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Land Use and Land Cover Analysis in Afghanistan

[1]Ahmad Millad Ibrahim Khil, [2] C. Sarala

M.Tech Student, Department of Civil Engineering, Jawaharlal Nehru Technological University, India

Professor of Water Resources, Department of Civil Engineering , Jawaharlal Nehru Technological University, India

Email - [1]ahmad.millad1676@gmail.com, [2] sarala2006@jntuh.ac.in

Abstract: *Informed planning and sustainable land management depend on tracking changes in land use and land cover (LULC). This study examines LULC dynamics in Afghanistan, a region that is experiencing substantial environmental and human-induced change. For the years 2000, 2010, 2020, and 2024, the primary goals are to create comprehensive LULC maps for the area . Using Landsat satellite imagery, the study classified the data using supervised methods and examined the relative contributions of different forms of land cover. Significant changes across many LULC categories were found in the study. Consistent growth in urban and built-up regions was a reflection of continued urbanization and rising human activity. Croplands grew, reaching 14,940.67 km² in 2020 from 12,985.57 km² in 2000, before leveling off. The amount of bare land, on the other hand, decreased dramatically from 338,190.07 km² in 2000 to 277,616.56 km² in 2024, demonstrating efforts at vegetation restoration and land reclamation. Grasslands, wooded savannas, and savannas also showed variations, while wetlands and confined shrublands had significant declines, suggesting possible environmental problems. A small increase in water bodies was observed, indicating either climatic changes or better management of water resources. This study offers important insights into the LULC trends in the region and draws attention to the dynamic changes in Afghanistan's geography. The results are a useful tool for policymakers and environmental planners, providing direction for enacting sustainable land-use policies and lessening the effects of LULC modifications.*

Key Words: *Land use/ cover, Remote Sensing, Geographic Information System.*

1. INTRODUCTION:

Changes in land use and land cover (LULC) play a crucial role in shaping the management of natural resources, maintaining ecological balance, and preserving environmental systems. Understanding and monitoring these changes are essential, particularly in areas experiencing rapid social, economic, and environmental shifts. Over the past few decades, global landscapes have been significantly altered due to urban expansion, agricultural growth, and environmental changes. Afghanistan, with its diverse geography and ecosystems, has undergone substantial LULC changes, impacting its water resources, natural ecosystems, and socioeconomic structures. Examining these transformations provides critical insights into their causes and effects, serving as a foundation for creating sustainable development plans.

Geographic Information Systems (GIS) and remote sensing (RS) are powerful tools for analyzing LULC changes. These technologies enable accurate analysis of spatial and temporal data derived from satellite imagery. By using these methods, researchers can create detailed land cover maps, detect patterns of change, and predict future LULC trends. The integration of GIS and RS has become a reliable, cost-effective approach to studying complex LULC dynamics in various regions.

This study focuses on Afghanistan, a country characterized by a mix of mountains, agricultural areas, and arid landscapes. It seeks to examine LULC changes between 2000 and 2024 using GIS and satellite imagery. The primary objectives include generating detailed LULC maps for the study area and conducting a thorough analysis of land cover changes within the specified time frame. The findings of this research aim to enhance understanding of Afghanistan's LULC patterns and support sustainable land use planning. By providing insights into spatial and temporal trends, this study will aid policymakers, environmental planners, and stakeholders in formulating strategies that balance environmental sustainability with development goals.

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2. LITERATURE REVIEW:

Geospatial technologies, such as Geographic Information Systems (GIS) and remote sensing (RS), have revolutionized the ability to monitor and assess land use and land cover (LULC) changes, supporting sustainable development initiatives. A study by İlgi Atay Kaya et al. (2020) in Bandırma, Turkey, analyzed Landsat images from 1987, 2003, and 2019 to track three decades of LULC changes. The research found forest expansion and wetland reduction, with agricultural lands increasingly converted into built-up areas near towns, transport routes, and industrial zones, particularly around the Manyas Lake Ramsar site, underscoring the need for effective land management.

