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Original Article

Identification of Land Use Land Cover (LULC) Changes Using Geo-Spatial Tools for Indrayani River Basin

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Abstract - *The hydrological and morphological processes of Land Use and Land Cover (LULC) have an impact on watersheds. Accurately measuring historical and current LULC characteristics is essential for determining the appraisal and management approach of a watershed. This study examines the LULC changes that occurred between 2000 and 2020. It predicts the changes in LULC for the period from 2020 to 2040 in the watershed using the MOLUSCE QGIS plug-in. The LULC classification in the Indrayani River Watershed utilizes remote sensing data from the cloud-free Sentinel 2B and Landsat series, namely the L5 TM and L7 ETM plus. The Kappa (K) coefficient is utilized to assess the accuracy of LULC maps, yielding an approximate accuracy of 77%. Over the past two decades, there has been a notable growth in the amount of settlement inside the watershed, with the proportion rising from 7.31% to 10.24% of the total area. The expansion of urban areas has occurred through the encroachment upon agricultural land and vegetation cover, leading to the transformation of vegetation cover into urban areas. The present study examines the alterations in land use and land cover resulting from the rapid process of urbanization occurring within the designated study region.*

Keywords - *Watershed, Watershed management, LULC, Geospatial tool, Remote sensing.*

1. Introduction

Economic stability, food security, social transformation and other related services are impacted by the watershed, which is a complex socio-political-ecological-geographical entity. Careful preservation of natural resources is necessary to make sustainable development. The term "land cover" describes the various biological and physical features that make up the land's surface [9].

Contrarily, land use includes a variety of human activities, such as farming, cutting down trees, and constructing buildings, all of which can alter the surface-level natural processes [23]. In addition to physical factors like height, slope, and geology, social and institutional factors also have a role in determining LULC [27].

Anthropogenic landscapes, which include the conversion of once-natural terrain into things like farms, pastures, cities, and reservoirs, are evidence of the way in which humans have altered the natural world. Humans have modified about 85% surface of the earth, and about 40% of the total land has been brought under farming [30].

The objectives of the development and the local terrain are two factors that could influence these watershed size selection parameters. The long-term viability of any kind of development depends on protecting natural resources. The exponential increase in the economy, the proliferation of industries, and the unchecked growth in the population have all contributed to the perpetually changing land use pattern [11,12]. Suburban areas' shifting coverage of land and its use patterns can be attributed to two main causes: the development of residential and industrial zone [19].

Several environmental elements have been affected, either directly or indirectly, by changes in the coverage of land and its use. The study's findings could aid planners in making better use of current water resources and achieving a more equal distribution of the resource, both of which are contributing to a precipitous increase in the demand for water.

Analyzing the changes that follow from changes in land cover and usage is key to understanding their dynamics; doing so calls for a separate data structure in addition to information on thematic changes. Understanding human-natural interactions requires research on different features of the surface of the earth. Findings from the most recent study corroborate that the tremendous change in LULC pattern causes changes in climatic patterns, especially in urban areas [21, 33]. It is observed that for the present study area, no research has been conducted in comparison with the aim of the present study and considering the rapid industrialization and urbanization of the study area region, it becomes necessary to predict future trends and explore the possibilities to tackle this vital water issue.

It is very important to conduct the study to find out the trend of the LULC Change through analysis and to predict the future LULC Change to face and overcome the water scarcity issue, which may crop up due to limited water resources and rapid industrialization and urbanization compelling LULC Change. By focusing on the study area watershed, the present study sought to improve understanding of LULCChange. This study aims to assess the LULC Change in the study area from 2000 to 2020 by using the geospatial tool.

The objectives of the present study are (i) to categorize and delineate the change in various types of land use and land cover (LULC) as well as the patterns of LULC Change in the study area during the period from 2000 to 2020 and (ii) to make a prediction of LULC Change in the future, upto the year 2040. It is estimated during the present study that future geographical and temporal changes in coverage of land and its use using the MOLUSCE plug-in in QGIS software, which is based on QGIS [4, 18, 24, 29].

MOLUSCE refers to the Method of evaluating LULC Change in order to evaluate, model, and simulate LULC Change. This modelling tool is available in QGIS 2.0 [5, 25]. Coverage of land and its use change analysis, modelling, and simulation were the primary goals of developing this plug-in. Many approaches are applicable to conduct the LULC Change analysis, which is implemented using MOLUSCE plug-in [3, 4, 17, 18].

However, the prediction of LULC Change has not been carried out to explore possibilities of finding out the scale of the water scarcity issue for proper planning and management of the water resources. The study area has an ever-increasing water need due to the development of numerous industrial estates by MIDC and, obviously increase in demand for habitational and commercial spaces, putting the region's limited water supplies under a lot of pressure.

2. Material and Methods

2.1. Study Area

The study area consists of the Indrayani River watershed. The Indrayani River originates from Kurvande village near Lonavala, Pune, at coordinates 18° 43'56" N and 73° 22'13" E, and it begins at an elevation of 564 m above MSL. Close to the Indrayani River meets the Bhima River near Tulapur in the Pune district.

The study site covers an area of 990 sq. km, and the distance travelled during the river journey is around 97 km. Lonavala, Vadgaon, Dehu Road, Alandi, and Chakan are some of the major towns in the Indrayani River basin. There are five dams with modest to intermediate capacities: Bhushi, Lonavala, Valvan, Shirawata, and Andhra, across the Indrayani River and its tributaries. A number of industries have sprung up in the areas surrounding major transportation corridors.

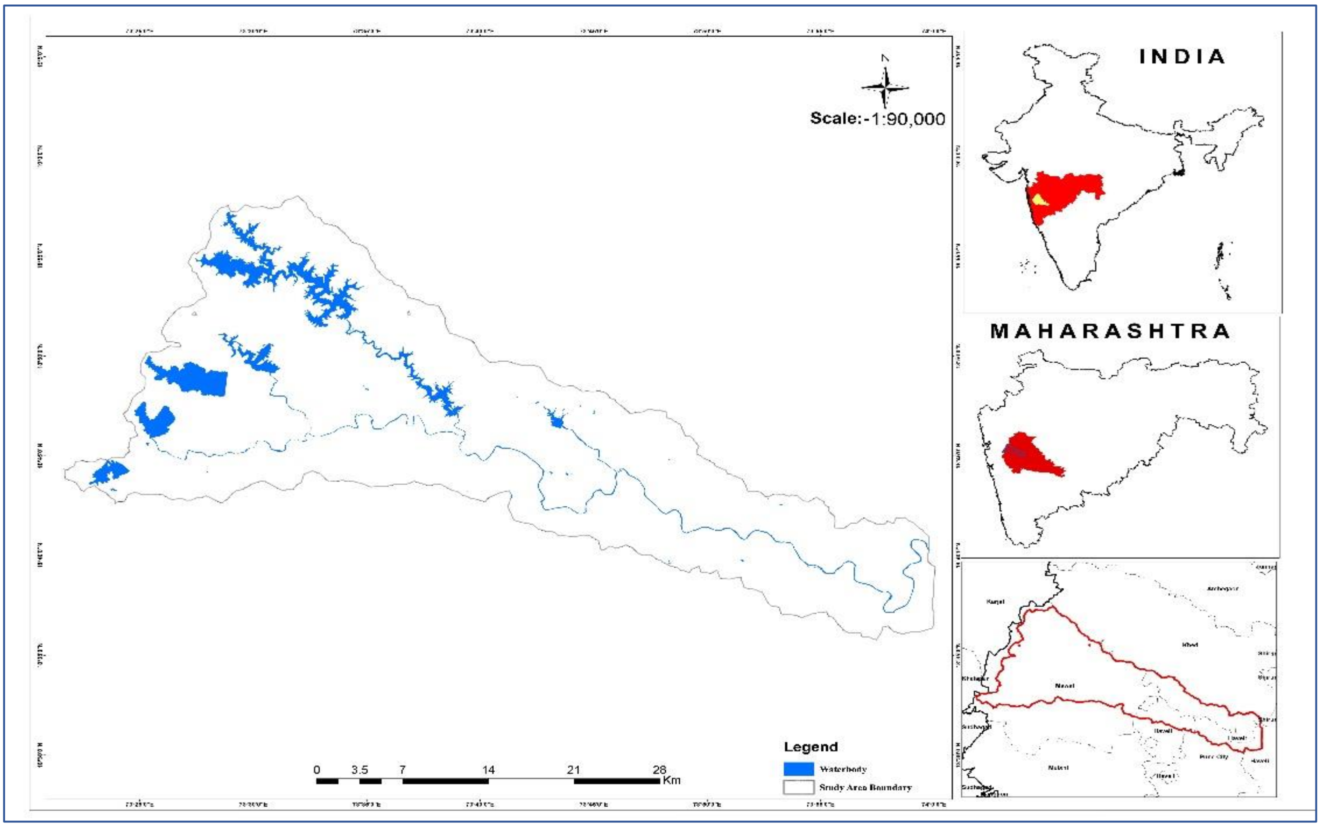


Fig. 1 Location map of indrayani river watershed

2.2. Data Collection and Image Pre-Processing

Prior to LULC Change detection, it is essential to geo-process satellite images to develop a distinct correlation between the gathered data and on-ground occurrences. The purpose under consideration encompasses a singular and primary objective [14]. The LULC maps used in this study were made with toposheets. Also, the satellite images are used to observe how LULC Change occur over the time period in the study area. All of them have decent spatial qualities, an acceptable price-to-quality ratio, and strong spectral coverage with seven bands spanning the visible to infrared spectrum

LULC Change patterns for the years 2000, 2005, 2010, 2015 and 2020 were mapped using satellite images taken by Landsat 5 and 7 and Sentinel 2A. ERDAS IMAGINE programme was used to perform an unsupervised classification. The watershed was divided into five classes according to the value of various landscape components, and spatial data were analyzed by assigning per-pixel signatures, as shown in Table 1. With the MOLUSCE plug-in for QGIS, you can easily verify the relationship between LULC data and geographical parameters using a number of popular methods [3,18].

