

Spatio-temporal Dynamics of Urban Expansion: A Case Study of Sandhikharka Municipality

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Abstract

Understanding the effects of urbanization and creating sustainable planning strategies requires a thorough analysis of urban growth patterns at various spatial and temporal levels. The aim of this paper is to explore the pattern of urban growth and its social, economic, and environmental impacts at the municipal level. This study examines the spatiotemporal pattern of urban growth in Sandhikharka Municipality, Arghakhanchi District of Nepal, from 2000 to 2019. Urban expansion is readily apparent in nearly every urban center, including Sandhikharka. As one type of land use expands, it inevitably leads to a reduction in another. If forests, grasslands, and other wooded areas diminish due to urban growth, the adverse impact on the environment becomes evident. Similarly, the reduction of cultivated land to accommodate urban development directly affects food production and sovereignty. Encroaching upon riverbeds for urban expansion exposes the town to increase vulnerability to flooding hazards. Thus, analyzing changes in landcover and urban growth reveals various environmental, social, and economic implications. The methodological approach applied in this study involved analyzing three commonly used indicators: The Urban Spatial Expansion Index, the Urban Expansion Intensity Index, and the Urban Spatial Expansion Rate. Additionally, visual interpretation of land cover maps and graphs of their area was conducted for further analysis. This study found that the annual rate of urban expansion steadily increased from 2000 to 2019. The study revealed a consistent increase in forest cover whereas

cropland cover significantly decreased. Most notably, the riverbed and cultivated land were predominately converted into built-up areas, whereas grassland, other wooded land, and cultivated land were changed into forest cover. This suggests that the urban expansion of Sandhikharka does not directly impact on landscape degradation and reflects effective community forestry governance, legal protection mechanisms. However, there is a serious concern regarding the increased risk of flooding and the adverse effects on food yield and, consequently, food sovereignty.

Keywords: *urbanization, spatiotemporal dynamics, urban expansion, landcover change*

Introduction

Urbanization is the transition from traditional rural living to modern urban environments (Ojiako *et al.*, 2023). It transforms the relationships among social and cultural variables like demography, economy, politics, and ideology (Love, 2021). In the nineteenth century, only 15% of the world's population lived in cities, but this increased significantly in the twentieth century, with projections that by 2050, 64% of people in developing countries and 86% in industrialized countries will be urbanized (Humbal *et al.*, 2023). Understanding the effects of urbanization and creating sustainable planning strategies require a thorough analysis of urban growth patterns at various spatial and temporal levels (Subasinghe *et al.*, 2016). There is no universally accepted definition of what constitutes urban (Bhattarai *et al.*, 2023). Different countries adapt various demographic, spatial and economic criteria to define urban areas (Roggema, 2020). The areas that meet the specified criteria are defined as urban areas (Dijkstra *et al.*, 2021). The number of urban centers in Nepal increased from 58 in 2013 to 293 in 2017 (Sapkota, 2022). This transition from a predominantly rural to an emerging urban economy has been possible with governmental decisions that merged rural administrative units and designated them as municipalities, which are considered urban units in Nepal's administrative structure (Joshi, 2023). Rural-to-urban migration is another significant factor driving urban growth in Nepal. However, this rapid urbanization has led to unplanned land use, the shrinking of open spaces, haphazard construction, and inadequate services, which have become prominent urban features across Nepal, mirroring the growth patterns of many urban centers worldwide (Timsina *et al.*, 2020). To effectively plan landscape and urban development, it is crucial to understand the spatiotemporal dynamics of urban growth (Bulti & Anteneh, 2023). Understanding this dynamic and its linkage with other land use changes together with their implications is a complex phenomenon. The objective of this study was to examine the spatiotemporal pattern of urban growth and its social, economic, and environmental impacts at Sandhikharka Municipality of Nepal analyzing a series of landcover data spanning from 2000 to 2019.

There are various approaches in practice for exploring this dynamic. Among various available methodology for spatiotemporal analysis, the three commonly used methods namely the urban spatial expansion index (USEI) (Bulti & Eshete, 2023), The urban expansion intensity index (UEII) (Indrawati *et al.*, 2020) and the urban spatial expansion rate (USER) (Bulti & Eshete, 2023) were used for the analysis. The visual interpretation of the landcover maps (Shreeve, 1980) and graphs for analyzing the spatial and temporal patterns of changes was also executed.

