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Geospatial Assessment of Land Use Land Cover Dynamics and Peri-Urban Expansion in the Bidadi Industrial Corridor, Bengaluru Metropolitan Periphery, Karnataka

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ABSTRACT

Peri-urban landscapes are undergoing profound transformations driven by accelerated urban expansion, particularly along the rural–urban continuum. This investigation undertakes a sophisticated assessment of land use–land cover (LULC) dynamics, focusing on spatial delineation, temporal variation, and urban sprawl diagnostics within the Bidadi industrial belt, enclosed by a 5-kilometer analytical buffer. Multi-temporal geospatial interpretation was conducted utilizing high-resolution satellite datasets IRS LISS III (2012) and IRS LISS IV (2024) to capture the evolving anthropogenic imprints on the terrestrial matrix. LULC classifications followed NRSC's Level II classification, with field verification to enhance the accuracy. Key changes include a 176% increase in built-up land, a 92% rise in agricultural plantations, and a 63% growth in barren rocky areas. Cropland has decreased by 40%, degraded forest areas shrunk by 31%, and fallow land reduced by 5%. Grazing land was increased by 225%, while forest plantations and mixed vegetation decreased slightly. About 3% reduction in water bodies, and land without scrub surged by 700%. The 2024 LULC classification map demonstrated a robust overall accuracy of 93.87%, signifying high thematic reliability. Class-specific user's accuracy values spanned from 82.35% to a perfect 100%, while producer's accuracy ranged between 88.23% and 100%, underscoring the precision in both classification allocation and omission assessments. Furthermore, the Kappa coefficient yielded a value of 0.927, reflecting an exceptionally strong level of concordance beyond random chance, indicative of near-perfect classification agreement. Urban sprawl was directed towards the north and northwest direction, with ribbon and scattered sprawl patterns. Sustainable development practices are being increasingly emphasized in Bidadi to promote long-term environmental, social, and economic sustainability.

KEYWORDS: *Land use land covers change; peri-urban area; Urban Sprawl; Change Detection*

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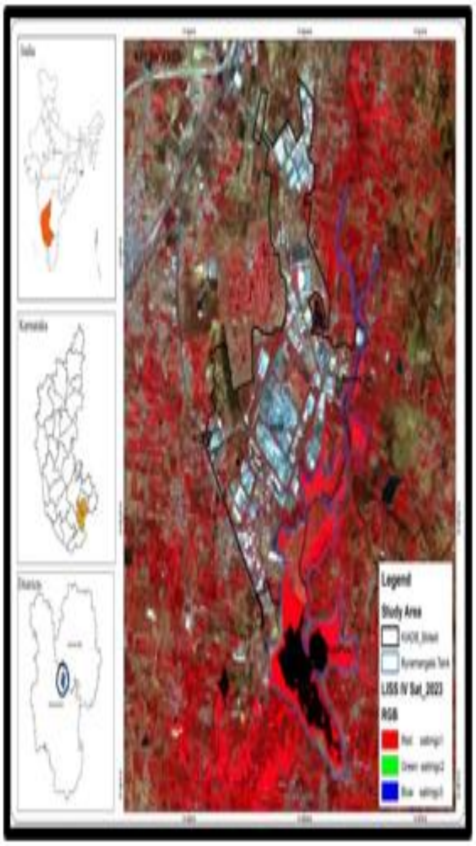
1. INTRODUCTION

Urban encroachment and transformations in land use and land cover (LULC) within the peripheries of rapidly expanding cities in the Global South have increasingly garnered the focus of urban geographers as well as city and regional planning experts. Escalating population density has been identified as the primary catalyst driving both LULC alterations and the proliferation of urban sprawl (Rahman, 2016). The magnitude and extent of land use/land cover (LULC) changes underway in many parts of the world are influenced by socioeconomic and biophysical factors (Viana et al., 2019). Land use and land cover (LULC) changes in peri-urban areas are a significant consequence of rapid urbanization, particularly at the rural-urban fringe. According to (Seto et al., 2011), peri-urban areas are hotspots for urban expansion, where the pressure of growing populations and economic activities leads to substantial changes in land cover. As (Liu et al., 2014) pointed out, these changes were significantly affecting the ecosystem services, local climate regulation, and biodiversity. Monitoring transformations in land use and land cover (LULC) is imperative for informed spatial planning and the strategic stewardship of land resources in the context of sustainability (Salem et al., 2020).

