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Assessment of Land Use Land Cover (LULC) Changes and Prediction using Random Forest, Remote Sensing and GIS at Bagalkote City in Bagalkote District, Karnataka, India

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ABSTRACT

Background: LULC analysis helps understand land use patterns and supports sustainable land management. Bagalkote City has undergone major changes due to the Almatti Dam's submergence, leading to urban relocation and rapid expansion.

Methods: Landsat IV (1991) and Sentinel-2 (2021) images were classified into four categories using ArcGIS 10.8. MLC and Random Forest algorithms were applied for classification and change detection. Accuracy was validated through confusion matrices and ground-truthing, achieving 87.2% and 89.6% accuracy for 1991 and 2021, respectively.

Result: Built-up areas increased by 1295.87% (28.25 km²), mainly due to leapfrog development into zones like Vidyagiri and Navanagar. Urban expansion was analysed within Bagalkote's boundary and a 4 km buffer.

Key words: Confusion matrix and MLC algorithm, Google earth engine (GEE), Land use land cover (LULC), Random forest, Remote sensing and GIS.

INTRODUCTION

Land use land cover (LULC) transforms assessment by remote sensing and geographic information systems (GIS) remains needed for conception city growth then environmental sustainability. Random forest (RF) has emerged as a robust classification algorithm for LULC studies due to its capability to import huge datasets then improve classification accuracy (Belgiu *et al.,* 2016). Google earth engine (GEE), a cloud-created geospatial platform, assists large-scale LULC investigation by integrating machine learning models such as RF with vast satellite imagery (Gorelick *et al.,* 2017). Several studies have applied RF in GEE for LULC classification and prediction. (Jain *et al.,* 2021) validated the use of RF and GEE towards display then predict LULC changes in India, achieving high classification accuracy. Similarly, Roy *et al.* (2020) used Landsat data to study urban growth and LULC dynamics, emphasizing the efficiency of RF in urban landscape analysis. Studies by Sharma *et al.* (2019); Ghosh *et al.* (2019) applied RF models near assess city sprawl and predict future LULC patterns in Indian cities, highlighting the significance of predictive modeling in urban planning. While various studies have analyzed LULC changes in Indian contexts, limited research has focused on Bagalkote City, where post-Almatti Dam rehabilitation has significantly altered the urban landscape (Patil *et al.,* 2015). Integrating RF with GEE offers an opportunity to predict future LULC changes in Bagalkote, which is essential for sustainable land management and urban growth. Recent studies by Thapa *et al.* (2009); Sinha *et al.* (2020) also stress the importance of hybrid models for predicting urban expansion, further validating the use of RF in dynamically changing landscapes. LULC investigation in Karnataka has shown major transformations driven by urbanization, industrialization and agricultural modifications. Bangalore witnessed rapid urban growth from 1991 to 2021, with a 925% increase in built-up areas, primarily analyzed using remote sensing (Sudhira *et al.,* 2004; Ramachandra *et al.,* 2012). Similarly, Mysore experienced significant urban sprawl with a reduction in green spaces and an increase in impervious surfaces between 1991 and 2018 (Ramachandra *et al.,* 2016). Hubli-Dharwad exhibited land conversion from agriculture to urban areas, indicating unsustainable urban growth (Sharma *et al.,* 2019). LULC dynamics in Davangere revealed shifting patterns with agricultural land loss and urban expansion (Basavarajappa *et al.,* 2017). In Shimoga, satellite data indicated major land use changes driven by socio-economic growth (Rao *et al.,* 2003). LULC studies in Bagalkote identified drastic

