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ORIGINAL RESEARCH PAPER

Application of GIS and Remote Sensing Techniques for Detection and Analysis of Spatio-Temporal Changes in Land Use and Land Cover in Rampurhat Block-II, Birbhum, Eastern India

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A R T I C l E I N F O

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A B S T R A C T

The terrestrial surface of the earth constitutes a finite portion of the biosphere, referred to as "land," that encompasses a complex array of attributes immediately above or below the surface, including the near-surface climate, soil and terrain typology, surface hydrology (such as shallow lakes, rivers, marshes, and swamps), near-surface sedimentary formations and associated groundwater reserves, vegetation and faunal populations, human settlement patterns, and physical evidence of past and current human activities (FAO, 1995, p. 6). It is well acknowledged that land serves as the foundation upon which human civilization has been constructed and flourished, as it is the most elementary resource of human society. However, the quantifiable amount of land available is unalterable, thus necessitating the judicious and scientifically informed utilization of this precious resource for the preservation of human existence. In light of this, the examination of land use patterns assumes paramount importance for resource planning, cultural development, and regional or national economic growth. The present study endeavours to analyse the trend of land use and land cover changes in the Rampurhat CD Block -II from 2000 to 2020, a crucial task in view of the current global scenario of changing land use patterns.

Introduction

Understanding what change implies in the analysis of land use and land cover change is first necessary in order to recognize change in real-world situations. At its most basic level, land use and land cover change relate to quantifiable adjustments to the geographical extent (increases or decreases) of a certain kind of land use or land cover, respectively. It is important to keep in mind that, even at this level, the capacity to detect and measure change depends on the geographic scale; the more information that is available at the spatial scale, the more changes in the spatial extent of land use and land cover that can be monitored and recorded.

However, when it comes to both land use and land cover, the definition and conceptualization of change are considerably broader. In the context of shifting land cover, the associated literature makes a distinction between two types of change: conversion and modification. Land cover conversion is the process of switching from one type of cover to another. Land cover alteration involves altering the structure or function without completely switching from one type to another; examples include productivity, biomass, or phenology changes (Skole

1994, 438). In other words, the land cover, or distribution of plant, water, soil, and other physical features on Earth's surface, determines the surface's physical qualities. Land use is the term used to describe how people and their habitats use the land. The terms "land use" and "land cover," despite the fact that land use is often inferred from the cover, are interchangeable because of their close association. Land use/cover and its dynamics have a substantial impact on the conditions and functioning of ecosystems. The dynamics of land use and land cover have profoundly changed the biogeochemical cycle, which in turn has had an impact on changes in surface atmospheric energy exchanges, carbon and water cycling, soil quality, biodiversity, the ability of biological systems to meet human needs, and ultimately the climate at all scales. As a result of growing urbanization, land use patterns have experienced major changes. The region might be harmed by urban sprawl if current residential zones are expanded (Tore et al., 2014; Nanda and Yeh, 2014; Hosseini et al., 2010).

The geology, lithology, and soil characteristics of this research region are strongly related to its economic foundation. Land resources are directly tied to agricultural and extractive operations. Therefore, good utilization of these qualities is necessary for the region's growth. The study offers a broader perspective on how the LULC has changed over time. The study may give micro level data on land use dynamics and other applicable programmes for future planning. This research also identifies issues with people's perspectives on land usage and the issues those individuals are having.

Review of Literature

Some of the key elements of the work or review of the literature includes agricultural land use; models of land use and land cover change, use of remote sensing and geographic information system (RS & GIS), regional development and disparity, and other statistical methodologies. Numerous books, papers, journals, and other publications have made extensive use of information pertaining to the author's study area. Here is a quick summary of what a literature review entails.

RS &GIS TECHNIQUES: In the field of land study, Remote Sensing (RS) and Geographic Information Systems (GIS) techniques offer numerous applications. One of the key applications is the utilization of land cover satellite imagery to examine temporal and geographical changes in land use. The Digital Elevation Model (DEM) provides valuable information, including surface elevation data, relief characteristics, and three-dimensional representations of the studied region. This information enables the assessment of terrain and is widely used by researchers for identifying geomorphic features such as landform, relief, slope, drainage pattern, contour, etc. (Chatterjee, 1982).

