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Detection of Land Use and Land Cover Change in Jammu District using Remote Sensing and GIS Techniques

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Abstract: Jammu District has under gone a massive change in its land use and land cover in last 30 years. It has grown 2.5 times in its population in past 3 decades and simultaneously the infrastructure supporting the population growth has increased altering the overall land cover. With the growing population the demand for arable land, infrastructure development, land resource management becomes an obligation for effective optimization of resources and policy formulation and implementation. In this research the land use land cover change detection and analysis in last 30 years from 1993 to 2023 is attempted for the first time. The classification is achieved by supervised image classification of Landsat 5 and Landsat 9 Level 1 imagery acquired from USGS. The classification scheme is developed for five classes viz. Water Bodies, Built-Up Area, Agriculture, Barren Land and Forests. Change detected is -3% for water bodies, +5% for built-up area, +29 % for agricultural land, -22% for barren land, -9% for forest cover. The percentages are calculated of the total area. The overall accuracy is maintained at 87% for year 1993 and 78% for year 2023.
Keywords: Land Use/Land Cover (LULC) Classification, Land Use Land Cover Change, Supervised Image Classification, Jammu District, Maximum Likelihood Classification, Landsat Imagery.

I. INTRODUCTION

In past 100 years of rapid urbanization and anthropogenic action, the earth surface has undergone a drastic change. With increase in population, human settlements have increased, forest cover has decreased and a substantial area has been converted to agriculture to meet the demands of growing population. Similarly, the Water Bodies such as Lakes, Rivers and Wetlands have also shrunk due to human encroachment and increased water demands. All the resources on Earth are overstretched to meet the increasing demands, causing a massive change on earth's surface.

Such a rapid and unsustainable change on earth surface requires effective Planning and Monitoring to access its impact on environment and plan its mitigation. Conventionally, physical surveys were done to calculate the areas of Forest, Agricultural Land and Settlements and calculate their change from time to time. But such surveys are time and resource intensive and are prone to errors when extended to large areas. To solve this remote sensing and GIS techniques can be employed to map earth's surface, analyze data and create scientific models which can be helpful in understanding the different land classes.

In India there is only 2.3 % of terrestrial land area, while it has 17% of the global population and 11% of the global livestock. The pressure on the Indian land mass is almost 4-6 times the global average. In the last 40 years the area under crop has almost remained constant at around 140±2.0 Mha (Roy and Murthy, 2009). To sustain the ever-increasing population there is need of intensive agriculture, which annually withdraws around 2000-2500 x 106 m³ of water, thereby putting a stretch on existing water resources. In view of all this, due attention has to be given to develop national policies of various sectors of land management that involves Land Use change detection.

II. STUDY AREA

The study area of Jammu is Winter Capital of Union Territory of Jammu and Kashmir. It is situated between 32° 55' and 33° 45' north latitude and 74° 33' and 75° 23' east longitude. The district consists of both plains and hilly terrain. Tawi River and a major tributary of Chenab are major water resources which flow through it.

The plains of Jammu city, located in the southern part of the district, are relatively flat and fertile. These plains are suitable for agriculture and are utilized for the cultivation of crops such as wheat, rice, maize, pulses, and vegetables. The agricultural activities in the plains contribute significantly to the local economy.

The terrain of northern part is majorly hilly. It is surrounded by hills and mountains, forming part of the Shivalik Range. The forest cover is habitat for diverse flora and fauna.

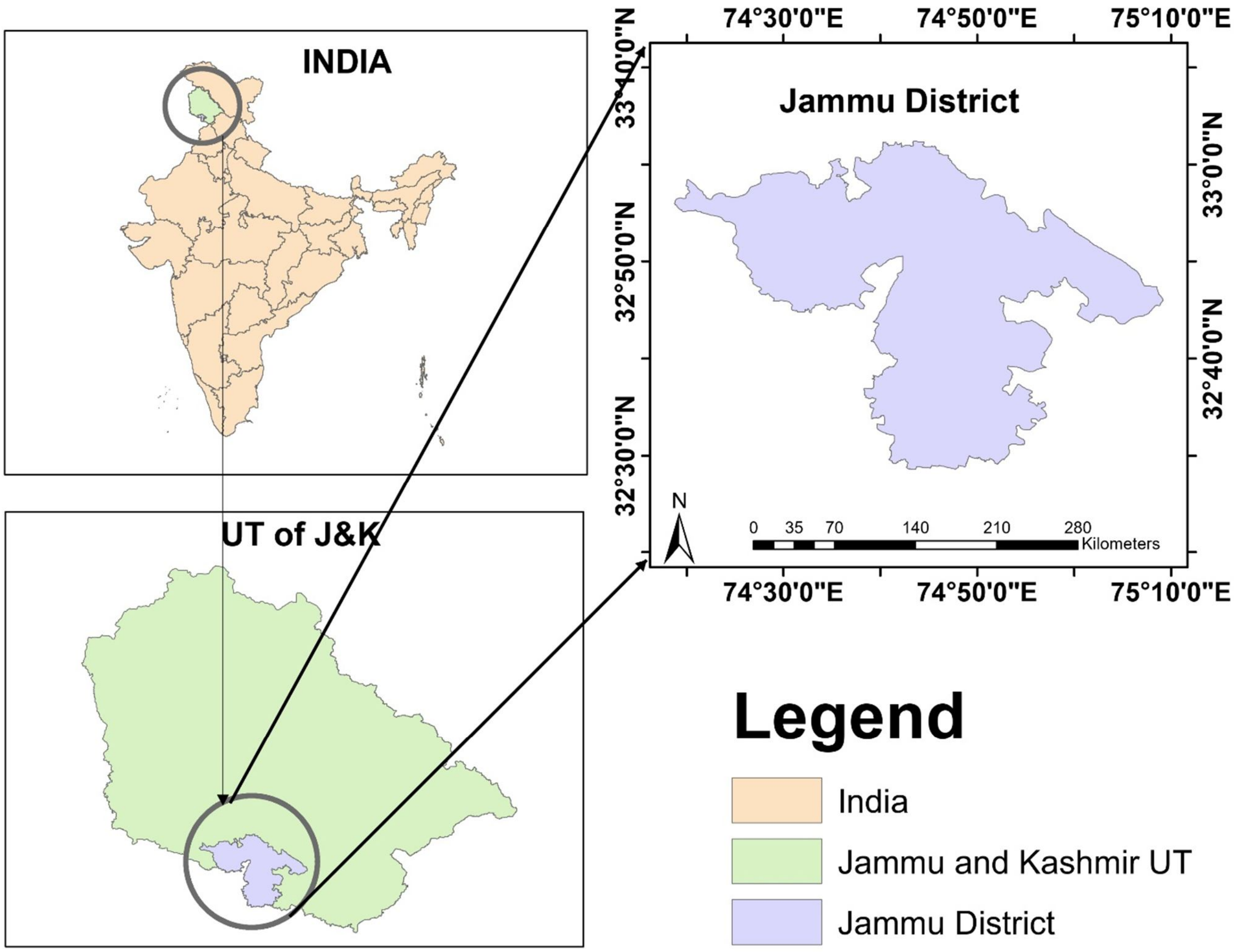

Fig. 1 Geo-referenced Map of Jammu District

III. OBJECTIVES

The following specific objectives are pursued in this research order to achieve the aim:

