# Urban Sprawl Analysis and LULC change assessment in Bengaluru Rural, Karnataka, India

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**Research Article**

**Keywords:** Land use cover change, Land use policy, Urban sprawl, Landsat images, Image classification

**Posted Date:** August 11th, 2022

**DOI:** https://doi.org/10.21203/rs.3.rs-1855333/v1

# Abstract

Urban regions have grown and developed more quickly around the world. The amount of productive land is significantly reduced by the expansion of the urban perimeter. To ensure sustainable urban growth, research in urban sprawl analysis and land use land cover (LULC) change assessment is crucial. Bengaluru is one of the fastest growing metropolitan cities across the world, and its growth has a significant impact on neighbouring regions. Hence an attempt is made to evaluate the influence of urban sprawl on LULC in the Bengaluru rural district, which surrounds the Bengaluru urban region. In this study, temporal changes in LULC over two decades are assessed by employing remote sensed data and GIS tools. The study area is categorized into five LULC classes: settlement, waterbody, vegetation, agriculture, and barren land. Landsat images of two different timescales are classified using the supervised image classification technique in ERDAS software. The maximum likelihood technique is used for classifying the image, and the accuracy of the classified image is evaluated by accuracy assessment. The study revealed that urban sprawl significantly influenced the LULC classes study area.


# Introduction

Urban areas have been a significant part of the development of society since the beginning of time. They have been instrumental in setting the stage for significant economic, political, and social changes. Due to their rapid emergence and evolution, they have become the main drivers of economic and social change worldwide (Sun et al. 2013; Meng et al. 2022). Urbanization is a gift to society as it allows people to live in a more orderly manner. However, it can also be a curse if it is not planned and appropriately controlled (Mohan et al. 2011; Rimba et al. 2021). In 2008, the world passed a significant historical milestone when urban regions began to house half of the global population.

Moreover, developing countries have seen the majority of the expansion in the urban population (Nations 2009; Mohan et al. 2011; Zhong et al. 2022). The global urban population is projected to expand by 72% between 2000 and 2030, while the built-up areas of cities with 100,000 or more residents are projected to grow by 175% (Angel et al. 2005). Although only a small portion of the world's land surface is an urban region, rapid urbanization has caused significant changes to the natural landscape and affected the environment and society (Berling-Wolff and Wu 2004; Mundia and Aniya 2006; Bhat et al. 2017). Rapid urbanization has created various opportunities for the development of new urban areas. However, it can also lead to the growth of cities and towns beyond their juridical boundaries to accommodate the increasing urban population (Mosammam et al. 2017; Jiang et al. 2022). Due to rapid urbanization, there has been a growing interest in learning more about its effects on the environment. This is because various aspects such as the loss of arable land and the reduction in the natural vegetation cover have been identified as potential threats to developing new urban areas. Unplanned and uncontrolled urbanization has severely affected the environment and society (López et al. 2001; Chadchan and Shankar 2012). It has also led to various health risks, including air pollution, traffic accidents, and occupational hazards (Li et al. 2012). Migration from other places, economics, and the accessibility of basic facilities in metropolitan areas are the main drivers of urbanization (Barnes et al. 2002; Epstein et al. 2002).

Urban sprawl is a type of land disturbance that occurs when the increasing population living in an area causes the urban perimeter to extend beyond its original boundaries (Bhat et al. 2017; Sarif and Gupta 2022).. It has been criticized for its harmful effects on the environment and the availability of productive land. This type of development has been characterized by its large-scale encroachment and inefficient use of land resources. Due to the widespread urbanization of rural regions, urban expansion has also destroyed the natural landscape. One of the most common factors leading to environmental degradation is the increasing number of cities and their perimeter. Due to many driving forces, LULC is changing quickly (Rasool et al. 2018; Nega and Balew 2022). The rich agricultural land that used to be the main factor for the development of many cities is now being eaten away. The loss of prime farmlands has also caused severe damage to the environment. The marginal lands that were previously used for agriculture are not able to compensate for the loss of these lands. The land use patterns of a region are influenced by various aspects such as land availability, the socioeconomic factors that affect its development, and the time and space that humans can avail (Mohan et al. 2011; Mir and Ahmed 2014; Hashim et al. 2020; Hossain and Moniruzzaman 2021). Planning for land use is a significant problem and difficulty for both environmentalists and town and country planners when attempting to create sustainable economic growth in an eco-friendly way. For a very long time, remote sensing technology has been utilized to investigate how urbanization affects LULC change. (Sun et al. 2013, 2016; Bharath et al. 2021). Through this study, researchers can gain a deeper understanding of the human-environment interactions (Dewan et al. 2012). One of the most common factors that have led to the LULC change is the urban sprawl, which is characterized by deforestation and cropland displacement, which reduces the amount of arable land, habitat destruction, and reduces the number of natural vegetation regions (Byomkesh et al. 2012; Dewan et al. 2012; Du et al. 2013; Ma and Peng 2022).

The growth of suburban and urban regions necessitates increased land usage and encourages the shift from rural to urban settings (Mohan et al. 2011; Ferrari et al. 2019; Gao et al. 2020; Soliman and Soliman 2022; Wang et al. 2022). For instance, the development of new urban areas has a significant impact on the agricultural lands that are located in these areas (Vasisth 2018; Parmar et al. 2022; Reda et al. 2022). Understanding the effects of urbanization on the environment can help planners identify areas of potential improvement (Gorelick et al. 2020; Belay and Mengistu 2021).

Geographic information systems (GIS) and remote sensing (RS) can also help planners and environmentalists identify the various aspects that affect the LULC change with reliable accuracy and cost-effectiveness (Jin et al. 2019; Hashim et al. 2020). These technologies are helpful in the formulation and implementation of sustainable development strategies. GIS is a systematic tool utilized for analyzing spatial data and can be used for assessing the changes and forecasting the changes that affect the environment. RS is a type of technology that uses airborne and spaceborne sensors to collect data of an object without coming in contact (Jin et al. 2019; Mahmoud et al. 2019). This type of data collection can be used to study the environmental changes and predict future scenarios. Using GIS and RS technology, scientists can gain a deeper knowledge of the effects of urbanization on the LULC change (Wang et al. 2018). This technology has been used in various studies to monitor and simulate the changes in urban land use patterns. Due to its cost-effective and temporal frequency, RS techniques are commonly used for land use change analysis. This technology can also help planners and environmentalists understand the various factors that affect LULC change. It can also provide them with valuable information about the urban areas they plan to develop (Hashim et al. 2020).