2.3. Analysis of LULC

Polygons encircling representative sites were drawn up for selecting training samples for the different LULC categories, already determined. Spectral fingerprints of the pixels comprising these polygons were used to document the various land cover classifications derived from the satellite images. It is necessary to see that the LULC Change is clear and proper results are obtained for the spectral signature. These images were then subjected to maximum likelihood unsupervised classification.

For the purpose of making LULC maps, an unsupervised classification of a satellite image obtained from the USGS website was employed. The whole map is comprised of five distinct categories: water bodies, urban regions, vegetation, arable land, and desert terrain. These theme maps show LULC for the years 2000,2005, 2010, 2015 and 2020 on a 1:700000 scale, as per Table 2.

Table 1. Satellite data specifications

Satellite	Sensor	Path/Row	Year of Data Acquisition	Spectral Bands	Resolution
Landsat-5	Thematic Mapper	147/047	2000/2005	Blue, Green, Red. NIR, 1,2,3,4	30 M
Landsat-7	Enhanced Thematic Mapper	147/047	2010	Blue, Green, Red. NIR, 1,2,3,4	30 M
Sentinel 2A	MS	43QCA/QA43C	2015/2020	Blue, Green, Red. NIR, 2, 3, 4,8	30 M

Table 2. Land classes delineated as per supervised class

Sr. No.	Land Class	Class Description	Color Code
1	Agriculture	Crop fields	Green
2	Barren	Land areas of exposed soil and barren areas influenced by human influence	Copper
3	Built-up / Settlements	Residential, commercial, industrial, transportation, roads, mixed urban	Red
4	Vegetation	Mixed Forest lands	Bottle green
5	Water bodies	Rivers, open water, lakes, ponds and reservoirs	Blue

The LULC maps for the study area watershed for the years 2000, 2005, 2010, 2015, and 2020 have been presented in Figures 2, 3, 4, 5, and 6, respectively. These figures are arranged in a classification system. Table 3 provides a summary of these classes, while Figure 7 provides a graphical representation of Table 3, which highlights the information presented in Table 3.