1) To create a land use and land cover map of 1993 using Landsat-4 MS imagery.
2) To create a land use and land cover map of 2023 using Landsat-9 TM imagery.
3) To create geo-referenced Shape file of Jammu District by digitizing physical map.
4) To perform accuracy assessment of the created maps.
5) To create Change Detection Map depicting change in different classes in 30 years.
6) To calculate the area under each of the land classes and calculate the area converted from one class to another.
7) To analyze the LULC change data.

IV. JUSTIFICATION OF RESEARCH

The population of District Jammu has grown by 200% in last 3 decades and to support the growing population the infrastructure has also developed, altering the existing the land use/land cover of the district. Hence, a comprehensive research is required to be done to map the changes in various classes of land and study its impact.

V. METHODOLOGY

The methodology employed consists of collection of Geo-spatial data from satellite and processing it into final form.

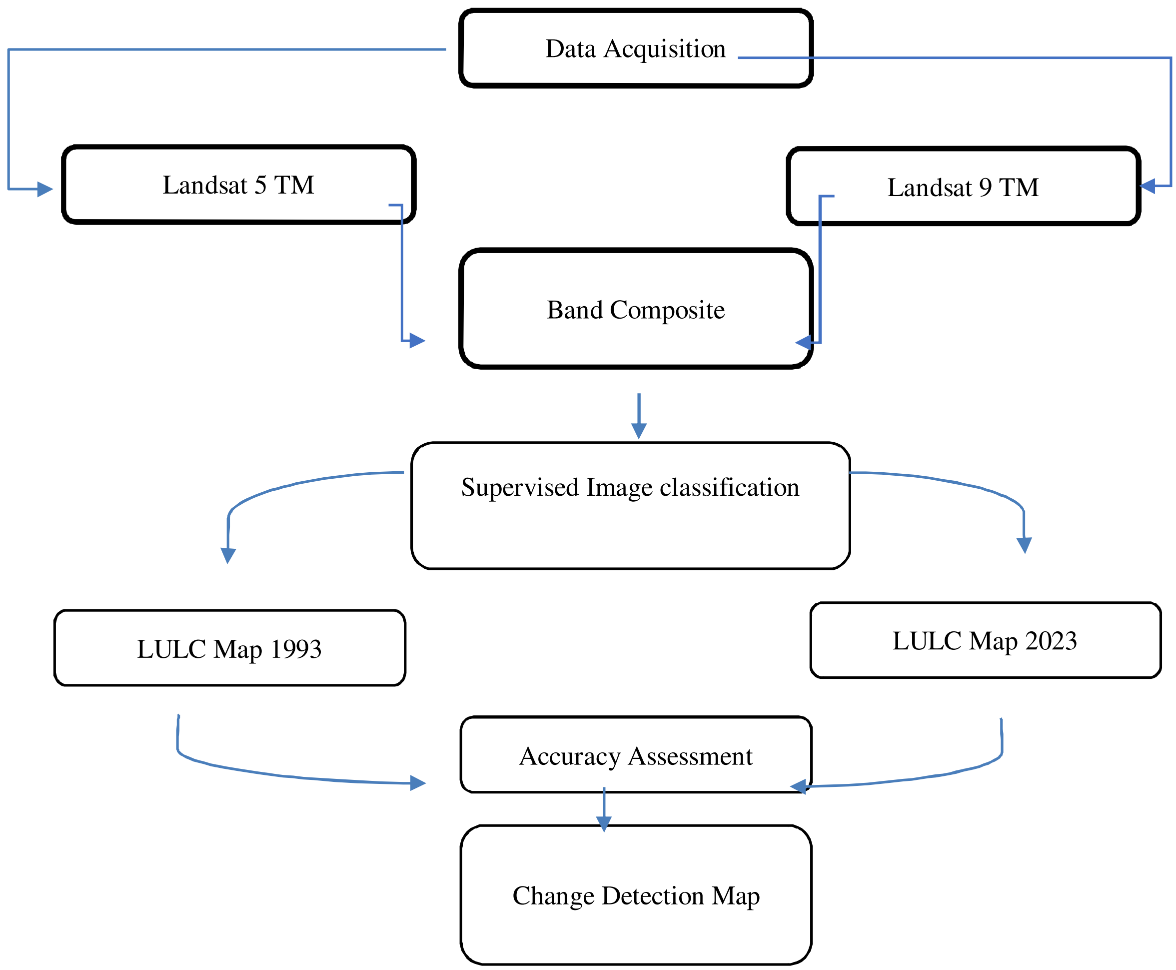

Fig. 2 Flow Chart of Methodology

A. *Data Acquisition*

Data of satellite imagery is collected from USGS (United States Geological Survey). Following is the detail of data acquired.

TABLE I
DETAILS OF THE SPATIAL DATA USED

S.No.	Data Type	Sensor	Date	Bands	Path/Row	Resolution	Cloud Cover	Source
1.	Landsat 5 TM Imagery	Thematic Mapper (TM)	6/12/1993	1,2,3,4	149/37	30m	1%	USGS
2.	Landsat 9 OLI Imagery	Operational Land Imager (OLI) and Thermal Infra Sensor (TIRS)	22/5/2023	1,2,3,4,5,6,7,8,9	148/37	Band 1-7 are 30m. Band 9-11 are 15m.	1.26%	USGS

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B. Band Composite

All the bands are combined to form Band composite with Image Processing tools. It is done by merging separately 7 bands of Landsat 5 and 9 bands of Landsat 9.

The band composite is then checked for different colour codes of RGB.

