

Land Use Land Cover Change Dynamics in Urban Watersheds of Butwal Sub-Metropolitan City in Western Nepal

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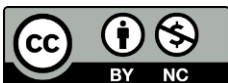
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ABSTRACT

Land use and land cover (LULC) change is an important indicator of the environmental and socio-economic impacts of rapid urbanization. This study analyzes LULC dynamics in Butwal Sub-Metropolitan City, Nepal, between 2003 and 2017 and examines the factors associated with these changes and their potential environmental and watershed implications. A remote sensing and GIS based approach was employed for assessing LULC changes and land-use transition pathways, using Landsat satellite imagery and spatial analysis. The results showed significant land-use change over the 2003–2017 study period. The built-up area increased by 97.4%, largely replacing agricultural land, which declined by 14.79%. Forest cover slightly increased by 1.84%, while sand areas decreased by 68.67% and water bodies increased by 35.77%. The spatial patterns observed, combined with the demographic data, distribution of infrastructure, and secondary information, indicate that population growth, urban sprawl, and infrastructure development were among the most important factors contributing to the observed LULC change. The findings highlight the need for sustainable land-use policies, green infrastructure, and improved urban planning to ensure environmentally sustainable urban development in Butwal.

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1. INTRODUCTION

Land use and land cover (LULC) change is one of the most important indicators of environmental change and urban expansion. In many parts of the world, urban expansion has drastically altered natural and agricultural landscapes into built up

urban areas, causing significant environmental, hydrological and socio-economic consequences [1]. Emerging urban areas in developing countries like Nepal are undergoing rapid land transformation led by infrastructure investment, human migration and economic diversification [2].

Land use change in urban watersheds is particularly sensitive because conversion of vegetation and agricultural land can change surface runoff, groundwater recharge, and flood susceptibility [3]. Impervious surface coverage continues to exacerbate ecological imbalance, underscoring the need for understanding of LULC dynamics, hydrology and urban development interaction [4].

Butwal Sub-Metropolitan City has undergone rapid urbanization in the past 20 years resulting from changes at its boundary level, driven by population growth (both due to natural population growth and rural-urban migration), infrastructure development (such as transportation roads) and growing commercial activities [5]. Served by the Siddhartha and Mahendra Highways as a major economic corridor, the city has experienced widespread transformation of agricultural lands, sandy areas, and forest margins into built-up areas, exerting severe stress on watershed systems and environmental sustainability land [6].

This study combines LULC transition pathway analysis and watershed-based environmental change assessment in a fast-growing Himalayan city, highlighting a method that goes beyond previous studies on LULC changes and urban growth in Nepal. The study concept is not new, but it points at the implications of certain pathways of land conversion for the sustainability of the watershed, hydrological processes, and risks for the urban environment, in particular for the pathway of agriculture-to-urban and sand-to-urban conversion and for the landscape scale of localized forest fragmentation. Integrating spatial land transformation with watershed implications, this study presents a holistic approach for sustainable urban planning along with watershed management in the case of developing Himalayan cities.

The primary objective of this study is to analyze the dynamics of land use and land cover change in Butwal Sub-Metropolitan City between 2003 and 2017. Specifically, the study aims to assess the extent and spatial patterns of land-use transformation, examine the major factors associated with the observed changes using spatial and secondary evidence and evaluate their environmental and watershed implications using GIS and remote sensing techniques.

2. MATERIALS AND METHODS

2.1. Study Area

Butwal Sub-Metropolitan City is situated in Rupandehi District in the western part of Nepal with an area of about 101.60 km² and located between 27.61°N to 27.74°N latitude and 83.36°E to 83.50°E longitude (Figure 1).

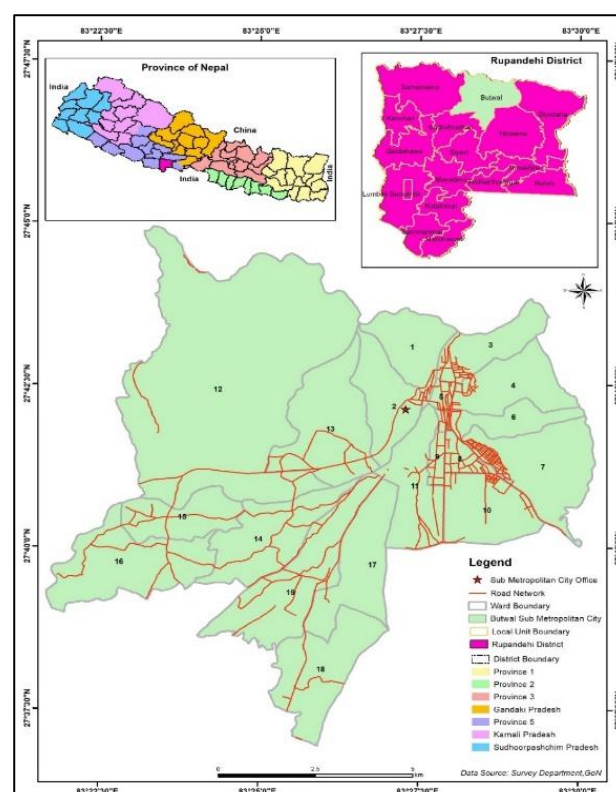


Fig. 1. Map of the Study Area.

From a geographical point of view, the city is located in the Bhabar and Chure physiographic regions, where the settlement, drainage and urban development have been controlled by the river systems of Tinau and Dano. The municipality consists of 19 wards and a population of 138,742 according to the 2011 census (Figure 2). Migration from the nearby hill districts such as Palpa, Arghakhanchi, Gulmi have significantly affected population growth. Being located at the junction of Siddhartha and Mahendra highways, Butwal is a hub for commerce and transportation. The major physical and spatial features of the study area (elevation, physiography, slope, aspect, drainage, road network and settlement distribution) are presented in Figures 3–10 and form the geographical context of the observed land use and land cover changes.

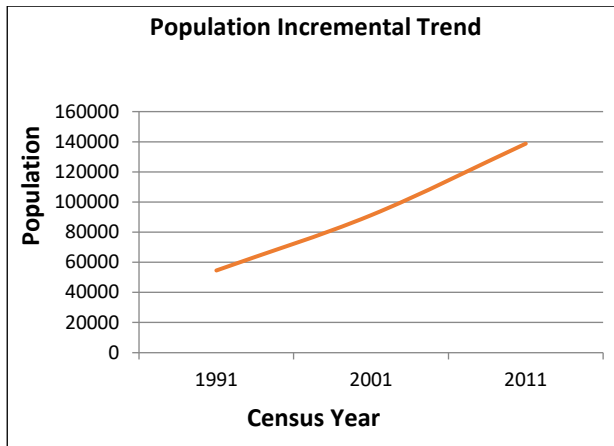


Fig. 2. Population Growth and incremental of households of Butwal Sub Metropolitan City from 1991 to 2011.

