__Original Research Article__

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

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 landuse categories: water bodies, open shrubs, forests, agricultural land, settlements, and fallow land.

Place and Duration of Study: It is 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 scrub, 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**(Malani and Yadav, 2022).** Land UseLand Cover (LULC) mapping distinguishes between land cover (surface features like vegetation and water) and land use (human activities)**(Vivekananda et al., 2020)**. 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**(Arveti et al., 2016)**.

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**(Lillesand and Kiefer, 2009**). A GIS is a comprehensive tool for managing, analysing, and presenting spatial data, allowing the study of complex geographic phenomena**(Kiran et al., 2022).** 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**(Chaudhary and Kumar, 2017)**.

Understanding LULC is pivotal for assessing the interplay between human activities and the environment, as well as for predicting changes**(Roy et al., 2024).** Land cover comprises the physical surface components such as vegetation, urban infrastructure, water bodies, and bare soil**(Mishra et al., 2019)**. 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**(Kumar et al., 2016)**. 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**(Haque andBasak, 2017)**. Keeping in mind the importance of information on land use land cover for spatial planning, the present study was undertakento evaluate LULC dynamics over a specified period in the sub-upper Krishna basin of Maharashtra, India, using RS and GIS.

2. Material 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 5400km^2. 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**(Sawant et al., 2020).**

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**(Sawant et al., 2020).** 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**(Bagwan and Gavali, 2023).** 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.**

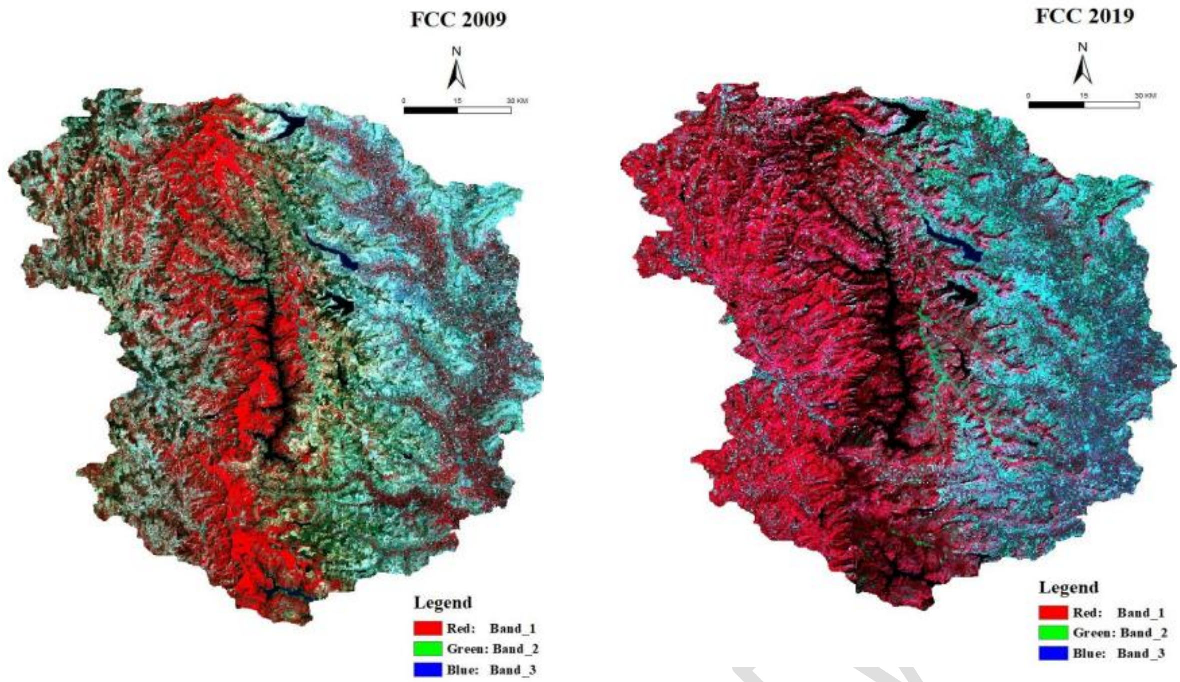

Fig. 1: FCC Image of LISS III sensor for the year 2009 and 2019

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**(Shukla et al., 2014).**

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 **(Duraisamy et al., 2018).** 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 datadigitally**(Abraham and Kundapura, 2022).** Methodology adopted in this work is presented in **Fig 2.**