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transformations following the construction of Almatti Dam, with increased built-up areas post-rehabilitation (Kumar *et al.,* 2024). Mangalore's coastal regions witnessed intense urbanization and shoreline changes due to development pressures (Narayan *et al.,* 2015). Tumkur's LULC changes highlighted a shift from agricultural land to residential and commercial zones (Srinivas *et al.,* 2015). Udupi's coastal areas experienced LULC alterations due to tourism and urban growth, assessed using multi-temporal satellite imagery (Hebbar *et al.,* 2021). Kolar exhibited a steady growth in urban areas (Manjunatha *et al.,* 2016). Belgaum experienced consistent urban sprawl along major transportation corridors (Patil *et al.,* 2017). LULC analysis of Hassan showed rapid spatial growth with high impervious surface expansion between 2000 and 2020 (Shankar *et al.,* 2020). Bellary's land cover analysis indicated mining-related degradation and reduction in vegetative cover (Prakash *et al.,* 2018). Mandya district witnessed changes in agricultural practices due to urban expansion (Vijay *et al.,* 2021). Bangalore's forest transitions revealed significant deforestation, linked to socio-economic changes (Nagendra *et al.,* 2010). Bagalkote's landscape dynamics post-Almatti Dam showed intense urbanization and urban area proliferation (Kumar *et al.,* 2020). Haveri district experienced LULC shifts due to population growth and urbanization (Shashidhar *et al.,* 2020). Advanced GIS and remote sensing tools have enabled precise LULC classification, ensuring data accuracy for future modeling and sustainable development (Bharath *et al.,* 2017). Analyzed reservoir-induced LULC changes in Bagalkot using remote sensing and GIS, highlighting post-submergence transformations (Kumar *et al.,* 2024). LULC is to examine land use patterns and helping forecast future sustainable terrestrial management. (Seyam *et al.,* 2023). Recent studies have employed GIS and remote sensing techniques to assess LULC dynamics (Hassen *et al.,* 2022). Land use changes influenced by agricultural practices and fallow patterns have been explored in Bihar, India (Kumar and Prasad, 2018). Modelling approaches like CLUMondo offer predictive insights for agricultural restructuring (Nguyen and Tran, 2023). Additionally, land policy implementation significantly impacts spatial land use trends (Le and Pham, 2024).

MATERIALS AND METHODS

Study area

Bagalkot local planning lies at 16°08′27.1373″-16°12′25.0265″ to 75°36′39.7573″-75°43′23.5697″. It has a surface area of 49.06 km^2 and a 533 meters above mean sea elevation. Bagalkote taluk is surrounded bilgi, Badami, mudhol and muddebihal in the north, south, east and west respectively (Kumar *et al.,* 2024). Location Map of Study area (Fig 1).

Methodology

In the Arc Map 10.8 software has been used for the analysis and classification of satellite images, thematic maps and calculations are carried in Microsoft excel. The land use land cover (LULC) mapping process is shown in a (Fig 2).

The research work was carried out at the Karnataka state remote sensing applications centre (KSRSAC), Bengaluru, which served as the primary source for geospatial data and technical support. The study and analysis were conducted during the period from January 2023 to December 2023.

Data acquisition

Multi-temporal optical satellite images were acquired from two primary sources are IRS LISS-IV Data: High-resolution images with a spatial resolution of 23.5 m, useful for land use classification and Sentinel-2 Data: Multi-spectral imagery with improved temporal and spatial resolution (10 m-20 m) to assess recent LULC changes. Ground-truthing was conducted through field surveys and validation using GPS points to assess classification accuracy.

Pre-processing and geo-rectification

The acquired images were pre-processed to enhance accuracy are radiometric correction to correct atmospheric distortions, geometric correction to align the images with reference ground control points (GCPs) and geo-rectification to ensuring images are projected into a uniform coordinate system for accurate overlay and analysis. Landsat-IV TM (Thematic Mapper) images from 7 August 1991 at a resolution of 23.5 m and Sentinal 2 data from 27 December 2021 at a resolution of (10 m-20 m).