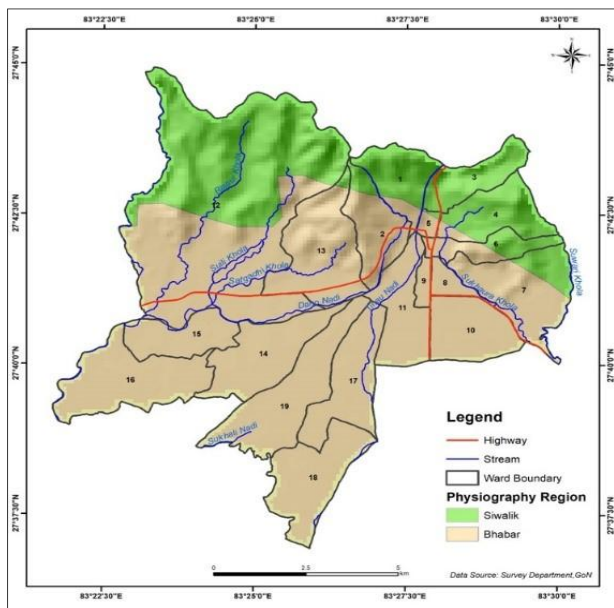


Fig. 3. Physiography distribution.

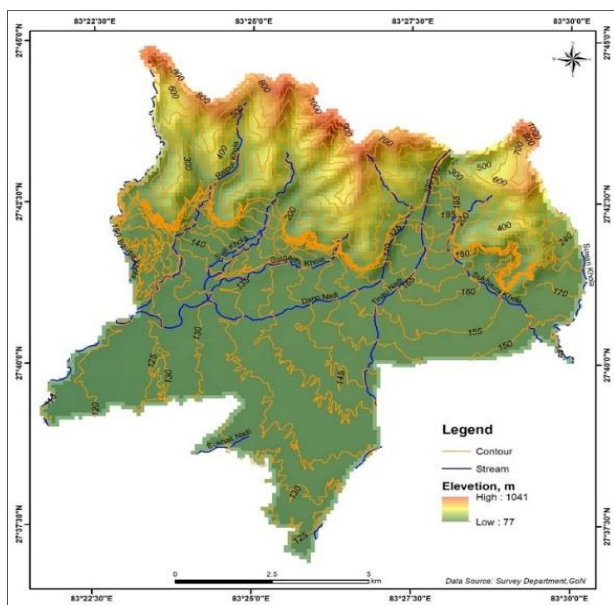


Fig. 4. Digital Elevation Model.

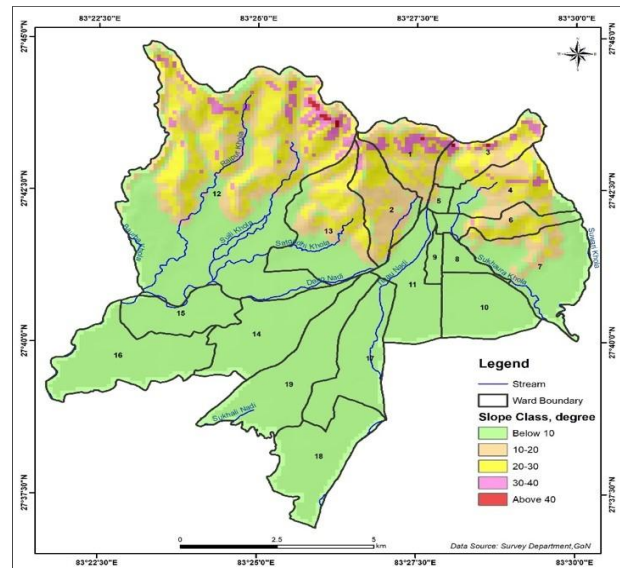


Fig. 5. Elevation Distribution.

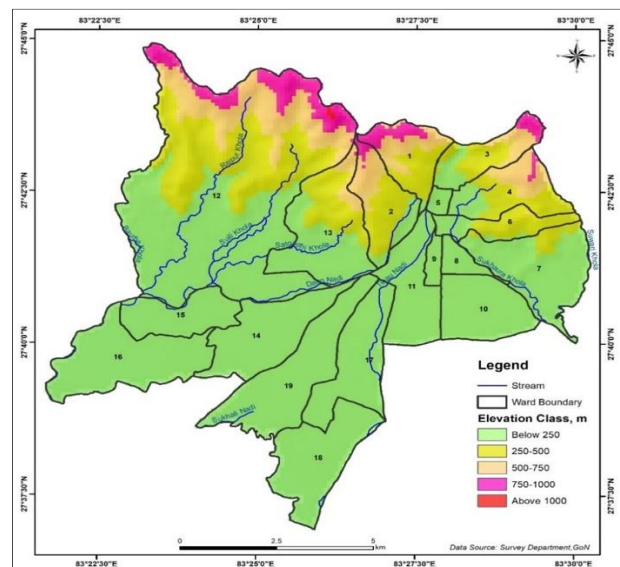


Fig. 6. Slope gradient.

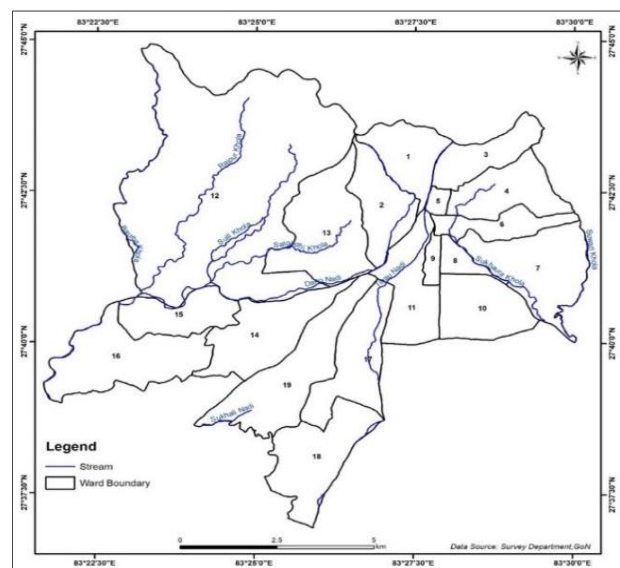


Fig. 7. Drainage network.