2. MATERIAL AND METHODS

Study Area

Bidadi, a town in the Ramanagara district of Karnataka, India, is located approximately 32 kilometres southwest of Bangalore (Fig 1, Fig 2). Geographically positioned at latitude 12°47'57.5"N and longitude 77°23'11.6"E, and at an altitude of 764 meters, Bidadi benefits from its proximity to Bangalore, making it an integral part of the Bangalore metropolitan region. It has gained prominence as a major industrial hub, primarily due to the presence of large manufacturing facilities like the Toyota Kirloskar Motor plant.



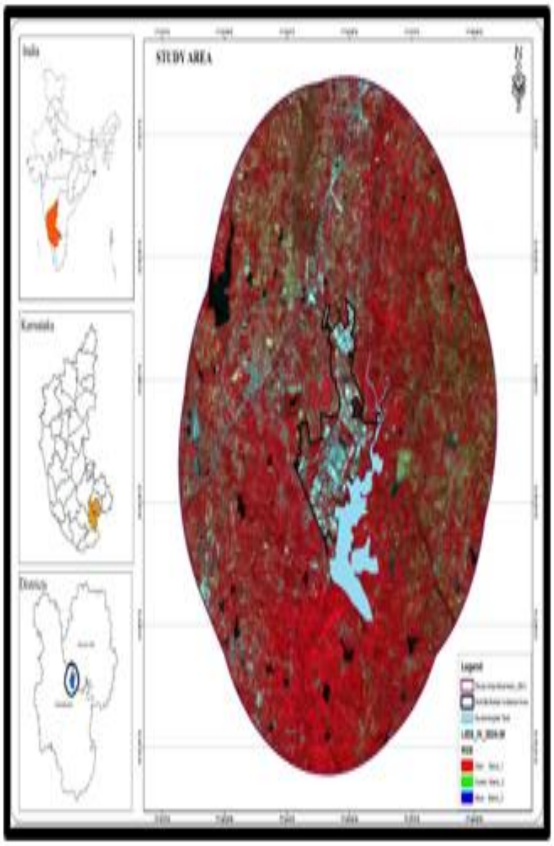


Figure 1: Study area map of Bidadi industrial area **Figure 2: Study area map of Bidadi industrial area with 5km buffer**

Data Sources and Software used

The specific topographic sheet was employed for this study, 57H/5, 57H/6, 57H/9, 57H/10 at a scale of 1:50,000 and effectively cover the areas of interest within Bidadi (Fig 7). Satellite data products of IRS P6 LISSIII of 23.5m resolution for 2012 and IRS LISS IV of 5.8m resolution for 2024 imageries were procured form National Remote Sensing Centre (NRSC). The thematic maps were generated using GIS (Geographic Information System) techniques and QGIS Software (version 3.34.9) and Arc GIS (version 10.8.4). In addition, Google Earth Pro played a crucial role in comparing land use data with satellite imagery.

3. METHODOLOGY

Satellite imagery from different sensors such as IRS LISS III for 2012 and IRS LISS IV for 2024 was obtained for multi-temporal analysis (Fig 3). The satellite images were processed using QGIS software to meet the specific requirements of the study. Ground Control Points (GCPs) were collected during field visits and used to rectify the images for accurate positioning (Fig 11).