C. Supervised Image Classification

In Supervised Image Classificationis training samples or reference data is provided to train a classification algorithm or model, which then assigns the remaining pixels in the image to the defined classes based on their spectral characteristics.

It is developed for the following 5 classes in this research:

TABLE II

DESCRIPTION OF DIFFERENT LAND CLASSES

S.No.	Land Class	General Description of the Land Class
1.	Water Bodies	Areas covered by Rivers, Streams, Lakes and Water Channels
2.	Built-Up Area	Settlements, City/Town concentrations, Developed Areas and Roads
3.	Agriculture	Irrigated Agricultural Area and Agricultural fallow land.
4.	Barren Land	Areas devoid of vegetation: sediments, exposed rocks, landslide zones, degraded forest areas etc.
5.	Forests	Thick Vegetation, grooves of evergreen and deciduous trees, Shrubs and Area under Agroforestry

D. Maximum Likelihood Classification

It is done for Supervised Image classification after the Training Sample is made. It is based on statistical principles and aims to assign each pixel in an image to the most likely class based on its spectral characteristics. The Maximum Likelihood Classification algorithm assumes that the pixel values for each class in the image follow a specific statistical distribution, often assumed to be a multivariate normal distribution. The algorithm estimates the parameters of these distributions from the training samples provided by the user, such as mean vectors and covariance matrices for each class.

E. Extraction of Study Area

The study area shape file is created by digitizing the physical map and is then extracted from the classified layer of the map using the Masking tools.

F. Land Use Land Cover Map

The prepared Land Use Land Cover map is then inserted with scale, legends, latitude and longitude etc for final processing.

VI. RESULTS AND DISCUSSIONS

Results obtained from the Supervised Image Classification of the Satellite Imagery is represented in Fig 3, Fig 4, Fig 5, Fig 6 and Fig 7 and numerically in Tables III, IV, V, VI and VI.

A. Land Use Land Cover 1993

Land Use Land Cover of 1993 is shown in Fig.3 and Fig. 4 and the corresponding data is tabulated in the following tables.

TABLE III

RESULT OF LAND USE LAND COVER 1993

Category	Area (Sq. km.)	Percentage
Water Bodies	132.581782	6%
Built-Up Area	96.213851	5%
Agriculture	512.374671	25%
Barren Land	508.091127	24%
Forests	846.317841	40%

