversity; Part C – Socio-economic activity; Part D – Leisure; Part E – Social values; Part F – Integrated map based on the cumulative score of indicators.

As a result of implementing the MCE method, specific areas within the region were identified (the territorial unit used was the boundaries of the amalgamated territorial communities of the region, as defined by legislative acts adopted by the Verkhovna Rada and the Cabinet of Ministers of Ukraine in June–July 2020). These areas were determined to have the highest value in terms of recreational and tourism activities.

However, relying solely on the results of the MCE is insufficient for zoning the region based on landscape and recreational characteristics. While MCE allows for the integration of numerous diverse criteria into the assessment process, it does not account for territorial features such as the area size, spatial density, or the qualitative condition of specific objects. For this reason, the author combined the multi-criteria evaluation with the cartographic method.

For this purpose, the results of the territory analysis obtained through the Multi-Criteria Evaluation method (Figure 3F) were combined, with equal weighting, with the recreational–tourism attractiveness scheme (Figure 2B), which compensates for the previously noted limitations of the MCE method. This integrated approach made it possible to identify the key areas suitable for developing the recreation and tourism system in the Prydniprovsk region.

3.3. Operationalising MCE for Plannig: Regional–District–Zone

The analysis of the internal structure of recreational (tourist) regions and the subsequent processing of cartographic analysis materials led to the conclusion that the Prydniprovsk recreational region represents a group of recreational districts and zones, forming recreational clusters of various hierarchical levels (local, district, and regional) within the corresponding territories of the region. These clusters are characterized by shared natural and historical-cultural resources.

To strengthen the spatial logic and functional hierarchy of recreational planning, the study introduces a three-tier classification of territorial units: region – district – zone. This system of territorial units was originally proposed by Yu. Belokon in the 2000s for the entire territory of Ukraine (Dipromisto) and has since been established at the legislative level.

The parameters of the region, districts, and zones are as follows: the area of the Prydniprovsk region – 47.9 thousand km ², of a district – 0.5 to 5 thousand km ², of a zone – 0.025 to 0.5 thousand km ²[46, 47]. In accordance with the defined parameters of the main structural units of the Prydniprovsk region's recreational system, the study identifies 11 recreational districts (see Table 2), delineated through the aggregation of amalgamated territorial communities (based on administrative boundaries established under the legislation of Ukraine as of June–July 2020), and over 30 recreational zones with varying levels of development, diverse specializations, and distinct prospects for future growth (Fig. 4).

The combination of cartographic analysis and multi-criteria evaluation (MCE) made it possible to conduct a detailed assessment of the region's recreational resources and to identify areas most suitable for the development of the recreational and tourism sector. The synthesis of these methods is presented in Figure 4, which introduces a district-level classification and a hierarchical zoning structure for practical application in planning.

Each district was evaluated for internal spatial heterogeneity and classified according to its dominant recreational profile (e.g., ecological, historical–cultural, balneological, or mixed-use). This classification was based both on the quantitative outputs of the MCE model and on the functional–morphological structure of the landscape, as determined through GIS-based analysis.

Accordingly, Figure 4 represents a higher-resolution spatial interpretation designed to support targeted recreational planning. It translates the abstract suitability values from Figure 3F into concrete regional planning zones, each with defined characteristics and functions. This transformation enables a clearer visualization of the recreational structure at the district scale.

