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APPLICATION OF REMOTE SENSING & GEOGRAPHIC INFORMATION SYSTEM IN FOREST CHANGE DETECTION OF SIMILIPAL BIOSPHERE RESERVE

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ABSTRACT

Rapid urbanization and population growth have altered land use and land cover in the Similipal Biosphere Reserve, impacting crucial activities such as tasar sericulture. Understanding and quantifying the spatio-temporal dynamics of these changes and their driving factors is essential for developing effective policies and monitoring mechanisms to support tasar sericulture alongside urban growth. This study aimed to analyze land use and land cover changes in the Similipal Biosphere Reserve using geospatial technology and land use change modelling. We obtained and pre-processed satellite data from Landsat-ETM+, Landsat 4 (MSS), and Landsat TM using ArcGIS. We used the generated land cover maps with the Land Change Modeller to quantify land use and land cover changes and examine transitions between land cover classes. Our results showed a significant increase in the area of Sal dense forest over the last 15 years, from 18.82% in 1985 to 67.63% in 2005, which is beneficial for tasar silk production as Sal trees are crucial for rearing tasar silkworms. Conversely, cropland decreased from 44.24% in 1985 to 16.00% in 2005, and water bodies slightly decreased from 1.31% in 1985 to 1.10% in 2005. Mixed forest increased from 1.90% in 1985 to 7.23% in 2005. To support tasar sericulture and sustainable land management, we recommend special attention to wise land resource use and management practices, secure land possession systems, regulated population growth, and integrated environmental rehabilitation programs.
Keywords: Landsat- ETM, Landsat-4 MSS, Geospatial Technology, Land Use Change Modelling.

Introduction

The terms "Forest Area" and "Forest Cover" often cause confusion due to their distinct definitions. "Forest Area" refers to geographic regions documented as forests in government records, predominantly including Reserved Forests (RF) and Protected Forests (PF), established under the Indian Forest Act of 1927. Additionally, forest areas encompass regions recorded as forests in revenue records or constituted as such under any state act or local laws. Conversely, "Forest Cover," as used in the State Forest Report (SFR), denotes all lands exceeding one hectare in size with a tree canopy density of more than 10%. While "forest area" describes the legal status of land according to government records, "forest cover" indicates the actual presence of trees on any land. Forests play a crucial role in shaping the composition and character of the land surface. Vegetation cover information serves as an indirect indicator of land use and is highly relevant for environmental studies. Forests are essential for life, providing habitat for millions of species, protecting the soil from erosion, producing oxygen, storing carbon dioxide, and regulating climate. They also supply food, shelter, medications, and numerous other resources vital for human survival. Forests purify the air we breathe and the water we drink. Mapping landscape processes such as vegetation, land use/land cover, soil surveys, and geological mapping traditionally relies on hierarchical systems. Diagnostic features or measures are selected based on the survey's aim, with the required data varying accordingly. Various methods exist to identify changes in the earth's surface, treating environmental variables as patterns occurring at specific scales.

Recent research has continued to emphasize the importance of forest monitoring and management, especially with the advent of advanced technologies like Geographic Information Systems (GIS) and remote sensing. These tools have gained significant recognition for their role in mapping natural resources and environmental modeling (FAO, 2020). Satellite data offer advantages such as synoptic coverage, data consistency, global reach, readability, precision, and maximum accuracy (Global Forest Watch, 2023). Remote sensing and GIS are powerful tools for environmental monitoring, helping to assess the spatiotemporal distribution of land use/land cover (LULC) and ecological connectivity (Global Forests Report, 2023). Verburg *et al*. (2002) categorized the causes of land use and land cover change into direct (proximate) and indirect (underlying) factors. The use of GIS and remotely sensed data for mapping forest cover change and urban development is increasingly attracting attention among professionals. Monitoring LULC changes has been a popular research topic among geoscientists, aiming to define optimal techniques for natural resource management and environmental change monitoring (Malaviya *et al*., 2010; Anil *et al*., 2011). The potential of remote sensing and GIS in forestry has been established over many years through the use of aerial photos and satellite image interpretations in forest cover change detection analysis, cover map generation, and inventory analysis. Multi-temporal data facilitate change detection analyses, allowing remote sensing to bring together numerous tools for a better understanding of deforestation's scope and rate. Comparing images from earlier years with recent scenes enables the measurement of changes in forest cover size and extent (Forest Pulse, 2023).

