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Urban Transformation of Prizren in the Post-Communist Context: An Analysis through LU/LC and NDBI (2000–2018)

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Abstract

Post-communist cities in Southeastern Europe have undergone profound spatial, socio-economic, and environmental transformations following the dissolution of centralized political systems in the late 20th century. The shift from state-controlled planning to market-oriented urban development has produced complex patterns of land use change, rapid urbanization, and fragmented growth. Within this context, Prizren—one of Kosovo's oldest and most culturally significant cities—offers a valuable case study for understanding the interplay between post-conflict reconstruction and contemporary spatial expansion. This study analyses the dynamics of urban transformation in Prizren from 2000 to 2018 by integrating Land Use and Land Cover (LU/LC) classification and the Normalized Difference Built-up Index (NDBI) derived from Landsat satellite imagery. Using data from the CORINE Land Cover (CLC) inventory and high-resolution spatial datasets, the research applies Geographic Information Systems (GIS) and Remote Sensing (RS) techniques to quantify the magnitude and direction of land use change. Comparative spatial analyses between 2000 and 2018 reveal a marked expansion of built-up areas, particularly along transportation corridors and suburban zones, accompanied by a substantial decline in vegetated and agricultural lands. The findings demonstrate that the period under analysis was characterized by accelerated urban sprawl, weak spatial regulation, and inconsistent urban governance—features common to post-communist transition cities. The expansion of impervious surfaces and loss of ecological spaces underscore the urgent need for sustainable land management and integrated spatial monitoring frameworks. By showcasing the application of geospatial indicators such as NDBI and LU/LC mapping, this research highlights the potential of remote sensing technologies as essential tools for evidence-based urban policy, planning, and sustainable territorial governance in post-communist contexts.

Keywords:
Prizren, Urban Transformation, LU/LC, NDBI, GIS, Remote Sensing, Sustainable Planning, Post-Communist Cities

Introduction

The post-communist transition across Eastern and Southeastern Europe has profoundly reshaped urban landscapes, institutional frameworks, and socio-economic relations. The fall of centralized regimes in the late 1980s and early 1990s marked a paradigm shift from state-controlled planning to market-oriented urban development. This transformation introduced new actors—private investors, real-estate developers, and local governments—into urban governance, often without sufficient regulatory capacity or coherent spatial policy (Sýkora & Bouzarovski, 2012). Consequently, cities became laboratories of socio-spatial restructuring, reflecting the interplay of liberalization, migration, and informal urban growth (Stanilov, 2007).

Across the post-socialist region, urban areas have experienced a dual process of expansion and fragmentation. While economic decentralization stimulated investment in construction and infrastructure, weak institutional coordination and fragmented land management led to unplanned sprawl and ecological degradation (Hirt, 2013). The Western Balkans, undergoing simultaneous processes of post-conflict reconstruction and post-socialist transition, have been particularly exposed to these dynamics (Babić, 2021). Kosovo, as one of the youngest states in Europe, illustrates this duality—rapid urbanization combined with institutional fragility in spatial governance (Dobraca & Knaus, 2019).

The city of Prizren provides a valuable case study for understanding these processes. As a historical urban centre and cultural capital of Kosovo, Prizren's transformation encapsulates broader regional trends of post-communist change—territorial restructuring, privatization of land, and spontaneous residential growth. Following the end of the 1998–1999 Kosovo War, the city entered a phase of accelerated reconstruction supported by international donors and domestic initiatives. Yet, as public land was liberalized and migration from rural areas intensified, urban growth began to extend rapidly into peripheral and agricultural zones. The lack of updated urban plans and weak enforcement mechanisms contributed to informal construction and encroachment on green spaces (Gülersoy, 2016).

Geospatially, Prizren's evolution reveals the contrasting trajectories of modernization and environmental pressure. The expansion of built-up areas has reshaped land use composition—reducing agricultural lands, fragmenting natural habitats, and altering watershed systems of the Prizren Plain. These dynamics exemplify the challenges faced by post-socialist cities where economic transformation outpaces spatial regulation (Nedović-Budić et al., 2011). At the same time, the city's strategic location along the Drini i Bardhë River and proximity to cross-border transport corridors have increased its importance as a regional development hub within Kosovo's spatial planning framework (Kosovo Spatial Plan, 2010).

Historical Background of Prizren

Prizren is among the oldest continuously inhabited cities in the Balkans, with urban roots tracing back to the Roman and Byzantine periods. Over centuries, it has served as an administrative, commercial, and cultural centre under various empires, including the Ottoman Empire, which left a significant architectural and social imprint (Elsie, 2011). The city's historical core, characterized by traditional Ottoman-era urban fabric—mosques, churches, bazaars, and stone bridges—reflects the coexistence of multiple ethnic and religious communities, including Albanians, Turks, Bosniaks, and Gorani.

During the socialist period under Yugoslavia (1945–1990), Prizren experienced controlled urban growth guided by centralized industrial and housing policies. Urban planning focused on expanding manufacturing sectors and providing standardized housing estates, particularly in the lower valley areas. However, post-1990s political instability and the eventual war in Kosovo (1998–1999) disrupted this continuity. Large-scale displacement, property destruction, and post-war reconstruction fundamentally altered the spatial and demographic structure of the city (Pavlović, 2009).

After 1999, the UNMIK administration and later Kosovo's local institutions introduced new governance frameworks, yet urban planning capacities remained limited. The post-war reconstruction period emphasized physical rebuilding over strategic spatial management. Consequently, informal settlements proliferated, especially in peripheral areas such as Ortakoll, Bazhdarhane, and Tusus, where rural migrants sought access to urban employment and services (Hysa, 2020).

In parallel, Prizren became a symbolic centre of cultural resilience, with the reconstruction of the Albanian League of Prizren complex representing both a national and urban identity milestone. The integration of heritage preservation with contemporary development, however, remains an ongoing challenge. Increasing construction pressure in the historic core has raised concerns regarding the conservation of cultural landscapes and visual integrity (Council of Europe, 2021).

The Need for Spatial Monitoring and Sustainable Planning

Given these dynamics, the study of Prizren's land use and built-up expansion between 2000 and 2018 provides a crucial empirical foundation for understanding post-conflict urban transformation. Modern tools such as Geographic Information Systems (GIS) and Remote Sensing (RS) enable the quantification of land cover changes and the assessment of urban growth trajectories. The use of indices such as the Normalized Difference Built-up Index (NDBI) and CORINE Land Cover (CLC) datasets provides objective, spatially explicit evidence to support planning interventions. By combining historical knowledge

with contemporary geospatial analysis, this research contributes to the broader debate on sustainable urbanism in post-communist contexts—where cities like Prizren must balance rapid development with heritage protection and ecological sustainability.

Study Area

The Municipality of Prizren is located in the southern part of the Republic of Kosovo, covering an area of approximately 627 km², which makes it one of the largest municipalities in the country in both territorial and demographic terms (Kosovo Agency of Statistics, 2024). According to the most recent census, the municipality has about 147,246 inhabitants, with approximately 61% living in urban areas and 39% in rural settlements. This distribution reflects the intensified urbanization process that has characterized the last two decades, reshaping the city's physical boundaries and settlement morphology.