However, the use of DEM also presents some limitations, including the choice of the base level (Xinjian, 2002). Despite this, researchers such as Sinha et al., 2000; Engelsman, 2002, Martinez et al., 2009; Chatterjee & Thakur, 1982 have utilized DEM to determine surface water potential zones, flood proneness, and other geospatial features. In addition to DEM, maps of Land Use and Land Cover (LULC), Land Surface Temperatures (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NWDI), and other data were prepared using Landsat-8 (Category-1) and LISS-3 data.

The author of the research paper also collected satellite imagery and topographical sheets (72P/12) to identify changes in land use. In conclusion, RS and GIS techniques provide a wealth of information that enables the examination of geographical and temporal changes in land use, and the identification of geospatial features.

AGRICULTURE: The edifice of the Indian economy is founded upon agriculture, a vocation held in high esteem since the inception of civilization in India. In the fiscal years 2008-2009, agriculture constituted a contribution of 15.7% to India's Gross Domestic Product (GDP). The realm of agricultural research has been the subject of numerous projects in various regions of India, encompassing a diverse array of objectives and perspectives, such as agriculture in conjunction with agro-industrial advancement, agriculture intertwined with micro-financial development, alterations in Land Use and Land Cover (LULC) and its ramifications on agriculture, and additional research endeavors (More, 1980; Mishra, 1987; Rajasekharan, 2000; Aherwkar, 1967). The forecasting of crop yields can be achieved through several methods including, but not limited to, the cropping pattern (percentage of arable land utilized for different crops during a designated time frame), crop combination, and relative yield index as noted by Sing and Dhellon, 1984; Huasain, 1996.

LAND USE LAND COVER MODEL: The Land Use Land Cover Model constitutes a pivotal mechanism for monitoring and documenting long-term environmental transformations. The stewardship of land resources is inextricably linked to the Land Use

Land Cover (LULC) paradigm, which represents the quintessentially elemental and conspicuous features of the earth's surface that serve as a barometer for human-induced perturbations. As such, alterations in land use and land cover are paramount for geoscientific investigation and hold a seminal significance within the context of geoscience research (Wenlong Li, 2020).

LAND RESOURCE MANAGEMENT IN NATIONAL CONTEXT: A comprehensive understanding of Land Resource Management within a National Context is imperative. In 1940, S. Chatterjee embarked on an investigation of land usage in India.

Under the auspices of S.P. Chatterjee, a comprehensive survey of land use was executed in the districts of 24 Parganas and Howrah (Chatterjee, S.P., 1945, 1952). The results of this survey revealed the impact of soil, climate, and other non-physical factors on the utilization of land for various purposes such as agriculture, commerce, transportation, population pressure, and other land uses (Shafi, 1960) undertook a systematic examination of land use and management in western Uttar Pradesh, laying a robust foundation for future land use surveys that would encompass an assessment of both land capacity and sustainability (Shafi, 1960).

