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RESEARCH ARTICLE

Agrarian Transformation and Livelihood Vulnerability: A Village-Scale Analysis of Land Use Dynamics in Tribal Jharkhand, India

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ABSTRACT

Background and Purpose: As tribal landscapes in India face unprecedented pressure from modernization, Agro-climatic Zone IV in Jharkhand serves as a critical flashpoint for shifting socio-ecological dynamics. This study examines land use and land cover (LULC) changes to understand how biophysical transitions intersect with rural livelihood vulnerability, by focusing on three purposively selected tribal villages, Borma, Asanbani, and Raksi. The research explores the drivers of change, including demographic shifts, state-led developmental governance, and market-driven land fragmentation. The primary goal is to provide a localized evidence base to support sustainable tribal land-use policies in rainfed agrarian systems.

Methods: The research utilizes a socio-ecological framework integrated with multi-temporal satellite imagery spanning from 2012 to 2016. Remote sensing data was substantiated through rigorous ground-truth validation and geospatial change detection techniques. To capture the human dimension of these transitions, the study integrated quantitative geospatial analysis with qualitative insights gathered from focused group discussions with local tribal communities. This hybrid approach allowed for a comprehensive mapping of both physical land-use shifts and the underlying socio-economic catalysts driving them.

Results: Findings reveal a significant and concerning transformation in land patterns, characterized by a critical decline in agricultural land, most notably reaching 9.19% in Borma. Simultaneously, builtup areas experienced a massive surge, peaking at 37.98% in Asanbani, driven by escalating population pressure and rising land values. The data highlights a growing conflict between infrastructure expansion and traditional agricultural sustainability. Furthermore, the analysis identifies a trend toward increasing fallow land, which signals heightened ecological insecurity and a potential breakdown of traditional rainfed farming systems under the weight of market-driven fragmentation.

Conclusion: The study highlights the urgent need for nuanced, village-scale interventions to protect tribal livelihoods from the adverse effects of rapid agrarian transformation. The results demonstrate that infrastructure-led growth often comes at the cost of agricultural resilience, necessitating a policy shift toward ecological security and the protection of tribal land rights. By bridging the gap between geospatial data and community experiences, this research provides a framework for policymakers to address land-use conflicts, ensuring that developmental governance in Jharkhand does not further marginalize vulnerable agrarian populations.

KEYWORDS

Land Use Land Cover, Change Detection, Geographical Information System, Jharkhand

1. INTRODUCTION

The emerging technologies in relation to geospatial and geographical information systems in agriculture have provided newer opportunities to understand the cropping situation of a locale over a period of several years. Such technologies have enabled the scientists and the farmers to undertake precision farming with better deployment of resources in the actual field conditions for maximizing the production and productivity of the farm. The implementation of geospatial technologies in agriculture has been in existence since the early 1990s (Sood et al., 2015; Yisa et al., 2019). With the advancement of technology, the gradual popularization,

and the offering on a customer-friendly platform, it is now possible for farmers to estimate the spatial and temporal variability of the soil, relief features, and vegetation coverage, etc., using remote sensing-geographical information system (RS-GIS) tools.

Land use and land cover (LULC) detection through RS-GIS tools is another area where the interactions of human activities with natural resources could be studied minutely, providing an elaborate picture of changes within a particular period of time (Tiwari & Khanduri, 2011; Mir & Ahmed, 2014; Nanda et al., 2017; Bera & Prakash, 2018). Such information is of immense importance to policy makers, scientists,

researchers, and farmers to understand the land utilization in a better way, leading to sustainable utilization of natural resources. Thus, such tools provide opportunities for the advanced management of ecosystems in close interaction with socio-economic management for efficient planning and decision making (Ghosh et al., 2020). The analysis of data collected from the remote sensing satellites provides comprehensive change detection analysis at local, regional, and global levels, providing an important linkage between the researchers conducted on the localized stations to regional, national, and global research in the field of conservation and diversity studies (Wilkie & Finn, 1996; Haque & Basak, 2017).

The long-term LULC analysis of multi-temporal and multi-sensor satellite images for a trend analysis is important to study the long-term changes in the considered study area (Das & Angadi, 2020; Roy & Inamdar, 2019; Saleem et al., 2018). A few researchers focused on the delineation of the groundwater potential (Kumar, 2018; Murmu et al., 2019) through geospatial analysis in Jharkhand. There have been limited studies on the agroclimatic region IV of Jharkhand state, India, which is experiencing problems related to deterioration of environmental quality, loss of agricultural lands, along with decreasing cover of forests (Kumar et al., 2018; Parishwad & Parishwad, 2017; Reddy et al., 2020). The study is situated within the Agrarian Transformation framework, which posits that rural landscapes in developing Asia are transitioning from subsistence-based farming to diversified, often vulnerable, socio-economic structures. In Jharkhand, this is characterized by the bifurcation of holdings due to demographic shifts along with a decline in primary agricultural assets (land and water), increasing dependency on the service sector. Further, Ecological Security is defined in the study's context as the land's capacity to provide consistent ecosystem services (food, water, and forest products) to tribal communities.

Therefore, this research intends to bridge the gap between the attempts made to understand the typologies of tribal villages in Jharkhand state of India using LULC and a change detection study. The objectives of the research are to study the LULC change of three villages located in agroclimatic zone IV of Jharkhand and to study the changes occurring in different agroclimatic classes over a time period of three years.