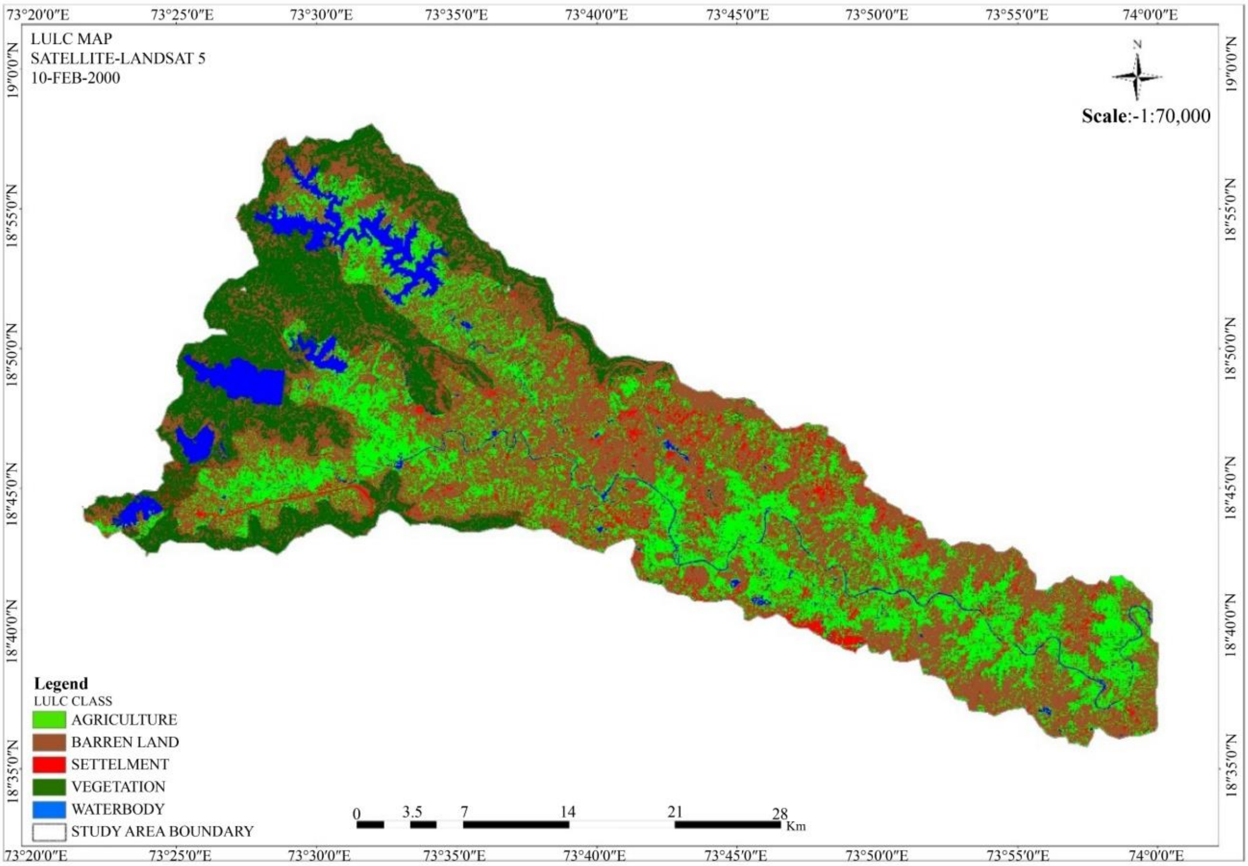


Fig. 2 LULC map of Indrayani river watershed for the year 2000

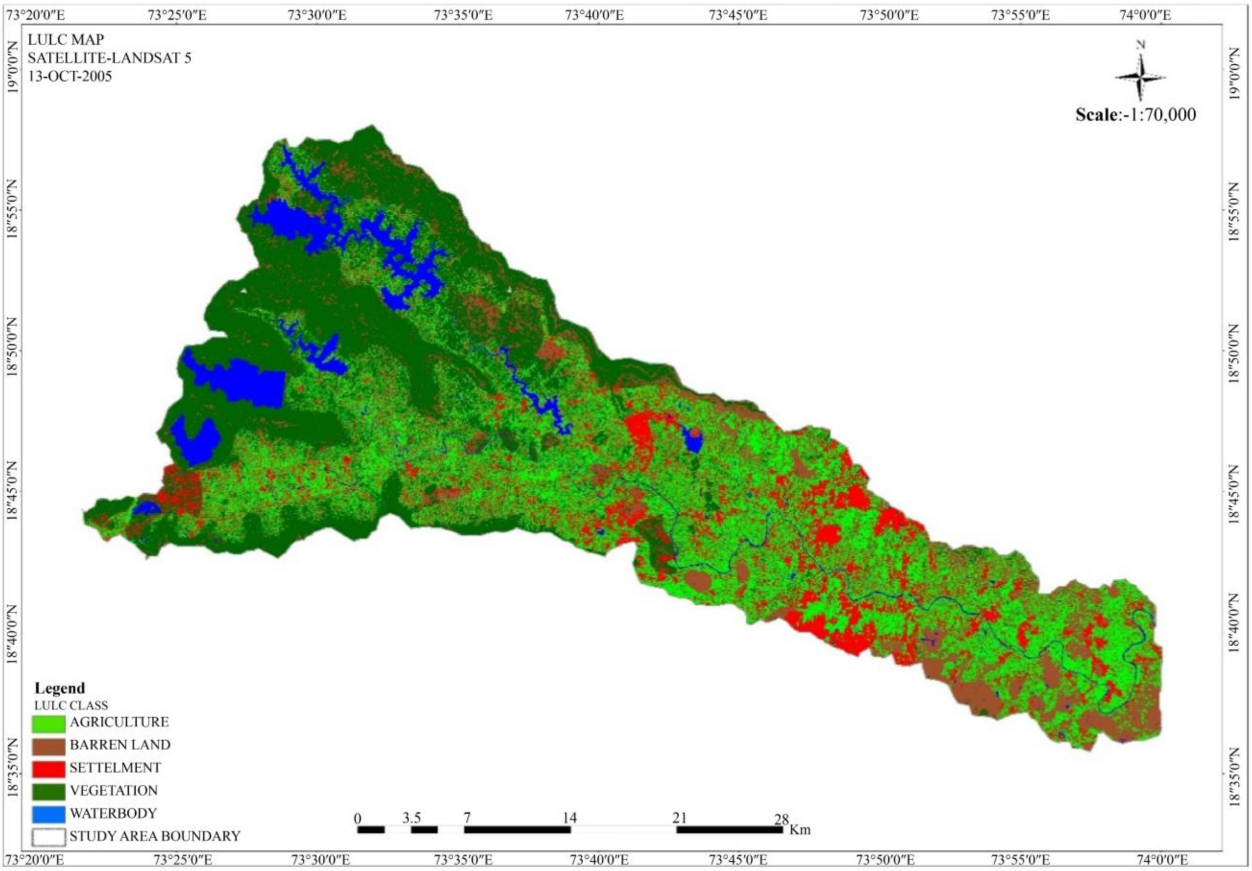


Fig. 3 LULC map of Indrayani river watershed for the year 2005

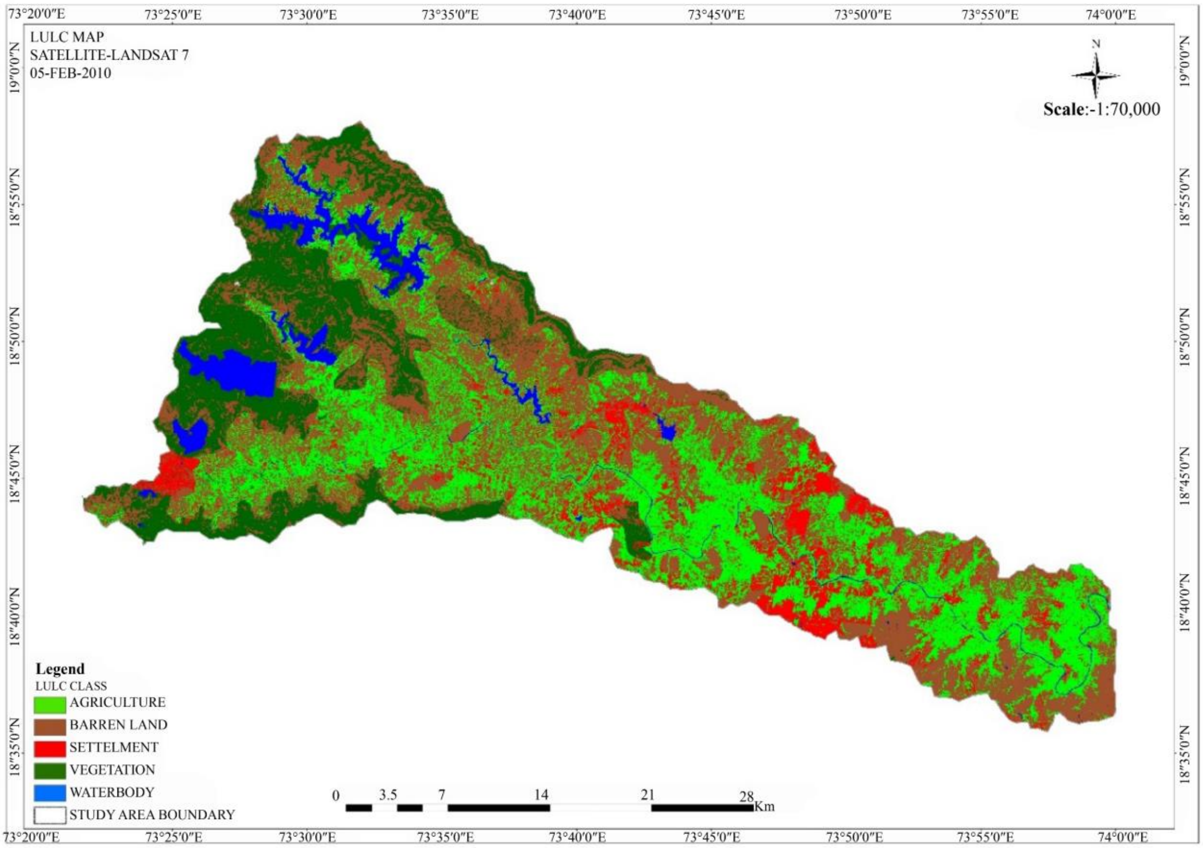


Fig. 4 LULC map of Indrayani river watershed for the year 2010

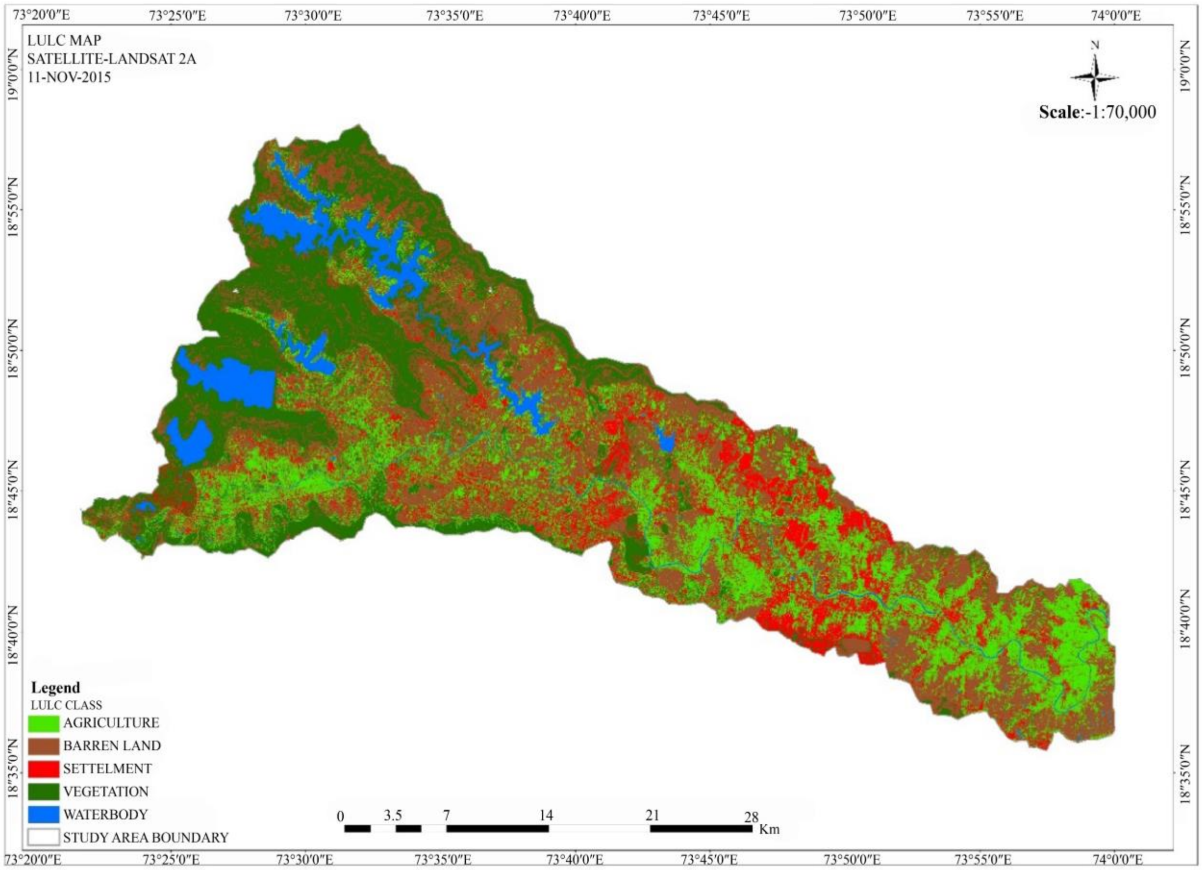


Fig. 5 LULC map of Indrayani river watershed for the year 2015

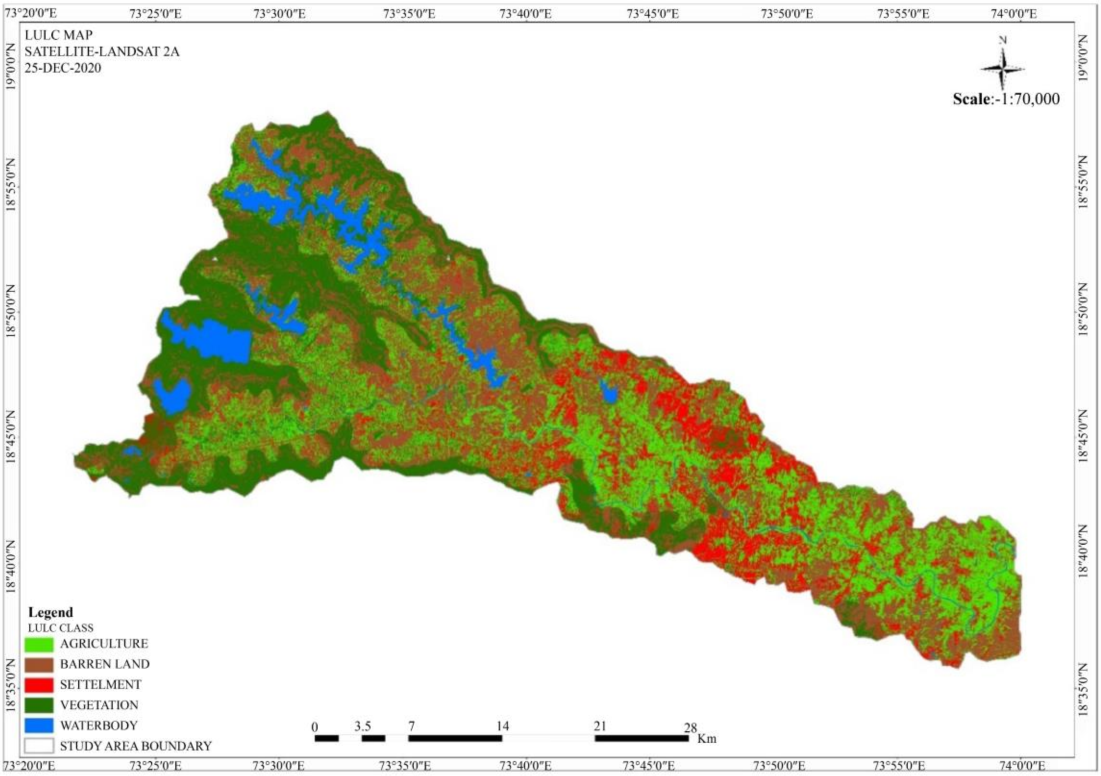


Fig. 6 LULC map of Indrayani river watershed for the year 2020

Table 3 shows the summary of LULC classification with the LULC Change for the period from 2000 to 2020.

Table 3. LULC classes and their respective changes in the Study Area for the period from the year 2000 to 2020

LULC Class / Year/ Area	2000 km²	% Change	2005 km²	% Change	2010 km²	% Change	2015 km²	% Change	2020 km²	% Change
Agriculture	286.30	26.39	288.65	26.60	304.18	28.03	262.24	24.16	257.30	23.72
Barren land	440.69	40.61	407.95	37.59	403.79	37.21	388.16	35.77	381.04	34.56
Built-up	79.34	7.31	82.63	7.61	95.24	8.78	101.90	9.39	105.11	10.23