In another study, Nitin Mishra et al. (2019) investigated urban growth in Doon Valley, India, using satellite data from 1995 to 2015. Results showed a rise in urban and agricultural areas, coupled with a decline in green spaces and water bodies. Similarly, Ripudaman Singh et al. (2021) studied Central Haryana, India, using data from 1975 to 2020, identifying significant urban and agricultural expansion alongside a reduction in vegetation. These studies highlight GIS critical role in shaping sustainable land use policies and preserving ecosystems.

3. OBJECTIVE OF THE STUDY:

Using remote sensing data and GIS techniques, the study aims to create land use and land cover maps for the study area (Afghanistan) by classifying different types of land cover and analyzing their spatial distribution.The study uses GIS and remote sensing to produce intricate maps of Afghanistan's land cover and land usage. It focuses on recognizing and categorizing different forms of land cover, including metropolitan areas, water bodies, and vegetation. To find patterns and trends, the spatial distribution of these traits is examined. This method offers crucial data to help Afghanistan's land management and planning efforts be successful.

Afghanistan is a landlocked country in South-Central Asia that is well situated between the Middle East, Central Asia, and South Asia. It is located between latitudes 29° and 39° North and longitudes 60° and 75° East. Afghanistan is bordered to the north by Turkmenistan, Uzbekistan, and Tajikistan, to the east and south by Pakistan, and to the west by Iran. Afghanistan's importance as a crossroads for various cultural and economic contacts in the region is further highlighted by the fact that it is connected to China by a small northeastern corridor. Afghanistan, which covers an area of over 652,000 square kilometers, has a diverse terrain that includes lush plains, enormous deserts, and rocky mountain ranges.The country's climate and accessibility are shaped by the Hindu Kush mountain range, which passes through its center. These mountains progressively give way to agricultural plains in the north, fruitful valleys in the east, and dry deserts in the southwest. Afghanistan's varied height and geography result in a variety of temperature zones, ranging from arid and semi-arid weather in lowland areas to harsh winters in higher locations. Land use and land cover (LULC) patterns are greatly impacted by the nation's climate and geographic variety, underscoring the significance of tracking these changes for sustainable resource management. Afghanistan is vulnerable to environmental problems such soil erosion, deforestation, and drought due to its location and natural features, which emphasizes the need for a thorough analysis of its land use and environmental dynamics.

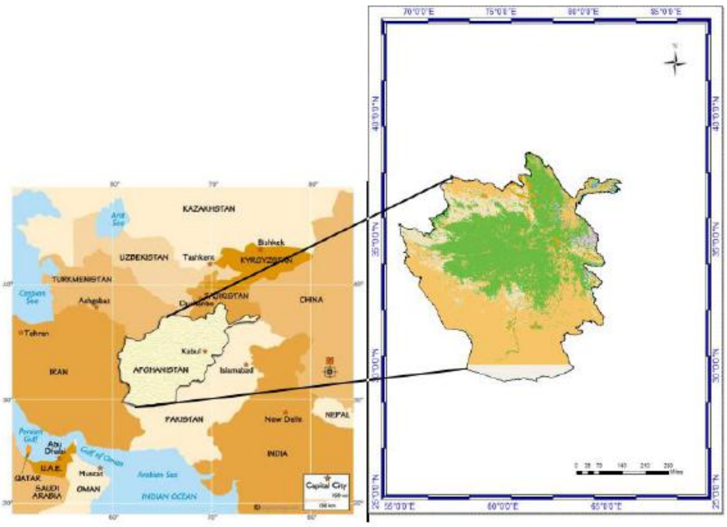

Fig3.1: Location Map of the Study Area

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4. RESEARCH METHODOLOGY:

A. Data Sets

The research area's land use and land cover data came from dependable sources, including DIVA-GIS and the United States Geological Survey (USGS). Comprehensive land cover and satellite imagery databases from the USGS are frequently utilized for environmental monitoring and analysis. For geographic study, DIVA-GIS provides worldwide spatial data, such as geographic borders and land cover classifications. Because of their accuracy and applicability, these datasets were selected to guarantee that the research on land use changes is grounded in reliable and up-to-date geospatial data.

