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RESEARCH ARTICLE

Land use and land cover change and rainfall variability in Baglung municipality, Baglung, Nepal: implications for water resource management

Roja Shakya, Rezina Shanker & *Indira Parajuli

Central Department of Environmental Science, Institute of Science and Technology, Tribhuvan University, Kirtipur, Kathmandu, Nepal

**Corresponding author: indira.parajuli@cdes.tu.edu.np*

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ABSTRACT

Land use and land cover (LULC) change is considered a major indicator of environmental transformation influenced by natural processes and human activities. This study aims to analyze land use and land cover change in Baglung Municipality, Gandaki Province, Nepal, for the years 2016 and 2026 using Sentinel-2 satellite imagery and supervised classification techniques in a GIS employing the Maximum Likelihood Classification method. Five major land use classes were identified in the study area: agricultural land, forest and vegetation, settlement and built-up area, barren land, and water bodies. Spatial analysis was conducted to evaluate the distribution and temporal changes of these land cover categories. Additionally, rainfall trend analysis was conducted using long-term DHM meteorological records (1995-2025), applying the Mann-Kendall test and Sen's slope estimation in R software. The results showed notable LULC changes during the study period. Agricultural land decreased from 42.92 km² in 2016 to 25.16 km² in 2026, while forest and vegetation increased from 47.67 km² to 63.30 km². Settlement and built-up areas increased from 2.22 km² to 8.95 km², whereas barren land decreased from 4.84 km² to 0.57 km². Water bodies showed a slight decline from 1.37 km² to 1.03 km². The classification achieved overall accuracies of 87.74% and 85.20% for 2016 and 2026, respectively. Rainfall exhibited a weak decreasing trend (Sen's slope= -2.24 mm/yr), and the trend was statistically insignificant (p= 0.859). The findings demonstrate substantial landscape transformation, particularly agricultural land loss and expansion of settlement and built-up areas. The observed decline in water bodies cannot be directly attributed to long-term rainfall trends based on the available data. The study provides baseline information for land-use planning, watershed conservation, and sustainable water resource management in Baglung Municipality.

Keywords: ***GIS, remote sensing, sentinel-2 satellite imagery, water resources***

1. INTRODUCTION

Land is an important natural resources that supports agriculture, settlements, infrastructure, forests, and ecosystem services essential for human well-being and sustainable development (Ellis et al., 2021; UNCCD, 2022). In developing countries such as Nepal, growing population and development pressure have increased demand for land, leading to changes in land use and land cover (LULC) over time (Bhandari et al., 2022; Heald & Spracklen, 2015). Land use refers to how people utilize land, while land cover describes its physical and biological features, such as forests, croplands, water bodies, and built-up areas (Lambin et al., 2003). Changes in land use can consequently alter land cover, making LULC analysis useful for understanding landscape changes and supporting sustainable land management (Ellis et al., 2013).

LULC change has become one of the key focus in global environmental change research because it directly influences ecosystem processes, climate systems, and biodiversity distribution (Verburg et al., 2015). Changes in land cover can affect water cycles, carbon storage, soil quality, and atmospheric conditions, thereby influencing environmental sustainability at local and global scales (Foley et al., 2005). Studies have shown that human activities such as agricultural expansion, deforestation, urbanization, and infrastructure development are the major drivers of land use and land cover changes worldwide (Song et al., 2018).

In mountainous countries like Nepal, LULC change has even greater environmental significance due to fragile ecosystems and steep terrain (Li et al., 2017). Small modifications in land cover in mountain regions can cause significant impacts such as soil erosion, landslides, biodiversity loss, and changes in hydrological processes (Uddin et al., 2018). Nepal is also characterized by diverse landscapes and rich biological resources, making proper land management essential for sustainable development and environmental conservation (Bhandari et al., 2022). Therefore, monitoring and analyzing LULC changes is crucial for planning, resource management, and environmental protection.

LULC change is also recognized as an important factor influencing water resources and watershed conditions (Puno et al., 2019). The movement, storage, and availability of surface water and groundwater can be affected by the modification of landscape characteristics, including alterations in vegetation cover, agricultural land and built-up areas (Barron et al., 2013; Bellot et al., 2001; Han et al., 2017). The expansion of impervious surfaces associated with urbanization may reduce rainfall infiltration, while changes in vegetation cover can influence watershed functions and water conservation (Foley et al., 2005; Lamichhane & Shakya, 2019). Understanding LULC dynamics is therefore important not only for monitoring landscape transformation but also for supporting integrated land and water resource management.

In Nepal, where many communities depend on local water sources for domestic use, agriculture, and ecosystem services, assessing the potential implications of land use change on water resources is increasingly important for sustainable environmental planning (Bhattarai & Adhikari, 2022). In addition to land use change, rainfall variability is an important factor influencing hydrological processes and water availability (Boyaj et al., 2020; Mathew et al., 2021). Changes in precipitation patterns can alter surface runoff, ground water recharge, and stream flow dynamics within watersheds (Strauch et al., 2015; Zaqout & Andradóttir, 2024). Understanding rainfall trends together with LULC dynamics provides a more comprehensive assessment of potential impacts on local water resources and watershed sustainability.

