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Decadal land use/land cover change detection using remote sensing and GIS techniques of Panumariya block, Dheemarkheda, Katni district, Madhya Pradesh, India

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Abstract

Research on land use and land cover (LULC) changes is critical to comprehending landscape change and promoting sustainable management of resources. This paper analyses 10-year LULC dynamics in Panumariya Block, Dheemarkheda Tehsil, Katni District, Madhya Pradesh, based on remote sensing and GIS. Supervised classification was done on multi-temporal Landsat satellite images of 2000, 2010 and 2020 using the Maximum Likelihood algorithm. The research revealed that there were five LULC primary categories: agricultural land, forest, built-up area, water bodies, and barren land. According to the results, there was an expansion in agricultural and built-up lands and a decline in forests. The results underline that GIS-based monitoring will be of great interest in comprehending the changes happening to the environment and informing sustainable land management activities in the area.

Keywords: Land Use; Land Cover; Remote Sensing; GIS; Landsat; Classification; Agriculture; Forests; Change Detection; Sustainability

Introduction

1.1 Concept of land use and land cover

The analysis of Land Use and Land Cover (LULC) describes the distribution and changes in land resources using their spatial patterns due to natural events and human actions. Land cover is a physical attribute of the surface, such as forests, water bodies, agricultural land, barren land, and land use describes how these surface attributes are used by humans, e.g., agriculture, settlements, and economic activities (FAO, 2024). According to global land statistics, in 2022, agricultural land had a total area of approximately 4.78 billion hectares, which is over a third of all the land areas of the world and illustrates the significant anthropogenic impact on land-based systems. The issue of LULC transformation monitoring is relevant since any alterations of vegetation, agricultural development and urbanisation influence biodiversity, climate regulation and ecosystem services. Adjustments of forests and agricultural landscapes can affect surface temperature, water levels and ecological stability. Thus, systematic LULC evaluation offers key evidence towards sustainable management of land.

1.2 Importance of LULC change detection

The large-scale population increase, agricultural intensification, and the development of infrastructure are key causes of land change. The overall effect of intensifying human activities is to turn natural scenery into farms and urban centres. Katni district has grown from a population of 1,064,167 in 2001 to 1,292,042 in 2011, which is 21.41 per cent, and which shows that the district will be under pressure

from increased demand on land resources in the region (District Administration Katni, 2026) ^[14]. Temporal LULC analysis aids in determining the direction and change in magnitude of the landscape. Resource planning, forest conservation and agricultural management are supported with such information. In the case of Panumariya Block, Dheemarkheda, the analysis of the alteration of agricultural land under cultivation in relation to forest cover, settlements and barren land is necessary to learn about the environmental trends in the locality.

1.3 Application of remote sensing and GIS

Remote sensing and Geographic Information System (GIS) methods offer viable methods of tracking changes in the land over a large-scale region and a long time. Satellite monitoring allows drawing comparisons between past land conditions and detecting spatial changes. Landsat programme has been able to record a long-term history of agriculture, forest, water and human-driven landscape changes due to the consistent Earth observation data it has been able to provide since 1972 (Wulder et al., 2022) ^[5]. Decadal LULC studies can be done using Landsat imagery because of its medium-resolution, continuous archive. The post-classification comparison and GIS-based classification techniques enable scholars to measure the changes between an array of land-use categories (Crawford et al., 2023) ^[1].

1.4 Need for the present study

Even though past LULC research has studied the change at a district and a regional scale, there is less literature on the

block-level patterns of change in Panumariya Block, Dheemarkheda, Katni District. Thus, the proposed research utilises remote sensing and GIS analysis to examine the dynamic changes of LULC decadal and facilitates the sustainable management of agricultural resources, forests and villages.

1.5 Objectives

1. To create land use/ land cover maps of Panumariya Block under various years.
2. To analyse decadal changes in different LULC categories.
3. To determine significant as well as land transformation factors.

