Hindawi
Discrete Dynamics in Nature and Society
Volume 2023, Article ID 8077644, 15 pages
https://doi.org/10.1155/2023/8077644

Research Article

Evaluation of Land Use/Land Cover Changes due to Urban Sprawl in Bengaluru Rural, Karnataka, India

A. Bharath,[1] **M. Manjunatha**,[1] **T. V. Reshma**,[1] **Ranjitha B. Tangadagi**,[1] **and Sifatullah Bahij**[2]

[1]*Department of Civil Engineering, GITAM School of Technology, GITAM University, Bengaluru, Karnataka, India*
[2]*Faculty Member of Civil and Industrial Construction Department, Kabul Polytechnic University, Kabul, Afghanistan*

Correspondence should be addressed to Sifatullah Bahij; sifatullah.bahij@kpu.edu.af

Received 2 June 2023; Revised 8 September 2023; Accepted 11 October 2023; Published 17 October 2023

Academic Editor: Emilio Jiménez Macías

The availability of productive land is significantly impacted by the global phenomenon of urbanization. The amount of land available for food production and other essential activities decreases as cities grow because the urban perimeter encroaches on rural and natural areas. Conducting research on urban sprawl analysis and land use land cover (LULC) change assessment is essential in ensuring sustainable urban growth. Bengaluru, a rapidly expanding metropolitan city, has a significant impact on the area around it, making it a prime location for this kind of study. In this study, authors sought to assess how urban sprawl affected LULC in the Bengaluru rural district that surrounds the city of Bengaluru. The study evaluated changes in LULC over a two-decade period using remote sensing data and GIS tools. Five LULC classes were used to categorize the study area: settlement, waterbody, vegetation, agriculture, and barren land. The maximum likelihood technique was used to classify Landsat images from three different time periods using the supervised image classification method in the ERDAS software. Accuracy assessment was used to gauge the classified images' accuracy. The study's important findings showed how the LULC classes in the study area have been negatively impacted by the urban sprawl. The study emphasizes the significance of ongoing research in LULC change assessment and urban sprawl analysis to ensure sustainable urban growth and safeguard the availability of productive land.

1. Introduction

Urban areas have been crucial in influencing the course of human history. They have acted as crucibles for progress, innovation, and creativity. Urbanization has accelerated over time and is now one of the most important forces transforming the global economy and society [1, 2]. As a result, new lifestyles, values, and aspirations have emerged, changing the way people live, work, and interact with one another. Urbanization has many advantages, but if it is not properly managed, it can present serious problems. Congestion, pollution, and the loss of open spaces can result from the rapid growth and expansion of urban areas. Additionally, urbanization has severely impacted the quantity and quality of resources such as water, land, and energy. The rate of urbanization has greatly accelerated recently. The world witnessed a historic turning point when urban areas started to hold more than half of the world's population in 2008 [3]. In order to ensure sustainable growth and development, urban areas must be carefully planned and managed.

In addition, the majority of the growth in the urban population has occurred in developing nations [3, 4]. Between 2000 and 2030, it is anticipated that the world's urban population will increase by 72%, while the built-up areas of cities with 100,000 or more inhabitants are anticipated to increase by 175% [5]. Even though urban areas make up a relatively small portion of the planet's land area, rapid urbanization has had a significant negative impact on the environment, society, and the natural landscape [6, 7]. Numerous opportunities for the growth of new urban areas have been made possible by rapid urbanization. To accommodate the growing urban population, it can also cause cities and towns to expand outside of their legal boundaries

[8, 9]. A growing number of people are interested in finding out more about the effects of rapid urbanization on the environment. This is due to the fact that a number of factors, including the disappearance of arable land and a decline in the amount of natural vegetation cover, have been noted as potential obstacles to the creation of new urban areas. Unplanned and uncontrolled urbanization has severely affected the environment and society [10–12]. It has also led to various health risks, including air pollution, traffic accidents, and occupational hazards [13]. Migration from other places, economics, and the accessibility of basic facilities in metropolitan areas are the main drivers of urbanization [14, 15].

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 [16]. 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 [17]. 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 are 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 [3, 18, 19]. 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 [20, 21]. Through this study, researchers can gain a deeper understanding of the human-environment interactions [22]. Urban sprawl, which is characterized by deforestation and cropland displacement, which reduces the amount of arable land, habitat destruction, and a decrease in the number of natural vegetation regions, is one of the most frequent factors that have contributed to the LULC change [23, 24].

Increased land use and the migration from rural to urban areas are encouraged by the growth of suburban and urban areas [3, 25–29]. For instance, the creation of new urban areas has a big effect on the agricultural lands that are present there [30, 31]. Planners can find potential areas for improvement by understanding how urbanization affects the environment [32, 33].

Planning professionals and environmentalists can also identify the various factors influencing the LULC change with dependable accuracy and cost-effectiveness using geographic information systems (GIS) and remote sensing (RS) [34–37]. The creation and application of sustainable development strategies are made easier by these technologies. GIS is a methodical tool used for spatial data analysis. It can be used to evaluate changes and predict changes that will have an impact on the environment. RS is a branch of technology that gathers information about an object without making physical contact by using airborne and spaceborne sensors [34, 38–40]. Future scenarios can also be predicted, and environmental changes are studied using this kind of data collection.

Scientists can learn more about how urbanization affects the LULC change by using GIS and RS technology [41]. In numerous studies, this technology has been used to track and model changes in urban land use patterns. RS techniques are frequently used for land use change analysis because they are economical and frequently used over time. Additionally, this technology can assist environmentalists and planners in comprehending the various aspects of LULC change. Additionally, it may give them important knowledge about the cities they intend to grow [42]. The goal of this study is to examine how urban sprawl affects the LULC in the study area. It also presents recommendations to improve the policies and procedures related to developing new urban areas.

2. Study Area

The Bangalore rural district is in the southeastern 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 a 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 of 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. With the help of remote sensing data, this study examines the district's various thematic layers.

3. Materials and Methods

The study analyses LULC changes in the study area using a variety of datasets and software tools. The research is essential because urban sprawl has become a major issue in many locations, and it is critical to develop efficient management strategies for its expansion. ERDAS and ArcGIS are two software tools used in the study to examine how urban sprawl affects LULC in the area. Figure 2 presents the methodology for this study in detail, outlining the steps taken to gather, prepare, and examine the data. It entails gathering satellite imagery, carrying out image classification, evaluating accuracy, and charting the evolution of the LULC.

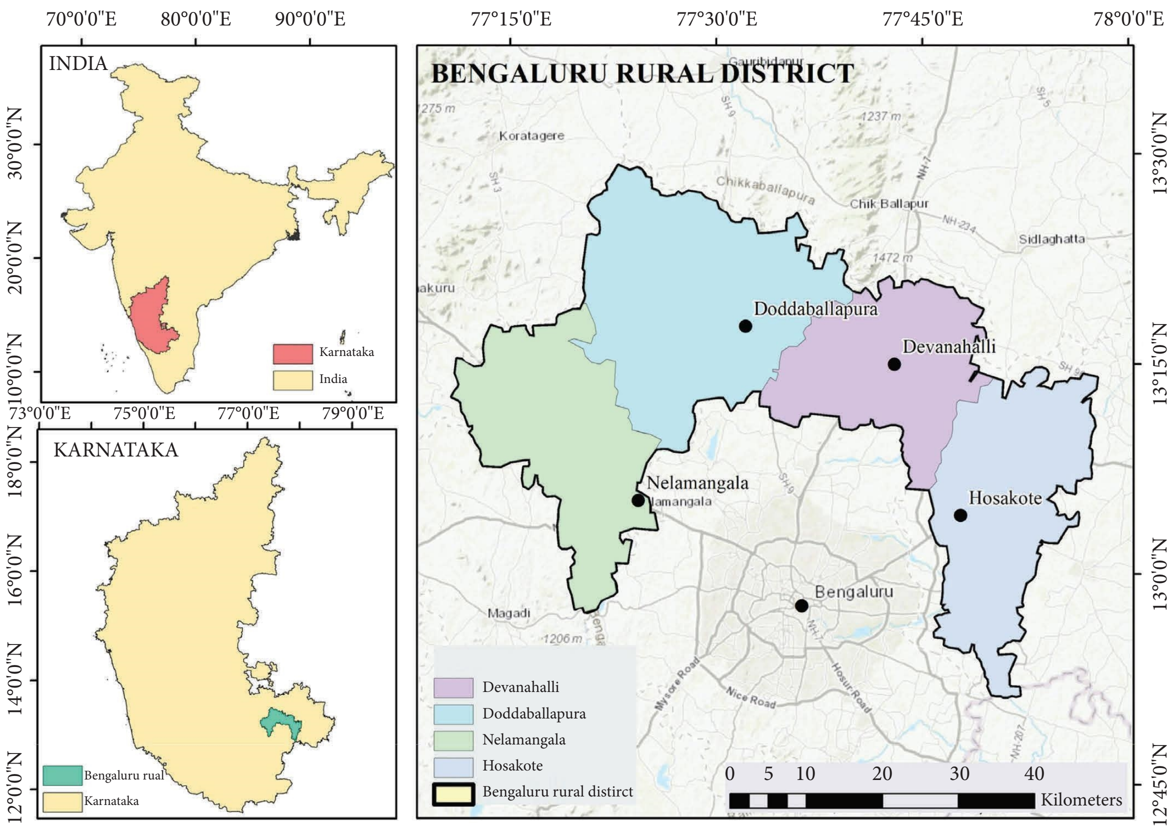


Figure 1: Location of the study area.