Modern geospatial technologies such as Remote Sensing and Geographic Information System (GIS) have become essential tools for land use land cover analysis (Bao Pham et al., 2024; Kabisch et al., 2019). Remote sensing enables researchers to obtain repeated observations of large geographic areas and track environmental changes over time (Campbell, 2011). GIS is a computer-based system used for storing, analyzing, and visualizing spatial data related to geographic features (Longley et al., 2015). The integration of remote sensing and GIS provides powerful capabilities for mapping land cover, detecting temporal changes, and analyzing spatial patterns across different time periods (Townshend et al., 1992).

Baglung Municipality in western Nepal has been experiencing noticeable environmental and land transformation due to increasing urbanization, population growth, and infrastructure development in recent years. In Nepal, urban growth and socio-economic development have significantly influenced land transformation, especially in hilly municipalities where agricultural land, forest areas, and built-up areas are undergoing continual change (Devkota et al., 2023). Land transformation is largely driven by rapid population growth, urban expansion, and infrastructure development, particularly in developing countries where institutional capacity for land management is often limited (Lambin & Meyfroidt, 2011). Despite this, systematic information on the spatial and temporal LULC changes within Baglung Municipality is limited, which limits effective urban planning and environmental management. Therefore, this study aims to analyze land use and land cover change in Baglung Municipality using remote sensing and GIS techniques, with four specific objectives: (i) to prepare LULC maps for the years 2016 and 2026; (ii) to analyze spatial changes in each land cover category between the two years; (iii) to identify the dominant patterns of land transformation within the municipality during the study period and (iv) to assess the potential implications of land use and land cover change on water resources in Baglung Municipality using long-term rainfall trend analysis and changes in water bodies.

2. METHODOLOGY

2.1 Study area

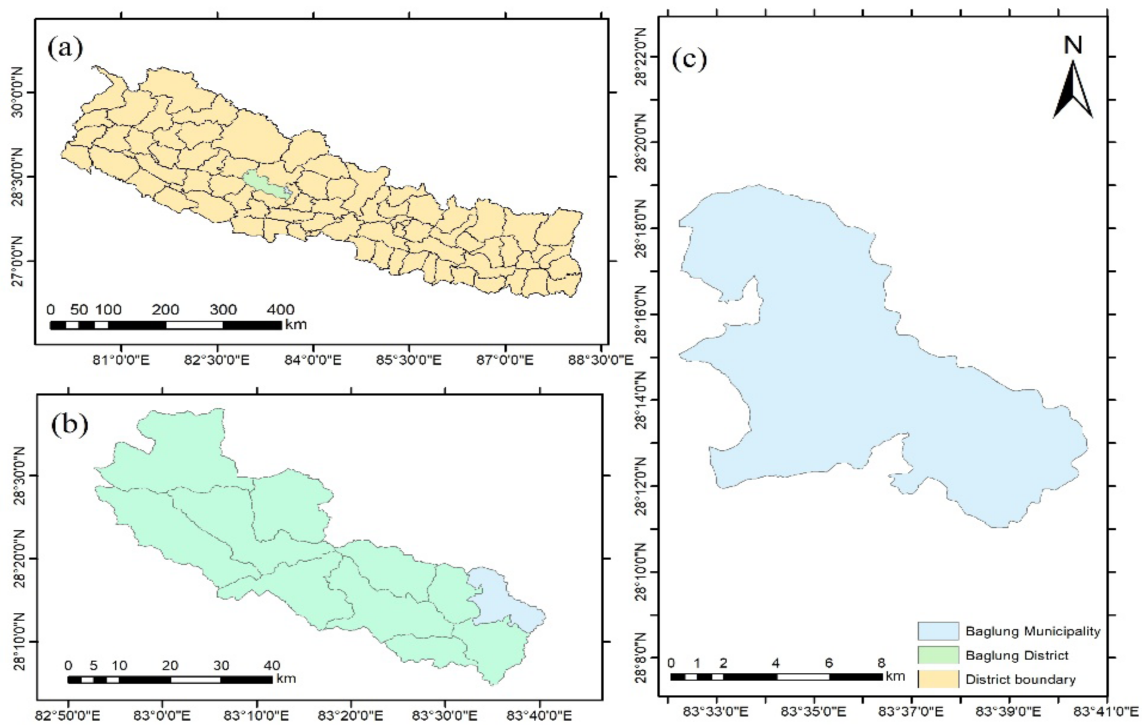

Fig. 1: Map showing (a) location of Baglung District in Nepal; (b) location of Baglung Municipality within Baglung District; (c) administrative boundary of Baglung Municipality.

The study was conducted in Baglung Municipality, located in Baglung District of Gandaki Province, the mid-hill region of western Nepal. The municipality is centered at approximately 28°16' N latitude and 83°36' E longitude, comprising 14 administrative wards. The area is situated on a plateau overlooking the Kali Gandaki River valley, south of the Dhaulagiri Himal. The climate of the area is generally subtropical to temperate, characterized by warm summers and mild winters with annual average temperature ranging from 19°C and 26°C (Baglung Municipality, 2024). These geographic and climatic conditions influence the land use and land cover patterns within the municipality (Fig. 1).

2.2 Sentinel-2 image processing

Appropriate satellite data for the study area were selected to analyze land use and land cover change in Baglung Municipality. Sentinel-2 satellite images with low cloud cover were obtained from the Copernicus Data Space Ecosystem browser (https://browser.dataspace.copernicus.eu/), operated by the European Space Agency (ESA). Sentinel-2A Level-2A imagery for the year 2016 and Sentinel-2C Level-2A imagery for the year 2026 were used for the analysis. Sentinel-2 provides multispectral imagery at 10 m spatial resolution in the visible and near-infrared bands.