This study aims to analyze the impact of urban sprawl on the LULC in the study area. It also presents recommendations to improve the policies and procedures related to developing new urban areas.

### Study area

The Bangalore Rural District is in the South-Eastern part of Karnataka State, India, as shown in Figure 1. It has a geographical area of 2305 $km^2$, and its population is 9,90,923 as per the 2011 Census. The district's average elevation is 600 to 900 meters from sea level. Due to the existence of various Hills, it is considered a spur of the Eastern Ghats. The rock formation that is found in these areas is regarded as part of the Gneiss category. The granite gneisses found in the Taluks of Nelamangala and Devanahalli have also contributed to the development of captivating landscapes. The district has three significant tributaries, namely the Kanva, the Arkavati, and the Dakshina Pinakini. The area is composed of granite characterized by various textures and colors, and it is rich in red-colored soil. The area Bangalore Rural District has been witnessing a large area of urbanization in recent years; as a result, there has been a drastic change in vegetation, cut down of trees due to road widening, and builders and developers have invested a massive amount in the development. This study is conducted to analyze the various thematic layers of the district using remote sensing data.

## Materials And Methods

The study is conducted using various data sets to analyze the LULC changes in the area. Understanding the dynamic phenomenon of urban sprawl is very important to developing effective strategies to manage the growth of this region. The study utilizes two software tools ERDAS and ArcGIS. A detailed methodology has been presented in Figure 2.

### Data acquisition

Using the multi-spectral satellite images, the study can analyze the LULC changes in the area. The United States Geological Survey (USGS) Earth Explorer offered them and was obtained using the Landsat. The images gathered throughout two time periods are examined for slight seasonal fluctuation. The various data utilized in this investigation are highlighted in Table 1.

Table 1. Details about the study area

| Data | Source | Satellite | Date of acquisition | Properties |
|---|---|---|---|---|
| Satellite images | USGS-Earth Explorer | Landsat 7 | 03/2001 | 30m resolution |
| | (earthexplorer.usgs.gov) | Landsat 8 | 04/2021 | |

### Image Pre-Processing & Image Classification

Prior to image classification, the data collected by the satellite are improved using histogram equalization (Mallupattu and Sreenivasula Reddy 2013) to increase the accuracy of image interpretation by adjusting their contrast. For image classification, a supervised classification technique is used, which allows the user to define the training sites (Mallupattu and Sreenivasula Reddy 2013; Chowdhury et al. 2020). The image processing and classification is performed using the ERDAS software. The study area is divided into five LULC classes: agriculture, vegetation, settlement, barren land, water body, and vegetation. The polygons are then drawn to represent training stations for each category, and Google earth pro is used for this purpose (Das Kangabam et al. 2019; Tsai et al. 2019). Finally maximum likelihood method is used to produce a final classified image.

### Accuracy Assessment

This process aims to compare the classified images with the ground truth points to determine how well they represent the real world (Das Kangabam et al. 2019; Chowdhury et al. 2020). In the study, the accuracy of the classified images is measured using evaluating the parameters like overall accuracy and Kappa coefficient. This is done by comparing the classified pixels with real-world ground truth points. The random sampling method uses two hundred fifty ground truth points to determine the accuracy of classified images (Abd El-Kawy et al. 2011, Das Kangabam et al. 2019, Tsai et al. 2019).

### LULC Change Assessment

The study results are expected to provide a comprehensive view of the LULC distribution in the study area at two timescales. Further, the classified images of two time periods are compared to determine the extent of urban sprawl's influence on LULC changes. (Chowdhury et al. 2020).

## Results And Discussion

Getting a comprehensive view of the LULC changes in the area over time is very important to developing effective strategies to manage the growth of this region. It is also very challenging to classify and map the land cover pattern due to the complexity of the process. With the increasing number of techniques and algorithms used in image processing, it is now possible to perform the same operation on satellite images. The satellite images for 2001 and 2021 are downloaded from USGS and classified using ERDAS software by supervised image classification technique. The LULC scenarios for all the two periods are discussed in the sections below.

### LULC scenario for the year 2001

Figure 3 is the thematic representation of LULC classes in the study area in the year 2001. Table 2 gives the details about different LULC statistics for the year 2001. It can be noticed that in the year 2001, the study area was dominated by vegetation with an area of 891.87 km$^2$ (38.68%) and followed by agriculture with 838.88 km$^2$ (36.38%) and other classes like barren land covering 465.25 km$^2$ (20.18%), settlement area 63.29 km$^2$ (2.74%), and water body 46.39 km$^2$ (2.01%). In the study area, water bodies refers to lakes and ponds.

Table 2. Land use land cover details for year 2001 and 2021

| LULC class | LULC in 2001 | | LULC in 2021 | |
|---|---|---|---|---|
| | Area (km$^2$) | (%) | Area (km$^{2)}$ | (%) |
| Settlement | 63.29 | 2.74% | 346.12 | 15.01% |
| Vegetation | 891.87 | 38.68% | 109.04 | 4.73% |
| Agriculture land | 838.88 | 36.38% | 1254.25 | 54.40% |
| Barren land | 465.25 | 20.18% | 584.96 | 25.37% |
| Water | 46.39 | 2.01% | 11.17 | 0.48% |
| Total area | 2305.68 | 100% | 2305.539 | 100% |

### LULC SCENARIO FOR THE YEAR 2021

Figure 4 is the thematic representation of LULC classes in the study area in the year 2021. Table 2 gives the details about different LULC statistics for the year 2021. It is noticed that in the year 2021, the study area was dominated by agriculture with an area of 1254.25 km$^2$ (54.40%) and barren land of 584.96 km$^2$ (25.37%), then followed by settlement area of 346.12 km$^2$ (15.01%), vegetation 109.04 km$^2$ (4.73%), and water body 11.17 km$^2$ (0.48%).

### LULC SCENARIO FOR THE YEAR 2001 TO 2021

Comparing classified images from 2001 to 2021 will indicate how the LULC has changed. Between this time, there was a significant decrease in the area covered by vegetation and water classes, while there was an increase in settlements, barren land, and agricultural land (Table 4). Vegetation land decreased by 87.77%, and waterbody area shrank by 75.93%. Whereas settlement area has risen from 63.29 km$^2$ to 346.12 km$^2$, agricultural land has risen from 838.88 km$^2$ to 1254.25 km$^2$, and barren land has risen from 465.25 km$^2$ to 584.96 km$^2$. The majority of the vegetation land has been converted into agricultural land and settlement due to increased urban expansion and population. Figure 6 represents the amount of coverage each LULC class had in the year 2001 and 2021, while Figure 7 show the percentage change in LULC classes from 2001 to 2021.