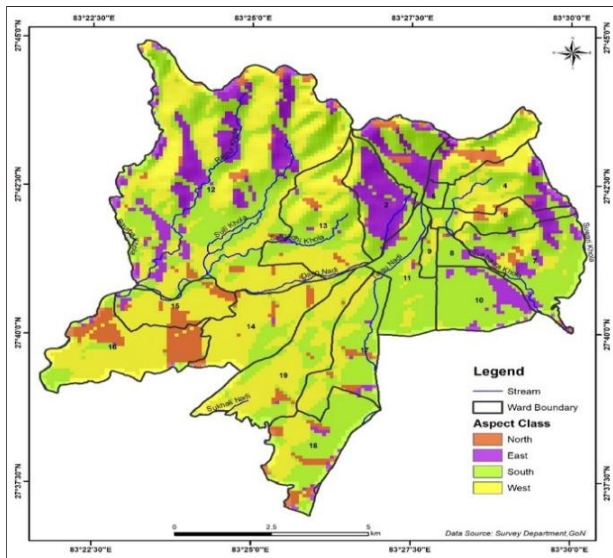


Fig. 8. Aspect map.

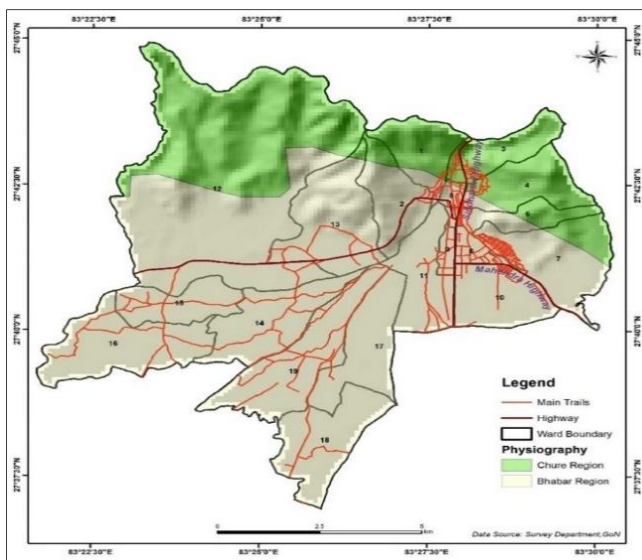


Fig. 9. Road Network

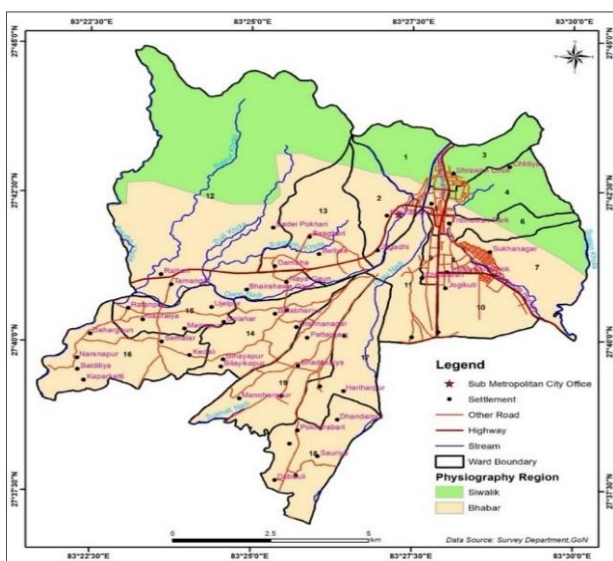


Fig. 10. Settlement distribution

2.2 Research Design and Data Sources

The research design used in this study was remote sensing and GIS based research design used to evaluate the dynamics of LULC in Butwal Sub-Metropolitan City. Landsat satellite data was the main spatial data source for detecting and quantifying LULC changes, and high-resolution Google Earth data was used to aid in land-cover interpretation and to assess land-cover classification accuracy. To interpret the spatial changes, additional sources such as topographic maps, census data, municipal reports and government maps that were relevant to the changes were used to give geographical and socio-demographic context. Spatial processing, supervised classification, change detection, and land-use transition analysis were performed using ArcGIS while tabulation and descriptive calculations were performed using MS Office tools.

Landsat 7 ETM+ (2003) and Landsat 8 OLI (2017) images were used from the USGS Earth Explorer database. The datasets were selected because they provide an appropriate temporal interval for monitoring LULC dynamics and because their spatial resolution is suitable for monitoring land use dynamics in urban environments. Temporal consistency between images was maintained by using images only with similar seasonal conditions and limited cloud cover.

The year 2003 and 2017 were chosen to reflect two important phases of the urban development of Butwal. The 2003–2017 study period captured significant changes according to population growth, infrastructure development and urbanization providing an adequate time span for assessing long-term LULC and urban watershed dynamics. Nevertheless, using just two temporal datasets might not be sufficient in capturing the spectrum of intermediate land-use transitions and short-term changes throughout the study period.

2.3 Image Processing and Land Use Classification

LULC classification was performed using Landsat 7 ETM+ imagery from 2003 and Landsat 8 OLI imagery from 2017 in ArcGIS 10.8, and with the help of high-resolution Google Earth imagery for visual interpretation and reference data development.

Image preprocessing included geometric and radiometric correction, layer stacking, mosaicking, clipping, and image enhancement. All datasets were projected to UTM Zone 44N (WGS 1984) to ensure spatial consistency. A supervised Maximum Likelihood Classification (MLC) algorithm was applied using spectral signatures and Google Earth imagery to classify six land use categories: agriculture, forest, built-up area, barren land, sand area, and water body.

The classified maps were refined through visual interpretation and manual editing. Land use changes and transition pathways between 2003 and 2017 were then quantified using post-classification comparison, spatial statistics, and area calculation techniques in ArcGIS.

2.4 Accuracy Assessment and Validation

The classification accuracy was assessed according to Congalton and Green [7]. For each land-use class, a stratified random sampling approach was used to select independent validation (reference) points, which ensured adequate representation of all land-use classes for the accuracy assessment. A total of 300 independent validation points were used per classified image (2003 and 2017), comprising 50 points for each of the 6 land-use classes: agriculture, forest, built-up area, barren land, sand area, and water body. Validation points

were randomly located within each land-use class and were independent of the training samples used in supervised classification. High-resolution imagery from Google Earth and topographic maps were used to assign a reference land use class to each validation point. These independent reference data were then compared to the corresponding classified land-use categories to develop an error (confusion) matrix.

Producer's accuracy and user's accuracy were determined for each land use class to assess omission and commission error, respectively. Producer's and user's accuracies for each LULC class are presented in Table 1 and demonstrate good classification accuracy for all land-use classes. The overall accuracy and Kappa coefficient were then computed to evaluate the overall reliability of the classified maps. The overall classification accuracy of 2003 land-use map was 85.6% and the Kappa coefficient was 0.82; the overall classification accuracy of 2017 land-use map was 88.3% and the Kappa coefficient was 0.85; indicating a strong agreement between the classified maps and the independent reference data (Table 2). The results show that the accuracy of the classification is acceptable, and the classified maps were considered sufficiently reliable for subsequent LULC change detection and analysis.

Table 1. Classification Accuracy Assessment of Land Use Classification.