Vegetation	223.18	20.57	245.05	22.58	234.14	21.58	269.50	24.84	280.12	25.82
Waterbody	55.58	5.12	60.82	5.61	47.76	4.41	63.29	5.83	61.53	5.67
Total	**1085.10**	**100**	**1085.10**	**100**	**1085.10**	**100**	**1085.10**	**100**	**1085.10**	**100**

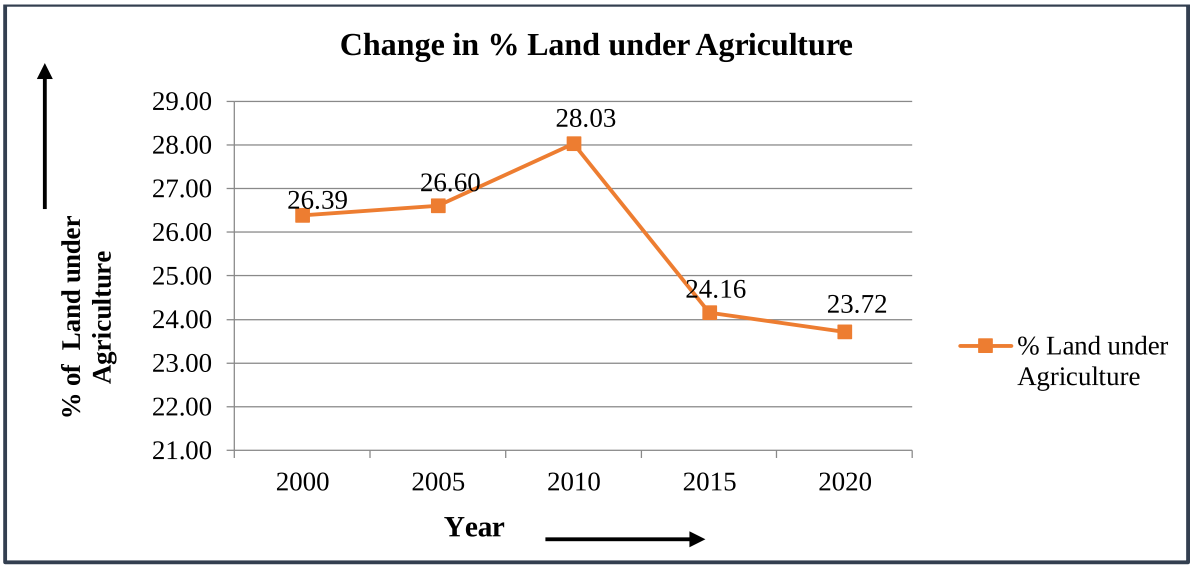


Fig. 7 Change in % land under agriculture in the study area for the period from the year 2000 to 2020

Figure 7 exhibits that there is a trend of decline in the area under agriculture, having the exception in the initial period, which is observed due to the rapid development and urbanization, and the shrinking of farming is consistent in the region of the study area.

From Figure 8, it can be seen that there is a trend of decline in the area under barren land, which shows the clear trend of bringing land under development due to opportunities for economic progress being created as a consequence of industrialization and urbanization of the study area region.

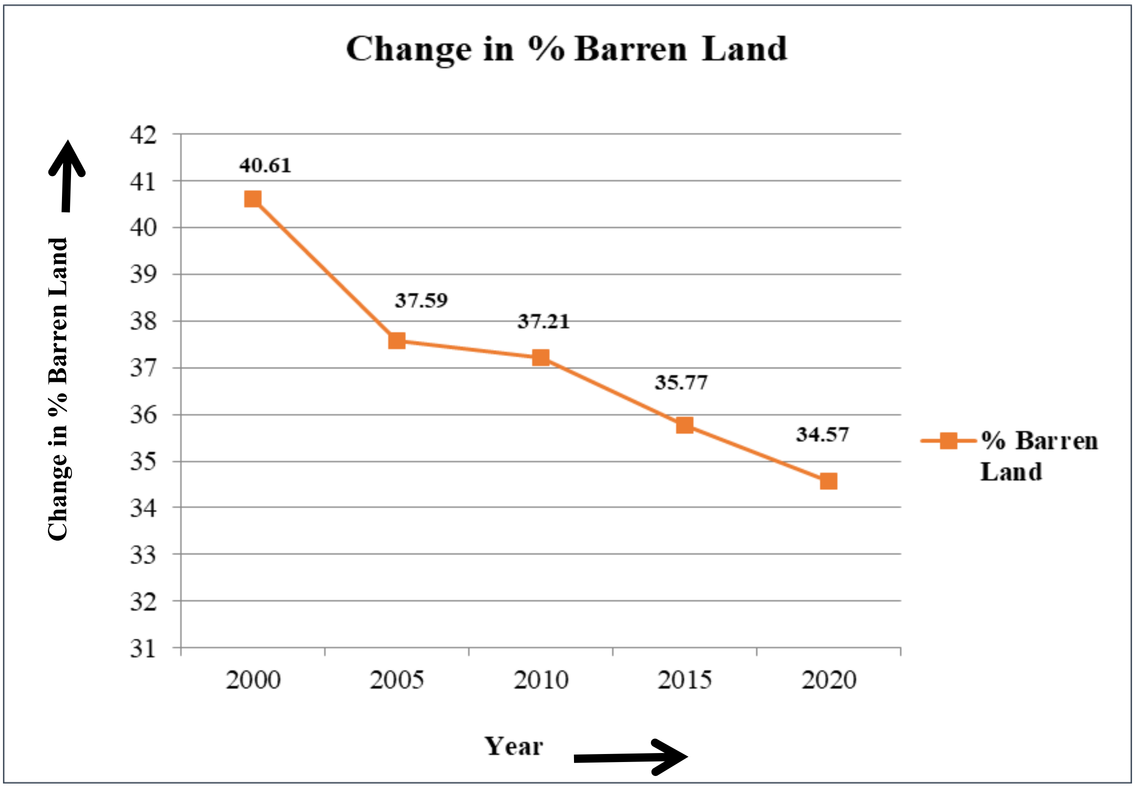


Fig. 8 Change in % barren land in the study area for the period from the year 2000 to 2020