Table 4. Land use land cover details for the year 2001 to 2021

| Year/ land cover class | Land cover area in $km^2$ | | | Changes in % |
|---|---|---|---|---|
| | 2001 | 2021 | Changes from 2001 to 2021 | |
| Settlement | 63.29 | 346.12 | 282.83 | 446.91% |
| Vegetation | 891.87 | 104.04 | -787.83 | -87.77% |
| Agriculture land | 838.88 | 1254.25 | 415.37 | 49.51% |
| Barren land | 465.25 | 584.96 | 119.71 | 25.73% |
| Water | 46.39 | 11.12 | -35.27 | -75.93% |

**LULC change scenario Taluk-wise**

An attempt is made to compare the LULC change scenario Taluk-wise, i.e., Nelamangala, Doddaballapura, Devanahalli, Hosakote. Table 4 highlights the distribution of each LULC class in 2001 and 2021 and indicates the percentage change that has happened in two decades, taluk-wise. Figure 8 depicts the distribution of LULC classes, and Figure 9 illustrates the differences in LULC classes, Taluk-wise graphically.

The general comparison of each LULC class between 2001 and 2021 reveals that LULC has changed significantly during the past 20 years. There has changed significantly in LULC around the last 20 years in each of the taluks. It is noticed that there has been a substantial increase in settlement in all the taluks as all the taluk centres are close to the border of Bengaluru Urban. And each of them is connected with either National or State Highways; with the ease of transportation, Bengaluru Rural has noticed a severe urban sprawl. Due to the urban expansion, there has been a major change in the LULC pattern. In the considered period, the settlement has increased by 446.91%, 177.89%, 326.11%, and 246.36% in Nelamangala, Doddaballapura, Devanahalli, and Hosakote taluks, respectively. Agricultural land has increased by 49.51%, 75.63%, 57.36% and 113.47%. While vegetation area has decreased by 87.77%, 86.3%, 87.64%, and 88.98%, and waterbody area has decreased by 75.93%, 78.06%, 74.88%, and 83.51%, respectively, among four taluks. Barren land has increased by 25.73%, 2.95%, and 8.67% in Nelamangala, Doddaballapura, and Hosakote taluks, respectively, whereas there has been a decrease in barren land in Devanahalli taluk by 0.22%.

Table 4. Land use land cover details of the study area Taluk-wise

| Taluk Name | Particular | Settlement | Vegetation | Agriculture | Barren | Water |
|---|---|---|---|---|---|---|
| Nelamangala | Area in 2001 ($km^2$) | 27.70 | 171.16 | 268.07 | 56.44 | 11.52 |
| | Area in 2021 ($km^2$) | 97.99 | 18.15 | 268.67 | 145.39 | 4.70 |
| | % Change | 253.68% | -89.40% | 0.22% | 157.60% | -59.19% |
| Doddaballapura | Area in 2001 ($km^2$) | 24.98 | 269.13 | 258.76 | 201.02 | 17.66 |
| | Area in 2021 ($km^2$) | 69.42 | 36.88 | 454.46 | 206.94 | 3.87 |
| | % Change | 177.89% | -86.30% | 75.63% | 2.95% | -78.06% |
| Devanahalli | Area in 2001 ($km^2$) | 22.21 | 178.66 | 156.89 | 91.40 | 7.55 |
| | Area in 2021 ($km^2$) | 94.65 | 22.09 | 246.88 | 91.20 | 1.90 |
| | % Change | 326.11% | -87.64% | 57.36% | -0.22% | -74.88% |
| Hosakote | Area in 2001 ($km^2$) | 28.38 | 252.90 | 134.96 | 116.32 | 9.65 |
| | Area in 2021 ($km^2$) | 98.28 | 27.86 | 288.09 | 126.41 | 1.59 |
| | % Change | 246.36% | -88.98% | 113.47% | 8.67% | -83.51% |

### Accuracy assessment

The accuracy assessment was performed by a random sampling method that involved selecting 250 points randomly from the collected images. Results revealed that the overall accuracy was 87.31% and 85.86% while the Kappa co-efficient was 0.869 and 0.847 for classified images of year 2001 and 2021. The results indicate that the accuracy of the classified images is acceptable.

## Conclusion

Bengaluru Rural District is experiencing rapid urbanization, due to which the area has noticed a significant change concerning LULC distribution. The current study aimed to assess the amount and pattern of LULC changes in the study area. The study depicted that there has been an increase in settlement areas due to increased population and urban encroachment. As a result, there has been an increase in agricultural land and barren land but a significant reduction in vegetation and water bodies. It is noticed that most of the vegetation area is converted to settlement and agricultural land. Due to improper land use planning in the study area, most water bodies are dried up, which might severely threaten water availability and recharge. Also, the study area has noticed increased barren land due to land degradation. The study also revealed that using remote sensing and GIS in mapping and assessing the LULC changes in an area can be very beneficial. This method can help in identifying the areas where significant changes are happening. Some of the recommendations based on the study's findings include establishing effective management strategies for the multiple resources affected by these changes in Bengaluru Rural District.

1. Surface water resources in the area are getting depleted; the government should take measures to manage the surface water levels.
2. Prediction of regional population and development needs to ensure wise land resource usage.
3. Government should introduce a plan to ensure maximum use of barren land by promoting afforestation.
4. One of the most effective strategies that the Karnataka Forest department can implement is the promotion of tree planting. This can be done through the establishment of effective partnerships with non-governmental organizations.
5. Government should ensure planned housing and settlement programs for the upcoming period.

# Declarations


### Funding

The authors declare that no funds, grants, or other support were received during the preparation of this research work.


### Competing Interests

None.

### Authors contribution

**Bharath Ashwathappa**: Conceptualization, Investigation, Methodology, Writing - original draft. **Bhumika Das**: Methodology, Writing - review and editing, Supervision. **Manjunath Maddikeari**: Resources, Software, Data curation, **Reshma T Vishweshwaraiah**: Formal analysis, Software and Investigation, **Ranjitha B Tangadagi**: Writing - review and editing, Formal analysis and Investigation.