2. Review of Literature

2.1 Remote sensing application in lulc studies

Temporal analysis of Land Use and Land Cover (LULC) has been deemed an essential aspect of remote sensing and GIS due to the possibility of monitoring extensive geographical regions through satellite images. Tiwari et al. (2017) ^[11] note that multi-temporal satellite data and supervised classification methods constitute a good framework that can be used to detect landscape change. Studying the watershed of the Banjar River, Madhya Pradesh, they relied on Landsat imagery and GIS-based classification to observe the different types of land use. In the study, the overall classification accuracy was 89.70 per cent and 91.91 per cent, which validated the reliability of satellite-based LULC mapping for environmental monitoring. According to Xu et al. (2022) ^[12], time-series Landsat data is extremely useful in the long-term monitoring of land cover due to the long-term global data archive, consistency in spatial resolution, and historical value. The report pointed out that Landsat 8 offers good results in the identification of landscape alteration linked to agricultural extension, alteration of forests and urbanisation. Landsat observations have been available since the 1970s, and they have allowed scientists to make decadal evaluations of land transformation and comprehend long-term environmental trends. The paper by Sam and Balasubramanian (2023) ^[8] suggests that the use of Landsat-based classification and the Maximum Likelihood Classification (MLC) algorithm could serve as an effective tool to detect changes in agricultural lands, settlements, and water resources. Their observations were on Kanyakumari district, India, and studied the LULC changes over 2000-2020 and found that the settlement area grew by 49.89%. These results indicate the significance of temporal comparison to comprehending the anthropogenic change in landscape as well as neighbourhood planning.

2.2 Land use change studies in India

Population growth, agricultural intensification, urbanisation and infrastructure expansion have contributed to the transformation of land-use in India. As Xu et al. (2022) ^[12] indicate, the growing human pressure often leads to replacing natural vegetation with an agricultural or built-up environment. Assessments, which have been based on remote sensing, have revealed that such changes affect the ecological conditions and ecosystem services to a large extent. According to Samuel et al. (2020) ^[9], urbanisation has caused substantial transformation of agricultural and open lands to urban features. Madhya Pradesh (2009-2018) used GIS

classification and satellite imagery in the Kaliasot Watershed study. The analysis found a growth of 35.86 per cent in built-up area (68.93 km²), and agricultural area decreased because of expansion of settlements and development of infrastructure. Another significant cause of LULC change in central India is mining activities. In Tiwari et al. (2016) ^[6], the Sadhera Mines area of the Satna district of Madhya Pradesh was analysed using Landsat 8 and Landsat TM images between 2015-16 and 2009-10 using the Satna-Sadhera district. The report also stated that mining spaces expanded by 287.46% and the dense forest declined by 60.21%, indicating the influence of industrial mining on the surrounding scenery.

2.3 LULC studies in madhya pradesh

Madhya Pradesh LULC studies have shown that there are close links between natural resource changes, land transformation, and agricultural activities. The GIS-based observations of the Banjar River watershed (Tiwari et al., 2017) ^[11] managed to record variations in forest, agriculture, barren land and water resources, which led to enhanced watershed management practices. According to Tiwari et al. (2016) ^[6], the Karani-Satna landscape was altered due to industrial and mining activities. The study also established that mining incorporated a reversal of land-use pattern within the vicinity of the mines and vegetation cover, and a continuous observation within the environmentally sensitive zones was required. Thakur et al. (2022) ^[10] reviewed the maximum likelihood classifications of the LULC impacts of coal mining in Anuppur, Madhya Pradesh based on Landsat photos of Landsat-5 and Landsat-8. The research revealed that original vegetation was reduced by 13.74 km² and mines increased by 15.84 km², demonstrating the effects of industry on the landscape of forestry in the long-term.

