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# Urban Expansion and Land Use Transformation in Kosovo:
## Insights from GIS Analysis

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**Abstract**

This study investigates the patterns and implications of urban expansion in Kosovo, utilizing Geographic Information Systems (GIS), Global Human Settlement Layer (GHSL), and CORINE land cover data. The research examines how urban expansion, influenced by post-conflict socio-economic transformations and urban policies, has reshaped Kosovo's urban landscape. Focusing on the spatial distribution and intensity of urban growth, changes in population density, and the conversion of natural and agricultural lands into urban areas, the study provides a comprehensive overview of the dynamics of urban expansion. By evaluating these trends, the research aims to offer insights into the challenges and opportunities for sustainable urban planning in Kosovo. The findings are intended to inform policymakers and contribute to the broader discourse on urban development in transitional economies.

Keywords: Urban Expansion, Kosovo, GIS, Urban Planning, Socio-economic Shifts, Land Use Transformation.

# Contents

# 1 Introduction

Urban development is a complex process that involves the growth of urban areas, changes in population density, and shifts in how land is used (Lu, Shang, Ruan, & Jiang, 2023). These elements are essential for understanding how cities grow and change, especially since by 2050, cities are expected to house around 68% percent of the world's population, totaling about 6.3 billion people (United Nations, 2018). Given this rapid urbanization, it's crucial to address how cities expand physically into surrounding rural or undeveloped areas because failing to do so can lead to several critical issues. Urban expansion involves building new infrastructure, homes, commercial spaces, and other urban facilities and it is driven by factors like population growth, economic development, and the increasing demand for housing and services, often transforming natural landscapes into built environments and impacting land use and population density (Lu et al., 2023). Unplanned urban expansion can result in inefficient land use, leading to urban sprawl. This sprawl often consumes valuable agricultural land and natural habitats (Brueckner, 2000), which can negatively impact food security and biodiversity. Secondly, without proper planning, urban growth can strain infrastructure and public services. Cities may struggle to provide adequate housing, transportation, sanitation, and healthcare, leading to diminished quality of life for residents (UN-Habitat, 2020c). Furthermore, unchecked urban expansion can exacerbate socio-economic inequalities. As cities grow haphazardly, informal settlements often emerge, lacking basic services and infrastructure. These areas are typically home to the urban poor, who face significant challenges in accessing education, employment, and healthcare (World Bank, 2023). Lastly, rapid and poorly managed urbanization increases the vulnerability of cities to environmental risks. Expanding into floodplains, for instance, heightens the risk of flood-related disasters, especially as climate change intensifies (UN-Habitat, 2020a). Proper urban planning can mitigate these risks by ensuring that growth occurs in safer, more sustainable areas.

Cities need to ensure there is enough land that is affordable, well-serviced, and accessible to manage this growth effectively. This requires planners, governing bodies and other stakeholders involved to secure enough land for public works and spaces before development begins (Angel, Blei, Civco, & Parent, 2012). Without such measures, the land and housing markets may not function properly, leading to unplanned and disorderly expansion, especially in less developed countries (UN-Habitat, 2021). This often results in inadequate land for local streets, segregated neighborhoods, unequal distribution of basic services, traffic congestion, and compromised pedestrian routes (UN-Habitat, 2020a).

Kosovo provides a striking example of a developing nation grappling with the complexities of urban expansion. Despite efforts towards economic and social growth, the lack of comprehensive development plans has led to distinctive urban growth patterns, influenced by its unique historical and socio-political context. Since the end of the Serbian occupation in 1999 and Kosovo's declaration of independence in 2008, the country has undergone rapid socio-economic and political changes that have significantly influenced urban expansion, particularly in its capital, Prishtina (Boussauw, 2012). Population growth, economic liberalization, and the urgent need for infrastructure development have driven this expansion (Vöckler, Plath-Moseley, & Os-Thompson, 2008), however, the rapid and often unplanned nature of this growth has posed several challenges, including disparities in service provision, land use conflicts, and environmental degradation (Boussauw, 2012).

Kosovo's urban expansion mirrors broader trends observed in transitional economies, where urban growth is often driven by the need to accommodate rising populations and stimulate economic activities. However, this growth frequently occurs without comprehensive urban planning, resulting in inefficient land use and environmental challenges (Fan et al., 2022). The historical context of Kosovo's urban development is marked by its turbulent past and subsequent efforts to rebuild and modernize its cities. Following the conflict in the late 1990s, many rural areas in Kosovo were devastated. The conflict resulted in significant destruction of property, infrastructure, and agricultural land. This led to a mass movement of people seeking safety and better living conditions in urban areas, which were perceived as more secure and offering better economic opportunities (UN-Habitat, 2020b). Urban centers, particularly the capital Pristina, became hubs for economic activities and international aid efforts. The influx of international organizations and the reconstruction efforts concentrated in these urban areas created jobs and attracted many people from rural areas (Alkhateeb, Storie, & Külvik, 2024). Efforts to rebuild and modernize Kosovo after the conflict focused heavily on urban areas. This included rebuilding infrastructure, establishing new institutions, and improving public services in cities, which in turn attracted more people from the countryside (UN-Habitat, 2021). The political changes following Kosovo's declaration of independence in 2008 also played a role in this urban migration. The new government and international presence in urban areas meant that these cities were at the center of political activity and decision-making, further incentivizing people to move to urban centers (Alkhateeb et al., 2024).

A significant factor contributing to Kosovo's urban expansion challenges was the lack of comprehensive development plans during the interim government period managed by the United Nations Mission in Kosovo (UNMIK) from 1999 to 2008 (Boussauw, 2012). This period was characterized by political instability and a focus on immediate post-conflict recovery rather than long-term urban planning. The interim administration did not prioritize urban development or try to regulate it, leading to unregulated and haphazard construction activities (Boussauw, 2012). According to Kai Vöckler, this era witnessed "turbo urbanism," a term describing rapid and often chaotic urban growth without strategic planning (Vöckler et al., 2008). The absence of effective governance and urban management during this time resulted in the transformation of agricultural and natural lands into urban areas without proper infrastructure or service provision, exacerbating urban sprawl and environmental degradation (Vöckler et al., 2008; Boussauw, 2012). The lack of comprehensive housing policies further complicated the situation. The housing sector faced significant challenges, including a shortage of affordable housing and poor-quality construction. Many residential areas developed without adherence to urban planning standards, leading to fragmented urban growth and inefficient land use (Vöckler et al., 2008; UN-Habitat, 2020c). This unplanned expansion has created disparities in service provision, with some areas lacking basic infrastructure such as roads, water supply, and sanitation facilities (Veliu Rexhepi, Careva, & Roth-Čerina, 2022). These issues highlight the critical need for effective urban planning and governance to manage urban growth sustainably.

Kosovo's urban expansion mirrors broader trends in transitional economies where urban growth aims to accommodate rising populations and stimulate economic activities (Alkhateeb et al., 2024). However, this growth often occurs without comprehensive urban planning, leading to inefficient land use and environmental challenges. Understanding these dynamics is crucial for developing effective urban planning policies and strategies that address rapid urbanization and support sustainable development in Kosovo. Geographic Information Systems (GIS) are crucial for analyzing these pat-

terns and providing data-driven insights that inform urban development strategies. GIS technology allows for the detailed mapping and analysis of spatial data, helping planners visualize urban growth trends, identify areas in need of infrastructure improvements, and optimize land use planning to support sustainable development (Li & Yeh, 2004). However, the use of GIS in Kosovo is still limited, particularly at a national scale. While some studies have utilized GIS for specific projects, there is a lack of comprehensive, nationwide data that can inform broader urban development efforts. This deficiency in data collection and analysis hampers effective urban management and planning. Without robust GIS data, it is challenging to make informed decisions regarding land use, infrastructure development, and environmental protection.