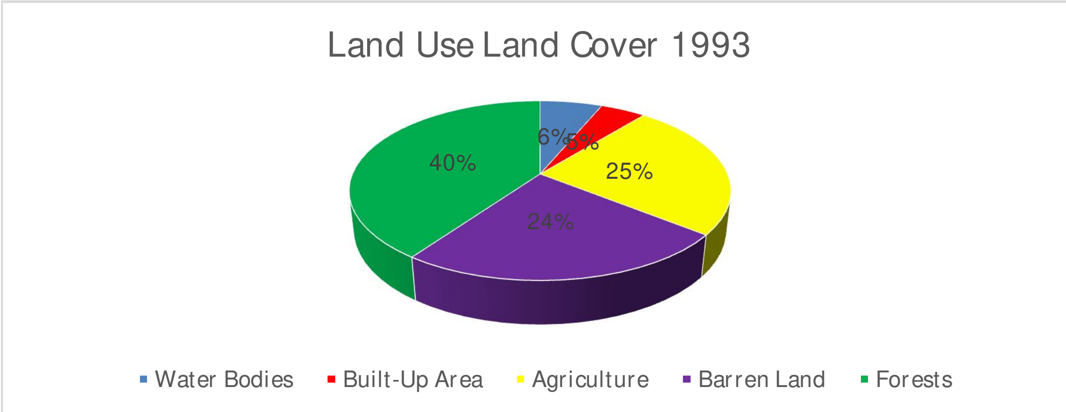

Fig.3 Land Use Land Cover of year 1993

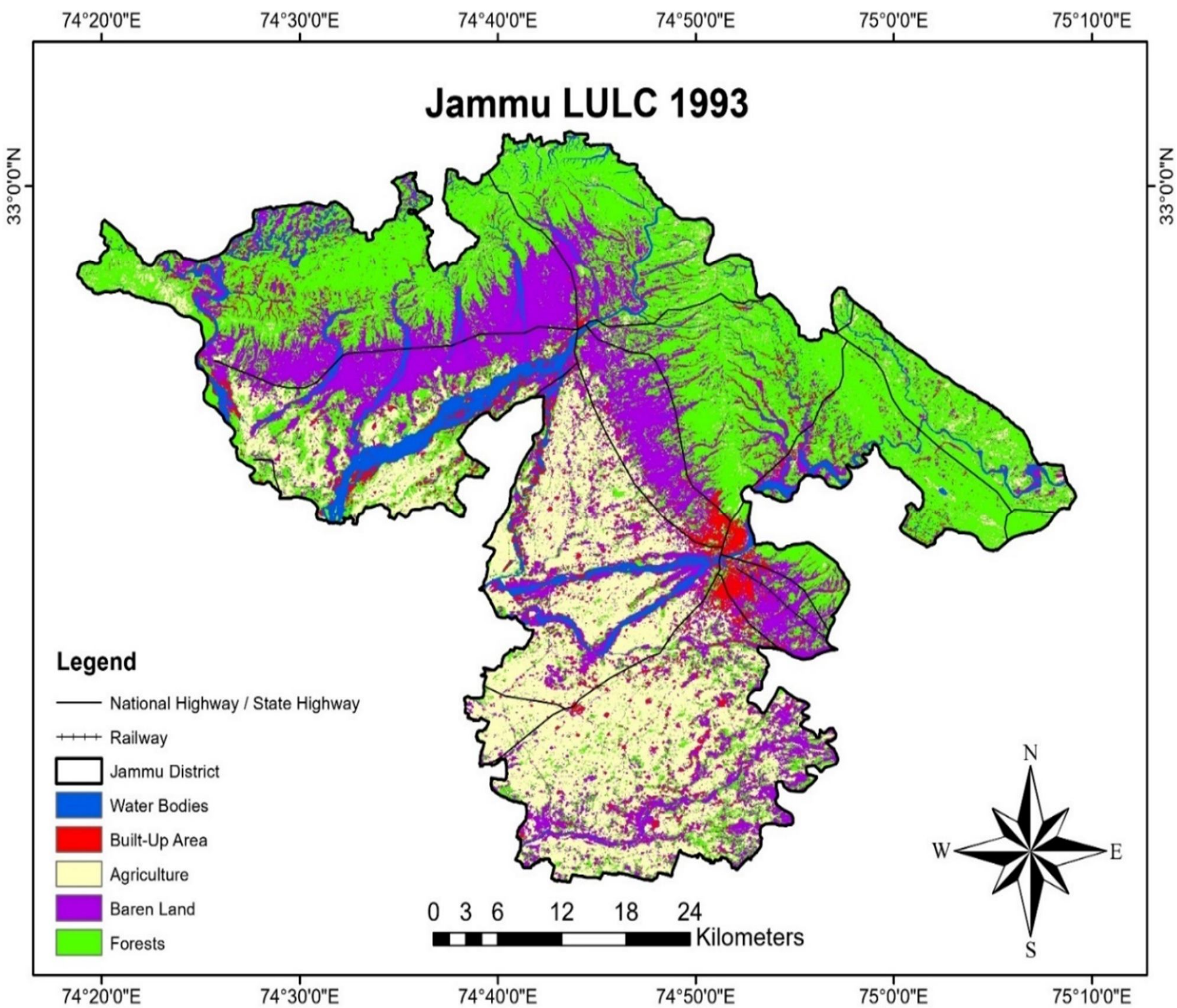

Fig. 4 Land Use and Land Cover Map of 1993

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B. Land Use Land Cover 2023

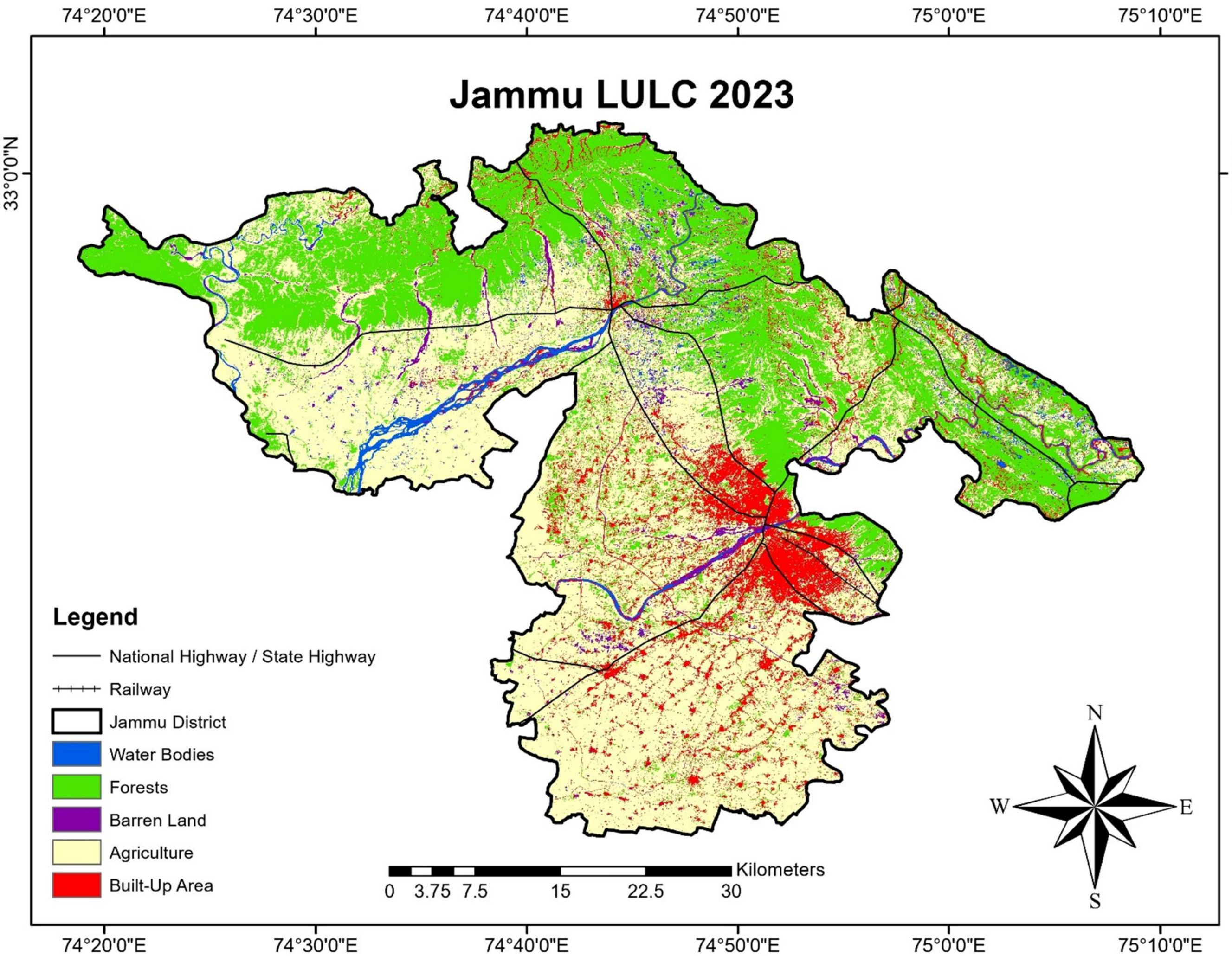

Fig. 5 Land Use Land Cover Map of year 2023

TABLE IV
LAND USE LAND COVER DATA OD YEAR 2023

Category	Area (sq. km)	Percentage
Water Bodies	56.684461	3%
Built-Up Area	209.862345	10%
Agriculture	1132.845213	54%
Barren Land	46.195441	2%
Forests	650.175704	31%

C. Land Use Land Cover Change

In the classification scheme developed for five classes viz. Water Bodies, Built-Up Area, Agriculture, Barren Land and Forests, area water bodies have shrunk by 3%, built-up area has increases by 5%, area under agriculture has increased 29%, barren land has decreased by 22% and forest cover has decreased by 9% for forest cover.

Out of the all five classes the area under agriculture has increased substantially by probable conversion of barren land to agricultural land but that can be confirmed only after detailed class-wise change detection.