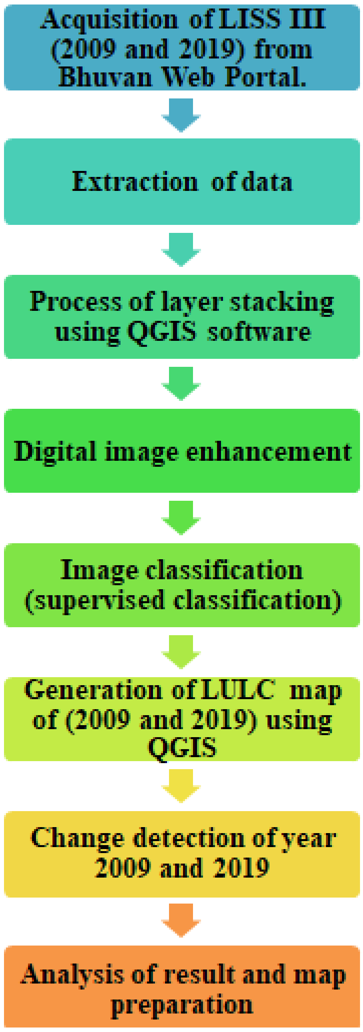

Fig. 2: Flowchart of methodology for analysing LULC dynamics

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.**

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

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.