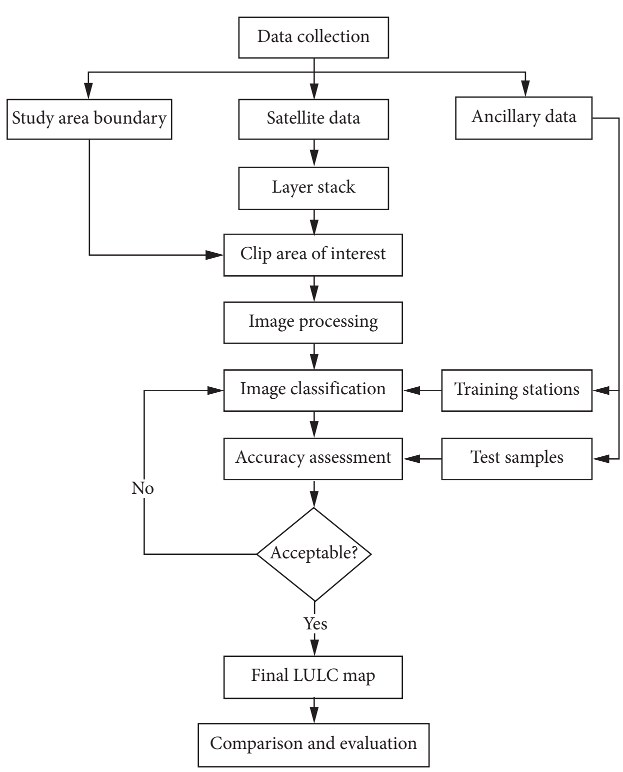


Figure 2: Methodology for LULC mapping and change detection.

3.1. Data Acquisition. The study utilizes multispectral satellite images to analyse the area's LULC changes. These images are obtained from the United States Geological Survey (USGS) Earth Explorer using Landsat, a satellite program that collects images of the Earth's surface. The study examines images gathered over three different periods with minimal seasonal fluctuations. The details of various data utilized in this investigation are presented in Table 1.

3.2. Image Preprocessing and Image Classification. The data gathered by the satellite are first enhanced by applying atmospheric correction and histogram equalization in order to produce accurate and understandable images [43]. Any distortion or noise brought on by atmospheric conditions (absorption and scattering, atmospheric turbulence, aerosol particles and pollution, cloud cover, water vapor, humidity etc.) during data collection can be eliminated with the aid of atmospheric correction. The images are then subjected to histogram equalization to boost contrast and facilitate interpretation. The images are then categorized into various LULC classes using a supervised classification technique. The user can specify the training sites using this method [43, 44]. Five LULC categories, agriculture, settlement, barren land, water body, and vegetation, are used to categorize the study area. Using Google Earth Pro, polygons are created as training stations to represent each category

Table 1: Details about the study area.

Data	Source	Satellite	Date of acquisition	Properties
Satellite images	USGS-Earth Explorer (https://earthexplorer.usgs.gov)	Landsat 5 Landsat 7 Landsat 8	03/2001 03/2011 04/2021	30 m resolution

[45, 46]. Image processing and classification tasks are carried out using the ERDAS software. The maximum likelihood approach is then used to create the final classified image. This technique, which is based on probability theory, is frequently used in the analysis of remote sensing images to classify pixels into various types of land cover [45, 46].

3.3. Accuracy Assessment. How accurately the classified images depict the real world is determined in part by the accuracy assessment procedure. In this study, the overall accuracy and Kappa coefficient are two metrics that are used to assess accuracy of the classified images. The classified pixels are compared to ground truth points located in the real world to accomplish this. Two hundred and fifty ground truth points are chosen using the random sampling method, and the accuracy of the classified images is then evaluated [45, 46]. Finding the degree of agreement between the classified images and the ground truth points is the goal of this process. The percentage of correctly classified pixels is measured by overall accuracy, and the degree of agreement over and above what would be predicted by chance alone is assessed by the Kappa coefficient [44, 46].

3.4. LULC Change Assessment. The study is anticipated to provide a thorough understanding of the distribution of LULC over three distinct time periods in the study area. To determine the effect of urban sprawl on LULC changes, the classified images from the three time periods will also be compared [44]. The study's findings may offer insights for creating practical plans to control regional growth after data analysis.

3.5. Evaluation Population Growth. The population data of both Bengaluru rural and Bengaluru urban districts are collected from the census department from the years 1901 to 2011. Then, the population is forecasted for the year 2021 using geometric increase method, where the percentage increase in population with respect to every decade is calculated using equation (1), and then average percentage of population growth of all the decades is computed using equation (2). Finally using this average value, the population is forecasted for the year 2021 using equation (3).

$$r_i = \frac{\text{Increase in population}}{\text{Initial population}} \text{ x } 100, \tag{1}$$

$$r = \frac{1}{n}\sum r_i, \tag{2}$$

$$P_x = P_o\left[1 + \frac{r}{100}\right]^x, \tag{3}$$

where r_i represents the rate of population growth of decade, r represents the average rate of population growth, n represents the number of decades, P_o represents the last known population, P_x represents the predicted population for the x^{th} decade, and x represents the number of decades between P_o and P_x.

4. Results and Discussion

Having a thorough understanding of how LULC evolves over time is essential for creating strategies that effectively control regional growth. However, due to the complexity of the process, mapping and classifying land cover patterns can be difficult. Fortunately, improvements in algorithms and image processing methods have made it possible to carry out these operations on satellite images. In this study, satellite images from the United States Geological Survey (USGS) were downloaded for the years 2001, 2011, and 2021, and they were then categorized using the ERDAS software and a supervised image classification technique. The following sections go into more detail about the resulting LULC scenarios for both times. These results are anticipated to offer a thorough overview of the LULC distribution over time in the study area.

4.1. LULC Scenario for the Year 2001. Figure 3 shows a thematic representation of LULC classes, Figure 4 represents the normalized difference vegetation index (NDVI) in the study area for the year 2001, and Table 2 contains comprehensive data on various LULC statistics for the same year. It is evident that vegetation dominates the study area, taking up 891.87 km^2 (38.68%) in total. Agriculture is the second most extensive land use, covering an area of 838.88 km^2 (36.38%). The other land cover classes include barren land, covering 465.25 km^2 (20.18%), settlement area occupying 63.29 km^2 (2.74%), and water bodies, which covers 46.39 km^2 (2.01%) of the study area. Water bodies in this context refer to lakes and ponds. These findings suggest that the study area is primarily dominated by natural vegetation and agricultural activities.

4.2. LULC Scenario for the Year 2011. Figures 5 and 6 depict the LULC distribution and NDVI in the study area during the year 2011, and the detailed information regarding different LULC statistics for the year 2011 is provided in Table 2. As shown in Table 2, in the year 2011, agriculture has dominated all other land uses in the region, covering an area of 1183.48 km^2 (51.33%), followed by barren land, covering an area of 510.52 km^2 (22.14%). Significant growth was also seen in the settlement area, which now occupies 219.36 km^2 (9.51%) of the study area. On the other hand, vegetation

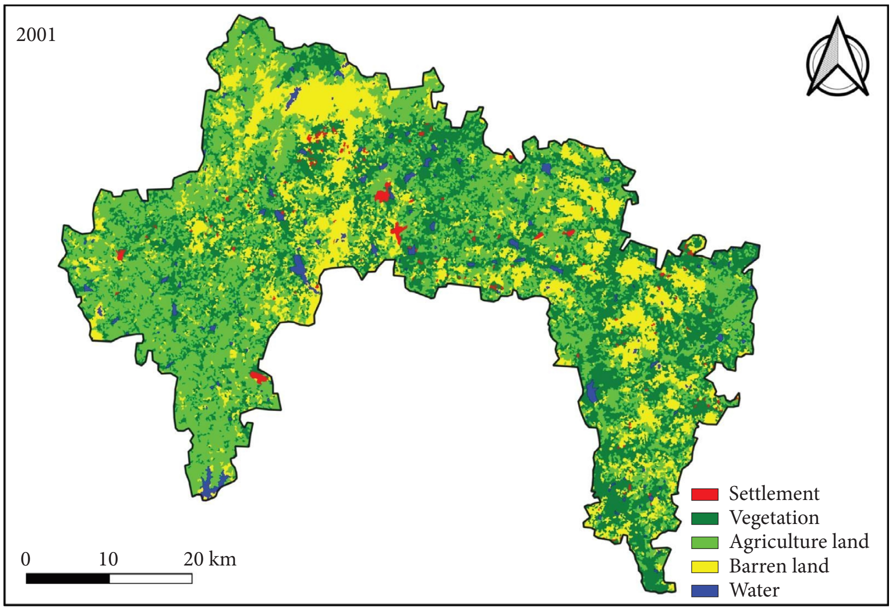


Figure 3: Classified image of year 2001.