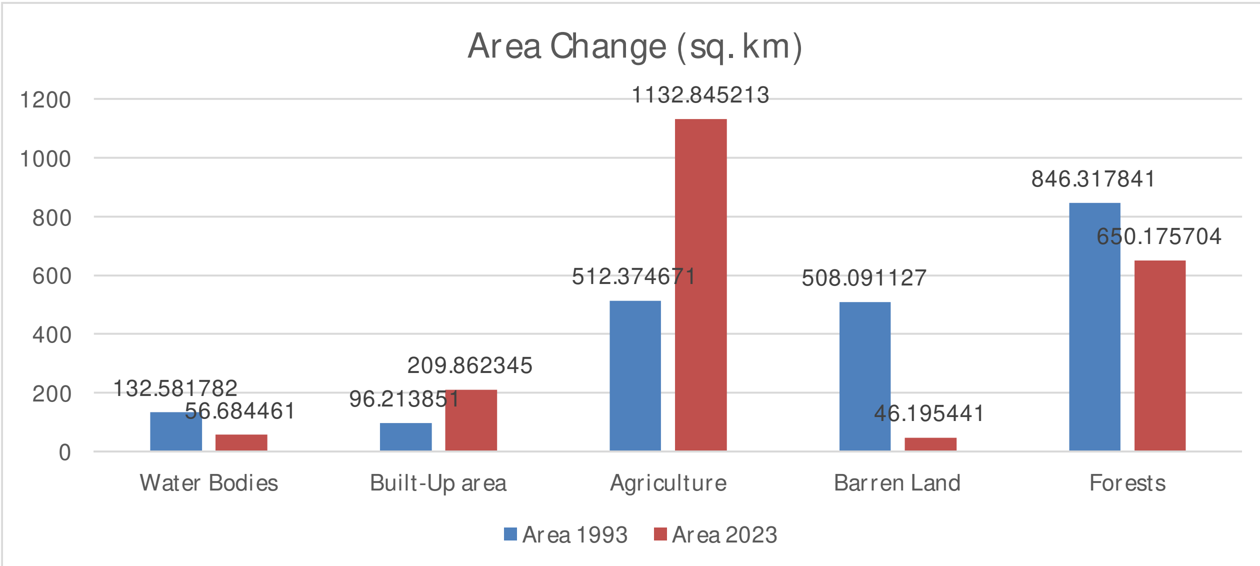

Fig. 6 Bar Graph depicting Land Use Land Cover change (1993-2023)

D. *Class-wise Change Detection*

The class-wise change detection Map shown in Fig. 7 and data is shown in Table V and Fig. 7.

TABLE V
CLASS-WISE CHANGE DETECTION

S.No.	Change Detection Analysis (1993-2023)	Area Change (sq. km.)
1.	Agriculture -Agriculture	410.250205
2.	Agriculture -Barren Land	4.603503
3.	Agriculture -Built-Up Area	42.897233
4.	Agriculture -Forests	50.70176
5.	Agriculture -Water Bodies	3.726923
6.	Barren Land -Agriculture	338.045507
7.	Barren Land -Barren Land	13.875247
8.	Barren Land -Built-Up Area	64.370033
9.	Barren Land -Forests	80.979435
10.	Barren Land -Water Bodies	10.658114
11.	Built-Up Area -Agriculture	43.160719
12.	Built-Up Area -Barren Land	3.629839
13.	Built-Up Area -Built-Up Area	37.420444
14.	Built-Up Area -Forests	9.74511
15.	Built-Up Area -Water Bodies	2.209508
16.	Forests -Agriculture	279.859214
17.	Forests -Barren Land	5.957039
18.	Forests -Built-Up Area	45.536111
19.	Forests -Forests	499.428752
20.	Forests -Water Bodies	15.003042
21.	Water Bodies -Agriculture	60.916984
22.	Water Bodies -Barren Land	18.110268
23.	Water Bodies -Built-Up Area	19.531073
24.	Water Bodies -Forests	8.896983
25.	Water Bodies -Water Bodies	25.057419