Based on the urban expansion studies in the previous literature, urban expansion causes damage to land covers such as agricultural land, wetland, vegetation, and forest (Nasar-U-minallah *et al.*, 2021). Contrary to common findings, this study revealed that the urban expansion of Sandhikharka did not significantly damage the forest cover, suggesting no direct impact on environmental issues (Guan *et al.*, 2023). However, the expansion of urban built-up areas affected cropland cover in the municipality, leading to a reduction in food production and adverse impacts on food security (Xie *et al.*, 2020). The encroachment upon the riverbed for urban expansion signals a flood-prone pattern of urban growth (Rijal *et al.*, 2018). In the current study, the urban expansion patterns of Sandhikharka city were determined using multi-temporal landcover data from the period between 2000 to 2019. Further, the temporal pattern of urban land changes was examined across four-time intervals (2000–2005, 2005–2010, 2010–2015 and 2015–2019). The results of this study showed that the rates of urban expansion in Sandhikharka municipality varied between 2000 and 2019, with a notable acceleration in urbanization during the period between 2015–2019. The significant increase in urbanization between 2015 and 2019 can be attributed to three main reasons. First, the 2015 Gorkha earthquake caused many people to migrate from rural to urban areas for safer living conditions. Second, the 2015 Constitution of Nepal gave local governments more autonomy and responsibilities, prompting rural people to move to urban centers for better opportunities. Third, many people are using remittance money to buy land and build homes in Sandhikharka, as Arghakhanchi receives substantial remittances, with about 45,000 youths working abroad in countries like India, Qatar, Malaysia, Saudi Arabia, and the UAE (Acharya, 2023).

Materials and Methods

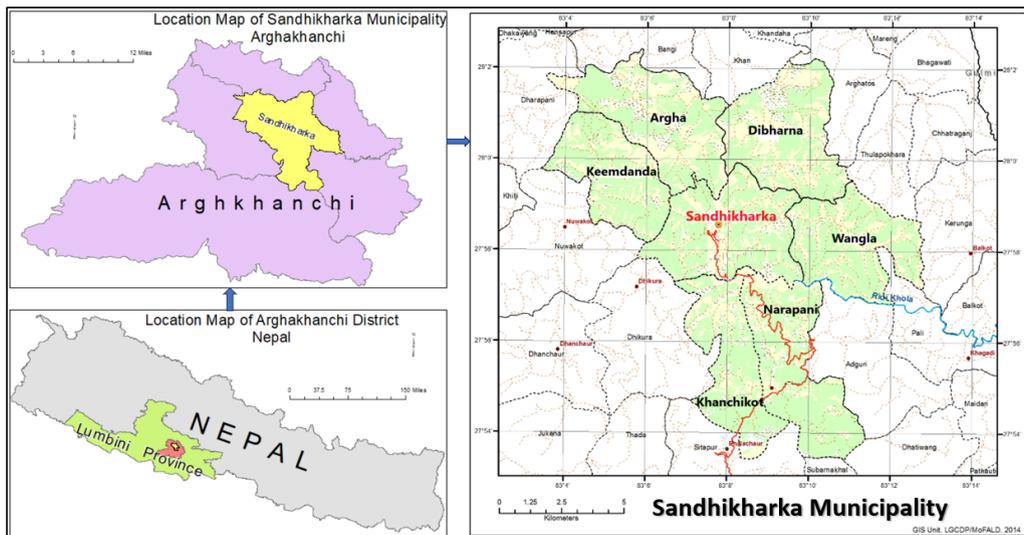
Study Area

Sandhikharka is the administrative headquarters of Arghakhanchi district in Lumbini Province, Nepal (Poudel *et al.*, 2021). It became a municipality in 2014 and is a rapidly urbanizing hilly town situated in a valley formed by three rivers. Located at an elevation of approximately 960 meters, it lies between the Argha and Khanchi hills, which give the district its name. The Bangi, Ghoche, and Bhadri rivers converge at

Chutrabeshi within Sandhikharka, and are sometimes collectively called Tribeni. The fertile soil and geographic features, including the nourishing rivers, contribute to the area's agricultural prosperity. Sandhikharka has a population of 41,917 (NSO, 2023) and covers an area of 129.42 km². It comprises six former Village Development Committees that were amalgamated with the then Sandhikharka Municipality to form a new unified administrative entity, namely Sandhikharka Municipality, as illustrated in Figure 1. This town is also the researcher's birthplace. These are the reasons why Sandhikharka was selected as the study area.

Figure 1

Study Area (Sandhikharka Municipality)



Spatial Data Acquisition and Preparation

The annual landcover data of 30m × 30m resolution was accessed from the Regional Database System (RDS) portal, developed by the International Centre for Integrated Mountain Development (ICIMOD, 2019). This temporal land use/land cover data (2000–2019) was developed using a harmonized and consistent classification system to support the assessment and monitoring of landcover change in the country and to serve as a key dataset in various thematic applications. This annual landcover data set of Nepal has been created through the National Landcover Monitoring System (NLCMS) for Nepal. The system utilizes openly accessible remote sensing data (Landsat) and a cloud-based machine learning structure within the Google Earth Engine (GEE) platform

to produce annual land cover maps. These maps are generated using a standardized and coherent classification system (ICIMOD, 2022).