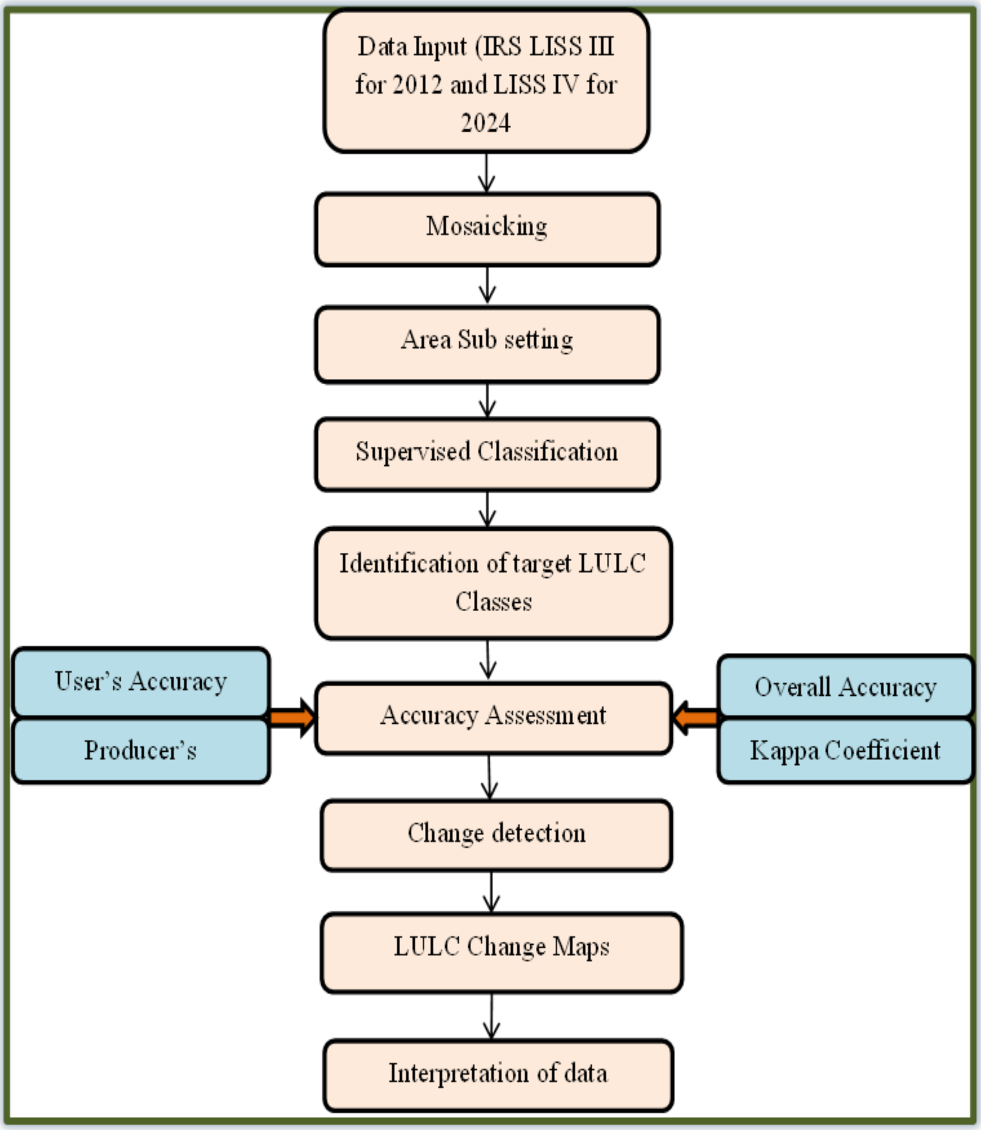
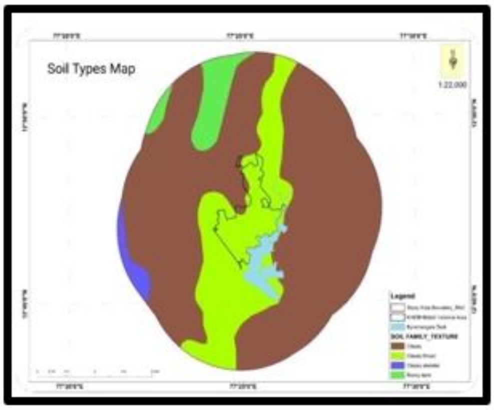