Land Use Class	Producer's Accuracy (%)	User's Accuracy (%)
Agriculture	87	84
Forest	90	88
Built-up Area	89	91
Barren Land	80	78
Sand Area	83	81
Water Body	92	94

Table 2. Overall Classification Accuracy and Kappa Coefficient.

Indicator	2003	2017
Overall Accuracy (%)	85.6	88.3
Kappa Coefficient	0.82	0.85

2.5 Error Analysis

The classification provided a satisfactory level of accuracy, but there were several uncertainties caused by spectral similarity for barren land, sand, and built-up area as well as mixed pixels,

shadowing effects, seasonal differences, and the moderate spatial resolution of Landsat imagery. To reduce these errors, local ground truthing and visual interpretation with high-resolution imagery of Google Earth images were used, followed by post-classification adjustment.

However, some small land transformations, such as fine-scale urban features and narrow riverbank settlements may have been missed. The use of only two temporal data sets (2003 and 2017), however, does not provide enough information to describe intermediate land-use change or short-term change within the study period. The use of more detailed images and repeated observations in the future would decrease the uncertainty and give a better understanding of urban-development and watershed changes.

3. RESULTS

3.1 Land Use Pattern and Change between 2003 and 2017

Land use and land cover (LULC) dynamics of Butwal Sub-Metropolitan City (SMC) was analyzed for the period 2003 to 2017, which showed significant spatial changes. The area, percent change and magnitude of change for each land-use category are summarized in Table 3 and the annual rate and intensity of change over the study period are summarized in Table 4. In both 2003 and 2017, the most prevalent LULC category was forest, followed by agricultural land. In 2003, forest covered 51.22 km² (50.41%) of the study area, while

agricultural land occupied 32.93 km² (32.41%). Built-up land accounted for 8.85 km² (8.71%), whereas sand, barren land, and water bodies covered 6.00 km² (5.91%), 1.37 km² (1.35%), and 1.23 km² (1.21%), respectively. The spatial distribution of land use and land cover classes in 2003 is shown in Figure 11.

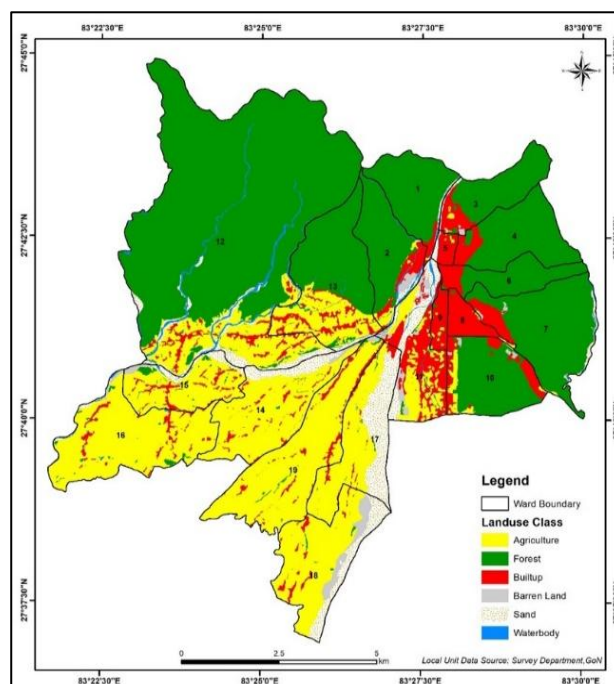


Fig. 11. Land Use Map 2003 of Butwal Sub Metropolitan City.

Table 3. Land Use of Butwal Sub Metropolitan City between 2003 and 2017.

S.N.	Landuse Class	2003		2017		Change	
		Area (Sq.Km)	Area (%)	Area (Sq.Km)	Area (%)	Area (Sq.Km)	Area (%)
1	Agriculture	32.93	32.41	28.06	27.62	(4.87)	(14.79)
2	Barren Land	1.37	1.35	0.36	0.35	(1.01)	(73.72)
3	Built Up	8.85	8.71	17.47	17.19	8.62	97.4
4	Forest	51.22	50.41	52.16	51.34	0.94	1.84
5	Sand	6.00	5.91	1.88	1.85	(4.12)	(68.67)
6	Water body	1.23	1.21	1.67	1.64	0.44	35.77
Total Area		101.60	100.00	101.60	100.00		

Table 4. Annual Rate and Intensity of Land Use Change between 2003 and 2017

Land Use Class	Net Change (Sq. Km)	Percentage Change (%)	Annual Change (Sq. Km/Year)
Agriculture	-4.87	-14.79	-0.35
Barren Land	-1.01	-73.72	-0.07
Built-up	+8.62	+97.40	+0.62
Forest	+0.94	+1.84	+0.07
Sand	-4.12	-68.67	-0.29
Water Body	+0.44	+35.77	+0.03

The 2017 land-use distribution is illustrated in figure 12, which is compared with 2003, and demonstrates an increase in built-up areas and a decrease in agriculture area. By 2017, forest area increased slightly to 52.16 km² (51.34%), whereas agricultural land declined to 28.06 km² (27.62%). The most dramatic increase was for the built-up area at 17.47 km² (17.19%), growing by 8.62 km² (97.4%) over the period of the study. Sand area declined substantially from 6.00 km² to 1.88 km² (68.67%), while barren land decreased from 1.37 km² to 0.36 km². The water bodies, however, have grown from 1.23 km² to 1.67 km², primarily driven by changes at the local level in the urban watershed.

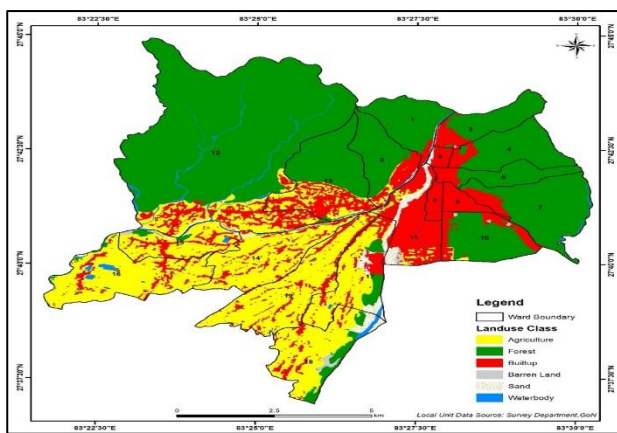


Fig. 12. Land Use Map of 2017 of Butwal Sub Metropolitan City.

3.2 Pathway of Land Use Change

Table 5 presents, the land use transition matrix illustrating the major pathways of land conversion within the study area between 2003 and 2017. The dominant land transformation pathway was the conversion of agricultural land into built-up area. Approximately 6.20 sq. km of agricultural land was converted into built-up surfaces, indicating extensive urban encroachment into productive agricultural zones.