This study aims to analyze the patterns and implications of urban expansion in Kosovo from 1990 to 2020, utilizing advanced global geospatial datasets to provide insights into the spatial distribution and intensity of urban growth, changes in population densities, transformations of land use, and future impacts on surrounding land use categories. The findings will inform sustainable urban planning and policy-making in Kosovo, contributing to the broader discourse on urban development in transitional economies.

## 1.1 Research Questions

This study is guided by the following research questions:

I What are the patterns of urban expansion in Kosovo from 1990 to 2020?
*This question aims to identify the spatial distribution and intensity of urban growth over three decades.*

II How have population densities changed in response to urban expansion in Kosovo?
*This question explores the shifts in population densities associated with urban growth, highlighting areas of significant demographic change.*

III Which land classes have been replaced by urban areas, and what are the implications of these land use changes?
*This question examines the environmental impacts of urban expansion through the transformation of natural and agricultural lands into urban areas using CORINE land cover data.*

IV What are the future implications of urban expansion on surrounding land use categories in Kosovo?
*This question investigates the proximity of various land use categories to urban areas and assesses the potential future impacts of continued urban expansion using buffer analysis.*

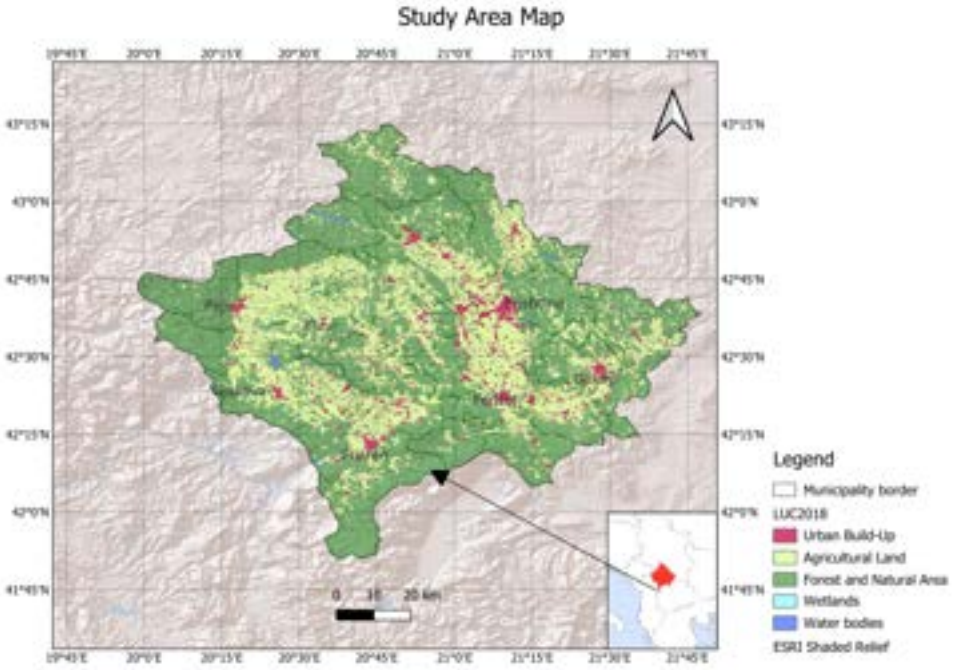


Figure 1: This map depicts Kosovo's geographical distribution and land use in 2018, including urban build-up areas, agricultural lands, forests, wetlands, and water bodies. Major cities such as Prishtina, Prizren, Peja, Gjakova, and Mitrovica are indicated, showing urban expansion and land use patterns. An inset map shows Kosovo's location within the Balkans.

## 1.2 Study Area

Kosovo, located in the central Balkans, spans approximately 10,887 square kilometers and features a diverse topography that includes fertile plains, mountainous regions, and a network of rivers. These geographical characteristics make the region rich in biodiversity and agricultural potential. The Sharr Mountains, along with the Dukagjini and Kosovo plains, are notable geographical features that contribute to the country's landscape diversity (Bank, 2023). With a population of around 1.8 million people (Figure 1), Kosovo has undergone significant demographic changes, especially in its urban centers. Pristina, the capital and largest city, serves as the primary political, economic, and cultural hub of the country. This city has been at the forefront of Kosovo's post-conflict development, significantly influencing the nation's urban dynamics (UN-Habitat, 2020c).

| Year | Population | Increase | Growth Rate() |
|---|---|---|---|
| 1950 | 764,000 | - | - |
| 1960 | 944,000 | 180,000 | 23.6 |
| 1970 | 1,219,996 | 275,996 | 29.2 |
| 1980 | 1,500,000 | 280,004 | 22.9 |
| 1990 | 1,956,000 | 456,000 | 30.4 |
| 2000 | 1,810,000 | -146,000 | -7.5 |
| 2010 | 2,200,000 | 390,000 | 21.5 |
| 2020 | 1,870,000 | -330,000 | -15.0 |

Table 1: Kosovo's Population Growth (1950-2020). Source: Kosovo Agency of Statistics

Other major cities, such as Prizren, Peja, Gjakova, and Mitrovica as seen in Figure 1, have also seen significant urban expansion (Bank, 2023). Urbanization in Kosovo has had profound socio-economic impacts. The expansion of urban areas has improved access to services, created better economic opportunities, and enhanced living standards. However, this rapid growth has also introduced challenges such as traffic congestion, inadequate waste management, and pressure on existing infrastructure (UN-Habitat, 2020c). Environmental concerns have emerged due to the conversion of agricultural land and green spaces into urban areas, affecting local ecosystems and biodiversity. Issues such as pollution and the urban heat island effect have become more pronounced, necessitating efforts to incorporate green spaces into urban planning and promote sustainable development practices (Bank, 2023; UN-Habitat, 2020c). Additionally, Kosovo faces significant water scarcity issues. The country relies heavily on both surface and groundwater resources, but these are often insufficient to meet demand, particularly during dry seasons. The scarcity of water resources is compounded by inefficiencies in water management and distribution, making it a critical issue that needs to be addressed to ensure sustainable development and adequate water supply for its population (Bank, 2023). In summary, while urbanization has brought significant benefits to Kosovo, it also presents a range of challenges that need to be managed through careful planning and sustainable development strategies. Understanding Kosovo's geographical, demographic, and environmental context is crucial for developing effective policies and interventions.

# 2 Literature Review

Understanding urban expansion is pivotal for effective city planning and resource allocation. This literature review delves into the methods and definitions employed in the quantitative measurement of urban growth. Drawing from recent scholarly articles and studies, it highlights key themes in measuring urban expansion and supports the methodology used in analyzing urbanization and land cover changes in Kosovo.

## 2.1 Key Themes in Measuring Urban Expansion

### 2.1.1 Remote Sensing and GIS Technologies

Remote sensing and GIS technologies are indispensable for urban expansion studies, providing essential tools for accurate mapping and analysis of urban growth over time. These technologies enable researchers to capture detailed, high-resolution data on urban dynamics, facilitating the monitoring and management of urbanization processes. Liu and Yang (2015) utilized multi-temporal satellite data to analyze urban growth, demonstrating the effectiveness of remote sensing in capturing urban dynamics and tracking changes in urban areas . Their study highlighted the capability of remote sensing to provide continuous and comprehensive data, which is crucial for understanding temporal changes in urban landscapes. Weng and Lo (2001) discussed the spatial analysis of urban growth impacts using Landsat data, emphasizing the significance of satellite imagery in urban studies . This approach allows for detailed observation of urban sprawl and its environmental impacts, making it a valuable resource for sustainable development planning. Landsat data, with its long history and global coverage, offers a unique perspective on urbanization trends and their ecological consequences. In Kosovo, Berila and Isufi (2021) showcased the potential of GIS and remote sensing to track urban sprawl in Prishtina. Their study employed landscape metrics to measure the extent and pattern of urban sprawl over two decades, providing a comprehensive view of urban dynamics in the region. By integrating GIS with remote sensing data, they were able to produce detailed spatial analyses that informed urban planning and policy-making. This integration not only aids in visualizing current urban growth patterns but also helps predict future trends, thereby supporting proactive urban management strategies.