Figure 3: Methodology flow chart for obtaining LULC Maps

The various steps of layer staging, mosaicking, and sub-setting were carried out according to the defined study boundaries. Thematic maps were developed by combining Survey of India topographic maps and satellite remote sensing data. A hybrid classification technique was used to digitally classify land use and land cover. A digital database was generated using the QGIS GIS package, enabling the extraction of relevant statistics. LULC classifications were performed for the data of 2012 and 2024. Thematic layers for LULC were extracted from the classified data. Vector layers for Bidadi and Bidadi Industrial Area were overlaid on the satellite imagery during area extraction. A 5 km buffer zone was created around the Bidadi Industrial Area. The classification followed NRSC's Level II LULC standards. Field verification was conducted to improve the accuracy of the spatial classification analysis. Thematic maps were finalized, and relevant statistics were generated to conclude the analysis. Accuracy evaluation was conducted exclusively for the 2024 LULC map and was extrapolated to the 2012 LULC dataset, given the consistency in methodological protocols employed for decadal LULC mapping (Roy et al., 2015). The ArcGIS software was used to generate the stratified random points, these random points have been overlaid on Google Earth imagery and computation of accuracy was carried out in MS-Excel. Existing maps and information were also supported for the accuracy assessment.

4. RESULTS AND DISCUSSION

An integrated examination of land use–land cover delineation, temporal change detection, peri-urban expansion dynamics, underlying drivers, and resultant implications within the Bidadi industrial zone and its encompassing 5 km buffer region.



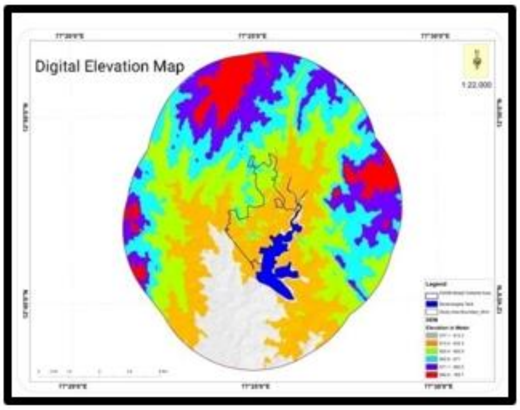
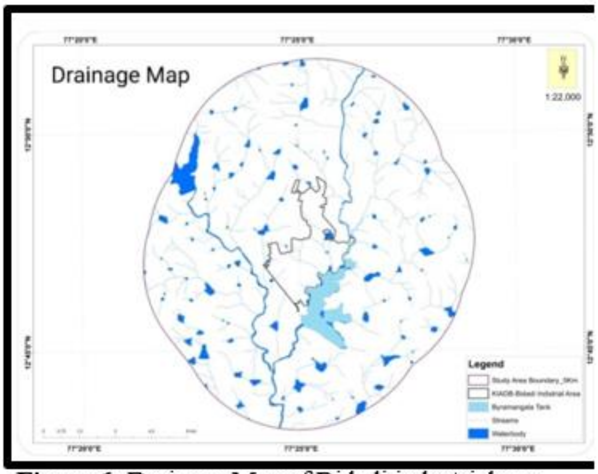


Figure 4: Soil characteristics map of the Bidadi industrial area with 5km buffer **Figure 5: Digital elevation map of Bidadi industrial area with 5km buffer**

The soil data was obtained from the Karnataka State Remote Sensing Application Centre, Bengaluru (Fig 4), and is being used as secondary data to analyse the terrain and soil types in Bidadi. The region features a range of soil types, including clayey, clayey mixed, rocky land, and clayey-skeletal soils. Clayey soil, with a clay content exceeding 45%, is notable for its fine particles and dense structure, providing a high capacity for water retention. Its elevation ranges between 700 and 900 meters (about 2,300 to 3,000 feet) above from the mean sea level (Fig 5). The terrain was characterized by gently rolling plains interspersed with occasional rocky outcrops and low hills, a common feature of the Deccan landscape. This elevation contributes to Bidadi's relatively moderate climate, with cooler temperatures compared to coastal areas. Bidadi exhibits typical semi-urban drainage characteristics influenced by its topography. The region's gently undulated terrain and hilly area guide water through various streams and rivers. The primary drainage system consists of small to medium-sized streams that follow a dendritic pattern, where the streams branch out like tree limbs. These streams feed into larger water bodies such as the Arkavathi River, a tributary of the Cauvery River, one of Karnataka's major rivers (Fig 6).