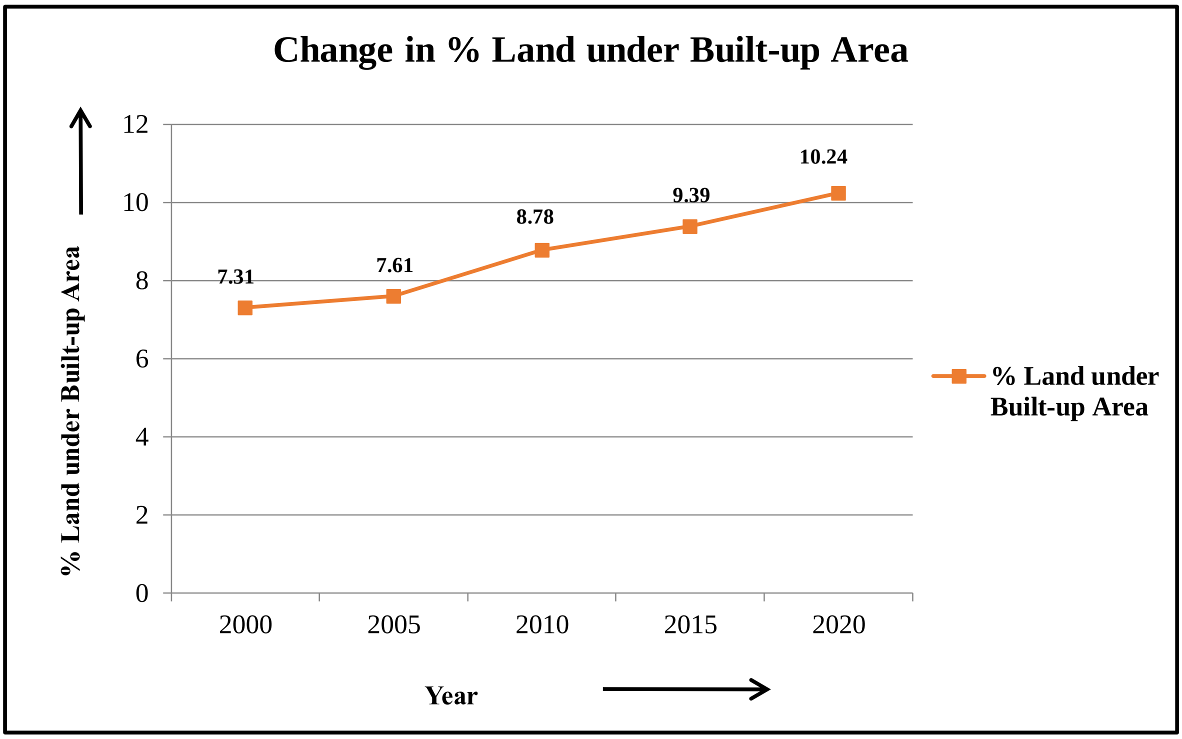


Fig. 9 Change in % land under built-up area in the study area for the period from the year 2000 to 2020

From Figure 9 it can be seen that there is a trend of rise in the area under built-up area, which shows the clear trend of bringing land under development due to rapid and consistent industrialization and urbanization of the study area region. This indicates the demand for industrial, residential and commercial construction to cater for the needs of the increasing industrialization and population growth.

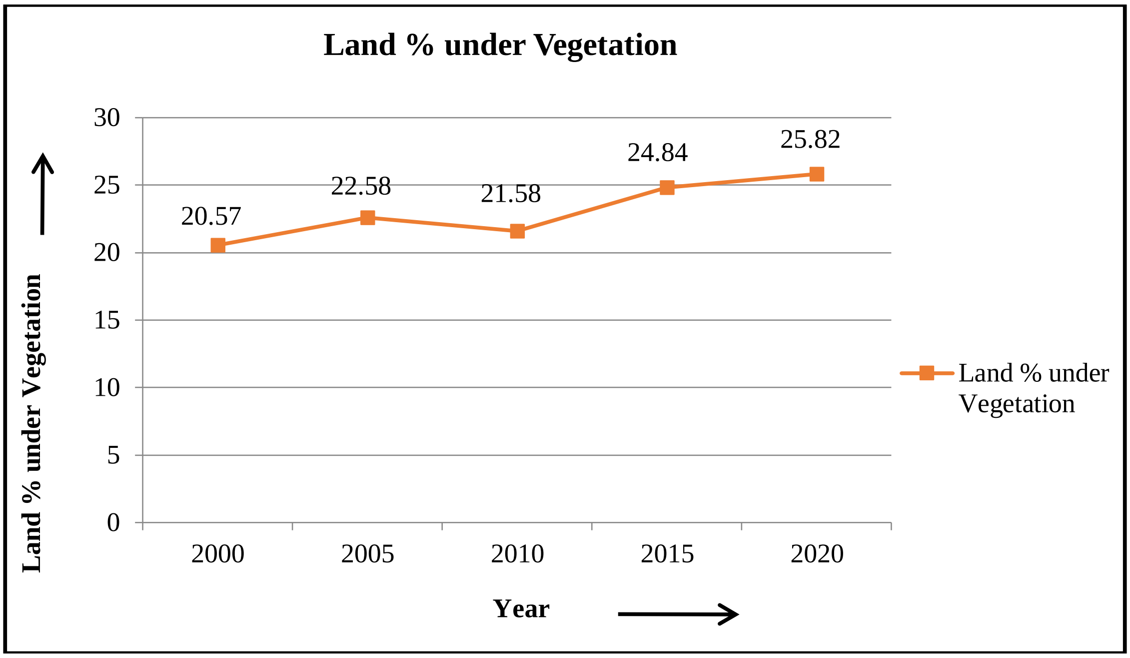


Fig. 10 Change in % land under vegetation in the study area for the period from the year 2000 to 2020

Due to the continuous development of spaces for residential and its supportive usages, there is a moderate rise in the area under vegetation in the study area with an exception for the year 2010, which shows a slight decrease, as shown in Figure 10.

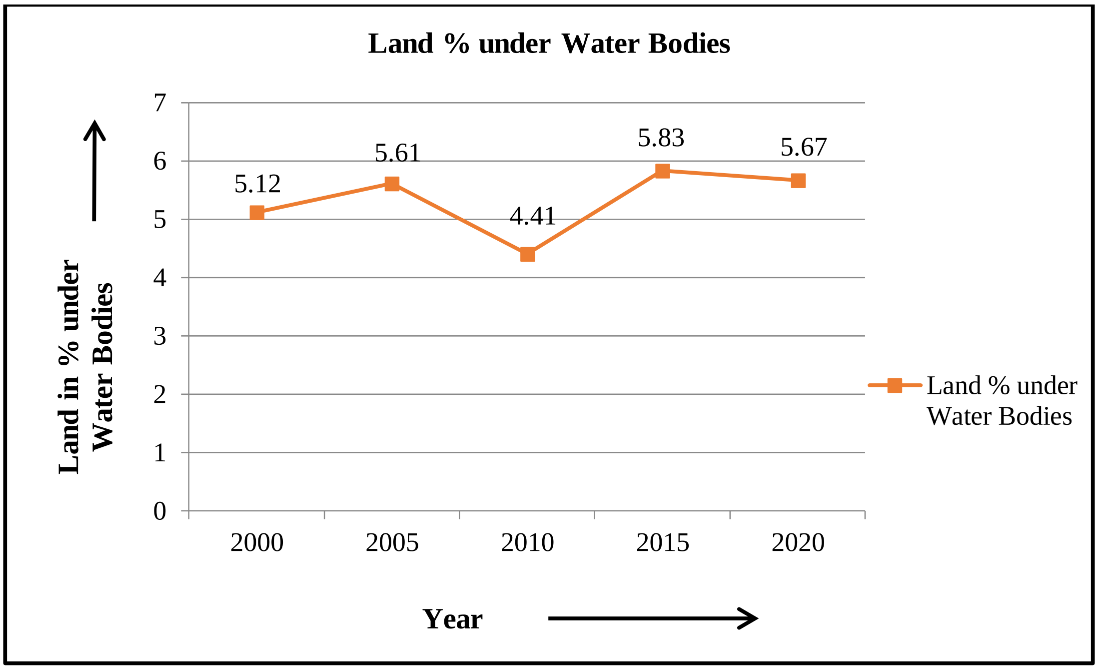
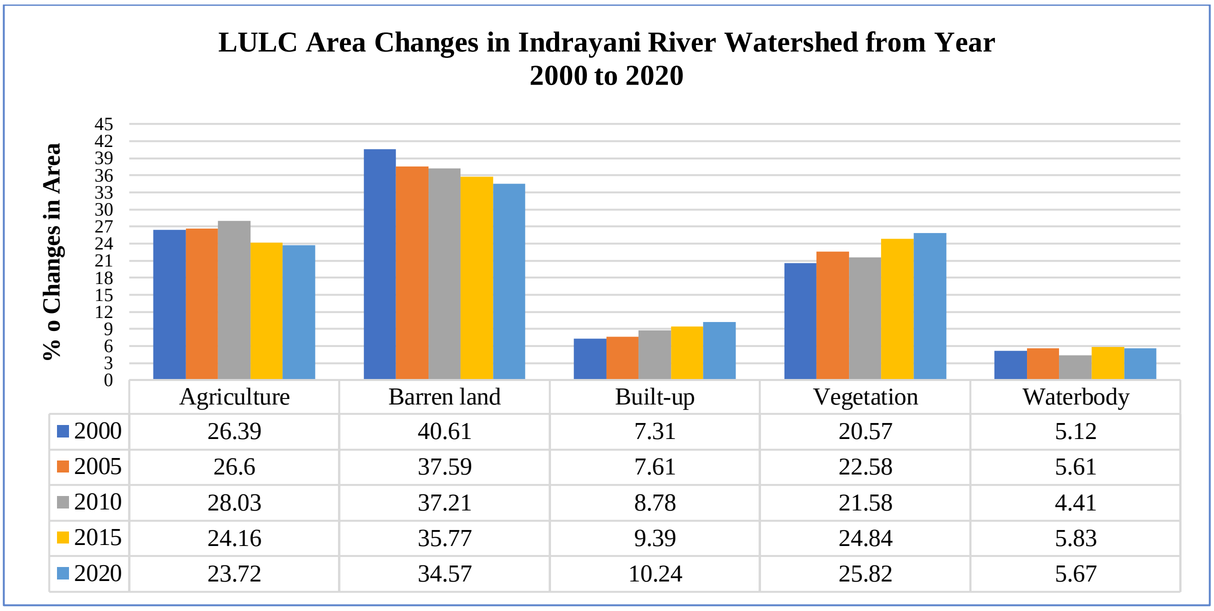