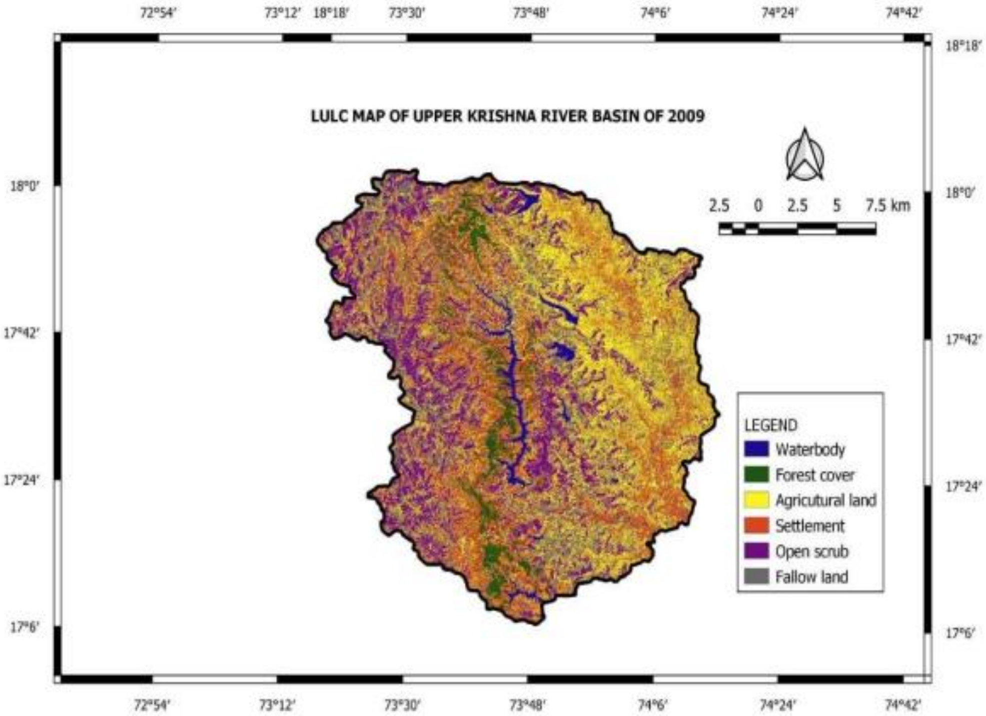

Fig. 3:LULC Map of the study area for the year 2009

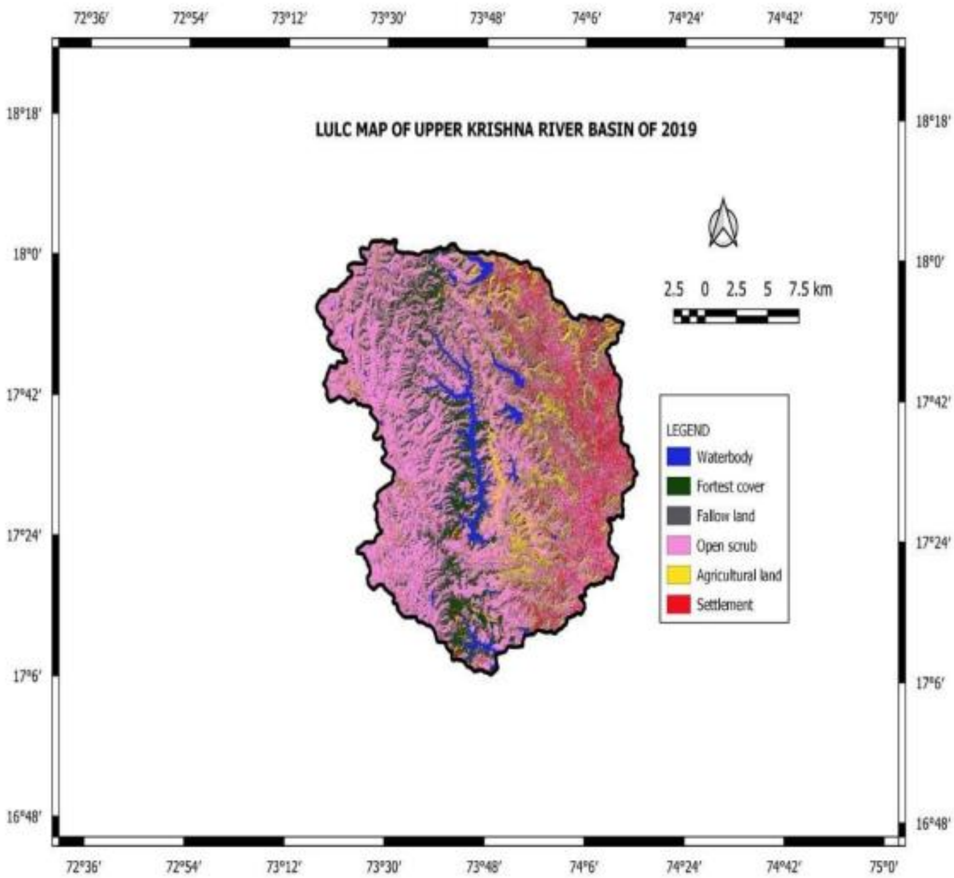

Fig. 4:LULC Map of the study area for the year 2019

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 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