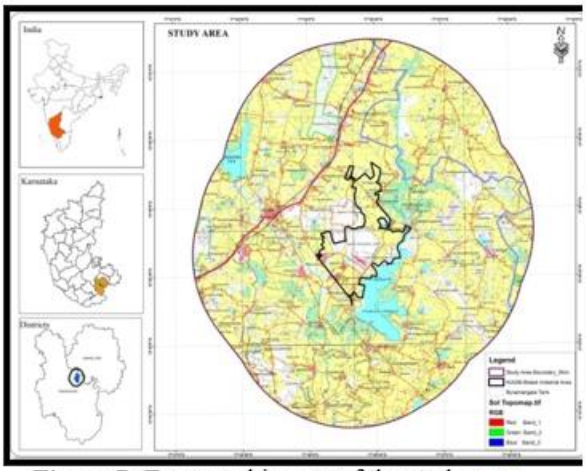


Figure 6: Drainage Map of Bidadi industrial area with 5km buffer **Figure 7:** Topographic map of the study area

Land use land cover map of the study area was generated using supervised classification method for the years 2012 and 2024 (Fig 8, Fig 9). Land Use Land Cover (LULC) change in Bidadi industrial area within 5km buffer from 2012 to 2024, showing shifts in various land use categories over this period. Significant changes was include a substantial increase in built-up land by 176%, which suggests considerable urbanization or expansion of infrastructure. Agricultural plantations were also expanded by 92%, while barren rocky areas were increased by 63%, indicating possible land degradation. However, cropland has decreased dramatically by 40%, possibly due to the conversion of agricultural land into urban area or other land uses. Degraded forest area was shrunken by 31%, and fallow land has slightly decreased by 5%. The grazing land was shown a remarkable increase of 225%, potentially due to reclamation or improved land management practices. Both forest plantations and mixed vegetation areas were indicated as light decrease by 5% and 5%, respectively, while water bodies werealso noticed by reduction of 3%. Interestingly, land without scrub has surged by 700%, possibly indicating an increase in barren or cleared area (Table 1).

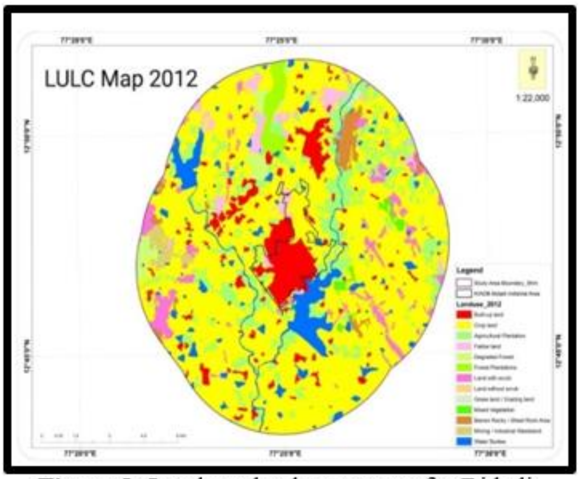


Figure 8: Land use land cover map for Bidadi industrial area with 5km buffer 2012