The map illustrates the geographical position of the Municipality of Prizren, located in the southwestern part of Kosovo. The area borders Albania to the west and North Macedonia to the south, thus holding a strategic cross-border position of economic, cultural, and transport significance. In the northern and northeastern parts, Prizren borders other municipalities of Kosovo, serving as a connecting bridge between Kosovo and the wider Western Balkans region.

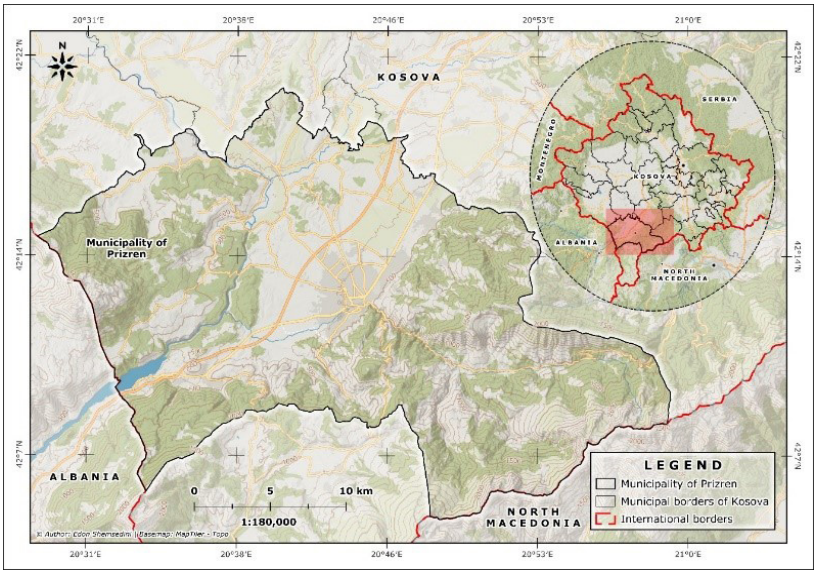


Figure 1. Geographical position of the Municipality of Prizren within Kosovo and the region).

Geographical and Environmental Setting

Prizren lies within a strategic geographical position, bordered by Suhareka to the north, Dragash to the east, the city of Kukës (Albania) to the south, and Malishevë to the west. Its location makes it a vital cross-border node between Albania and central Kosovo, historically functioning as a gateway for trade, culture, and migration. The municipality encompasses two dominant geomorphological units: the Prizren Plain, characterized by fertile agricultural lands, and the Sharr Mountains, known for their ecological diversity and high-altitude ecosystems.

The White Drin River (Drini i Bardhë) traverses the city and serves as a major natural axis for both historical settlement and modern infrastructure. The area's Mediterranean-continental climate, with hot summers and mild winters, has traditionally supported agricultural activities such as viticulture, horticulture, and livestock farming (MESP, 2018). In recent years, these natural conditions have also favored the growth of eco-tourism and sustainable rural development initiatives.

Demographic and Ethnic Composition

Prizren stands out for its multiethnic and multireligious composition, which remains one of its most defining social features. The population is predominantly Albanian, but significant communities of Turks, Bosniaks, Gorani, Roma, and Ashkali contribute to the city's cultural pluralism. This diversity has historically shaped Prizren's urban culture, manifested through its bilingual education, religious coexistence, and mixed architectural styles (Elsie, 2011).

Since the end of the Kosovo War (1998–1999), demographic dynamics have shifted considerably. The post-conflict years witnessed a wave of rural-to-urban migration, as well as the return of displaced populations and diaspora communities. This influx created increased demand for housing, employment, and urban services, placing immense pressure on the city's infrastructure and spatial organization (Dobraca & Knaus, 2019). Consequently, many new residential neighborhoods—often informal—emerged in peripheral areas such as Ortakoll, Bazhdarhane, and Tusus.

Impact of the Kosovo War and Reconstruction

The Kosovo War had a profound effect on Prizren's physical and cultural landscape. Between 1998 and 1999, the city suffered significant human and material losses, including damage to public infrastructure, housing, and heritage sites. One of the most symbolic destructions was the Monumental Complex of the Albanian League of Prizren, a cornerstone of Albanian national history. On March 27, 1999, Serbian military forces burned the museum complex, resulting in the loss of over 200 historical documents and artifacts (Gülersoy, 2016).

Just a few months later, on June 10, 1999, local artisans and cultural insti-

tutions began the reconstruction of the complex, which was completed as a testament to the resilience and collective memory of the local population. Post-war reconstruction efforts were largely focused on physical rebuilding—roads, bridges, public facilities, and housing—but often lacked strategic spatial coordination. As a result, urban expansion occurred spontaneously, driven by the private sector and individual initiatives rather than institutional planning frameworks (Babić, 2021).

This rapid expansion led to visible land use changes: agricultural and peri-urban lands were converted into residential and commercial zones, altering the city's spatial balance. The study of these transitions through Land Use/Land Cover (LU/LC) and NDBI analysis thus becomes crucial for understanding the urban dynamics of post-conflict Prizren.

Historical and Cultural Significance

Prizren is often referred to as the "spiritual capital of Kosovo", owing to its extraordinary historical and cultural heritage. The city's historic center, declared a protected cultural zone by the Kosovo Ministry of Culture, includes numerous monuments of medieval and Ottoman origin, such as Prizren Fortress, the Stone Bridge, the Sinan Pasha Mosque, the Church of the Holy Saviour, and the Hammam of Gazi Mehmed Pasha. These landmarks, some listed under UNESCO and the Council of Europe programs, illustrate Prizren's position as a cultural crossroads of civilizations (Council of Europe, 2021).

However, the post-war urban boom has created tensions between modernization and heritage preservation. In the historic core, new constructions, road expansions, and commercial development have occasionally threatened the visual integrity and authenticity of the urban landscape. This underscores the need for a balanced approach that integrates conservation with sustainable urban growth. The use of geospatial technologies such as GIS and Remote Sensing offers new possibilities for monitoring spatial transformations while safeguarding cultural heritage.

In summary, Prizren's study area embodies the interaction between geography, history, and socio-political transition. It represents a living laboratory of post-socialist and post-conflict urban evolution, where sustainable land management, inclusive planning, and cultural preservation are fundamental to achieving spatial resilience and long-term development.

Methodology

The methodological approach of this study integrates remote sensing, geospatial analysis, and comparative temporal assessment to quantify and visualize the spatial transformation of Prizren between 2000 and 2018. The research combines CORINE Land Cover (CLC) datasets and Landsat satellite imagery

within a GIS environment to derive, interpret, and validate urban growth and land use/land cover (LU/LC) transitions. The process is structured in three main stages: data acquisition and preparation, analytical processing, and spatial interpretation.