Table 2. Characteristics of Recreational Districts of the Prydniprovsk Region

№	Name	Profile	Area (thousand km²)
I	Kropyvnytskyi	Resort (balneology) and tourism (cultural heritage)	1.873
II	Svitlovodsk	Recreational (Svitlovodsk Regional Landscape Park), recreational (water sports), and tourism (local history)	2.146
III	Kobeliaky	Recreational (Nyzhniovoroskllianskyi Regional Landscape Park and Luchkivskyi Landscape Reserve) and recreational (water sports)	1.389
IV	Verkhnodniprovs'kyi	Recreational (landscape reserve) and recreational (water sports)	1.045
V	Petrykivka	Resort (balneology), recreational (Oril National Nature Park), recreational (water sports and recreation bases), and tourism (cultural heritage)	1.290
VI	Cherneche-Pereshchepyne	Recreational (Pryorils'kyi Landscape Reserve), tourism (local history)	1.187
VII	Samara-Pavlohrad	Resort (balneology), recreational (landscape reserves “Mezhyrichchia,” “Samarskyi Bir,” “Vasylkivskyi Steppe,” “Mar’yn Hai,” “Petropavlivski Lymany,” landscape park “Samarski Plavni”), recreational (water sports and recreation bases), tourism (cultural heritage and local history)	2.161
VIII	Dnipro-Zaporizhzhia	Recreational (Dnipro-Oril Nature Reserve, landscape parks “Dnipro Forests,” “Dnipro Rapids,” “Samarski Plavni,” general geological reserve “Dnipro Rapids”), recreational (water sports and recreation bases), tourism (cultural heritage and industrial tourism)	3.187
IX	Kamianka-Marhanets	Recreational (National Nature Park “Velykyi Luh”), recreational (water sports), and tourism (local history)	2.412
X	Apostolove-Nikopol	Recreational (Bazavluts'kyi, Kamiansko-Bazavluts'kyi, and Bohdanivskyi Landscape Reserves), tourism (cultural heritage and industrial tourism)	1.836
XI	Kryvyi Rih	Resort (balneology) and tourism (cultural heritage and industrial tourism)	1.611

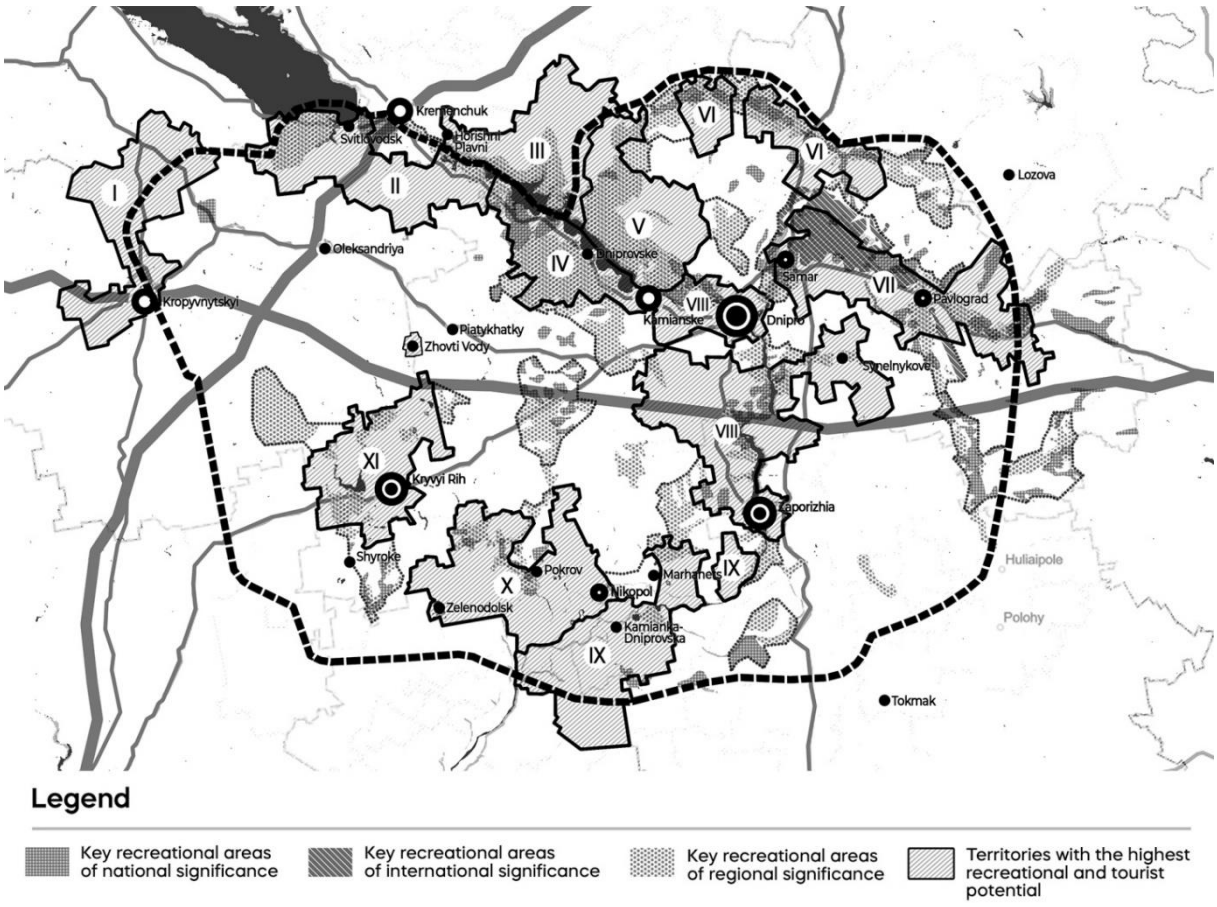


Figure 4. Scheme of Recreational Zoning of the Prydniprovsk Region of Ukraine

In turn, Figure 5 presents an enlarged view of one such district - Kryvyi Rih - to illustrate a detailed zoning scheme at the subregional level. It highlights local recreational clusters and corridors, as well as demonstrates how general spatial priorities can be translated into implementable land-use solutions.

