Journal of Scientific Research and Reports

Volume 30, Issue 12, Page 630-639, 2024; Article no.JSRR.127707
ISSN: 2320-0227

Decadal Change in Land Use and Land Cover Dynamics: A Comprehensive Assessment of the Kharun Catchment

Vipin Kumar Mishra [a*], Dhiraj Khalkho [a++], Vinay Kumar Pandey [a++] and Shruti Verma [a#]

[a] *Department of Soil and Water Conservation Engineering, SVCAET & RS, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jsrr/2024/v30i122707

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/127707

Original Research Article

Received: 07/10/2024
Accepted: 09/12/2024
Published: 24/12/2024

ABSTRACT

Land Use and Land Cover (LULC) changes exert profound influences on environmental and resource dynamics, particularly in developing regions experiencing rapid urbanization and agricultural expansion. This study investigates LULC changes over a 30-year period (1992–2022) in the Kharun catchment, part of the upper Mahanadi basin in Chhattisgarh, India. Encompassing 4,143.17 km² across six districts, the catchment plays a critical role in supporting agricultural and urban activities. Landsat imagery from 1992, 2002, 2012, and 2022 was analyzed using supervised classification with Remote Sensing (RS) and Geographic Information System (GIS) tools to categorize six LULC types: water bodies, forests, urban areas, upland paddy fields, lowland paddy

---

[++] *Professor & Chief Scientist;*
[#] *Assistant Professor;*
**Corresponding author: E-mail: mvipin508@gmail.com;*

Cite as: *Mishra, Vipin Kumar, Dhiraj Khalkho, Vinay Kumar Pandey, and Shruti Verma. 2024. "Decadal Change in Land Use and Land Cover Dynamics: A Comprehensive Assessment of the Kharun Catchment". Journal of Scientific Research and Reports 30 (12):630-39. https://doi.org/10.9734/jsrr/2024/v30i122707.*

fields, and barren land. The results reveal dynamic and significant LULC changes. In 1992, water bodies (2.00%), forests (4.86%), and urban areas (1.92%) occupied smaller portions of the landscape, while barren land accounted for 28.64%. By 2002, water bodies slightly increased to 2.12%, forests decreased to 3.98%, urban areas expanded to 3.21%, and barren land reduced to 27.80%. Urban expansion became pronounced by 2012, with urban areas rising to 6.42%, while forests further declined to 3.11%, and barren land reduced to 26.30%. By 2022, water bodies expanded to 2.63%, forests declined significantly to 2.77%, and urban areas surged to 9.35%, indicative of extensive deforestation and urbanization. Barren land continued to decrease, covering 24.15%. These findings highlight the urgent need for integrated land-use management strategies that balance developmental needs with environmental conservation. Policy frameworks should prioritize reforestation initiatives, sustainable urban planning, and soil and water conservation practices to mitigate the adverse effects of deforestation and land degradation. Regular and systematic monitoring of LULC dynamics at the catchment scale is essential to support informed decision-making, ensuring ecological integrity and socio-economic sustainability in rapidly developing regions.

Keywords: LULC; GIS; remote sensing; Kharun catchment; sustainable management; urbanization; deforestation.

1. INTRODUCTION

Land cover refers to the physical characteristics of the Earth's surface, encompassing the distribution of vegetation, water bodies, soil, and other natural features. In contrast, land use pertains to how humans utilize land for various purposes, such as agriculture, urban settlements, and industrial activities. Although land use is generally inferred from land cover, the terms are often used interchangeably due to their interrelated nature. For instance, a settlement represents land cover, but when specifying its functional aspects, such as residential or industrial use, it reflects land use (Chaudhary et al., 2008). Changes in land use and land cover (LULC) have emerged as critical components of natural resource management and environmental monitoring strategies (Nema et al., 2017). Satellite-based Earth observation plays a pivotal role in understanding the temporal dynamics of human activities and their impact on natural resources. In contexts characterized by rapid and unrecorded land use transformations, satellite imagery provides objective insights into landscape utilization. Over recent decades, Earth observation data have become indispensable for mapping terrestrial features, managing resources, and analyzing environmental changes (Zubair, 2006; Karale et al., 2024).

Numerous studies have employed advanced remote sensing and GIS techniques to map and analyze LULC changes. Rao and Narendra (2006) and Boakye et al. (2008) utilized unsupervised classification methods in their investigations, leveraging ERDAS Imagine software for image classification and map preparation.