The second major transition pathway involved the conversion of sand area into forest, agriculture, and built-up area. About 1.37 sq. km of sand area changed into forest, while 1.29 sq. km was transformed into built-up area. These transitions were primarily concentrated along riverbank and floodplain areas.

Forest conversion into built-up area was comparatively lower, accounting for 0.57 sq. km. However, localized forest transformation was observed in settlement expansion zones and road-accessible areas. Some reciprocal land conversions were also observed, including forest to agriculture, water body to agriculture, and barren land to built-up area.

Table 5. Land Use Change Matrix between 2003 and 2017 of Butwal Sub Metropolitan City.

Land Use Class	Land Use Change Matrix						Total Area 2003 (Sq.Km)
	Agriculture	Forest	Built-up	Barren Land	Sand	Water body	
Agriculture	25.8	0.43	6.20	0.09	0.05	0.36	32.93
Forest	0.63	49.64	0.57	0.04	0.02	0.32	51.22
Built-up	0.00	0.00	8.80	0.00	0	0.05	8.85
Barren Land	0.23	0.37	0.48	0.17	0.11	0.01	1.37
Sand	1.21	1.37	1.29	0.06	1.56	0.51	6.00
Water body	0.19	0.35	0.13	0.004	0.14	0.42	1.23
Total Area 2017 (Sq.Km)	28.06	52.16	17.47	0.36	1.88	1.67	101.60

The transition matrix indicates that built-up area experienced continuous expansion mainly through the transformation of agricultural land and sand area. In contrast, agricultural land, sand area, and barren land experienced net reduction over the study period.

The transition matrix shows that urban growth was mainly due to agricultural land. Approximately 6.20 sq. km of agricultural land was transformed into built-up area which was responsible for 71.9% of

total built-up growth during the study period. The sand area added 1.29 sq. km (15.0%) whereas barren land contributed 0.48 sq. km (5.6%). All three land categories combined accounted for more than 92% of total urban expansion. This result shows that urban growth in Butwal has been mainly driven by the loss of productive food-producing land and riverbank environments indicating increasing pressure both on landscape areas that agricultural production, as well as watershed resources.

3.3 Changes in Agriculture Land

The net loss in agricultural land from 2003 to 2017 was 4.87 km². The major pathways of agricultural land conversion are summarized in Table 6, and the spatial distribution of agricultural land change is displayed in Figure 13. Agricultural land experienced the largest conversion (6.20 km²) and most of this land was converted along the Mahendra Highway in Wards 11, 12 and 13. Relatively smaller conversion of agricultural land to forest, water bodies, barren land and sand areas took place in addition. Some other areas, however, that were considered as sand, forest, water bodies or barren land were converted to agricultural land, accounting for 2.26 km².

Table 6. Changes of Agriculture Land between 2003 and 2017 in Butwal Sub Metropolitan City.

Pathway	Area (Sq.Km)
A to F	0.43
A to B	6.20
A to BL	0.09
A to S	0.05
A to W	0.36
F to A	0.63
BL to A	0.23
S to A	1.21
W to A	0.19
Net Change of Agriculture	(4.87)

(Note: A = Agriculture, B = Built-up, BL = Barren Land, S = Sand, W = Water body, F = Forest)

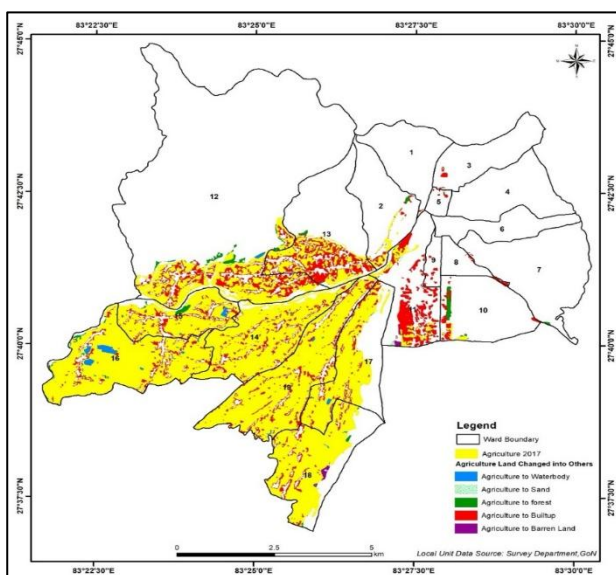


Fig. 13. Pattern of Agriculture Land Changes between 2003 and 2017 of Butwal Sub Metropolitan City.

Figure 13 also reveals that the decline of agricultural land occurred in accessible low-lying areas, which were well connected by road networks, with growing urban settlements, reflecting the importance of urban transport infrastructure in determining agricultural land loss. In general, the decline in agricultural area is due to the growing need for residential, commercial and infrastructure development.

3.4 Changes of Built-up Area

Built-up area experienced the most significant increase among all land use categories during the study period. The spatial distribution of the growth of built-up areas is shown in Figure 14 and Table 7 provides a summary of key land conversion pathways that have led to this growth. The net increase in built-up area was 8.62 km² between 2003 and 2017. The major contributor to built-up expansion was agricultural land, followed by sand area and barren land.

Table 7. Changes of Built-up Area between 2003 and 2017 in Butwal Sub Metropolitan City.

Pathway	Area (Sq.Km)
A to B	6.20
F to B	0.57
BL to B	0.48
S to B	1.29
W to B	0.13
B to W	0.05
Net Change of Built-up	8.62

Approximately 6.20 sq. km of agricultural land was converted into built-up area, while 1.29 sq. km of sand area and 0.48 sq. km of barren land were transformed into urban surfaces. Minor conversions of forest and water body into built-up area were also observed.

The expansion of built-up area was concentrated mainly in Wards 11, 12, and 13, particularly around highway corridors, market centers, and settlement clusters. The spatial growth pattern suggests corridor-based urban expansion influenced by transportation accessibility and increasing land demand.

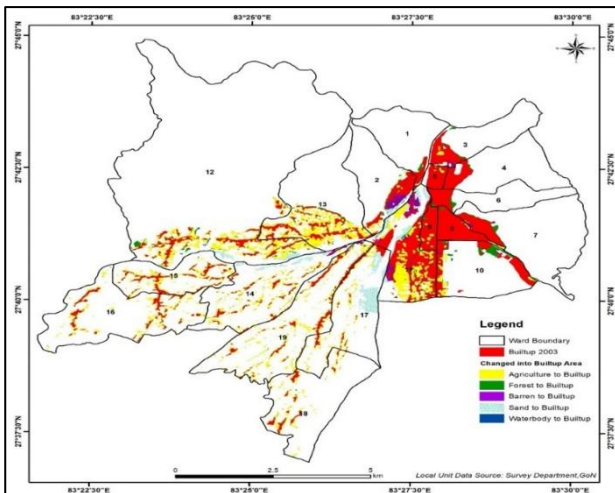


Fig. 14. Pattern of Built-up Land Changes between 2003 and 2017 in Butwal Sub Metropolitan City.