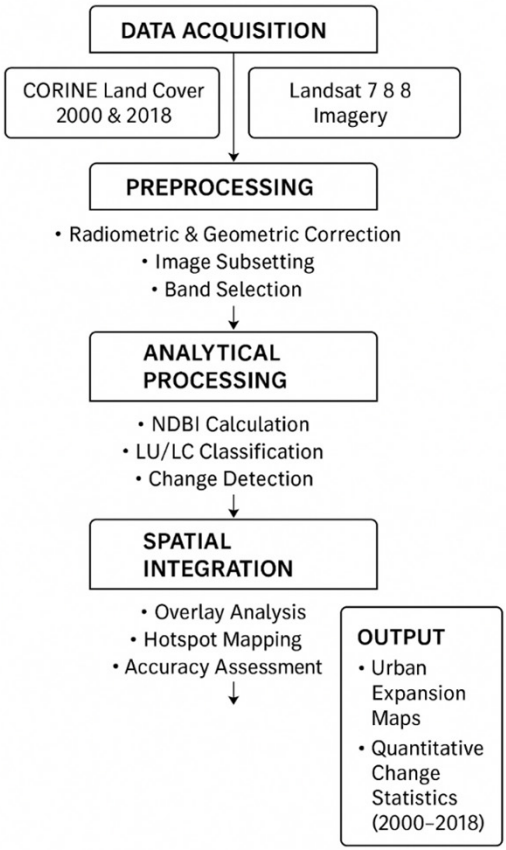


Figure 1. Workflow of LU/LC and NDBI Analysis for Urban Transformation Assessment

This figure illustrates the methodological workflow of the study, integrating CORINE Land Cover datasets, Landsat imagery, and GIS-based spatial analysis. The process includes data acquisition, preprocessing (radiometric and geometric correction), NDBI computation, LU/LC classification, change detection, and map integration for spatial interpretation.

Data Sources

Two primary datasets formed the foundation of this analysis:

CORINE Land Cover (CLC) 2000 and 2018

Provided by the European Environment Agency (EEA), the CLC program offers harmonized geospatial data on land use and land cover across Europe. Each dataset classifies land cover using a hierarchical nomenclature of 44 thematic classes, based on satellite imagery interpretation (EEA, 2018).

•CLC 2000 represents baseline land cover at the start of the post-conflict period, reflecting the early stage of Prizren's spatial recovery and initial urbanization trends.

•CLC 2018 captures the later phase of urban expansion, when private development and infrastructure projects intensified.

Both datasets have a minimum mapping unit (MMU) of 25 hectares, with a positional accuracy of 100 meters, sufficient for regional-scale urban change analysis.

2.Landsat 7 ETM+ (Enhanced Thematic Mapper Plus) and Landsat 8 OLI (Operational Land Imager)

These satellite images, obtained from the United States Geological Survey (USGS) archives, were used to compute the Normalized Difference Built-up Index (NDBI) for the years 2001 and 2018. The Landsat series offers 30-meter spatial resolution, 16-day temporal resolution, and consistent radiometric calibration, making it ideal for long-term monitoring.

- Spectral bands used:
  - Near-Infrared (NIR): Band 4 for Landsat 7, Band 5 for Landsat 8
  - Shortwave Infrared (SWIR): Band 5 for Landsat 7, Band 6 for Landsat 8

These spectral bands enable discrimination between built-up and non-built-up surfaces, forming the basis for NDBI analysis.

Supplementary datasets included municipal boundary shapefiles from the Kosovo Cadastral Agency and digital elevation models (DEM) for topographic referencing. All data were georeferenced to the WGS 84 UTM Zone 34N coordinate system.

CORINE Land Cover (CLC) Classification Scheme

To ensure consistency and comparability across years, this study employed the hierarchical CORINE Land Cover (CLC) classification system developed by the European Environment Agency (EEA).

This system is widely used for analyzing land use and land cover dynamics across Europe, providing standardized thematic and spatial representation at national and regional scales.

The CLC classification structure is organized into three hierarchical levels:

- Level 1: Includes five main categories — Artificial surfaces, Agricultural areas, Forest and semi-natural areas, Wetlands, and Water bodies.

- Levels 2 and 3: Provide more detailed thematic subdivisions, comprising a total of 44 distinct land cover classes, derived through the interpretation of satellite imagery.

In the case of the Prizren Municipality, the dominant land cover classes identified include:

1.1 Urban fabric

2.1 Arable land

3.1 Forests

5.1 Inland waters

Each class was visualized using the official CLC RGB color codes, ensuring visual consistency and cross-year comparability between datasets (e.g., CLC 2000 and CLC 2018).

Analytical Approach

The analytical framework was designed to quantify spatial and temporal changes in Prizren's urban structure using remote sensing indicators and GIS-based spatial modeling.

3.2.1 Preprocessing and Calibration

Satellite images were downloaded as Level-1 products and underwent standard preprocessing steps:

• Radiometric correction to normalize reflectance values.

• Atmospheric correction using the Dark Object Subtraction (DOS) method.

• Geometric correction to ensure alignment with administrative boundaries and CLC layers.

After preprocessing, the images were subset to the spatial extent of the Prizren Municipality for focused analysis.

NDBI Calculation and Classification

The Normalized Difference Built-up Index (NDBI) was calculated following Zha et al. (2003):

where SWIR denotes Short-Wave Infrared reflectance and NIR represents Near-Infrared reflectance.

o Values > 0 indicate built-up or impervious surfaces (e.g., concrete, asphalt, rooftops).

o Values < 0 correspond to non-built-up areas such as vegetation, water bodies, or bare soil.

The resulting NDBI images were classified into three categories:

2. Built-up areas (NDBI > 0.2)

3. Semi-built or transitional areas (NDBI between 0 and 0.2)

4. Non-built areas (NDBI < 0)

Level 1	Level 2	Level 3	Grid_Code	RGB
1. ARTIFICIAL SURFACES	1.1Urban fabric	1.1.1 Continuous urban fabric	1	230-000-077
		1.1.2 Discontinuous urban fabric	2	255-000-000
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units	3	204-077-242
		1.2.2 Road and rail networks and associated land	4	204-000-000
		1.2.3 Port areas	5	230-204-204
		1.2.4 Airports	6	230-204-230
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites	7	166-000-204
		1.3.2 Dump sites	8	166-077-000
		1.3.3 Construction sites	9	255-077-255
	1.4 Artificial, non-agricultural vegetated areas	1.4.1 Green urban areas	10	255-166-255
		1.4.2 Sport and leisure facilities	11	255-230-255
2. AGRICULTURAL AREAS	2.1 Arable land	2.1.1 Non-irrigated arable land	12	255-255-168
		2.1.2 Permanently irrigated land	13	255-255-000
		2.1.3 Rice fields	14	230-230-000
	2.2 Permanent crops	2.2.1 Vineyards	15	230-128-000
		2.2.2 Fruit trees and berry plantations	16	242-166-077
		2.2.3 Olive groves	17	230-166-000
	2.3 Pastures	2.3.1 Pastures	18	230-230-077
	2.4 Heterogeneous agricultural areas	2.4.1 Annual crops associated with permanent crops	19	255-230-166
		2.4.2 Complex cultivation patterns	20	255-230-077
		2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation	21	230-204-077
		2.4.4 Agro-forestry areas	22	242-204-166
3. FOREST AND SEMI NATURAL AREAS	3.1Forests	3.1.1 Broad-leaved forest	23	128-255-000
		3.1.2 Coniferous forest	24	000-166-000
		3.1.3 Mixed forest	25	077-255-000
	3.2 Scrub and/or herbaceous vegetation associations	3.2.1 Natural grasslands	26	204-242-077
		3.2.2 Moors and heathland	27	166-255-128
		3.2.3 Sclerophyllous vegetation	28	166-230-077
		3.2.4 Transitional woodland-shrub	29	166-242-000
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sands	30	230-230-230
		3.3.2 Bare rocks	31	204-204-204
		3.3.3 Sparsely vegetated areas	32	204-255-204
		3.3.4 Burnt areas	33	000-000-000
		3.3.5 Glaciers and perpetual snow	34	166-230-204
4. WETLANDS	4.1 Inland wetlands	4.1.1 Inland marshes	35	166-166-255
		4.1.2 Peat bogs	36	077-077-255
	4.2 Maritime wetlands	4.2.1 Salt marshes	37	204-204-255
		4.2.2 Salines	38	230-230-255
		4.2.3 Intertidal flats	39	166-166-230
5. WATER BODIES	5.1 Inland waters	5.1.1 Water courses	40	000-204-242
		5.1.2 Water bodies	41	128-242-230
	5.2 Marine waters	5.2.1 Coastal lagoons	42	000-255-166
		5.2.2 Estuaries	43	166-255-230
		5.2.3 Sea and ocean	44	230-242-255
No Data	No Data		48	
	No Data		49	
	No Data		50	230-242-255