Fig. 11 Change in % land under water bodies in the study area for the period from the year 2000 to 2020

With the rapid increase in footprints of industrial activities and also residential, commercial, institutional and other supportive activities, there is a tremendous rise in the water demand in the study area, and the same is being catered through the available water resources in the form of dams and Indrayani River. Land under water bodies is depicted in Figure 11 with a fluctuation for the years 2010 and 2020, which shows slight fluctuation.



	Agriculture	Barren land	Built-up	Vegetation	Waterbody
2000	26.39	40.61	7.31	20.57	5.12
2005	26.6	37.59	7.61	22.58	5.61
2010	28.03	37.21	8.78	21.58	4.41
2015	24.16	35.77	9.39	24.84	5.83
2020	23.72	34.57	10.24	25.82	5.67

Fig. 12 LULC classes and changes in the study area for the period from the year 2000 to 2020

Figure 12 shows that water bodies did not grow significantly over the 20-year period but that the built-up area changed dramatically from 7.31% to 10.24% and that vegetation increased from 20.57% to 25.82%. This suggests that water demand increased during this time, but the land under water bodies has a small effect on LULC Change as compared to the land under built-up area and vegetation.

Simultaneously, there was a significant decline in agricultural land from 2000 to 2020, falling from 26.39% to 23.72%, which overall impact on water requirements. So, the prediction of future changes in LULC is very important to understand the development of the area and its water demand.

2.4. Prediction of LULC Change in the Study Area

Human activities, including urbanization, fragmentation due to agricultural activities and loss of green space, severely impacted the environment and regional settings. Urbanization is expected to be as main cause of farmland and loss of vegetation cover as well as tree canopy, which significantly causes climate change and human survival. Peri-urban built-up areas have increased drastically due to urbanization and industrial expansion.

Urban environments have been affected by impermeable surfaces. Long-term satellite photography is utilized to investigate complex LULC processes. Figure 12 shows the development that occurred in the Indrayani River watershed in the last 2 decades. The MOLUSCE plug-in in QGIS software provides modelling with spatio-temporal transitioning prospects and also prediction future scenes of changes in the LULC is a significant contributor to the success of the present research project.

The MOLUSCE plug-in is used to analyze, model and simulate LULC Change. This model has seven components,

- Input
- Evaluation Correction
- Change in Area
- Transition Potential Modelling
- Cellular Automata Simulation
- Model Validation
- Message

Figure 13 shows the methodology for the prediction of LULC Change in the future.

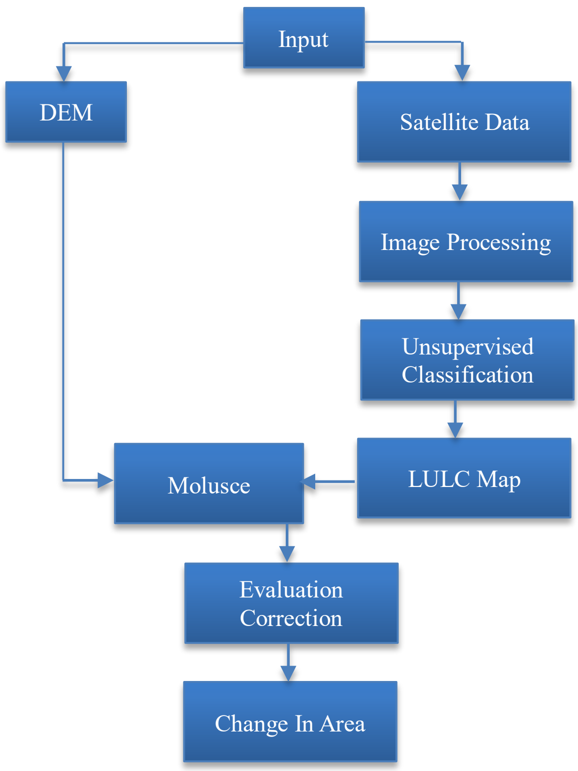


Fig. 13 Flow diagram showing methodology for prediction of LULC change in the study area