2. METHODS

The study utilized the Survey of India (SOI) toposheets (scale 1:50,000) as well as Resourcesat-1/Resourcesat-2: LISS III Ortho satellite data available from Bhuvan store, National Remote Sensing Centre (NRSC, 2020), from the years 2012-2016 for the three villages. Landsat data from the United States Geological Survey (USGS) is also made use of in case of low-quality data from the latter. The ground truth study was conducted by capturing the coordinate data from specific farms in the village using the GIS Cloud Android mobile application (GIS Cloud,

2020). The LULC analysis was conducted through the ERDAS and QGIS geographic information system platforms to generate various thematic layers covering the change detection over the years. The classification of images is performed using the Maximum Likelihood Classification (MLC) method. The methodology adopted for the study is represented as a flowchart (Figure 1).

2.1 Locale of the Study

The agro-climatic zone of Jharkhand comprises three zones (Zone IV, V, and VI). Three different villages from three different districts in Zone IV (Central and north eastern plateau) are purposively selected for the study on the basis of distinct geological and biophysical features of the villages. The selected villages are Borma (25.2098° N, 87.3538° E) in Godda district, Asanbani (24.3215° N, 87.1809° E) in Dumka district, and Rakshi (24.7720° N, 87.6717° E) in Sahibganj district of Jharkhand. These villages are selected to represent the typological diversity of Agro-climatic Zone IV. Borma represents areas with complex soil variations; Asanbani reflects villages experiencing high Ridge-to-Valley erosion; and Rakshi illustrates the impact of irregular mountain topography on arable land distribution. The villages under study are mostly rural, with an average distance of around 40 km from the nearby town/ city. Almost 94% of the households in the village are dependent on agriculture and allied activities for sustenance. The last three decades have experienced a rapid increase in the population of the villages, which has led to the bifurcation of agricultural landholdings and increased area under settlements. The groundwater table in the villages varies between 5-7.5 m during pre-monsoon and 12-18 m during monsoon. Tube well is the major source of irrigation in all the villages. The villages are distinct with the presence of an irregular mountain range dividing the village of Rakshi into arable and non-arable land. Different soil types are present in the village of Borma, in which only specific crops can be grown. Asanbani village has the presence of high ridges and valleys bounded by mountains, along with the presence of poor soil fertility due to extensive erosion, acidity, and low retaining capacity. Such soil makes it difficult to grow more than one crop in a farming year. Increased literacy levels and enhanced extension intervention in the villages have resulted in a complex change in land use with increased activities in the field of horticulture and cultivation of cash crops. The location of the study area is depicted in Figure 2.

2.2 Classification Accuracy and Validation

The reliability of the LULC maps generated through the MLC algorithm is rigorously tested using an Error Matrix (Confusion Matrix). This process is essential to ensure that the transition from satellite reflectance data to thematic classes such as Agriculture, Builtup, and Forest is statistically significant and free from systematic bias.

