International Journal of Enhanced Research in Educational Development (IJERED)
ISSN: 2320-8708, Vol. 14 Issue 2, March-April, 2026

Analysing Land Use Land Cover Change in the Ghaggar Watershed using Remote Sensing and GIS

Arpit[1], Prof. (Dr.) Sudhir Malik[2]

[1]Research Scholar, Department of Geography, Baba Mastnath University, Asthal Bohar-124021, Rohtak, Haryana
[2]Department of Geography, Baba Mastnath University, Asthal Bohar-124021, Rohtak, Haryana

ABSTRACT

Land use and land cover (LULC) change is one of the most significant indicators of environmental transformation and human interaction with natural landscapes. Monitoring these changes is essential for understanding their impact on watershed hydrology, land degradation, and sustainable resource management. The present study examines the spatial and temporal dynamics of land use and land cover in the Ghaggar watershed using multi-temporal satellite imagery and Geographic Information System (GIS) techniques. Landsat satellite images of 1985 and 2025 were analysed to identify major land-use categories and assess landscape transformation over a four-decade period. The satellite images were processed and classified using supervised classification methods to generate thematic land-use maps depicting categories such as agricultural land, forest land, grassland, barren land, built-up areas, and water bodies. Change detection analysis was conducted to quantify the extent and patterns of land-use transitions within the watershed. The results reveal that agricultural land is the dominant land-use category in the Ghaggar watershed and has expanded gradually over the study period due to increasing demand for agricultural production and improved irrigation facilities. At the same time, built-up areas have increased noticeably, reflecting population growth and infrastructure development in the region. Certain natural land cover types, such as forests and grasslands, have experienced a gradual decline in some parts of the watershed due to agricultural expansion and human activities. The study also highlights that terrain characteristics play an important role in shaping the spatial distribution of land-use categories, with forested areas largely confined to the upper catchment regions of the Shivalik foothills and agricultural land dominating the plains. The findings of the study demonstrate that remote sensing and GIS techniques provide effective tools for monitoring land use changes and understanding landscape dynamics in watershed environments. The observed land-use transformations have important environmental implications, particularly for soil erosion, runoff generation, and ecosystem sustainability. The study emphasises the need for sustainable land management practices and integrated watershed planning to maintain ecological balance and ensure long-term environmental stability in the Ghaggar watershed.

Keywords: Land Use Land Cover (LULC), Remote Sensing, Geographic Information System (GIS), Watershed Analysis, Land Use Change, Ghaggar Watershed.

INTRODUCTION

Land use and land cover (LULC) are among the most dynamic components of the Earth’s surface and play a crucial role in shaping environmental processes and landscape transformation. Land cover refers to the physical materials present on Earth's surface, such as vegetation, soil, water, and built-up areas, whereas land use describes how humans utilise land resources for activities such as agriculture, settlement, forestry, and infrastructure development. Changes in land use and land cover have significant implications for environmental sustainability, hydrological processes, biodiversity conservation, and socio-economic development. Over the past few decades, rapid population growth, urban expansion, agricultural intensification, and infrastructure development have significantly altered natural landscapes across many parts of the world. These changes have led to environmental challenges, including deforestation, soil erosion, land degradation, and declining water resources.

Monitoring and analysing land-use and land-cover changes have therefore become essential for sustainable environmental planning and resource management. Understanding how land-use patterns evolve over time helps identify the drivers of landscape transformation and assess their impact on natural ecosystems. In watershed environments, land use change is particularly important because it directly influences hydrological processes such as runoff generation, infiltration, evapotranspiration, and sediment transport. For instance, conversion of forested land into agricultural fields or urban areas often reduces vegetation cover and increases surface runoff, thereby accelerating soil erosion and sedimentation in river systems. In recent years, advances in Remote Sensing and Geographic Information Systems (GIS) technologies have significantly improved the ability to monitor land-use and land-cover changes at regional and watershed scales. Satellite imagery provides repeated and consistent observations of the Earth's surface, allowing researchers to detect changes in land cover over time. GIS techniques facilitate the processing, analysis, and visualisation of spatial data, enabling the mapping and quantification of land-use transitions with greater accuracy. The integration of remote sensing and GIS has therefore become a powerful tool for environmental monitoring, watershed management, and land resource planning.