### 2.1.2 Population Data and Urban Density

Gridded population data sources such as GHSL, WorldPop, and LandScan offer high-resolution population data that are essential for understanding urbanization patterns. (?, ?) provided a comprehensive atlas of human settlements using GHSL, which is instrumental for urban density research. Their work highlighted the utility of high-resolution spatial data in mapping and analyzing human settlements globally. Schneider, Friedl, and Potere (2010) mapped global urban areas using MODIS data, offering valuable insights into urban density measurements. Their study demonstrated the importance of detailed spatial data in understanding the distribution and density of urban populations. Validation of these data sources is crucial to ensure accuracy. Kussul, Yailymova, Drozd, and Shelestov (2021) validated the reliability of GHSL data for urban studies, emphasizing the importance of high-resolution spatial data in monitoring urban growth. Their research underscored the necessity of reliable data for effective urban planning.

### 2.1.3 Land Cover Classification

Land cover classification systems like CORINE Land Cover (CLC) are essential for detailed classification of land cover types, providing a standardized approach to monitor and analyze land use changes over time. Bossard, Feranec, Otahel, et al. (2000) provided a comprehensive technical guide on CLC, which is fundamental for land use analysis. The CLC system categorizes land cover into various classes based on satellite imagery, offering detailed and accurate data crucial for environmental monitoring and urban planning.

### 2.1.4 Spatial Analysis Techniques

Spatial analysis techniques, such as buffer analysis and zonal statistics, are crucial for assessing urban growth. Wu and Hobbs (2002) synthesized key research priorities in landscape ecology, including buffer analysis methods. Lambin, Geist, and Lepers (2003) explored land-use change dynamics, underlining the importance of spatial analysis in understanding urban expansion. More advanced spatial data processing, such as integrating image descriptors for classification, was demonstrated by Li and Yeh (2004), illustrating how symbolic machine learning (SML) can be utilized to analyze spatial restructuring of land use patterns for future studies . Isufi and Berila (2022) employed geospatial technology to analyze land use and cover changes in Prishtina, emphasizing the role of remote sensing in urban studies. Their research utilized high-resolution satellite imagery to track changes in land cover over two decades, providing valuable insights into the impacts of urbanization in the capital of Kosovo.

## 2.2 Supporting Methodology for Kosovo Study

### 2.2.1 Data Preprocessing

Accurate data preprocessing is critical for effective analysis. This includes georeferencing and clipping datasets to a common coordinate system, ensuring all data focuses specifically on Kosovo boundaries. Foley et al. (2005) emphasized the global consequences of land use and the importance of precise data preprocessing to facilitate accurate and meaningful analysis. This step ensures that all spatial data used in the study is aligned and consistent, which is crucial for accurate analysis and comparison.

### 2.2.2 Temporal Analysis

Temporal analysis involves examining periods of urban growth through binary raster maps. Seto, Güneralp, and Hutyra (2012) provided a framework for such analysis by forecasting global urban expansion, allowing researchers to identify and evaluate growth trends over time. By analyzing changes over different time periods, researchers can gain insights into the pace and patterns of urbanization, which are essential for long-term urban planning and policy-making.

### 2.2.3 Urban Density and Population Density Maps

Detailed spatial analysis using hexagonal grids offers a nuanced understanding of urban density. Hexagonal grids are preferred over traditional square grids because they minimize edge effects and provide a more accurate representation of spatial relationships. Batty (2013) explored new methods in urban science, including innovative grid generation techniques that improve the accuracy and detail of urban density maps. By using hexagonal grids, researchers can achieve a higher resolution and a more precise depiction of population distribution and urban density patterns. These techniques provide a more granular view of population distribution, allowing for better analysis of urban form and structure. The uniformity and equal distance between hexagon centers enhance spatial analysis, making it easier to identify clusters and patterns within urban environments, which is crucial for effective urban planning and resource allocation.

### 2.2.4 Land Use Change Analysis

Identifying and quantifying land cover changes is essential for understanding urban expansion. Verburg, Neumann, and Nol (2011) highlighted several challenges in utilizing land use data, particularly the inconsistencies and gaps that can arise from different data collection methods and varying spatial and temporal resolutions. They stressed the importance of robust analysis methods to ensure accurate interpretation of land use changes over time. Their study specifically pointed out that integrating various data sources, such as remote sensing and national inventories, can mitigate some of these challenges. They also emphasized the necessity of harmonizing classification systems to enhance the comparability and reliability of land use data.

## 2.3 Urban Planning in Post-Conflict Settings

### 2.3.1 Challenges and Opportunities

Post-conflict urban planning presents unique challenges. Boussauw (2012) examined the transition from centralized to decentralized urban planning in post-conflict Kosovo, highlighting the complexities of implementing effective urban policies in an unstable environment. He detailed how the lack of established governance structures and the urgent need for reconstruction often lead to uncoordinated urban development. Boussauw emphasized that in the absence of strategic planning, urban growth can become chaotic, exacerbating issues such as unequal service provision, environmental degradation, and inefficient land use. He argued that effective governance and strategic planning are crucial to manage urban growth sustainably in such contexts. Establishing clear regulatory frameworks and engaging local communities in the planning process can help create more resilient and equitable urban environments.

### 2.3.2 Rapid Urban Development

Kai Vöckler's concept of "turbo urbanism," discussed extensively in his book Prishtina is Everywhere - Turbo Urbanism: the Aftermath of a Crisis, provides a comprehensive analysis of the rapid and often unplanned urban development in Kosovo following the conflict. Vöckler's work delves into the phenomenon of "turbo urbanism," which describes the explosive and uncontrolled urban growth driven by post-conflict reconstruction, economic liberalization, and population influxes. This era witnessed chaotic and unregulated construction, leading to significant challenges in urban governance, infrastructure, and environmental sustainability. Vöckler highlights several critical

issues resulting from this rapid development, such as inadequate infrastructure, poor housing quality, and environmental degradation. He argues that the lack of strategic urban planning during this period has resulted in long-term negative consequences for the urban landscape of Kosovo.

## 2.4 Policy and Institutional Influences

### 2.4.1 Compact City Strategies

Gashi and Ramadani (2022) highlighted the use of GIS in promoting compact city strategies in Kosovo. They demonstrated how policy interventions could influence urban form by identifying and promoting areas suitable for densification, thereby curbing urban sprawl. Their study showed that adopting compact city strategies could lead to more efficient land use and better urban sustainability outcomes.

### 2.4.2 Housing Policies

Veliu Rexhepi et al. (2022) reviewed housing policies in Kosovo from 1947 to 2021, emphasizing the need for comprehensive urban planning to address the challenges of unplanned urban growth. Their review highlighted the evolution of housing policies and their impact on urban development patterns. They stressed the importance of developing holistic housing policies that align with broader urban planning goals to ensure sustainable urban growth.