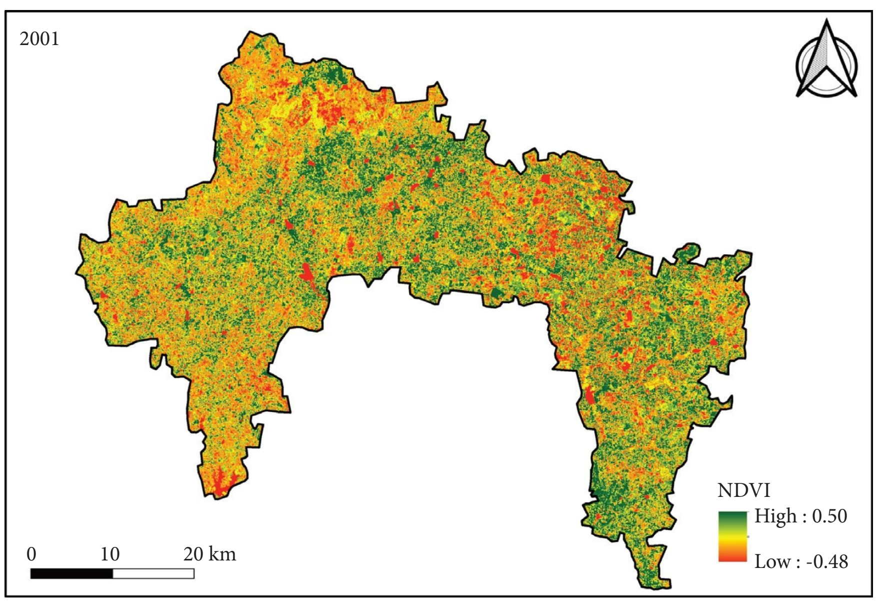


Figure 4: NDVI for the year 2001.

Table 2: Land use land cover details for the years 2001 and 2021.

LULC class	LULC in 2001		LULC in 2011		LULC in 2021	
	Area (km^2)	(%)	Area (km^2)	(%)	Area (km^2)	(%)
Settlement	63.29	2.74	219.36	9.51	346.12	15.01
Vegetation	891.87	38.68	382.71	16.6	109.04	4.73
Agriculture land	838.88	36.38	1183.48	51.33	1254.25	54.40
Barren land	465.25	20.18	510.52	22.14	584.96	25.37
Water	46.39	2.01	9.61	0.42	11.17	0.48

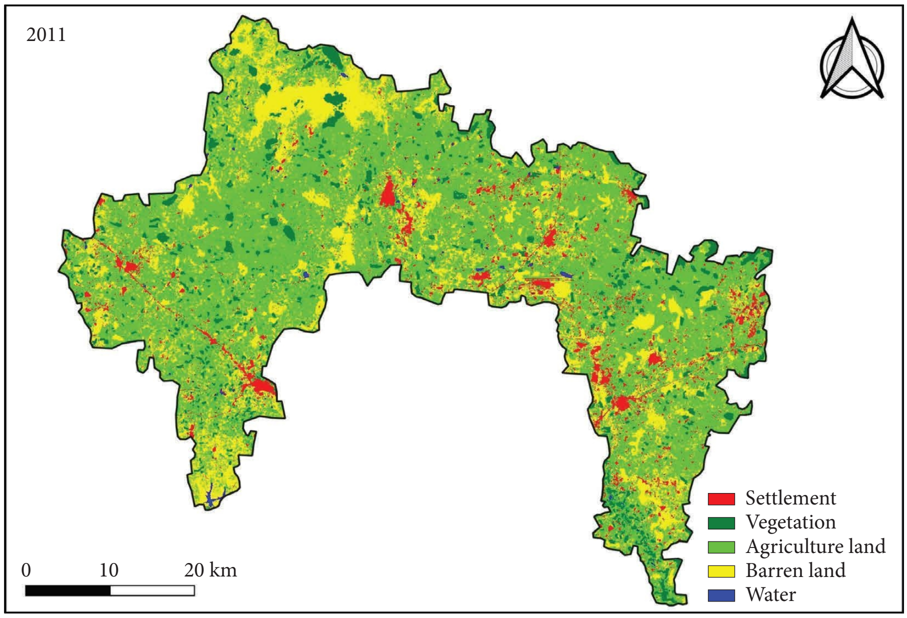


Figure 5: Classified image of the year 2011.

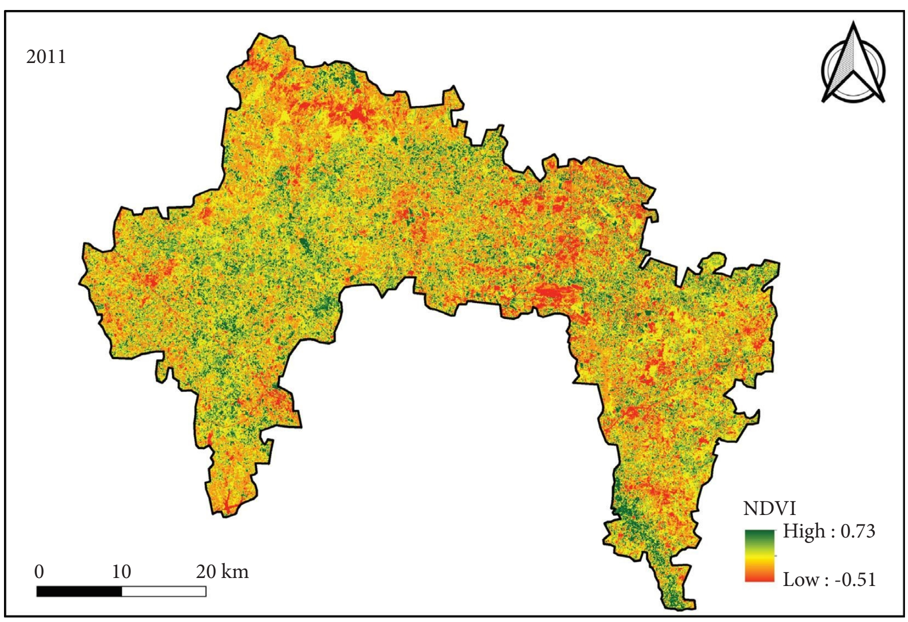


Figure 6: NDVI for the year 2011.

decreased to 382.71 km^2 (16.6%), and the study area's only water body covered just 9.61 km^2 (0.42%).

4.3. LULC Scenario for the Year 2021. Figures 7 and 8 depict the thematic representation of LULC distribution and NDVI in the study area for the year 2021, and detailed information regarding different LULC statistics for the year 2021 is provided in Table 2. As shown in Table 2, in the year 2021, agriculture has surpassed all other land uses in the region, covering an area of 1254.25 km^2 (54.40%), followed by barren land, covering an area of 584.96 km^2 (25.37%). Significant growth was also seen in the settlement area, which now occupies 346.12 km^2 (15.01%) of the study area. On the other hand, vegetation decreased to 109.04 km^2 (4.73%), and the study area's water body covered just 11.17 km^2 (0.48%). The environment and the socioeconomic circumstances of the region may be significantly impacted by these changes in LULC, necessitating better management and planning.

4.4. LULC Scenario for the Years 2001 to 2021. Understanding how the LULC has changed over the past 20 years is made possible by comparing classified images from 2001 to 2021. According to the findings, the area

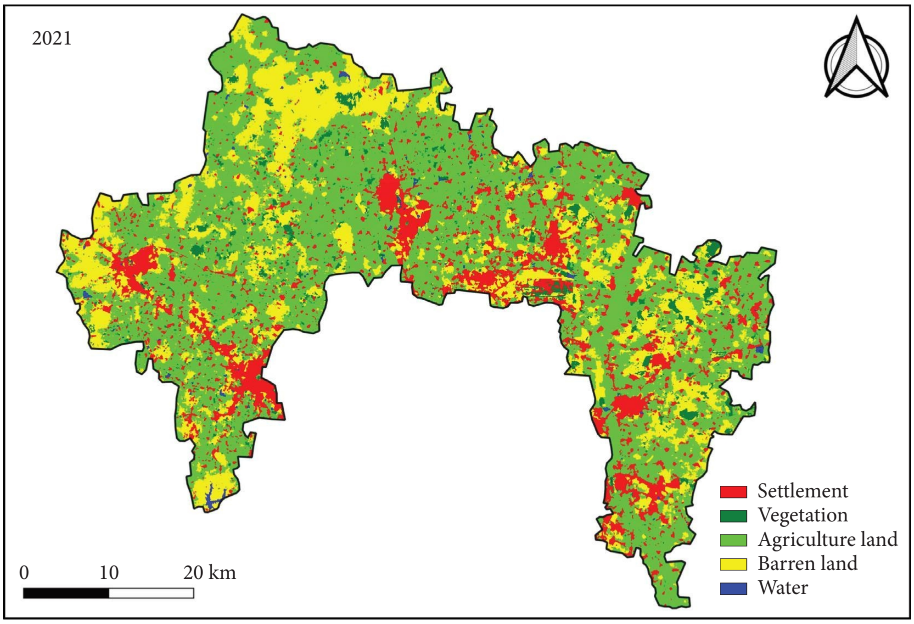


Figure 7: Classified image of the year 2021.