The Ghaggar watershed, located in northwestern India, is a dynamic landscape where land-use patterns have undergone significant transformation due to agricultural expansion and human activities. The watershed originates in the Shivalik foothills of the outer Himalayas and flows through fertile alluvial plains before dissipating in arid regions downstream. This physiographic diversity creates a complex environmental system in which terrain, climate, soil characteristics, and human land-use practices interact to shape landscape patterns. Agriculture is the dominant land use activity in the region, supported by fertile soils and seasonal rainfall. Increasing population pressure and changing economic activities have led to the gradual expansion of cultivated land and built-up areas within the watershed.

Changes in land use within the Ghaggar basin have important implications for environmental sustainability. Expansion of agricultural land often reduces natural vegetation cover, increasing susceptibility to soil erosion and land degradation. Similarly, the growth of settlements and infrastructure can alter natural drainage patterns and increase pressure on water resources. Monitoring these land-use changes is therefore essential for understanding the watershed's environmental dynamics and for developing strategies for sustainable resource management.

Several studies worldwide have demonstrated the usefulness of remote sensing techniques for detecting land-use and land-cover changes. Multi-temporal satellite imagery enables researchers to examine how landscapes evolve over time and quantify the rate and direction of land-use transformation. In watershed studies, LULC mapping is particularly important because land use patterns directly influence hydrological behaviour and sediment transport processes. Identifying changes in vegetation cover, agricultural expansion, and urban growth can help planners design effective conservation measures and sustainable land management practices. In the context of the Ghaggar watershed, analysing land-use and land-cover change is particularly important because the region lies in a transitional zone between the Himalayan foothills and the Indo-Gangetic plains. The interaction between natural terrain conditions and human land-use practices has produced a diverse landscape in which agricultural fields, forests, grasslands, and settlements coexist. Understanding how these land use categories have changed over time provides valuable insights into the environmental pressures affecting the watershed.

The present study aims to analyse land-use and land-cover changes in the Ghaggar watershed using multi-temporal satellite imagery and GIS techniques. By comparing land-use patterns across time periods, the study seeks to identify major trends in land transformation and evaluate their environmental implications. The specific objectives of the study include mapping the spatial distribution of land-use categories within the watershed, analysing temporal changes in land-cover patterns, and examining the relationship between terrain characteristics and land-use distribution.

The findings of this research are expected to contribute to a better understanding of landscape transformation in the Ghaggar basin and provide valuable information for sustainable watershed management. By identifying areas where significant land-use change has occurred, the study can support policymakers and environmental planners in developing strategies to reduce land degradation, protect natural vegetation, and promote sustainable agricultural practices. Ultimately, integrating remote sensing and GIS techniques into land-use analysis offers an effective approach to monitoring environmental change and guiding long-term resource management in watershed environments.

STUDY AREA

The Ghaggar watershed is located in northwestern India and is an important hydrological system in the region. The watershed originates in the Shivalik foothills of the outer Himalayan range and flows southwestward through the plains before gradually dissipating in the arid regions further downstream. The Ghaggar River and its tributaries constitute the basin's main drainage system and play a significant role in transporting runoff and sediment from upstream mountainous areas to downstream plains.

Physiographically, the watershed exhibits considerable diversity, which significantly influences land use patterns and environmental processes within the basin. The upper catchment areas of the watershed lie within the Shivalik hill region, which is characterised by rugged terrain, steep slopes, and relatively fragile sedimentary formations. These areas are generally covered by forest vegetation and grasslands and are prone to soil erosion due to intense rainfall and unstable geology. Numerous small streams originate in this region and contribute to the development of the watershed's drainage network. Moving downstream, the terrain gradually transitions into gentle slopes and extensive alluvial plains. These plains are among the most productive agricultural regions in the watershed and are characterised by fertile soils deposited by fluvial processes over long geological periods. Agriculture is the dominant land-use activity in these areas, and the landscape is largely composed of cultivated fields, interspersed with rural settlements and small urban centres. The relatively flat terrain and fertile soils have encouraged extensive agricultural development, making the plains an important component of the regional economy.