Land cover data for Nepal from the years 2000, 2005, 2010, 2015, and 2019 was downloaded from the RDS in GeoTIFF format with Geographic Coordinate System-World Geodetic System 1984 (GCS WGS 1984) coordinate systems. This dataset includes eleven land cover classes: Forest, Other Wooded Land (OWL), Grassland, Cropland, Built-up Area, Water Body, Riverbed, Bare Soil, Bare Rock, Snow, and Glacier.

The freely available administrative boundary data was accessed and downloaded from the National Spatial Data Center (Geoportal) of the Survey Department in shapefile format (.shp) with the GCS WGS 1984 coordinate system. The administrative boundary layer contains Local Government (Urban Municipalities and Rural Municipalities) administrative boundaries according to the new structure of Nepal (Survey Department, 2024) The Sandhikharka municipality was selected and exported as a separate polygon shapefile of the municipality boundary.

Being both data in the same coordinate system, the land cover raster data of the years 2000, 2005, 2010, 2015 and 2019 were clipped with the municipality boundary to get the small subset of the landcover data within the municipality by making a model for batch processing using clip tool of data management toolbox using ArcGIS software.

The landcover data was then projected to the UTM Projection system to get the area of each land cover in an understandable unit (meter square) with WGS 1984 UTM Zone 44N because the location of Sandhikharka municipality lies around 83°14'48"E longitude and UTM 44N zone covers 78°E to 84°E(Carnes, 2011). The projection was performed by making a model for batch processing using project raster tool of data management toolbox rather than doing one by one processing.

The area of all landcovers of all the datasets was calculated by adding 'Area' field to all the attribute tables of the corresponding landcover classified data and using field calculator ($\text{Area} = \text{Count} * \text{grid size squared}$). As a result, both attribute information and spatial information of the landcover classes for all five years (2000, 2005, 2010, 2015 and 2019) were obtained.

Research Methods

Selecting methodologies for analyzing the spatiotemporal expansion of built-up areas is a complex task, influenced by various factors such as data availability, study area characteristics, and research objectives. This complexity poses challenges for

researchers and practitioners in making well-informed decisions (Bulti & Anteneh, 2023). It underscores the importance of having comprehensive information about the available approaches, their strengths, limitations, and applicability to different contexts. Such knowledge is crucial for selecting the most suitable methodology that aligns with the research goals and ensures the robustness of the analysis results.

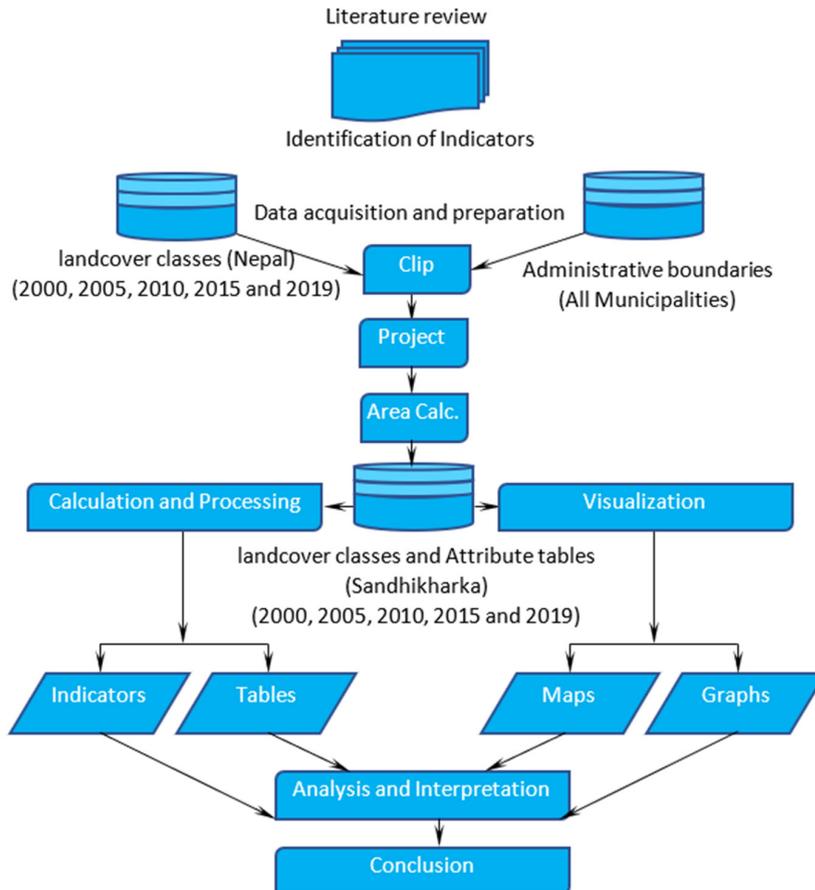
In this study, a comprehensive literature review was conducted and various methodologies for analyzing the spatiotemporal patterns of urban growth were considered. The landscape expansion index (LEI) can be used to identify types of landscape expansion by describing the process of landscape pattern changes across two or more points in time (Liu *et al.*, 2010). Growth indices such as the Average Annual Urban Expansion Rate (AUER), Urban Growth Coefficient (UGC), Expansion Intensity Index (UEII), and Urban Expansion Differentiation Index (UEDII) can be utilized to quantify the rate, intensity, and patterns of urban expansion across the study area throughout the study period (Akubia & Bruns, 2019). Fractal dimension measures provide an alternative approach for studying urban expansion dynamics and serve as effective tools for globally comparing urban morphology (Lu *et al.*, 2014). As a key indicator in urbanization, the Urban Spatial Expansion Index (USEI) captures the extent of growth and spatial transformation in urban built-up areas, quantifying changes in urban land cover over time (Zhang *et al.*, 2023). The Urban Expansion Intensity Index (UEII) can quantitatively assess variations in urban spatial expansion, helping identify urban growth preferences and compare the speed or intensity of urban land use changes over a specific period (Manesha *et al.*, 2021). The Urban Spatial Expansion Rate (USER) is a metric that quantifies the rate at which urban areas expand over a given time period. It measures the percentage increase in urban land cover within a specific region, allowing researchers and planners to understand how quickly urbanization is occurring (Digafe *et al.*, 2023). This rate is essential for monitoring urban growth, assessing the impact of land use changes, and planning sustainable urban development (M. Liu *et al.*, 2016). Among these, three commonly used methods were selected as indicators of urban expansion: The Urban Spatial Expansion Index (USEI), the Urban Expansion Intensity Index (UEII), and the Urban Spatial Expansion Rate (USER). These methods were chosen for their effectiveness in capturing different aspects of urban expansion dynamics.