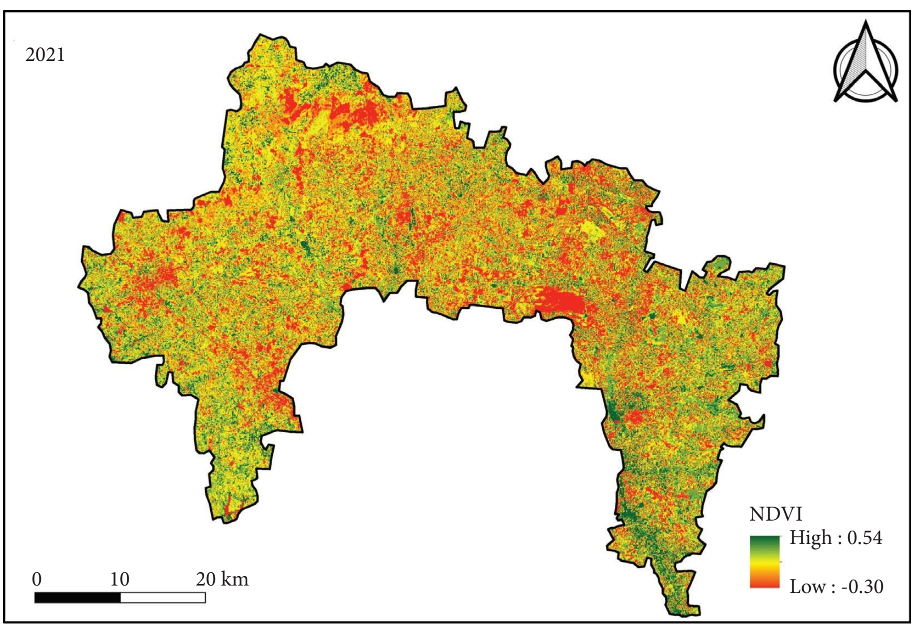


Figure 8: NDVI for the year 2021.

occupied by vegetation and water classes has significantly decreased, whereas settlements, arid land, and agricultural land have increased. While the area of waterbodies has decreased by 75.93%, the area of vegetation-covered land has decreased by 87.77%. Agricultural land increased from 838.88 km^2 to 1254.25 km^2, while the settlement area increased from 63.29 km^2 to 346.12 km^2, and arid land increased from 465.25 km^2 to 584.96 km^2. The majority of the once-vegetated land has been turned over to agriculture and settlements, primarily because of the growth of cities and their inhabitants. Figure 9 displays the coverage each LULC class had in the years 2001 and 2021 to help visualize these changes. Figure 10 shows the percentage change in LULC classes from 2001 to 2021 in contrast. Insightful information about the effects of urbanization on land use in the area is provided by these figures, which highlight the significant changes in LULC in the study area over the course of two decades. The transition of LULC from one class to another class is represented in Figure 11.

4.5. LULC Change Scenario Taluk-Wise. A taluk-wise comparison was performed to better comprehend the LULC change scenario. Figures 12 and 13 show the

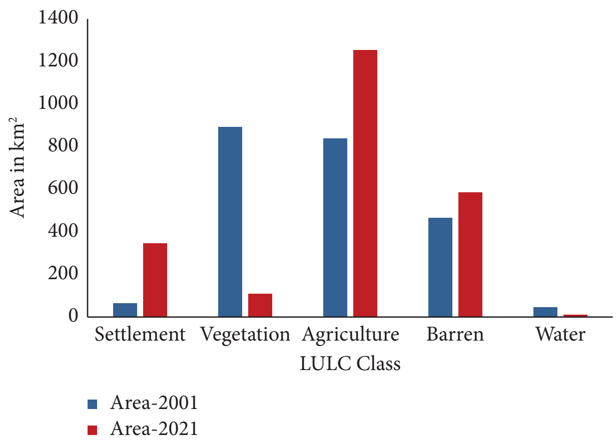


Figure 9: Spatial distribution of LULC classes in the years 2001 and 2021.

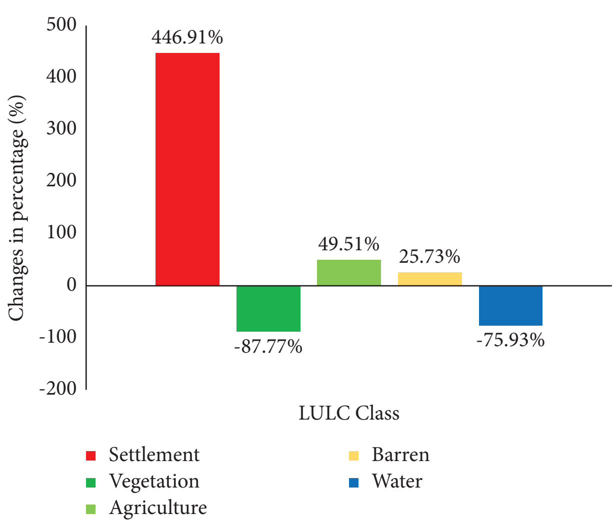


Figure 10: Percentage changes in LULC classes from the years 2001 to 2021.

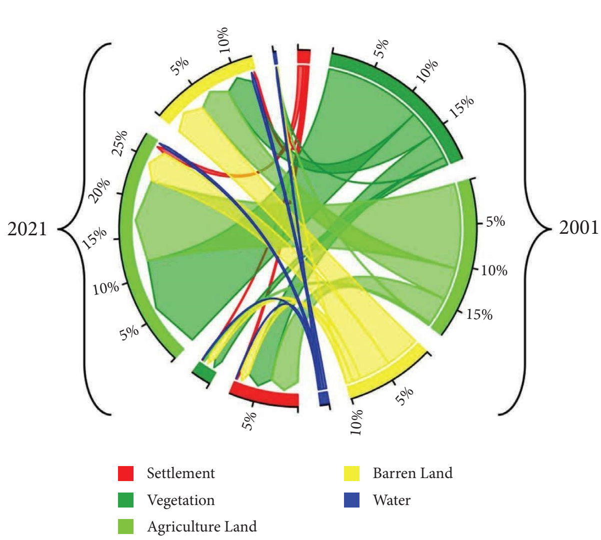


Figure 11: Transition of LULC classes between 2001 and 2021.

distribution of each LULC class in each taluk in 2001 and 2021, as well as the percentage change that has taken place over the past two decades. Figure 14 represents the LULC transition taluk-wise between the years 2001 and 2021. Every LULC class between 2001 and 2021 was compared, and the results show that over the past 20 years, there have been significant changes in LULC across all taluks. All of the taluks have seen a significant increase in population due to their proximity to the Bengaluru urban border and their connectivity via state or national highways, which makes convenient transportation. Due to this, Bengaluru rural has experienced severe urban sprawl, which has significantly altered the LULC pattern. The number of settlements has increased in the taluks of Nelamangala, Doddaballapura, Devanahalli, and Hosakote by 253.68%, 177.89%, 326.11%, and 246.36%, respectively.

All the taluks have experienced significant increases in agricultural land except for Nelamangala taluk, with gains of 0.22%, 75.63%, 57.36%, and 113.47%, respectively. However, over the same time period, the four taluks' vegetation areas decreased by 89.4%, 86.3%, 87.64%, and 88.98%, respectively, and their waterbody areas decreased by 59.91%, 78.06%, 74.88%, and 83.51%, respectively. Barren land has increased by 157.6%, 2.95%, and 8.67% in Nelamangala, Doddaballapura, and Hosakote taluks, respectively. Interestingly, there has been a decrease in barren land in Devanahalli taluk by 0.22%. The taluk-wise comparison thus highlights the significant changes that have taken place in LULC over the last 20 years. The rapid urbanization in the region has led to a decline in vegetation and waterbody areas and an increase in settlements and agricultural land.

4.6. Accuracy Assessment. A random sampling method was used to conduct an accuracy assessment in order to ensure the LULC classification's dependability. From the gathered images, a total of 250 points were randomly chosen, and the classified images were assessed. The classification was found to be reasonably accurate with an overall accuracy of 87.31%, 86.57%, and 85.86% for the years 2001, 2011, and 2021, respectively. Additionally, it was determined that the years 2001, 2011, and 2021 had Kappa coefficients of 0.869, 0.872, and 0.847, respectively, which indicates a good level of agreement between the classified image and the reference data. These findings imply that the classified images can be trusted for additional investigation and decision-making.