At the regional level, the analysis covers the Prydniprovsk region as a whole, serving as a strategic planning unit. At the district level, the focus shifts to the morphological types of recreational landscapes and their relationship to the region's functional zoning. The study identifies three dominant morphotypes:

- nodal or cluster morphotypes, typically formed around cultural heritage sites, protected areas, or urban green spaces - appropriate for concentrated tourist activities and infrastructure development (Fig. 6A);
- linear morphotypes, such as river valleys and green corridors along gullies and ravines, suitable for ecological tourism, trails, and scenic routes (Fig. 6B);
- mosaic morphotypes (landscape mosaic, mosaic pattern, spatial mosaic), often found in rural or peri-urban areas, characterized by fragmented yet diverse landscapes ideal for low-impact recreation (e.g., camping, agritourism) (Fig. 6C).

A detailed analysis revealed that the Kryvyi Rih recreational district - used here as an example to illustrate the main morphotypes of the region's recreational zones - comprises two nodal (cluster) zones, three linear zones, and two mosaic zones.

These morphological characteristics directly correspond to the categories of functional zoning: recreational, mixed-use, conservation, and buffer zones. This approach aligns spatial planning strategies with both the physical structure of the landscape and the recreational suitability of the Prydniprovsk region.

Limitations and Future Work. One limitation of the present study is the absence of empirical field validation. Due to the ongoing military conflict in Ukraine, which at present remains active along the territorial boundary of the Prydniprovsk region, access to certain areas was restricted, making field surveys impossible for safety reasons. As a result, the proposed spatial model should be regarded as a strategic and conceptual framework rather than a plan ready for immediate implementation.

Accordingly, the present research serves a preliminary analytical function, providing a scientific foundation for future spatial planning decisions.

The multi-criteria evaluation made it possible to conduct a detailed assessment of the region's recreational resources and to identify the areas most favorable for the development of the recreational and tourism sector. This study provides a foundation for further in-depth development of the region's recreation system at the district level. Comparable approaches have been applied to post-industrial regions in Poland, Germany and China [4, 6, 22], yet the specific integration of cultural landscape values and conflict zoning in Ukraine's industrial belt remains unique.