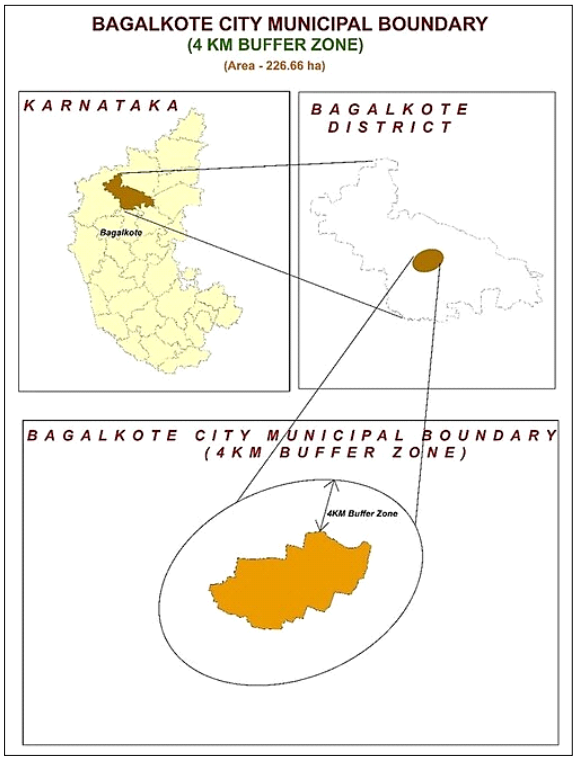


Fig 1: Location map of study area: Bagalkote municipal boundary area with 4 km buffer.

Base map and administrative boundary integration

Base map and administrative boundary data for the Bagalkote City were obtained and validated against the satellite images. This step ensured accurate delineation of boundaries and integration of collateral data.

Visual image interpretation

Visual interpretation of satellite imagery is analysing spectral, spatial and temporal characteristics, incorporating collateral data and city municipal boundaries to enhance classification accuracy and Identifying initial LULC classes for the base year (1991-2021).

GIS analysis and LULC change detection (1991-2021)

GIS analysis was applied to Integrate ground-truth and collateral data, Detect and quantify changes in LULC patterns between 1991 and 2021 and Change detection was performed through post-classification comparison, highlighting spatial-temporal variations. Image Processing the Landsat-IV has 3 bands and Sentinal2 has 11 bands. There are four classes as follows Waterbody, Buildup area, Agriculture and Forest.

Accuracy assessment

The accuracy assessment using supervised classifier randomly produced 200 reference points utilizing stratified random sampling (Fig 3).

Data validation and quality check

The classified LULC maps were validated using City Municipal Boundary Data for spatial verification and Accuracy Assessment through confusion matrices and kappa statistics to evaluate classification consistency.

Random forest model development for prediction

The random forest (RF) algorithm to predict future LULC patterns. The training dataset was derived from change detection results and the model was validated using GEE. A cloud-based platform for model evaluation and refinement and Multiple iterations to optimize classification accuracy and reduce overfitting.

Prediction of LULC distribution for 2031

The optimized RF model used to forecast future LULC 2031. The projected maps provide insights into future city expansion and LULC changes.