The climate of the Ghaggar watershed is primarily subtropical monsoonal, characterised by hot summers, mild winters, and seasonal rainfall concentrated during the monsoon months. The majority of the annual precipitation occurs between June and September due to the southwest monsoon. Rainfall intensity during this period significantly influences runoff generation, soil erosion, and agricultural productivity within the watershed. Temperature variations follow a typical pattern of northern India, with high temperatures during the summer months and cooler conditions during winter.

The watershed supports diverse land use activities, including agriculture, forestry, grazing, and settlement development. Agricultural land constitutes the largest portion of the watershed area, while forested areas are mainly confined to the higher elevations of the Shivalik hills. Grasslands, barren lands, and built-up areas occupy smaller portions of the landscape but have shown gradual expansion due to increasing human activities. Understanding the spatial distribution and temporal changes in these land-use categories is essential for evaluating environmental changes and developing sustainable land-management strategies within the watershed.

METHODOLOGY AND DATA SOURCES

The analysis of land-use and land-cover change in the Ghaggar watershed was conducted using multi-temporal satellite imagery and geospatial datasets. Satellite images from different years were used to examine the spatial distribution of land-use categories and detect changes over time. The primary satellite datasets used in the study included Landsat imagery from 1985, 1995, 2005, and 2025, which provided consistent observations of the Earth's surface at regular intervals. Landsat satellite imagery is widely used in environmental studies due to its moderate spatial resolution and long historical record. These datasets enable researchers to analyse landscape changes over several decades and identify trends in land use transformation. In addition to satellite imagery, ancillary datasets such as topographic maps, watershed boundary data, and soil maps were used to support spatial analysis and interpretation.

Digital Elevation Model (DEM) data were also used to characterise terrain and assist in watershed delineation. DEM-derived parameters such as slope and elevation provide important information about terrain variability, which influences land use patterns and environmental processes within the watershed. The satellite images used in the study were first preprocessed to ensure accuracy and consistency in the analysis. Image preprocessing included geometric correction, atmospheric correction, and image enhancement. These procedures were necessary to remove distortions and improve the quality of the satellite images before classification. The satellite images were classified into land-use and land-cover categories using supervised classification techniques within a Geographic Information System (GIS) environment. Training samples representing different land use categories were selected based on visual interpretation and reference data. The classification process produced thematic maps showing the spatial distribution of various land-use classes within the watershed.

The major land use categories identified in the study include:

i. Agricultural land
ii. Forest land
iii. Grassland
iv. Barren land
v. Built-up areas
vi. Water bodies

These categories represent the major components of the landscape and provide a basis for analysing land use changes over time. To examine land-use changes within the watershed, classified maps from different years were compared using change-detection techniques. Change detection analysis involves identifying differences in land use patterns between two or more time periods. By comparing the classified images from 1985, 1995, 2005, and 2025, it was possible to determine how different land-use categories have expanded or declined over time.

The change detection analysis enabled the identification of major trends in land transformation, including agricultural expansion, reductions in forest cover, and the growth of built-up areas. Quantitative measurements of land-use changes were calculated by determining the area occupied by each land-use category across different years. All spatial analysis and mapping procedures were carried out using GIS software. GIS tools were used to process satellite imagery, classify land-use categories, calculate area statistics, and generate thematic maps depicting land-use patterns within the watershed. The integration of remote sensing and GIS techniques provided an efficient approach to analysing spatial data and detecting land-use changes across the watershed. The resulting maps and statistical data provide valuable insights into the evolution of the Ghaggar watershed's landscape over time. These findings form the basis for evaluating environmental changes within the watershed and for understanding the implications of land-use transformation for watershed processes.