Land is a fundamental natural resource that encompasses soil, water, and vegetation, collectively forming the ecosystem (Meshram et al., 2017; Gajbhiye et al., 2015; Sharma et al., 2011a). Over time, the increasing pressure of population growth and poor management practices have led to the rapid degradation of these resources. Socio-economic development and population expansion, coupled with long-term ecological imbalances, are further exacerbated by climate variability, erratic rainfall patterns, and sudden flood events, all of which disrupt the stability of ecosystems (Sharma et al., 2008; Meshram & Sharma, 2018; Sharma et al., 2018). Significant modifications to Earth's landscapes have been made to fulfill the growing food demands of humanity (Rao et al., 2019). However, indiscriminate land use, insufficient management strategies, and inadequate monitoring contribute to land degradation. Land use and land cover (LULC) are dynamic and undergo continuous transformation due to the interplay of socio-economic and environmental factors (Patil et al., 2017; Sharma & Seth, 2010; Sharma et al., 2015). Changes in LULC are intricately linked to external drivers, including anthropogenic activities and natural forces. These transformations reflect the ongoing adaptation of landscapes to meet societal needs while responding to environmental pressures (NRSC, 2019; Rao et al., 2020).

The atmospheric buildup within a system makes it essential to obtain comprehensive information on land use and land cover (LULC) for effective planning, development, and management of land resources (Patle & Awasthi, 2019). Understanding the Earth's system, especially in regions with untapped potential, necessitates such studies, particularly at the watershed scale. These studies are critical for monitoring resource availability and ensuring timely management interventions. According to Sharma and Seth (2010), a watershed is defined as a topographically delineated hydrological unit that channels surface runoff from precipitation through a network of streams, drains, or rivers to a single predefined outlet. The term *land use* refers to human activities or economic functions associated with specific land parcels, while *land cover* describes the physical features present on the Earth's surface. Satellite remote sensing plays a pivotal role in acquiring accurate information on LULC and detecting temporal changes (Palanichamy, 2018). This technology is especially advantageous for mapping inaccessible regions, such as mountainous terrains, swamps, or restricted forest plantations. In recent years, the demand for real-time information has grown significantly for critical decision-making processes (Pathak et al., 2018). The availability of robust datasets and reliable methodologies for analysis has become indispensable. The European Space Agency (ESA) provides SENTINEL satellite imagery, which is well-suited for various applications. SENTINEL-2 data, with its multi-spectral properties and high spatial resolution (ranging from 10 to 30 m), is particularly effective for LULC analysis (Demirkan & Duzgun, 2017; Patle et al., 2020). Spatial resolution, a key characteristic of satellite sensors, varies from a few centimeters to several kilometers, making it a critical factor in satellite-based studies. The multi-spectral capabilities of SENTINEL-2 allow for accurate LULC classification, facilitating comprehensive land cover assessments. Other satellite systems, such as IRS, IKONOS, LANDSAT, LISS, MODIS, NOAA-AVHRR, RADARSAT, and SPOT, are also widely employed for Earth observation. These satellites offer varying spatial and spectral resolutions to meet diverse research and operational requirements (Manakos & Levander, 2014). The versatility of SENTINEL-2's spatial resolution enables its effective application in LULC mapping, addressing the needs of resource management and environmental monitoring.

2. MATERIALS AND METHODS

2.1 Study Area

The study focuses on the Kharun River catchment, a key tributary of the Seonath River, located in the state of Chhattisgarh, India. The Kharun catchment covers an area of 4,143.17 km² and spans across six districts: Balod, Durg, Dhamtari, Raipur, Baloda Bazar, and Bemetra. Geographically, the catchment lies between latitudes 20°52'30" N to 21°54'36" N and longitudes 81°27'18" E to 82°06'18" E. Originating from Petechua in Balod district, the Kharun River flows for 164 km before joining the Seonath River near Somnath in Raipur district. This perennial river is vital for irrigation in Chhattisgarh and falls within the Upper Mahanadi Basin, which constitutes 58% of Chhattisgarh's geographical area. The Kharun catchment has been selected for this study due to the availability of long-term climate, hydrological, and land use data at the Patharidih gauging station.