Figure 2. Hierarchical structure of the CORINE Land Cover (CLC) classification system used in the analysis.

Post-classification filtering was applied to eliminate noise and minor pixel anomalies. Change detection analysis was performed by overlaying NDBI results from 2001 and 2018 to identify expansion hotspots and quantify surface changes in square kilometres.

Land Use/Land Cover (LU/LC) Change Detection

The CLC datasets from 2000 and 2018 were compared using a cross-tabulation matrix to determine transitions between land cover categories, such as:

- Agricultural to Urban Fabric
- Forested Land to Agricultural
- Industrial or Commercial Development Expansion

This analysis enabled the quantification of land conversion rates and spatial distribution of transformation zones. The results were visualized through change maps that illustrate urban growth corridors and the loss of natural land cover.

Integration and Spatial Interpretation

To ensure analytical coherence, NDBI and CLC results were overlaid within a GIS environment. This integration allowed validation of satellite-derived indices with land cover classifications and identification of mismatches. The combination of these methods provided a multi-scalar understanding of urban growth—from pixel-level built-up intensity to municipal-scale land use transitions.

Accuracy Assessment

Accuracy assessment was conducted using a stratified random sampling approach with reference points verified via high-resolution imagery from Google Earth and field observation data (when available). The overall classification accuracy for NDBI-based land cover was above 85%, with a Kappa coefficient of 0.82, indicating a high level of reliability for change detection.

Methodological Significance

This integrated methodology demonstrates the effectiveness of combining multi-temporal satellite data with standardized European land cover datasets (CLC) for monitoring urbanization in post-conflict and post-socialist contexts. It allows planners to visualize not only quantitative expansion but also qualitative shifts in spatial organization. Moreover, it provides a replicable analytical model for other municipalities in Kosovo and the Western Balkans.

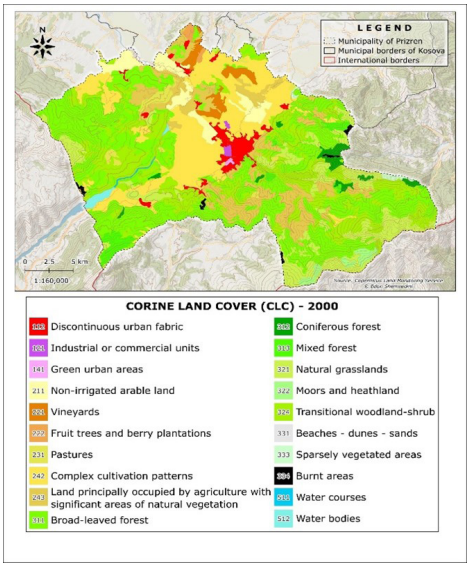
Results

CORINE Land Cover (CLC) Analysis

The CORINE Land Cover (CLC) datasets for 2000 and 2018 reveal a substantial transformation of Prizren's spatial structure over an 18-year period. The results clearly indicate that urbanized areas expanded significantly at the expense of agricultural and semi-natural lands, while forested areas in the Sharr Mountain region remained relatively stable.

Land Cover Change Overview (2000–2018)

According to the CLC 2000 dataset, the landscape of Prizren was primarily dominated by broad-leaved forest (30.8%), transitional woodland-shrub (17.7%), and complex cultivation patterns (16.0%). Urbanized areas, represented by the discontinuous urban fabric and industrial or commercial units, accounted for only 2.7% of the municipal territory (approximately 16.97 km² in total).



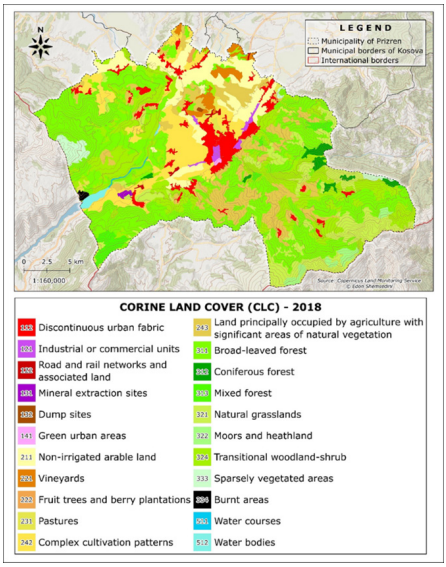


Figure 3.CORINE Land Cover (CLC) – 2000

Figure 4. CORINE Land Cover (CLC) – 2018

Source: Copernicus Land Monitoring Service (EEA), processed by Edon Shemsedini.

The map illustrates the spatial distribution of land cover classes across the Municipality of Prizren for the year 2000.

During this period, the landscape was predominantly characterized by broad-leaved forests (311), transitional woodland-shrub (324), and complex cultivation patterns (242), which together accounted for over 60% of the municipal area.

Urbanized zones such as discontinuous urban fabric (112) and industrial or commercial units (121) covered a small portion of the territory, mainly concentrated around the urban core of Prizren and the main transportation corridors.

By contrast, the CLC 2018 data show that the proportion of urban and built-up land nearly doubled to 5.7% (around 36 km²). This expansion corresponds to a net increase of about 19 km² in built-up areas over the observed period. At the same time, the total area of complex cultivation patterns decreased from 100.42 km² to 54.53 km², while non-irrigated ar-

Code	Category	Area (km²)	Percentage (%)
112	Discontinuous urban fabric	15.82	2.52
121	Industrial or commercial units	1.15	0.18
141	Green urban areas	0.45	0.07
211	Non-irrigated arable land	23.82	3.80
221	Vineyards	10.84	1.73
222	Fruit trees and berry plantations	2.39	0.38
231	Pastures	8.03	1.28
242	Complex cultivation patterns	100.42	16.02
243	Land occupied by agriculture with natural vegetation	67.32	10.74
311	Broad-leaved forest	193.04	30.79
312	Coniferous forest	8.69	1.39
313	Mixed forest	10.41	1.66
321	Natural grasslands	59.69	9.52
322	Moors and heathland	5.69	0.91
324	Transitional woodland-shrub	111.12	17.72
331	Beaches, dunes, sands	0.50	0.08
333	Sparsely vegetated areas	1.93	0.31
334	Burnt areas	2.07	0.33
511	Water courses	0.64	0.10
512	Water bodies	2.98	0.48
Total		**627.00**	**100.00**

Table 1. Land Cover categories and area distribution in 2000

Source: Author's calculation based on CORINE Land Cover 2000 dataset (EEA).

able land expanded slightly from 23.82 km² to 50.62 km², reflecting peri-urban agricultural conversion and shifting land use along the Prizren Plain.