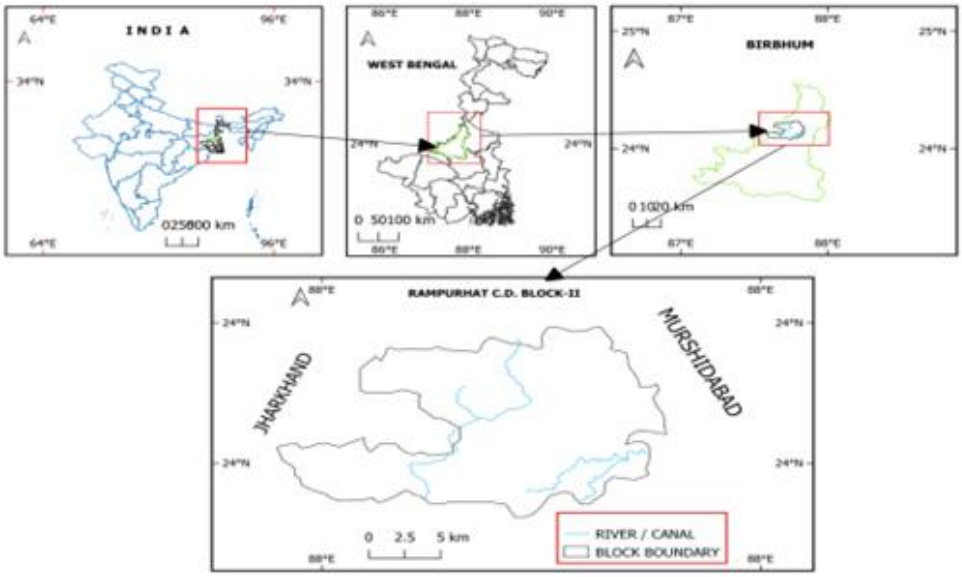

Figure 1. Study area map

Material and Methods

STUDY AREA

The Rampurhat II Community Development Block represents a crucial administrative constituent within the Rampurhat subdivision in the Birbhum district of the Indian state of West Bengal. This CD Block is an integral part of theBrahmani-Mayurakshi Basin, one of the Four sub-micro physiographic regions positioned between the north-flowing Brahmani River and the south-flowing Mayurakshi River. The Rampurhat II CD Block is circumscribed by the Rampurhat I CD Block to the west, the Nalhati I and Nalhati II CD Blocks to the north, the Nabagram and Khargram CD Blocks in the Murshidabad district to the east, and the Mayureswar I CD Block to the south. With a total area of 185.55 sqkm, the Rampurhat II CD Block encompasses 94 mouzas, 9gram panchayats, 95gram sansads, and 1 panchayat samity, and comprises of 91 inhabited villages. Law enforcement services within this CD Block are administered by the Margram and Tarapith police stations, and the primary administrative center is located in Margram. The gram panchayats/panchayat samiti of the Rampurhat II block are comprised of the following entities: Bishnupur, Budhigram, Dunigram, Hansan- I, Hansan- II, Kaluha, Margram- I, Margram- II, and Sahapur.

DATA USED: During this stage, we use a 1:50,000 topographical map (72p/12) to prepare the base map of the study area, and then we collect various satellite images from various sources (USGS-Earth Explorer, Bhuvan by ISRO). Mainly, we use the Linear Imaging Self-Scanning Sensor (LISS-III) for supervised image classification, the normalized difference vegetation index (NDVI), the soil adjusted vegetation index (SAVI), etc.

LAND USE LAND COVER CLASSIFICATION: Based on National Land Utilization and Land Cover Classifications, the following table (Table 1) shows several LU/LC classifications (Broad category).

Table 1. Description of Land Use Units of land cover

SL no.	LU/LC Category	Description
1	Water Bodies	River, Canal, Stream,
2	Vegetation	Forest, Degraded Forest, Plantation,
3	Crop Land	Mono crop land, Double or Multi crop land
4	Built-up Area	Settlement, Transport
5	Open Land	Cultivable waste, Stony waste