2.2 Data Collection

For the LULC classification of the Kharun catchment, Landsat images were obtained from the United States Geological Survey (USGS) Earth Explorer platform (http://earthexplorer.usgs.gov). The study utilized kharif season images captured by the Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) sensors for the years 1992, 2002, 2012, and 2022. These images were critical for analyzing land use and land cover changes over the 30-year period

Ground truth data for verifying the classification results and validating the LULC categories of the Kharun catchment were collected between 12th and 16th February 2018. To select representative sample points, the binomial probability theory was applied.

The LULC types of 1992, 2002, 2012, and 2022, the expected accuracy was set at above 95% with an allowable error of 5%, implying a 95% classification accuracy. A total of 376 ground truth points were collected using a Garmin handheld GPS receiver with an accuracy of ≤ 3 meters. In addition to field data, Google Earth was utilized to gather some reference data for earlier years, enhancing the verification process. Out of the 376 ground truth points, 188 were used for image classification, and the remaining 188 were allocated for accuracy assessment.

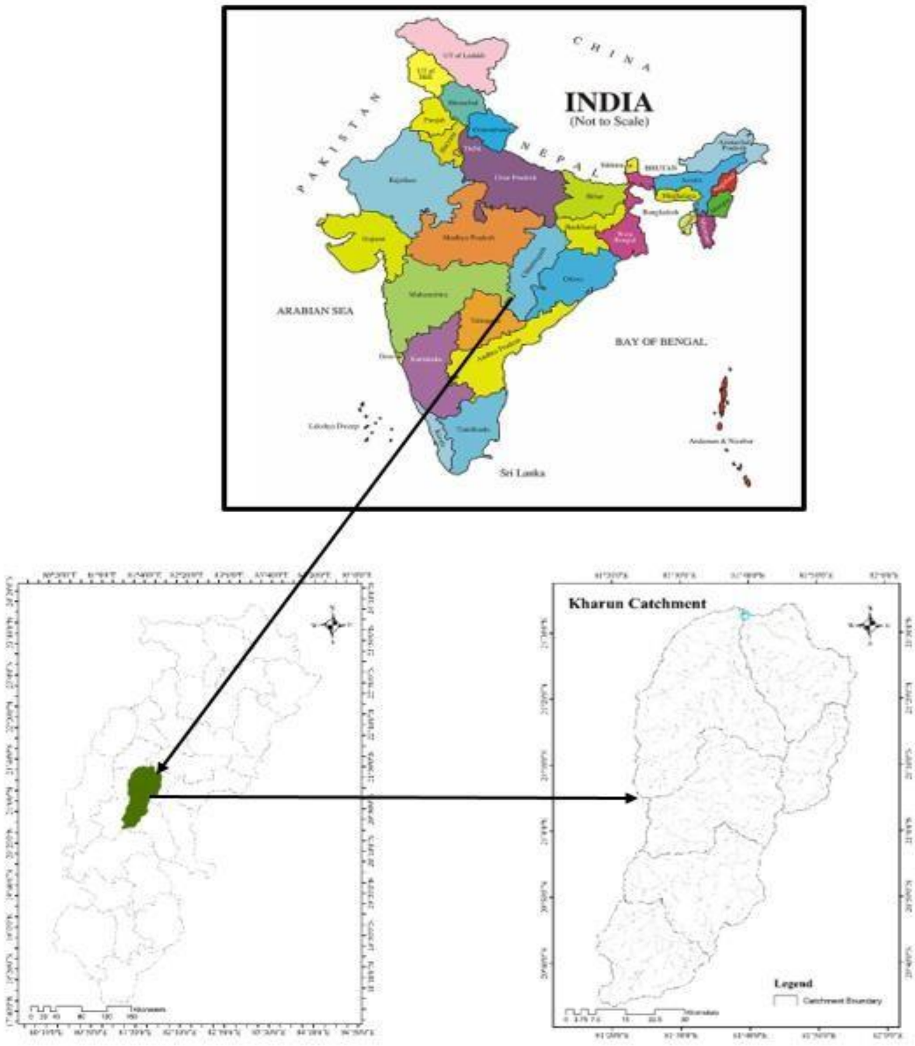

Fig. 1. Kharun catchment in Chhattisgarh

2.3 Data Processing and Analysis

Landsat images often contain distortions, necessitating pre-processing techniques such as radiometric, atmospheric, and geometric corrections to create a more accurate link between the data and the biophysical features being studied. For the Kharun catchment study, these corrections were applied to all four images using the Environment for Visualizing Images (ENVI) 5.3 software. Each image was geometrically corrected to align with the Universal Transverse Mercator (UTM) WGS84, Zone 44 North projection system. In addition to these corrections, image enhancement, mosaicking, and sub-setting were performed to prepare the data for analysis. A wavelet resolution merge technique was employed to improve the spatial resolution of the images, enhancing them from 30 m × 30 m to 15 m × 15 m using the pan-chromatic band from Landsat 8. Preliminary image interpretations were carried out using false color composites of red, green, and blue bands to aid in the visualization of land cover features. These processes were conducted using the Earth Resources Data Analysis System (ERDAS) Imagine 2015 software. The workflow applied in this study ensured that the images were of the highest quality for accurate LULC classification. image classification in the Kharun catchment study, supervised classification was conducted using the Maximum Likelihood Classifier (MLC) algorithm in ArcGIS 10.5 to determine the LULC categories. The MLC algorithm works by assessing the probability that a given pixel belongs to a particular class.

2.4 Post-Classification Analysis