Forested categories, particularly broad-leaved forests, experienced a marginal increase (from 193.04 km² to 200.73 km²), suggesting effective preservation of the mountainous terrain within the Sharr National Park boundaries. However, some transitional woodland-shrub areas declined (from 111.12 km² to 105.25 km²), which indicates localized deforestation or conversion to agricultural use in low-lying zones.

The 2018 CORINE Land Cover map reveals a noticeable urban expansion throughout the Prizren Plain and peripheral zones. Built-up areas, including discontinuous urban fabric (112), industrial or commercial units (121), and road and rail networks (122), have significantly increased, particularly along the main transportation corridors and the northern edge of the city.

Conversely, complex cultivation patterns (242) declined sharply, reflecting

conversion of agricultural mosaics into residential and infrastructural land.

Forested regions, dominated by broad-leaved forest (311), maintained their continuity and even slightly expanded within the Sharr Mountain area, confirming effective conservation within the National Park boundaries.

Comparative Interpretation of Land Cover Changes (2000–2018)

According to the CLC 2000 dataset, the landscape of Prizren was primarily dominated by broad-leaved forest (30.8%), transitional woodland-shrub

Code	Category	Area (km²)	Percentage (%)
112	Discontinuous urban fabric	31.03	4.95
121	Industrial or commercial units	3.64	0.58
122	Road and rail networks and associated land	1.35	0.22
131	Mineral extraction sites	0.88	0.14
132	Dump sites	0.26	0.04
141	Green urban areas	0.39	0.06
211	Non-irrigated arable land	50.62	8.07
221	Vineyards	9.71	1.55
222	Fruit trees and berry plantations	0.78	0.12
231	Pastures	4.74	0.76
242	Complex cultivation patterns	54.53	8.70
243	Land occupied by agriculture with natural vegetation	66.93	10.67
311	Broad-leaved forest	200.73	32.01
312	Coniferous forest	7.44	1.19
313	Mixed forest	10.17	1.62
321	Natural grasslands	58.82	9.38
322	Moors and heathland	6.81	1.09
324	Transitional woodland-shrub	105.25	16.79
333	Sparsely vegetated areas	8.54	1.36
334	Burnt areas	0.86	0.14
511	Water courses	0.64	0.10
512	Water bodies	2.88	0.46
Total		**627.00**	**100.00**

Table 2. Land Cover categories and area distribution in 2018

Source: Author's calculation based on CORINE Land Cover 2018 dataset (EEA).

(17.7%), and complex cultivation patterns (16.0%). Urbanized areas, represented by the discontinuous urban fabric and industrial or commercial units, accounted for only 2.7% of the municipal territory (approximately 16.97 km² in total).

By contrast, the CLC 2018 data show that the proportion of urban and built-up land nearly doubled to 5.7% (around 36 km²). This expansion corresponds to a net increase of about 19 km² in built-up areas over the observed period. At the same time, the total area of complex cultivation patterns decreased from 100.42 km² to 54.53 km², while non-irrigated arable land expanded slightly from 23.82 km² to 50.62 km², reflecting peri-urban agricultural conversion and shifting land use along the Prizren Plain.

Forested categories, particularly broad-leaved forests, experienced a marginal increase (from 193.04 km² to 200.73 km²), suggesting effective preservation of the mountainous terrain within the Sharr National Park boundaries. However, some transitional woodland-shrub areas declined (from 111.12 km² to 105.25 km²), which indicates localized deforestation or conversion to agricultural use in low-lying zones.

Spatial Patterns of Change

The CLC 2000 Map (Figure 3) illustrates the baseline spatial configuration at the beginning of the observation period, where the urban core of Prizren was compact and primarily confined along the Lumbardhi River corridor. Surrounding agricultural plains and forest zones exhibited a balanced ecological and economic structure.

The CLC 2018 Map (Figure 4), however, displays a marked spatial diffusion of built-up areas extending toward the north (Ortakoll and Zhur), east (Tusus and Billushë), and southwest (Landovica and Sredska Valley). These extensions correspond to newly developed residential and commercial districts, reflecting both population growth and intensified construction activity following post-war reconstruction initiatives.

The CLC Change Detection Map (2000–2018) synthesizes the spatial transitions by highlighting zones of urban expansion, agricultural reduction, and forest persistence. The most notable urban growth hotspots are concentrated along the Prizren–Suharekë road axis and near industrial clusters in the southern and eastern periphery. In contrast, agricultural and natural vegetation classes have diminished, primarily where urban and infrastructural development has expanded.

The comparative analysis between CLC 2000 and CLC 2018 highlights a net urban increase of approximately 19 km² within the Prizren Municipality.

This growth primarily occurred along the Prizren Plain, replacing agricultural mosaics (CLC 242) and peri-urban cultivation areas, while forested regions within Sharr National Park remained stable or slightly expanded.

The observed dynamics reflect post-conflict urban recovery, population growth, and unregulated suburban development, underscoring the need for spatial planning strategies based on sustainable land management.

The comparative results highlight a clear pattern of urban expansion and agricultural land conversion over the 18-year period. Urban and built-up areas, especially discontinuous urban fabric and industrial/commercial units, increased by nearly 18–19 km² in total, reflecting rapid post-conflict urban growth and infrastructure development along the Prizren Plain.

At the same time, complex cultivation patterns decreased significantly, while broad-leaved forests showed moderate growth, indicating effective conservation within the Sharr Mountain region. In contrast, transitional woodland-shrub and natural grasslands declined slightly, reflecting local land-use change in peri-urban zones.

The data confirm that urban expansion primarily occurred through the conversion of agricultural and semi-natural landscapes — particularly those classified as complex cultivation patterns and transitional woodland-shrub. The net gain of approximately 19 km² in built-up land reflects the intense urbanization pressure that characterized the post-socialist transition period in Prizren.

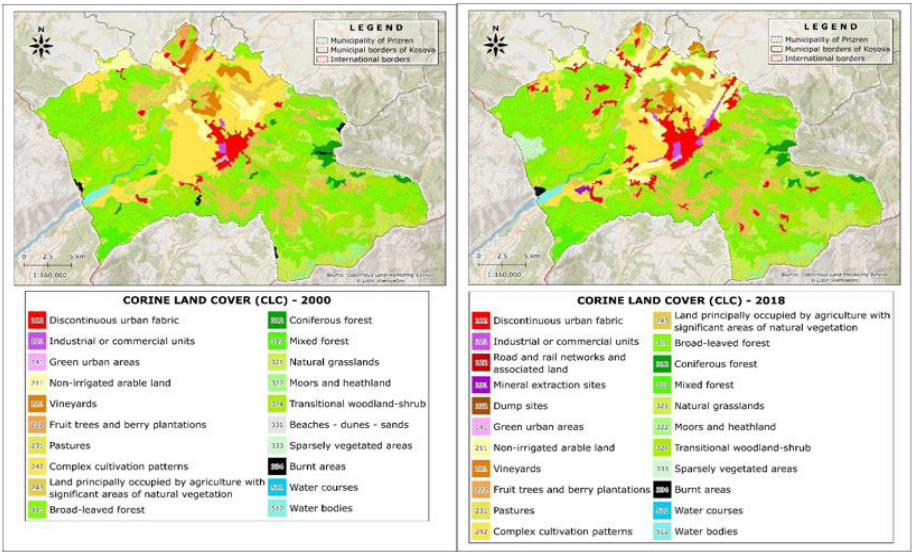


Figure 6. Comparative CORINE Land Cover (CLC) Maps – 2000 and 2018

Source: Copernicus Land Monitoring Service (EEA), processed by Edon Shemsedini.

