



Analysing Decadal Land Use Land Cover Dynamics in the Sub-Upper Krishna Basin of Maharashtra, India Using Remote Sensing and GIS

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Authors' contributions

This work was carried out in collaboration among all authors. Authors OSK and BKG designed the study. Authors AGB and VP managed the software analyses. Authors SM and AG managed the literature searches. Author OSK wrote the first draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2024/v46i12297

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:

<https://www.sdiarticle5.com/review-history/111867>

Original Research Article

Received: 15/11/2023

Accepted: 19/01/2024

Published: 22/01/2024

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ABSTRACT

Aims: This study was conducted to examine Land Use Land Cover (LULC) dynamics in Maharashtra's sub-upper Krishna basin from 2009 to 2019 using remote sensing and geographical information system (GIS), focusing on water bodies, vegetation, soil, settlements, and their changes.

Study Design: Employing remote sensing and GIS for LULC mapping (2009-2019) the study used a maximum likelihood classifier in supervised classification, identifying six land use categories: water bodies, open shrubs, forests, agricultural land, settlements, and fallow land.

Place and Duration of Study: It was conducted in the sub-upper Krishna basin, Maharashtra, over ten years' data (2009-2019).

Methodology: The study utilised satellite remote sensing and GIS tools for LULC mapping. A supervised classification was applied with a maximum likelihood classifier to categorize land. The changes in water bodies, open shrubs, forests, agricultural land, settlements, and fallow land were analysed using GIS approach.

Results: It was seen that, over the decade, fallow land decreased by 3.03%, while agricultural land and settlements grew by 7.32% and 4.3%, respectively. Tree cover increased by 9.85%, water bodies by 0.93%, and open scrubland decreased by 1.77%. Institutional factors, easier water access, and technological and economic factors drove these changes.

Conclusion: The study advocates the effective use of satellite remote sensing to monitor LULC changes, identifying key drivers, including institutional and technological factors, contributes to sustainable development planning. The findings aid predictions for future land use changes, supporting effective land management and conservation strategies in the region.

Keywords: Remote sensing; GIS; LULC; change detection; Krishna Basin; sustainability.

1. INTRODUCTION

Land, encompassing soil, water and ecosystems, faces growing pressure from population growth and human activities [1]. Land Use Land Cover (LULC) mapping distinguishes between land cover (surface features like vegetation and water) and land use (human activities) [2]. It is vital for resource management, ecological models, and environmental monitoring. Satellite imagery and geographic information system (GIS) play a crucial role in tracking changes in land use and cover, especially in large areas, aiding in land management and urban expansion studies [3].

Remote sensing (RS) is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation [4]. A GIS is a comprehensive tool for managing, analysing, and presenting spatial data, allowing the study of complex geographic phenomena [5]. It encompasses a broad field within geo-informatics that deals with location-based information and systems designed to break down intricate earth surface features for understanding and decision-making [6].

Understanding LULC is pivotal for assessing the interplay between human activities and the environment, as well as for predicting changes [7]. Land cover comprises the physical surface components such as vegetation, urban infrastructure, water bodies, and bare soil [8]. Mapping land cover is vital for on-going monitoring, resource management, and planning. Land use characterizes how people utilize land for socio-economic activities, necessitating initial mapping and continuous monitoring [9]. Change detection identifies alterations over time and aids resource management. The combination of satellite data and GIS allows for interpretation, with post-classification comparison being a widely used method [10]. Keeping in mind the importance of information on land use land cover for spatial planning, the present study was undertaken to evaluate LULC dynamics over a specified period in the sub-upper Krishna basin of Maharashtra, India, using RS and GIS.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study area encompasses the upper Krishna River basin in Maharashtra, spanning from approximately 17°N to 18°N latitude and 73°30'E to 74°30'E longitude, covering about 5400 km². It

originates in the Western Ghats near Mahabaleshwar, reaching an elevation of 1377 m. The region exhibits varied soil types, including black soil, red soil, and lateritic soil. The terrain is undulating, with an annual rainfall ranging from 1300 mm to 2100 mm, with a distinct wetter western part and a semi-arid eastern region. The average temperature ranges from 22°C to 34°C [11].