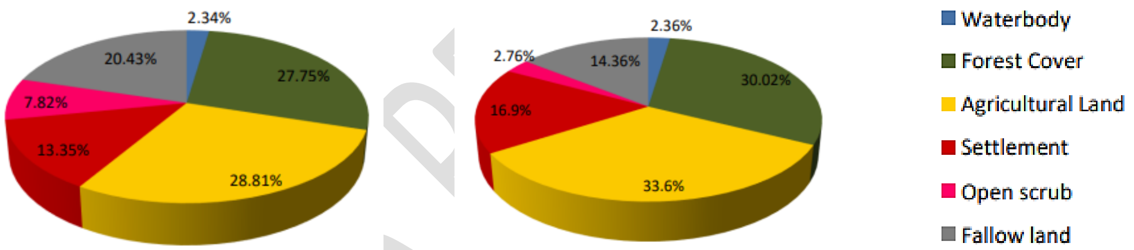

Fig. 5:Percentage area of LULC in the study area for the year 2009 and 2019

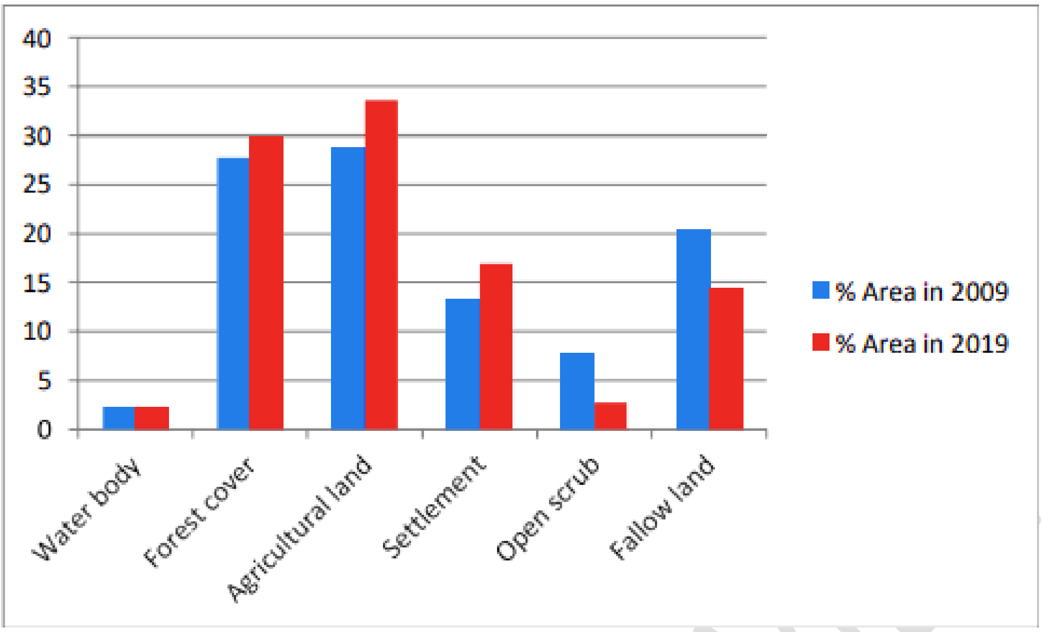

Fig. 6: LULC Comparison of the study area for the year 2009 and 2019

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 (2021)**who reported similar LULC changes in the upper Bhima river basin of India.

The land use maps for the years2009 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.

3.7 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.

4. References

Abraham A and Kundapura S. Spatio-temporal Dynamics of Land Use Land Cover Changes and Future Prediction Using Geospatial Techniques. Journal of the Indian Society of Remote Sensing.2022; 50(11): 2175-2191.

Arveti A, Etikala B and Dash P. Land use/land cover analysis based on various comprehensive geospatial data sets: a case study from Tirupati area, south India. Advances in Remote Sensing.2016;5(2): 73.

Bagwan WA andGavali RS. Dam-triggered Land Use Land Cover change detection and comparison (transition matrix method) of Urmodi River Watershed of Maharashtra, India: a Remote Sensing and GIS approach. Geology, Ecology, and Landscapes.2023; 7(3): 189-197.

Chaudhary BS and Sanjeev K. Use of RS and GIS for land use/land cover mapping of KJ watershed. India International Journal of Advances in Remote Sensing and GIS. 2017; 5: 85-92.

Duraisamy V, Bendapudi R and Jadhav A. Identifying hotspots in land use land cover change and the drivers in a semi-arid region of India. Environmental Monitoring Assess.2018; 190: 535.

Haque I. and Basak R. Land cover change detection using GIS and remote sensing techniques: a spatio-temporal study on Tanguar Haor, Sunamganj Bangladesh. Egyptian Journal of Remote Sensing and Space science.2017; 34(2): 251-263.

Kiran S, Kumar R, Gogoi K. Land Use/Land Cover Dynamics During 2001 And 2021 Using Google Earth Engine and GIS in Ramagundam Coal Mining Area, A Part of Pranhita

Godavari Valley, Southern India. Journal of Scientific Research of the Banaras Hindu University.2022; 66(1): 63-68.

Kumar K, Kumar V and Kumar D. Land use and land cover change detection in Gagas river valley watershed using remote sensing and GIS. International Journal of Research in Engineering and Applied Sciences.2016; 6(5):31-37.

Lillesand TM and Kiefer RW. Remote Sensing and Image Interpretation, textbook of Jain Wiley and Sons, Asia Private Limited Singapore 6thedition,2009.

Malani U and Yadav SM. Impact of historical and future land use land cover on spatial-temporal variation ofdischarge and sediment load of Upper Tapi Basin, India. Water Supply. 2022; 22(11): 8266-8286.

Mishra P, Raib A and Rai S. Land use and land cover change detection using geospatial techniques in the Sikkim Himalaya, India. The Egyptian Journal of Remote Sensing and Space Sciences.2019; 23(2): 133-143.

Roy SK, Alam MT, Mojumder P, Mondal I, Kafy AA, Dutta M, and Mahtab SB. Dynamic assessment and prediction of land use alterations influence on ecosystem service value: A pathway to environmental sustainability. Environmental and Sustainability Indicators. 2024; 21: 100319.

Samal DR and Gedam SS. Assessing the impacts of land use and land cover change on water resources in the Upper Bhima river basin, India. Environmental Challenges.2021; 5: 1-13.

Sawant PN, Atre AA, Bansod RD, Gorantiwar SD, Upadhye SK and Gavit BK. Temporal Analysis of Land Use/Land Cover Change in the Krishna River Sub-basin Using Google Earth Engine. Journal of Agriculture Research Technology.2020; 45(3): 177-184.

Shukla S, Khire MV and Gedam SS. Monitoring Land Use/Land Cover changes in a river basin due tourbanization using remote sensing and GIS approach. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Technical Commission VIII Symposium.2014; XL-8: 949-953.

Vivekananda GN, Swathi R and Sujith A. Multi-temporal image analysis for LULC classification and change detection. European Journal of Remote Sensing.2020;54(10):1-11.