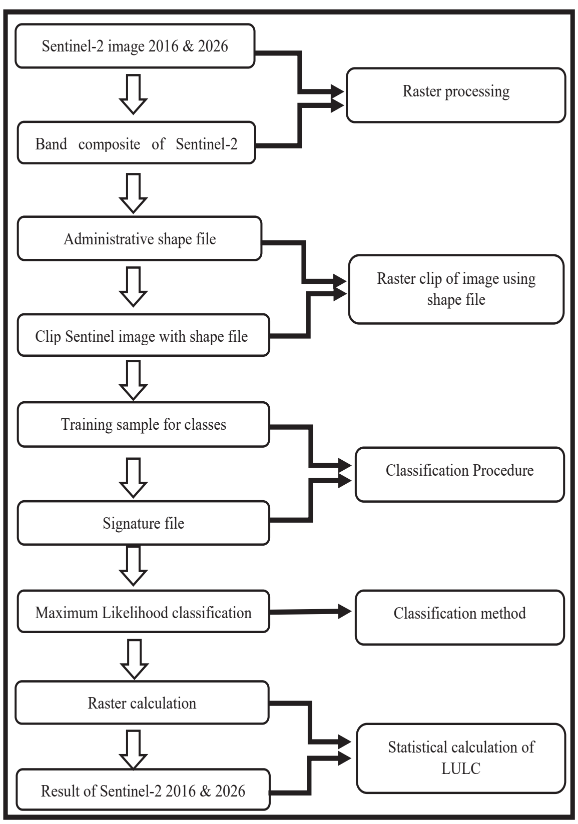

Fig. 2: Flow chart of proposed method for analysis.

All satellite datasets were projected to the Universal Transverse Mercator (UTM) coordinate system with the World Geodetic System 1984 (WGS 1984 UTM Zone 45N). The downloaded images were pre-processed and clipped to the administrative boundary of Baglung Municipality to extract the study area. The extracted images were classified into five land use and land cover (LULC) classes: Agriculture land, Barren land, Forest and Vegetation, Settlement and Built-up area, and Water bodies. Supervised classification using the Maximum Likelihood Classification (MLC) method was applied to classify the satellite images.

The supervised classification process begins with selecting training areas for each land cover class, followed by generating signature files, and finally classifying the entire image based on the spectral signatures of the training areas (Miranda et al., 2018). In this study, composite bands of the Sentinel-2 imagery were created by stacking the 10 m resolution bands including Blue (Band 2), Green (Band 3), Red (Band 4), and Near-Infrared (Band 8), along with SWIR 1 (Band 11) and SWIR 2 (Band 12), which have a native resolution of 20 m. Before band composition, Band 11 and Band 12 were resampled from 20 m to 10 m resolution using the resample tool in ArcGIS to ensure all bands were at a consistent spatial resolution and then clipped using the municipality boundary shapefile. Training samples were prepared for each LULC class based on visual interpretation of the satellite images and knowledge of the study area. Using these training samples, signature files were generated and Maximum Likelihood Classification was performed. The Maximum Likelihood classifier assigns each pixel to the class with the highest probability, assuming that the statistical values for each class follow a normal distribution (Miranda et al., 2018).

Finally, the classified images were analyzed to calculate the area and spatial distribution of each land use and land cover class. The raster calculator and attribute table were used to derive area statistics for each category. All image processing, classification, and spatial analysis were carried out using ArcGIS version 10.8.1 (Fig. 2).

Table 1: Details of Sentinel-2 imagery used for LULC analysis

Year	Satellite	Processing Level	Acquisition Date	Tile ID	Product ID
2016	Sentinel-2A	Level-2A	12-Dec-16	T44RQS	S2A_MSIL2A_20161212T050212_N0500_R119_T44RQS_20231015T045859.SAFE
2026	Sentinel-2C	Level-2A	14-Jan-26	T44RQS	S2C_MSIL2A_20260114T050151_N0511_R119_T44RQS_20260114T083610.SAFE

Source: Copernicus Data Space Ecosystem.

2.2.1 Accuracy Assessment

The accuracy of the LULC classification was assessed using validation sample points prepared in ArcGIS 10.8.1. The classified values were assigned to the sample points in ArcGIS, while Google Earth Pro was used to visually verify the reference land-cover classes. The classified and references values were compared using a confusion matrix to calculate producer's accuracy, user's accuracy, overall accuracy, and the kappa coefficient (Thapa & Sunar, 2025; Twisa & Buchroithner, 2019).

The use of Google Earth Pro as the reference source may introduce some uncertainty due to differences in image acquisition dates and spatial resolution between the reference imagery and Sentinel-2 imagery. In addition, spectral similarities among forest and vegetation, agricultural fallow land, and barren land may contribute to confusion between these classes. Therefore, the accuracy results and observed LULC changes were interpreted with consideration of these potential sources of uncertainty.

2.3 Rainfall trend analysis

Annual rainfall data for the periods 1995-2025 were obtained from the Department of Hydrology and Meteorology (DHM), Nepal, from the Baglung station (Index No.605; GSID: 142) located in Baglung Municipality. The station is situated at latitude 28.2636° N, longitude 83.6003° E, and an elevation of 964 m above mean sea level. Years (1998, 2001 and 2002) with insufficient rainfall observations were excluded from the analysis to avoid bias in annual rainfall estimation following standard climatological quality-control procedures. Rainfall trends were analyzed using the non-parametric Mann-Kendall trend test and Sen's slope estimator, which have been widely applied in precipitation trend studies in Nepal (Arra et al., 2025; Luo et al., 2024; Nyikadzino et al., 2020; Panthi et al., 2015).