The dominance of agricultural land conversion in built-up expansion indicates that urban growth has mainly been developed through outward expansion into peri-urban agricultural zones rather than redevelopment within existing urban areas. This trend shows a greater land demand accompanied by the increase in population growth, commercial development and transportation infrastructure expanding.

3.5 Changes in Forest Area

There was a relatively low amount of overall change in forest area compared to other land use categories. Figures 15 and 16 show the rates of change for other land-use categories and the forest categories respectively over the period between 2003 and 2017. The data shows that the area of the forest increased most from sand, with an increase of 1.37 km², followed by the smaller gains from agricultural land (0.43 km²), barren land (0.37 km²), and water bodies (0.35 km²). This improvement was primarily seen in the Ward 17 and northern watershed areas.

At the same time, forest land was also being lost in localized areas to built-up areas, agriculture, water bodies, barren land and sand. Localized forest loss occurred with an estimated loss of about 0.63 km², with urban development and agriculture causing localized pressure at agricultural areas where 0.57 km² of forest was converted into built-up areas. The major forest conversion pathways are summarized in Table 8, which indicates that the forest cover

increased by 0.94 km² during the study period. Despite overall expansion in the forest area, the findings suggest that in those areas where settlement expansion and infrastructure development occurred, there was continued fragmentation and land conversion.

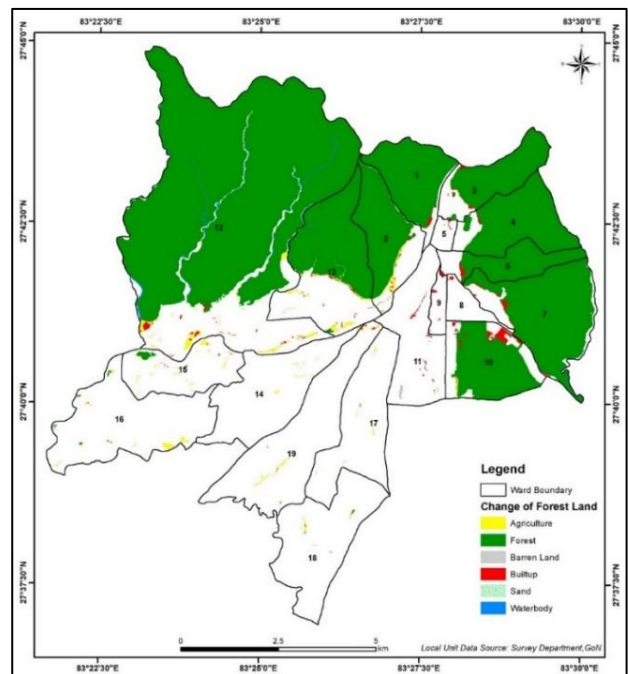


Fig. 15. Changing pattern of Other Land Use into Forest between 2003 and 2017 in Butwal Sub Metropolitan City.

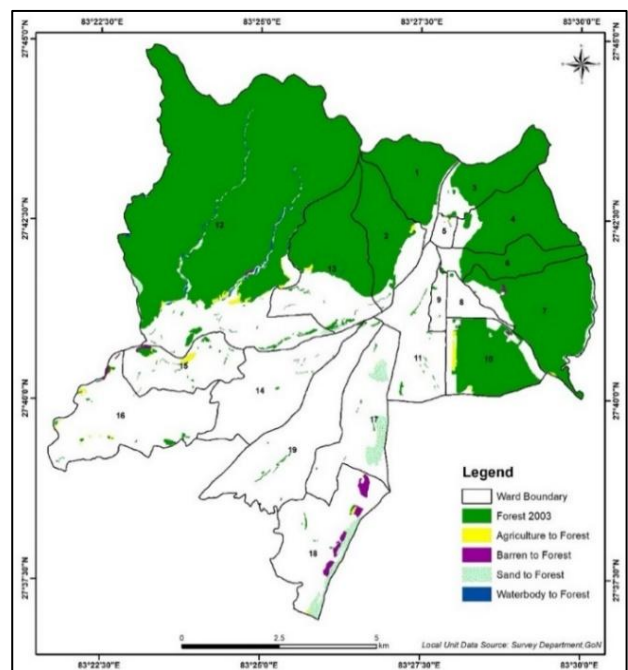


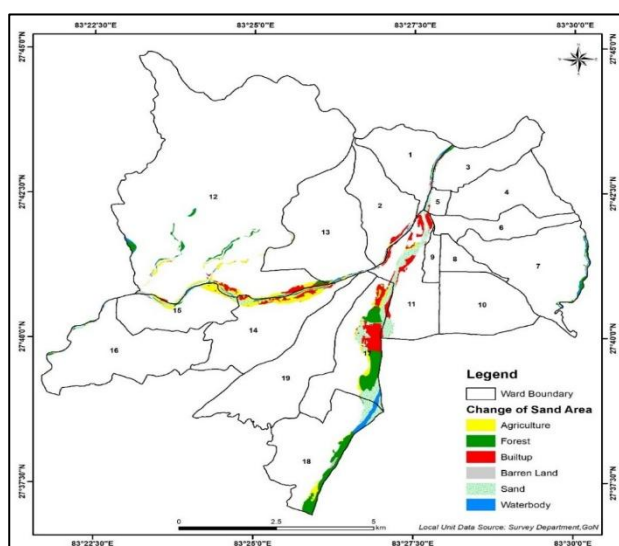
Fig. 16. Changing pattern of Forest into Other Land Use between 2003 and 2017 in Butwal Sub Metropolitan City.

Table 8. Changes of Forest between 2003 and 2017 in Butwal Sub Metropolitan City.

Pathway	Area (Sq.Km)
A to F	0.43
BL to F	0.37
S to F	1.37
W to F	0.35
F to B	0.57
F to A	0.63
F to BL	0.04
F to S	0.02
F to W	0.32
Net Change of Forest Coverage	0.94

3.6 Changes of Sand Area

One of the largest land use changes in the study area was a significant decrease in sand area, amounting to 4.12 km² between 2003 and 2017. The spatial pattern of the sand area conversion is shown in Figure 17, and the number of transitions for each major land use pathway is summarized in Table 9.

**Fig. 17.** Changing pattern of Sand Area into Other Land Use between 2003 and 2017 in Butwal Sub Metropolitan City.**Table 9.** Changes of Sand Area between 2003 and 2017 in Butwal Sub Metropolitan City.