RESULTS AND ANALYSIS

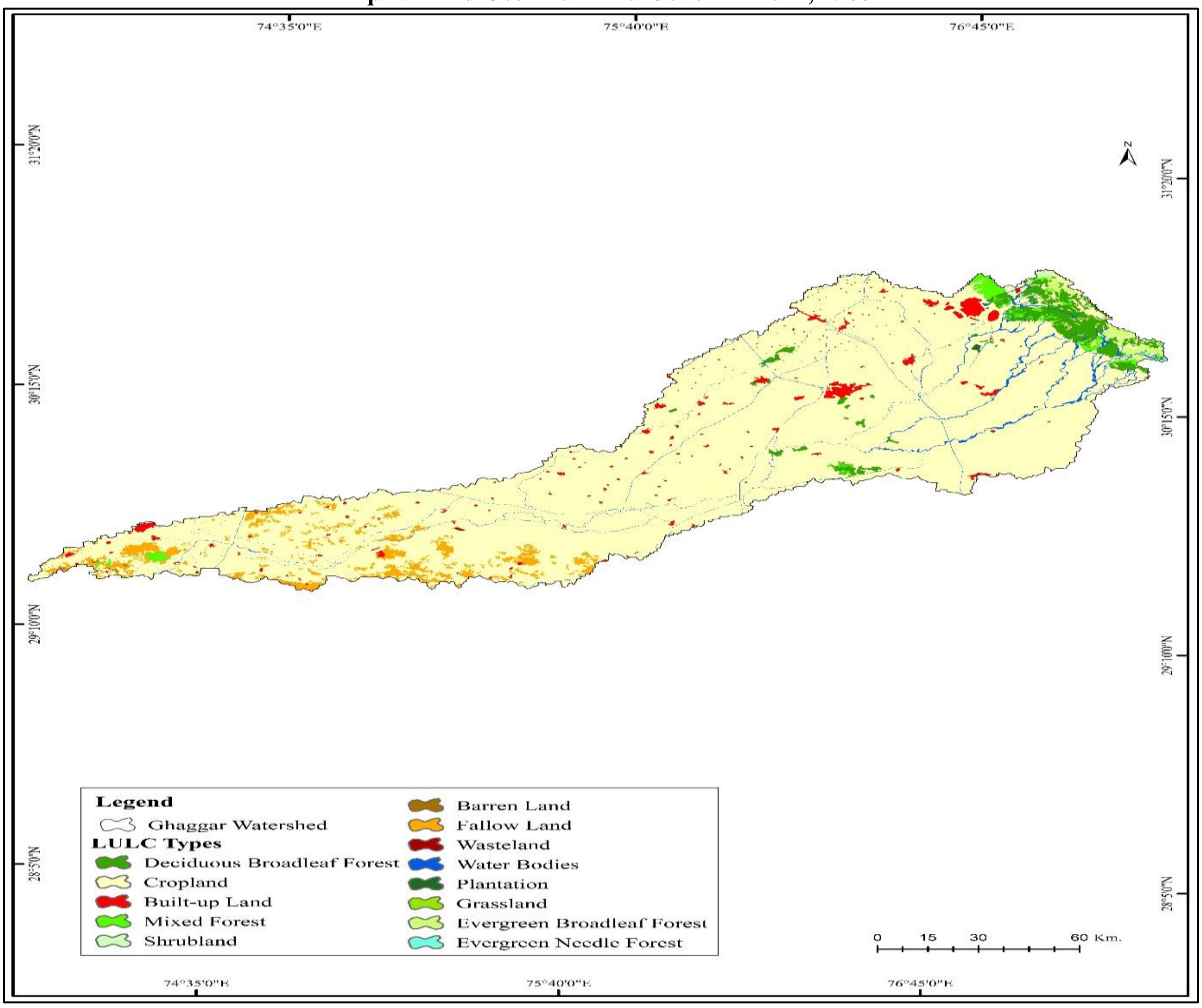
The analysis of land use and land cover (LULC) patterns in the Ghaggar watershed provides important insights into the spatial distribution and temporal transformation of the landscape over the past several decades. Using multi-temporal satellite imagery from 1985, 1995, 2005, and 2025, the study identified major land-use categories and evaluated changes within the watershed over time. The integration of remote sensing and GIS techniques enabled accurate mapping of land-use classes and facilitated quantitative assessment of land-use transitions within the basin.