Additionally, visual interpretation of land cover maps and graphs was conducted to complement the quantitative analysis, despite its limitations for further analysis (Karsidi, 2004). This process involved a detailed examination of the maps and graphs to identify and interpret changes in land cover types over time. This visual analysis provided invaluable insights into how the urban area of Sandhikharka Municipality has expanded and changed over the study period.

To guide the overall workflow of this study, a methodological diagram is presented in Figure 2. This diagram likely outlines the step-by-step process followed in this research study, including identification of indicator, data collection, analysis, and interpretation.

Figure 2

Workflow Diagram of the Study



Indicators of Urban Expansion Analysis

Early research on urban expansion in the mid-20th century focused on descriptive approaches to understanding city growth, with studies examining the physical extent of cities and factors like population density (Burgess, 1925). In the 1970s and 1980s, advances in remote sensing and Geographic Information Systems (GIS) transformed urban expansion analysis, enabling more precise mapping and monitoring of urban sprawl. The

use of satellite imagery allowed researchers to study urban expansion quantitatively and track changes in land cover over time (Sun *et al.*, 2020). The 1990s saw the development of spatial metrics and indices, such as the Fractal Dimension Index (FDI), Urban Growth Coefficient (UGC), and Urban Spatial Expansion Index (USEI), which provided standardized tools for evaluating and comparing urban morphology and growth patterns (Batty & Longley, 1994). In the 21st century, researchers have increasingly focused on urban expansion's environmental and social impacts, using indices like the Urban Expansion Intensity Index (UEII) and Urban Spatial Expansion Rate (USER) to examine urbanization intensity, sustainability, and resilience (He *et al.*, 2014). This research utilized three indicators: the Urban Spatial Expansion Index (USEI), the Urban Expansion Intensity Index (UEII), and the Urban Spatial Expansion Rate (USER).

Urban Spatial Expansion Index

The Urban Spatial Expansion Index (USEI) is a metric used to evaluate urban area expansion by measuring the spatial growth and changes in urban land-use categories, reflecting the extent of growth and transformation in urban built-up areas as a key aspect of urbanization (Zhang *et al.*, 2023). It quantifies the extent of urban expansion per unit of time over the study period, using a linear change model. The USEI for a particular urban area is calculated using Equation (1). When the time unit is set to a year, it represents the annual change in built-up areas, Figure 3 (a).

$$USEI = \frac{A_{t_1} - A_{t_0}}{\Delta t} \quad (1)$$

Where, A_{t_0} and A_{t_1} denote areas of built-up land at a time t_0 and t_1 , respectively, and Δt is the length of time from the time t_0 to t_1 . When Δt is in a unit of the year, then USEI is the annual average expansion of built-up area over the study period (Bulti & Anteneh, 2023).