After the initial classification, post-classification analysis was carried out. This involved a comparative assessment of classifications from different time periods, pixel by pixel, using a simple mathematical approach. The process also included accuracy assessments and change detection. A classification accuracy assessment was conducted based on 188 ground truth points, representing different LULC categories in the study area. An error matrix was used to statistically assess the accuracy of the classification, evaluating how well the classified pixels matched the reference data. The overall accuracy, user accuracy, and producer accuracy were then calculated from the error matrix. The overall accuracy measures the accuracy of the entire classification, user accuracy reflects the likelihood that a pixel classified on the map represents the actual class on the ground, and producer accuracy indicates how well pixels of a given cover type were classified during training.

The results of user, producer, and overall accuracies were analyzed mathematically to evaluate the performance of the LULC classification for the Kharun catchment. The accuracy assessment for the Kharun catchment LULC classification was performed using several key metrics, including user accuracy, producer accuracy, and overall accuracy. In addition to these metrics, Kappa analysis was conducted to assess the reproducibility and agreement between the classified land cover map and the reference dataset. A Kappa value of 0.8 or higher is considered indicative of good classification accuracy, while a value of 0.4 or below suggests poor classification. This metric helps to account for the possibility of chance agreement between the classified map and reference data.

2.5 Change Detection Techniques for LULC

To detect LULC changes in the Kharun catchment, change detection techniques were employed to identify variations in land cover between different time periods. Change detection helps recognize alterations in features of interest on digital images over two or more dates. The post-classification comparison (PCC) method was used, which relies on pixel-based analysis to provide detailed information on changes, offering insights into "from-to" transitions in land cover. Using ArcMap 10.5, a change matrix was generated to track gains and losses in each LULC category over the study periods, specifically between 1992-2002, 2002-2012, 2012-2022, and overall, from 1992 to 2022.

3. RESULTS AND DISCUSSION

The results of this study reveal significant land use and land cover (LULC) changes in the Kharun catchment area over the period from 1992 to 2022. Water bodies, which occupied 2.00% of the area in 1992, showed a marginal increase to 2.05% by 2002. Although there was a slight decrease to 2.03% in 2012, by 2022, water bodies had expanded to 2.63%, representing a 0.63% increase from 1992. This trend suggests improvements in water conservation measures or the natural expansion of water bodies within the catchment area.