## 2.5 Validation and Limitations

### 2.5.1 Validation

Ground-truth data and cross-referencing with other studies are crucial for ensuring the accuracy of remote sensing data. Congalton and Green (2019) discussed principles for assessing the accuracy of remotely sensed data, highlighting the importance of validation. Accurate validation methods ensure that the data used in urban studies is reliable and can be confidently used for planning and decision-making.

### 2.5.2 Limitations

Addressing the absence of historical data is a significant challenge in urban studies. Verburg et al. (2011)highlighted data gaps and challenges in land use studies, emphasizing the need for robust validation methods to ensure accurate analysis. Historical data is often incomplete or inconsistent, which can hinder the accuracy of long-term urban growth studies. Developing methods to address these gaps is crucial for improving the reliability of urban studies.

# 3 Data and Methodology

The methodology for this study involves a comprehensive analysis of urbanization and land cover changes in Kosovo, utilizing advanced geospatial datasets and literature review. By combining satellite imagery, population data, and land cover classifications, we aim to understand the patterns and drivers of urban expansion and their impacts on the environment. The methodology also includes a thorough review of existing literature to contextualize the findings and ensure the robustness of the analysis.

## 3.1 Data Sources

This study employs several key datasets, each providing crucial insights into different aspects of urbanization and land cover as shown in Table 2 below:

| **Data Source** | **Description** | **Years Available** | **Resolution** | **Attributes** | **Provider** |
|---|---|---|---|---|---|
| GHSL - POP (Population) | Global Human Settlement Layer - Population data | 1990, 2000, 2010, 2020 | 100 m | Population counts per grid cell | European Commission, Joint Research Centre (JRC) |
| GHSL - BUILT-S (Urban Built-up) | Global Human Settlement Layer - Built-up areas | 1990, 2000, 2010, 2020 | 100 m | Extent and density of built-up areas | European Commission, Joint Research Centre (JRC) |
| CORINE Land Cover | Coordination of Information on the Environment (CORINE) Land Cover data | 2000, 2006, 2012, 2018 | 100 m | Land cover classification (44 classes) | European Environment Agency (EEA) |
| GADM (Administrative Boundaries) | Global Administrative Areas database | Current | Varies by country | Country and municipality boundaries | Global Administrative Areas (GADM) |

Table 2: Data Sources Used for Urbanization and Land Use Analysis in Kosovo

## 3.2 Global Human Settlement Layer (GHSL) Dataset Description

Global Human Settlement Layer (GHSL) dataset to analyze urbanization and land cover changes in Kosovo. Developed by the European Commission's Joint Research Centre (JRC), the GHSL provides detailed spatial data on human settlements and population dynamics worldwide (JRC Publications Repository, 2023). This dataset integrates high-resolution satellite imagery from the Landsat and Sentinel missions, census data, and volunteered geographic information sources, leveraging advanced spatial data processing technologies to extract valuable information. It combines historical multispectral data from the Landsat series, including Landsat-8, with high-resolution optical imagery from Sentinel-2. This integration allows for detailed urban mapping and long-term analysis of urban growth patterns (JRC Publications Repository, 2023). The dataset employs symbolic machine learning (SML) methodologies, incorporating radiometric and morphological image descriptors to accurately classify and quantify built-up areas, this process involves multi-scale image analysis and object-oriented shape recognition, enabling precise delineation of urban areas (JRC Publications Repository, 2023). Covering the period from 1975 to 2030 and updated at five-year intervals, the GHSL dataset facilitates a comprehensive analysis of urban growth and changes over time. It provides sub-pixel built-up fraction estimates at a 10-meter resolution, distinguishing between residential and non-residential built-up surfaces. The population component of the GHSL integrates census data with remote sensing information to produce gridded population estimates, allowing for a detailed examination of population density changes and their correlation with urban expansion. For this study, two key components of the GHSL Data Package 2023 (GHS P2023) are utilized: GHS-BUILT-S R2023A and GHS-POP R2023A. The GHS-BUILT-S R2023A component offers a spatial raster dataset of built-up surfaces derived from multi-temporal satellite imagery. It integrates data from Landsat missions, including Landsat-8, and Sentinel-2, covering the period from 1975 to 2030. The dataset includes sub-pixel built-up fraction estimates at a 10-meter resolution, making it ideal for detailed urban growth analysis. For this study, a 100-meter resolution raster was used to balance detail and computational efficiency. The GHS-POP R2023A component provides gridded population estimates, combining census data with satellite imagery. Spanning from 1975 to 2030, with data available at five-year intervals, this component is provided at a 100-meter spatial resolution. It is crucial for understanding how population density changes correspond with urban expansion, enabling a comprehensive analysis of the relationship between urban growth and demographic shifts.

## 3.3 CORINE Land Cover (CLC) Dataset Description

The CORINE (Coordination of Information on the Environment) Land Cover (CLC) dataset, developed by the European Environment Agency (EEA), is an essential resource for analyzing land cover changes across Europe. This dataset provides a detailed classification of land cover into 44 categories, such as artificial surfaces, agricultural areas, forests, semi-natural areas, wetlands, and water bodies. The classification is derived from the interpretation of high-resolution satellite images, supplemented with ancillary data and field verification to ensure accuracy and consistency. The CLC data is updated at regular intervals, allowing for the monitoring of land cover dynamics over time. For the purposes and scope of this study, we utilized the Level 1 classification of the CLC dataset, which includes the broadest categories of land cover. This level of classification was chosen because it offers a comprehensive overview of major land cover types, facilitating an understanding of large-scale land use patterns and trends. The broad categories at Level 1 are sufficient to identify significant changes and trends in land cover over the study period without becoming overly detailed or complex, as seen in Table 3. The CLC dataset's inclusion of multiple time points allows us to analyze land cover changes in Kosovo from 2000, 2006, 2012, and 2018. However, the CLC inventory for 1990 is missing for Kosovo, posing a challenge for historical comparisons. Despite this gap, the available data from subsequent years provides valuable insights into how land use patterns have evolved in response to urban expansion and environmental changes.

| **Level 1** | **Description** |
|---|---|
| 1. Artificial Surfaces | Areas predominantly occupied by urban structures and infrastructure |
| 2. Agricultural Areas | Lands primarily used for agricultural purposes, including crops and pastures |
| 3. Forests and Semi-Natural Areas | Natural and semi-natural vegetation, including forests, grasslands, and shrublands |
| 4. Wetlands | Areas with saturated soil conditions, such as marshes and peat bogs |
| 5. Water Bodies | Inland and marine waters, including rivers, lakes, and coastal areas |

Table 3: CORINE Land Cover Classification (Level 1)

## 3.4 Temporal Analysis (Research Question 1)

To analyze the pattern of urban expansion we conducted a temporal analysis using the GHS-BUILT-S R2023A dataset from the Global Human Settlement Layer (GHSL). This dataset provides built-up surface data at a high spatial resolution for the years 1990, 2000, 2010, and 2020. By analyzing these datasets, we aimed to identify significant periods of urban growth and understand the spatial dynamics of urbanization over time. To begin, we processed the GHS-BUILT-S datasets by creating binary raster maps to distinguish between urban and non-urban areas. This simplification was necessary to clearly identify areas of urban expansion. In each binary raster,

built-up areas were assigned a value of 1 (urban), and all other areas were assigned a value of 0 (non-urban). This reclassification was done using the Raster Calculator tool in QGIS, ensuring consistency across all time periods. Next, we performed change detection analysis to identify urban expansion between each pair of consecutive years (1990-2000, 2000-2010, 2010-2020). This was achieved by subtracting the earlier binary rasters from the later ones (e.g., built2000 - built1990, built2010 - built2000, and built2020 - built2010). The resulting rasters highlighted areas where urbanization occurred during each period, providing a clear temporal dimension to the study. To quantify these changes, we employed zonal statistics using administrative boundaries. The Zonal Statistics tool in QGIS calculated the total urban area for each time period. This method allowed us to assess the magnitude of urban growth in each period. The visual representation of these changes was crucial for understanding the spatial patterns of urbanization. We created maps for each period, showing the extent of urban areas in yellow against a purple background representing non-urban areas.