Land Use and Land Cover Pattern in 1985

The land use and land cover map for 1985 represents an earlier stage of landscape conditions within the Ghaggar watershed. During this period, the watershed was largely characterised by natural vegetation and agricultural land. Agricultural land constituted the dominant land-use category, occupying a significant portion of the plains, where fertile soils and relatively gentle slopes provide favourable conditions for crop cultivation. The agricultural landscape consisted primarily of cultivated fields interspersed with rural settlements and irrigation infrastructure.

Forested areas were concentrated in the Shivalik foothills, where higher elevations and steep slopes limited extensive agricultural activity. These forested regions played an important ecological role in stabilising slopes, preventing soil erosion, and maintaining hydrological balance within the watershed. Grasslands were also present in certain parts of the watershed, particularly in transitional areas between forested zones and cultivated plains. Barren land and sparsely vegetated areas were distributed in smaller patches across the watershed, especially in regions with poor soil fertility or rugged terrain. Built-up areas were relatively limited during this period, primarily confined to small settlements and rural habitations.

Map 1: Land Use and Land Cover Pattern, 1985

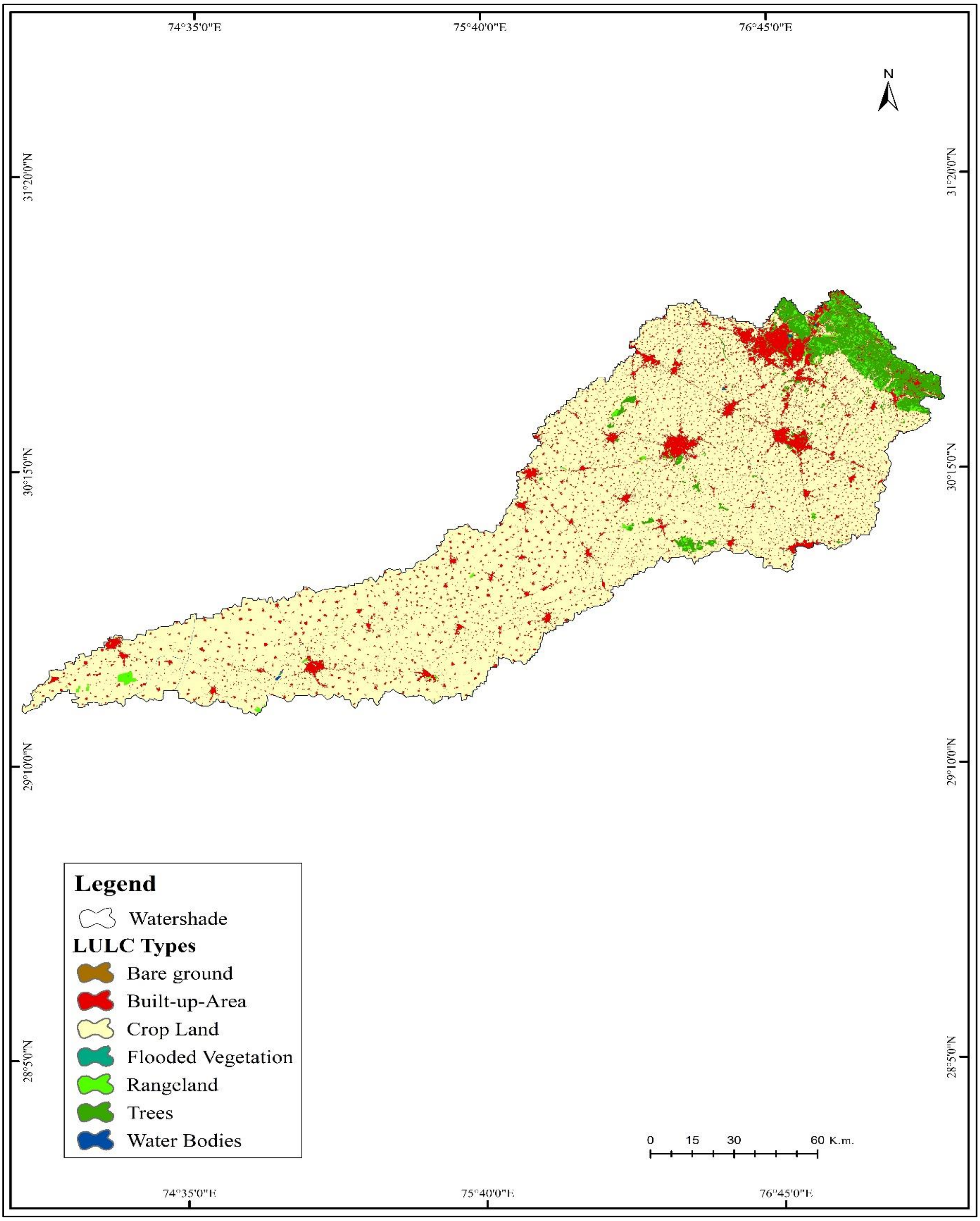


Source: Prepared by Research Scholar with the help of Arc-GIS

Land Use and Land Cover Pattern in 2025

The most recent land-use map for 2025 shows significant changes in the landscape of the Ghaggar watershed. Agricultural land remains the largest land-use category.

Map 2: Land Use and Land Cover Pattern, 2025



Source: Prepared by Research Scholar with the help of Arc-GIS

The spatial distribution of agricultural land has undergone considerable change due to shifting land management practices and population pressure. Built-up areas have expanded more rapidly during this period compared to earlier decades. Urbanisation and infrastructure development have contributed to the growth of towns and settlements within the watershed. The expansion of built-up areas has often occurred at the expense of agricultural land and open spaces, reflecting the increasing demand for residential and commercial land. Forest cover in the upper catchment areas has remained relatively stable in some regions due to conservation measures and environmental awareness programs.