4.7. Population Growth Scenario. The population data from 1901 to 2011 are used to forecast the population for the year 2021 using geometric increase method. Figure 15 shows the population growth rate and Figure 16 shows the population of Bengaluru rural and Bengaluru urban districts. The average growth rate and the predicted population are highlighted in the figures. It is noticed that the average growth rates for Bengaluru rural and Bengaluru urban districts are 14.58% and 34.94%, respectively. And the predicted populations for the year 2021 for Bengaluru rural and Bengaluru urban district are 11,35,438 and 1,29,83,226, respectively. The increased population especially in the Bengaluru urban

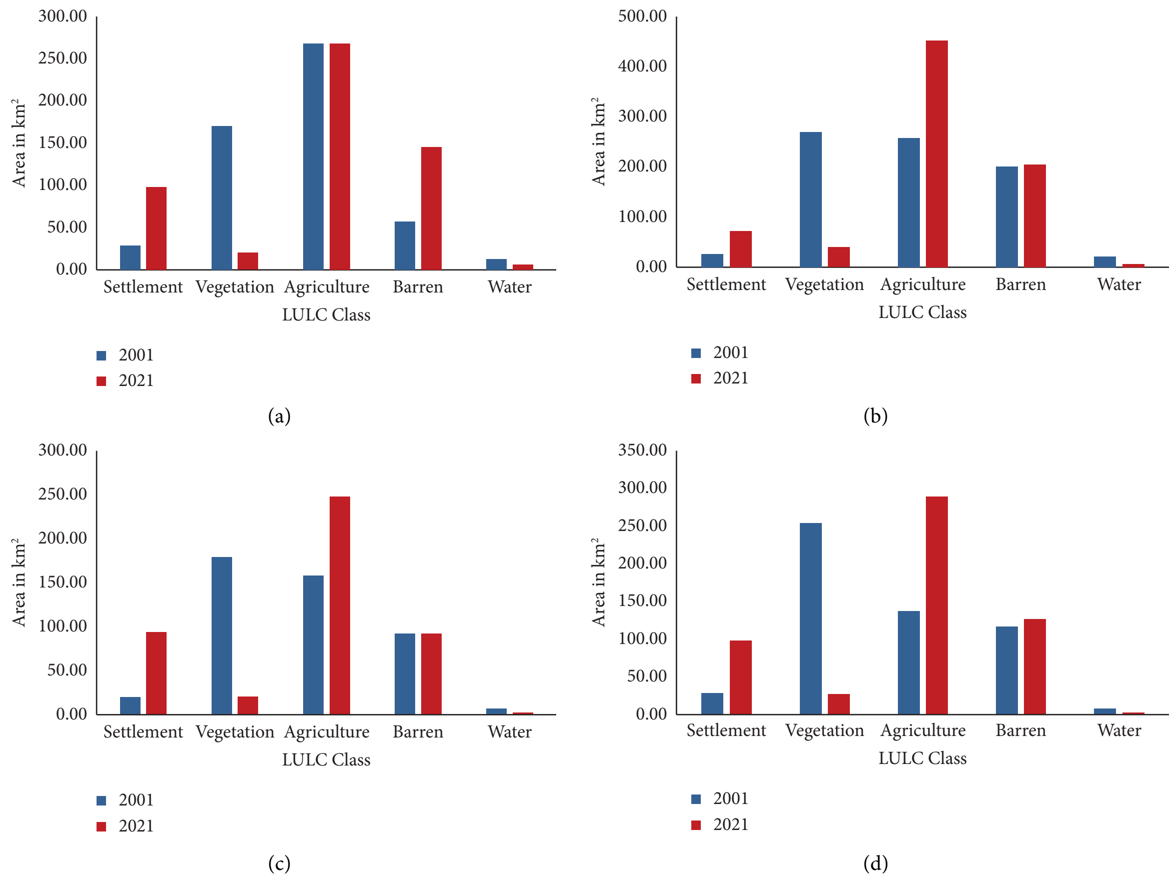


Figure 12: Distribution of LULC classes from the years 2001 to 2021, taluk-wise (a) Nelamangala, (b) Doddaballapura, (c) Devanahalli, and (d) Hosakote.

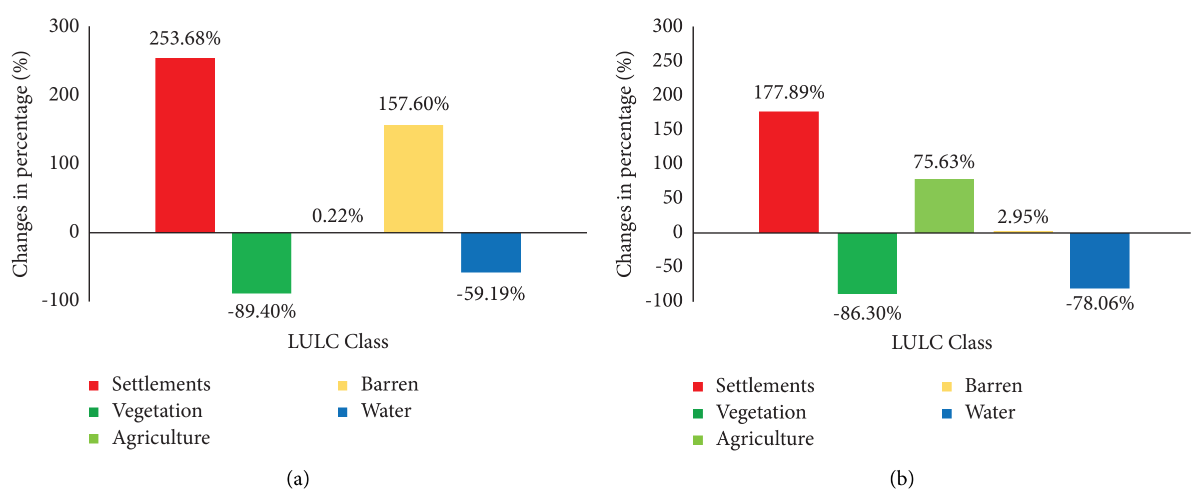
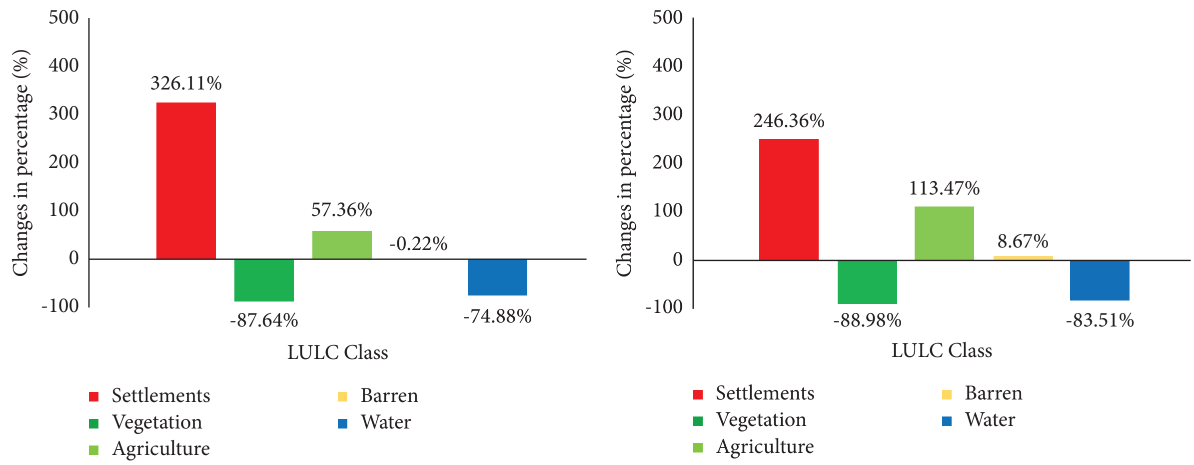
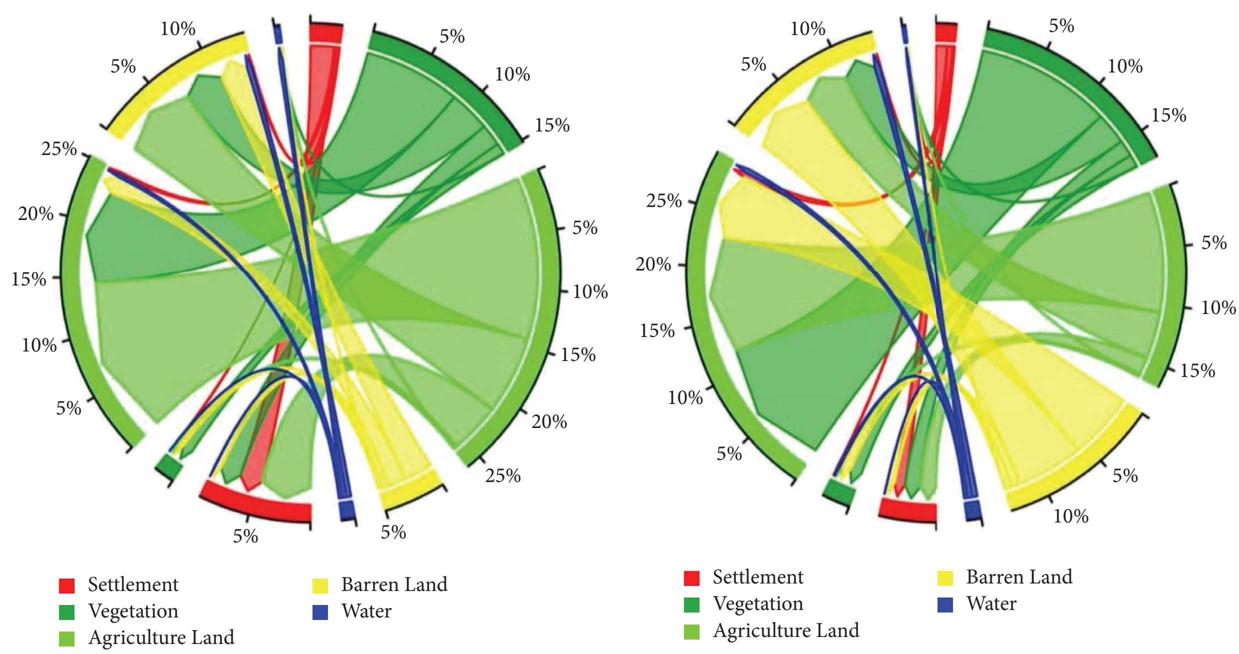