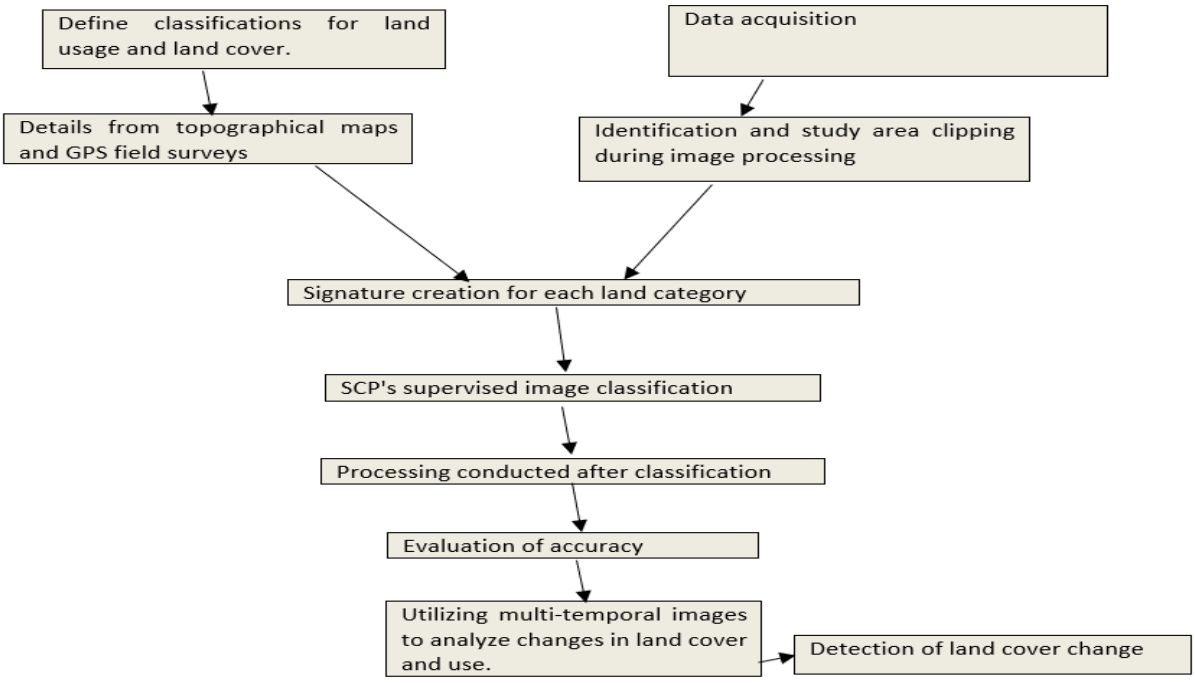

Figure 2. Methodology flow chart

Results and Discussion

In this subsection, the author makes an effort to evaluate the patterns of land use and land coverage in the study region for the years 2000 and 2020. Table 2 shows that we separated LU/LC into 5 macro classes. Author created the map (Figure 2) using quantum geographic information systems and semi-automatic classification supervised plugging. Water bodies, vegetation, crop land, built-up areas, open land, and other land uses are now grouped into thirteen sub-categories under five primary categories. The author has classified the current LULC in this section using the "National land use categorization system." We'll look at how land usage and land cover have changed over time from 2000 to 2020 in this section.

CROP LAND: The agricultural activities dominate the Indian subcontinent, and CD Block Rampurhat II is no exception. On the basis of their manner of production, the entire research region is classified into two major categories: double crop land and mono crop land. Agricultural land or Crop Land

occupies approx 33.02 square kilometers, or 18.19percent of the overall study area. CD Block Rampurhat II also has both irrigated and rain-fed farming methods.

BUILT-UP AREA: Built-up areas are defined as a location where a large portion of the land is covered by a building structure and is used for human habitation or living dwelling space. Towns, villages, hamlets, and linear settlements developed along roads, transportation, power, and communication infrastructure, and areas occupied by retail centers, mills, industrial commercial complexes, and other educational and health institutions, fall under this category of land use. This unit takes up 20.10 percent of the study's overall area, which is approximately 36.49 square kilometers.

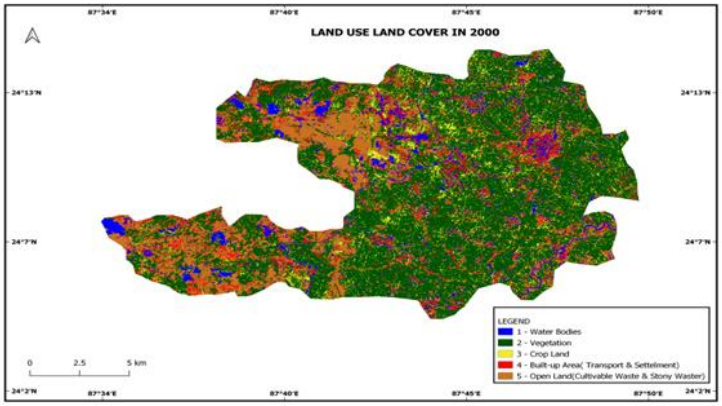

Figure 3. Land use Land cover in 2000

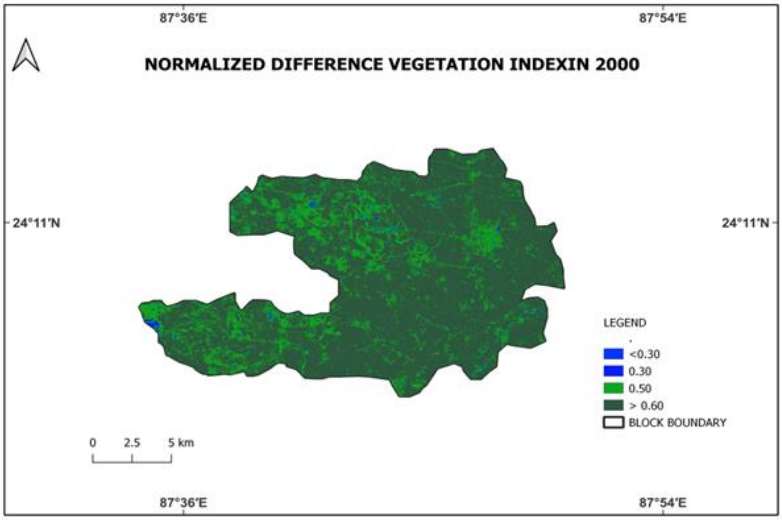

Figure 4. Normalized Difference Vegetation Index

VEGETATION: The verbiage "vegetation" pertains to the terrestrial flora that encompasses a multitude of biotic entities including, but not limited to, shrubs, trees, grasses, etc. In the specified study area, the presence of forest, degraded forest cultivated vegetation can be observed. The area of examination encompasses 31.30 square kilometers, constituting a proportion of 17.19 percent of the overall vegetal coverage.