Urban Expansion Intensity Index

The Urban Expansion Intensity Index (UEII) can be used to quantitatively assess differences in urban spatial expansion, recognize urban growth preferences, and compare the speed or intensity of urban land use changes over a specific period (Manesha *et al.*, 2021). UEII is determined using Equation (2), where a higher value indicates rapid urban expansion (Bulti & Anteneh, 2023).

$$UEII = \frac{\Delta A_{\Delta t}}{A_L} \times \frac{1}{\Delta t} \quad (2)$$

In the provided context, UEII is used to quantify the intensity of change over a specific time interval (e.g., $t_1 - t_0$). It measures the area of land that transitions from non-built-up to built-up during this interval ($\Delta A_{\Delta t}$), relative to the total area of the landscape (A_L) and

the time span of the interval (Δt). By normalizing the mean annual expansion based on the total land area, UEII enables comparison of results across different time periods. It can also help identify patterns in urban growth preferences and compare the speed or intensity of land use changes in a specific urban area over time. Comparing the annual urban expansion intensity of different spatial units allows for the quantitative comparison of urban expansion characteristics across various study periods(Liu *et al.*, 2016).

Urban Spatial Expansion Rate

The Urban Spatial Expansion Rate (USER), also known as the Urban Spatial Growth Rate (USGR), is a metric that indicates the pace of urban development and the evolving spatial structure of a specific urban area over time. Understanding the rate of change in land use is essential for grasping the conversion process linked with urban expansion and development (Wang *et al.*, 2023). USER is based on the premise that urban growth conforms to an exponential pattern, akin to the annual rate of compound interest. Equation (3) below is used to compute the USGR, Figure 3 (b).

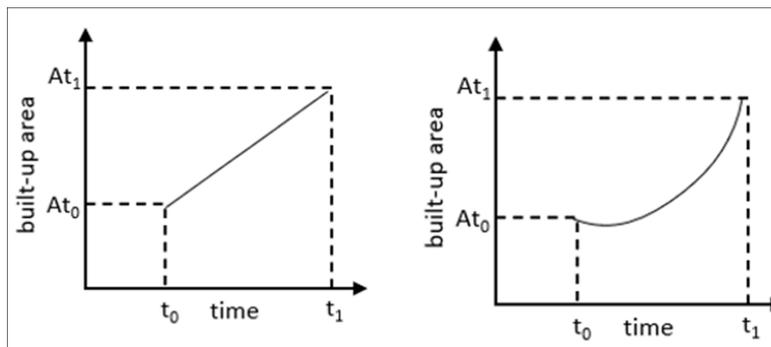
$$USER = \left(\frac{A_{t_1}}{A_{t_0}} \right)^{\frac{1}{\Delta t}} - 1 \quad (3)$$

In the equation, A_{t_0} and A_{t_1} denote of built-up areas at a time t_0 (initial) and t_1 (final), respectively, and Δt is the time elapsed between t_0 and t_1 . When Δt is measured in years, USER gives the annual rate of change in the spatial extent of built-up land. By standardizing urban expansion, USER eliminates size effects, making it easier to compare urban growth across different spatial zones and years, as well as among different cities (Bulti & Anteneh, 2023).

Figure 3 (a)

Graph of USEI

(b) Grsph of USER



Source: Bulti & Anteneh, 2023

Results and Discussion

Identification of Urban Expansion Indicators

As discussed, urban expansion analysis utilizes a variety of indicators to assess the rate, intensity, and spatial patterns of urban growth, aiding planners and researchers in understanding the impacts of urbanization on land use, the environment, and socioeconomic factors. This research applied three such indicators: the Urban Spatial Expansion Index (USEI), used by Zhang *et al.* (2023) to track urban growth and its impact on surrounding land uses in cities within the Yellow River Basin; the Urban Expansion Intensity Index (UEII), employed by Manesha *et al.* (2021) to identify regions experiencing accelerated urban expansion in a Sri Lanka case study; and the Urban Spatial Expansion Rate (USER), utilized by Wang *et al.* (2023) to analyze urban growth in Chengdu, western China, where significant increases in urban land were observed.

Spatial Analysis Outputs

Land Cover Types

The land cover classification for Nepal and its corresponding Intergovernmental Panel on Climate Change (IPCC) categories are as follows (FRTC, 2022).

Nepal	Forest	OWL	Grassland	Cropland	Built-up area	Water body	Riverbed	Bare soil	Bare rock	Snow	Glacier
IPCC	Forest	Forest	Grassland	Cropland	Settlements	Water body	Water body	Other	Other	Other	Other

However, only six of the eleven land cover types, as shown in Table 1, are present within the study area. From the spatial analysis outputs, the areas of different landcover classes were found to be as shown in Table 1.

Table 1

Distribution of Land Use / Land Cover in Different Years (area in m²)

Land cover	2000	2005	2010	2015	2019
Forest	61638609	66619918	66712064	69612691	71922353
Riverbed	18125	17337	15761	15761	16549
Built-up	154453	166274	227740	279748	654851
Cultivation	62148587	59773289	58782792	54893982	53260442
Grassland	3809330	1874715	2350685	2269518	1931455
Other Wooded Land	1230897	548467	910959	1928300	1214351
Total	129000000	129000000	129000000	129000000	129000000

Source: Calculated based on National Landcover Monitoring System (NLCMS) for Nepal's annual landcover data of 30m × 30m resolution accessed from the Regional Database System (RDS) portal, developed by the International Centre for Integrated Mountain Development (ICIMOD, 2019).