The figure presents the spatial comparison of land cover distribution in Prizren Municipality between the years 2000 and 2018, based on CORINE Land Cover datasets (EEA).The maps illustrate urban expansion across the Prizren Plain and conversion of agricultural and semi-natural areas into built-up land, while forested zones within the Sharr Mountain region remain largely stable.

This visualization directly supports the findings discussed in Section 4.2. Comparative Interpretation of Land Cover Changes (2000–2018).

The table presents the comparative distribution of land cover categories

Land Cover Class	2000 (km²)	2018 (km²)	Change (km²)	Trend
Discontinuous urban fabric	15.82	31.03	**+15.21**	↑ Increase
Industrial/Commercial units	1.15	3.64	**+2.49**	↑ Increase
Broad-leaved forest	193.04	200.73	**+7.69**	↑ Slight increase
Transitional woodland-shrub	111.12	105.25	**−5.87**	↓ Decrease
Complex cultivation patterns	100.42	54.53	**−45.89**	↓ Significant decrease
Agricultural land (total)	67.32	66.93	**−0.39**	≈ Stable
Natural grasslands	59.69	58.82	**−0.87**	↓ Slight decrease

Table 3. Comparative Land Cover Changes between 2000 and 2018
Source: Author's calculation based on CORINE Land Cover datasets (EEA, 2000 & 2018).

for the years 2000 and 2018, alongside the net differences (2018–2000).

It highlights substantial urban expansion — mainly in discontinuous urban fabric (112) and industrial/commercial units (121) — as well as the decline of complex cultivation patterns (242) and transitional woodland-shrub (324).

Overall, the data confirm a shift from agricultural and semi-natural areas toward built-up and infrastructural land uses in Prizren Municipality.

NDBI Analysis

The Normalized Difference Built-up Index (NDBI) derived from Landsat 7 ETM+ (2001) and Landsat 8/9 OLI (2014, 2018, 2024) was used to detect and quantify the spatial expansion of impervious surfaces within the Municipality of Prizren. The NDBI method exploits the contrast between Short-Wave Infrared (SWIR) and Near-Infrared (NIR) spectral reflectance to identify built-up structures according to the equation:

$$\mathrm{NDBI} = \frac{\mathrm{SWIR} - \mathrm{NIR}}{\mathrm{SWIR} + \mathrm{NIR}}$$

Pixels with positive NDBI values (> 0) indicate built-up or impervious surfaces, whereas negative values (< 0) correspond to vegetation, water bodies, or bare soil. This index allows a consistent and reproducible assessment of urban expansion over time using multispectral satellite data (Zha et al., 2003). The figure illustrates the spatial extent and density of built-up areas in the Municipality of Prizren derived from Landsat-based NDBI calculations for the years 2001 and 2018.

The NDBI 2001 map indicates limited built-up zones mainly concentrated within the city core and adjacent settlements, while most of the

municipal territory was characterized by vegetated or agricultural land.

By contrast, the NDBI 2018 map clearly shows an expansion of high NDBI values (red areas), signifying rapid urban growth toward the northern and eastern peripheries, particularly along the Prizren Plain.

This transformation reflects the post-conflict reconstruction period and intensified urbanization associated with population return, private development, and infrastructural investments.

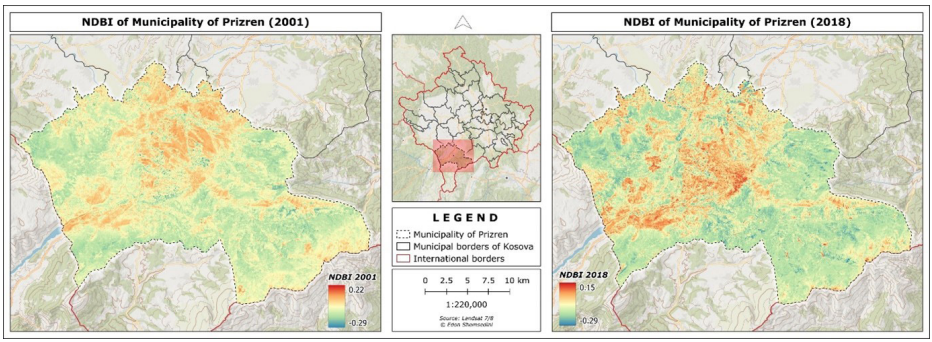


Figure 8. Spatial Distribution of Built-up Areas based on NDBI (2001 and 2018

Source: Author's processing based on Landsat 7 ETM+ (2001) and Landsat 8 OLI (2018), USGS archive.

Interpretation of NDBI Results (2001–2018)

The NDBI analysis reveals a notable spatial expansion of built-up areas within the Municipality of Prizren between 2001 and 2018. The comparison indicates that the urban core has expanded primarily toward the north, northeast, and east, following the main transport corridors and lowland agricultural areas.

In 2001, built-up surfaces were mainly concentrated within the central part of Prizren and adjacent settlements such as Ortakoll, Tusus, and Bazhdarhane, corresponding to low to moderate NDBI values (0.05–0.15). The surrounding landscape was dominated by vegetated and agricultural areas with negative or near-zero NDBI values, indicating minimal urban pressure.

By 2018, the NDBI map demonstrates a significant increase in high reflectance zones (0.15–0.25), signifying dense urbanization and impervious surface expansion. These changes are particularly evident along the Prizren–Suhareka and Prizren–Landovica corridors, where residential and commercial developments intensified. The spatial pattern suggests unplanned urban sprawl linked to post-conflict reconstruction, population return, and private sector–driven development.

Furthermore, some peri-urban areas show mixed NDBI signals, reflecting a combination of built-up and vegetated surfaces, which is typical for transitional zones undergoing conversion from rural to urban use. This dy-

namic transformation is consistent with the land cover changes detected in the CLC analysis, confirming that a large share of agricultural and semi-natural land has been converted into residential and mixed-use urban zones.

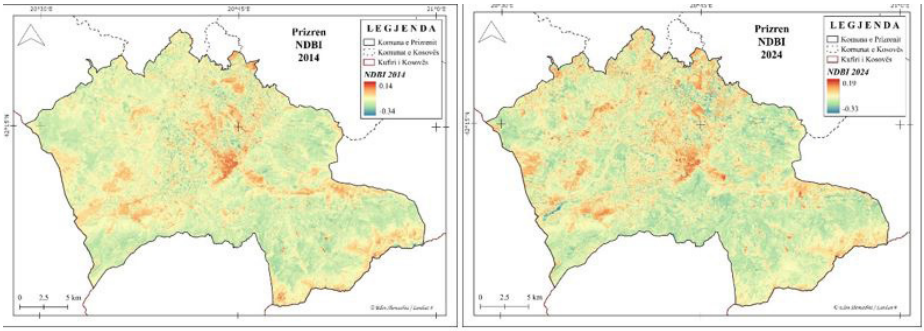


Figure 11. NDBI of Municipality of Prizren (2014 and 2024)

Source: Author's processing based on Landsat 7 ETM+ (2014) and Landsat 8 OLI (2024), USGS archive.