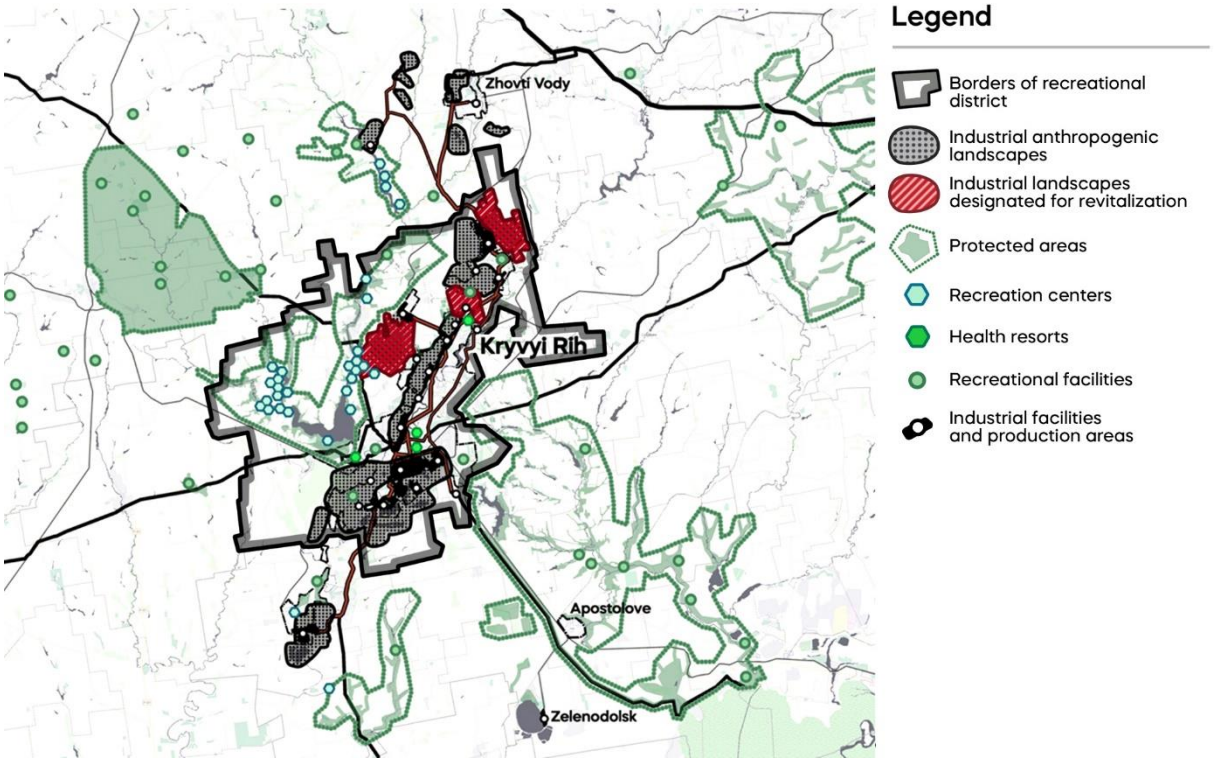


Figure 5. Scheme of Recreational Zoning of the Kryvyi Rih Recreational District

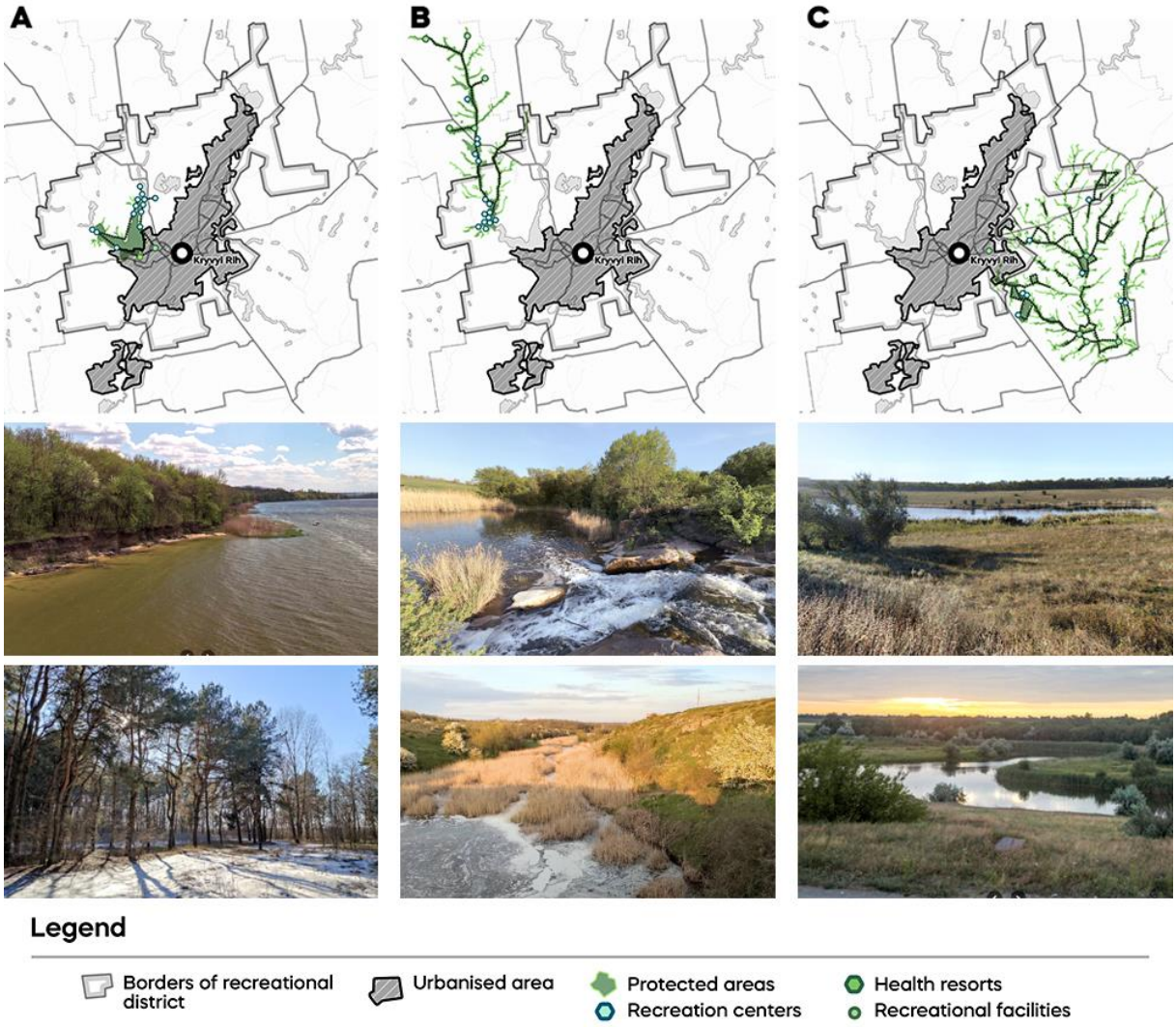


Figure 6. Morphological Types of Recreational Landscapes of the Kryvyi Rih Recreational District

4. Discussion

This study integrates cartographic analysis with multi-criteria evaluation (MCE) to construct a region–district–zone hierarchy for recreational planning in the post-industrial landscape of the Prydniprovsk region. By operationalising five thematic dimensions - biodiversity, cultural heritage, socio-economic activity, leisure opportunities, and public values - and combining them with morphological typologies (linear, nodal/cluster, and mosaic patterns), the framework moves beyond conventional GIS suitability mapping towards conflict-sensitive, implementation-oriented zoning. The approach explicitly anticipates land-use frictions (e.g., tourism–mining interfaces) and proposes buffer zones and dual-use scenarios, positioning the model for phased post-war recovery and policy uptake across scales.

Placed against recent literature, our contribution is complementary yet distinct. First, juxtaposing this study with G. Gamboa et al. [40], whose MCE approach we draw on, highlights both differences and complementarities. Both studies delineate priority areas; however, whereas G. Gamboa et al. [40] elicit stakeholder preferences and embed them in a territory-management model, this study introduces morphotype-aware zoning and conflict-sensitive rules that address land-use frictions arising from industrial and economic activity. Methodologically, the studies are complementary: the participatory weighting and prioritization in G. Gamboa et al. [40] can be layered onto our hierarchical zoning as a validation and governance mechanism, while the territorial taxonomy and implementation logic articulated here provide a scalable planning instrument that extends value mapping into allocative, conflict-aware decisions at regional and subregional scales.