Urban Expansion Indicators

Based on the built-up area in 2000, 2005, 2010, 2015, and 2019, the indicators—the Urban Spatial Expansion Index (USEI), the Urban Expansion Intensity Index (UEII), and the Urban Spatial Expansion Rate (USER)—were calculated for the four intervals: 2000–2005, 2005–2010, 2010–2015, and 2015–2019, using equations (1), (2), and (3). The results of these calculations are presented in Table 2 below.

Table 2

Urban Expansion Indicators

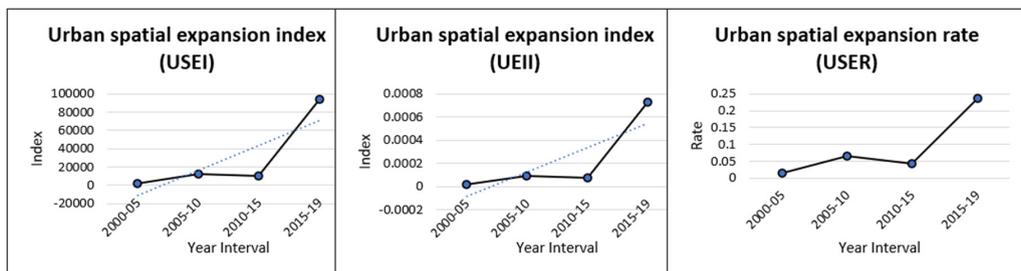
Urban spatial expansion index (USEI)			
2000-05	2005-10	2010-15	2015-19
2364.108538	12293.22797	10401.69532	93775.5985
Urban spatial expansion index (UEII)			
2000-05	2005-10	2010-15	2015-19
1.83263×10^{-05}	9.53×10^{-05}	8.06×10^{-05}	0.000727
Urban spatial expansion rate (USER)			
2000-05	2005-10	2010-15	2015-19
0.014858	0.064935	0.041995	0.236926

Source: Calculated on the basis of Table 1

The analysis of the indicators reveals a clear trend in the rate of urban expansion in Sandhikharka Municipality from 2000 to 2019 (Figure 4). The data indicates a consistent increase in the rate of expansion per year over this period. Specifically, the rate of urban expansion reached its highest point between 2015 and 2019, indicating a period of rapid growth in the urban area. Conversely, the expansion rate was at its lowest between 2000 and 2005, suggesting a slower pace of urban development during this time frame.

Figure 4

Urban Expansion Dynamics by Indicators

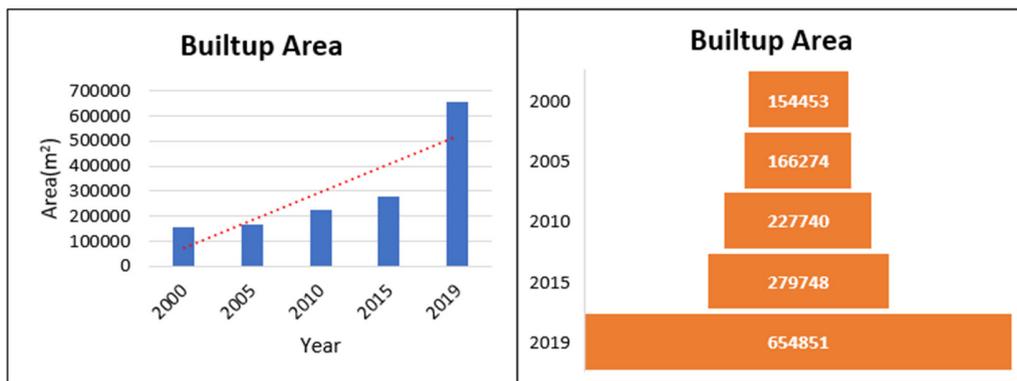


Despite the overall increasing trend, there are some notable fluctuations in the annual expansion rates. For instance, there was a slight decrease in the rate of urban growth between 2010 and 2015 compared to the period between 2005 and 2010. These variations in expansion rates could be attributed to a variety of factors, including social, physical, political, and economic factors.

Various factors may contribute to these variations, including migration patterns driven by infrastructure development initiatives, which act as a pull factor for rural-to-urban migration. A recent study on in-migration to Ratnanagar Municipality, Chitwan, found that 16% of migrants were attracted by access to higher education, 20% by urban amenities, and 30% by better job and business opportunities (Dhakal, 2022). Major happenings, such as the 2015 earthquake, also play a role; a working paper published by Himalayan Adaptation, Water, and Resilience (HI-AWARE) shortly after the disaster indicated that the Gorkha earthquake prompted both internal and external migration, impacting the migrant population in numerous ways (Maharjan *et al.*, 2015). Additionally, political developments—such as the Maoist insurgency, the promulgation of the new constitution, and the nation’s shift from a unitary to a federal structure—may have influenced urban expansion patterns. However, these factors were not analyzed in detail in this study, suggesting potential areas for further research from this perspective.