Pathway	Area (Sq.Km)
S to A	1.21
S to F	1.37
S to B	1.29
S to BL	0.06
S to W	0.51
A to S	0.05
F to S	0.02
BL to S	0.11
W to S	0.14
Net Change of Sand Area	(4.12)

The greatest percentages of the sand area were converted to forest (1.37 km²), built-up areas (1.29 km²), and agriculture (1.21 km²) and these changes took place primarily around riverbanks and floodplain lowlands. Smaller areas of sand being converted to barren land (0.06 km²) and water bodies (0.51 km²) were also noted. On the other hand, only some areas of agriculture, forest, bare land and water bodies were turned into sand. The findings also show that a large portion of riverbank lands and riverbeds have been altered as a result of rapid urban expansion and land use change, with the result that the watershed environment is being increasingly stressed.

3.7 Changes of Barren Land

Barren land decreased from 1.37 km² in 2003 to 0.36 km² in 2017, resulting in a net reduction of 1.01 km². The spatial distribution of barren land conversion is presented in figure 18, where it is seen that most barren areas were converted to built-up land, forest and agricultural land, especially in areas with high rates of urban growth. Some 0.48 km² of barren land was turned into built-up land, 0.37 km² into forest and 0.23 km² into agriculture. The conversion of agricultural land, forest and sand area into barren land was also seen in isolated areas but to a very limited extent. Results overall suggest a steady decrease in barren land as a result of land use and urbanization. Table 10 provides a summary of the major pathways of land-use change that involved barren land between 2003 and 2017, including the size of each change and the overall change in barren land over the study period.

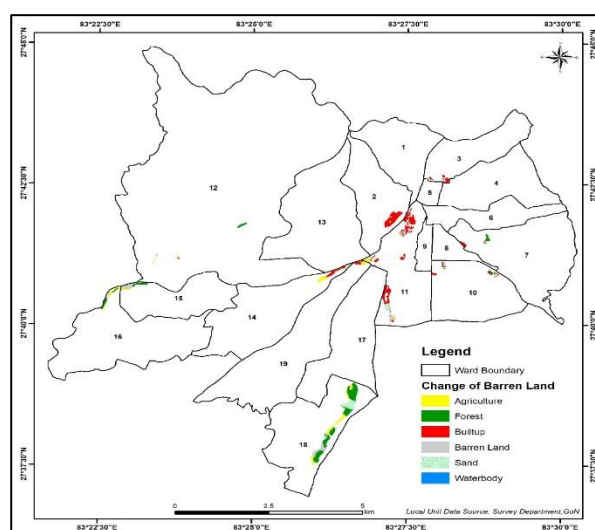
**Fig. 18.** Changing Pattern of Barren Land into Other Land Use between 2003 and 2017 in Butwal Sub Metropolitan City.

Table 10. Changes of Barren Land between 2003 and 2017 in Butwal Sub Metropolitan City.

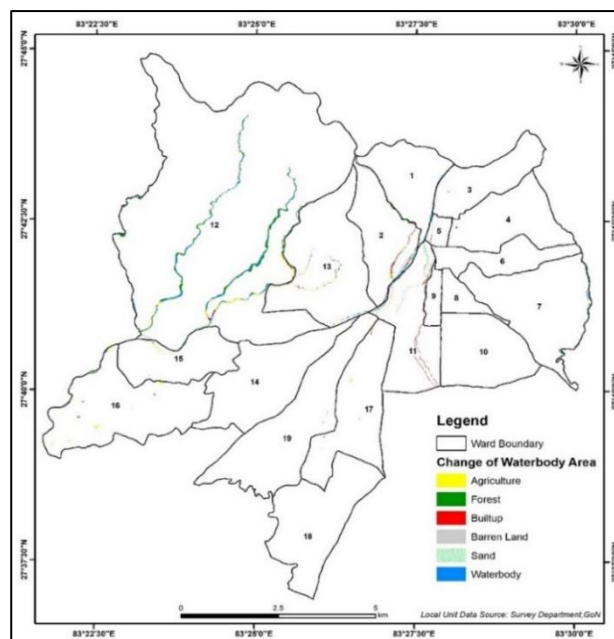
Pathway	Area (Sq. Km)
BL to A	0.23
BL to F	0.37
BL to B	0.48
BL to S	0.11
BL to W	0.01
A to BL	0.09
F to BL	0.04
S to BL	0.06
W to BL	0.004
Net Change of Barren Land	(1.01)

3.8 Changes in Water bodies

The net change in water bodies was small, increasing by 0.44 km² from 2003 to 2017. The expansion was primarily due to the conversion of forest land, agricultural land and sand areas into water bodies. About 0.51 km² of the sand area and 0.36 km² of the agriculture area were converted into water bodies; 0.32 km² of forest was also converted into water bodies. Other water bodies were, on the other hand, changed into forest, built-up area, barren land, and sand area. Changes in water bodies are summarized in Table 11, which reveals that the greatest increase in water bodies was related to converting sand areas, while minimal losses occurred for other land-use categories. The spatial distribution of water bodies converted is shown in figure 19 and shows that water body conversions were mainly located in river corridors and lowlands of the urban watershed. The results indicate that there were some hydrological changes during the study period, possibly related to changes in the river flow and urban development and occurring on a local scale.

Table 11. Changes of Water Body between 2003 and 2017 in Butwal Sub Metropolitan City.

Pathway	Area (Sq.Km)
W to A	0.19
W to F	0.35
W to B	0.13
W to BL	0.004
W to S	0.14
A to W	0.36
B to W	0.05
F to W	0.32
BL to W	0.01
S to W	0.51
Net Change of Water Body	0.44

**Fig. 19.** Changing pattern of water body into Other Land Use between 2003 and 2017 in Butwal Sub Metropolitan City.

4. DISCUSSION

4.1 Factors Associated with Land Use and Land Cover Change

The rapid transformation of land use in Butwal Sub-Metropolitan City seems to be linked with urbanization, population growth, migration, infrastructure development, and economic diversification. The extensive growth in built-up space, especially in areas along transport routes and accessible peri-urban land, shows that there is a close link between urban development and the encroachment on agricultural land [8]. The spatial patterns are similar to those observed in other fast-growing cities in Nepal, where urbanization has been observed to be shrinking agricultural land over time due to population growth, migration, and infrastructure development stressors [9]. In particular, the findings from the Rupandehi District emphasize the significant changes in land cover and the pressing need for sustainable urban planning to address agricultural degradation and ecosystem preservation [10].

The conversion of agricultural land into built-up area was identified as the dominant land transformation pathway in the study area. This pattern indicates increasing pressure on productive agricultural land surrounding

transportation corridors and accessible lowland areas [11]. Expansion of highways, commercial centers, and public infrastructure has significantly increased land values and stimulated settlement growth in peri-urban areas. Similar observations have been documented in previous studies conducted in Butwal and other urbanizing regions of Nepal [12]. This trend underscores the urgent need for sustainable urban planning to mitigate the adverse effects of rapid urbanization on agricultural land and food security in the region.