Figure 13: Continued.



(c) (d)

Figure 13: Percentage changes in LULC classes from the years 2001 to 2021, taluk-wise (a) Nelamangala, (b) Doddaballapura, (c) Devanahalli, and (d) Hosakote.



(a) (b)

Figure 14: Continued.

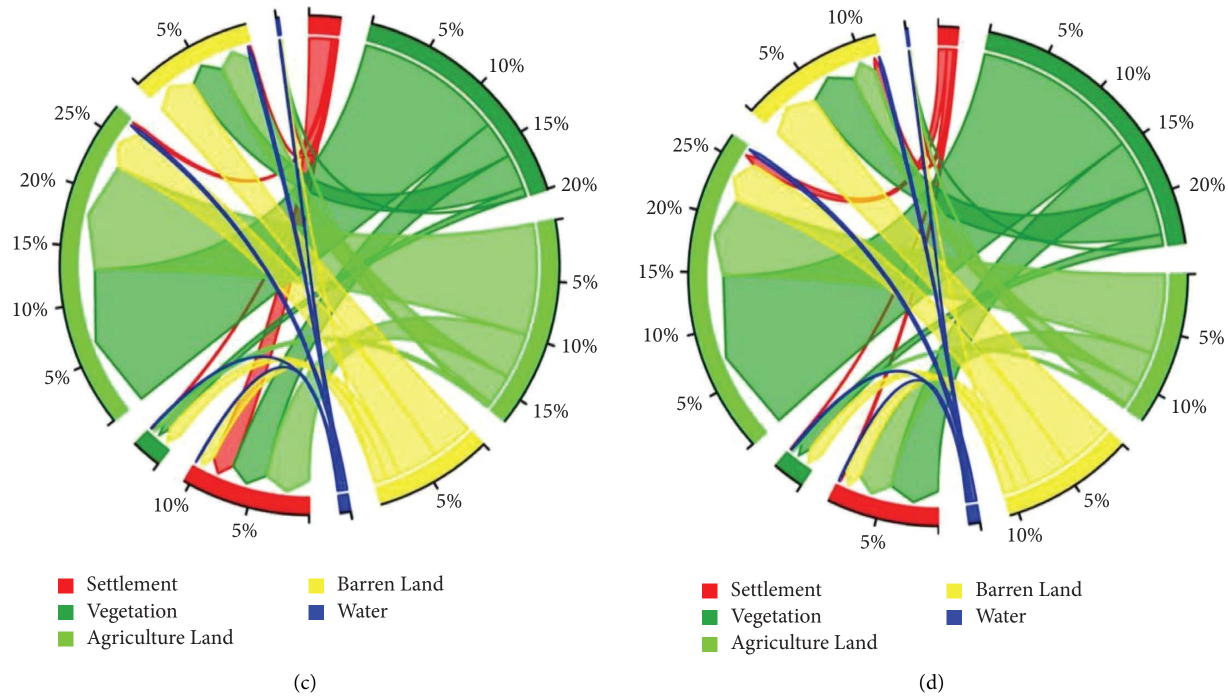


FIGURE 14: LULC transition between the years 2001 and 2021, taluk-wise (a) Nelamangala, (b) Doddaballapura, (c) Devanahalli, and (d) Hosakote.

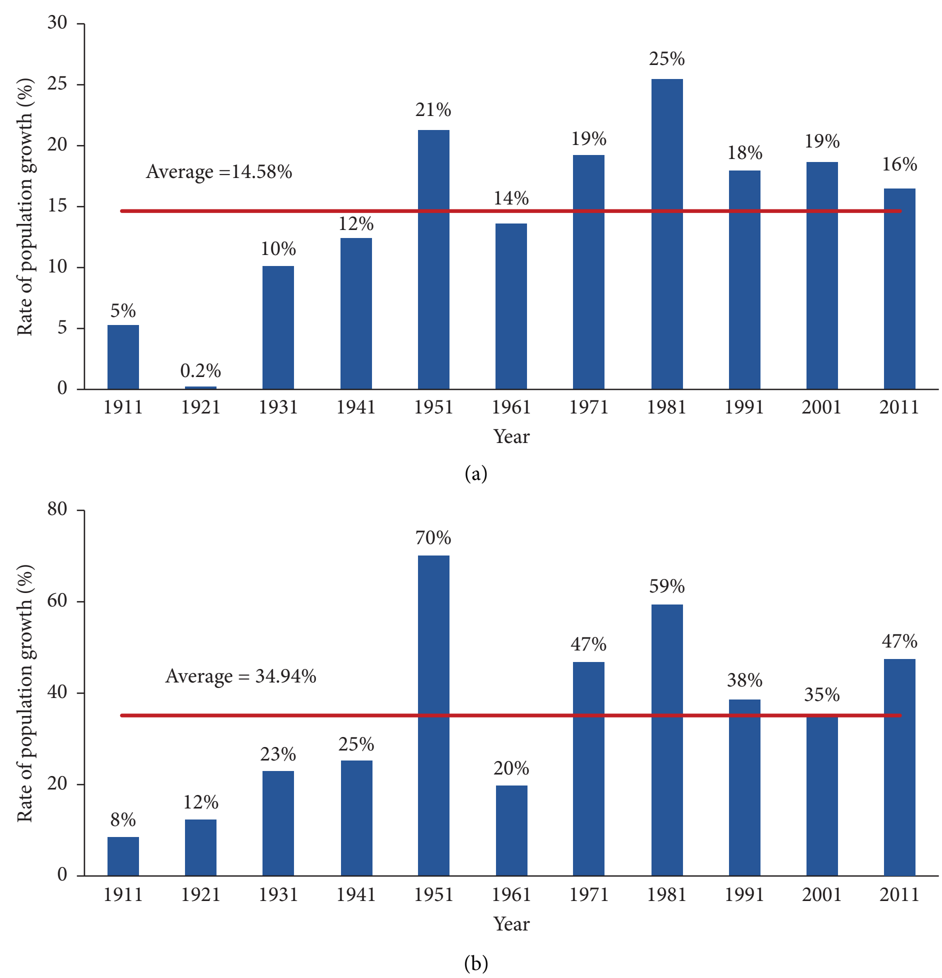
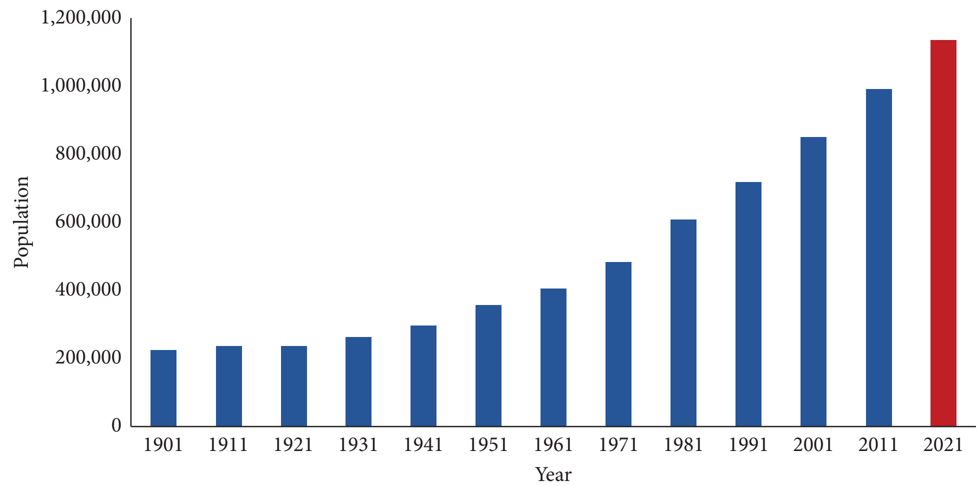
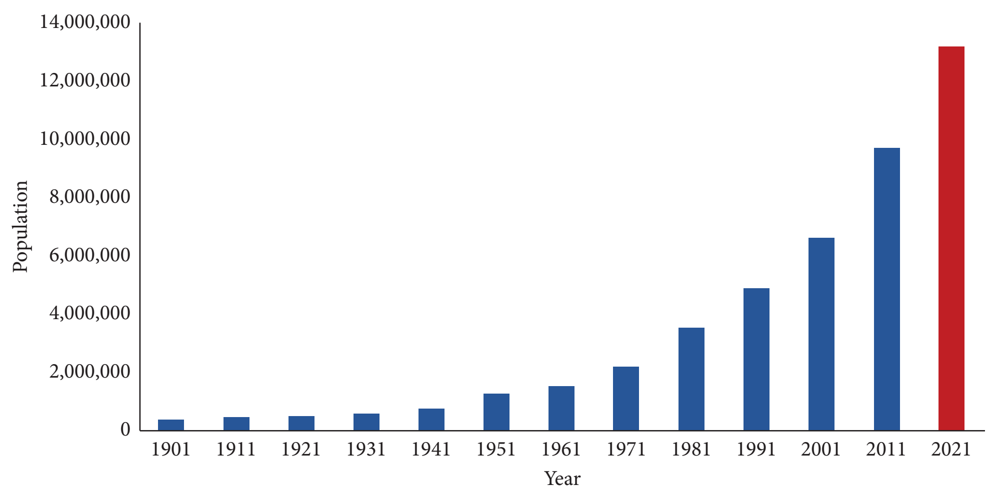