Forest cover exhibited a consistent and alarming decline over the study period. In 1992, forests covered 4.86% of the area, which decreased to 4.39% by 2002. This downward trend continued, with forest area shrinking to 3.05% by 2012 and further reducing to 2.77% by 2022, resulting in a total decrease of 2.09% from the baseline year. The ongoing deforestation may be attributed to agricultural expansion, urbanization, or other anthropogenic pressures, necessitating urgent conservation efforts. Settlement areas, conversely, showed a sharp increase, reflecting rapid urbanization. In 1992, settlements occupied 1.92% of the area. This increased to 2.66% by 2002, then surged to 6.60% by 2012, and further expanded to 9.35% by 2022, representing a 7.43% increase over the 30-year period. The rapid urban expansion indicates population growth and the need for sustainable urban planning to balance development and resource conservation. Upland paddy fields exhibited a slight decrease over the decades. In 1992, upland paddy covered 28.74% of the study area, with a marginal decline to 28.62% by 2002, and further reductions to 28.49% in 2012 and 28.21% by 2022. This modest decline suggests a stable but slightly diminishing trend in upland paddy cultivation, potentially due to changing agricultural practices or competing land uses. Similarly, lowland paddy fields showed minor fluctuations. In 1992, lowland paddy covered 29.05% of the area. The coverage increased slightly to 29.09% by 2002 but decreased to 28.65% by 2012 and further to 28.41% by 2022, reflecting a 0.64% decrease over the study period. These fluctuations might indicate adjustments in cultivation techniques or reallocation of land for other uses. Barren land experienced a notable decline, covering 28.64% of the area in 1992, which decreased to 28.18% by 2002. This decline accelerated by 2012, with barren land occupying 26.48%, and continued to 24.15% by 2022, marking a total reduction of 4.48%. The significant reduction in barren land suggests the implementation of improved land management practices, afforestation, or the conversion of barren land to agricultural or settlement purposes. Fallow land showed slight variations throughout the study period. In 1992, fallow land covered 4.79% of the area, increasing to 5.01% by 2002 but then slightly decreasing to 4.70% in 2012 and further declining to 4.47% by 2022. These variations may be linked to intermittent agricultural practices or temporary abandonment of cultivation.

Overall, the analysis of LULC changes from 1992 to 2022 highlights key trends, including the expansion of water bodies, rapid urbanization, consistent deforestation, and adjustments in agricultural practices. These findings underscore the need for integrated land management approaches that promote sustainable urban growth, forest conservation, and the efficient use of agricultural land.