### Ethical Approval

Not Applicable

### Consent to Participate

Not Applicable

### Consent to Publish

Not Applicable

### Availability of data and materials

It will be available based on reasonable request to the corresponding author.

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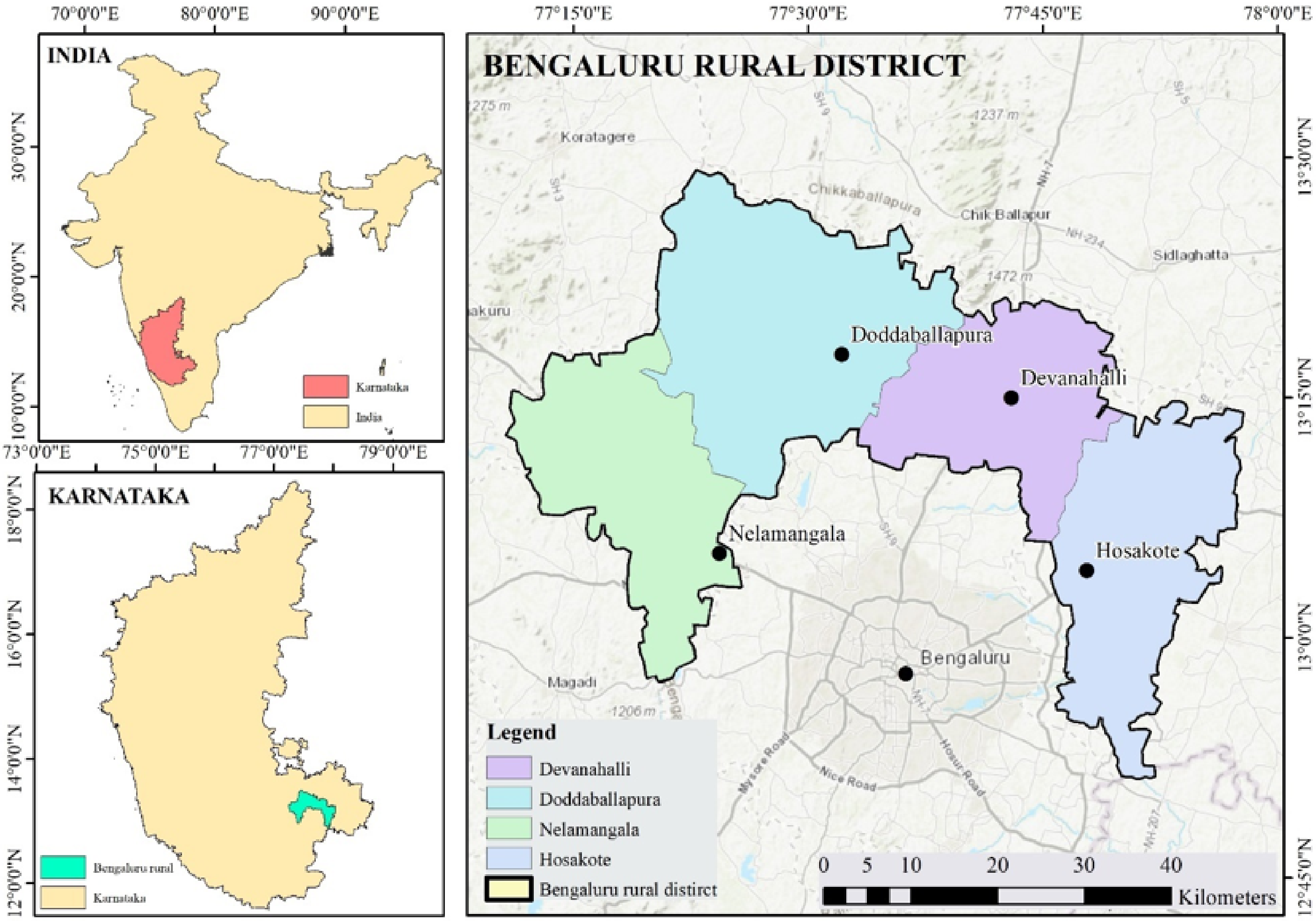
# Figures