The Mann-Kendall test evaluates the presence of a statistically significant increasing or decreasing trend in a time series (Fattah et al., 2024; Silva et al., 2015). The Mann-Kendall test statistic (S) is calculated as

$$S = \sum_{K=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_K)$$

Where,

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} +1, & \text{if } x_j - x_k > 0 \\ 0, & \text{if } x_j - x_k = 0 \\ -1, & \text{if } x_j - x_k < 0 \end{cases}$$

Where, x_j and x_k are rainfall observations at times j and k, respectively, and n is the total number of observations. The null hypothesis (H_O) states that no monotonic trend exists in the rainfall series, whereas the alternative hypothesis (H_1) states that a significant increasing or decreasing trend is present. Trends were considered statistically significant at $p < 0.05$.

The magnitude of the detected trend was estimated using Sen's slope estimator, which calculates the median slope of all possible pairs of observations (Islam et al., 2025). The slope between two observations is computed as:

$$Q_i = \frac{x_j - x_k}{j - k}, j > k$$

The Sen's slope estimate (*Q*) is the median of all calculated slopes:

$$Q = \text{Median}(Q_i)$$

A positive Sen's slope indicates an increasing rainfall trend, whereas a negative value indicates a decreasing trend (Jiqin et al., 2023; Ray et al., 2021). The magnitude of Sen's slope reflects the strength of the trend, with larger absolute values indicating greater rates of change (Helsel et al., 2020).

Statistical analyses and graphical visualization were performed using RStudio 2026.07.0+139.

3. RESULTS

Table 2 presents the area, percentage, and changes in area share of the LULC classes in Baglung Municipality between 2016 and 2026.

Table 2: Distribution and Change of Land Use/Land Cover Classes in Baglung Municipality (2016–2026).

Class/LULC Area	2016		2026		Change in area share, % points (2016–2026)
	Area (km²)	%	Area (km²)	%	
Agriculture land	42.92	43.35	25.16	25.41	-17.94
Barren land	4.84	4.89	0.57	0.57	-4.32
Forest and Vegetation	47.67	48.14	63.30	63.93	15.79
Settlement and Built-up	2.22	2.24	8.95	9.04	6.80
Water bodies	1.37	1.39	1.03	1.04	-0.34

3.1 Accuracy Assessment

The accuracy assessment showed overall accuracies of 87.74% (Kappa coefficient = 0.8451) for 2016 and 85.20% (Kappa coefficient = 0.815) for 2026, indicating good agreement between the classified maps and reference data. Agricultural land had the lowest producer's accuracy in both years, while barren land showed lower user's accuracy in 2026, suggesting some confusion with fallow agricultural and sparsely vegetated areas. Despite these uncertainties, the classification accuracy was satisfactory for assessing LULC changes over the study period.

Table 3: Accuracy assessment of LULC classification for 2016 and 2026.

LULC Class	2016		2026	
	Producer's Accuracy (%)	**User's Accuracy (%)**	**Producer's Accuracy (%)**	**User's Accuracy (%)**
Forest and vegetation	93.1	100	84.9	90
Barren land	85.71	85.71	92.3	72
Water bodies	100	87.5	100	98
Settlement and built-up area	93.75	75	82.4	84
Agricultural land	73.08	86.36	70.7	82
Overall Accuracy	87.74		85.2	
Kappa Coefficient	0.8451		0.815	

3.2 Land use/land cover analysis for year 2016

In 2016, the land use pattern of Baglung Municipality was largely characterized by the dominance of natural vegetation along with extensive agricultural practices (Fig. 3). Forest and vegetation were the dominant category, covering 47.67 km² and making up 48.14% of the total area. Agricultural land followed as the second major class, covering 42.92 km² (43.35%), indicating the significant role of agriculture in the mid-hill region. Built-up or settlement areas were relatively limited, with an area of 2.22 km² (2.24%), suggesting a low level of urban expansion during that period. Barren land, including rocky surfaces and areas with minimal vegetation cover, extended over 4.84 km² (4.89%). Water bodies represented the least coverage among all classes, occupying only 1.37 km², which is 1.39% of the total mapped area.

3.3 Land use/land cover analysis for year 2026

By 2026, noticeable changes had occurred in the land cover distribution of Baglung Municipality (Fig. 4). Forest and vegetation remained the dominant and showed a significant increase, expanding to 63.30 km², which accounts for 63.93% of the total area, an increase of over 15 km² compared to 2016. In contrast, agricultural land experienced a marked decline, decreasing to 25.16 km² (25.41%), which is substantially lower than its previous extent. The area under settlement and built-up land increased to 8.95 km² (9.04%), indicating rapid urban growth and expansion of peri-urban areas over the ten-year period. Barren land was reduced drastically to only 0.57 km² (0.57%), suggesting that most previously exposed or unused land had been converted or covered. Water bodies also showed a slight reduction, declining to 1.03 km², representing 1.04% of the total area.