## 3.5 Urban Density Population Density Maps (Research Question 2)

For the urban density population density maps, we utilized the hexagonal grid generation function from the MMQGIS plugin in QGIS. This function requires a boundary file (in formats such as .shp, .gpkg, etc.) to define the spatial extent for the grid. We used the Kosovo boundary file to set these bounds. For this study, hexagonal grids were generated at approximately 1 km resolution. This resolution was chosen to balance the need for detailed spatial analysis with computational efficiency. We used the Global Human Settlement Layer Population (GHSL-POP) dataset and the Built-Up (BUILD-S) dataset for the years 1990, 2000, 2010, and 2020. To isolate urban population density, we divided the GHSL-POP by the GHSL-BUILD-S dataset for each respective year (i.e., pop1990 / builds1990, pop2000 / builds2000, etc.). This division allowed us to focus specifically on the density of populations within urban environments. The standardized and categorized GHSL data was then joined to the hexagonal grids, assigning population values to each hexagon cell. The resulting datasets were joined to the hexagonal grid by location, to create the urban population density maps. To clean up the data and save storage space, hexagons with NULL population values were removed from the final datasets. It is worth mentioning that, while our study chose to use the total number of population points within each hexagon as our major aggregation statistic, other statistics such as the number of points or proportion might also be determined; however, for the scope of this study, we only used sum statistics.

## 3.6 Land Use Change Analysis (Research Question 3)

To analyze land use changes in Kosovo between 2000 and 2018, we utilized CORINE Land Cover datasets for the years 2000, 2006, 2012, and 2018. These datasets were reclassified into simplified categories: Urban, Agricultural, Natural Land and Forests, Wetlands, and Water Bodies. Each dataset was clipped to the boundaries of Kosovo using QGIS to focus the analysis on the study area. For each pair of consecutive years (2000-2006, 2006-2012, 2012-2018), we performed an intersection of the respective land cover layers to identify changes in land cover types. A new field was added to classify the type of land cover change (e.g., Agricultural to Urban, Forest to Urban, Water to Urban). The area of each change was calculated and converted to hectares. This intersection process allowed us to accurately identify and quantify the transitions between different land cover types over time. The Group Stats plugin in QGIS was employed to summarize the total areas of each change type, excluding areas that

did not change. This approach allowed for a precise calculation of land use changes, highlighting the significant urban expansion driven primarily by the conversion of agricultural and forested lands. The results were recorded in a summary table, providing a clear overview of the extent of urban expansion in Kosovo over the three periods studied. Additionally, we quantified the overall changes in land cover types over the years, offering a comprehensive understanding of the patterns and drivers of land use change. To visualize these changes, we created a map showing the land cover transitions from 2000 to 2018. The process involved generating a classified urban layer for 2018 and intersecting it with the land cover layers from 2000. Specific colors were assigned to different types of changes: red for urban expansion, green for agricultural to urban conversion, dark green for forest to urban conversion, and blue for water to urban conversion. This visual representation made it easy to interpret the spatial distribution and types of land cover changes over the study period.

## 3.7 Buffer Analysis of Land Use Changes Around Urban Areas

To assess the proximity of various land use categories to urban areas using land use change (LUC) data, we conducted a buffer analysis with QGIS. Buffer zones of 1 km around urban areas were created to capture the immediate peri-urban regions most likely influenced by urban sprawl. We used the Kosovo boundary file to set the spatial extent for these buffer zones, applying the Buffer tool in QGIS with the urban area layer as the input and specifying a buffer distance of 1 km. Once the buffers were generated, we intersected them with LUC data using the Intersection tool in QGIS. This step produced a new layer combining attributes from both the buffer zones and the LUC data. To analyze land use within the buffer zones, the intersected layer was processed to determine the total area of each land use category. This was achieved using the Group Stats plugin, which facilitated the calculation of the sum of areas for each land use type within the buffer zones. Areas with 0 or NULL values were removed from the final datasets to ensure that only relevant data was retained for analysis. Although time constraints did not allow for the identification of specific areas at risk of future urban expansion, this buffer analysis methodology provided a framework for understanding the proximity of various land use categories to urban areas. To visualize these changes, we created a map and summarized the findings in a table, illustrating the spatial distribution and extent of different land use categories within the 1 km buffer zones around urban areas.

# 4 Results

The results of this study are presented through the following analyses: temporal analysis of urban expansion, population density changes, and land use change analysis.

## 4.1 Temporal Analysis of Urban Expansion

The temporal analysis utilized the GHSL built-up area datasets to assess urban expansion in Kosovo from 1990 to 2020. The urban area data were analyzed for three periods: 1990-2000, 2000-2010, and 2010-2020.

| Period | Total Urban Expansion (hectares) |
|---|---|
| 1990-2000 | 124,437 |
| 2000-2010 | 216,215 |
| 2010-2020 | 176,649 |

Table 4: Urban Expansion in Kosovo (1990-2020)

The analysis reveals significant trends in urban growth in Kosovo over the three decades. As we see in Table 4, from 1990 to 2000, Kosovo experienced urban expansion totaling approximately 124,437 hectares. This growth accelerated dramatically between 2000 and 2010, with the urban area increasing by 216,215 hectares. The period from 2010 to 2020 saw a slight decrease in the rate of expansion, with the total urban area increasing by 176,649 hectares. These trends highlight the dynamic nature of urban growth in Kosovo. The highest rate of expansion occurred in the first decade of the 21st century, possibly reflecting post-conflict reconstruction and economic development efforts. The subsequent decade showed a stabilization of growth rates, suggesting a potential shift in urban development patterns towards more controlled and sustainable growth.

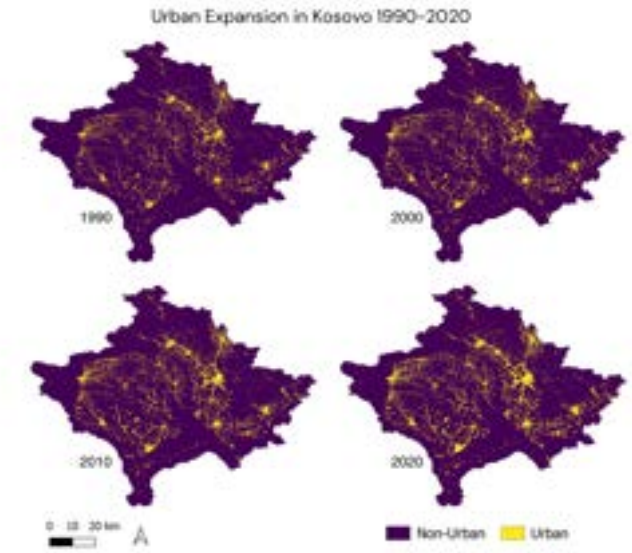


Figure 2: The maps illustrate the spatial distribution and extent of urban areas for the respective years.

**Figure 2 Interpretation**

I **1990 Urban Expansion Map**: The map shows that in 1990, urban areas were primarily concentrated around Pristina, the capital city. Smaller urban centers such as Mitrovica, Peja, Prizren, and Gjakova also show some urban development. The urban footprint is relatively small, reflecting the pre-conflict state of urbanization.