## Figure 1

Location of the study area

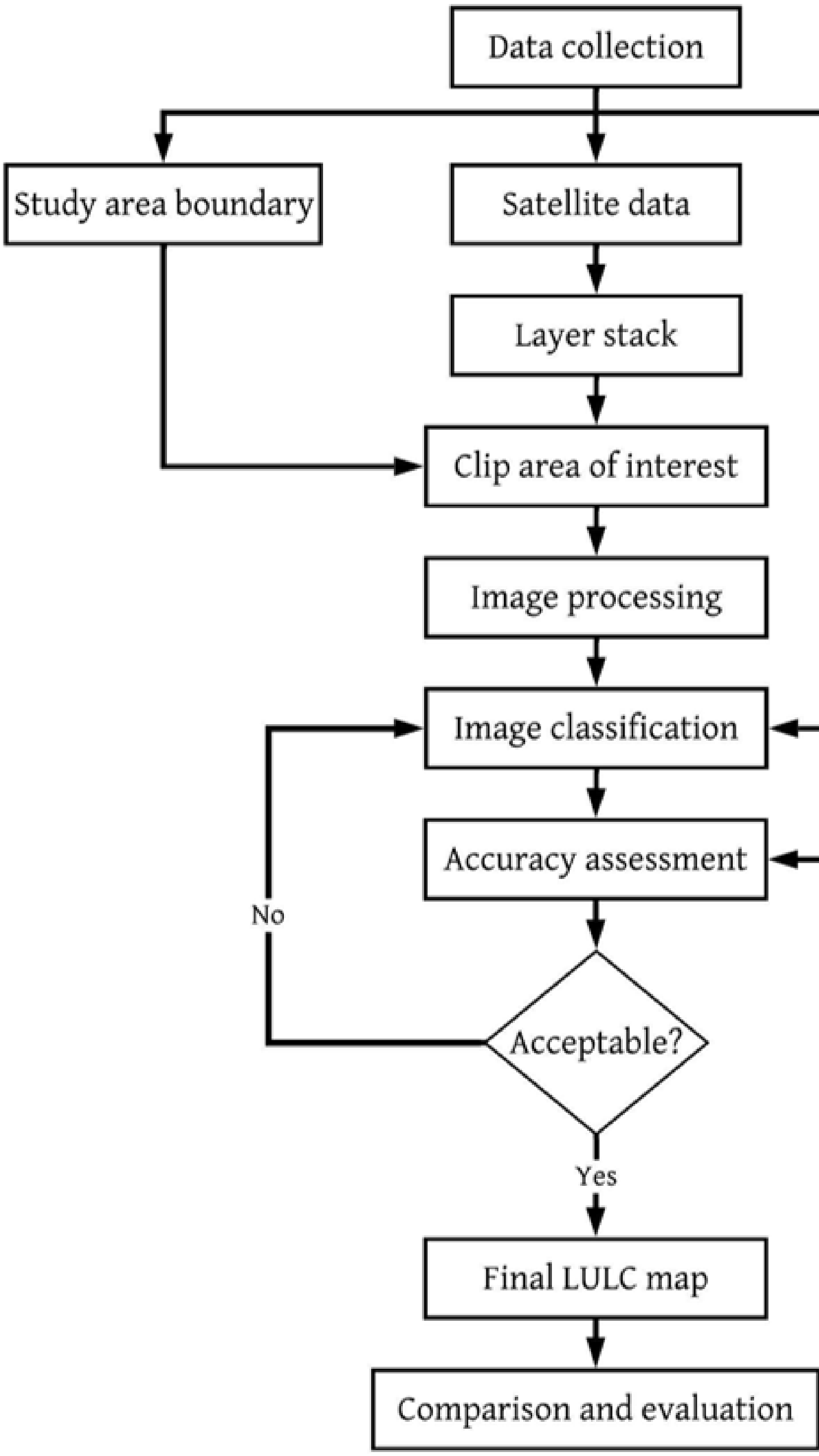
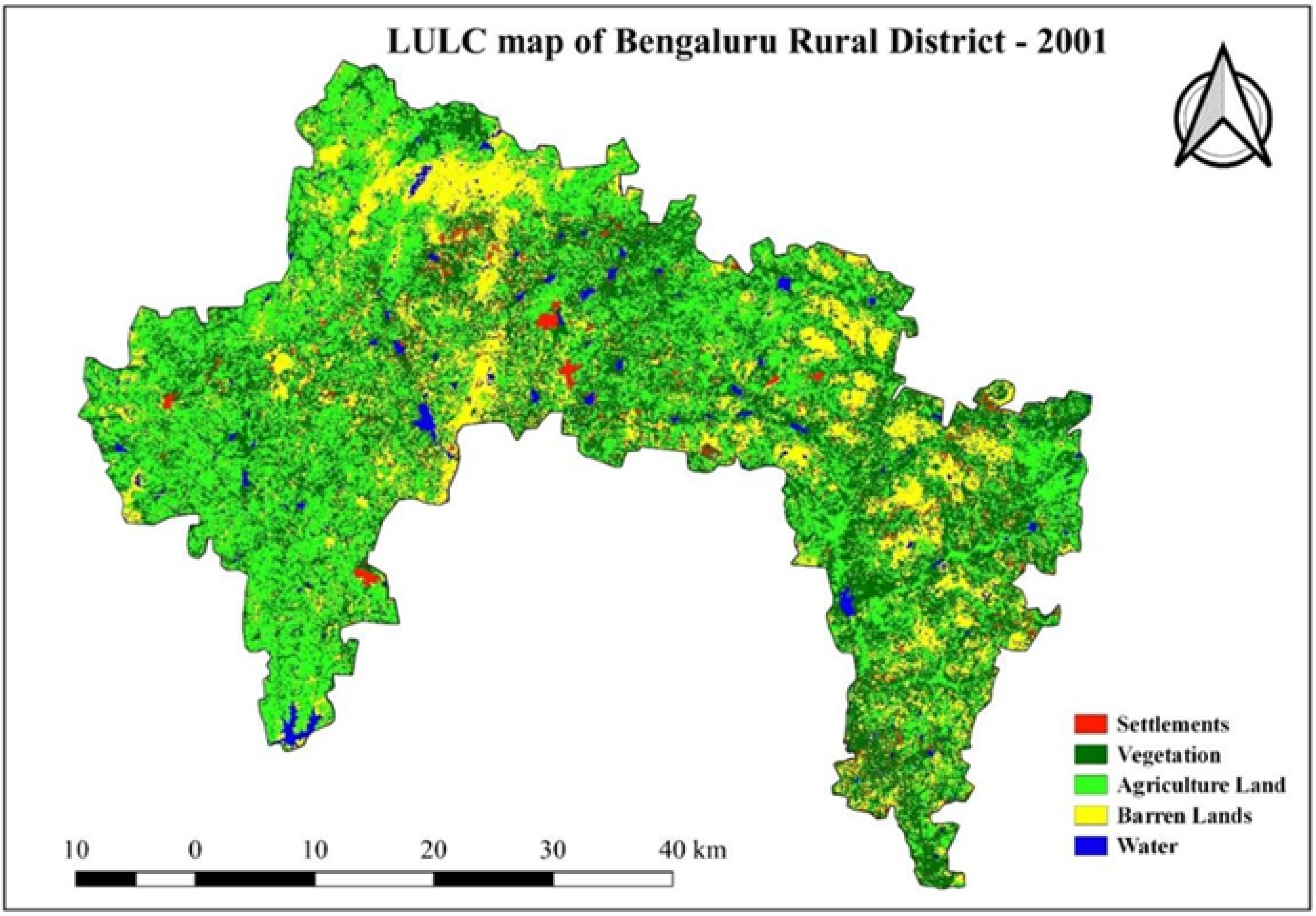