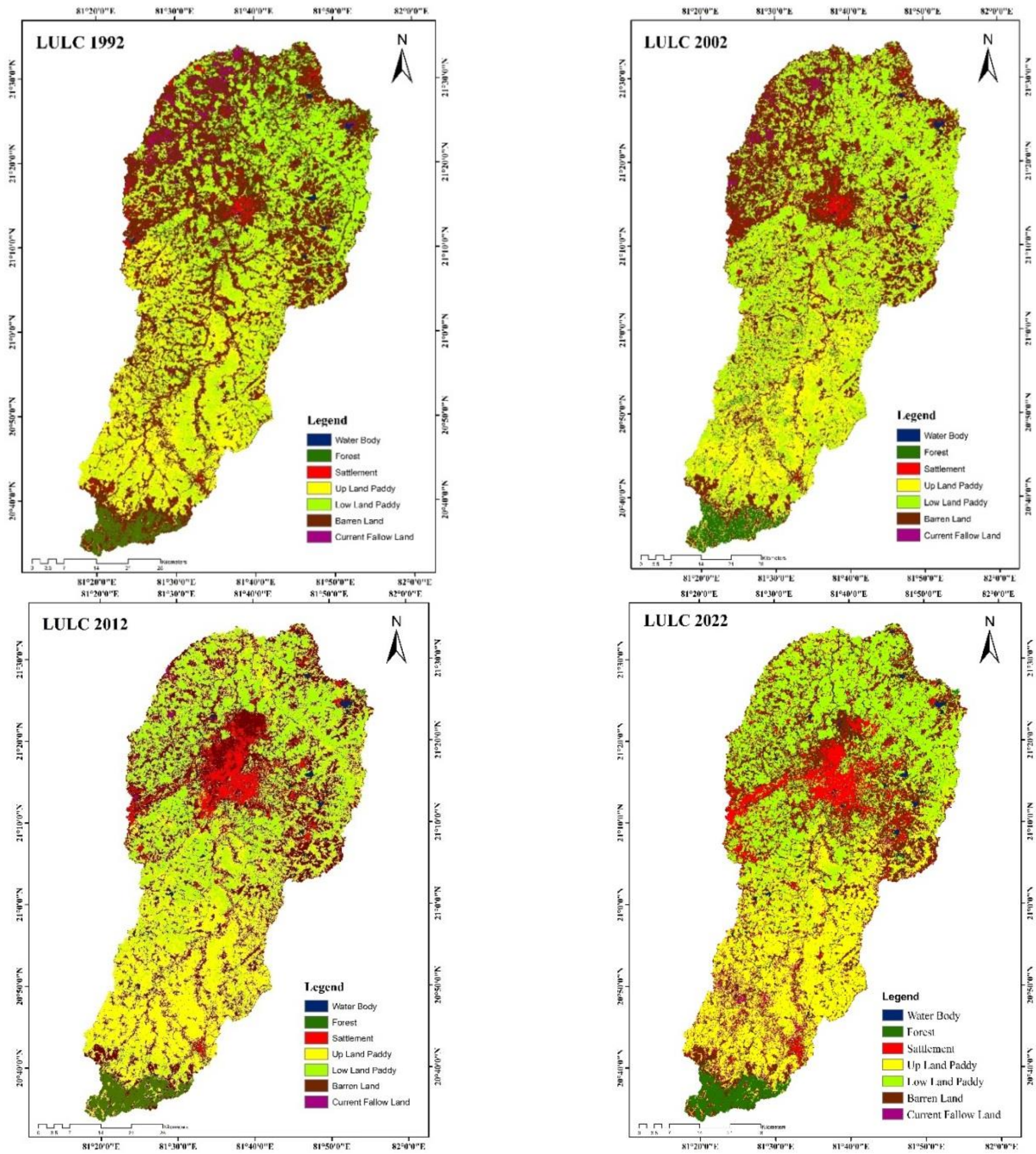

Fig. 2. Land use Land cover map of study area

Table 1. Land Use/ Land Cover Classification

S. No.	Class name	Area in km^2				% area in 1992	% area in 2002	% area in 2012	% area in 2022
		1992	2002	2012	2022				
1	Water body	82.90	85.11	84.28	109.16	2.00	2.05	2.03	2.63
2	Forest	201.36	182.04	126.31	114.96	4.86	4.39	3.05	2.77
3	Settlement	79.57	110.02	273.54	387.360	1.92	2.66	6.60	9.35
4	Up land paddy	1190.93	1185.69	1180.32	1168.59	28.74	28.62	28.49	28.21
5	Low land paddy	1203.63	1205.06	1187.17	1177.27	29.05	29.09	28.65	28.41
6	Barren land	1186.40	1167.58	1096.98	1000.73	28.64	28.18	26.48	24.15
7	Fallow land	198.36	207.64	194.54	185.09	4.79	5.01	4.70	4.47

Table 2. Percentage Change of Land Use/ Land Cover

S. No.	Class Name	% Area in 1992	% Area in 2002	% Area in 2012	% Area in 2022	% Change Compare To 1992		
						2002	2012	2022
1	Water body	2.00	2.05	2.03	2.63	0.05	0.03	0.63
2	Forest	4.86	4.39	3.05	2.77	-0.47	-1.81	-2.09
3	Settlement	1.92	2.66	6.60	9.35	0.74	4.68	7.43
4	Up land paddy	28.74	28.62	28.49	28.21	-0.13	-0.26	-0.54
5	Low land paddy	29.05	29.09	28.65	28.41	0.03	-0.40	-0.64
6	Barren land	28.64	28.18	26.48	24.15	-0.45	-2.16	-4.48
7	Fallow land	4.79	5.01	4.70	4.47	0.22	-0.09	-0.32

3.1 Accuracy Assessment

The accuracy assessment of the supervised classification for the Kharun catchment using Landsat imagery from 2002, 2012, and 2022 demonstrates reliable classification performance across the evaluated years. The overall classification accuracies for 2002 and 2012 were consistent at 83%, with a marginal improvement observed in 2022, reaching 89%. The Kappa statistics also reflected this trend, improving from 0.81 in the earlier years to 0.86 in 2022, indicating enhanced agreement between the classified and reference data. Across all three years, certain LULC classes, such as "Upland Paddy," "Lowland Paddy," and "Forest," consistently exhibited high classification accuracy, with producer and user accuracy values typically exceeding 90%. These results indicate the robustness of the classification model in capturing the spectral signatures of these categories. Conversely, classes like "Current Fallow" and "Barren Land" displayed variability in accuracy, particularly in 2022, where "Barren Land" showed a perfect producer accuracy of 100% but a significantly lower user accuracy of 37%, suggesting potential misclassification due to spectral confusion with other land cover types.