II **2000 Urban Expansion Map**: By 2000, there is noticeable urban expansion in Pristina, indicating early post-conflict reconstruction efforts. Other cities such as Mitrovica, Peja, Prizren, and Gjakova also exhibit growth, albeit more moderate. This period marks the beginning of significant demographic shifts and urbanization post-1999 conflict.

III **2010 Urban Expansion Map**: The urban areas have expanded significantly by 2010, particularly in Pristina, which shows extensive growth. This period corresponds with significant international aid and investment in infrastructure and housing. Urban sprawl is evident around major cities, reflecting increased rural-to-urban migration.

IV **2020 Urban Expansion Map**: By 2020, urban expansion continues, but at a slightly reduced rate compared to the previous decade. Pristina remains the focal point of urban growth, with substantial expansion in its suburbs. Other cities like Mitrovica, Peja, Prizren, and Gjakova also show expanded urban areas. This period may indicate more controlled urban growth, possibly due to better urban planning and governance.

## 4.2 Population Density Changes

Population density changes were analyzed using hexagonal grids to assess urban population densities for the years 1990, 2000, 2010, and 2020. The GHSL-POP data were used to calculate population densities within urban areas.

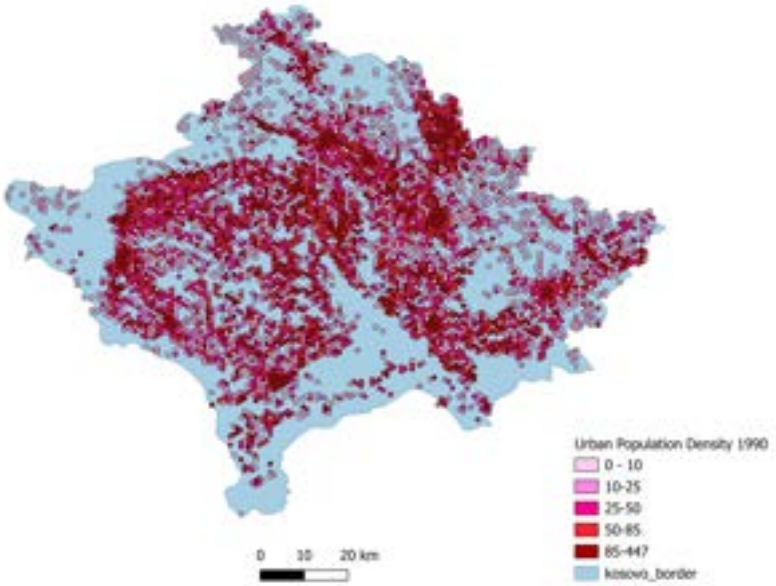


Figure 3: 1990

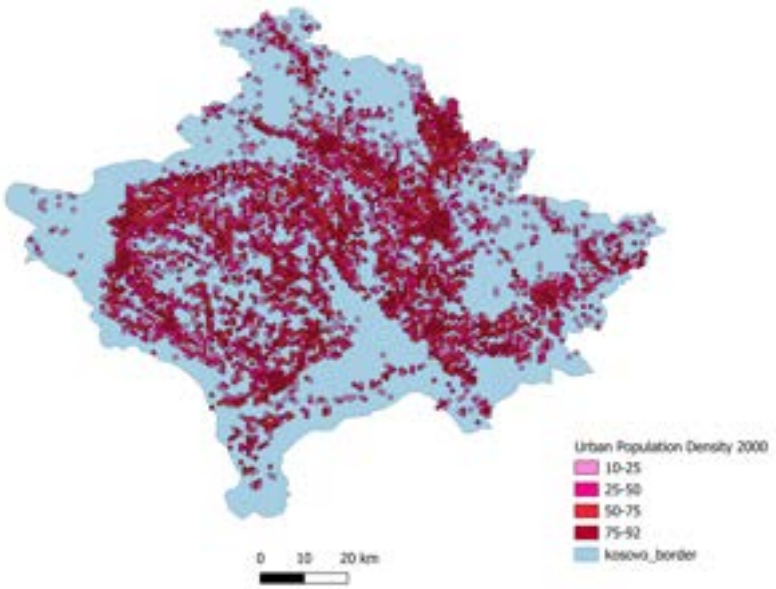


Figure 4: 2000

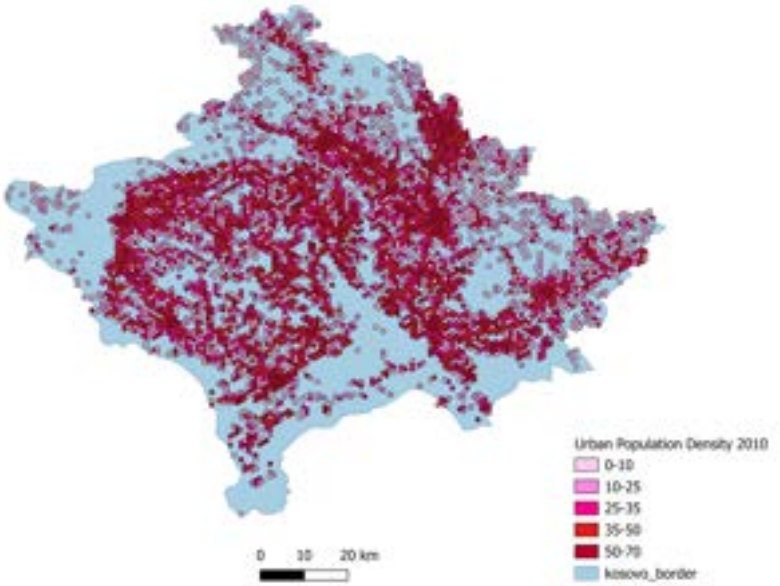


Figure 5: 2010

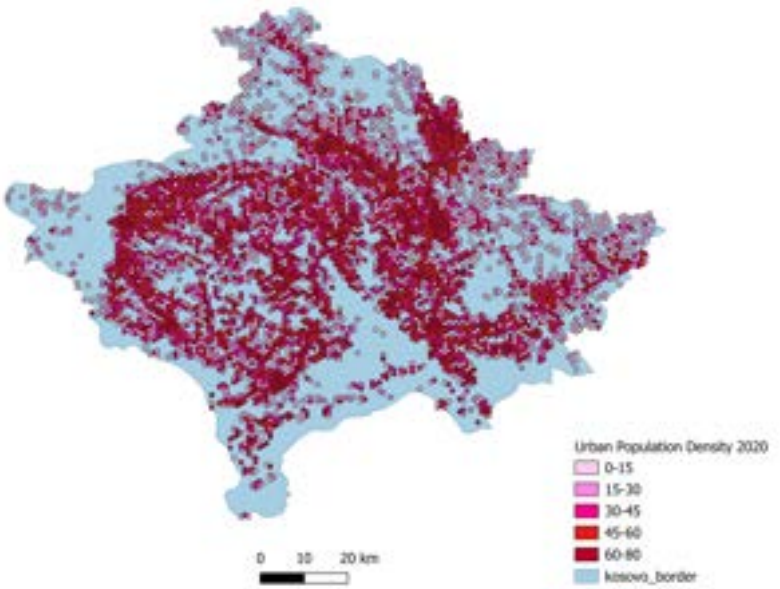


Figure 6: 2020

**Figures 4 - 6 Interpretation**

I **1990 Population Density Map**: The population density in 1990 was relatively low, with Pristina having the highest density. Other cities such as Mitrovica, Peja, Prizren, and Gjakova show moderate population densities, reflecting pre-conflict demographic distributions.