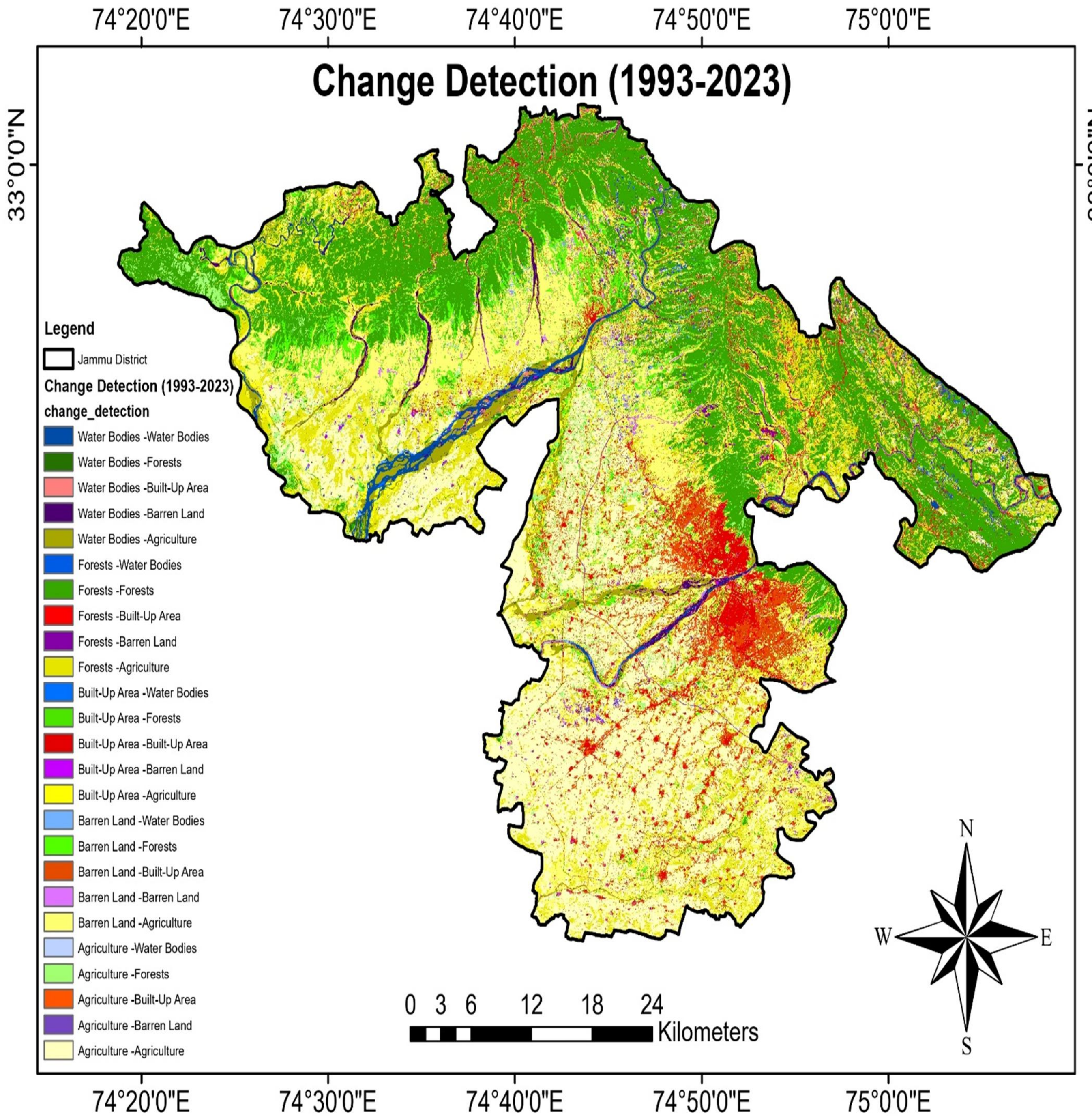

Fig. 7 Class-Wise Change Detection Map (1993-2023)

In the above map Water Bodies-Water Bodies, Forest-Forest etc. represent areas of the particular classes that are not converted to any other class. Maximum change detected is of Forest to Agriculture is 279.85 km^2 and Barren land to Agriculture is 338.04 km^2. The map is created by dissolving the polygon files of the maps of 1993 and 2023. The accuracy of this map depends upon the maps of 1993 i.e. 87% and 2023 i.e. 78%. Overall accuracy of this map lies between 78% and 87%.

The detailed Chart of Class-wise Change detection graph is shown in Fig.8.

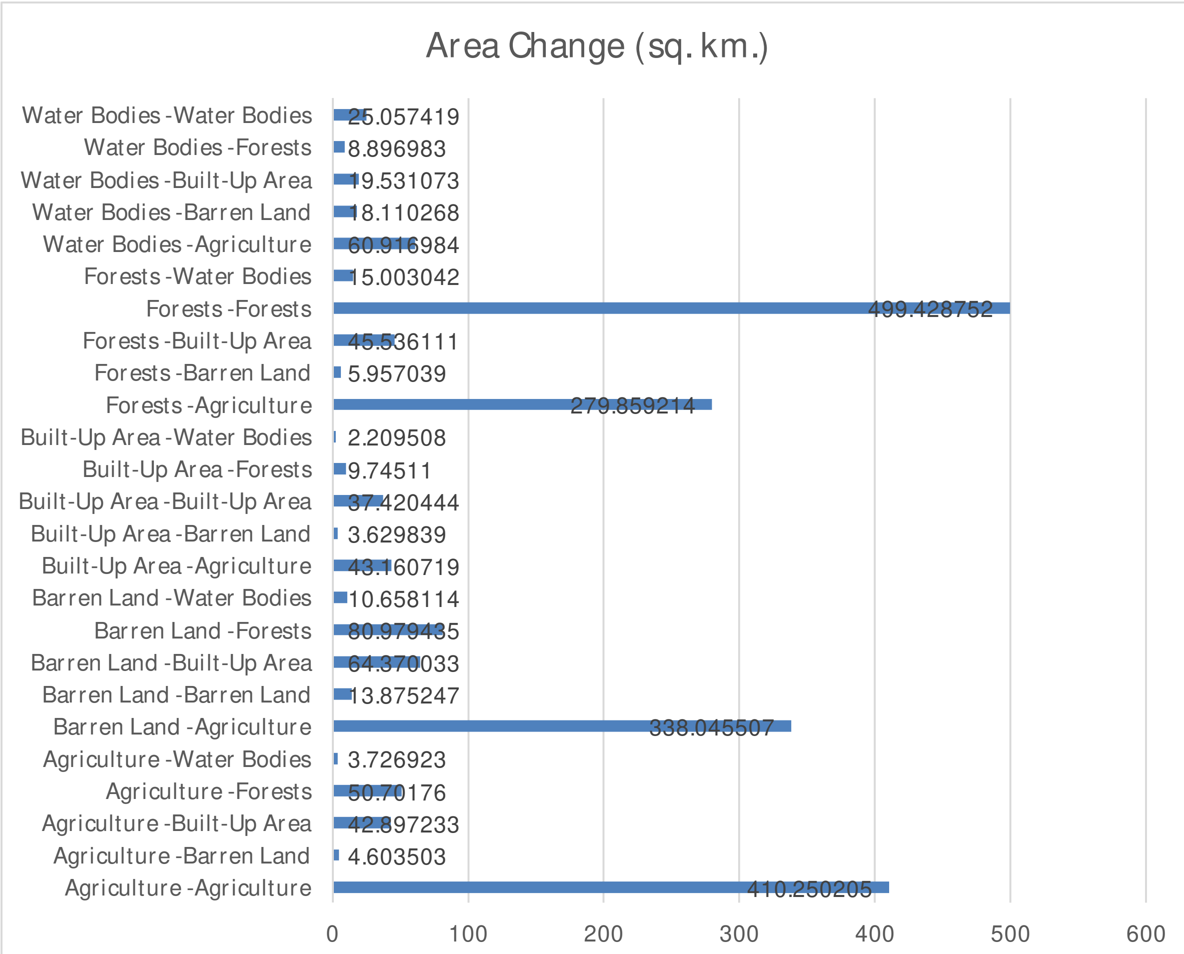

Fig. 8 Class-Wise Data of Conversion of one class to another

VII. ACCURACY ASSESSMENT

The accuracy assessment of the result is a necessary step to evaluate the usability of the data. In this research, the accuracy assessment is carried out by comparing 100 random points on the classified map and the actual map. The classes correct are noted and Users Accuracy and Producers Accuracy is calculated. Kappa coefficient is calculated to check the reliability of data.