2.2 Software and Tools Used

The LULC mapping as well as change detection in upper Krishna River basin was carried out using digital image classification technique. For digital image classification of satellite images following software were used.

- QGIS- This was used for classification by visual interpretation and to create the LULC pattern.
- Microsoft word- This was used basically for the presentation of the research.
- Microsoft Excel- This was used in producing the bar graph.

2.3 Data Acquisition, Image Enhancement and Classification

To recognize the change detection in LULC between 2009 and 2019, LISS III images of November 2009 and April 2019 were downloaded from bhuvan (www.bhuvan.gov)

portal [11]. LISS III image have spatial resolution of 23.5 m. Multispectral images were chosen because they enclosed the period of intended study and their resolutions are suitable for classification of images. The land cover maps were executed only for these images. LISS III satellite images for a period of ten years (2009-2019) were used for LULC map preparation of study area. The multispectral, multi-temporal LISS III satellite data of the study area were acquired for two years (2009 and 2019) for the months of October and February, respectively.

A base map at a scale of 1:50000 from the Survey of India were used and image processing was conducted in QGIS software. LISS III data downloaded was subjected to layer stacking to generate False Colour Composites (FCCs). Layer stacking combined multiple band images into single images and a sub setting tool was used to extract the study area, saving images as Area of Interest (AOI). Supervised image classification, a vital aspect of remote sensing and pattern recognition, was employed in this study [12]. It involved categorizing pixels based on known identity samples. The maximum likelihood classifier was used to classify image classes, ensuring precise selection and distribution of training areas. Stacked images were combined to create a comprehensive LULC map. The satellite images of the study area for the year 2009 and 2019 are shown in Fig. 1.

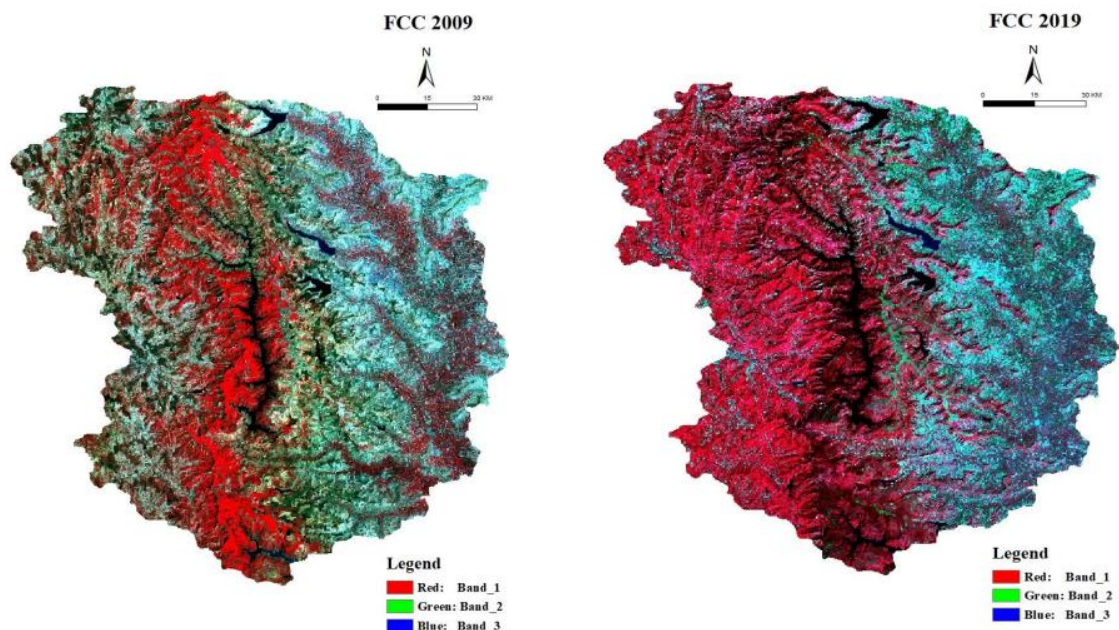


Fig. 1. FCC Image of LISS III sensor for the year 2009 and 2019

2.4 Preparation of LULC Map and Change Detection

The LULC map preparation involved screen visual interpretation of satellite images. Visual interpretation keys, including tone, texture, size, and pattern, were cross-referenced with Google Earth, Survey of India toposheets, and field checks. The study area from 2009 and 2019 satellite images was digitized using QGIS, establishing LULC classes such as Agriculture, Waste Land, Settlement, Forest, Open Scrub, and Water Bodies. Toposheets at a 1:50000 were scanned and geo-referenced based on latitudinal and longitudinal coordinates [13].