It is a well-established fact that robust vegetation serves as an efficacious absorber of the electromagnetic spectrum, primarily owing to its lush greenery which consists of chlorophyll. This pigment exhibits a high degree of reflectivity in the green light spectrum while displaying a marked capacity for

absorption in the blue and red-light spectrum, thereby appearing verdant to the human eye. The foliage of healthy plants boasts a high Near Infrared (NIR) reflectance between 0.70 and 1.30 meters, the basis of which lies in the internal structure of the plant leaves and the utilization of two Liss-3 bands that are used in the computation of the Normalized Difference Vegetation Index (NDVI) through the following formula.

NDVI = (Near infrared – Red) / (Near infrared + Red), Where NIR= BAND 4 and RED=BAND3

The Normalized Difference Vegetation Index (NDVI) serves as a metric to evaluate the verdancy and profusion of vegetation. The NDVI scale extends from 1 to -1, wherein the higher values reflect a more abundant and flourishing vegetative cover, while the lower values suggest a less thriving or absent vegetation. In the present study locale, the peak NDVI value recorded was 0.60, which symbolizes an opulent and robust vegetative cover found in the northern and north-western, as well as South-eastern regions, particularly in the alluvial plains of Bramhani and Dwarka. Approximately 70% of the study locale exhibited moderate to low NDVI values, while the minimum values were recorded in the stony waste land situated in the south-western part of the study area.

To ascertain the precision of NDVI, a novel technique referred to as the Soil Adjusted Vegetation Index (SAVI) was employed. In areas with scanty vegetative cover, the SAVI is primarily implemented to correct for the impact of soil illumination on NDVI values. The soil brightness adjustment factor (L) was set at 0.5 to address the majority of land cover maps. SAVI is calculated as the ratio between the near-infrared (NIR) and red (R) values, with values ranging from +1 to -1. A high soil adjusted vegetation index value implies a low extent of vegetative cover on the surface, with an inverse relationship between vegetative cover and the SAVI (L) value.

The following equation was utilized to calculate SAVI:

SAVI = ((NIR - Red) / (NIR + Red + L)) x (1 + L)

Where:

NIR = Near-infrared band pixels' values

Red = values from the near red band of pixels

L = the degree of vegetation present, with a constant value of 0.5 in regions with a moderate amount of green vegetation.

The results of the soil-adjusted vegetation index analysis revealed that 80% of the study area was characterized by moderate to abundant vegetative cover, with an L value exceeding 0.40. Conversely, the residual 20% of the area was deemed to have inadequate vegetative cover.