Table 4.1: Data used

Variables	**Source**
Land use/ Land cover	USGS Science for the changing world https://www.usgs.gov/
Digital study area	DIVA-GIS https://diva-gis.org/

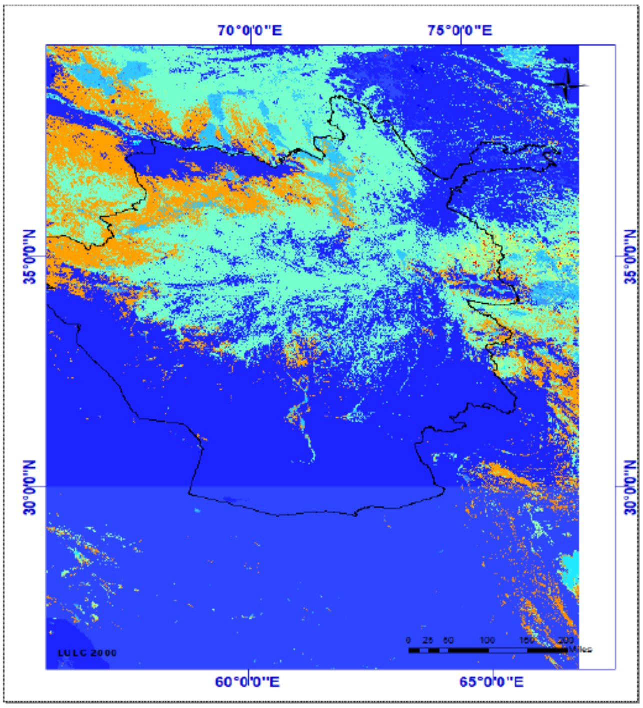

Fig 4.1: Satellite images of the year 2000

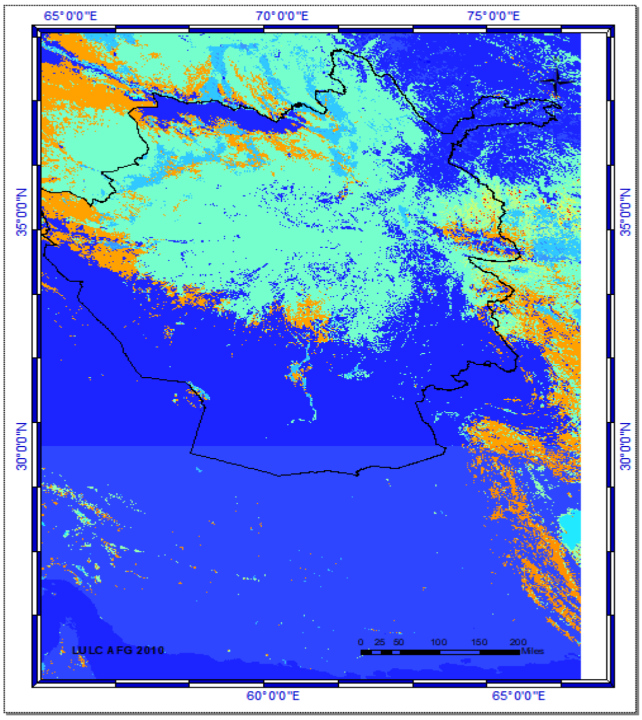

Fig 4.2: Satellite images of the year 2010

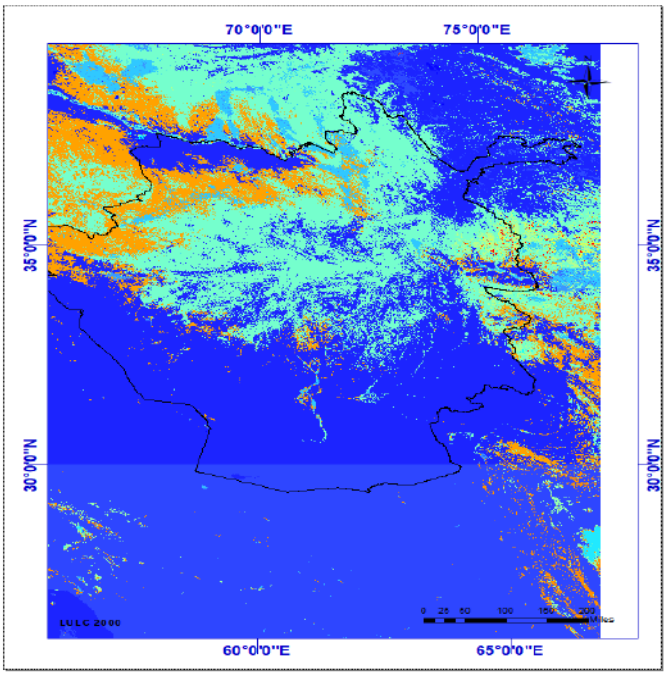

Fig 4.3: Satellite images of the year 2020

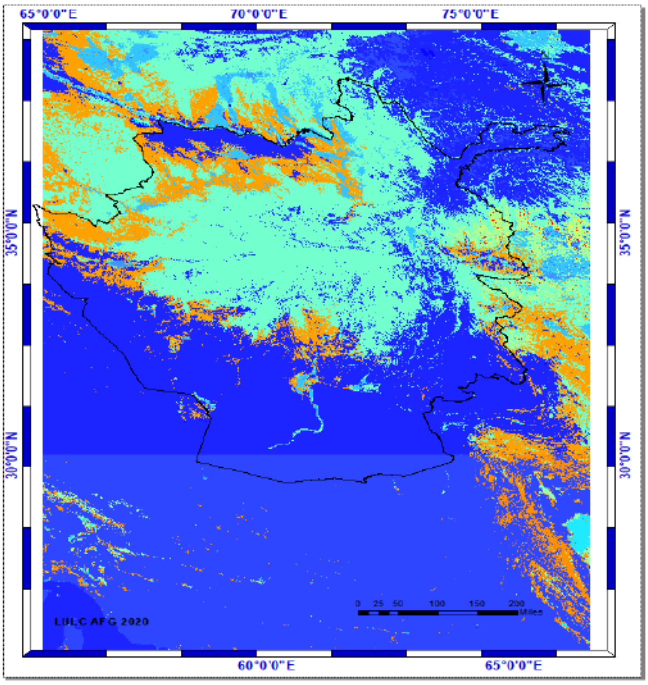

Fig 4.4: Satellite images of the year 2024

B. RESEARCH TECHNIQUE

This study on "Land Use and Land Cover Analysis in Afghanistan" employs a thorough methodology that combines remote sensing and GIS tools. Satellite data from 2000, 2010, 2020, and 2024, including sources like Landsat, MODIS, and Sentinel, are used to assess changes in land cover across Afghanistan. GIS layers, such as elevation, hydrology, and administrative boundaries, are integrated to provide a broader context. The data is preprocessed to enhance accuracy through steps like cloud removal, image alignment, and atmospheric and radiometric corrections. Supervised classification techniques are applied to categorize the land into types such as urban areas, forests, grasslands, wetlands, croplands, and water bodies. Advanced machine learning algorithms, including Random Forest and Support Vector Machine, are used to improve the precision of classification, with training datasets sourced from high-resolution images and ground-truth data. The results are validated using confusion matrices and accuracy assessments. This methodology, incorporating both spatial and temporal analysis, provides a comprehensive understanding of land cover changes in Afghanistan over the study period.

5. RESULTS :

The analysis of land use and land cover (LULC) changes in Afghanistan from 2000 to 2024, using remote sensing and GIS technologies, reveals significant transformations influenced by both socioeconomic and environmental factors. The findings show a clear trend of urban expansion, agricultural development, and shifts in natural vegetation. Urban growth is concentrated around major cities, while agricultural lands have expanded into areas that were once natural or semi-natural. Additionally, deforestation and wetland loss are evident, driven by both climatic factors and human activities like agriculture and logging. The study also identifies regions where urbanization has accelerated, largely due to population growth and infrastructure improvements. These changes highlight the complex interplay between human land use and environmental shifts, stressing the need for sustainable land management approaches to balance development with conservation.