The overall improvement in accuracy metrics over the three decades reflects advancements in data processing techniques and classification methodologies. Despite this, challenges remain in achieving uniformly high accuracy for all LULC classes, underscoring the complexity of land cover dynamics and the need for continued refinement in classification approaches. These findings provide a reliable basis for analyzing land use and land cover changes in the Kharun catchment, contributing to informed decision-making in watershed management and planning.

4. CONCLUSION

the findings of this study underscore the significant impacts of LULC changes on the environment and highlight the need for integrated land management strategies. The increase in water bodies, urbanization, and shifts in agricultural practices, alongside the worrying deforestation trends, emphasize the need for sustainable approaches to land and resource management in the Kharun catchment. Effective policies must be developed to mitigate land degradation, promote reforestation, and ensure the long-term sustainability of the region's water and soil resources The analysis of land use and land cover (LULC) changes in the Kharun catchment over the past three decades reveals substantial shifts, notably the expansion of water bodies and rapid urbanization, alongside significant deforestation. The increase in water bodies, from 2.00% in 1992 to 2.63% in 2022, suggests improved water conservation, while the sharp decline in forest cover, from 4.86% to 2.77%, raises concerns about increased sediment yield and reduced water retention capacity. The dramatic urban expansion from 1.92% to 9.35% likely exacerbates runoff, contributing to higher sediment loads in water bodies. The decline in barren and fallow land indicates land-use intensification, but the overall trends highlight the need for sustainable land management to mitigate the adverse effects of LULC changes on water and sediment yield. Effective policies are crucial for balancing development, reducing erosion, and ensuring long-term watershed health.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

ACKNOWLEDGEMENT

The authors would like to thank Central Water Commission, Bhubaneshwar, for authorizing the use of data essentially for study and research purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Boakye, E., Odai, S. N., Adjei, K. A., & Annor, F. O. (2008). Landsat images for assessment of the impact of land use and land cover changes on the Barekese catchment in Ghana. *European Journal of Scientific Research, 22*(2), 269–278.

Chaudhary, B. S., Saroha, G. P., & Yadav, M. (2008). Human-induced land use land cover changes in the northern part of Gurgaon District, Haryana, India: Natural resources census concept. *Journal of Human Ecology, 23*(3), 243–252.

Demirkan, D. C., & Duzgun, H. S. (2017). *Land use and land cover classification of Sentinel 2-A images* (Thesis).

Gajbhiye, S., & Sharma, S. K. (2015). Application of remote sensing and GIS approach for prioritization of watershed through sediment yield index. *International Journal of Innovative Research*, 1.

Gajbhiye, S., Sharma, S. K., Tignath, S., & Mishra, S. K. (2015). Development of geomorphological erosion index for Shakker watershed. *Journal of the Geological Society of India, 86*(3), 361–370.

Hakkenberg CR, Dannenberg MP, Song C, Ensor KB. Characterizing multi-decadal, annual land cover change dynamics in Houston, TX based on automated classification of Landsat imagery. International journal of remote sensing. 2019 Jan 17;40(2):693-718.

K.N., & Narendra, K. (2006). Mapping and evaluation of urban sprawling in the Mehadrigedda watershed in Visakhapatnam metropolitan region using remote sensing and GIS. *Current Science, 91*(11), 1552–1557.

Karale OS, Gavit BK, Bhat AG, Paradkar V, Mukherjee S, Gupta A. Analysing Decadal Land Use Land Cover Dynamics in the Sub-Upper Krishna Basin of Maharashtra, India Using Remote Sensing and GIS . J. Exp. Agric. Int. [Internet]. 2024 Jan. 22 [cited 2024 Nov.26];46(1):87-95. Available from: https://journaljeai.com/index.php/JEAI/article/view/2297

Manakos, I., & Lavender, S. (2014). *Remote sensing in support of the geo-information in Europe.* Remote Sensing and Digital Image Processing, 18.

Meshram, S. G., & Sharma, S. K. (2018). Application of principal component analysis for grouping of morphometric parameters and prioritization of watershed. In V. P. Singh, S. Yadav, & R. Yadav (Eds.), *Hydrological Modeling: Select Proceedings ICWEES-2016* (pp. 447–458). Springer.

Meshram, S. G., Sharma, S. K., & Tignath, S. (2017). Application of remote sensing and geographical information system for generation of runoff curve number. *Applied Water Science, 7*(4), 1773–1779.