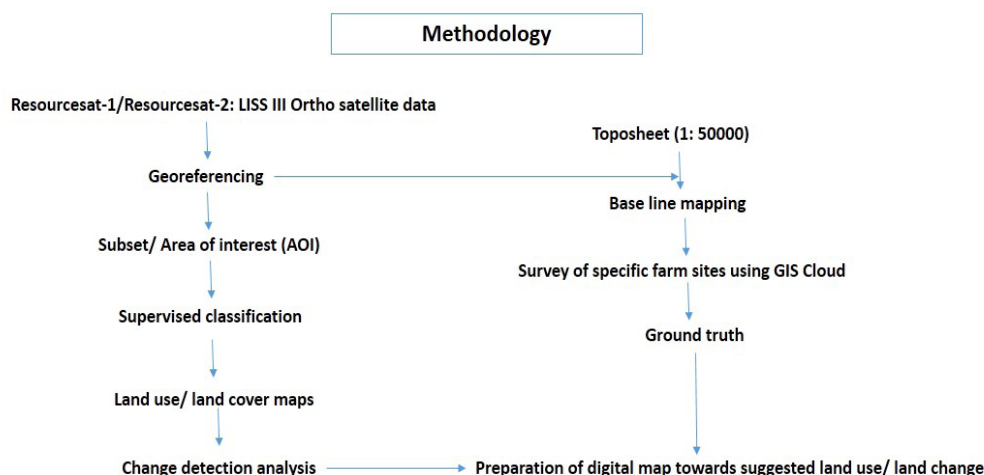


Figure 1 Flow Chart Describing the Preparation of Digital Maps towards LULC

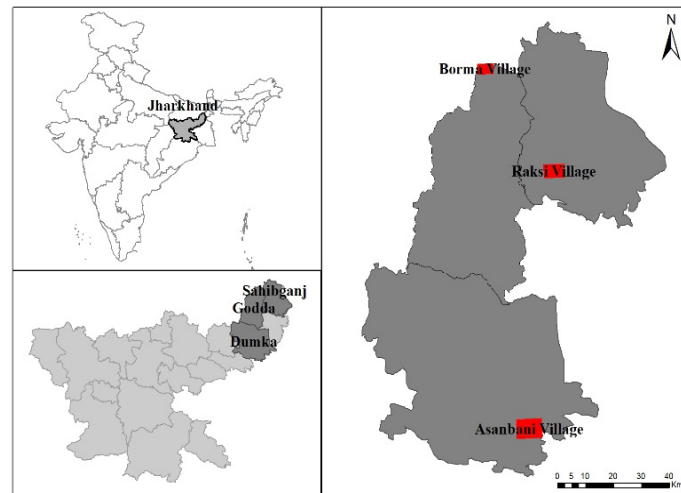


Figure 2 Location of the Study Area

2.2.1 Ground Truth and Sample Design

The validation utilized 120 reference points (approximately 40 per village) collected through two primary methods. Ground truth data were obtained through a direct field survey using the GIS Cloud mobile application (GIS Cloud, 2020), which recorded high-precision geographic coordinates from specific farms and settlement locations across Borma, Asanbani, and Raksi villages. In addition, reference data were used to verify locations that were difficult to access in the field. High-resolution Google Earth imagery and SOI toposheets at a scale of 1:50,000 were consulted to confirm land-use characteristics in these areas and ensure the reliability of the validation dataset.

2.2.2 Accuracy Metrics

The performance of the classification was assessed using three principal accuracy indicators: Overall Accuracy, Producer's and User's Accuracy, and the Kappa Coefficient. Overall Accuracy represents the proportion of correctly classified pixels relative to the total number of reference pixels. Producers' and Users' Accuracy were used to evaluate omission errors (pixels belonging to a class but not classified as such) and commission errors (pixels incorrectly assigned to a class). The Kappa Coefficient measures the statistical agreement between the classified map and the reference data while accounting for agreement that may occur by chance. The overall classification accuracy for the 2012–2016 period was 88.00%, with a Cohen's Kappa coefficient of 0.84. According to Landis and Koch (1977), a Kappa value above 0.80 indicates strong agreement, confirming that the observed LULC transitions reliably represent the biophysical changes occurring in Agro-climatic Zone IV.

2.3 Integrated Qualitative Analysis

To go beyond descriptive spatial statistics, focus group discussions (FDGs) were conducted with local farmers and village elders in all three sites. These discussions were designed to validate the LULC findings and identify the socio-economic drivers behind observed changes, such as the impact of government housing schemes (in Asanbani) or the failure of irrigation infrastructure leading to fallow land expansion (in Raksi). This integration allows for a triangulated interpretation of spatial data through the lens of local agrarian experience.

3. RESULTS AND DISCUSSION

3.1 LULC of Borma Village during February 2012 and February 2015

The LULC statistics of Borma village in Godda district of Jharkhand for the years 2012 and 2015 are depicted in Figures 3 and 4 below.

Figures 3 and 4 show the different classes of LULC used for the change detection study within a period of three years, from 2012 to 2015. The

multi-temporal LULC mapping and change detection analysis are carried out for the study to categorize five distinct classes, which are fallow land, agriculture, forest, builtup area, and waterbody.

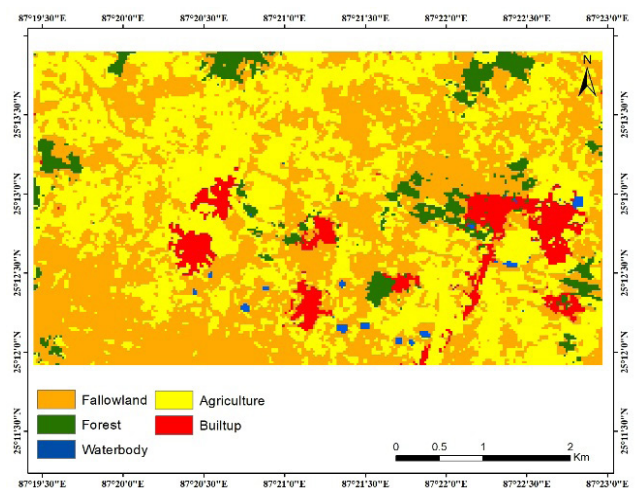


Figure 3 LULC Map of Borma Village during February 2012

Source: Generated from the LISS III Ortho satellite data, NRSC (2020).

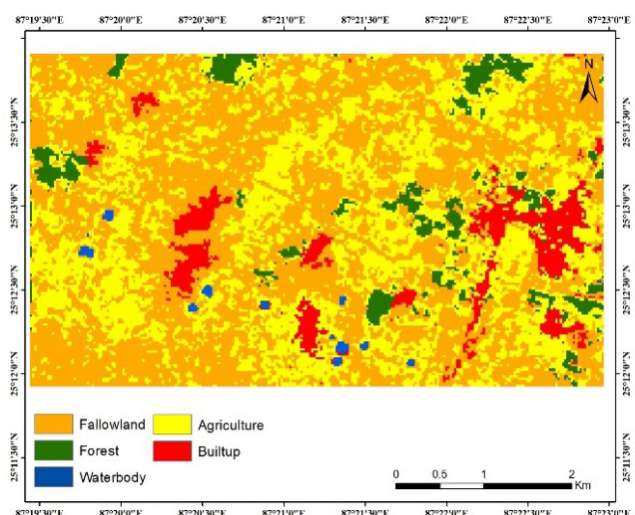


Figure 4 LULC Map of Borma Village during February 2015

Source: Generated from the LISS III Ortho satellite data, NRSC (2020).