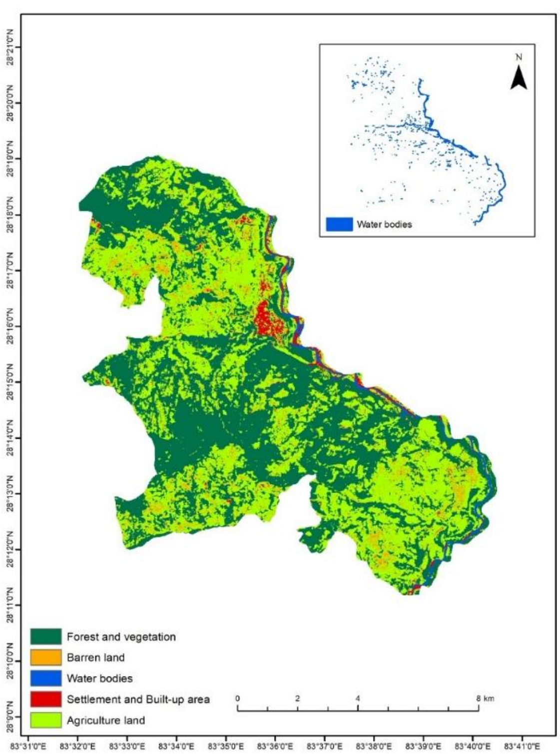

Fig. 3: Spatial LULC map of Baglung Municipality 2016.

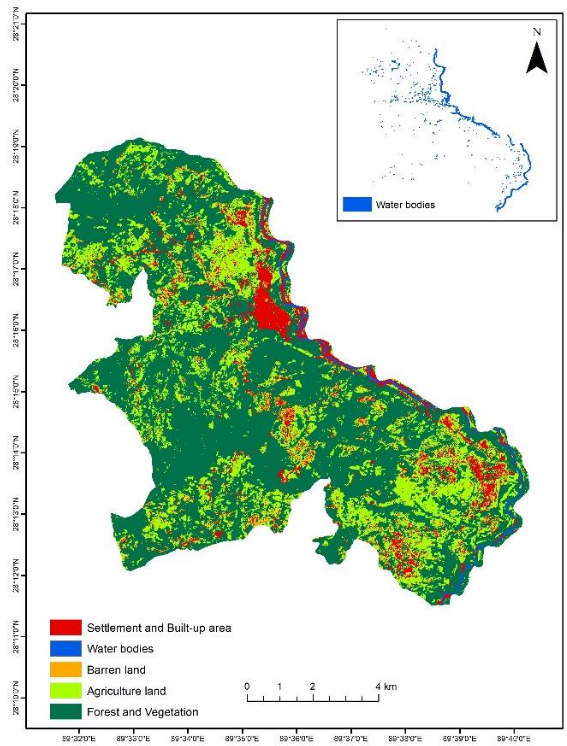

Fig. 4: Spatial LULC map of Baglung Municipality 2026.

3.4 Land use and land cover change from 2016 to 2026

The comparison between 2016 and 2026 shows clear changes in the land use and land cover pattern of Baglung Municipality (Fig. 5). Forest and vegetation show the highest increase among all classes, with an addition of about 15.63 km². This change pattern aligns with a decline in agricultural land, which may be associated with abandoned or less productive farmland gradually transforming into vegetation. Agricultural land shows the highest loss, decreasing by around 17.76 km². On the other hand, settlement and built-up area increased by about 6.73 km², which clearly indicates rapid urban growth in the municipality. Barren land also decreased significantly

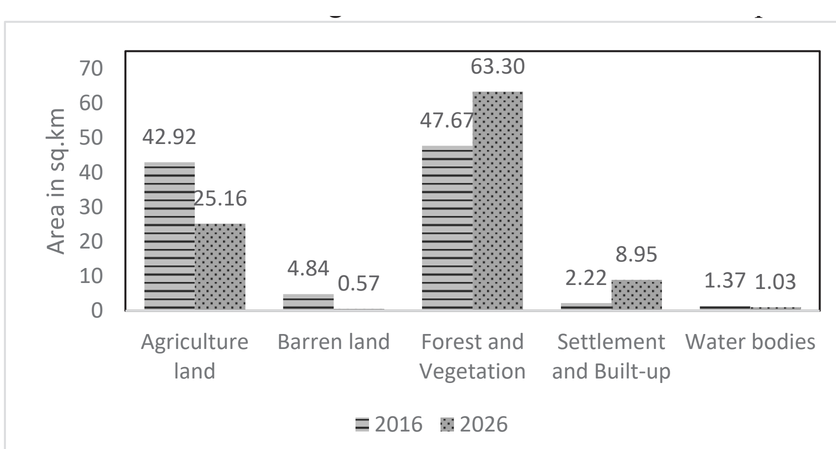

Fig. 5: Comparison of LULC class areas in Baglung Municipality for 2016 and 2026, showing changes in agriculture land, barren land, forest and vegetation, settlement and built-up areas, and water bodies.

by around 4.27 km², suggesting that previously barren areas may have been converted into other land cover categories, including vegetation and built-up areas. Water bodies show only a small decrease of about 0.34 km². Overall, the LULC change from 2016 to 2026 in Baglung Municipality shows an increase in vegetation cover along with expansion of settlement areas, while agricultural land has decreased significantly and barren land showed a substantial decrease of about 4.27 km² (Fig. 5).

3.5 Land use and Land cover transition from 2016 to 2026

The LULC transition analysis revealed notable conversions among land cover classes in Baglung Municipality between 2016 and 2026 (Fig. 6). The largest conversion was from agricultural land to forest and vegetation, covering 17.04 km^2, followed by agricultural land to settlement and built-up area. Barren land was also mainly converted to settlement and built-up area (1.60 km^2) and forest and vegetation (0.92 km^2). 44.88 km^2 of forest and vegetation and 20.87 km^2 of agricultural land remain unchanged.