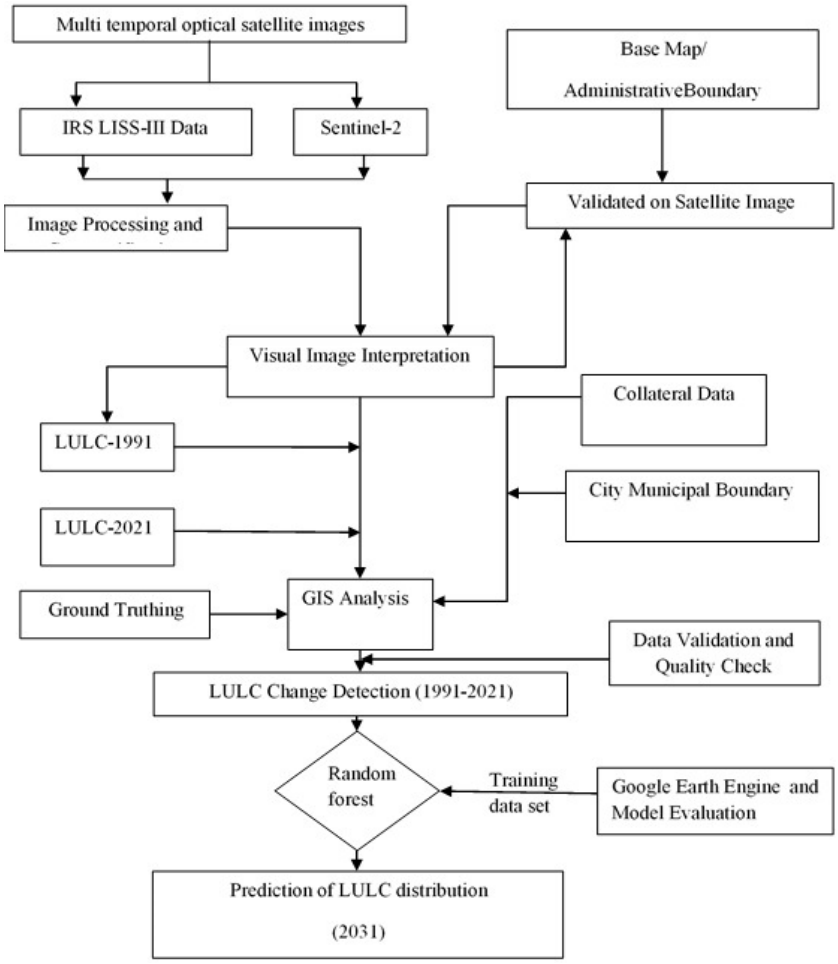


Fig 2: The land use landcover (LULC) mapping process is shown in a flowchart.

RESULTS AND DISCUSSION

LULC pattern of Bagalkote city in 1991

Fig 4 presents the LULC map layout produced using Landsat 4 TM imagery, along with a pie chart. Additional details, including the zone spreading of land forms in hectares, square kilometers and percentage. Accuracy assessment parameters such as producer accuracy, user accuracy, overall accuracy and the Kappa coefficient for the year 1991. Agricultural (206.76 km^2 or 91.22%), forest (12.47 km^2, 5.50%), waterbody (5.23 km^2, 2.30%) and buildup area (2.18 km^2).

LULC pattern of Bagalkote city in 2021

The Sentinel-2 data used to generate LULC map for 2021 illustrated in (Fig 5). According to the statistics, agricultural land (149.74 km^2, 66.06% of the total area) and forest cover (27.69 km^2, 12.21%) dominated the land use in 2021. Other land use categories include built-up areas (30.43 km^2, 13.42%) and water bodies (18.79 km^2, 8.28%). The LULC

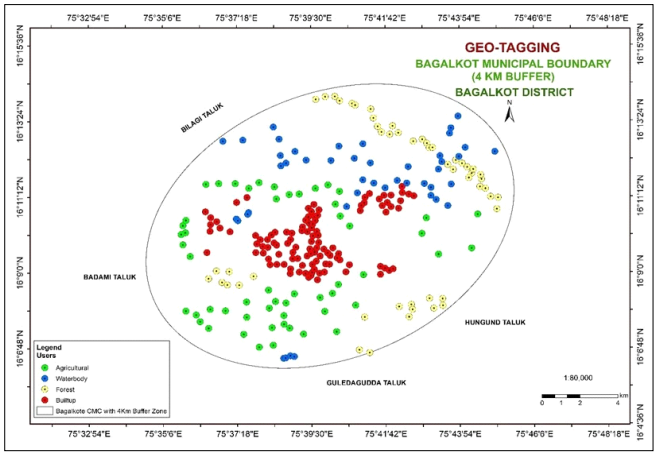


Fig 3: Geo-tag 200 random points used for the accuracy assessment of the LULC map 2021.