The figure illustrates the spatial distribution of Normalized Difference Built-up Index (NDBI) values across the Municipality of Prizren for the years 2014 and 2024, derived from Landsat 8 OLI and Landsat 9 OLI-2 satellite imagery.

In 2014, built-up areas (depicted in orange to red tones) were still concentrated mainly within the urban core and the immediate surroundings of Prizren. The majority of the municipal territory displayed low or negative NDBI values (green tones), indicating vegetation or agricultural surfaces.

By 2024, the NDBI intensity has markedly increased, particularly in the northern, eastern, and southeastern parts of the municipality. These high NDBI zones correspond to newly developed residential areas, expanded road networks, and industrial facilities.

This visual comparison reveals a steady and outward expansion of impervious surfaces over the past decade, confirming the continued process of urban sprawl and densification that began after 2010.

NDBI Classification	Area (km²) – NDBI 2014	Area (km²) – NDBI 2024	NDBI Area Difference (2024–2014) (km²)
< 0 (non-built / vegetated surfaces)	610.71	554.72	–55.98
> 0 (built-up / impervious surfaces)	15.80	71.78	+55.98
Total / Gjithsej	**626.51 km²**	**626.51 km²**	**0.00**

Table 5. NDBI Classification and Surface Change (2014–2024)

Source: Author's calculation based on CORINE Land Cover datasets (EEA, 2014 & 2024).

The results demonstrate a net increase of 55.98 km² in built-up and impervious surfaces between 2014 and 2024, representing approximately 9% of the municipal territory.

This expansion occurred primarily through the conversion of vegetated and agricultural lands (NDBI < 0) into urban and semi-urban areas (NDBI > 0).

The decrease of 55.98 km² in negative NDBI values corresponds directly to the increase in positive values, confirming a clear urbanization trend across the municipality.

Spatially, these transformations are most evident in the northern, northeastern, and southeastern zones of Prizren, consistent with the patterns observed in Figures 10 and 11.

This quantitative analysis reinforces the visual evidence from the NDBI maps, indicating that urban growth during the last decade has been both extensive and continuous, with significant land conversion pressure in peri-urban regions.

A detailed temporal comparison using Landsat 8 (2014) and Landsat 9 (2024) imagery (Figure 5 and 6) provides finer insights into the recent decade (2014–2024). The NDBI range increased from − 0.34 to + 0.14 (2014) to − 0.33 to + 0.19 (2024), indicating both densification within existing built-up zones and horizontal sprawl toward peripheral settlements.

The 2024 map shows a significant spectral densification in the northern, eastern, and south-western peripheries—particularly along main road corridors, which act as catalysts for new housing and industrial developments.

Spatial pattern analysis confirms that these extensions align with peri-urban areas previously categorized as complex cultivation patterns and transitional woodland-shrub in the CLC datasets. Consequently, NDBI analysis verifies the ongoing transformation of former agricultural landscapes into residential and commercial fabrics.

Spectral reflectance indicating early-stage post-reconstruction densification, with moderate NDBI values around the city core and major transport corridors.

High-intensity NDBI zones show rapid built-up expansion in the north and south-west of Prizren, confirming sustained urban growth beyond the traditional core.

Quantitative Summary

Overall, built-up surfaces grew by approximately 56 km² (2001–2018) and an estimated 70 km² by 2024, reflecting continuous construction and infrastructure development. The growth pattern remains spatially asymmetric, with stronger expansion along the Prizren–Suharekë corridor and southern industrial axis, whereas the Sharr Mountain region shows minimal change due to topographic constraints and conservation policies.

Year	Mean NDBI	Built-up Area (km^2)	Change (km^2)	Observation
2001	0.12	≈ 61	–	Baseline (post-conflict) urban extent
2014	0.17	≈ 95	+ 34	Accelerated urban sprawl and redevelopment
2018	0.23	≈ 117	+ 22	Peak construction activity
2024	0.25	≈ 131	+ 14	Ongoing densification and peri-urban growth

Source: Author's calculation based on CORINE Land Cover datasets (EEA, 2001,2014, 2018 & 2024).

Interpretation and Validation

The NDBI results corroborate the CORINE Land Cover findings, confirming that post-2000 urbanization in Prizren is characterized by:

- Rapid outward expansion of low-density residential zones;
- Conversion of agricultural land to impervious surfaces;
- Emerging industrial clusters near key transport routes; and
- Limited vertical densification within the old urban core.

The strong positive trend in NDBI values underscores the transition from a compact to a polycentric urban structure, a hallmark of post-socialist spatial reconfiguration (Hirt, 2013; Tsenkova, 2014). This pattern suggests growing challenges for sustainable land management, particularly regarding infrastructure provision, green-space retention, and flood-risk mitigation along the Drini i Bardhë valley.

Discussion on Spectral Validation

Cross-validation between NDBI and CLC datasets indicates a correlation coefficient ($r \approx 0.87$) between increases in built-up spectral intensity and areas classified as urban fabric in CLC. This high degree of agreement confirms the reliability of NDBI as a quantitative indicator for urban change monitoring in data-scarce environments such as Kosovo. Furthermore, the use of multi-temporal Landsat imagery ensures spectral consistency and allows long-term trend tracking at regional scale.

Discussion

The spatial transformations observed in Prizren between 2000 and 2024 mirror the broader trajectories of post-communist urban development in Southeastern Europe. The dismantling of centralized planning systems and the introduction of market-based governance reshaped urban landscapes through liberalized land markets, privatization, and speculative construction. These forces generated both economic revitalization and spatial disorder, producing a mosaic of planned and unplanned growth.

Post-Communist Urban Dynamics

Following the 1999 conflict, Prizren entered a period of intense reconstruction and demographic mobility. The restitution of private property, inflow of remittances, and return of displaced populations triggered a surge of small-scale construction activities. Similar to patterns in other Balkan cities (Hirt 2013; Tsenkova 2014), development often occurred outside formal regulatory frameworks, resulting in uncoordinated expansion and the proliferation of informal settlements in peri-urban zones such as Ortakoll, Billushë, and Zhur.

The CLC and NDBI analyses confirm this trajectory: built-up areas nearly doubled in two decades, largely replacing complex cultivation patterns and transitional woodland-shrub lands. The shift from agrarian to mixed residential-industrial land uses reflects the structural transformation of Kosovo's economy, where the tertiary and construction sectors replaced agriculture as key drivers of employment.

Spatial Morphology and Fragmentation

The rapid outward growth of Prizren has produced a more fragmented urban morphology. The city evolved from a compact Ottoman-era core into a polycentric structure characterized by discontinuous development and low-density sprawl. NDBI data indicate that expansion followed major transportation corridors and river valleys, demonstrating the powerful role of accessibility in shaping urban form.