A. Land use/ cover status

The percentage cover of barren areas increased little from 54.83% in 2000 to 55.63% in 2024, indicating their continued dominance of the landscape. This indicates that arid and semi-arid conditions are still common in Afghanistan, with little vegetation development in these regions. Overgrazing, deforestation, or climate change-related land degradation could be the cause of the marginal increase.

Grasslands had significant expansion, growing from 194,766.83 km² in 2000 to 239,387.14 km² in 2024, and their cover percentage increased from 31.59% to 38.87%. Due to deforestation, agricultural land abandonment, or altered precipitation patterns, forests and croplands are probably being converted into grasslands, which is the cause of this trend.

Croplands: from 2000 and 2024, croplands decreased from 12,985.57 km² to 12,557.53 km². Reduced agricultural activity was reflected in the percentage cover, which likewise decreased from 2.10% to 2.03%. Water scarcity, soil erosion, or sociopolitical instability that affects farming methods could be the cause of this decline. Built-up and urban areas: between 2000 and 2024, urban areas grew slightly, from 1,184.71 km² to 1,195.43 km². At roughly 0.19%, the percentage cover stayed almost unchanged. Slow growth suggests limited urban expansion, which may be hampered by lack of infrastructure development in many areas, geographic limitations, or conflicts.

Open Shrublands: Over time, open shrublands decreased from 62,694.71 km² in 2000 to 48,118.10 km² in 2010, and then increased to 76,227.01 km² in 2024. This unpredictability may be due to changes in the climate, the reallocation of grassland or barren regions, or land recovery processes. Wetlands and Water Bodies: There were minor increases in the area covered by wetlands and water bodies, which may be the result of better water resource management or hydrological changes brought on by climate change. Between 2000 and 2024, wetlands expanded from 294.29 km² to 47.65 km², while water bodies grew from 21.89 km² to 33.70 km².