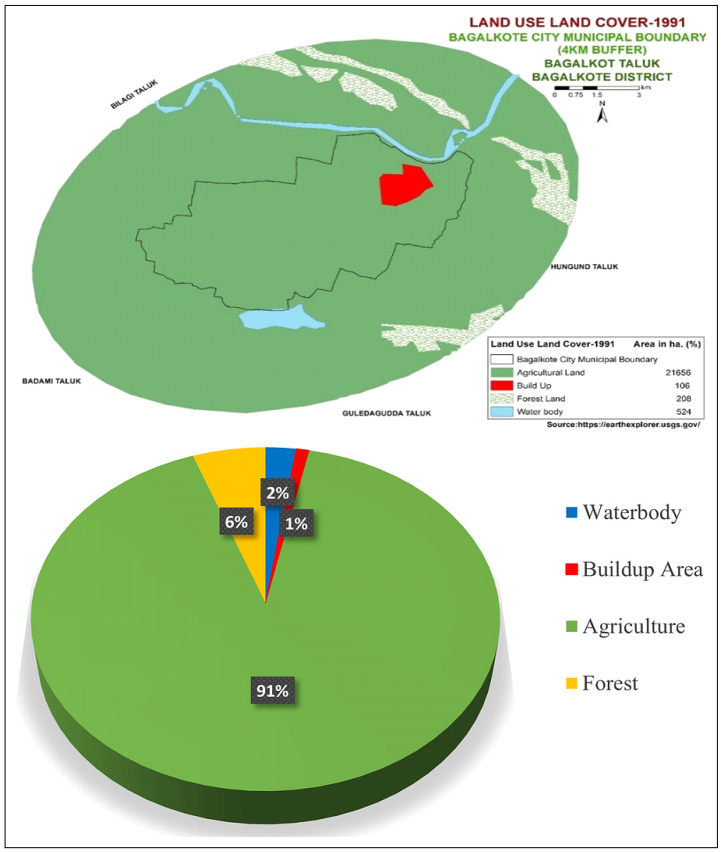


Fig 4: LULC pattern and piechart of Bagalkote city in 1991.

categories in to hectares and square kilometers, along with their percentages, producer accuracy, overall accuracy, user accuracy and kappa coefficient for 2021. The LULC patterns changed significantly between 1991 and 2021.

LULC change detection from 1991 to 2021

The LULC change detection. Around the past three decades, agricultural land includes much declined by approximately 57.02 km^2. Conversely, water bodies, forests and built-up areas have extended by 13.56 km^2, 15.22 km^2 and 28.25 km^2, respectively, over the last three decades. Notably, the built-up area has experienced the highest percentage increase (28.25%), indicating a concerning trend of rapid urbanization. Fig 6 illustrates a comparative analysis of land use area changes across different classes, while Table 1 provides a cross-tabulation of the LULC data.

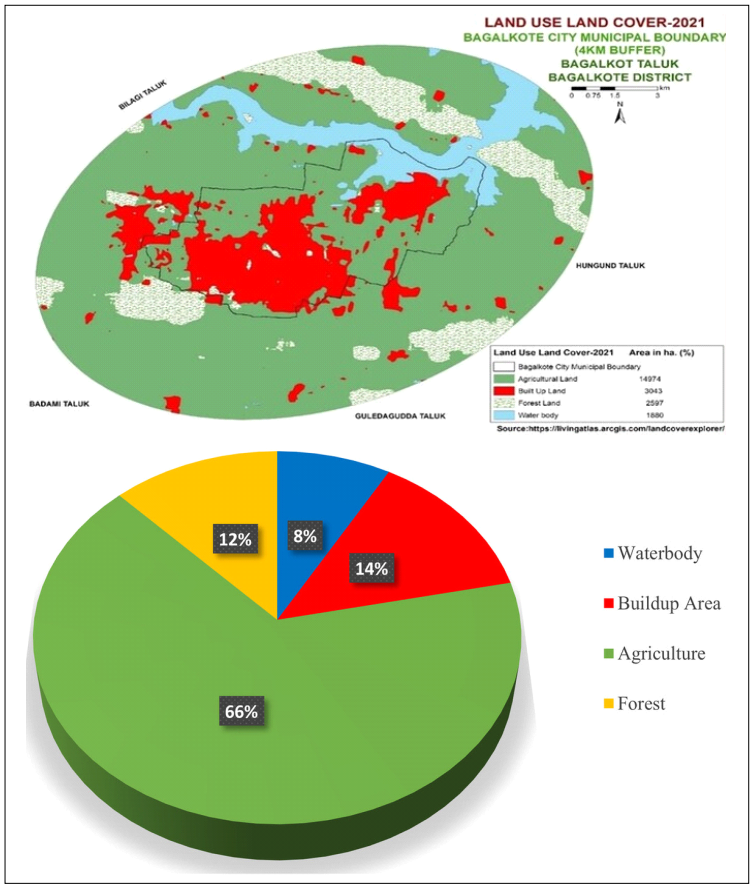


Fig 5: LULC pattern and pie chart of Bagalkote city in 2021.