II **2000 Population Density Map**: By 2000, population densities in Pristina have increased significantly, indicating the influx of people into the capital post-conflict. Other urban areas also show increased densities, albeit less pronounced than Pristina. This reflects the immediate post-conflict urbanization and migration patterns.

III **2010 Population Density Map**: The map shows a significant increase in population density in Pristina and other major cities. This period corresponds with substantial rural-to-urban migration, economic development, and housing expansion. The increased densities in urban centers highlight the demographic shift towards urban areas.

IV **2020 Population Density Map**: By 2020, urban population densities have continued to rise, particularly in Pristina. The map indicates a more balanced distribution of population density across urban areas, suggesting better planning and distribution of urban services and housing.

## 4.3 Land Use Change Analysis

The land use change analysis focused on the transition of land classes to urban areas from 2000 to 2018 using CORINE Land Cover datasets. The analysis identified changes in land use categories, such as agricultural land, forest and natural land, wetlands, and water bodies converted to urban areas as shown in Table 5 and visualised in Figure 7.

| Period | Agricultural to Urban (ha) | Forest to Urban (ha) | Water to Urban (ha) |
|---|---|---|---|
| 2000-2006 | 49,396.4 | 115,703 | 3,997 |
| 2006-2012 | 73,390.2 | 162,110 | 4,022 |
| 2012-2018 | 5,920.3 | 4,013.89 | 0 |

Table 5: Land Use Changes to Urban

**2000-2006**
During the period from 2000 to 2006, Kosovo experienced significant urban expansion. Agricultural land conversion to urban areas totaled 49,396.4 hectares, while forest to urban conversion accounted for 115,703 hectares. Additionally, 3,997 hectares of water bodies were transformed into urban areas. This period's total urban expansion reached 169,096.4 hectares, indicating robust development activities, particularly in deforested regions.
**2006-2012**
From 2006 to 2012, the rate of urban expansion increased even further. Agricultural land converted to urban areas rose to 73,390.2 hectares, and forest land conversion reached 162,110 hectares. Water bodies converted to urban areas remained relatively stable at 4,022 hectares. The total urban expansion during this period was 239,522.2 hectares, highlighting an intensification of urban development, likely driven by economic growth and increased urbanization efforts.

**2012-2018**
The period from 2012 to 2018 showed a significant slowdown in urban expansion. Agricultural land conversion to urban areas decreased sharply to 5,920.3 hectares, and forest to urban conversion dropped to 4,013.89 hectares. There was no notable conversion of water bodies to urban areas during this period. The total urban expansion was 9,934.19 hectares, suggesting a stabilization in urban growth, potentially due to more effective land use policies and planning regulations.

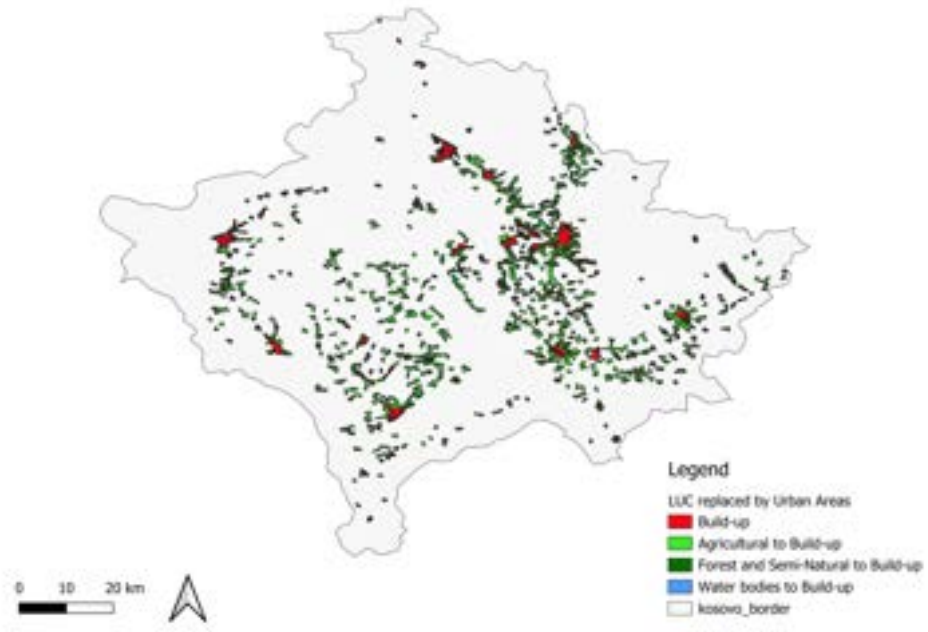


Figure 7: **LUC Replaced by Urban Areas**: This map highlights specific areas where land classes have been replaced by urban build-up. The red areas indicate new urban developments, primarily at the expense of agricultural and natural lands. This conversion is most prominent around major cities, showing the pressure on land resources due to urban expansion.

# 5 Discussion

The results of this study provide comprehensive insights into the patterns and implications of urban expansion in Kosovo from 1990 to 2020. The temporal analysis highlights periods of significant growth, particularly from 2000 to 2010, reflecting post-conflict reconstruction and economic development. Population density maps reveal increasing urban densities, indicating demographic shifts towards urban areas. The land use change analysis underscores the environmental impact of urban expansion, with substantial conversions of agricultural and forest lands to urban areas. The visual representations further illustrate the spatial dynamics of these changes

To understand the future implications of urban expansion and identify areas most affected by it, we conducted a buffer analysis within 1 km around urban areas, as shown in Figure 8 and Figure 9. This approach allowed us to quantify and visualize the impact of urban growth on various land use categories, particularly agricultural and natural lands, which are crucial for sustainable development.

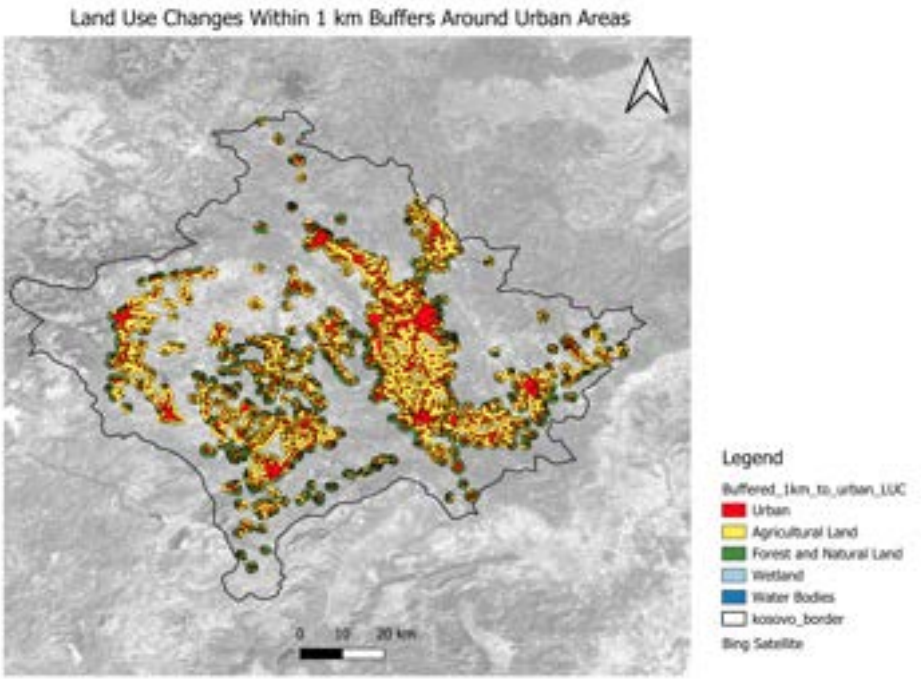


Figure 8: The map shows significant conversion of agricultural and natural lands to urban areas within 1 km buffers around urban centers. The highest conversions are observed around Pristina, Mitrovica, and Prizren. This reflects the expansion of urban areas into surrounding rural and natural lands, indicating urban sprawl and the need for better urban planning.