**Figure 2**

Methodology for LULC mapping & change detection




## Figure 3

Classified Image of Year 2001

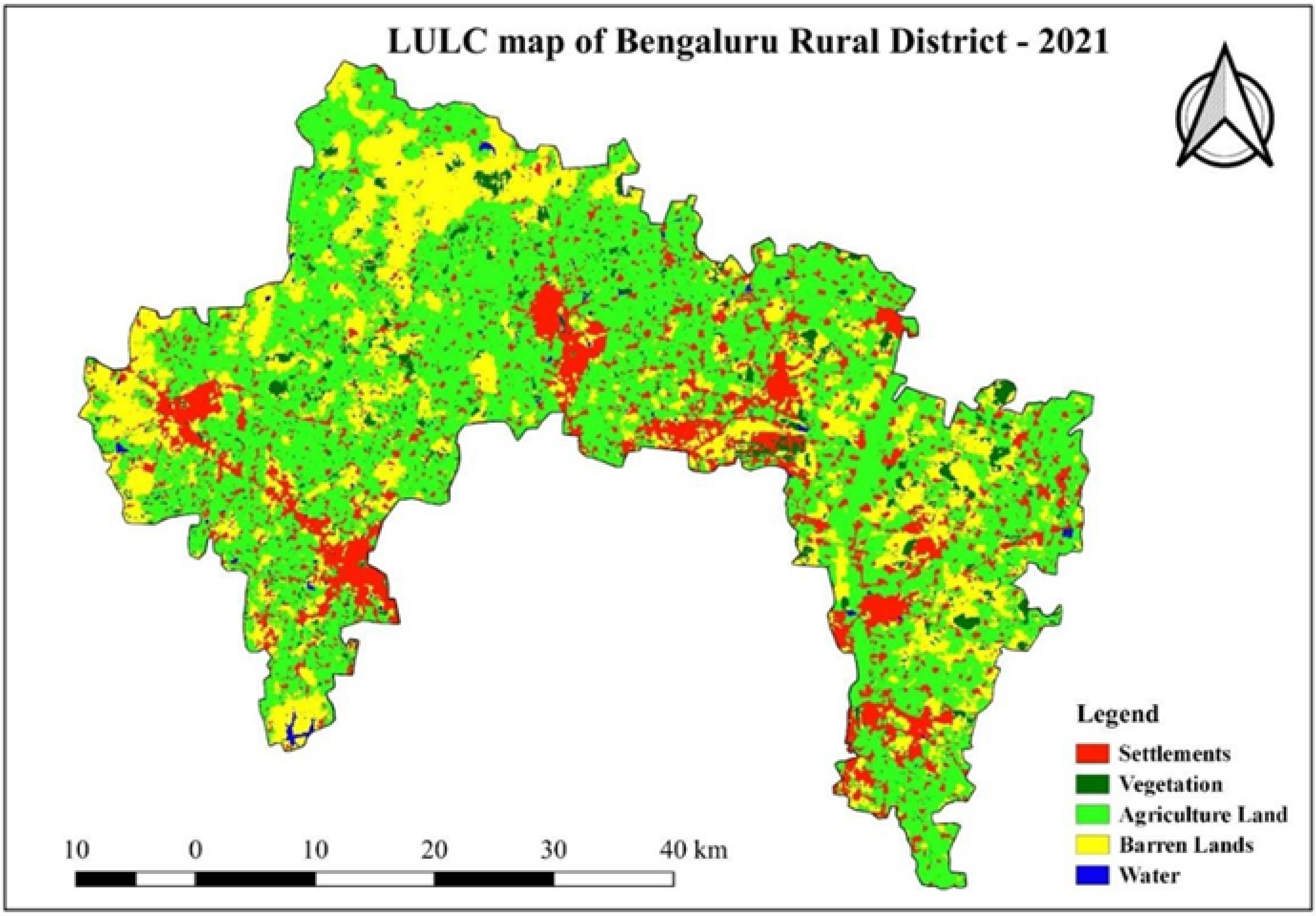



**Figure 4**

Classified Image of the Year 2021

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**Figure 5**

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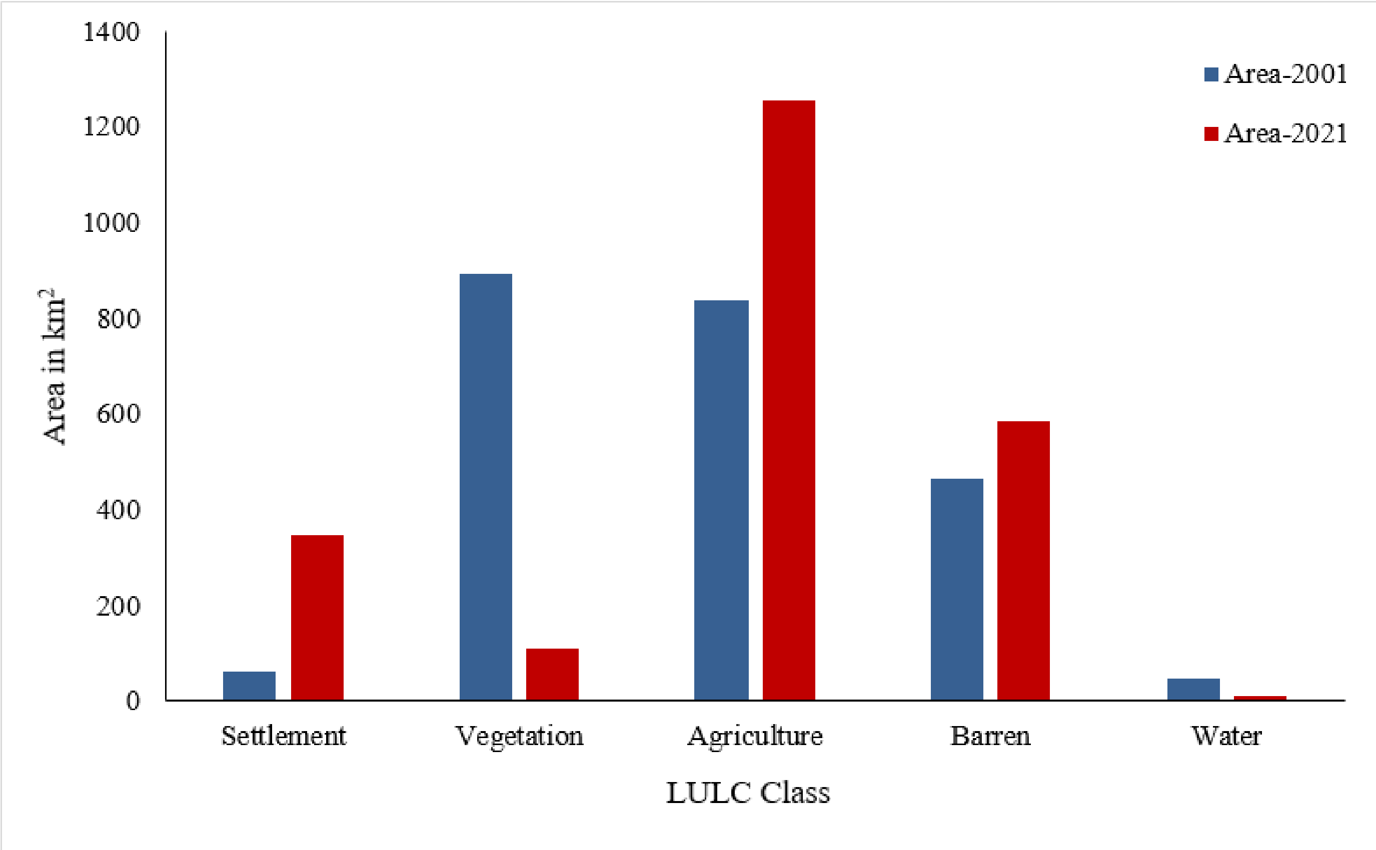