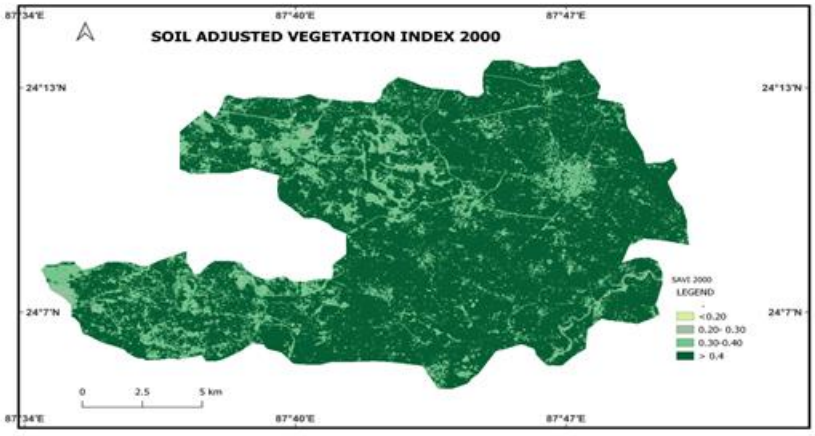

Figure 5. Soil Adjusted Vegetation Index

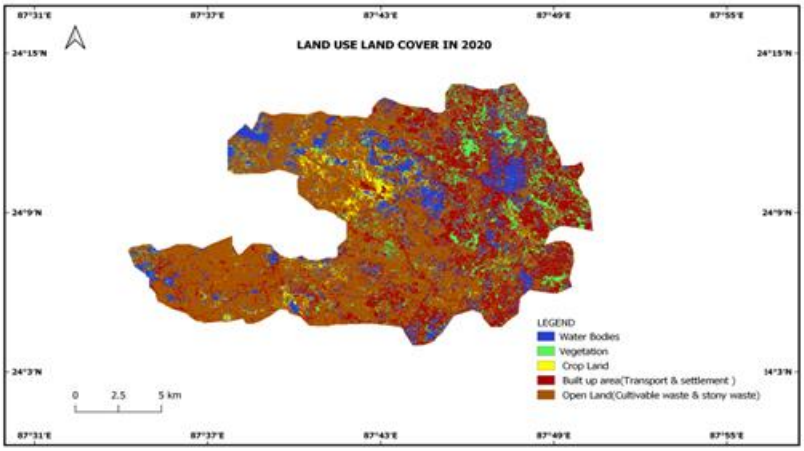

Figure 6. Land use Land cover map 2020

WATER BODIES: The present research locale is adequately serviced by the flow and discharge of the Dwarka, Chila, and Ghormora Rivers, which serve as effective conduits for drainage. The paramount channel of irrigation within this study area is the Mayurakshi-Bramhani Canal, linking the Mayurakshi River located in the southern reaches with the Bramhani River situated in the northern region. This canal encompasses a significant portion of the research area, occupying a total area of 33.02 square kilometers, or 18.19% of the entire research locale.

OPEN LAND: Cultivable waste land and stony waste comes under this unit. This unit occupies 28.82 square kilometers or 13.93 % of the total research region.

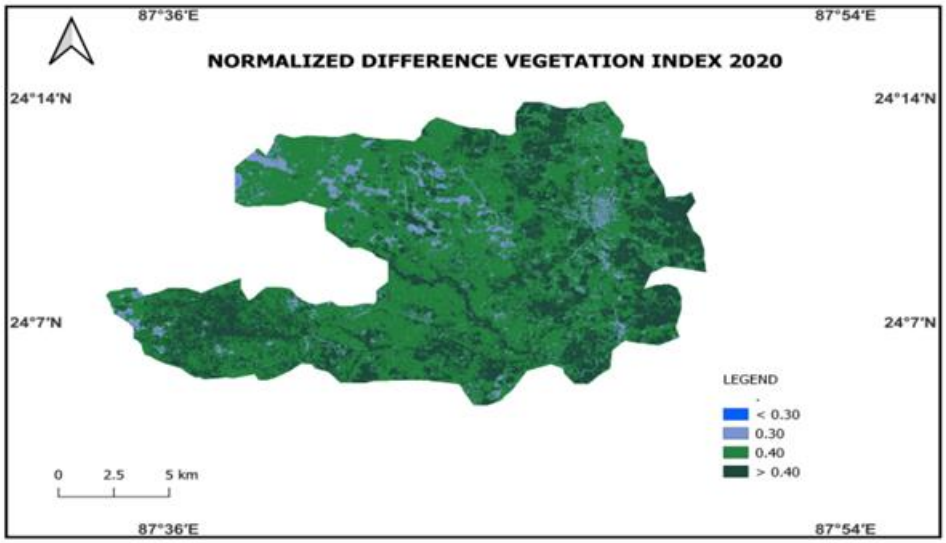

Figure 7. Normalized Difference Vegetation Index

The Land Use Land Cover Map of 2020 illustrates that the pattern and practice of land use land cover have undergone a significant transformation.

CROP LAND: This unit encompasses areas classified as cultivable waste land and stony waste, spanning 28.82 square kilometers or constituting 13.93% of the entire research locale.

WATER BODIES: A significant diminution has been observed in the extent of water bodies within the study area. This unit encompasses an area of 18.49 square kilometers, accounting for 10.19% of the total research locale.

VEGETATION: Furthermore, a significant reduction in vegetative cover has become apparent, with a decline

of 5.7 square kilometers in the total area covered. In order to gain a better understanding of the present vegetative state of the research locale, it is necessary to once again turn to the application of NDVI techniques. The accompanying NDVI map, depicted in Figure 3.5, demonstrates a notable decrease in the maximum value of the normalized difference vegetation index. It is evident that 80% of the study area was characterized by NDVI values that were either moderate or near to being low.