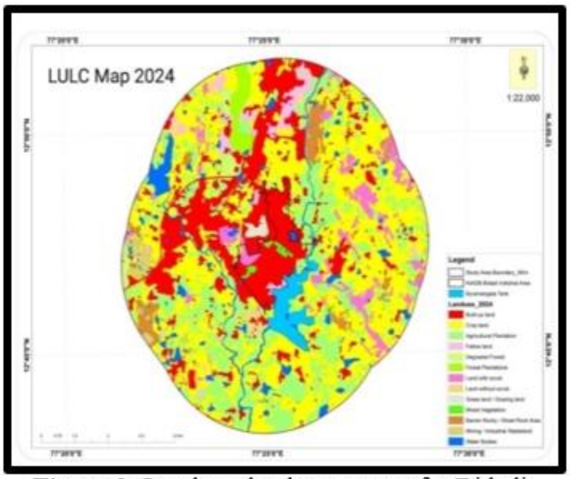


Figure 9: Land use land cover map for Bidadi industrial area with 5km buffer 2024

The graph (Fig 10) illustrates the land cover transformation in Bidadi Industrial Area. It clearly shows a dramatic increase in built-up area and a sharp decline in cropland between 2012 and 2024.

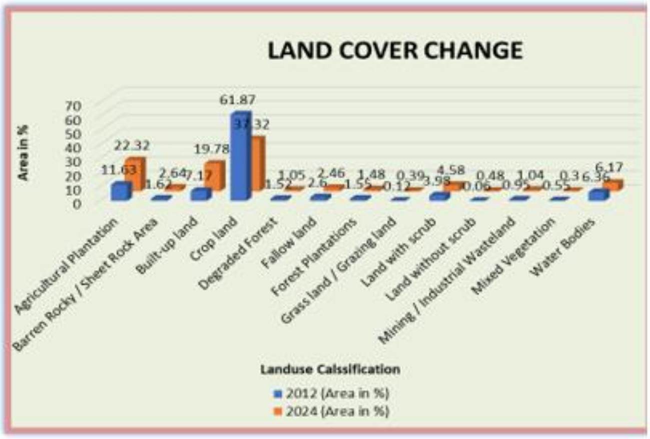


Figure 10: Land use Land cover change chart for Bidadi industrial area with 5km buffer

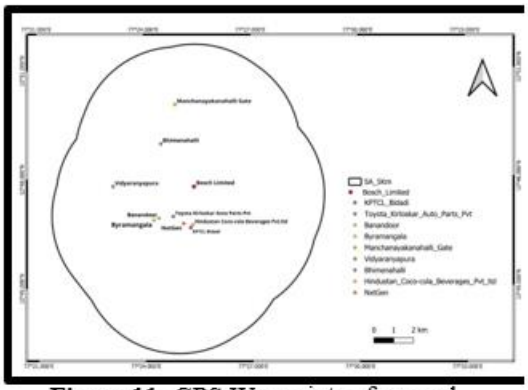


Figure 11: GPS Waypoints of ground truthing

Table 1: Land use Land cover change chart for Bidabi industrial area with 5km buffer

LAND USE LAND COVER CHANGE FROM 2012 TO 2024			
Land use Classification	**2012 (Area in %)**	**2024 (Area in %)**	**Change Percentage (%)**
Agricultural Plantation	11.63	22.32	92%
Barren Rocky / Sheet Rock Area	1.62	2.64	63%
Built-up land	7.17	19.78	176%
Crop land	61.87	37.32	-40%
Degraded Forest	1.52	1.05	-31%
Fallow land	2.6	2.46	-5%
Forest Plantations	1.55	1.48	-5%

Grass land / Grazing land	0.12	0.39	225%
Land with scrub	3.98	4.58	15%
Land without scrub	0.06	0.48	700%
Mining / Industrial Wasteland	0.95	1.04	9%
Mixed Vegetation	0.55	0.3	-45%
Water Bodies	6.36	6.17	-3%

The 2024 LULC classification map attained an overall accuracy of 93.8719%, which is considered sufficiently robust to warrant its use in subsequent analyses and change detection procedures (Yesserie, 2009; Wang et al., 2013). Class-wise user's accuracy values ranged between 82.35% and 100%, while producer's accuracy varied from 88.23% to 100%. The Kappa statistic, derived from the confusion matrix, yielded a value of 0.927, indicating a near-perfect level of agreement (Teferiet al., 2013; Wasigeet al., 2013) (Table 2 & 3).