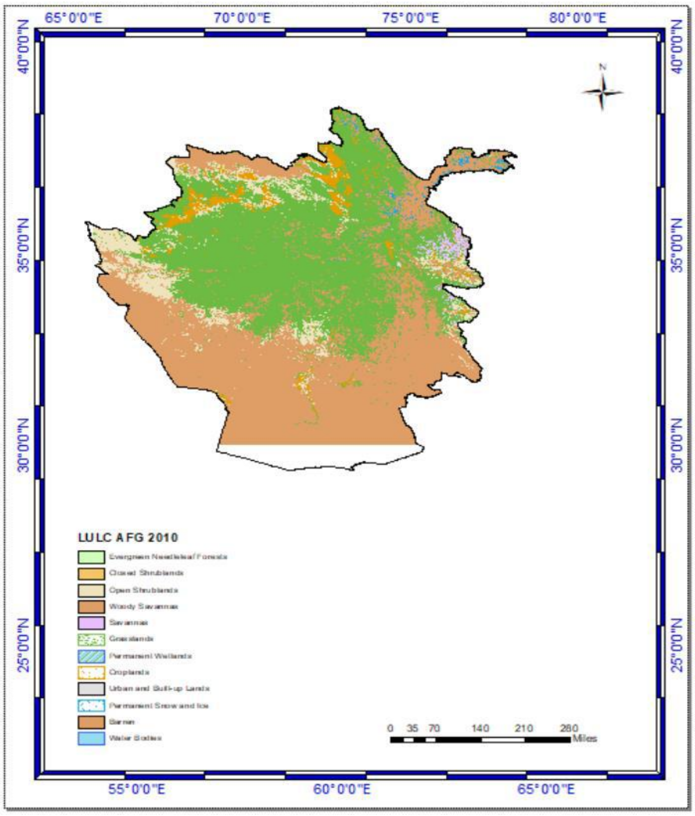

Fig 5.1: LULC map of the Study Area describe the year 2000

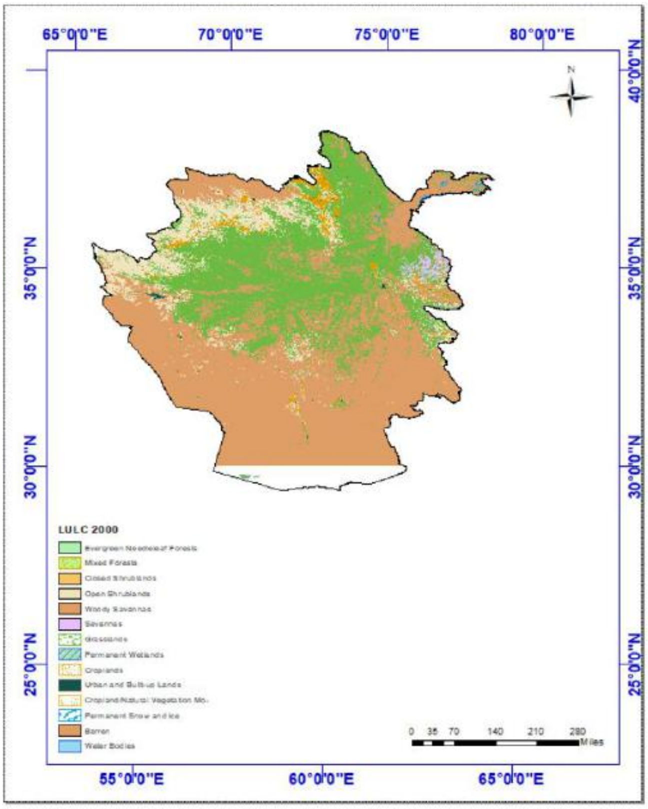

Fig 5.2 :LULC map of the Study Area describe the year 2010

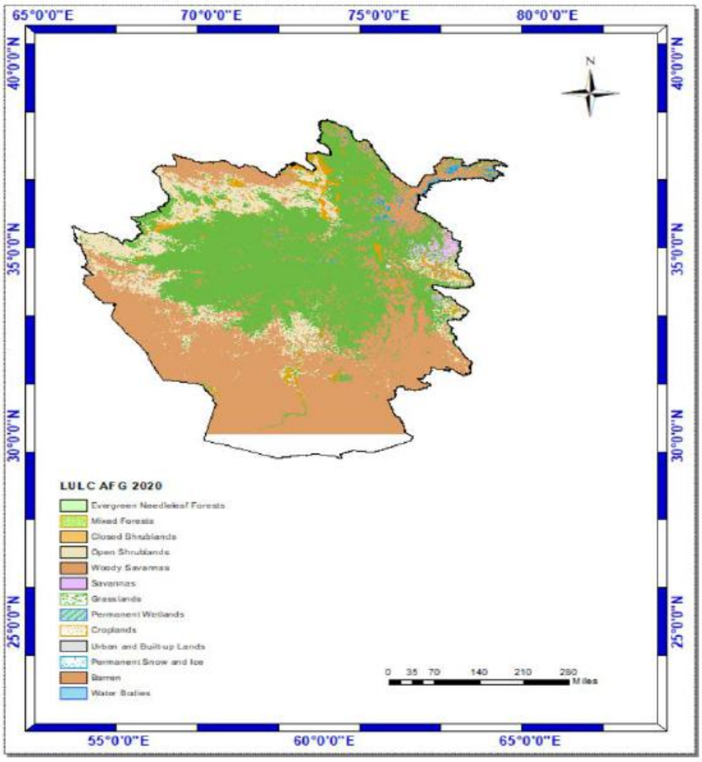

Fig 5.3: LULC map of the Study Area describe the year 2020

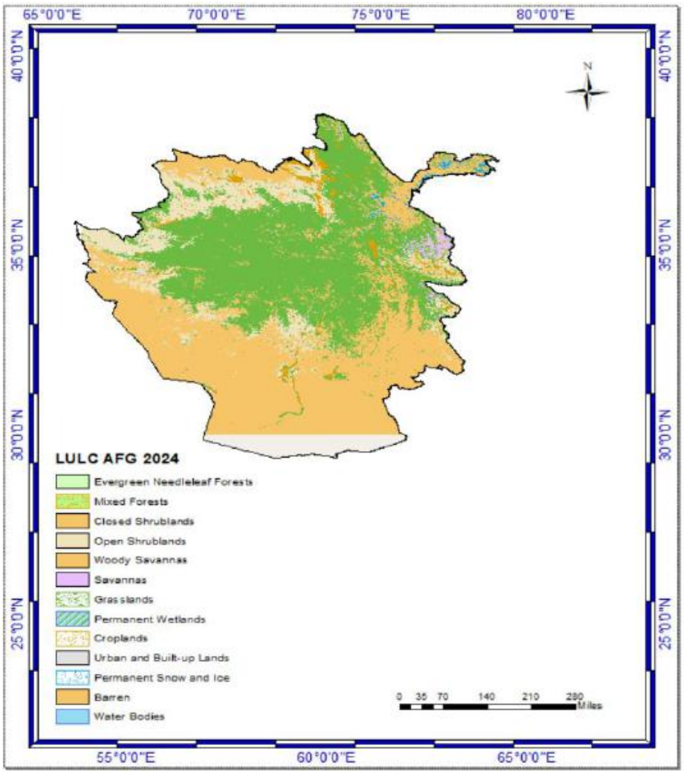

Fig 5.4 :LULC map of the Study Area describe the year year 2024

Table 5.1: The LULC Classifcation for the Area (2000-2024)

No	LULC CLASSIFICATION	Area in Km^2	Area Km^2	Area in Km^2	Area in Km^2
1	Evergreen Needleleaf Forests	234.8369	176.2348	195.9834	210.7948
2	Mixed Forests	-	-	0.4293	0.6440
3	Closed Shrublands	188.4703	31.3402	27.9056	29.8376
4	Open Shrublands	62694.7147	48118.1029	74713.2392	76227.0121
5	Woody Savannas	426.0975	409.7834	455.5057	498.8668
6	Savannas	4439.1414	4797.3177	5006.9136	5010.3921
7	Grasslands	194766.8333	265391.5392	245019.3520	239387.1378
8	Permanent Wetlands	294.2907	10.5480	30.0522	47.6542
9	Croplands	12985.5672	23376.7588	14940.6730	12557.5324
10	Urban and Built-up Lands	1184.7102	1186.8331	1195.0048	1195.4342
11	Cropland/Natural Vegetation Mix	0.2417	-	-	-
12	Permanent Snow and Ice	1111.0732	3420.8596	3840.4583	3721.9676
13	Barren	338190.0747	278597.7843	271079.9883	277616.5600
14	Water Bodies	21.8952	31.1255	32.6281	33.7014