Odisha, located in the eastern region of India, spans approximately 155,707 km² with a population density of 269 individuals per km² (Chandramouli and General, 2011). The state lies between 17°49' and 22°34' North latitude and 81°27' and 87°29' East longitude, bordered by Jharkhand, Andhra Pradesh, West Bengal, and Chhattisgarh (Figure 1). According to the Köppen Climate Classification (Koppen, 1936), Odisha has a "Aw" (Tropical Savanna Climate), with an average annual rainfall of around 1,500 mm. The temperature ranges from 15°C to 35°C in winter and 30°C to 45°C in summer. The average elevation is about 600 meters above sea level, with higher altitudes in the western parts compared to the eastern parts (Topography | Government of Odisha). Odisha is renowned for its rich biodiversity, hosting a variety of unique flora and fauna. The region's tropical deciduous forests include tree species such as Sal, Teak, and Bamboo, and its mangrove forests provide critical habitats for species like the endangered saltwater crocodile. Odisha's fauna includes iconic species such as the Bengal tiger and Indian elephant, along with over 400 bird species (Odisha Tourism: Forest & Wildlife).

In the Similipal Biosphere Reserve, Sal species dominate the landscape. The tropical monsoon climate fosters a unique biodiversity, with 1,076 species of vascular plants, including 93 species of orchids, 300 species of medicinal plants, and 52 species of endangered flora. Notable endemic orchid species include *Eria meghasaniensis* and *Tainia hookeriana*. Other significant flora species are *Callicarpa arborea* (beautyberry), *Bombax ceiba* (cotton tree), and *Madhuca longifolia* (mahua). The biosphere reserve is home to 42 mammal species, 264 bird species, 39 reptile species, and 12 amphibian species, with approximately 52 fauna species considered at high risk. *Paradoxus jorandensis* is a valuable endemic fauna species found in the area. Additionally, the reserve hosts the Royal Bengal Tiger (*Panthera tigris*) and the Asiatic Elephant (*Elephas maximus*).

In the context of tasar sericulture, which relies heavily on Sal trees for rearing tasar silkworms, understanding forest cover dynamics is crucial. Sal trees are essential for the tasar sericulture industry, and the expansion of these forests aligns with global efforts to enhance forest cover for ecological and economic benefits. Ongoing advancements in geospatial technology and comprehensive monitoring of forest cover changes are vital for supporting sustainable practices in tasar sericulture. Policymakers and stakeholders must prioritize these technologies to ensure the resilience of both natural ecosystems and dependent livelihoods.

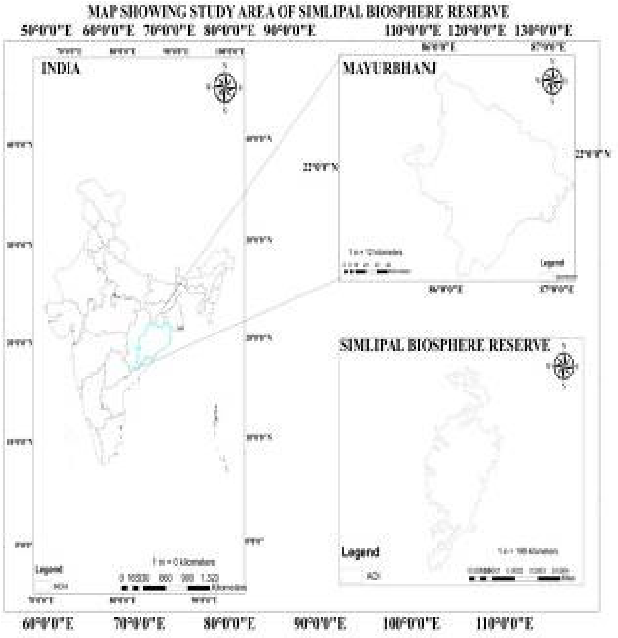


Fig. 1: Location map of the Study Area

Material and Methods

Data Collection and Preparation

To identify successive forest cover changes, we collected satellite imagery and ancillary data. The satellite images used in this study were from Landsat ETM+, Landsat 4 (MSS), and Landsat TM. Additionally, topographic maps from the Open Series at a scale of 1:50,000 were procured from the Survey of India. The Area of Interest (AOI) was generated using collateral or ancillary data, specifically a block-level map of the Similipal Biosphere Reserve, our study area.