Second, M. Ghasemi et al. [48] propose supply–demand "bundles" for nature-based recreation, clustering areas into surplus, deficit and balanced types using biophysical, accessibility and social indicators. While we also employ an MCE backbone, our model goes beyond service balancing to incorporate landscape morphology, heritage density, and conflict mitigation (buffering/dual-use) in a

region undergoing structural transition - shifting the purpose from rebalancing services to strategic territorial reconfiguration.

Third, M. Forsius et al. [49] couple spatially distributed models to explore regional pathways to carbon neutrality in Finland while considering biodiversity targets. That climate-biodiversity optimisation does not itself define a recreation-oriented taxonomy or zoning logic for post-industrial landscapes; however, our framework can dovetail with such modeling - for example, by aligning recreation corridors and zones with carbon-positive forestry and biodiversity hotspots, thereby co-benefitting climate and tourism objectives.

At the global equity scale, B. Chen et al. [50] demonstrate stark North–South disparities in human exposure to greenspace and high intra-urban inequality, underscoring exposure as a social outcome of provision and spatial configuration. We address a different frontier: repurposing post-industrial regional landscapes through an explicit ecological–cultural–economic lens, while recognising equity as a design constraint (public value and accessibility are embedded in our scoring) and enabling context-sensitive measures (e.g., buffers, staged opening, adaptive access).

Further positioning clarifies the boundary with urban analytics and conceptual syntheses. S. Z. Phua et al. [17] advance a dynamic knowledge-graph and agent-based approach to integrate heterogeneous city data for resilience and accessibility decision-making (The World Avatar). Their system-of-systems perspective targets operational intelligence for disaster response and mobility; our work addresses a different problem class - the territorial restructuring of a post-industrial region via a region–district–zone hierarchy, morphotype-aware zoning, and conflict-sensitive rules that reconcile recreation with extractive and legacy land uses.