Table 2: Confusion Matrix for multiple classes

CLASS NAME	Agricultural Plantation	Barren Rocky / Sheet Rock Area	Built-up land	Crop land	Degraded Forest	Dry Deciduous Forest	Fallow land	Forest Plantations	Grass land / Grazing land	Land with scrub	Land without scrub	Mining / Industrial Wasteland	Mixed Vegetation	Scrub Forest	Water Bodies	Total(User)
Agricultural Plantation	66	0	0	4	0	0	0	0	0	0	0	0	0	0	0	70
Barren Rocky / Sheet Rock Area	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Built-up land	6	0	42	2	0	0	0	1	0	0	0	0	0	0	0	51
Crop land	1	0	2	101	0	0	0	0	0	0	0	0	0	0	0	104
Degraded Forest	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10
Dry Deciduous Forest	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10
Fallow land	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	10
Forest Plantations	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	13
Grass land / Grazing land	0	0	0	1	0	0	0	0	9	0	0	0	0	0	0	10
Land with scrub	0	0	0	1	0	0	0	0	0	15	0	0	0	0	0	16
Land without scrub	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	10
Mining / Industrial Wasteland	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	10
Mixed Vegetation	0	0	0	1	0	0	1	0	0	0	0	0	8	0	0	10
Scrub Forest	0	0	0	0	0	0	0	0	0	2	0	0	0	8	0	10
Water Bodies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12
Total(Producer)	73	13	44	110	10	10	11	14	9	17	10	10	8	8	12	359

Table 3: Different Measurements from Confusion Matrix

CLASS NAME	USER ACCURACY (%)	PRODUCER ACCURACY(%)
Agricultural Plantation	94.2857	90.411
Barren Rocky / Sheet Rock Area	100	100
Built-up land	82.3529	95.4545
Crop land	97.1154	91.8182
Degraded Forest	100	100
Dry Deciduous Forest	100	100
Fallow land	100	90.9091
Forest Plantations	100	92.8571
Grass land / Grazing land	90.0	100
Land with scrub	93.75	88.2353
Land without scrub	100	100
Mining / Industrial Wasteland	100	100
Mixed Vegetation	80.0	100
Scrub Forest	80.0	100
Water Bodies	100	100

Peri-Urban Sprawl Identification

The built-up area was increased from 11.69 km² to 32.24 km² from the year 2012 to 2024 with a percentage change of 176. The study shows a remarkable suburban sprawl around Bidadi industrial area between 2012 and 2024, because 20.55 km² of land had been lost to built-up land during this period.

In terms of sprawl direction, the town was growing towards the north and north-west, respectively. The prime causes for such expansion were due to the availability of land at a considerable cheap rate in this area, a good transportation communicational network, industries, institutional amenities, and very close to the Bangalore city, etc.It was also noted that the town was witnessing 2 major kinds of sprawling i) Ribbon sprawl - characterized by linear development along the highways ii) Scattered development - where urban growth is dispersed, with isolated patches of built-up land.

5. CONCLUSION

The study of LULC change, suburban sprawl, and future developmental activities in the Bidadi Industrial area, a more structured and sustainable approach to development is essential. Reinforcement of land-use governance is imperative for regulating urban proliferation and curbing the depletion of arable land and ecological green zones .Zoning regulations should ensure that industrial and residential developments are concentrated in planned areas, with sufficient green buffers to maintain ecological balance. Encouraging compact and high-density development in the already built-up area will reduce the spread of low-density sprawl, preserving natural and agricultural lands. Additionally, infrastructure should be developed sustainably, prioritizing efficient transportation systems, waste management, and water supply to support the growing population and industrial activity without overwhelming local resources. Green spaces and ecological corridors must be integrated into the planning framework to promote environmental sustainability and enhance residents' quality of life. Promoting sustainable building practices and clean technologies in the industrial area can reduce the environmental degradation. And, continuous monitoring of LULC through geospatial technologies is vital to guide future development and prevent unsustainable sprawl patterns, balancing economic growth with environmental sustainability.

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