Ground Truthing

Google Earth, along with ground truthing, played a crucial role in ground assessment and verification. The primary data required for the study was extracted from satellite images. Specific topographic sheet maps (map numbers 73G14, 73J4, 73J7, 73J8, 73J12, 73K2, 73K3, 73K5, 73K6) at a scale of 1:50,000 were obtained from the Survey of India (SOI). Drainage networks, road networks, railway networks, and specific locations were manually digitized and geo-referenced according to WGS 1984 UTM ZONE 45N.

Methodological Framework

Figure 2 illustrates the methodological flow chart used in this study, detailing the procedures, methods, and steps to achieve the main aim of mapping vegetation cover changes in the Similipal Biosphere Reserve over 15 years, from 1985 to 2005.

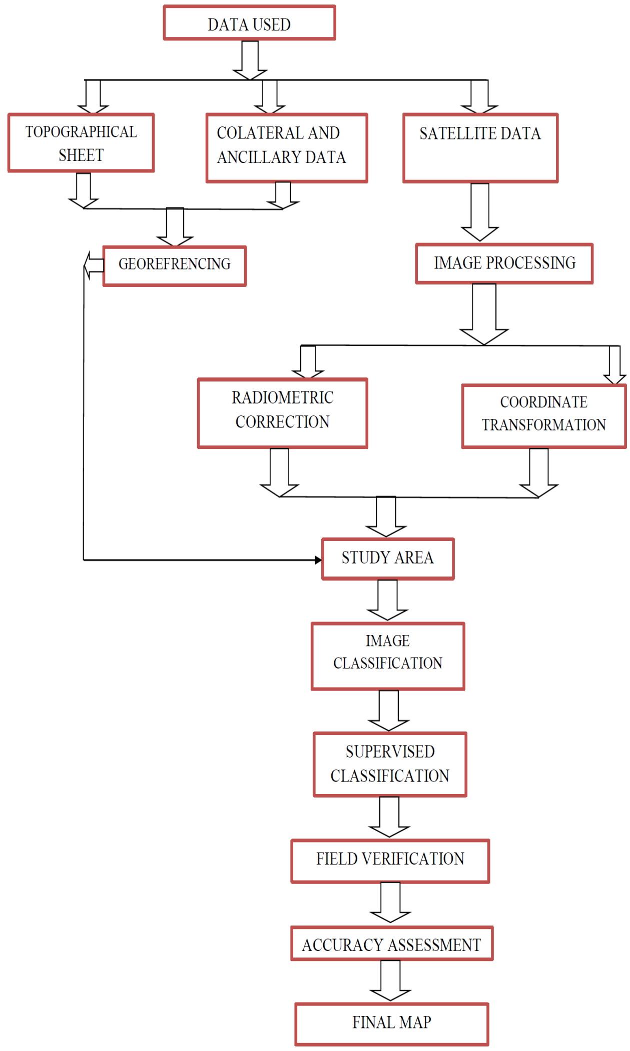


Fig. 2: Flow Chart of Methodology

Image Processing

The satellite images were downloaded from the Global Land Cover Facility of the University of Maryland (GLCF, 2013) and the United States Geological Survey (USGS). These images were spatially referenced using the Universal Transverse Mercator (UTM) projection with the World Geodetic System (WGS) 1984 UTM datum. The data sets were imported into ERDAS Imagine (Leica Geosystems, Atlanta, U.S.A.), a satellite image processing software, to create a false color composite (FCC). The layer stack option in the image interpreter toolbox was used to generate FCCs for the study areas.

Subsetting and Pre-Processing

Subsetting of satellite images was performed to extract the study area from both images by taking a geo-referenced outline boundary. The collected images were pre-processed through radiometric and geometric corrections. Radiometric corrections involved adjusting the data for sensor irregularities and unwanted sensor or atmospheric noise, ensuring the data accurately represented the reflected or emitted radiation measured by the sensor.