BUILT-UP AREA: Over the course of the last two decades, this unit has undergone a substantial increase, nearly doubling in size to occupy 76.05 square kilometers, or 41.89% of the study area. The expansion of this unit is the result of various factors, including population pressure and the process of urbanization. A substantial portion of previously unoccupied land has been converted into developed areas for various purposes, including the establishment of government institutions, roads, health facilities, and mining operations.

OPEN LAND: This unit encompasses both cultivable waste and stony waste areas. Over the last two decades, a decrease in the extent of this unit has been observed, indicating a trend towards its conversion into agricultural land, likely as a result of improvements in irrigation infrastructure. Currently, the unit encompasses 18.49 square kilometers, or 10.18% of the total study area. Some areas classified as stony waste, which are geologically affiliated with the *Chotonagpur Gneissic Complex*, have been noted to be disused and abandoned.

Change Detection

The alteration of Land Use and Land Cover (LULC) holds substantial implications in the global milieu of environmental change. Given the cyclical nature of such alterations, the application of satellite remote sensing data has demonstrated its efficacy in chronicling the changes in LULC patterns over time. Although the resultant geographical datasets may exhibit variations in their size or resolution, the utilization of Geographic Information System (GIS) techniques allows for a quantifiable evaluation of these changes (Sarma et al., 2001). The present investigation endeavors to illustrate the progression of LULC changes in the study area, Rampurhat- II CD Block, by employing a combination of charts, diagrams, and visual interpretation of processed satellite data, through the implementation of supervised classification methods. The accompanying map (Figure 3) demonstrates the evolution of LULC changes in the Rampurhat- II CD Block, between the years 2000 and 2020:

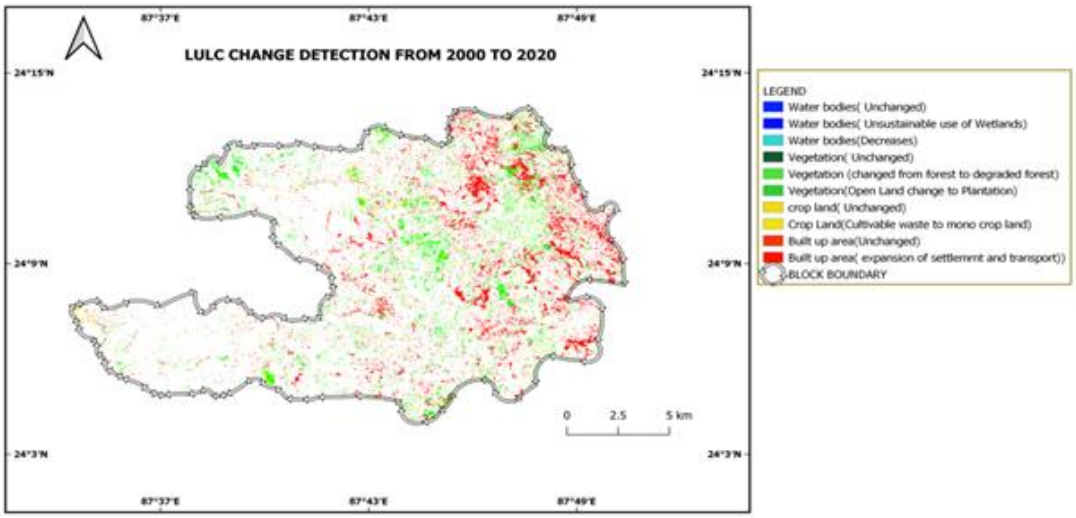

Figure 8. LULC Change Detection Map

This map reveals that forest land is converted to degraded forest due to various factors, but the most alarming factor is deforestation. Deforestation leads to desertification and changes the global environment. Some of the open land has been converted into plantations, which are primarily used for commercial purposes. However, the amount of productive cropland close to Tarapith village has decreased and has been changed into hotels, resorts, etc.; in other words, cropland has been changed into

a built-up area, which tries to predict a gradual drop in agricultural growth. The built-up area, or settlement, of this region grew very quickly without proper planning, which is unfavorable for long-term growth. (Figure 4) reveals that huge population pressure is the principal key to this situation. Due to reasons like rapid population growth and greater urbanization—which is especially true in emerging countries—many countries have definitely experienced an expansion in rural communities (Tassinari et al., 2010; Song and Liu, 2014). Unsystematic growth will lead to numerous ecological security concerns, such as local temperature rise (Yang et al., 2021; Zhao et al., 2021; Ren et al., 2022), flooding (Tiepolo and Galligari, 2021), water pollution (Kröger et al., 2012; Wu et al., 2012), and air pollution (Brani and Domasová, 2003; Ju et al., 2018; Zou et al., 2021).