Change detection was performed by comparing images pixel by pixel, effectively identifying alterations. Data from the two different images were analysed using cross-tabulation to

determine changes between 2009 and 2019. A change matrix was created using QGIS to compile information on overall LULC changes, including losses and gains in each class. Remote sensing techniques allowed for data collection over large areas in a digital format and facilitated integration and analysis [14]. The post-classification comparison method was employed, classifying each image independently and comparing pixel signatures to pinpoint areas of change. This process could be executed via supervised or unsupervised approaches, revealing both the occurrence and nature of changes. The comparison was conducted visually using GIS tools. Remote sensing, despite having limitations in spatial resolution, proved essential for acquiring and analysing LULC data [15]. Methodology adopted in this work is presented in Fig. 2.

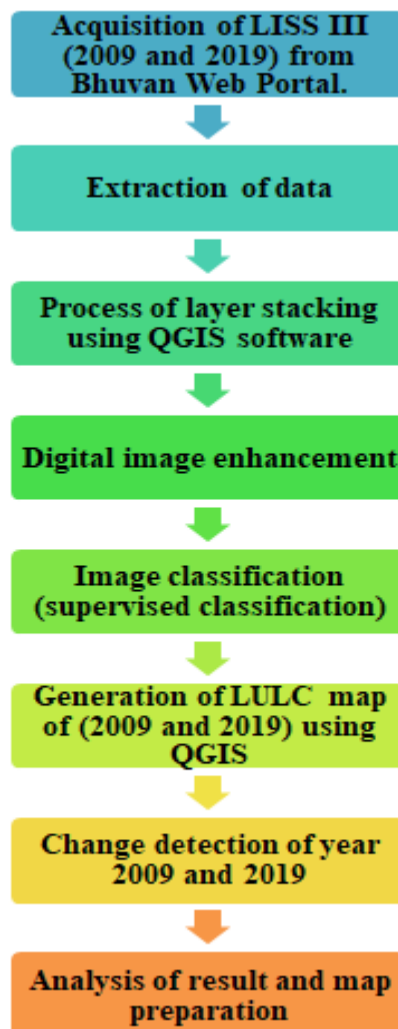


Fig. 2. Flowchart of methodology for analysing LULC dynamics

3. RESULTS AND DISCUSSION

3.1 Land Use/Land Cover (LULC) map

In FCC image, various land covers for the years 2009 and 2019 are shown by different colours, i.e., green is used for forest cover while pink indicates open scrub. Land use, land cover maps were prepared by different colours showing different land uses. The prepared map is shown in Fig. 3 and Fig. 4 for the years 2009 and 2019 respectively. The area statistics of the LULC of the study area is shown in Table 1.

In 2009, agriculture land was the prominent category, constituting 28.81% of the area, closely followed by forest cover at 27.75%. Fallow land accounted for 20.43%, while settlements occupied 13.35%. Open scrub and water bodies made up 7.82% and 2.34% of the land,

respectively. In 2019, agriculture land remained the dominant category, increasing to 33.6%, with forest cover closely trailing at 30.02%. Settlements expanded to 16.9%, while fallow land decreased to 14.36%. Open scrub and water bodies constituted 2.76% and 2.36% of the total land, respectively. These changes highlight shifts in land use patterns over the course of a decade, with agriculture and forest cover consistently being the primary categories, while settlement and fallow land experienced notable alterations.

3.2 Changes in Area under Different LULC

The percentage area as well as changes in LULC from 2009 to 2019 is shown in Table 2 and the same is represented as pie diagram in the Fig. 5 and comparison graph shown in Fig. 6.