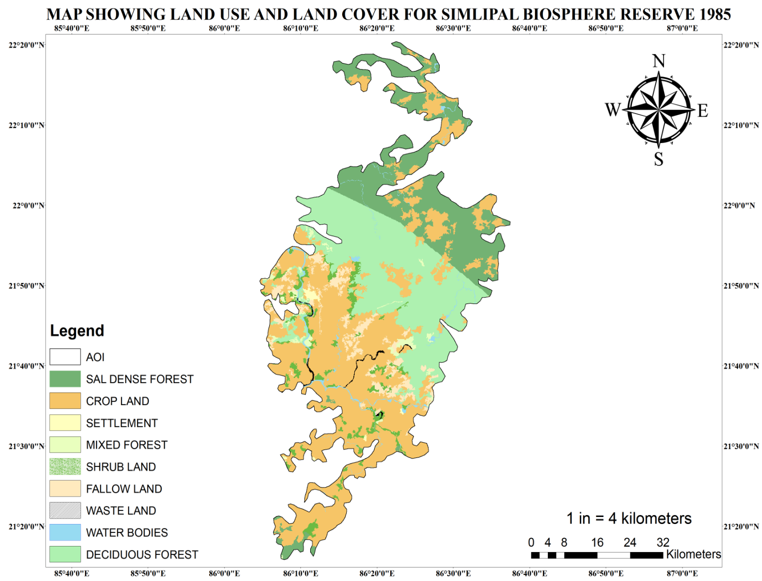
Image Enhancement and Transformation

Image enhancement aimed to improve the appearance of the imagery for better visual interpretation and analysis. Contrast stretching was performed to increase the tonal distinction between various features in a scene. Spatial filtering was used to enhance or suppress specific spatial patterns in an image. Arithmetic operations (subtraction, addition, multiplication, division) were performed to combine and transform the original bands into "new" images, which better displayed or highlighted certain features in the scene. These pre-processing, enhancement, and transformation operations were conducted using ERDAS IMAGINE.

Results and Discussion

Land Use and Land Cover (LU/LC) of Similipal Biosphere Reserve in 1985

The supervised classification of the 1985 LU/LC map identified nine distinct land cover classes within the Similipal Biosphere Reserve (Figure 3). The cropland area occupied the highest percentage, covering 124.680 square kilometers, which constitutes 44.24% of the total area. This land cover type was scattered throughout the study area. Deciduous forest followed, covering 83.539 square kilometers (29.64%), primarily located on the western side. Sal dense forest was the next significant class, occupying 51.067 square kilometers (18.12%), mainly in the northwestern part. Other land cover classes included fallow land (11.20 square kilometers, 3.97%), shrub land (8.41 square kilometers, 2.98%), and mixed forest (3.364 square kilometers, 1.90%). Water bodies, which include rivers and surface water, covered approximately 3.7 square kilometers (1.31%).



Serial No	Feature Class	Area Sq_Km	%
1	Sal Dense Forest	51.067 Sq_Km	18.12%
2	Crop Land	124.680 Sq_Km	44.24%
3	Settlement	1.24 Sq_Km	0.44%
4	Mixed Forest	5.364 Sq_Km	1.90%
5	Shrub Land	8.41Sq_Km	2.98%
6	Fallow Land	11.20 Sq_Km	3.97%
7	Waste Land	1.01Sq_Km	0.35%
8	Water bodies	3.7 Sq_Km	1.31%
9	Deciduous forest	83.539 Sq_Km	29.64%
TOTAL		281.8 Sq km	100%

Fig. 3: LU/LC classification of Similipal Biosphere Reserve in 1985

Land Use and Land Cover (LU/LC) of Similipal Biosphere Reserve in 1995

By 1995, the LU/LC map identified the same nine land cover classes with some noticeable changes (Figure 4). Cropland remained the largest class, but its area reduced to 120.895 square kilometers (42.89%). Deciduous forest also decreased, covering 77.257 square kilometers (27.41%), spread across the east-west direction. Sal dense forest slightly expanded to 53.077 square kilometers (18.83%), mainly in the northeastern part. Fallow land and shrubland increased to 11.815 square kilometers (4.19%) and 10.218 square kilometers (3.62%), respectively. Mixed forest remained stable at 3.364 square kilometers (1.19%). Water bodies occupied 3.461 square kilometers (1.22%).