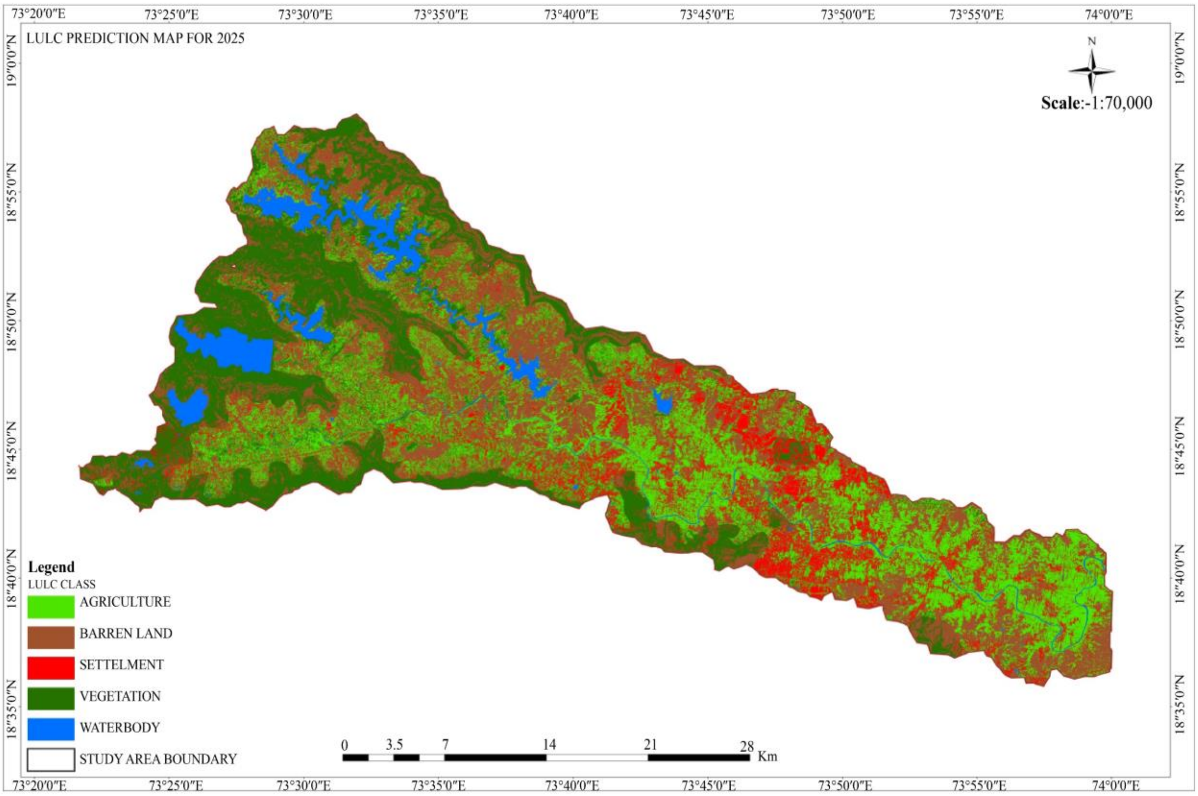


Fig. 14 Map showing prediction of LULC in the study area for the year 2025

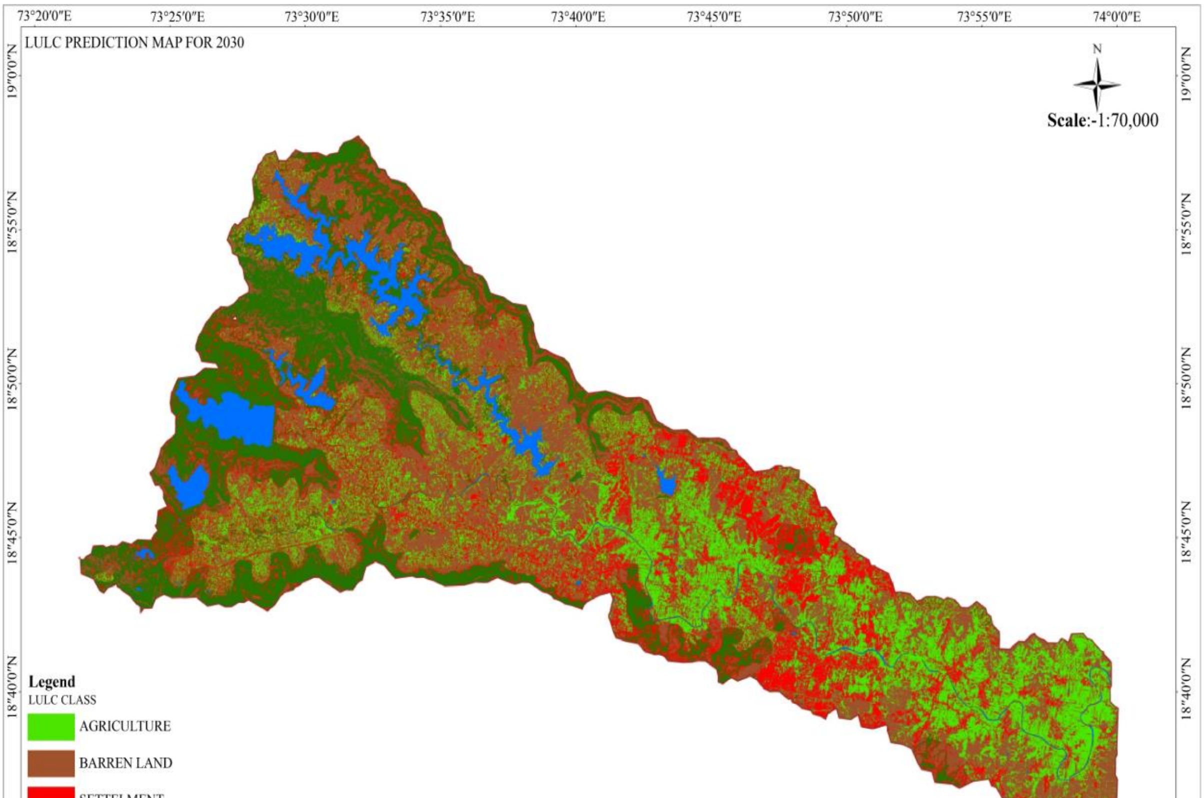


Fig. 15 Map showing prediction of LULC in the study area for the year 2030

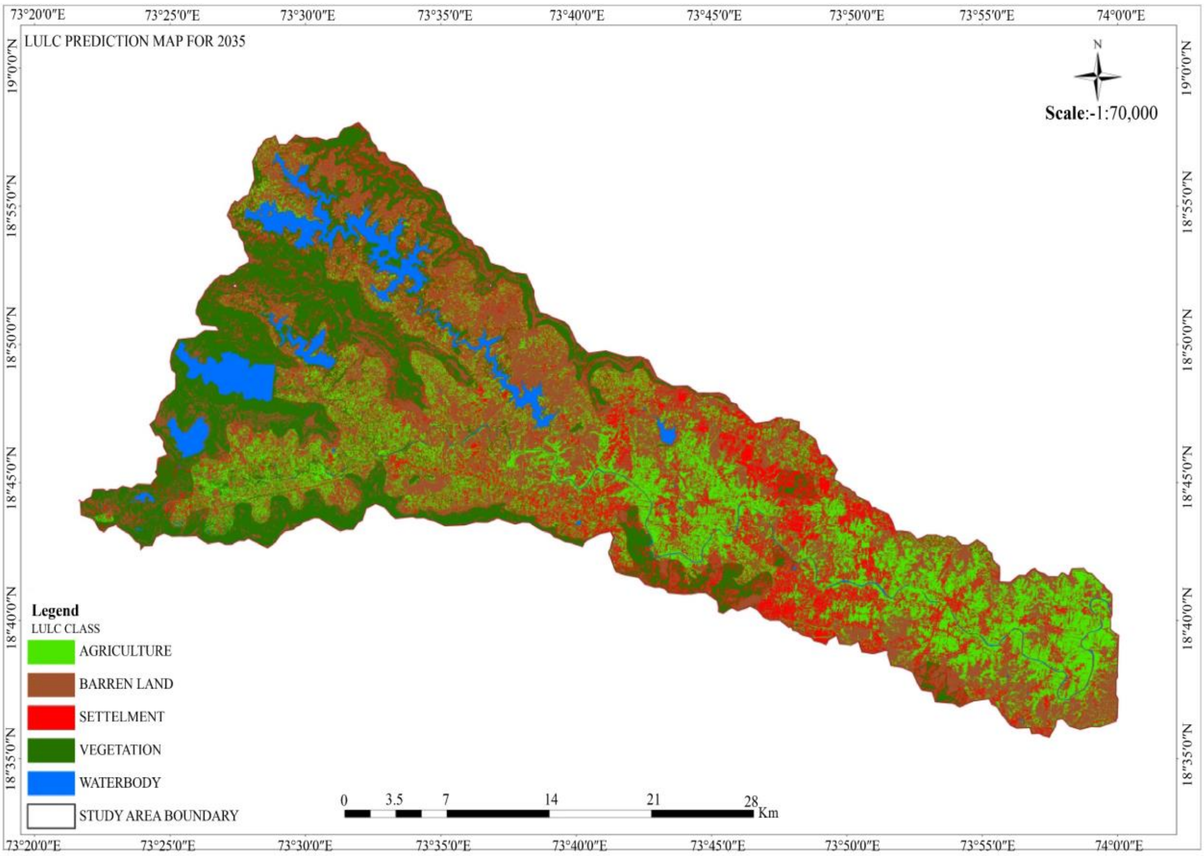


Fig. 16 Map showing prediction of LULC in the study area for the year 2035

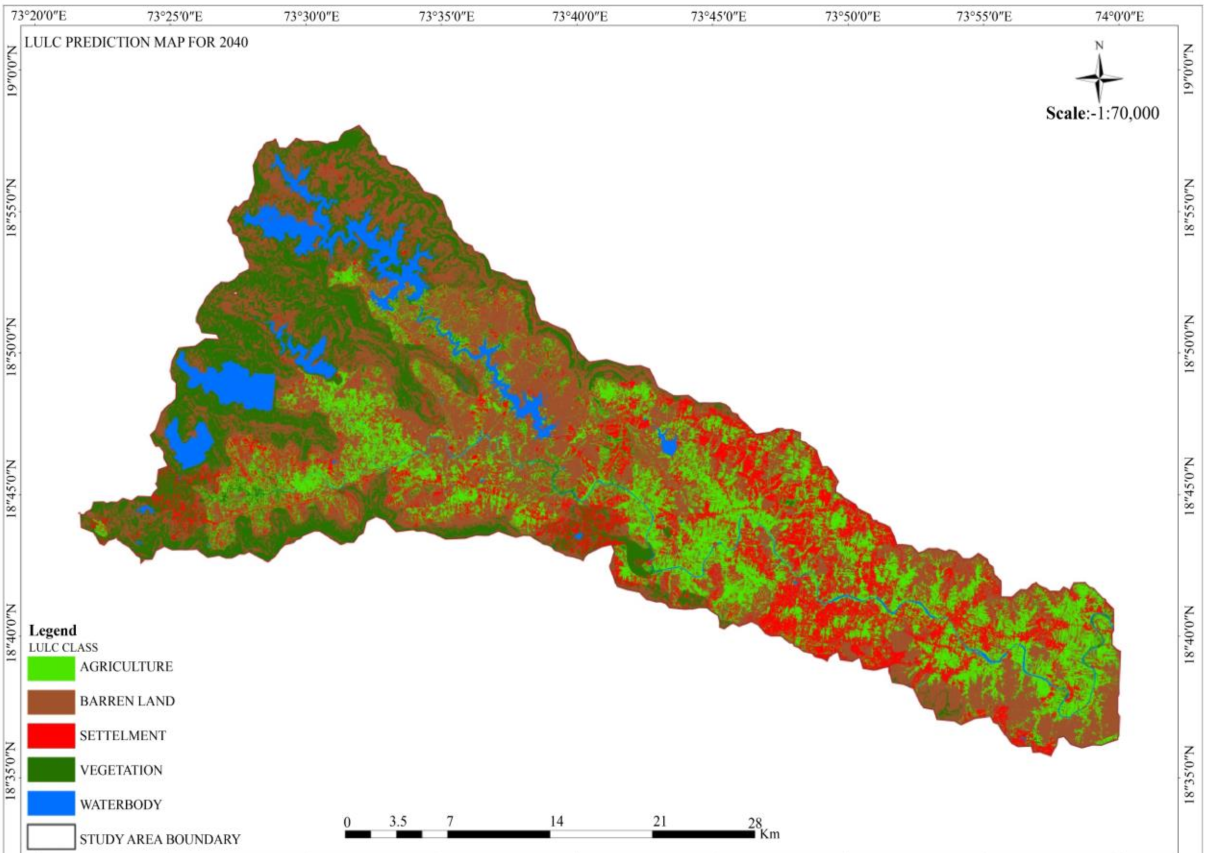


Fig. 17 Map showing prediction of LULC in the study area for the year 2040

Table 4. LULC classes and prediction of LULC change in the study area from year 2025 to 2040