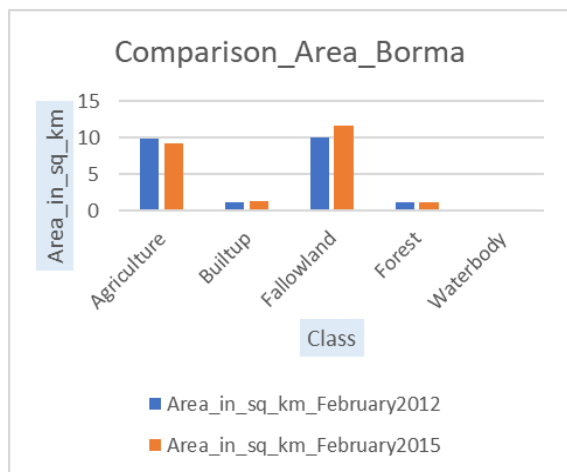


Figure 5 Change in the Area in Different Classes Understudy during February 2012 and February 2015

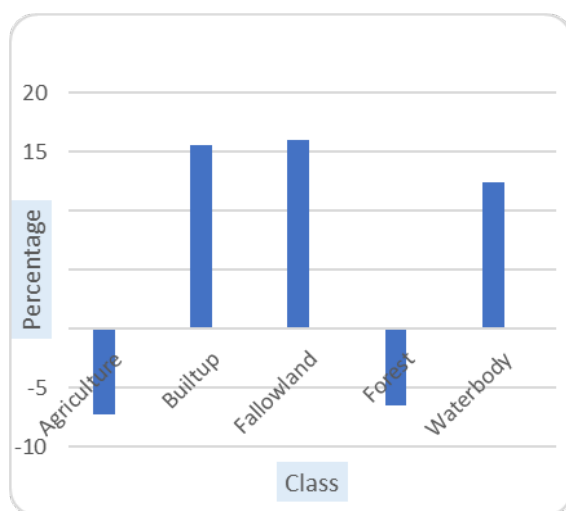


Figure 6 Percentage Change in Different Classes Understudy during February 2012 and February 2015

The change in LULC for different classes for Borma is demonstrated in Table 1, while the same is depicted in Figures 5 and 6 as a tabular representation with an absolute change (in area in km²) within different classes and percentage change within the same class during the three years, respectively. These reveal that Agriculture and fallow land were the primary classes. Agriculture witnessed a negative change of 7.21% during the years, while fallow land saw a 15.58% increase in area. The other vital classes, such as buildup and waterbody, experienced an increase of 15.58% and 12.41% increase, respectively, during the years, while forestland saw a decrease of 6.94% land area during the period.

The decrease in the area concerning agriculture, as validated by ground truth study and focused group discussion with farmers, was mainly attributed to the increase in the buildup area and fallow land. The rise in the village population, along with rising unemployment among the youth, has contributed to the increase in the buildup areas. Also, the increase in the value of the land has provided a thrust to the private agencies that divide the large chunk of land into smaller plots and offer it for sale.

3.2 LULC of Asanbani Village during January 2013 and January 2016

The LULC statistics of Asanbani village in Dumka district of Jharkhand for the years 2013 and 2016 are depicted in Figures 7 and 8.

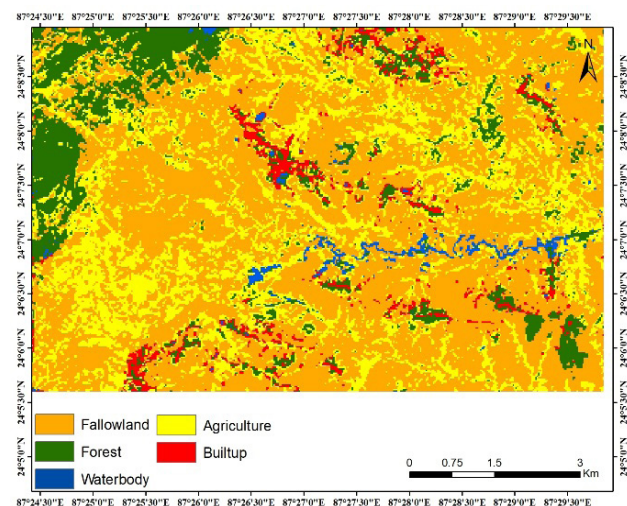


Figure 7 LULC Map of Asanbani Village during January 2013

Source: Generated from the LISS III Ortho satellite data, NRSC (2020), and Landsat data (USGS, 2020).

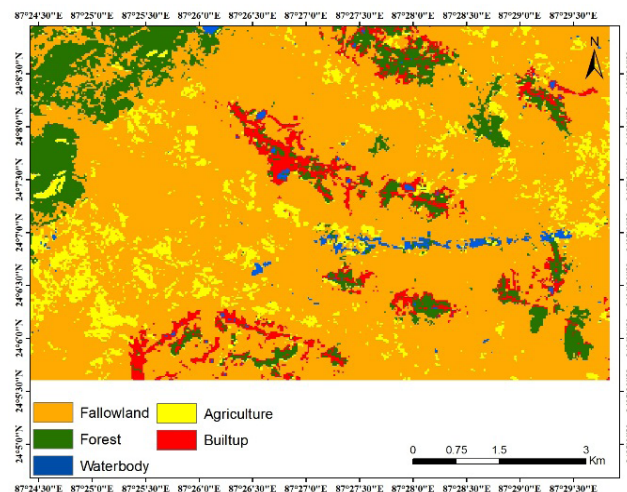


Figure 8 LULC Map of Asanbani Village during January 2016

Source: Generated from the LISS III Ortho satellite data, NRSC (2020), and Landsat data (USGS, 2020).