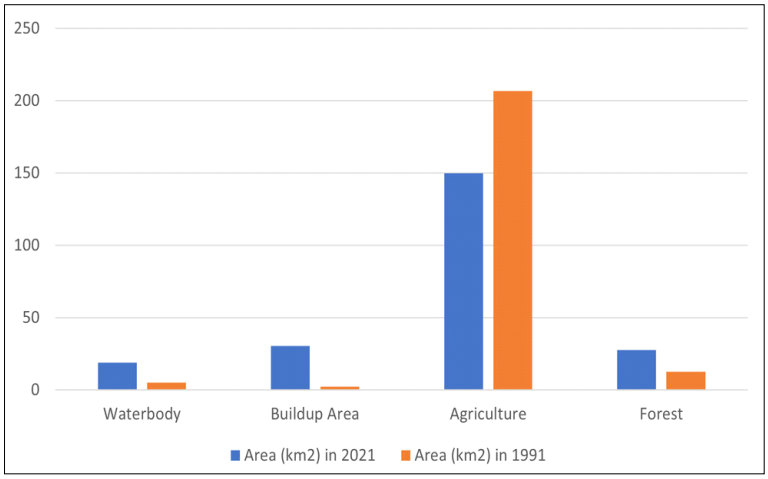


Fig 6: Area change diagram of the LULC Area in 1991 and 2021.

Change in agriculture

Fig 7 illustrates changes over agricultural land in Bagalkote City from 1991 to 2021. The dark-colored areas represent unchanged agricultural land, covering approximately 149.74 km^2, while the lighter-colored areas indicate land converted from non-agricultural to agricultural use, totaling 206.76 km^2. Cross-tabulation analysis reveals that a significant portion of agricultural land has transitioned to vegetation, likely due to shifts in farmers' livelihood activities. Over the last three decades, total agricultural land has declined by 57.02 km^2, raising concerns about food security due to the alarming rate of agricultural land reduction.

Change in forest

The variation in vegetational land is illustrated in Fig 8. The green areas represent unchanged forest land, covering approximately 12.47 km^2. The areas where non-forest land has transitioned to forest land are depicted in light green, covering about 15.22 km^2.

Change in buildup area

The foremost change observed in this area of interest the development of the built-up area, as shown in Fig 9. The built-up area takes increased more than ten times compared to 1991. In 1991, the built-up area was 2.18 km^2, which

Table 1: LULC change from 1991 to 2031.

Sum of area change (km^2)	LULC_1991 (km^2)	LULC_2021 (Final)	Change detection 1991-2021	LULC_2031 (Final)	Change detection 1991-2031
Agriculture	206.76	149.74	-57.02	72.98	-133.78
Buildup area	2.18	30.43	28.25	96.80	94.62
Forest	12.47	27.67	15.22	38.14	25.67
Water body	5.23	18.79	13.56	18.74	13.51
Grand total	226.66	226.66		226.66	

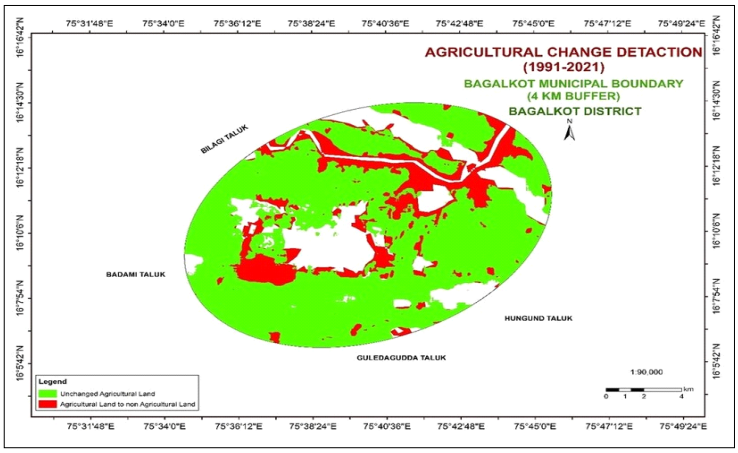


Fig 7: Change in agriculture land.