FIGURE 15: Population growth rate. (a) Bengaluru rural and (b) Bengaluru urban.



(a)



(b)

Figure 16: Past and predicted population. (a) Bengaluru rural and (b) Bengaluru urban.

district has influenced the rural district in terms of LULC changes as efforts are made to accommodate the population, thereby leading to shift in LULC patterns.

5. Discussion

The study area's LULC changes between 2001 and 2021 were analysed, and the results show that urban sprawl significantly altered the landscape. While there has been a noticeable increase in settlement, arid land, and agricultural land, the study area has seen a significant decrease in vegetation and water classes. The study's findings imply that the main factors influencing LULC changes in the study area have been population growth and urban area expansion.

Urban sprawl is evident by the conversion of vegetated land to agricultural land and settlement. From 63.29 km^2 in 2001 to 346.12 km^2 in 2021, the settlement area increased by 447.64%. Likewise, the area used for agriculture has grown by 49.74%, from 838.88 km^2 to 1254.25 km^2. Most likely, the expansion of agricultural production to meet the escalating demands of the expanding population is what has led to the increase in agricultural land. The loss of habitat and biodiversity in the study area has also been exacerbated by the conversion of vegetation land to agricultural land.

Another impact of urban sprawl is the rise in undeveloped land in the study area. The area of barren land has grown by 25.74%, from 465.25 km^2 in 2001 to 584.96 km^2 in 2021. The conversion of vegetation land and water bodies into settlements and agricultural lands, leaving behind degraded or unusable land, is most likely the cause of the rise in barren land. Significant concern is raised by the decline in vegetation on the study area's land and in its water bodies. Between 2001 and 2021, vegetation on land fell by 87.77%, and water bodies shrank by 75.93%. The ecosystem may get negatively impacted by the disappearance of vegetation and water bodies due to soil erosion, deteriorated water quality, and loss of wildlife habitat.

In conclusion, the LULC in the study area has been significantly impacted by urban sprawl. The loss of biodiversity and habitat has been exacerbated by the conversion of water bodies and vegetated lands into inhabited and arable land. Due to the conversion of vegetation land and water bodies into settlements and agricultural lands, an increase in barren land is a sign that the land is degrading.

6. Conclusions

The study unequivocally shows that over the past 20 years, the LULC pattern in the Bengaluru Rural district has undergone significant changes. The population growth and rapid urbanization in Bengaluru are primarily to blame for the changes because they have put stress on the nearby rural areas. The need to accommodate more people as the urban population grows has resulted in the conversion of natural and agricultural lands into settlements, roads, and other urban infrastructure. The study found that the number of waterbodies and vegetation has decreased, which is one of the most significant changes. Significant ecological effects from these changes include soil erosion, decreased biodiversity, and increased water runoff, which can cause flooding and water scarcity. On the other hand, due to the growth of agribusinesses and the conversion of natural habitats into croplands, there has been an increase in agricultural land and barren land. The expansion of agricultural land might have beneficial effects on the economy, such as raising food production and farmer income. However, it might also have detrimental effects on the environment, such as soil deterioration, water pollution from the use of pesticides and fertilizers, and biodiversity loss. Significant difficulties are also brought about by the growth of populated areas, including increased traffic, pollution, and demand on energy and water resources. Additionally, the growth of settlements may lead to the uprooting of local populations and the end of traditional ways of life.

The results of the study emphasize the significance of sustainable land use planning that strikes a balance between economic growth and environmental preservation. The study can be further extended to prioritize sustainable land management techniques that support biodiversity conservation and soil and water conservation and take into account the long-term effects of land-use change.

In conclusion, the study's findings have significant ramifications for the district of Bengaluru rural's sustainable development. The findings imply that better land use planning and management are urgently required to ensure that economic development is environmentally friendly and sustainable. The district can achieve a balance between economic development and environmental conservation, leading to a more sustainable and prosperous future, with proper land use planning and management.

Data Availability

The data used in this study are available upon reasonable request to the corresponding author.

Disclosure

The preprint of the earlier version of this paper is available in research square with the following DOI details: https://doi.org/10.21203/rs.3.rs-1855333/v1.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Bharath A conceptualized, investigated, and analysed the study and proposed the methodology; Manjunatha M. provided resources and software and curated the data; Reshma T. V. performed formal analysis, provided software, and investigated the study; Ranjitha B. Tangadagi wrote the original draft, performed formal analysis, and investigated the study; and Sifatullah Bahij investigated the study and proposed the methodology.

References

[1] C. Sun, Z. F. Wu, Z. Q. Lv et al., "Quantifying different types of urban growth and the change dynamic in Guangzhou using multi-temporal remote sensing data," *International Journal of Applied Earth Observation and Geoinformation*, vol. 21, pp. 409–417, 2013.

[2] Y. Meng, M. Wang, W. Xu, X. Guan, and D. Yan, "Structure construction, evolution analysis and sustainability evaluation of Water-Ecological-Economic system," *Sustainable Cities and Society*, vol. 83, Article ID 103966, 2022.

[3] M. Mohan, S. K. Pathan, K. Narendrareddy et al., "Dynamics of urbanization and its impact on land-use/land-cover: a case study of megacity Delhi," *Journal of Environmental Protection*, vol. 02, no. 09, pp. 1274–1283, 2011.

[4] S. Zhong, M. Wang, Y. Zhu, Z. Chen, and X. Huang, "Urban expansion and the urban–rural income gap: empirical evidence from China," *Cities*, vol. 129, Article ID 103831, 2022.

[5] S. Angel, S. Sheppard, D. L. Civco et al., *The Dynamics of Global Urban Expansion*, Citeseer, Princeton, NJ, USA, 2005.

[6] S. Berling-Wolff and J. Wu, "Modeling urban landscape dynamics: a review," *Ecological Research*, vol. 19, no. 1, pp. 119–129, 2004.

[7] C. N. Mundia and M. Aniya, "Dynamics of landuse/cover changes and degradation of Nairobi City, Kenya," *Land Degradation and Development*, vol. 17, no. 1, pp. 97–108, 2006.

[8] H. M. Mosammam, J. T. Nia, H. Khani, A. Teymouri, and M. Kazemi, "Monitoring land use change and measuring urban sprawl based on its spatial forms: the case of Qom city, Egypt," *The Egyptian Journal of Remote Sensing and Space Science*, vol. 20, no. 1, pp. 103–116, 2017.

[9] H. Jiang, H. Guo, Z. Sun et al., "Projections of urban built-up area expansion and urbanization sustainability in China's cities through 2030," *Journal of Cleaner Production*, vol. 367, Article ID 133086, 2022.

[10] E. López, G. Bocco, M. Mendoza, and E. Duhau, "Predicting land-cover and land-use change in the urban fringe: a case in Morelia city, Mexico," *Landscape and Urban Planning*, vol. 55, no. 4, pp. 271–285, 2001.

[11] J. Chadchan and R. Shankar, "An analysis of urban growth trends in the post-economic reforms period in India," *International Journal of Sustainable Built Environment*, vol. 1, pp. 36–49, 2012.