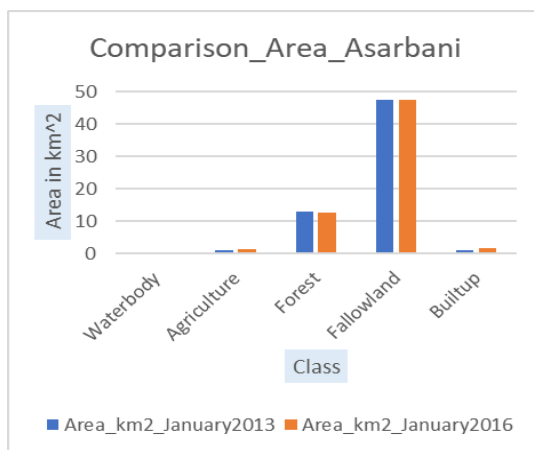
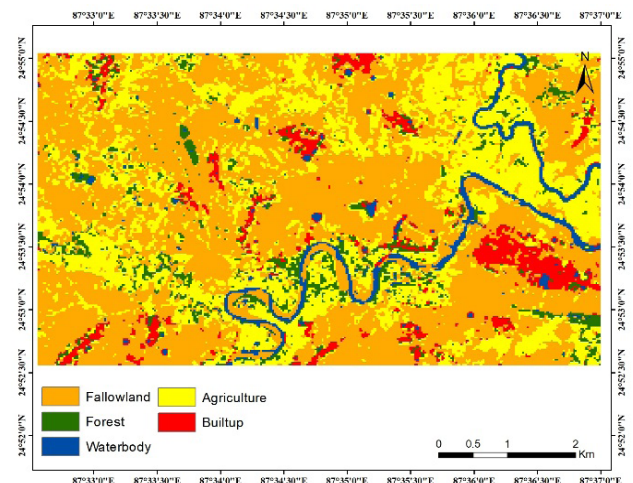
Figures 7 and 8 show the different classes of LULC used for the change detection study within a period of three years, from 2013 to 2016. The multi-temporal LULC mapping and change detection analysis were carried out for the study to categorize five distinct classes, which are fallow land, agriculture, forest, buildup area, and waterbody.

The change in LULC for different classes for Asanbani is demonstrated in Table 2, while the same is depicted in Figures 9 and 10 as a tabular representation with an absolute change (in area in km²) within different classes and percentage change within the same class during the three years, respectively, which reveal that fallow land and area under forest cover were the major classes. Fallow land witnessed a minor increase of 0.04% during the years, while the area under forest cover saw a decline of 3.66% area. The other essential classes, such as agriculture and water bodies, experienced an increase of 3.00% and 1.02%, respectively, during the years. The striking change was observed in the buildup area, which rose to 37.98% during the same period.

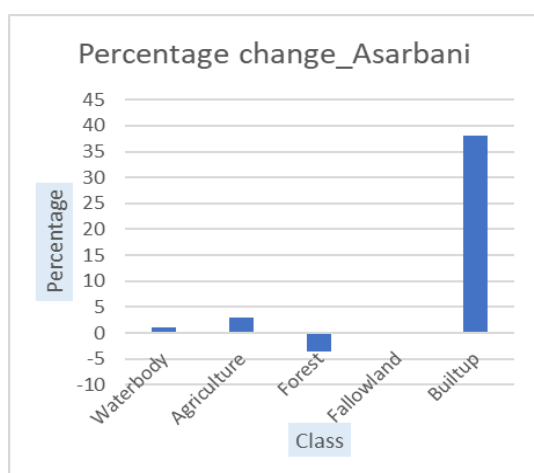
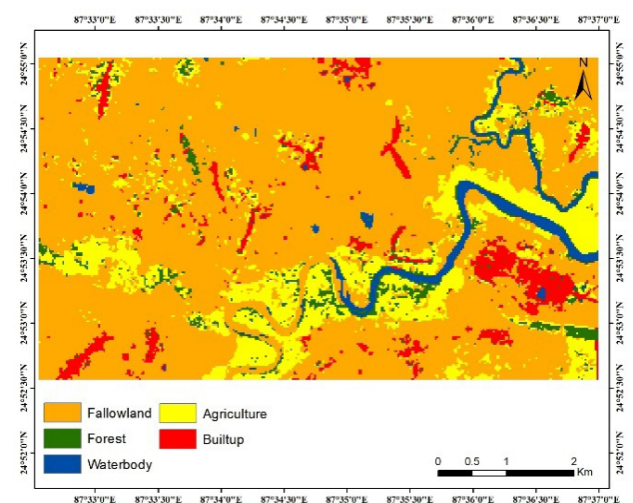
The increase in the buildup area, as validated by ground truth study and focused group discussion with farmers, was mainly attributed to the rise in governmental schemes operational in the village, resulting in the development of new schools along with a concrete washroom

Table 1 LULC Change for Different Classes in Borma Village (2012-2015)

Class	Area (km ²) in February 2012	Area (km ²) in February 2015	Change (in %)
Agriculture	9.9075	9.193125	-7.210446631
Builtup	1.179375	1.363125	15.58028617
Fallow Land	9.98	11.576875	16.0007515
Forest	1.17375	1.0975	-6.49627263
Waterbody	0.090625	0.101875	12.4137931

**Figure 9** Change in the Area in Different Classes Understudy during February 2012 and February 2015**Figure 11** LULC Map of Raksi Village during January 2012

Source: Generated from the LISS III Ortho satellite data, NRSC (2020).