Overall, the transition pattern shows that agricultural land experienced the greater conversion, mainly towards forest and vegetation and settlement and built-up areas.

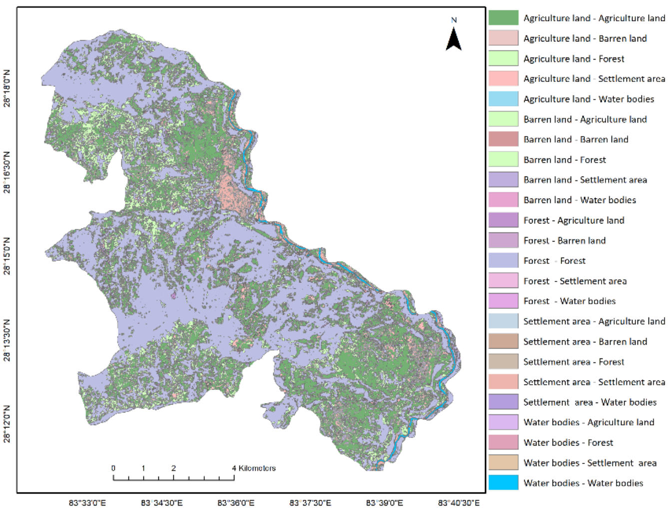

Fig. 6: Spatial Distribution of LULC Transitions in Baglung Municipality (2016-2026)

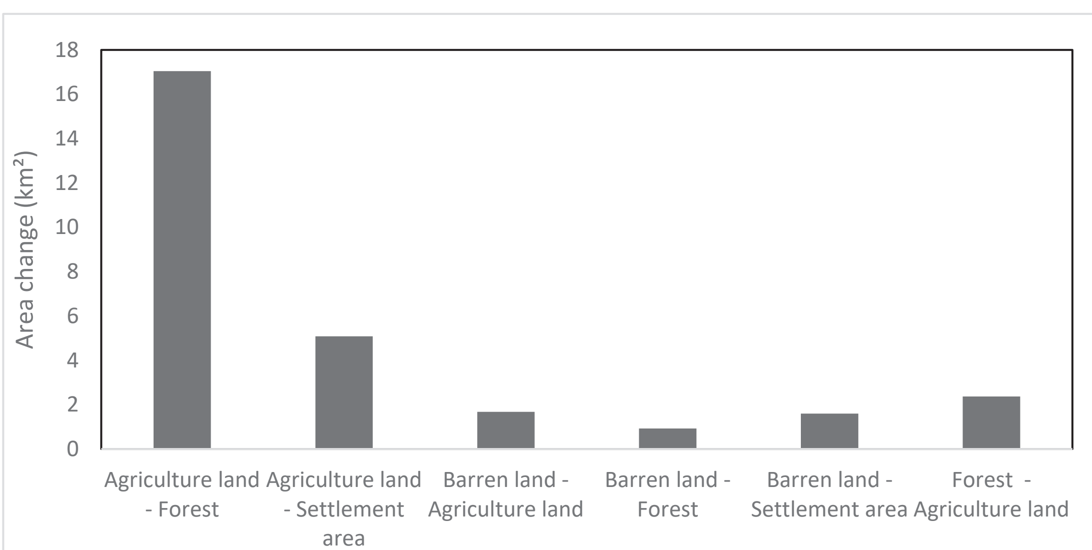

Fig. 7: Area of major LULC transitions in Baglung Municipality (2016-2026)

3.6 Rainfall variability and trend analysis

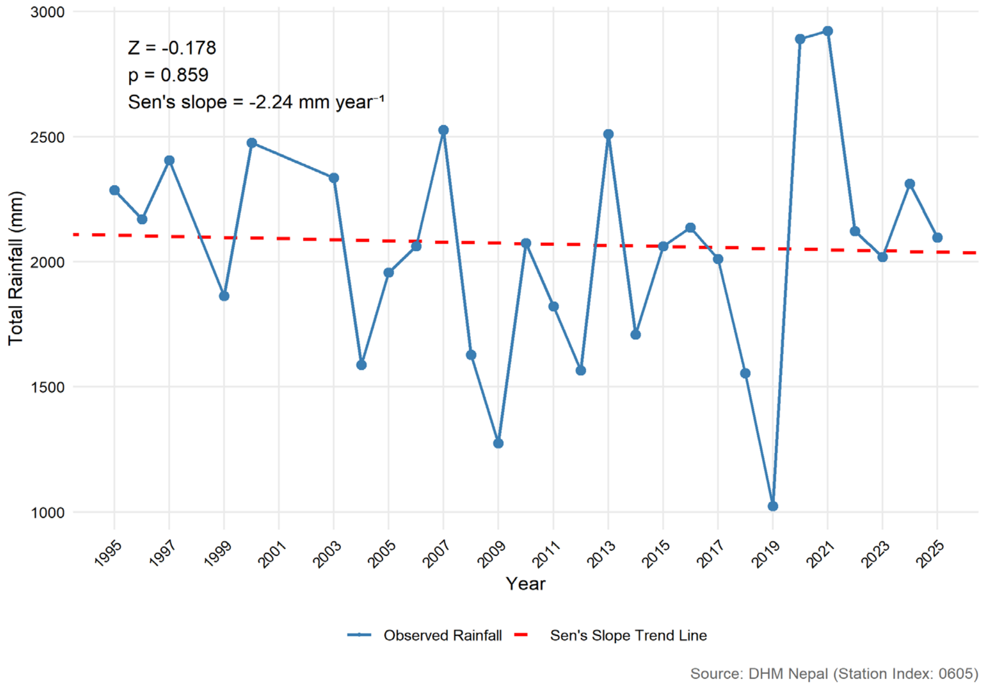

Fig. 8: Annual rainfall variability and Sen's slope trend line for Baglung Municipality during 1995-2025.