Finally, within the sustainability and visitor-management literature, L. K. Cerveny [51] documents that definitions and management paradigms for "sustainable recreation/tourism" are plural and context-dependent, shifting from environment-centric views toward socio-ecological framings. Our study operationalises these principles by translating multi-criteria evidence (ecological, cultural, socio-economic and public-value layers) into prescriptive, scale-linked zoning - turning abstract sustainability principles into allocative spatial decisions at regional and sub-regional levels. In parallel, W. Zong et al. [52] foreground equitable allocation of urban green space via demand–accessibility modeling at the city scale; we complement this line by orchestrating post-industrial regional landscapes where equity is one criterion among several, alongside morphology, heritage, and conflict-prone land uses.

Beyond the strands already reviewed, three recent studies help to further position our contribution. G. Han and E. Yang [53] examine how multidimensional tourism factors (spanning individual and industry levels) shape community resilience across time and regions, advancing an outcome-oriented perspective on tourism's socio-economic effects (resilience gains/losses) rather than on spatial restructuring per se. Our work complements this by supplying the territorial instrument that those outcomes would act upon: a region–district–zone hierarchy with morphotype-aware, conflict-sensitive zoning capable of orchestrating where and how recreation can consolidate resilience in post-industrial settings.

Focusing on Ukraine's wartime tourism system, K. Tomej and I. Bilynets [54] adopt a living-systems perspective to trace large-scale transformations and regenerative dynamics triggered by the invasion, illuminating how sectoral subsystems adapt, reorganise, and co-evolve under shock. While aligned with our post-war recovery lens, their analysis is system-theoretic and processual; we contribute the spatial grammar for translating those regenerative logics into allocative decisions (corridors, clusters, buffers and dual-use zones) embedded in a stabilisation-aligned rollout for regional planning.

At the interface of ecosystem services and recreation, M. Ghasemi [55] develops an integrated model to map cultural ecosystem services and recreation opportunities (ROES) in northern Iran, demonstrating the diagnostic value of MCDA-GIS for revealing where opportunities concentrate. Our framework extends this line from diagnosis to prescription: it layers cultural–ecological values with landscape morphology and land-use conflict mitigation, yielding implementable zoning (region–district–zone) and district profiles that are specifically tuned to post-industrial contexts and compatible with staged, conflict-aware activation.

Taken together, this work delivers more than a technical synthesis: it sets out an implementable planning grammar for post-industrial regions - linking a region-district-zone hierarchy with morphotype-specific rules, conflict-sensitive zoning (buffers and dual-use), and staged roll-out (Figs. 3F, 4A-B). In doing so, it converts multi-criteria evidence into operational territorial choices that reconcile ecological quality, cultural heritage, and legacy industry. What these strands typically lack when considered separately - a post-industrial, conflict-aware territorial taxonomy with clear implementation logic and a stabilisation-aligned time horizon - is provided here, offering a transferable model for transition regions where legacy industries, ecological assets, and cultural heritage must be orchestrated to unlock sustainable recreation and tourism.

5. Conclusions

The conceptual basis of the methodology applied in this study takes into account the influence of land use patterns and ecological factors on the spatial and planning

organization of the regional recreational system. It also considers the impact of industrialization and urbanization, which shape the cultural landscape and socio-economic dynamics of the Prydniprovsk region within the context of its industrial development, the spatial structure of industrial zones, and models of urban development in the region.

In order to analyze the condition and characteristics of the region's recreational resources, as well as to forecast the development of urban and recreational facilities, methods of statistical and comparative analysis of both quantitative and qualitative recreational indicators of the Prydniprovsk region were applied. The analysis was based on data from the State Statistics Service of Ukraine, and its results reveal a current deficiency of natural and recreational areas, while the majority of land remains reserved for agricultural use.

The advancement of the cartographic method enabled the identification of the location of recreational resources and historical-cultural heritage sites (including industrial heritage sites). This made it possible to outline areas of the highest historical and cultural significance (Dnipro – Kamianske – Novomoskovsk – Verkhnodniprovsk; Zaporizhzhia – Nikopol – Marhanets – Pokrov; Kryvyi Rih – Zhovti Vody – Shyroke) and to develop a conceptual model for the recreational and tourism system of the Prydniprovsk region, taking into account the structural organization of Ukraine's national recreational system.

The results may inform national spatial planning policies and serve as a replicable model for other post-industrial territories undergoing landscape transformation.

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