Certain forest patches have continued to experience degradation due to ongoing human activities. Grasslands and barren lands have exhibited fluctuating trends in response to land-use conversion and environmental conditions. Some previously barren lands have been brought under cultivation through improved irrigation and agricultural practices, while other areas remain sparsely vegetated due to unfavourable terrain conditions.

Land Use Change Analysis

A comparison of the land-use maps of 1985 and 2025 reveals several important trends in landscape transformation within the Ghaggar watershed. The most significant trend observed in the study is the expansion of agricultural land, driven by rising food demand and advances in agricultural technology.

Another notable trend is the increase in built-up areas, reflecting population growth and economic development within the watershed. Expansion of settlements has led to the conversion of agricultural and open land into residential and commercial areas. At the same time, certain natural land cover types, such as forests and grasslands, have experienced a gradual reduction due to human activities. The decline of natural vegetation can increase susceptibility to soil erosion and environmental degradation, particularly in areas with steep slopes and fragile soils.

Environmental Implications of LULC Change

The observed changes in land use patterns have important environmental implications for the Ghaggar watershed. Expansion of agricultural land and reduction of natural vegetation can influence hydrological processes such as runoff generation, infiltration, and groundwater recharge. Increased agricultural activities may also contribute to soil erosion, particularly in areas with steep slopes and erodible soils. The growth of built-up areas can alter natural drainage patterns and increase surface runoff due to impervious surfaces. Such changes may increase flood risk and reduce groundwater recharge potential.