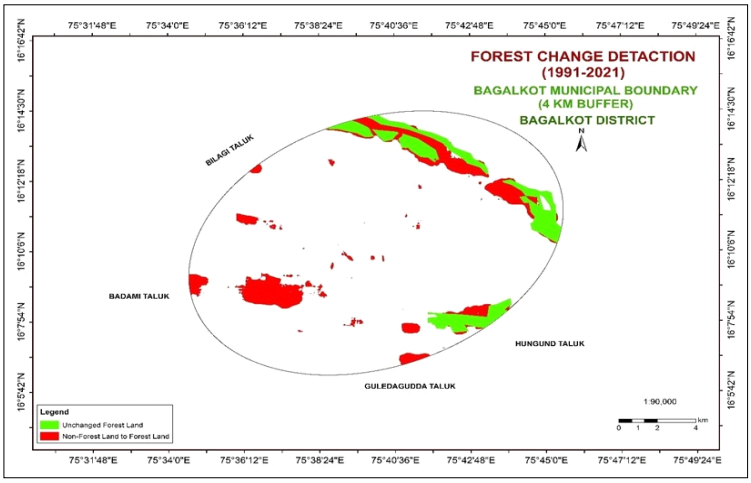


Fig 8: Change in forest.

expanded to 30.43 km^2 by 2021. This represents a rapid and significant transformation compared to other land use classes.In the figure, dark red indicates the unchanged built-up area of 2.18 km^2, while normal red represents newly developed built-up areas, which account for 28.25 km^2 of expansion. Detailed information is provided in Table 1.

Change in water body

The transformations in the waterbody stay illustrated in Fig 10. The waterbody area has enlarged by around 13.56 km^2. The navy-blue shade represents the unchanged waterbody, covering around 5.23 km^2, the blue color shows the newly occurred waterbody, which spans approximately 18.79 km^2.

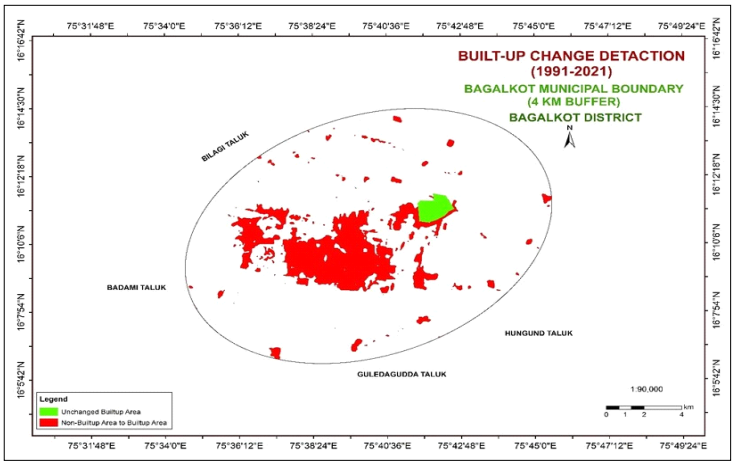


Fig 9: Change in buildup area.

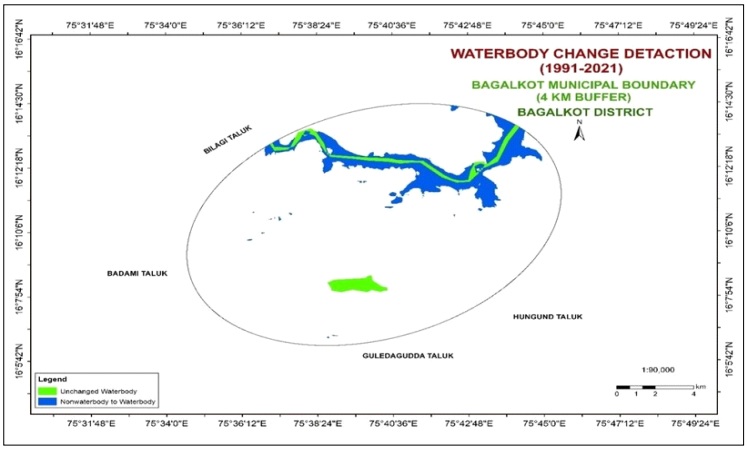


Fig 10: Change in water body.