LULC Classes	2025 km^2	%	2030 km^2	%	2035 km^2	%	2040 km^2	%
Agriculture	255.41	23.54	246.03	22.67	238.15	21.95	230.10	21.21
Barren land	378.97	34.93	371.52	34.24	379.49	34.97	391.10	36.04
Built-up	108.61	10.01	112.61	10.38	118.80	10.95	122.91	11.33
Vegetation	283.72	26.15	293.91	27.09	288.55	26.59	280.93	25.89
Waterbody	58.38	5.38	61.02	5.62	60.10	5.54	60.05	5.53
Total	**1085.10**	**100**	**1085.10**	**100**	**1085.10**	**100**	**1085.10**	**100**

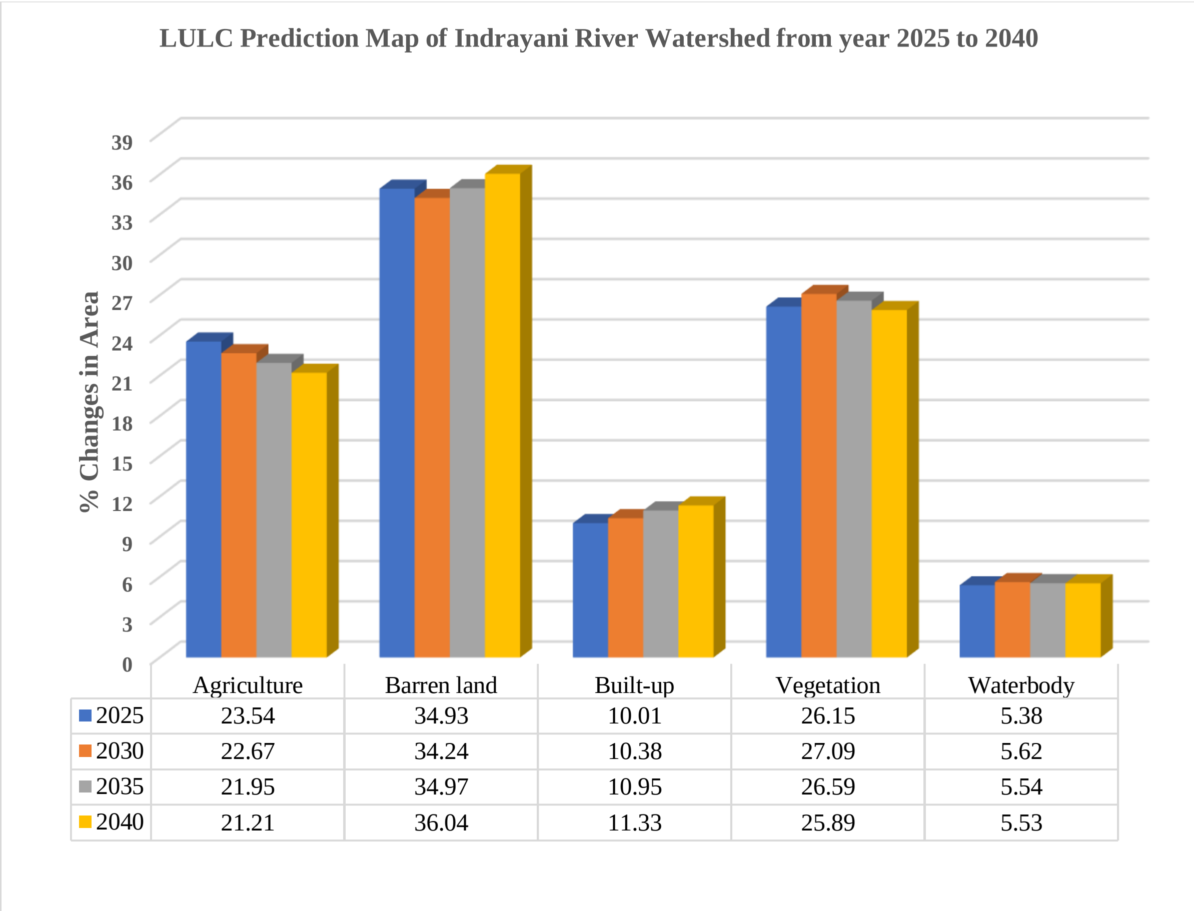


Fig. 18 Map showing prediction of LULC in the study area for the years from 2025 to 2040

Table 4 shows the summary of land classification, i.e. agricultural land, barren land, built-up, vegetation and water bodies, along with the changes in land use land cover prediction from year 2025 to 2040.

From Figure 18, it is observed that the water bodies may not grow in the next 20 years, but the built-up area could be changed dramatically from 10.01% to 11.33%, and the land under vegetation may decrease from 26.15% to 25.89%. As per this prediction, land under agriculture from 2025 to 2040 may reduce from 23.54% to 21.22%, which may have an overall impact on water demand for the study area. On the other hand, barren land may increase from 34.93% to 36.04% which shows there may be industrial as well as residential and other incidental development will take place in this region.

3. Results

3.1. Accuracy Assessment

The LULC classification and mapping process includes an essential component known as the post-classification accuracy assessment. This assessment is utilized to evaluate the degree of precision exhibited by the classified maps. These techniques are utilized for past studies to evaluate the accuracy of LULC maps that have been produced.

The Kappa equation is $$K = \frac{\mathrm{Po-Pe}}{1-\mathrm{Pe}} \quad (1)$$

Where,

Po presenting the proportion of correct land use predictions;

Pe represents the accidental consistency error.

Table 5. Actual and projected LULC from year 2020 to 2040 in the study area

LULC Classes	2020 km^2	%	2040 km^2	%	Overall, Classification Accuracy	Overall, Kappa (K^) Statistics
Agriculture	257.30	23.72	230.10	21.21	77.78 %	0.7131
Barren land	381.04	34.57	391.10	36.04		
Built-up	105.11	10.24	122.91	11.33		
Vegetation	280.12	25.82	280.93	25.89		
Waterbody	61.53	5.67	60.05	5.53		
Total	**1085.10**	**100**	**1085.10**	**100**		

3.2. Discussion

Worldwide, during the last century, huge and rapid urbanization has been taken place, which transformed the natural habitat and landscape layout in various parts of the world. It is also true for the area of the Indrayani River watershed where new industrial areas may be developed in the future. There are a number of physical and social factors that are the primary drivers of urbanization. These factors include geography, demographics, and economic expansion.

On the other hand, socio-economic progress has a major influence on the growth of population in metropolitan areas than overpopulation does. Concerns have been raised regarding food security, climate change and limitations of natural resources as a result of the scale and developing pace of the cities and sub-dividing the landscape patterns. A Kappa coefficient of around 78% was found to be associated with the land use prediction results that were produced from this study. The forecasted area indicates that there is a possibility that water bodies will not expand during the next twenty years. However, there is a significant change in the land under built-up area, increasing from 10.01% to 11.33%, and the percentage of vegetation shows a fall from 26.15% to 25.89%. From 2025 to 2040, according to this forecast, agricultural land will decrease from 23.54% to 21.22%, which will have an overall impact on the amount of water that is required.

On the other hand, vacant land may increase from 34.93% to 36.04%, which indicates that the industrial area may develop in this region. The previous year, which spans from 2000 to 2020, reveals that water bodies did not grow significantly over the period of 20 years. However, the built-up area changed dramatically from 7.31% to 10.24%, and vegetation increased from 20.57% to 25.82%.

This indicates that there is a rise in the water demand during said period. However, the growth of water bodies is relatively very small in comparison to the growth of built-up areas and vegetation. Similarly, a considerable decrease in the land under agricultural activities is observed for the period from 2000 to 2020, which has resulted in a decrease from 26.39% to 23.72% in land under agricultural activities, which has an overall impact on water demand. As a result, the forecasting of future changes in LULC is of utmost significance in order to comprehend the growth of the region and the water requirements of the region.

4. Conclusion

The present study examined the trend of LULC Change over time using Landsat data. Then it used these outcomes for the prediction of future scenarios for the Indrayani River watershed, which is already struggling with water availability issues due to rapid urbanization, forest and green area fragmentation, and large-scale industrialization in the study area.

Regional growth and environmental protection issues are already challenging, and these circumstances make them much more so. Migration, development policies and climate impact landscape patterns; these trends of LULC Change have been modelled and projected in the present study using physical and socio-economic factors. Another way to encourage sustainable development is to connect different policies related to the development of the region with agricultural activities. More elements and data need to be collected and used in future research to examine how they affect LULC patterns and their respective changes. The government shall take steps to conserve the water and also focus on augmenting and developing the water storage in the study area. It is also suggested to the government not only to develop the large dams but also to focus on the development of small watersheds like the Indrayani River so that future water demand can be met with the proper planning and management of available water resources which could make balance in demand and supply of water.

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