Monitoring land-use and land-cover changes is essential for developing sustainable watershed management strategies. The findings of this study highlight the importance of maintaining a balance among agricultural development, urban expansion, and the conservation of natural ecosystems to ensure long-term environmental sustainability within the Ghaggar watershed.

CONCLUSION

The present study analysed land use and land cover (LULC) changes in the Ghaggar watershed using multi-temporal satellite imagery and Geographic Information System (GIS) techniques. The analysis of satellite images of 1985 and 2025 enabled the identification of major land-use categories and the detection of significant landscape transformations within the watershed over the past four decades. The integration of remote sensing and GIS provided an efficient and reliable approach to mapping land-use patterns and evaluating their spatial and temporal changes. The results of the study reveal that agricultural land is the dominant land-use category in the Ghaggar watershed. The fertile alluvial soils of the plains and favourable climatic conditions have supported extensive agricultural development in the region. Over the study period, agricultural land has expanded gradually in several parts of the watershed, largely driven by population growth and rising demand for food production. The conversion of grasslands and barren lands into cultivated fields reflects the intensification of agricultural activities within the basin.

Another significant trend observed in the study is the steady increase in built-up areas. Urban expansion and infrastructure development have contributed to the growth of settlements within the watershed. Although built-up areas occupy a relatively smaller portion of the watershed compared to agricultural land, their expansion has been more rapid in recent decades. The development of towns, roads, and residential areas has transformed agricultural and open land into urban land uses. The study also indicates that natural vegetation and forest cover have experienced gradual changes over time. Forest areas are primarily concentrated in the upper catchment regions of the Shivalik foothills, where steep slopes and rugged terrain limit agricultural activities. Certain forest patches have been degraded by human activities, including grazing, fuelwood collection, and land conversion. The reduction of natural vegetation cover can increase the watershed's vulnerability to soil erosion and land degradation.

Grasslands and barren lands within the watershed have shown fluctuating trends during the study period. Some of these areas have been converted into agricultural land due to improved irrigation and land management practices, while others remain sparsely vegetated due to unfavourable terrain conditions or soil limitations. These land-use transitions reflect the dynamic interplay between environmental factors and human activities within the watershed. The observed land use changes have important environmental and hydrological implications. Changes in vegetation cover and expansion of agricultural and built-up areas can influence surface runoff, groundwater recharge, and soil erosion processes within the watershed. The reduction of natural vegetation in certain areas may increase susceptibility to soil erosion, particularly in regions with steep slopes and fragile soils. Similarly, the expansion of built-up areas can alter natural drainage patterns and increase the risk of flooding caused by impervious surfaces.

The findings of this study highlight the importance of continuous monitoring of land-use and land-cover changes in watershed environments. Remote sensing and GIS technologies provide powerful tools for detecting landscape transformations and assessing their environmental impacts. By identifying areas where significant land-use change has occurred, policymakers and environmental planners can design effective land-management strategies to protect natural ecosystems and promote sustainable resource use. For sustainable watershed management, it is essential to maintain a balance between agricultural development, urban expansion, and conservation of natural vegetation. Soil conservation measures, afforestation programs, and sustainable agricultural practices can help reduce environmental degradation and enhance the watershed's ecological stability. In addition, careful land use planning and regulation of urban expansion are necessary to minimise negative impacts on hydrological systems and agricultural land.

REFERENCES

[1] Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976). *A land use and land cover classification system for use with remote sensor data*. United States Geological Survey.

[2] Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment, 80*(1), 185–201.

[3] Horton, R. E. (1945). Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin, 56*(3), 275–370.

[4] Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources, 28*, 205–241.

[5] Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). *Remote sensing and image interpretation* (7th ed.). Wiley.

[6] Turner, B. L., Meyer, W. B., & Skole, D. L. (1994). Global land-use/land-cover change: Towards an integrated study. *Ambio, 23*(1), 91–95.

[7] Weng, Q. (2012). Remote sensing of land use and land cover change in urban environments. *International Journal of Remote Sensing, 33*(3), 613–626.