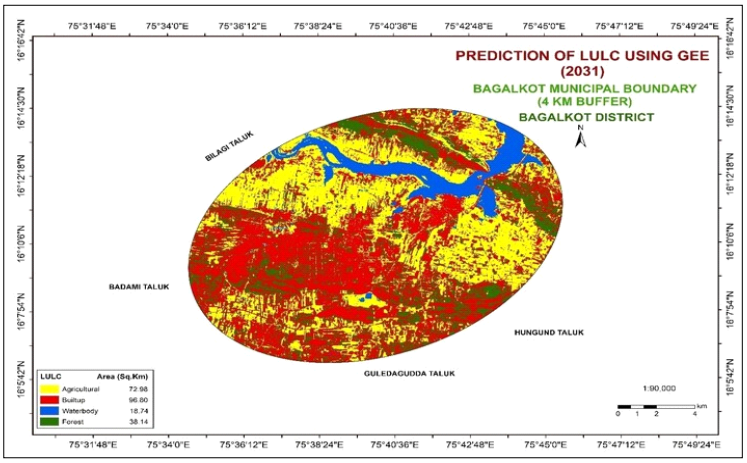


Fig 11: Google earth engine to predict 2030 land use land cover.

Detailed data is provided in Table 1. The spread in waterbodies may be attributed to patterns of human encroachment.

Predict 2031 land use land cover

The changes in the waterbody are illustrated in Fig 11. The table shows land use and land cover (LULC) changes from 1991 to 2031. Agriculture land has significantly decreased by 133.78 km^2, dropping from 206.76 km^2 to 72.98 km^2. This suggests that much agricultural land has been converted to other uses. The buildup area has grown substantially from 2.18 km^2 to 96.8 km^2, indicating rapid urbanization. Forest area increased by 25.67 km^2, possibly due to reforestation or conservation efforts. Waterbody areas also expanded by 13.51 km^2, which might be due to better water resource management or natural changes. Despite these changes, the total land area remained constant at 226.66 km^2. Detailed information is provided in Table 1. This means the changes are a result of land being reallocated among categories. The sharp rise in buildup area reflects growing infrastructure or residential development. Overall, the data highlights a clear shift from agricultural land to urban and ecological land uses. Bagalkote Prediction of LULC 2031 using Random forest from Sentinel-2 Satellite image bands.

CONCLUSION

The building of a dam at Alamatti on the Krishna River has an impact on Bagalkote city. People are getting properly after the submerged of Bagalkot City and the nearby villages. Due to this, the LULC pattern for the region that is for study has undergone a major shift. This is why this article uses remote sensing imagery and geographical technology. In 2001, the water storing project upriver of the reservoir remained initiated. The study shows that the main land uses in the area under study include forests, built-up areas, water bodies and agriculture. Waterbody, forest and built-up area conversion resulted in a 25.15% (57.02 km^2) decrease in agriculture, the study region's most important land use. The built-up terrain stands the second significant land use. witnessed an increase of 28.25% (28.25 km^2) due to the conversion of agricultural land into urban space. The conversion of agricultural land to forest area resulted in a 6.71% increase (15.22 km^2) in the study region's forest, the third most dominant land use. Agriculture land conversion to waterbody resulted in a 5.98% increase (13.56 km^2) in waterbodies, the third most significant land use in the study area. The study's findings demonstrate that the region's stakeholders and policymakers must be aware of Bagalkote City's rapid expansion and shifting land use patterns. Therefore, it is concluded that a significant LULC shift has been observed and that the research area goes metamorphosis terminated the late 20 years due to increased urbanization and industrial activity.

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Informed consent

This study did not involve human participants or animals. All data used were obtained from publicly available remote sensing and geographic information system (GIS) sources. Therefore, ethical approval and informed consent were not required.

Conflict of interest

The authors declare no conflict of interest.

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