Table 1. LULC for year 2009 and 2019

LULC class	Area (km ²) in 2009	Area (km ²) in 2019
Water body	126.21	127.26
Forest cover	1471	1620.9
Agricultural land	1555.05	1813.08
Settlement	720.82	912.92
Open shrubs	422.27	149.06
Fallow land	1103.42	775.55
Total	5398.77	5398.77

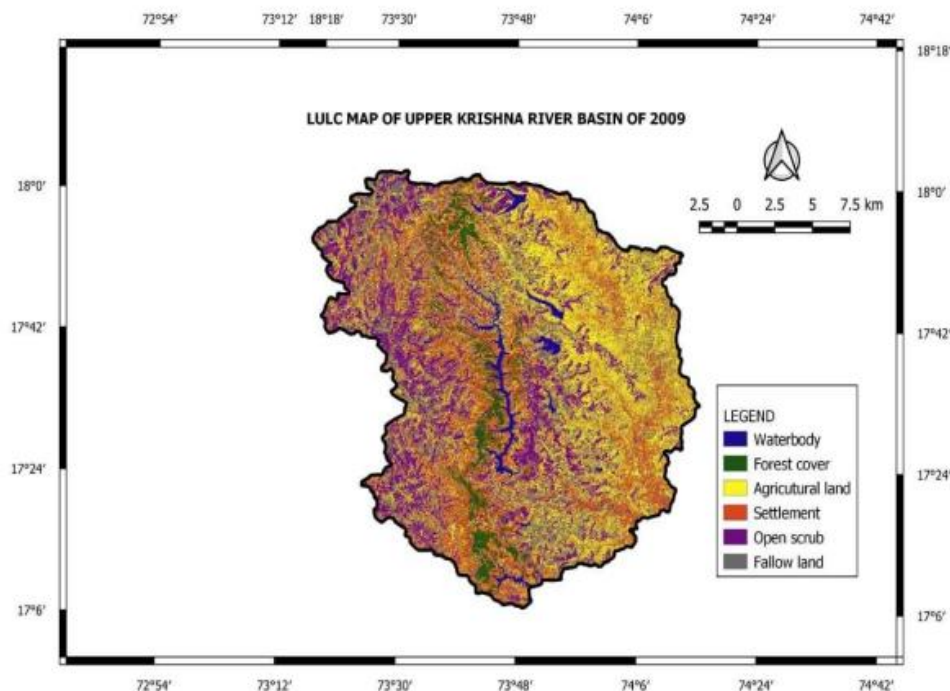


Fig. 3. LULC Map of the study area for the year 2009

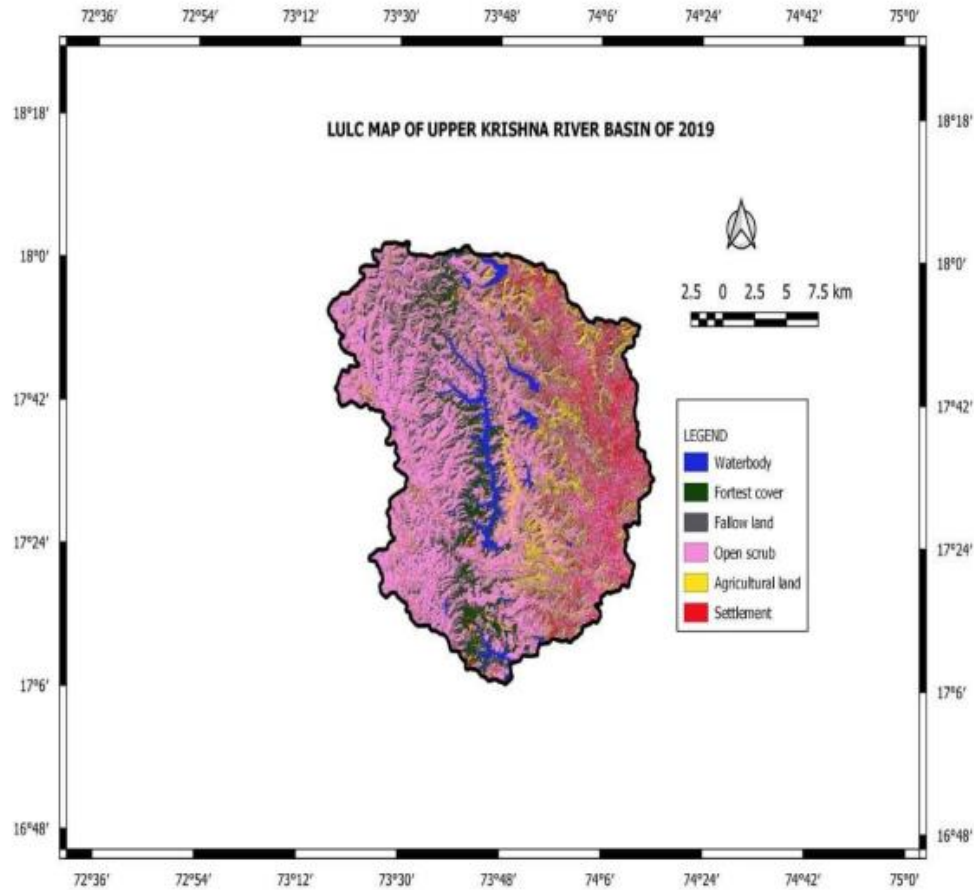


Fig. 4. LULC Map of the study area for the year 2019

Table 2. Percentage change for LULC from 2009 to 2019

Land use class	% Area in 2009	% Area in 2019	% Change
Water body	2.34	2.36	+0.02
Forest cover	27.75	30.02	+2.27
Agricultural land	28.81	33.6	+4.79
Settlement	13.35	16.9	+3.55
Open scrub	7.82	2.76	-5.06
Fallow land	20.43	14.36	-6.07