## Figure 6

Spatial distribution of LULC classes in the year 2001 and 2021

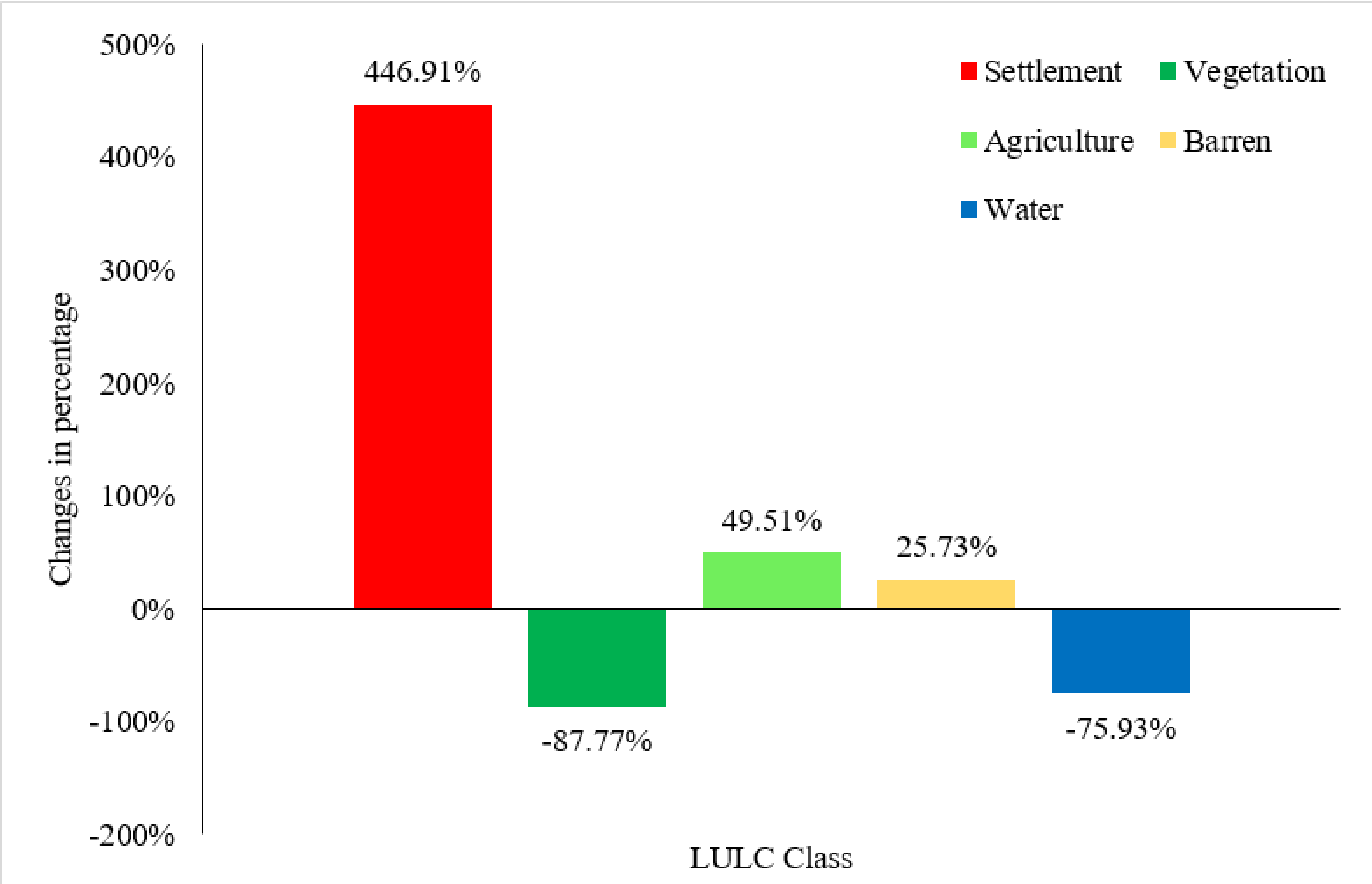
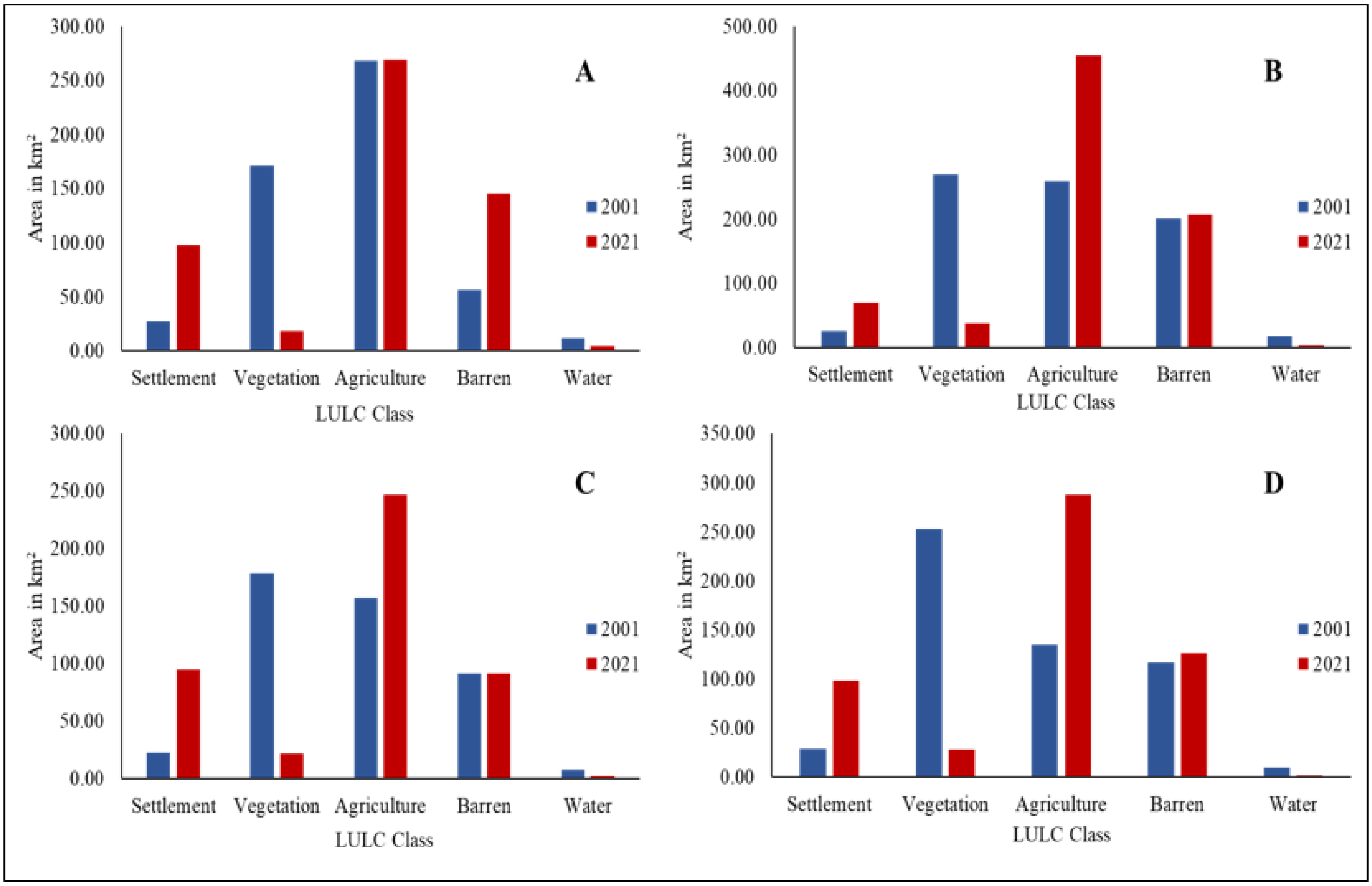