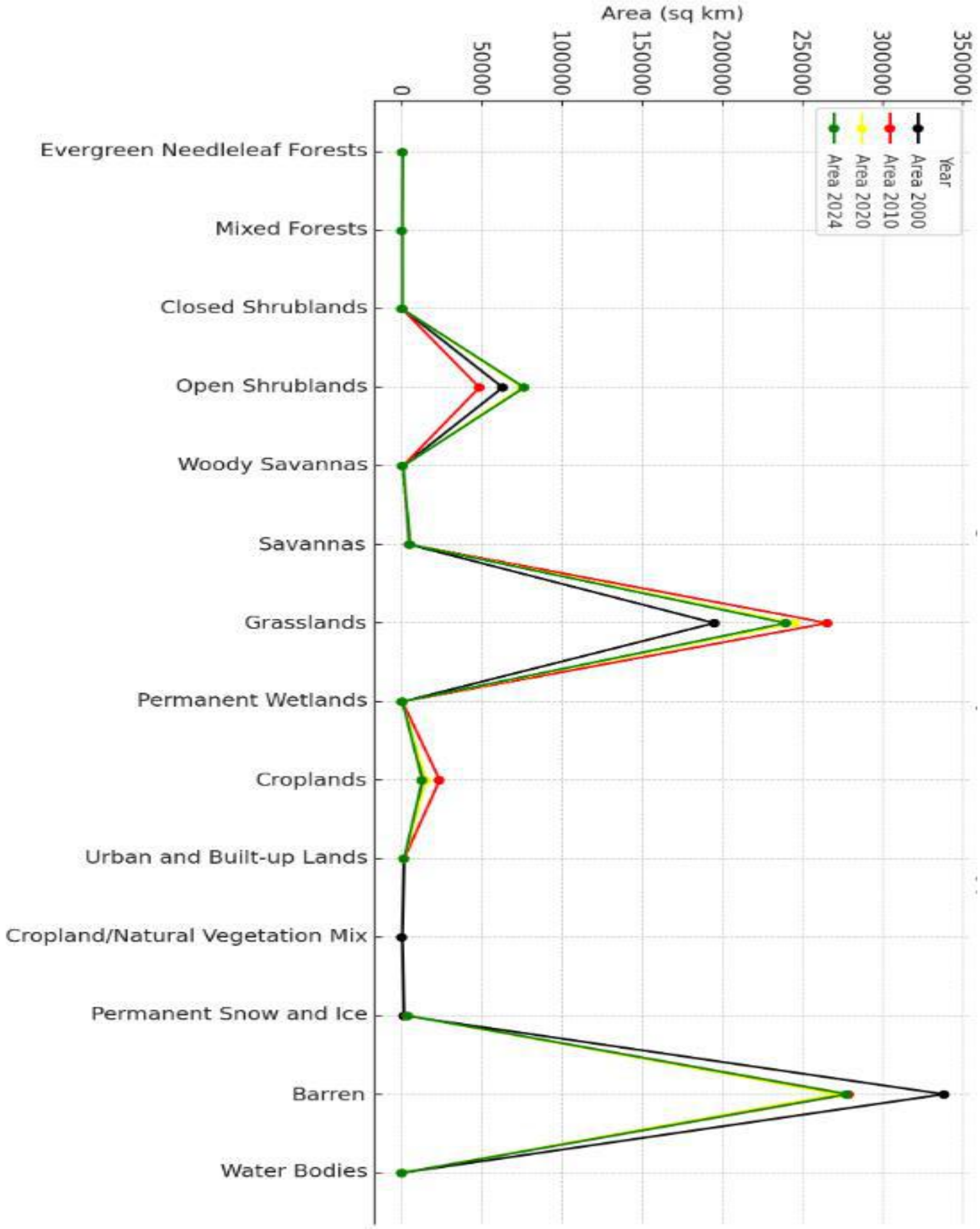

Fig 5.5 : Area change over time by land cover type

6. CONCLUSION:

Using remote sensing data, GIS methods, and ArcGIS software for spatial analysis and mapping, this study looked at the changes in Afghanistan's land use and land cover (LULC) between 2000 and 2024. The results show significant changes in the terrain caused by both human and natural forces. The main alterations are a decrease in croplands, a rise in grasslands and bare areas, little urbanization, and fluctuating patterns in water bodies and shrublands.

Critical issues including the effects of climate change, deforestation, decreased agricultural productivity, and sociopolitical instability are highlighted by these trends.
Accurate visualizations, hotspot studies, and the identification of spatial patterns of change were all made possible by the usage of ArcGIS. The dynamics of land modification throughout time were better understood thanks to these techniques. The study emphasizes how urgently sustainable land management techniques are needed to combat environmental deterioration, boost agricultural resilience, and guarantee efficient use of water resources. Urban areas' restricted growth also highlights how crucial it is to improve governance and infrastructure in order to promote economic growth. In order to help planners, environmental managers, and decision-makers create plans that support sustainable land use and development in Afghanistan, this study presents these findings.

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