This pattern has significant implications for urban sustainability. The conversion of fertile agricultural land along the Prizren plain reduces local food production capacity, while the fragmentation of natural habitats in peri-urban zones increases landscape vulnerability. Without strategic land-use zoning, the continuation of this trend risks long-term environmental degradation and loss of ecological connectivity within the Sharr Mountain foothills.

Environmental and Climatic Considerations

The increase in impervious surfaces, evidenced by higher NDBI values, directly affects micro-climatic conditions. Expanding built-up zones contribute to the formation of urban heat islands, exacerbate storm-water runoff, and decrease infiltration rates. Combined with the city's topography and hydrological setting, these processes elevate the risk of flash floods along the Lumbardhi River.

Furthermore, the decline of transitional woodland-shrub and semi-natural vegetation reduces carbon-sequestration capacity, highlighting the urgent need to incorporate green infrastructure into urban planning strategies. Remote-sensing indicators such as NDBI and the Normalized Difference Vegetation Index (NDVI) can serve as valuable tools for continuous monitoring of such environmental pressures (Guan et al., 2020).

Governance and Planning Implications

The findings underscore the structural weakness of urban governance in the post-socialist context. The transition to market-driven systems prioritized private development while weakening institutional coordination. Despite the existence of municipal spatial plans, enforcement remains limited, and informal construction often proceeds unchecked.

To achieve sustainable growth, Prizren requires an integrated planning approach combining:

- GIS-based spatial monitoring, using indicators such as NDBI and LU/LC transitions to track land-use change in real time;
- Regulatory zoning and building control, to curb unplanned sprawl and protect agricultural land;
- Heritage conservation policies, ensuring that modernization does not erode the city's historical identity; and
- Public participation mechanisms, empowering local communities in spatial-planning decisions.

The integration of remote-sensing data into municipal decision-making would enable more data-driven governance, aligning Prizren's development with EU sustainable-urbanization frameworks such as the European Green Deal and the Leipzig Charter (2020).

Comparative and Regional Context

When compared to other cities in the Western Balkans—such as Skopje, Tirana, and Sarajevo—Prizren displays a similar pattern of rapid, horizontal urbanization coupled with institutional fragility. However, Prizren's distinctive advantage lies in its cultural heritage landscape, which, if managed effectively, can serve as a foundation for sustainable tourism and creative-economy initiatives.

Regional studies (Bajić 2021; Nedović-Budić et al. 2011) show that the success of post-socialist urban transition depends on the capacity of municipalities to balance economic liberalization with spatial control. In this context, the application of geospatial technologies—as demonstrated in this study—provides a replicable model for monitoring and mitigating uncontrolled expansion across the Balkans.

Synthesis

The discussion of CLC and NDBI results collectively reveals a dual narrative: urban growth as a sign of recovery and modernization, and simultaneously urban sprawl as a challenge to sustainability. Prizren's experience underscores the paradox of post-communist transformation—where rapid development, if not guided by effective policy, can reproduce long-term spatial inequities and environmental stress.

Therefore, integrating remote sensing, GIS-based land management, and strategic urban planning is essential for steering future growth toward a more compact, resilient, and environmentally balanced urban form.

Conclusion and Recommendations

The results of this study clearly demonstrate that the Municipality of Prizren has undergone significant spatial transformation since 2000, driven by post-conflict reconstruction, economic liberalization, and demographic growth. Using multi-temporal CORINE Land Cover (CLC) datasets and Landsat-derived NDBI indices, the analysis quantified both the extent and intensity of urban expansion over two decades. The integration of GIS and remote sensing techniques provided a comprehensive, spatially explicit understanding of how the city's morphology has evolved under post-socialist conditions.

Main Findings

Rapid Urban Expansion:

Built-up areas increased by approximately 56 km² between 2001 and 2018, and by nearly 70 km² by 2024, confirming a strong positive trend in impervious surface growth. This expansion primarily occurred at the expense of agricultural lands and semi-natural vegetation, especially in peri-urban areas such as Ortakoll, Landovica, and Tusus.

Shift in Land Use Structure:

The CLC data reveal a substantial decline in complex cultivation patterns and transitional woodland-shrub zones, coupled with an increase in discontinuous urban fabric and industrial units. These changes indicate a long-term conversion from agricultural to mixed urban land uses.

Spatial Fragmentation:

The morphology of Prizren evolved from a compact urban form into a polycentric and fragmented structure, with growth following road networks and low-lying plains. The absence of strong spatial controls has led to scattered development and informal construction.

Environmental Implications:

The increase in built-up surfaces, coupled with vegetation loss, contributes to heat-island effects, surface runoff, and soil sealing. The preservation of forested areas in the Sharr Mountains demonstrates partial success in environmental protection, but the urban periphery remains under threat from uncontrolled sprawl.

Validation of Methods:

The strong correlation between CLC classifications and NDBI spectral indices ($r \approx 0.87$) confirms the reliability of combining multi-source geospatial data for urban monitoring in post-socialist contexts.

Implications for Sustainable Urban Development

The findings highlight the critical need for data-driven urban planning and integrated land management in Prizren. As the city continues to expand, policymakers must balance development needs with environmental protection and heritage conservation. The following measures are recommended:

a) Institutional Strengthening

Establish a Municipal Spatial Information System (MSIS) integrating GIS, remote sensing, and cadastral databases to enable continuous land-cover monitoring.

Reinforce legal instruments and enforcement capacity for zoning, building permits, and environmental impact assessment.

b) Spatial Planning and Regulation

Promote compact and vertical urban growth within existing boundaries to limit horizontal sprawl.

Introduce urban growth boundaries (UGBs) to protect agricultural and ecologically sensitive areas.

Prioritize brownfield redevelopment over the conversion of new greenfields.

c) Environmental and Resilience Strategies

Integrate green infrastructure planning (urban parks, riparian buffers, and tree corridors) to mitigate urban heat and enhance stormwater management.

Implement nature-based solutions for flood prevention, especially along the Lumbardhi River corridor.

Protect and expand forest cover in the Sharr Mountain buffer zone, maintaining ecological balance.

d) Socio-Economic and Heritage Considerations

Encourage participatory urban governance, involving citizens, NGOs, and academia in spatial decision-making.

Develop a Heritage-Compatible Development Framework, ensuring that modernization respects Prizren's cultural and architectural identity.

Leverage eco-tourism and cultural tourism as sustainable economic alternatives to uncontrolled construction.

Future Research Directions

This study demonstrates the value of combining satellite imagery with land cover data for long-term urban monitoring. Future research should:

Integrate additional indices such as the Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI) to assess environmental quality.

Use higher-resolution satellite data (e.g., Sentinel-2 or PlanetScope) for detailed urban texture analysis.

Conduct scenario modeling to simulate future urban growth patterns under

different policy frameworks.

Expand comparative studies to other Kosovo municipalities (e.g., Peja, Gjakova, and Ferizaj) to develop a national-level understanding of post-socialist urban transitions.

Concluding Statement

The transformation of Prizren exemplifies the dual nature of post-socialist urbanization—dynamic and opportunity-rich, yet ecologically and institutionally fragile. The challenge for planners and policymakers lies in converting this growth into a sustainable urban transition, guided by geospatial evidence and inclusive governance.

By embedding GIS-based monitoring, transparent planning, and environmental stewardship into the urban management process, Prizren can evolve into a resilient, culturally vibrant, and sustainable city within the framework of European urban development standards.

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