TABLE VI
ACCURACY ASSESSMENT OF YEAR 1993

OID	Class	Water Bodies	Built-Up	Agriculture	Barren Land	Forests	Total	Users Accuracy	Kappa
1	Water Bodies	18	1	0	1	0	20	90%	-
2	Built-Up	1	15	1	2	1	20	75%	-
3	Agriculture	0	0	20	0	0	20	100%	-
4	Barren Land	0	2	1	16	1	20	80%	-
5	Forests	0	0	2	0	18	20	90%	-
6	Total	19	18	24	19	20	100	-	-
7	Producers Accuracy	94.7%	83.33%	83.33%	84.21%	90%	-	87%	-
8	Kappa	-	-	-	-	-	-	-	0.8375

Overall Accuracy: 87%
Kappa Co-efficient: 0.8375

TABLE VII
ACCURACY ASSESSMENT OF YEAR 2023

OID	Class	Water Bodies	Forests	Barren Land	Agriculture	Built-Up	Total	Users Accuracy	Kappa
1	Water Bodies	12	3	1	2	2	20	60%	-
2	Forest	0	19	0	1	0	20	95%	-
3	Barren Land	1	0	14	3	2	20	70%	-
4	Agriculture	0	0	3	17	0	20	85%	-
5	Built-Up Area	1	1	1	1	16	20	80%	-
6	Total	14	23	19	24	20	100	-	-
7	Producers Accuracy	85.71%	82.6%	73.68%	70.83%	80%	-	78%	-
8	Kappa	-	-	-	-	-	-	-	0.725

Kappa Co-efficient: 0.725
Overall Accuracy: 78%

VIII. ANALYSIS AND INTERPRETATION OF LAND USE AND LAND COVER DATA

A. *Water Bodies*

From 1993-2023, the area under water bodies has been reduced to half from 132.58 km^2 to 56.68 km^2.Water bodies have faced maximum encroachment with 60.91 km^2 converted to agriculture, 18.11 km^2 converted to Barren land, 19.53 km ^{2} converted to Built-Up Area and 8.89 km^2 converted to forests.

Water bodies also saw an increase in other areas with 3.7 km^2 of agriculture land converted to Water bodies, 10.65 km^2 of barren land converted to water bodies and 15 km^2 of forest converted to water bodies.

Thereby, reducing the Water Bodies by 76 km^2.

This change is due to varied reasons like

1) Urbanization and Infrastructure Development: Urban areas expanded by 113 km^2 in past 30 years as per our study, this is done by reclaiming land for construction purposes. This led to the filling and conversion of water bodies into built-up areas or land for other purposes like roads, housing, industries, and commercial spaces.
2) Agricultural Expansion: The population of Jammu district has doubled from 783705 to 1744152. In many cases, water bodies have been converted into agricultural land occurs to meet the growing demands of food production. As population increased and agricultural practices intensified, water bodies were drained or filled to create more arable land for crop cultivation.
3) Deforestation and Land Degradation: Deforestation and land degradation in the catchment areas of water bodies could have lead to a reduction in their size and volume. When forests are cleared for agriculture, logging, or urban expansion, the natural water retention capacity diminishes, resulting in decreased water flow and reduced water body sizes.
4) Climate Change: Climate change influences the availability of water in an area. Changes in rainfall patterns, increased temperatures, and altered hydrological cycles can impact the water balance and cause the shrinkage or drying up of water bodies.
5) Dam Construction and Water Diversion: In past 30 years, multiple dams have been constructed on Chenab River taking the number to 7 functional dams. The construction of dams and diversion of water for irrigation or other purposes have a significant affect to the water bodies. These interventions can alter natural water flows, reduce water availability downstream, and potentially lead to the drying up of smaller water bodies.

B. *Built-Up Area*

Built-Up Area is doubled in last 30 years from 96.21 km^2 to 209.8 km^2. This is due to increase in population from 7837051 to 1744152.Also, Jammu being a capital city and a major educational hub in northern India, a significant amount of people migrate to Jammu to for their educational or livelihood needs. Thus, leading to a demand pushed infrastructure growth.

There are various reasons of this change are:
1) *Population Growth:* The population of Jammu district has doubled in last 30 years from 7837051 to 1744152. This is one of the primary drivers of urban expansion and the increase in built-up areas. As the population increases, there is a greater demand for housing, infrastructure, and commercial spaces, leading to the conversion of land into built-up areas.
2) *Infrastructure Development:* The development of infrastructure, including roads, highways, bridges, and utilities is increased substantially. As transportation networks and utility services expand to accommodate growing urban populations, more land is dedicated to infrastructure development.
3) *Housing Demand:* Increased urban populations and changing lifestyle preferences lead to a higher demand for residential housing. This demand drives the construction of housing complexes, apartment buildings, and residential areas, contributing to the expansion of built-up areas.
4) *Government Policies and Land Use Changes:* The government has frequently changes policies, land use planning, and zoning regulations can influence the conversion of land into built-up areas. If land use policies prioritize urban development or relax restrictions on land conversion, it can facilitate the expansion of built-up areas.
5) Informal Settlements and Slums: Many informal settlements and slums have grown on the outskirts of Jammu city. Such areas are occupied by refugees. These settlements have typically emerged on undeveloped or vacant land, leading to the expansion of urban areas.

C. Agriculture
Area under agriculture 29% in past three decades from 512.37 km^2 in 1993 to 1132 km^2 in 2023. Various factors analysed for this change are:
1) *Population Growth and Food Demand:* As stated earlier, population of Jammu district has doubled in last 30 years from 7837051 to 1744152. It led to an increased demand for food, which drives the expansion of agricultural land. As the population increases, more land is required for crop cultivation to meet the rising food requirements of the growing population.
2) *Technological Advances and Intensification:* The adoption of new technologies and agricultural practices, such as improved irrigation systems, mechanization, use of fertilizers, and high-yielding crop varieties, have enhanced agricultural productivity. These advancements have enabled farmers to cultivate larger areas of land, leading to an increase in the overall agricultural land.
3) *Government Policies and Support:* As majority of our population depends on agriculture, both Govt. of J&K and Govt. of India have adopted policies such as MSP, easy credits, free fertilisers etc. to offer incentives to farmers can encourage the expansion of agricultural activities.

D. Barren Land
Barren Land has significantly decreased by 22% from 508.09 km^2 to 46.19 km^2. The probable factors are given:
1) *Agricultural Expansion:* 338 km^2 of barren land has been converted to agriculture to meet the increasing demand for food due to population growth and changing dietary preferences. As farmers expand their cultivation areas, they may have reclaimed barren land through land clearing and soil improvement measures.
2) Reforestation and Afforestation Efforts: Reforestation and afforestation initiatives by planting trees or restoring vegetation cover on barren or degraded land. These efforts are done by government to increase forest cover, improve land productivity, enhance ecosystem services, and combat soil erosion. Reforestation and afforestation programs have converted 80 km^2 into forest by restoring vegetation cover.
3) Infrastructure Development and Urbanization: The expansion of infrastructure and urban areas led to the conversion of barren land into built-up areas. 64 km^2 of such land is claimed for development projects such as roads, residential complexes, commercial spaces, and industrial sites, resulting in the reduction of barren land.
4) Natural Succession and Ecological Processes: Over time, barren land undergoes natural succession, where vegetation gradually colonizes the area. This process can occur due to natural seed dispersal, windblown seeds, or the presence of persistent seed banks in the soil. Natural succession can contribute to the reduction of barren land as it transitions into more vegetated areas.