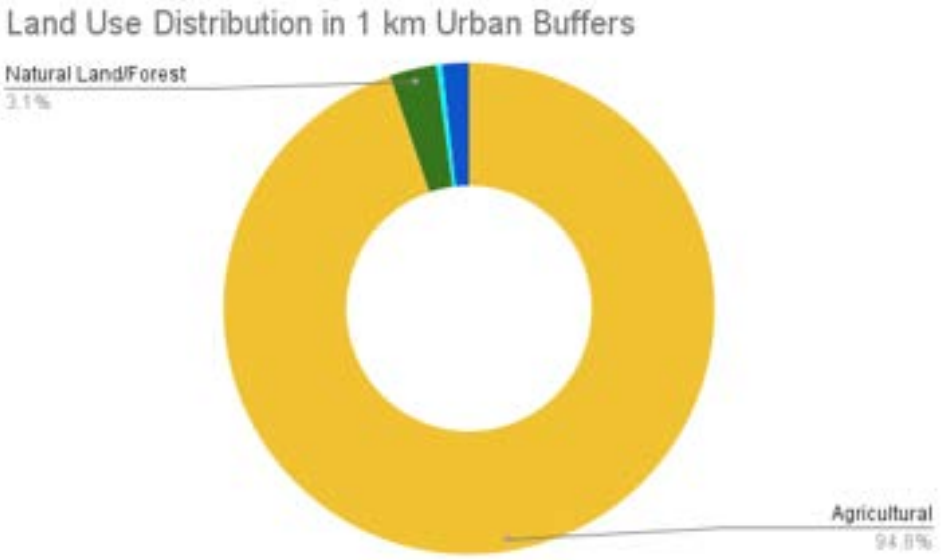


Figure 9: Distribution of land use within 1 km urban buffers, showing that 94.8% is agricultural land, 3.1% is natural land/forest, and the remainder is other land uses.

The analysis indicates that:

- **Agricultural Land**: Constitutes the vast majority of the land use within the buffer zones, accounting for 94.8%. This highlights the significant impact of urban expansion on agricultural areas, leading to the conversion of fertile land into urban space.
- **Natural Land/Forest**: Comprises 3.1% of the land within the buffer zones. This suggests some degree of conversion of natural habitats and forested areas into urban areas, raising concerns about biodiversity and ecological sustainability.
- **Wetlands and Water Bodies**: Occupy a minimal percentage of the land within the buffer zones, indicating limited but notable conversions of these critical ecosystems into urban areas.

#### 5.0.1 Implications of the Results

I **The findings have several important implications for urban planning and policy-making in Kosovo**: Agricultural Land Preservation: The significant conversion of agricultural land to urban areas suggests a trend of urban sprawl. This underscores the need for policies to protect fertile agricultural lands, ensuring food security and maintaining the agricultural economy. Urban growth boundaries and zoning regulations can help manage urban expansion and preserve agricultural areas.

II **Biodiversity Conservation**: The conversion of natural lands and forests to urban areas raises concerns about biodiversity loss and ecological balance. Establishing conservation zones and green belts around urban areas can help preserve these critical habitats and provide recreational spaces for urban residents.

III **Sustainable Water Resource Management**: The limited but notable conversion of wetlands and water bodies into urban areas highlights the need for sustainable water resource management. Given the scarcity of water resources, it is essential to implement water-efficient urban designs and protect wetlands to ensure the availability of clean water for urban populations.

IV **Integrated Urban Planning**: The findings emphasize the need for integrated urban planning approaches that balance urban growth with environmental sustainability. Policies should focus on compact city designs, mixed-use developments, and the integration of green infrastructure to create resilient and sustainable urban environments.

## 5.1 Validation of Results

The validation of results in this study presented certain challenges. While the datasets used, such as GHSL and CORINE Land Cover, are well-validated and widely accepted in urban studies, there were limited opportunities to perform ground-truth validation specific to Kosovo due to the lack of comprehensive local studies. However, comparisons with the findings of Berila and Isufi (2020) and Veliu (2022) provided some validation for the observed trends.

## 5.2 Limitations and Challenges

Despite the comprehensive approach, several limitations and challenges were encountered:

I **Validation Shortcoming**s: One of the primary limitations of this study was the validation of results. The lack of extensive ground-truth data and limited local studies made it challenging to fully validate the results. Future studies should aim to include more robust ground-truthing to enhance the reliability of the findings.

II **Missing 1990 CLC Data**: The absence of CORINE Land Cover data for 1990 posed a challenge for historical comparisons. This limitation was addressed by using GHSL built-up data to infer urban areas for the 1990 period. However, this substitution may not capture all land cover changes accurately.

III **Resolution of Datasets**: The resolution of 100 meters, while adequate for general analysis, may not capture very fine-scale urban changes. Higher resolution datasets could provide more detailed insights but were beyond the scope of this study.

IV **Temporal Gaps**: The analysis was conducted at decadal intervals, potentially overlooking nuanced yearly changes. More frequent data points could offer a finer understanding of urban expansion dynamics.

## 5.3 Future Directions

Based on the study outcomes, several specific recommendations for future research are proposed:

I **High-Resolution Data Analysis**: Future studies could utilize higher resolution satellite imagery to capture more detailed urban expansion patterns and land use changes.

II **Longitudinal Studies**: Conducting longitudinal studies with more frequent data points can provide a finer temporal resolution of urban growth trends.

III **Impact of Urban Policies**: Investigating the impact of specific urban planning policies and interventions on urban expansion could provide valuable insights into effective urban management strategies.

IV **Environmental Impact Assessments**: Further studies should focus on the environmental impacts of urban expansion, such as changes in ecosystem services, biodiversity, and climate change adaptation.

V **Sustainable Urban Design Practices**: Research into sustainable urban design practices that integrate green infrastructure, renewable energy, and efficient resource management can help mitigate the negative impacts of urban expansion.

# 6 Conclusion

This study provides a comprehensive analysis of urban expansion in Kosovo from 1990 to 2020, highlighting the significant growth and demographic shifts towards urban areas. The results emphasize the critical need for strategic urban planning and sustainable development policies to manage urban growth effectively and mitigate environmental impacts.

**Key Findings:**

- Significant urban expansion in Kosovo, particularly between 2000 and 2010, driven by post-conflict reconstruction and economic development.
- Increasing urban population densities, especially in Pristina, reflecting demographic shifts towards urban centers.
- Predominant conversion of agricultural land to urban areas, highlighting the importance of protecting fertile agricultural lands.
- Limited but notable conversions of natural lands, forests, and water bodies to urban areas, emphasizing the need for biodiversity conservation and sustainable water resource management.

**Recommendations:**

- Implement policies to protect agricultural lands and manage urban sprawl.
- Establish conservation zones and green belts to preserve natural habitats.
- Promote sustainable water management practices to protect wetlands and ensure water availability.
- Focus on integrated urban planning that balances growth with environmental sustainability.

By addressing these challenges and implementing the proposed recommendations, Kosovo can achieve balanced and sustainable urban growth, ensuring a resilient and prosperous future for its urban and rural communities. The study's findings contribute to the broader discourse on urban development in transitional economies and provide a foundation for future research and policy development.

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