**Figure 10** Percentage Change in Different Classes Understudy during February 2015 and February 2015**Figure 12** LULC Map of Raksi Village during January 2016

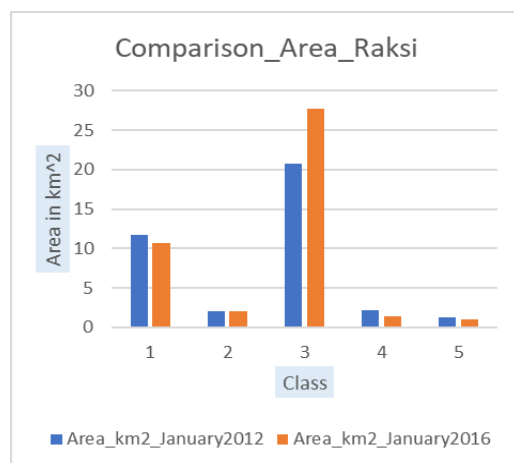
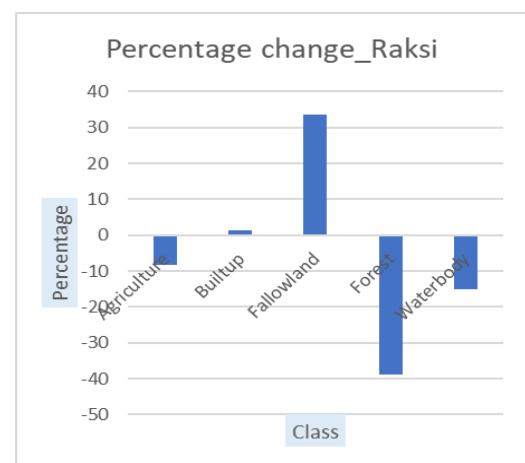
Source: Generated from the LISS III Ortho satellite data, NRSC (2020).

Table 2 LULC Change for Different Classes in Asanbani Village (2013-2016)

Class	Area (km ²) in January 2013	Area (km ²) in January 2016	Percentage Change
Waterbody	0.3519	0.3555	1.023017903
Agriculture	1.1385	1.1727	3.003952569
Forest	12.9672	12.492	-3.664630761
Fallow Land	47.4525	47.4759	0.04931247
Builtup	1.0899	1.5039	37.98513625

Table 3 LULC Change for Different Classes in Raksi Village (2012-2016)

Class	Area (km ²) in January 2012	Area (km ²) in January 2016	Percentage Change
Agriculture	11.69375	10.71602	-8.361133084
Builtup	2.03875	2.063125	1.19558553
Fallow Land	20.714375	27.685625	33.65416528
Forest	2.18125	1.334375	-38.8252149
Waterbody	1.206875	1.024375	-15.1216986

**Figure 13** Change in the Area in Different Classes Understudy during January 2012 and January 2016**Figure 14** Percentage Change in Different Classes Understudy during January 2012 and January 2016

in every house. Also, the village is primarily dependent on agriculture, along with fulfilling the labour requirements of the service sector. The proximity of the village to the district headquarters in Dumka (a distance of around 35 km) has resulted in the rapid development of the village, along with construction activities at a rapid pace. The value of land has prompted several farmers in the village to sell the plots as residential land. Asanbani is a very small village where the agricultural activities remained mostly constant during the three years, with almost all the farmers practicing similar cropping practices.

3.3 LULC of Raksi Village during January 2012 and January 2016

Figures 11 and 12 show the different classes of LULC used for the change detection study within a period of four years (from 2012 to 2016). The multi-temporal LULC mapping and change detection analysis were carried out for the study to categorize five distinct classes, which are fallow land, agriculture, forest, builtup area, and waterbody.

The change in LULC for different classes for Raksi is demonstrated in Table 3, while the same is depicted in Figures 13 and 14 as a tabular representation with an absolute change (in area in km²) within different classes and percentage change within the same class during the four years, respectively, which reveals that fallow land was the primary class. Fallow land witnessed a major increase of 33.65% during the years. The other essential categories, such as forest, waterbody, and agriculture, saw a decline of 38.82%, 15.12%, and 8.36%, respectively, during the years. The buildup area in the region experienced a nominal increase of 1.19% during the same period. The striking change was observed in the area under fallow land, which has risen to 33.65% during the same period.

The increase in fallow land area was validated by a ground truth study and a focus group discussion with farmers. The concern was mainly attributed to the lack of irrigation facilities during that year and the drying of the river stream. The river stream is the primary source of irrigation during the year 2016, which led to an increase in the fallow land in the village since the agricultural field could not be sown after the harvest of the Kharif crop. It could be authenticated by the decline of over 15% in the water bodies during the same period in the village. The forest cover has seen a significant decline during this period, since a lot of forested areas are either replanted or made suitable for growing cereal crops. The buildup area in the village has witnessed a slight increase with a rise of around 1% during 2012 and 2016.