Nema, S., Awasthi, M. K., & Nema, R. K. (2017). Spatial and temporal groundwater responses to seasonal rainfall replenishment in an alluvial aquifer. *Biosciences Biotechnology Research Communications, 10*(3), 431–437.

NRSC. (2019). Land use/land cover database on 1:50,000 scale. *Natural Resources Census Project, LUCMD, LRUMG, RSAA.* National Remote Sensing Centre, ISRO, Hyderabad.

Palanichamy, A. (2018). Land use/land cover mapping and analysis of Tiruchirappalli District, Tamil Nadu using geoinformatics. *International Journal of Latest Trends in Engineering and Technology, 9*(4), 161–165.

Pathak, R., Awasthi, M. K., Sharma, S. K., Hardaha, M. K., & Nema, R. K. (2018). Groundwater flow modeling using MODFLOW: A review. *International Journal of Current Microbiology and Applied Sciences, 7*(2), 83–88.

Patil, R. J., Sharma, S. K., Tignath, S., & Sharma, A. P. M. (2017). Use of remote sensing, GIS, and C++ for soil erosion assessment in Shakker river basin, India. *Hydrological Sciences Journal, 62*(2), 217–231.

Patle, D., & Awasthi, M. K. (2019). Groundwater potential zoning in Tikamgarh District of Bundelkhand using remote sensing and GIS. *International Journal of Agriculture, Environment and Biotechnology, 12*(4), 311–318.

Patle, D., Rao, J. H., & Dubey, S. (2020). Morphometric analysis and prioritization of sub-watersheds in Nahra Watershed of Balaghat District, Madhya Pradesh: A remote sensing and GIS perspective. *Journal of Experimental Biology and Agricultural Sciences, 8*(4), 447–455.

Rao, J. H., Hardaha, M. K., & Vora, H. M. (2019). The water footprint assessment of agriculture in Banjar River watershed. *Current World Environment, 14*(3), 476–488.

Rao, J. H., Patle, D., & Dubey, S. (2020). Implementation of morphometric analysis in prioritizing sub-watersheds: A remote sensing and GIS aspect. *Indian Journal of Pure and Applied Biosciences, 8*(4), 318–329.

Sharma, S. K., & Seth, N. K. (2010). Use of geographical information systems (GIS) in assessing the erosion status of watersheds. *Scientific Frontiers: A Journal of Multiple Science, 4*(4), 77–82.

Sharma, S. K., Gajbhiye, S., Nema, R. K., & Tignath, S. (2015). Assessing vulnerability to soil erosion of a watershed of the

Narmada basin using remote sensing and GIS. *International Journal of Innovative Research, 1*, 295

Sharma, S. K., Gajbhiye, S., Tignath, S., & Patil, R. J. (2018). Hypsometric analysis for assessing erosion status of a watershed using a geographical information system. In *Springer Proceedings on Hydrology* (pp. 263–276). https://doi.org/10.1007/978-981-10-5801-1_19

Sharma, S. K., Pathak, R., & Suraiya, S. (2012). Prioritization of sub-watersheds based on morphometric analysis using remote sensing and GIS techniques. *JNKVV Research Journal, 46*(3), 407–413.

Sharma, S. K., Seth, N. K., Tignath, S., & Pandey, R. P. (2011a). Use of geographical information systems in hypsometric analysis of watersheds. *Journal of the Indian Water Resources Society, 31*(3–4), 28–32.

Sharma, S. K., Seth, N. K., Tignath, S., & Shukla, J. P. (2011b). Land use/land cover mapping of the Gusuru River using remote sensing and GIS techniques. *JNKVV Research Journal, 45*(1), 125–128.

Sharma, S. K., Tignath, S., & Mishra, S. K. (2008). Morphometric analysis of a drainage basin using a GIS approach. *JNKVV Research Journal, 42*(1), 91–95.

Xian G, Shi H, Zhou Q, Auch R, Gallo K, Wu Z, Kolian M. Monitoring and characterizing multi-decadal variations of urban thermal condition using time-series thermal remote sensing and dynamic land cover data. Remote Sensing of Environment. 2022 Feb 1;269:112803.

Zubair, A. O. (2006). Change detection in land use and land cover using remote sensing data and GIS (A case study of Ilorin and its environs in Kwara State). (M.Sc Project). Department of Geography, University of Ibadan.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/127707