These results are consistent with studies in Nepal that identified agricultural land to be the dominant driver of urban expansion. Similarly, the conversion of agricultural land to built-up area was also significant in Hemja, Pokhara [13]. Ishtiaque et al. [14] have reported on similar trends of rapid urban growth and LULC change in the Kathmandu Valley, while Raut et al. [15] made similar observations in Pokhara Metropolitan City. Similarly, urban expansion activity in the eastern region was largely at the cost of productive agricultural land [16]. The current research corroborates these results and demonstrates that agricultural land accounted for nearly 71.9% of total urban growth in Butwal, further cementing the influence of peri-urban agricultural conversion on urban development patterns.

The rapid decline of sand area further reflects increasing modification of riverbank landscapes and floodplain environments. Expansion of informal settlements, urban encroachment, and land conversion along river corridors have substantially altered the natural geomorphological structure of the watershed system. Such transformation is commonly associated with uncontrolled urban growth in rapidly developing cities [17].

4.2 Environmental Impacts of Land Use and Land Cover Change

Loss of Agricultural Land

The conversion of agricultural land into urban and industrial areas has emerged as one of the most significant environmental impacts of LULC changes in Butwal. The current study showed a decrease of 4.87 sq. km of arable land between 2003 and 2017 of which 6.20 sq. km have been directly converted into built-up area. This

evidence reveals that urbanization has become the dominant driver of agricultural land loss in the municipality. This reduction in agricultural land has had a detrimental effect on local food production, increasing the city's reliance on imported food and making it more susceptible to external disruptions in supply [18]. The loss of farmland also has broader ecological consequences, as agricultural lands play a crucial role in providing ecosystem services such as water regulation and soil conservation [19]. Consequently, the findings highlight the urgent need for sustainable urban planning strategies to mitigate the adverse effects of urban sprawl on agricultural resources. These strategies should focus on preserving agricultural land, promoting urban green spaces, and implementing zoning regulations to balance growth with environmental sustainability.

Forest Fragmentation and Localized Land Conversion

Forests are vital for maintaining biodiversity, sequestering carbon, and regulating the water cycle [20]. Forests also play a crucial role in human health and well-being by providing essential ecosystem services that support livelihoods and food systems [21]. Forest cover experienced only a marginal net gain of 0.94 sq.km during the study period, often resulting in localized forest conversion nearby settlements and infrastructure.

Approximately 0.57 sq. km of forest was converted into built-up area and 0.63 sq. km into agricultural land. While on the other hand, forest gains were also the result of converting sand areas and other land categories to forest. The results suggest that although forest extent was largely maintained over large areas of the urban watershed, localized patterns of forest fragmentation and encroachment persisted within some human-environment systems.

Hydrological Changes and Increased Flood Risk

The loss of natural and agricultural surfaces to built-up areas can change hydrological processes in Butwal, by decreasing infiltration and may lead to an increase in surface runoff. Past research has demonstrated that greater impervious surfaces can lead to less ground-water recharge and more runoff [22]. These changes can lead to increased flood vulnerability in urbanizing watersheds [23,24].

The considerable decrease of sand area by 4.12 sq. km there in further reveals serious alteration of riverbank and floodplain habitats. Approximately 1.29 sq. km of sand area were converted into built-up areas, indicating a more intense urban sprawl along river corridors. The alteration of these land uses can affect natural infiltration and may lead to a greater amount of surface runoff and reduced natural watershed flood regulation.

4.3 Socio-Economic Impacts of Land Use and Land Cover Change

Housing and Infrastructure Challenges

The identified LULC changes could have significant socio-economic consequences in highly urbanized places like Butwal. The significant growth in urban development has led to the loss of agricultural land, highlighting potential conflicts with land use and productivity. Past research in other fast-growing cities in Nepal indicates that urban population growth, urban infrastructure development and other socio-economic factors are strongly linked to urban land growth [25]. The impacts of agricultural land-use change on agricultural productivity, food security, land value, housing cost, occupation and income sources of household can be also observed in the Tarai of Nawalparasi District [26]. These findings give a regional perspective that is relevant to understanding the socio-economic impacts of LULC change in Butwal.

Impact on Local Livelihoods

There is a possibility that agricultural land conversion into urban uses may impact livelihoods in Butwal. Previous research in Nepal has demonstrated that farmland change can lead to job changes, dependence on non-agricultural jobs, and less local agriculture production [27,28]. The results of these studies offer context for the significant amount of agricultural land lost in the present study.

4.4 Contribution of the Study

This study represents the integration of land-use transition pathway analysis with a watershed-based assessment of environmental change in an urbanizing Himalayan city, thus enriching the

LULC change literature. The current study illustrates how shifting agriculture to built-up area, sand-area changes, and area-scale fragmentation of forests can affect watershed sustainability and local environmental conditions, as opposed to studies that concentrate more on quantifying LULC change.

The methodological framework incorporates the validation of classification, the use of a transition matrix, the calculation of annual change rates and the explicit consideration of classification uncertainty, through remote sensing and GIS analysis. This integrated geospatial framework has allowed for the systematic identification of primary land-conversion pathways, and the provision of a spatially explicit understanding of urban expansion and associated landscape changes in the city of Butwal.

The study also offers quantitative evidence of a total 97.4% increase in built-up area in Butwal, where around 71.9% of the overall urban expansion has taken place through agricultural land conversion. These findings provide useful information to urban planners, watershed managers and decision-makers for effective and sustainable land-use planning as well as agricultural land conservation, and environmentally sensitive urban development in rapidly growing cities of Nepal.

5. CONCLUSION AND POLICY IMPLICATIONS

The study shows significant LULC change between 2003 and 2017 with the biggest changes being rapid built-up expansion, loss of agricultural land, significant reduction in sand land areas and localized conversion of forest land though there is a small net increase in forest land. These changes are reflective of the growing development demands on productive farmland, river corridors, and environmentally sensitive areas of the urban watershed. These observed patterns could be important for the functioning of the watershed, for the susceptibility to flooding, as well as for the livelihoods of the local communities and long-term urban sustainability.

The study shows that urban land expansion has been the major process of land transformation in Butwal between 2003 and 2017. The built-up area increased by 97.4%, primarily through the conversion of agricultural land and, to a lesser

extent, sand areas adjacent to river corridors. A substantial 71.9% of total urban expansion resulted from encroachment on farmland, indicating how intensively urbanization is now threatening productive and environmentally important landscapes.

Our results indicate that urban development should focus on conserving agricultural lands, preserving watersheds, and directing development along transport corridors and river systems. Geospatial monitoring coupled with land use planning can help reduce environmental degradation in the watershed and achieve more sustainable urban growth.

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