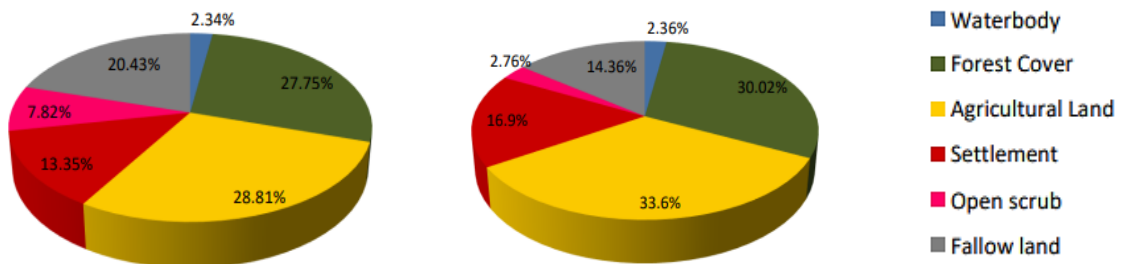


Fig. 5. Percentage area of LULC in the study area for the year 2009 and 2019

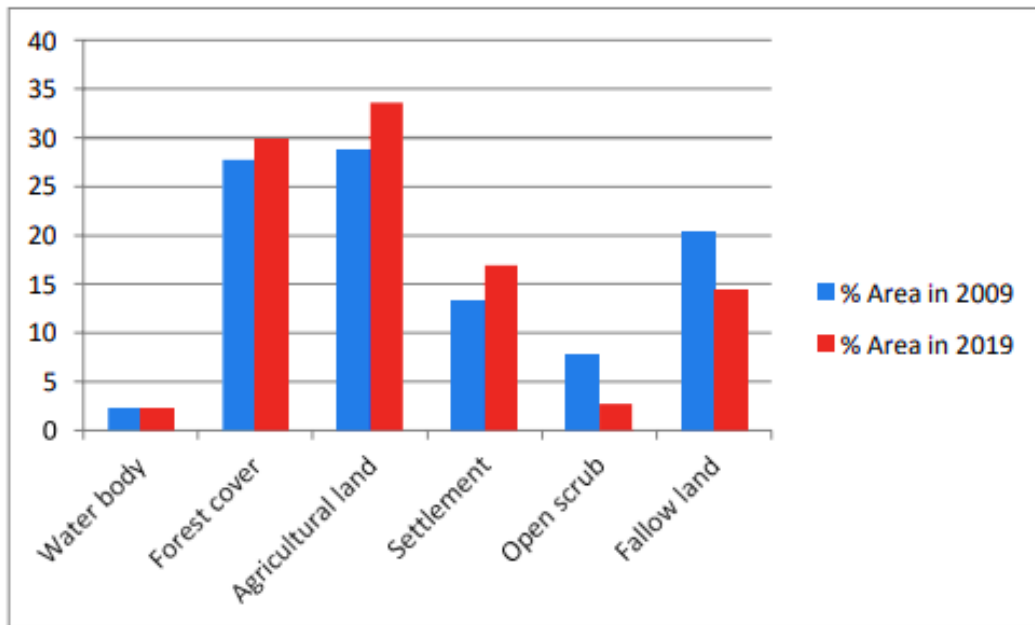


Fig. 6. LULC Comparison of the study area for the year 2009 and 2019

Table 2 reveals significant changes in land use patterns between 2009 and 2019 within the upper Krishna basin. Agriculture land expanded by 4.79%, reflecting increased agricultural activity. Fallow land decreased by 6.07%, possibly due to improved irrigation. Settlement areas notably increased from 13.35% to 16.9%, driven by population growth and rural-to-urban migration. Forest cover also saw a rise, growing from 27.75% to 30.02%. The expansion of crop areas along the Krishna river and the influence of the Koyna dam contributed to these changes. Open scrub areas decreased from 7.82% to 2.76%, primarily due to the growth of settlements. Water bodies increased slightly from 2.34% to 2.36%. The results are in conformity with the findings of Samal and Gedam [16] who reported similar LULC changes in the upper Bhima river basin of India.

The land use maps for the years 2009 and 2019 in Fig. 3 and Fig. 4 respectively showed substantial alterations. These changes can be attributed to factors like population growth, migration to urban areas, and an increased demand for settlements and agricultural land. The region witnessed an expansion in agriculture and forest cover, while fallow land decreased significantly. The trend is expected to continue with the on-going development of irrigation facilities. These shifts in land use patterns underscore the evolving dynamics of the upper Krishna basin over the past decade, as well as the critical role played by factors like population

growth, migration, and infrastructural development in shaping the landscape.