E. Forests
Area under forest cover has decreased by 9% from 846.31 km^2 in 1993 to 650.17 km^2 in 2023.

Various reasons researched for this area:

1) *Agricultural Expansion:* With expansion in agricultural areas, forested areas may have been cleared to make way for agriculture, including commercial crops, subsistence farming, and shifting cultivation. 279 km^2 of such land has been converted to agriculture.
2) *Logging and Timber Extraction:* Unsustainable logging practices, illegal logging, and timber extraction for commercial purposes has also led to forest degradation and deforestation. The removal of trees for timber, furniture, and other wood products contributes to the loss of forest cover. 5 km^2 of forest has been converted to barren.
3) *Infrastructure Development:* The infrastructure development in the region, including roads, highways, dams, and mining operations, has led to clearing forested areas. Construction activities associated with infrastructure development result in the conversion of forests into built-up areas, contributing to the reduction in forest cover.

IX. FUTURE SCOPE OF WORK

This research can be extended to increased number of land classes such as Shrubs, Grasslands, Horticulture Areas, Industrial Areas, Mining, Snow etc. Annual growth in horticulture area in Kashmir and parts of Jammu can be mapped and studied and expansion of coal mines in Jammu can also be tracked. More advanced studies can help in detecting the health of crops and horticulture areas, thereby helping in estimating the production for the season. This research can also be extended to assess the damage due to floods, forest fires etc. as they lead to temporary change in land use. With the use of Machine Learning and Artificial Intelligence Software the future land use trends can be predicted analysing the past land use data.

X. CONCLUSIONS

The study successfully classified the Land use Land cover of Jammu district into 5 classes with 87% and 78% accuracy. Jammu district over the past 30 years reveals significant transformations in the region. 5% decrease in area under water bodies and 9% decrease of area under forest cover is a significant and concerning change. These findings show the complex inter-connection between human activities, economic development, and environmental changes in shaping land use patterns in Jammu district. Sustainable land management practices, conservation efforts, and the implementation of policies that balance economic development with environmental preservation are crucial for mitigating the negative impacts of land use changes and promoting sustainable land use practices in the region.

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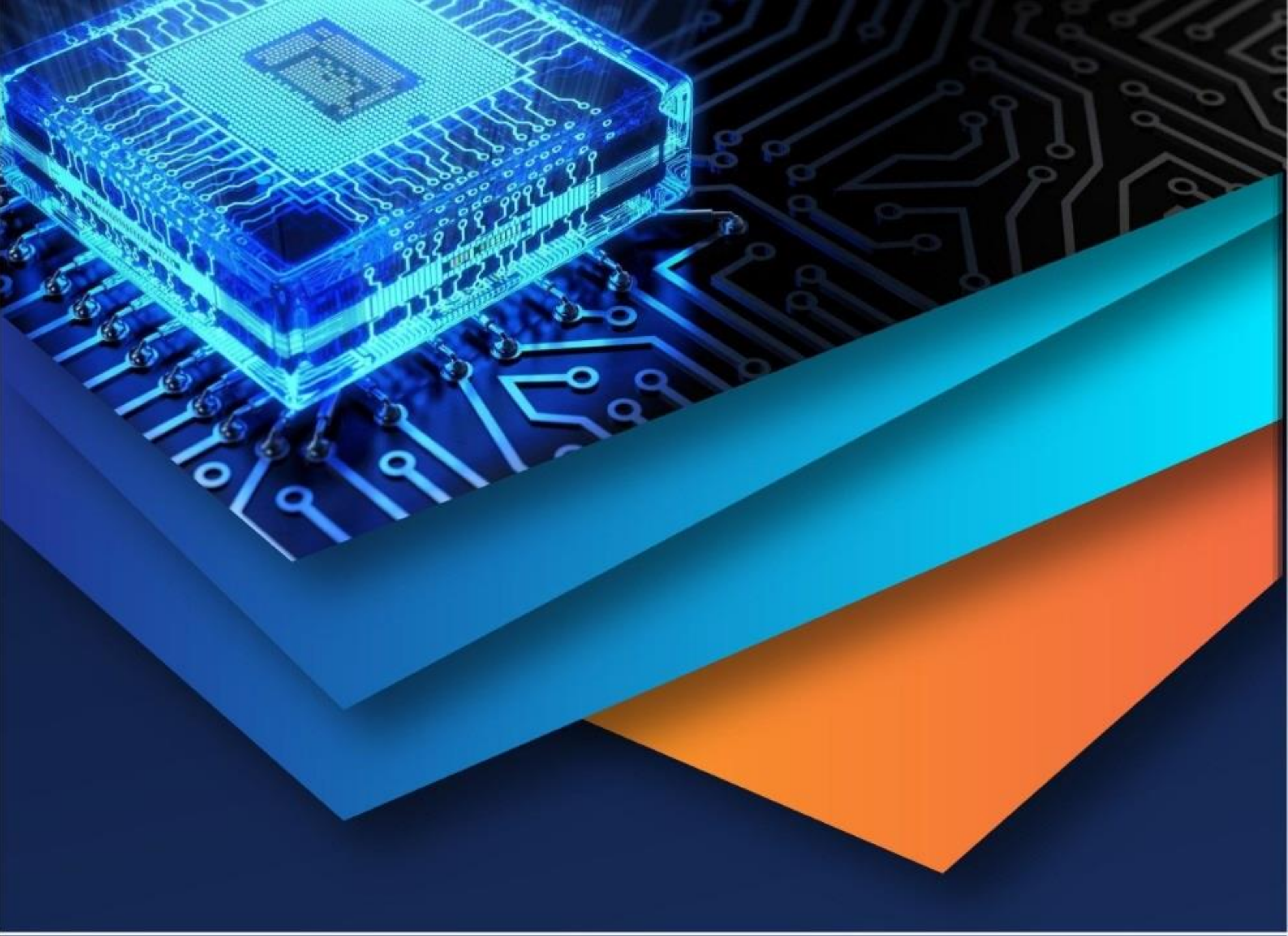

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