**Figure 7**

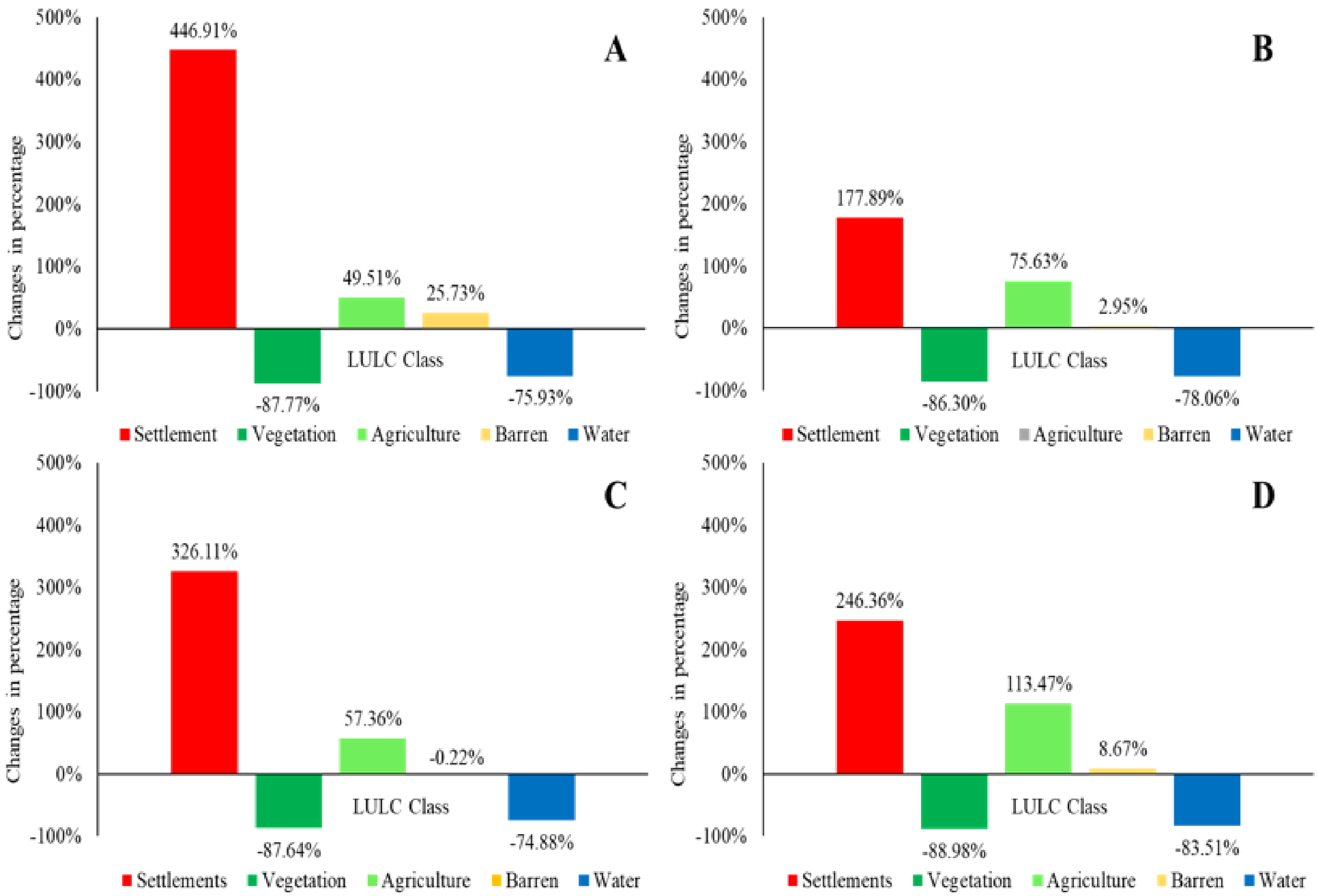
Percentage changes in LULC classes from the year 2001 to 2021




## Figure 8

Distribution of LULC classes from the year 2001 to 2021, Taluk-wise

A- Nelamangala, B- Doddaballapura, C- Devanahalli, D- Hosakote




## Figure 9

Percentage changes in LULC classes from the year 2001 to 2021, Taluk-wise

A- Nelamangala, B- Doddaballapura, C- Devanahalli, D- Hosakote