The outcomes of the study bear relevance in the current times because such an exhaustive analysis has never been made for the villages under Agroclimatic Zone IV of Jharkhand. The results could be utilized in the implementation of various developmental programmes in the region for increasing the agricultural cover of the villages, livelihood upliftment, planning and monitoring of resources, and reducing the ill effects of climate change, etc. (Ahmad et al., 2018; Das et al., 2018; Ranjan & Parida, 2019). The three villages are mostly rainfed, so proper utilization of the water resources and planning for increasing the cropping intensity is desirable (Ahmad & Goparaju, 2017; Singh et al., 2018; Kayet et al., 2019). The long-term planning of the underdeveloped villages in the region could be instrumental in providing better livelihood security for the farmers.

3.4 Social Interpretation

In Borma, the 15.58% increase in builtup area and 7.21% decrease in agriculture are not merely spatial shifts. FDGs revealed that rising land values have prompted private agencies to subdivide large agricultural plots for residential sale, reflecting a shift from agrarian production to real estate speculation. In Asanbani, the 37.98% rise in builtup area is directly linked to state-led development schemes. Villagers identified the construction of new schools and government-mandated household sanitation units as the primary drivers of this concrete expansion, while in Raksi, the 33.65% increase in fallow land highlights climatic vulnerability. The drying of river streams (confirmed by a 15.12% decline in water bodies) has rendered post-Kharif cultivation impossible for tribal farmers, signifying a breakdown in local ecological security.

4. CONCLUSION

The research is situated within a Socio-Ecological Framework for Agrarian Change, providing a holistic approach that bridges the gap between technical remote sensing observations and the lived reality of tribal livelihood security. This framework is operationalized through three interconnected pillars: Drivers of Change, LULC transitions, and Vulnerability Outcomes. The Drivers of Change serve as the primary inputs, including demographic shifts such as rapid population growth, state-led developmental governance through various local schemes, and market-driven forces like rising land values that lead to private land subdivision. These drivers catalyze LULC transitions, which constitute the observed biophysical processes, notably the conversion of productive agricultural fields into builtup areas and the significant expansion of fallow land due to water stress and irrigation deficiencies. Ultimately, these physical shifts manifest as Vulnerability Outcomes, where agricultural vulnerability and ecological insecurity, evidenced by the depletion of forest cover and the drying of water bodies, directly threaten the sustenance and long-term security of tribal communities in the region.

The findings of this study highlight a critical transition in Jharkhand's rural landscape, where a long history of underdevelopment and a persistent "rainfed dependency" are being exacerbated by unmonitored land-use transitions. While GIS and GPS technologies have proven instrumental in assessing these spatio-temporal changes, the overarching trend reveals a concerning decline in agricultural area paired with a rapid expansion of builtup zones, a shift that threatens the long-term viability of the farming sector. To safeguard regional ecological security and align with global mandates like SDG 15 (Life on Land) and SDG 2 (Zero Hunger), policy interventions must move beyond technical monitoring toward active governance. Specifically, there is an urgent need to regulate land conversion by curbing the speculative subdivision of fertile agricultural plots, as seen in Borma, and to incentivize water harvesting infrastructure to mitigate the "fallow land surge" identified in villages like Raksi. Furthermore, extension interventions should be strategically aligned with the growing local interest in horticulture and cash crops to provide sustainable livelihood diversification. Although LULC maps alone cannot capture the full complexity of the region's socio-economic and demographic drivers, this study provides a foundational overview and scientific insights necessary for effective land reclamation and policy planning. By integrating these digital insights with localized decision-making, policymakers can better navigate the trade-offs between necessary infrastructure development and the preservation of tribal agricultural livelihoods.

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REFERENCES

- Ahmad, F., & Goparaju, L. (2017). Land evaluation in terms of agroforestry suitability: An approach to improve livelihood and reduce poverty using a FAO-based geospatial methodology—A case study of Palamu district, Jharkhand, India. *Ecological Questions*, 25, 67-84. <https://doi.org/10.12775/EQ.2017.006>
- Ahmad, F., Uddin, M. M., & Goparaju, L. (2018). An evaluation of vegetation health and the socioeconomic dimension of vulnerability of Jharkhand state of India under climate change scenarios: A geospatial approach. *Environmental & Socio-economic Studies*, 6(4), 39-47. <https://doi.org/10.2478/environ-2018-0026>
- Bera, S., & Prakash, A. (2018). Forest cover change analysis based on remote sensing and GIS of West Singhbhum District, Jharkhand. *International Journal of Research in Applied Science and Engineering Technology*, 6(5), 1039-1050.
- Das, P., Behera, M. D., Patidar, N., Sahoo, B., Tripathi, P., Behera, P. R., & Krishnamurthy, Y. V. N. (2018). Impact of LULC change on runoff, base flow, and evapotranspiration dynamics in eastern Indian river basins during 1985–2005 using a variable infiltration capacity