Figure 5

Built-up Cover in Square Meter Trend and Comparison



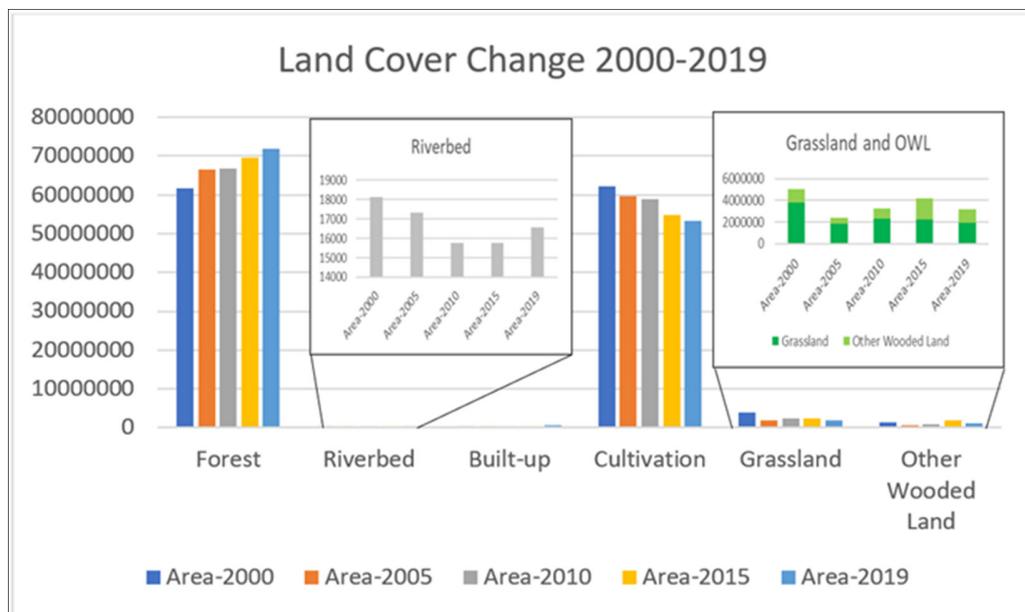
The trends in urban built-up coverage in Sandhikharka Municipality can be visually interpreted from graphs representing the years 2000, 2005, 2010, 2015, and 2019 (Figure 5). These graphs typically illustrate a consistent increase in built-up coverage over the years, with a more pronounced rise in the period from 2015 to 2019 compared to earlier years. This pattern suggests a period of rapid urban expansion in the municipality.

Additionally, there may be noticeable differences in the rate of increase between the periods 2000-2005, 2005-2010, and 2010-2015 (Figure 6). These differences reflect the variations in annual expansion rates previously discussed, indicating periods of faster or slower urban growth within the overall trend of increasing built-up coverage. These findings also affirm with the previous studies carried out by researchers in this field and substantiate with the fact that Nepal ranks among the top ten fastest urbanizing countries globally, with initially slow urban growth accelerating sharply post-2014/15, resulting in a dramatic and largely unplanned increase in urbanization, raising the urban population from 27% in 2014 to over 2.5 times by 2021 (Joshi, 2023) as urban expansion results from growing urban populations because increasing settlements require more land (Angel, 2023).

These visual representations provide a clear depiction of how urbanization has evolved in Sandhikharka Municipality over the study period, highlighting the municipality's changing landscape and the dynamics of its urban growth.