Annual rainfall in Baglung Municipality showed considerable inter annual variability during study period, ranging from 1023.7 mm in 2019 to 2922.38 mm in 2021 (Fig. 8). The Mann-Kendall test indicated a weak negative trend in rainfall ($Z = -0.178$, $\tau = -0.026$), although the trend was statistically insignificant ($p = 0.859$). Similarly, Sen's slope estimator indicated a negligible decline of 2.24 mm yr^{-1}; however, the substantial interannual variability and statistically insignificant Mann-Kendall result indicate that this decline cannot be considered a significant long-term trend. Despite substantial LULC changes between 2016 and 2026, no statistically significant long-term trend in annual rainfall was observed, and a direct association between the observed LULC changes and annual rainfall trends could not be established from the available data.

Table 4: Mann-Kendall test and Sen's slope analysis of annual rainfall in Baglung Municipality.

Parameter	Value
Mann–Kendall Z statistic	-0.178
Kendall's tau	-0.026
p-value	0.859
Sen's slope	-2.24 mm yr^{-1}
Trend direction	Weak decreasing
Statistical significance	Not significant

4. DISCUSSION

4.1 Change in land use pattern on forest and vegetation area

Forest and vegetation increased substantially during the study period. This finding may provide municipality-level spatial insight into forest recovery and indicates a notable change in land-use composition. This result is consistent with national trend. According to FRTC (2024), Nepal's forest area has been increasing in recent years, with the mid-hill region showing particularly notable forest recovery. Since Baglung Municipality lies in the mid-hill zone of Gandaki province, this finding aligns with the broader regional pattern. Community forestry has played an important role in this recovery. After Nepal's Forest Act of 1993, local communities were given rights to manage forests through Community Forest User Groups, which reduced illegal logging and open grazing and allowed natural regeneration. Tripathi et al., (2020), studied Tanahun district of the same Province, found that forest cover increased at 0.63% per year after community forestry was introduced, suggesting a similar process may have occurred in Baglung Municipality. Agricultural land abandonment may also contributed to vegetation recovery. Many people from Nepal's mid-hills have migrated abroad for work, leaving farmland uncultivated on steep and marginal slopes, where natural vegetation tends to grow back relatively quickly (Chhetri et al., 2023). Poudyal et al., (2023) identified outmigration-driven abandonment as a key reason for forest transition across Nepal's mid-hill community forests. The observed increase in forest and vegetation, together with the decline in agricultural land, may indicate a local land-use transition in Baglung Municipality. This pattern may be associated with the broader forest transition observed in Nepal's mid-hills, although the specific drivers were not directly assessed in this study. Additionally, as more households shifted to remittance-based incomes, livestock numbers may have declined, potentially reducing grazing pressure and allowing shrubs and young trees to establish on previously degraded hillslopes (Laudari et al., 2024).

4.2 Change in land use pattern on settlement and built-up area

Settlement and built-up area increased from 2.22 km² (2.24%) in 2016 to 8.95 km² (9.04%) in 2026. This rapid expansion reflects the ongoing urbanization trend observed across Nepal's hill municipalities. According to FRTC (2024), built-up areas in Nepal expanded exponentially after 2017, which corresponds with the period of rapid growth observed in this study. Devkota et al., (2023) also found that built-up areas have continuously increased in all major Nepali cities, mostly at the expense of agricultural land, which matches the pattern observed in Baglung Municipality. Population growth and rural-to-urban migration have been widely identified as the primary drivers of urban expansion in Nepal's mid-hill towns (Rimal, 2011). Baglung Municipality's status as a district headquarters has attracted public investment in roads, schools, and health facilities, which in turn draws people from surrounding rural areas. Additionally, remittance income from international labor migrants has been heavily channeled into residential construction, as homeownership is one of the most common investments made by remittance-receiving families in Nepal (Chhetri et al., 2023). This combination of migration, infrastructure development, and remittance-driven housing investment helps explain the scale of built-up expansion observed over the decade.

4.3 Change in land use pattern on agriculture land

Agricultural land experienced the most substantial decline of the study period, decreasing from 42.92 km² to 25.16 km². The transition analysis further showed that 17.04 km² of agricultural land was converted to forest and vegetation, while 5.09 km² was converted to settlement and built-up areas, confirming that both vegetation recovery and urban expansion contributed to the observed agricultural decline. This is a dramatic reduction and represents the largest change among all land cover classes.

The decline in agricultural land can be attributed to two primary processes: (i) conversion of farmland to built-up areas due to urban expansion, and (ii) agricultural abandonment leading to natural vegetation recovery, particularly in marginal or steep terrain. Urban expansion is widely recognized as one of the major drivers of agricultural land loss (Lambin & Meyfroidt, 2011). In Nepal's mid-hill regions, farm abandonment has been increasingly reported as out-migration and changing livelihood strategies reduce the agricultural workforce, allowing forests to naturally regenerate on former farmland (Bhandari et al., 2022).