2.4 Research gap

Past research shows that the transformation of LULC in Madhya Pradesh is largely linked to agricultural development, urban settlements and mining. Nevertheless, the majority of studies have worked on watershed, urban or district-scale assessments (Tiwari et al., 2017 ^[11]; Samuel et al., 2020) ^[9]. However, despite the fact that Tiwari et al. (2016) ^[6] have studied the effects of mining in Satna and Thakur et al. (2022) ^[10] analysed the effects of the mine in Anuppur, few studies have explored micro-level locations. Thus, the Dheemarkheda, Katni District, Panumariya Block needs to be thoroughly evaluated and assessed on the LULC level to clarify local transformations of land and enable its optimised management.

3. Materials and Methods

3.1 Study area

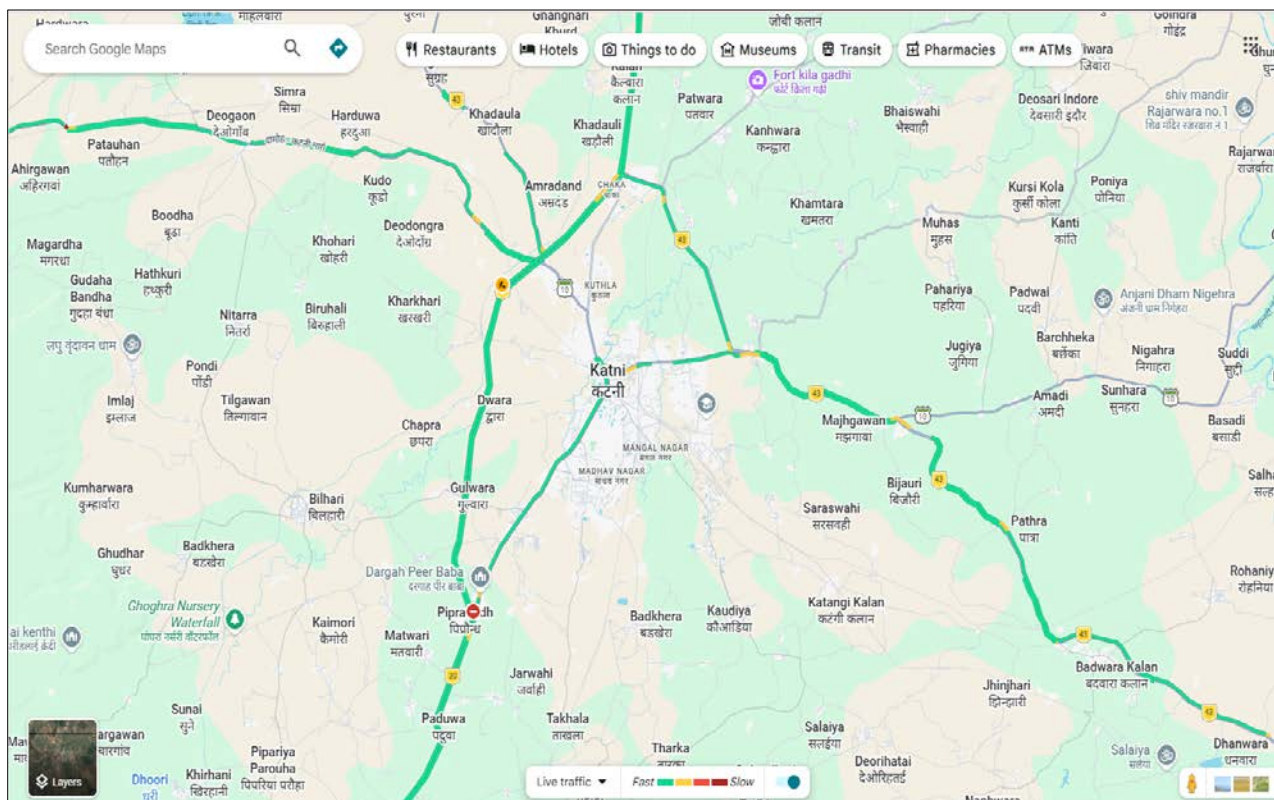
3.1.1 Location and geographical setting

This research discusses Panumariya Block, Dheemarkheda Tehsil, Katni District, Madhya Pradesh, India. Katni is 4,950 km long, with central India of the Mahakoshal region being 23°37' N to 24°37' N and 79°57' E to 80°58' E in longitude. Covering 192 villages, Dhamedarkheda is one of six tehsils (District Administration Katni, 2026) ^[14]. The region is characterised by farms, forests, hills, and mineral deposits at 400-700 m above sea level (Central Ground Water Board, 2022) ^[13].