[12] A. Bharath, M. Manjunatha, R. B. Tangadagi, and S. Preethi, "Environmental assessment for rainwater harvesting at gitam campus," *Journal of Green Engineering*, vol. 10, pp. 1776–1785, 2020.

[13] X. H. Li, J. L. Liu, V. Gibson, and Y. G. Zhu, "Urban sustainability and human health in China, east asia and southeast asia," *Current Opinion in Environmental Sustainability*, vol. 4, pp. 436–442, 2012.

[14] K. B. Barnes, J. Morgan, and M. Roberge, "Sprawl development: its patterns, consequences, and measurement hydro-cloud view project," 2002, https://www.researchgate.net/publication/251645410.

[15] J. Epstein, K. Payne, and E. Kramer, "Techniques for mapping suburban sprawl," *Photogrammetric Engineering and Remote Sensing*, vol. 68, pp. 913–918, 2002.

[16] P. A. Bhat, M. U. Shafiq, A. A. Mir, and P. Ahmed, "Urban sprawl and its impact on landuse/land cover dynamics of Dehradun City, India," *International Journal of Sustainable Built Environment*, vol. 6, no. 2, pp. 513–521, 2017.

[17] R. Rasool, M. U. Shafiq, P. Ahmed, and P. Ahmad, "An analysis of climatic and human induced determinants of agricultural land use changes in Shupiyan area of Jammu and Kashmir state, India," *Geo Journal*, vol. 83, no. 1, pp. 49–60, 2018.

[18] F. Hossain and D. M. Moniruzzaman, "Environmental change detection through remote sensing technique: a study of Rohingya refugee camp area (Ukhia and Teknaf sub-district), Cox's Bazar, Bangladesh," *Environmental Challenges*, vol. 2, Article ID 100024, 2021.

[19] A. A. Mir and P. Ahmed, "Microwatershed level conservation strategies for effective land management in Haheom watershed, Kashmir Valley (J and K)," in *Landscape Ecology and Water Management*, pp. 341–352, Springer, Berlin, Germany, 2014.

[20] A. Bharath, M. Manjunatha, R. B. Tangadagi, S. Preethi, and M. Dangeti, "Assessment of LULC changes for hesaraghatta watershed using GIS tools and remote sensed data," *Nature Environment and Pollution Technology*, vol. 20, pp. 1749–1756, 2021.

[21] L. Sun, J. Wei, D. H. Duan et al., "Impact of Land-Use and Land-Cover Change on urban air quality in representative cities of China," *Journal of Atmospheric and Solar-Terrestrial Physics*, vol. 142, pp. 43–54, 2016.

[22] A. M. Dewan, Y. Yamaguchi, and M. Ziaur Rahman, "Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh," *Geojournal*, vol. 77, no. 3, pp. 315–330, 2012.

[23] T. Byomkesh, N. Nakagoshi, and A. M. Dewan, "Urbanization and green space dynamics in Greater Dhaka, Bangladesh," *Landscape and Ecological Engineering*, vol. 8, no. 1, pp. 45–58, 2012.

[24] S. Du, P. Shi, and A. Van Rompaey, "The relationship between urban sprawl and farmland displacement in the Pearl River Delta, China," *Land*, vol. 3, no. 1, pp. 34–51, 2013.

[25] M. Wang, B. Yu, R. Zhuo, and Z. Li, "A geographic analysis on rural reconstruction-transformation-revitalization: a case study of jianghan plain in China," *Land*, vol. 11, no. 5, p. 616, 2022.

[26] B. Ferrari, V. Quatrini, A. Barbati, P. Corona, E. Masini, and D. Russo, "Conservation and enhancement of the green infrastructure as a nature-based solution for Rome's sustainable development," *Urban Ecosystems*, vol. 22, no. 5, pp. 865–878, 2019.

[27] A. M. Soliman and Y. A. Soliman, "Exposing urban sustainability transitions: urban expansion in Alexandria, Egypt," *International Journal of Urban Sustainable Development*, vol. 14, no. 1, pp. 33–55, 2022.

[28] Y. Gao, S. Shahab, and N. Ahmadpoor, "Morphology of urban villages in China: a case study of dayuan village in Guangzhou," *Urban Science*, vol. 4, no. 2, p. 23, 2020.

[29] B. Ashwathappa, "Urban sprawl analysis and lulc change assessment in bengaluru rural, karnataka, india," *Researchsquare*, 2022.

[30] S. Parmar, P. K. Thakur, M. Chauhan, and R. Lata, "Land use land cover change detection and its impact on land surface temperature of malana watershed kullu, Himachal Pradesh, India," in *Remote Sensing and Geographic Information Systems for Policy Decision Support*, pp. 235–263, Springer, Berlin, Germany, 2022.

[31] K. W. Reda, X. Liu, and Q. Tang, "Intra- annual variation of high and low- flow extremes associated with land use and climate change in the upper tekeze of the nile river basin," *Journal of Geophysical Research: Atmospheres*, vol. 127, no. 8, Article ID e2021JD036325, 2022.

[32] T. Belay and D. A. Mengistu, "Impacts of land use/land cover and climate changes on soil erosion in Muga watershed, Upper Blue Nile basin (Abay), Ethiopia," *Ecological Processes*, vol. 10, pp. 68–23, 2021.

[33] D. E. Gorelick, L. Lin, H. B. Zeff et al., "Accounting for adaptive water supply management when quantifying climate and land cover change vulnerability," *Water Resources Research*, vol. 56, no. 1, 2020.

[34] X. Jin, Y. Jin, and X. Mao, "Ecological risk assessment of cities on the Tibetan Plateau based on land use/land cover changes–case study of Delingha City," *Ecological Indicators*, vol. 101, pp. 185–191, 2019.

[35] S. Rahaman, P. Kumar, R. Chen, M. E. Meadows, and R. B. Singh, "Remote sensing assessment of the impact of land use and land cover change on the environment of barddhaman district, West Bengal, India," *Frontiers in Environmental Science*, vol. 8, pp. 1–15, 2020.

[36] V. K. A. Somayajula, D. Ghai, S. Kumar et al., "Classification and validation of spatio-temporal changes in land use/land cover and land surface temperature of multitemporal images," *Sustainability*, vol. 14, 2022.

[37] A. Bharath, K. K. Kumar, R. Maddamsetty, M. Manjunatha, R. B. Tangadagi, and S. Preethi, "Drainage morphometry based sub-watershed prioritization of Kalinadi basin using geospatial technology," *Environmental Challenges*, vol. 5, Article ID 100277, 2021.

[38] H. Mahmoud, R. Alfons, and R. M. Reffat, "Analysis of the driving forces of urban expansion in Luxor City by Remote sensing monitoring," *International Journal of Integrated Engineering*, vol. 11, pp. 296–307, 2019.

[39] L. F. Temgoua, A. L. Meyabeme Elono, Y. Mfonkwet Njiaghait, A. Ngouh, and C. Nzuta Kengne, "Land use and land cover dynamics in the Melap Forest Reserve, West Cameroon: implications for sustainable management," *Geology, Ecology, and Landscapes*, vol. 6, no. 4, pp. 305–315, 2021.

[40] A. Bharath, R. Maddamsetty, and U. Pawar, "Evaluation of the geomorphological scenario of shimsha river basin, Karnataka, India," *Water Science and Technology: A Journal of the International Association on Water Pollution Research*, vol. 87, no. 8, pp. 1907–1924, 2023.

[41] X. Wang, W. Gong, X. Huang, T. Liu, Y. Zhou, and H. Li, "Assessment of eco-environmental quality on land use and land cover changes using remote sensing and GIS: a case study of miyun county," *Nature Environment and Pollution Technology*, vol. 17, pp. 739–746, 2018.

[42] T. Solomon and P. Lukas, "Land use land cover analysis of the Great Ethiopian Renaissance Dam (GERD) catchment using

remote sensing and GIS techniques," *Geology, Ecology, and Landscapes*, pp. 1–13, 2022.

[43] P. K. Mallupattu and J. R. Sreenivasula Reddy, "Analysis of land use/land cover changes using remote sensing data and GIS at an urban area, tirupati, India," *The Scientific World Journal*, vol. 2013, Article ID 268623, 6 pages, 2013.

[44] M. Chowdhury, M. E. Hasan, and M. M. Abdullah-Al-Mamun, "Land use/land cover change assessment of Halda watershed using remote sensing and GIS," *The Egyptian Journal of Remote Sensing and Space Science*, vol. 23, no. 1, pp. 63–75, 2020.

[45] Y. H. Tsai, D. Stow, L. An, H. L. Chen, R. Lewison, and L. Shi, "Monitoring land-cover and land-use dynamics in fanjingshan national nature reserve," *Applied Geography*, vol. 111, Article ID 102077, 2019.

[46] R. Das Kangabam, M. Selvaraj, and M. Govindaraju, "Assessment of land use land cover changes in Loktak Lake in Indo-Burma Biodiversity Hotspot using geospatial techniques," *The Egyptian Journal of Remote Sensing and Space Science*, vol. 22, no. 2, pp. 137–143, 2019.