Serial No	Feature Class	Area Sq_Km	%
1	Sal Dense Forest	53.077 Sq km	18.83%
2	Crop Land	120.895 Sq km	42.89%
3	Settlement	0.961 Sq km	0.34%
4	Mixed Forest	3.364 Sq km	1.19%
5	Shrub Land	10.218 Sq km	3.62%
6	Fallow Land	11.815 Sq km	4.19%
7	Waste Land	0.82 Sq km	0.29%
8	Water bodies	3.461 Sq km	1.22%
9	Deciduous Forest	77.257 Sq km	27.41%
TOTAL		281.8 Sq km	100%

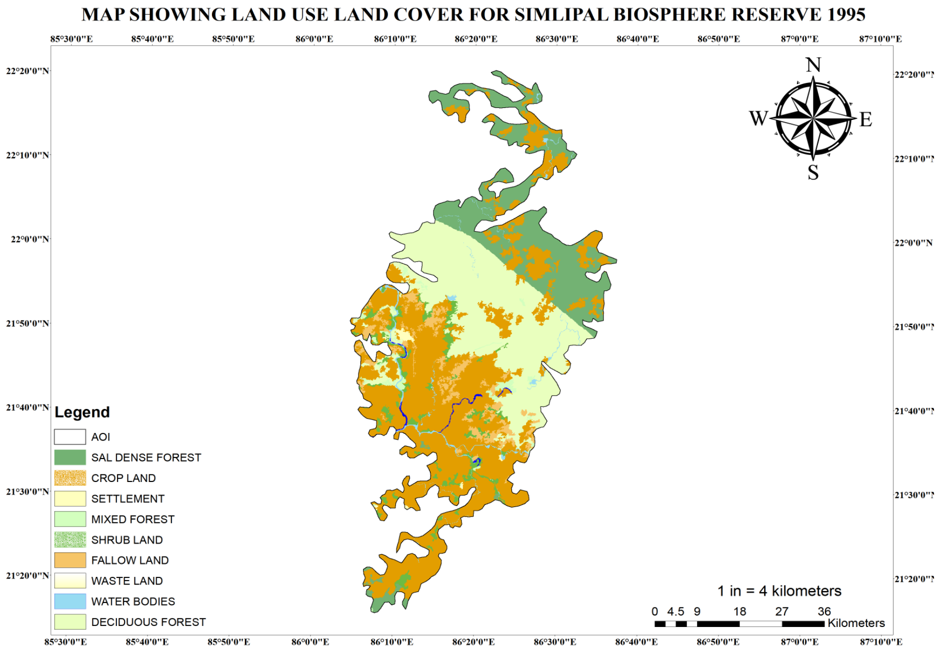


Fig. 4: LU/LC classification of Similipal Biosphere Reserve in 1995

Land Use and Land Cover (LU/LC) of Similipal Biosphere Reserve in 2005

The 2005 LU/LC map showed a significant transformation in land cover classes (Figure 5). Sal dense forest dramatically increased to 190.6 square kilometers, making up 67.63% of the total area, indicating a significant shift towards denser forest cover. This change is notable given the global emphasis on forest conservation and reforestation efforts (Rong & Fu, 2023). Conversely, cropland reduced substantially to 45.1 square kilometers (16.00%), reflecting a global trend of urban expansion and reduced agricultural land (Uddin *et al.*, 2023). Mixed forest area increased to 20.4 square kilometers (7.23%). The area of shrub land remained relatively stable at 10.1 square kilometers (3.58%), while barren land emerged as a new category, covering 8.6 square kilometers (3.05%).