(Source: Marefa, 2020) ^[17]

Fig 1: Location of Katni District in Madhya Pradesh, India (GIS-based map)



(Source: Katni Google Maps, 2026) ^[15]

Fig 2: Satellite Location of Katni District

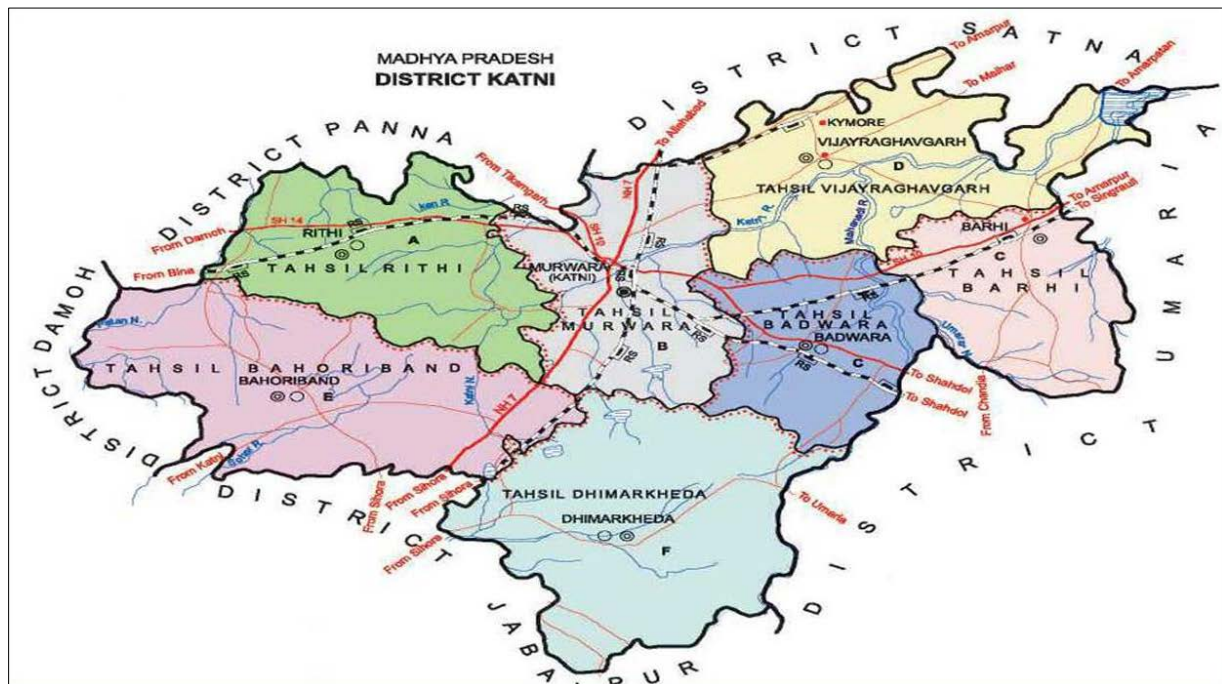
3.1.2 Drainage and water resources

Katni drainage system is predominantly a component of the Ganga River basin and, by a small percentage, the Narmada

basin. The Katni River, Chhoti Mahanadi, and Ken River are the main drainages (Central Ground Water Board, 2022) ^[13]. The subsistence in Dheemarkheda is primarily based on

rainfall and groundwater. The underlying agricultural land is mostly reliant on rainfall, with about 30% of the net sown area under irrigation. Groundwater is a major contributor to

the development of irrigation and changes in the agricultural land-use patterns.