- approach. *Journal of Earth System Science*, 127(2), 1-19. <https://doi.org/10.1007/s12040-018-0921-8>
- Das, S., & Angadi, D. P. (2020). Land use–land cover (LULC) transformation and its relation with land surface temperature changes: A case study of Barrackpore subdivision, West Bengal, India. *Remote Sensing Applications: Society and Environment*, 19, 100322. <https://doi.org/10.1016/j.rsase.2020.100322>
- Ghosh, D., Karmakar, M., Banerjee, M., & Mandal, M. (2020). Evaluating the rate of change and predicting future spatial patterns using a Markov chain model: A study from Baghmundi CD Block of Purulia district, West Bengal. *Applied Geomatics*. <https://doi.org/10.1007/s12518-020-00345-0>
- GIS Cloud. (2020). Getting started with mobile data collection. <https://www.giscloud.com/blog/getting-started-with-mobile-data-collection/>
- Haque, M. I., & Basak, R. (2017). Land cover change detection using GIS and remote sensing techniques: A spatio-temporal study on Tanguar Haor, Sunamganj, Bangladesh. *The Egyptian Journal of Remote Sensing and Space Science*, 20(2), 251-263. <https://doi.org/10.1016/j.ejrs.2016.12.003>
- Kayet, N., Chakrabarty, A., Pathak, K., Sahoo, S., Mandal, S. P., Fatema, S., & Das, T. (2019). Spatiotemporal LULC change impacts on groundwater table in Jhargram, West Bengal, India. *Sustainable Water Resources Management*, 5(3), 1189-1200. <https://doi.org/10.1007/s40899-018-0294-9>
- Kumar, M. (2018). Impact of land use/cover and climate variability upon hydrological process of Usri watershed, Jharkhand, India, Doctoral dissertation, Sam Higginbottom University of Agriculture, Technology and Sciences.
- Kumar, R., Ehrar, O., & Mahto, D. K. (2018). Satellite image-based land use land cover change analysis of Ranchi District, Jharkhand. *SGVU Journal of Climate Change and Water*, 5, 1-10.
- Landis, J. R., & Koch, G. G. (1977). An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics*, 33, 363-374. <https://doi.org/10.2307/2529786>
- Mir, A. A., & Ahmed, P. (2014). Microwatershed level conservation strategies for effective land management in Haheom watershed, Kashmir Valley (J & K). In *Landscape Ecology and Water Management*, 341-352.
- Murmu, P., Kumar, M., Lal, D., Sonker, I., & Singh, S. K. (2019). Delineation of groundwater potential zones using geospatial techniques and analytical hierarchy process in Dumka district, Jharkhand, India. *Groundwater for Sustainable Development*, 9, 100239. <https://doi.org/10.1016/j.gsd.2019.100239>
- Nanda, A. M., Mir, A. A., Malik, I. A., Ahmed, P., & Kanth, T. A. (2017). Evaluation of land use/land cover dynamics in Rembiara watershed of Kashmir Valley (J & K). *International Journal of Emerging Technology and Advanced Engineering*, 7(8), 519-527.
- NRSC. (2020). Bhuvan NOEDA Data Products. <https://bhuvan-app1.nrsc.gov.in/2dresources/bhuvanstore.php>
- Parishwad, O., & Parishwad, M. (2017). Assessment of environmental impacts using spatio-temporal analysis of satellite imagery for coal mining in Jharkhand, India. In E. Sonavane (Ed.), *Proceedings of the International Conference on Recent Advances in Civil and Environmental Engineering*, 1-6.
- Ranjan, A. K., & Parida, B. R. (2019). Paddy acreage mapping and yield prediction using Sentinel-based optical and SAR data in Sahibganj district, Jharkhand (India). *Spatial Information Research*, 27(4), 399-410. <https://doi.org/10.1007/s41324-019-00246-4>
- Reddy, R. S., Babu, G. A., & Reddy, A. R. M. (2020). Geospatial approach for the analysis of forest cover change detection using machine learning. *Geosfera Indonesia*, 5(3), 335-351. <https://doi.org/10.19184/geosi.v5i3.20157>
- Roy, A., & Inamdar, A. B. (2019). Multi-temporal land use land cover (LULC) change analysis of a dry semi-arid river basin in western India following a robust multi-sensor satellite image calibration strategy. *Heliyon*, 5(4), e01478. <https://doi.org/10.1016/j.heliyon.2019.e01478>
- Saleem, A., Corner, R., & Awange, J. (2018). On the possibility of using CORONA and Landsat data for evaluating and mapping long-term LULC: A case study of Iraqi Kurdistan. *Applied Geography*, 90, 145-154. <https://doi.org/10.1016/j.apgeog.2017.12.007>
- Singh, R. K., Singha, M., Singh, S. K., Debyeet, P., Tripathi, N., & Singh, R. S. (2018). Land use/land cover change detection analysis using remote sensing and GIS of Dhanbad district, India. *Eurasian Journal of Forest Science*, 6(2), 1-12. <https://doi.org/10.31195/ejejfs.428381>
- Sood, K., Singh, S., Rana, R. S., Rana, A., Kalia, V., & Kaushal, A. (2015). Application of GIS in precision agriculture. In *Proceedings of the National Seminar on Precision Farming Technologies for High Himalayas*, 4-5.
- Tiwari, K., & Khanduri, K. (2011). Land use/land cover change detection in Doon Valley (Dehradun Tehsil), Uttarakhand using GIS and remote sensing techniques. *International Journal of Geomatics and Geosciences*, 2(1), 34-41.
- U.S. Geological Survey. (2020). EarthExplorer. <https://earthexplorer.usgs.gov/>
- Wilkie, D. S., Finn, J. T., & Finn, J. (1996). Remote sensing imagery for natural resources monitoring: A guide for first-time users. Columbia University Press.
- Yisa, J., Olubadewo-Joshua, O., & Okosun, O. S. (2019). Utilization of GIS techniques as a decision support system for location of filling stations in Minna, Niger State, Nigeria. *Geosfera Indonesia*, 4(3), 247-263. <https://doi.org/10.19184/geosi.v4i3.9713>