The Krishna basin exhibited varying LULC characteristics. Major water bodies were concentrated in the western and north-western regions, whereas the eastern areas faced water scarcity. Forest cover was prominent in the western and north-western sections, often mixed with wasteland and fallow land in the south. Agricultural land dominated the basin, extending alongside forested areas. The central part housed the Satara city as a major built-up area, while rural built-up zones were scattered across the basin. These findings underline the evolving landscape dynamics in the Krishna basin, driven by agricultural expansion and increased settlement, which have significant implications for regional development and environmental conservation.

4. CONCLUSION

This study, conducted in the upper Krishna river basin using remote sensing and GIS techniques, has provided valuable insights into the dynamics of LULC changes over a decade. The analysis revealed significant shifts in LULC categories, with agriculture land expanding by 4.79% and settlements increasing by 3.55%. Notably, forest cover witnessed a growth of 2.27%, while fallow land and open scrub decreased by 6.07% and 5.06%, respectively. These changes can be attributed to population growth, urbanization, and

infrastructural development. The results underscore the pivotal role of remote sensing and GIS in monitoring and quantifying LULC changes, which is crucial for environmental management and sustainable resource planning. Additionally, this research contributes to the understanding of the intricate interplay between human activities and the environment, particularly in regions experiencing rapid economic growth. The findings have implications for spatial planning, highlighting the need for sustainable land use practices and conservation efforts in response to evolving landscape dynamics.

ACKNOWLEDGEMENTS

We express our sincere gratitude to Dr. A. S. College of Agricultural Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri for providing us necessary facilities for completion of this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:

The peer review history for this paper can be accessed here:
<https://www.sdiarticle5.com/review-history/111867>