4.4 Change in land use pattern on water bodies

The analysis shows a minor reduction in the area of water bodies during the study period. The observed decline may be associated with sedimentation, land encroachment, or seasonal fluctuations in river discharge. Water body dynamics are often influenced by climatic variations as well as anthropogenic activities such as irrigation and urban development (Jing et al., 2018).

The rainfall trend analysis from the Baglung Station indicated a weak decreasing trend in annual rainfall (Sen's slope = -2.24 mm/yr), but the trend was statistically insignificant ($p = 0.859$). Therefore, the available data do not provide empirical evidence to attribute the observed reduction in water body extent directly to long-term rainfall change or variability. Instead, land use and land cover transitions, particularly changes in vegetation cover and expansion of built-up areas, may have influenced surface runoff patterns, sediment transport, and water retention capacity. Similar relationships between LULC change and hydrological responses have been reported in Nepal and other Himalayan regions, where human-induced landscape modifications significantly affect water resources and water processes (Acharya et al., 2023; Panthi et al., 2015).

4.5 Change in land use pattern on barren land

Barren land showed a dramatic decrease from 4.84 km² to 0.57 km² between 2016 and 2026 (-4.32%). This indicates that almost all previously barren or exposed land within the municipality may have been converted into other land use categories, most likely vegetation cover given the simultaneous large increase in forest and vegetation. Such patterns are commonly observed when natural vegetation succession occurs on previously degraded or disturbed land, particularly in areas where human pressures on land have shifted (Weng, 2012). The near-complete disappearance of barren land in 2026 reflects the strong trend of vegetation recovery observed across the municipality.

4.6 Implications of land use and land cover change and rainfall variability for water resource management

The observed land use and land cover changes and rainfall variability provide separate considerations for water resource management in Baglung Municipality. The slight decline in water bodies from 1.37 km² (1.39%) in 2016 to 1.03 km² (1.04%) in 2026 occurred alongside changes in other land-use classes, including the expansion of settlement and built-up areas and the reduction in agricultural land. These LULC changes may potentially influence local hydrological processes through changes in surface permeability, runoff, and infiltration (Bhattarai & Adhikari, 2022; Jing et al., 2018; Lamichhane & Shakya, 2019). Separately, the rainfall trend analysis based on long-term meteorological records indicated no significant long-term change in precipitation during the study period. Thus the present analysis does not indicate a significant long-term rainfall trend that could explain the observed changes in water body extent.

The increase in forest and vegetation cover may provide some positive effects on the local hydrological system. Forests improve soil structure, enhance infiltration, reduce soil erosion, and help regulate stream flow. These functions may contribute to maintaining watershed health and supporting groundwater recharge. However, the hydrological benefits of increased forest cover may be reduced in areas experiencing rapid urban expansion, where the extent of impervious surfaces continues to increase (Lamichhane & Shakya, 2019).

Agricultural land declined substantially between 2016 and 2026, indicating a significant shift in the landscape. The conversion of agricultural land into built-up areas reduces permeable surfaces that naturally absorb rainfall and support groundwater recharge. Similar studies in Nepal have reported that land use change associated with urban development can alter runoff patterns, reduce infiltration, and increase pressure on local water resources (Poudel et al., 2024).

Although this study did not directly assess groundwater or stream flow, the observed land cover changes and rainfall variability highlight the importance of integrating land use planning with water resource management. Protecting recharge areas, conserving existing water bodies, and encouraging sustainable urban development can help maintain water availability and improve watershed resilience. Continuous monitoring of land use and land cover using remote sensing and GIS can also support informed planning and sustainable management of water resources.

5. CONCLUSIONS

This study assessed LULC changes in Baglung Municipality between 2016 and 2026 using Sentinel-2 imagery and supervised classification. The analysis showed substantial transformation of the municipal landscape, characterized by a decline in agricultural land and barren land, increase in forest and vegetation cover and expansion of settlement and built-up areas. The transition analysis further indicated considerable conversion of agricultural land to forest and vegetation and settlement and built-up areas. The classification results showed satisfactory accuracy for both study years supporting the use of the derived LULC maps for assessing the observed spatial changes.

The rainfall analysis indicated considerable interannual variability but no statistically significant long-term trend in annual rainfall during the study period. The observed reduction in water bodies extent should be interpreted cautiously. Based on the available LULC and rainfall data, this study doesn't establish that the decline in water bodies was caused by LULC change or rainfall variability. Water body dynamics may be influenced by multiple interacting environmental and anthropogenic factors which were not directly assessed in the study.

The study provides baseline information on LULC dynamics in Baglung Municipality and highlights the importance of continued LULC monitoring for land-use planning and watershed management. Studies incorporating filed-based hydrological observations and other relevant environmental factors are recommended to better understand the processes influencing local water resources.

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AUTHORS' CONTRIBUTIONS

The first author conducted the major part of the research, including data collection, analysis, interpretation and preparation of the initial draft of the manuscript. The second author contributed to the research activities, data analysis and interpretation, scientific discussion, and improvement of the manuscript. The third author, who is the Professor and corresponding author, provided overall academic guidance and supervision, contributed to the interpretation of the results, critically reviewed and revised the manuscript, and coordinated the final preparation of the paper. All authors contributed to the development of the study and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no financial, personal, or professional conflicts of interest that could have influenced the research, analysis, or conclusions presented in this study.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request through direct email communication.

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