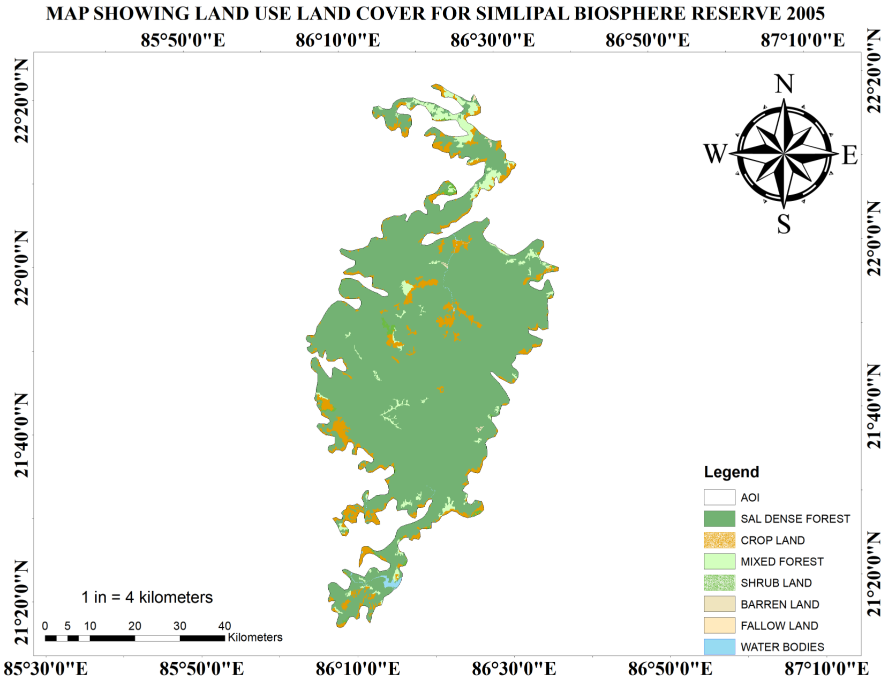


Fig. 5: .LU/LC classification of Similipal Biosphere Reserve in 2005

Serial No	Feature Class	Area Sq_Km	%
1	Sal Dense Forest	190.6 Sq Km	67.63%
2	Crop Land	45.1 Sq Km	16.00%
3	Mixed Forest	20.4 Sq Km	7.23%
4	Shrub Land	10.1 Sq Km	3.58%
5	Barren Land	8.6 Sq Km	3.05%
6	Fallow Land	3.9 Sq Km	1.38%
7	Water bodies	3.1 Sq Km	1.10%
TOTAL		281.8 Sq km	100%

The observed LU/LC changes from 1985 to 2005 in the Similipal Biosphere Reserve highlight the dynamic nature of land cover transformations influenced by both natural processes and anthropogenic activities. The significant increase in Sal dense forest area suggests successful reforestation or natural forest regeneration, which aligns with global trends towards enhancing forest cover to combat climate change and biodiversity loss (Rong & Fu, 2023). The reduction in cropland area over the same period is indicative of urbanization pressures, a pattern observed worldwide where agricultural lands are often converted for urban development (Uddin *et al.*, 2023). This shift has profound implications for local ecosystems, food security, and socio-economic conditions.

The stability in mixed forest and shrubland areas, along with the emergence of barren land, underscores the importance of continuous monitoring and sustainable land management practices. These changes necessitate adaptive management strategies to balance development needs with environmental conservation. In conclusion, the LU/LC changes in the Similipal Biosphere Reserve over the past two decades reflect broader global environmental trends. Policymakers must prioritize sustainable land use practices, secure land tenure systems, and implement integrated environmental rehabilitation programs to mitigate adverse impacts and promote ecological resilience.

Conclusion

This study highlights the significant land use and land cover (LU/LC) changes in the Similipal Biosphere Reserve over a period of 20 years, from 1985 to 2005. Using geospatial technology and land use change modeling, we observed substantial transformations influenced by both natural processes and anthropogenic activities. These changes have profound implications for tasar sericulture, a critical activity in the region. The increase in Sal dense forests is a positive development for tasar sericulture, providing a more robust environment for silk production. However, the reduction in cropland and the emergence of barren land require integrated land management practices to ensure sustainable development. Ensuring secure land tenure systems and implementing effective environmental rehabilitation programs are crucial for supporting tasar sericulture and maintaining ecological balance. It was observed that the LU/LC changes in the Similipal Biosphere Reserve over the past two decades reflect broader global environmental trends. Policymakers must prioritize sustainable practices and integrated management strategies to ensure the long-term health of the biosphere reserve and the livelihoods it supports.

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