Table 2. Land Use Land Cover change chart

LU/LC Category	Area(sq.km) Year-2000	%cover year-2000	Area(sq.km) Year-2020	%cover year-2020	Changes in sq.km (2020 - 2000)	Remarks
1.Water Bodies	33.02	18.19	18.49	10.19	-14.43	Decrease
Vegetation	31.20	17.19	25.50	14.05	-5.7	Decrease
Crop Land	54.46	30.00	43.00	23.69	-11	Decrease
Built-up area	36.49	20.10	76.05	41.89	+39.56	Increase
Open Land	28.82	13.93	18.49	10.18	-3.75	Decrease

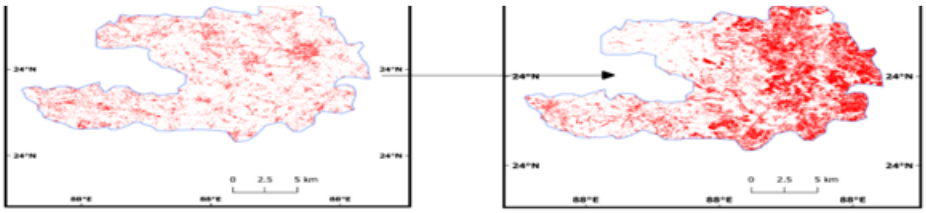

Figure 9. Built-up area in 2000 and 2020
Source: Made by author using supervised image classification (Accuracy) tools.

Conclusion

The purpose of the research paper, entitled " Application of GIS and Remote Sensing Techniques for Detection and Analysis of Spatio-Temporal Changes in Land Use and Land Cover in Rampurhat Block-II, Birbhum, Eastern India," was to investigate and determine the alterations in the utilization and coverage of land resources in the study area over time, with a focus on its current state. Upon conducting a comprehensive analysis, the study reached the conclusion that the current mode of land usage is not conducive to long-term sustainability and growth.The key issues affecting the study area were identified as the conversion of the rich cropland in the Mayurakshi-Bramhani inter-fluvial region into built-up areas, deforestation, and the decline of water bodies. The unchecked and unplanned expansion of settlements is a pressing concern in the region. The long-term analysis of land use change from 2000 to 2020 revealed that several critical land uses, such as medium- to fairly-dense forests, open forests, various types of water bodies, and fertile crop lands, displayed a declining trend, while other land uses, such as built-up areas, demonstrated an upward trend.

The application of topographical and remote sensing data within a Geographic Information System (GIS) framework facilitated an effective methodology for analyzing LULC change modeling within the study area. The decline in water bodies has resulted in irrigation problems, particularly with regards to river lift irrigation. It is recommended that the preservation of the environment and the expansion of agriculture must be given priority to mitigate these challenges.

The study endeavors to achieve a detailed examination, but the researcher acknowledges the limitations and strives to perform further in-depth analysis at the village level.

Conflict of Interest

We affirm that this study was conducted with complete impartiality and without any financial or personal conflicts that could have impacted the results and conclusions. We prioritize the integrity and objectivity of our research to uphold its credibility and reliability.

Author Contributions

The authors of this scholarly work have synergistically coalesced to bring forth its realization. The initial spark of ideation was garnered by the corrospondence author, who also demonstrated a high level of proficiency in data aggregation and statistical synthesis, as well as contributing substantively to the methodology section. The other author lent his expertise in the realm of critical analysis and also made significant contributions to the data gathering process. It is imperative to note that all authors were involved in the empirical data collection phase and participated actively in the refinement of the manuscript's composition.

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We would like to extend our gratitude to the Indian Space Research Organization (ISRO) for making their data readily available on their website. The data gathered from ISRO has been a critical component of this research and has greatly enriched our findings.

Abbreviation

- LULC: Land Use Land Cover
- GIS: Geographical Information System
- RS: Remote Sensing
- NDVI: Normalized Difference Vegetation Index
- NIR: Near Infrared
- SAVI: Soil Adjusted Vegetation Index
- DEM: Digital Elevation Model
- NWDI: Normalized Difference Water Index
- LST: Land Surface Temperature
- CD: Community Development Block

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