Figure 6

Trend of Landcover Change



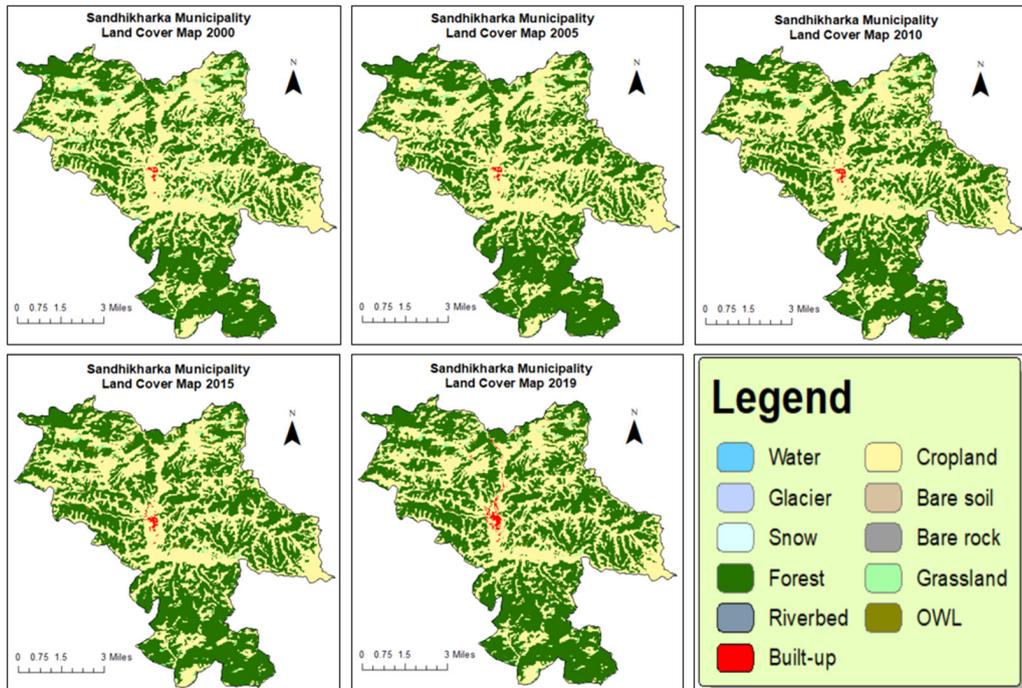
Furthermore, analyzing the overall land cover change from the graphs would reveal that only the forest cover and built-up cover are consistently increasing, while the other land

cover types show a decreasing trend, although with fluctuations in different periods. This indicates a clear shift in land use dynamics, with urbanization and reduction of the cultivated land being the dominant trends driving land cover changes in Sandhikharka Municipality over the study period.

This indicates a significant shift in land use patterns, with agricultural and other landcovers being converted to built-up areas and forests, and other landcover types such as riverbed other wooded land or grasslands decreasing over time.

Figure 7

Spatial Pattern of Landcover at Different Years



Although a detailed quantitative analysis of land cover change was beyond the scope of this study, visual interpretation of land cover maps suggests a notable transformation: agricultural land and riverbeds have been converted to built-up areas, while agricultural land, grasslands, and other wooded land have shifted to forest cover. This indicates a dynamic shift in land use patterns, with some areas undergoing urbanization and others reverting to forested landscapes. Figure 7 illustrates these spatial land cover patterns

over different years; built-up areas in 2000 and 2005 were largely confined to the core town and its immediate periphery, while expansion gradually spread along riverbanks in 2010 and 2015 and surged along the riverbanks by 2019 together with the peripheral expansion.

Conclusions

This study on exploring spatio-temporal dynamics of urban expansion in Sandhikharka Municipality utilized land cover data from ICIMOD, analyzing urban expansion indicators and interpreting graphs and maps of land cover changes at various time points throughout the study period. Based on the analysis conducted, following conclusions can be drawn regarding the spatiotemporal pattern of urban growth in Sandhikharka Municipality from 2000 to 2019:

The rate of urban expansion per year has shown a consistent increasing trend over the study period, with the expansion rate peaking between 2015 and 2019. This indicates a rapid pace of urbanization in the municipality.

While the overall trend shows an increase, there are variations in expansion rates over shorter periods. For example, the expansion rate was at its lowest between 2000 and 2005 and showed a slight decrease between 2010 and 2015 compared to the period between 2005 and 2010. These variations could be attributed to various factors such as migration, infrastructure development, natural disasters like the 2015 earthquake, and socio-political changes like the promulgation of the constitution and restructuring of the nation to a federal structure.

Contrary to common findings, this study reveals that the urban expansion of Sandhikharka has not harmed the forest cover, suggesting a selective land conversion process rather than generalized landscape degradation. This indicates that urban growth is being spatially directed toward more accessible, low-slope, and privately owned agricultural parcels and marginal riverine areas, which are economically easier to convert compared to regulated or community-managed forest lands. The stability of forest cover may reflect effective community forestry governance, legal protection mechanisms, or the topographic constraint of forested hill slopes that are less suitable for urban construction. Scientifically, this pattern implies a transition from agrarian land use to built-up dominance without immediate forest encroachment, representing a structural shift in peri-urban land systems. However, the decline in agricultural and riverbed areas raises concerns about food security, hydrological balance, and increased

flood vulnerability, indicating that environmental pressure is being redistributed rather than reduced.

The findings emphasize the crucial need for sustainable planning approaches to manage urban growth and mitigate its impacts on urban resilience, the environment, disaster risk, and natural resource optimization. Understanding the dynamics of urban expansion is essential for developing effective policies and strategies to ensure the sustainable development of Sandhikharka Municipality.

While this study provides valuable insights, further research is needed to understand the specific drivers of urban expansion and their impacts in greater detail. This could involve a more in-depth analysis of the socio-economic, political, and environmental factors influencing land use change in the municipality.

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