(Source: Department of Land Resources, 2026) ^[19]

Fig 3: Location of Dheemarkheda Tehsil

3.1.3 Climate

The tropical monsoon climate can be characterised as summer, monsoon and winter. June-September rainfall is an average of the Southwest monsoon season. One definite case study of Dheemarkheda watershed revealed that the humidity is basically 88% and 13% in monsoon and summer,

respectively. The maximum speed of wind in July was the highest (17.92 km/hr), and in December the lowest (9.28 km/hr) (ICAR Krishikosh, 2021) ^[16]. Climate change influences the life cycles of crops, vegetation, and surface water.

3.1.4 Soil characteristics



Watershed Development Component-Pradhan Mantri Krishi Sinchayee Yojana (WDC-PMKSY) 2.0



Department of Land Resources, Ministry of Rural Development

Report SB3-Project wise Distribution of Area According to Irrigation Status, Ownership Status, Land Classification and Number of Crops as per Baseline Survey

State : MADHYA PRADESH District : KATNI											All area in ha.									
S. No.	Project	Total Project Area	Plot Area	Irrigation Status(Area)			Ownership(Area)				Classification of Land(Area)						No of Crops(Area)			
				Protective Irrigation	Assured Irrigation	No Irrigation	Private	Government	Community	Others	Culturable Waste Land	Degraded Land	Rainfed Land	Forest Land Plantation	No Plantation	Others	No Crops	Single Crops	Double Crops	Multiple Crops
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	KATNI-WDC - 1 /2021-22	6257.00	8823.000	7570.010	11.1100	1241.880	6495.730	2285.920	1.4200	39.9300	8.1200	81.8200	8450.150	210.9800	0	71.9300	1126.660	3231.720	4240.680	12.9600
2	KATNI-WDC - 2 /2021-22	6350.00	6349.750	6296.840	1.4700	51.4400	2025.450	4324.300	0	0	17.8900	91.9100	6238.480	0	0	1.4700	4347.760	1995.190	6.8000	0
Grand Total		12607.00	15172.75	13866.85	12.5800	1293.320	8521.180	6610.220	1.4200	39.9300	26.0100	173.7300	14688.63	210.9800	0	73.4000	5474.420	5226.910	4247.480	12.9600

wdcpmkys 2.0 - MIS Website hosted and maintained by National Informatics Center. Data presented in this site has been updated by respective State Govt./UT Administration and DoL.R 17/08/2026 08:40 PM

(Source: Department of Land Resources, 2026) ^[19]

Fig 4: Baseline Land Resource Characteristics, Katni District, Madhya Pradesh

Geological and topographical conditions have an effect on the characteristics of the soil. Deep medium black soil is the most prevalent type of soil reported in the Dheemarkheda watershed, favouring the growth of crops of wheat, soybean,

gram and vegetables (ICAR Krishikosh, 2021) [16]. The depth of soil, slope and the pattern of vegetation affect LULC patterns and agricultural productivity.



(Source: One Five Nine, n.d.)

Fig 5: Dheemerkheda village, Katni district

3.2 Materials

3.2.1 Data collection and preparation

To detect decadal LULC changes, multi-temporal satellite images are obtained on the Earth Explorer site of the United States Geological Survey. Landsat data were chosen because

of their longevity, similar resolution and landscape observation applicability. They analysed the images to detect changes in agricultural land, forest, constructions, water bodies and barren land.

Table 1: Satellite Data in the Decadal LULC Change Detection of Panumariya Block in Dheemarkheda, Katni District

Data	Source	Year	Spatial Resolution
Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery	USGS Earth Explorer	2000	30 m
Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery	USGS Earth Explorer	2010	30 m
Landsat 8 Operational Land Imager (OLI) imagery	USGS Earth Explorer	2020	30 m

Table 2: Spatial Data Used for Study Area Description

Dataset	Source	Purpose
Katni District location map	Marefa GIS map	Identification of district location within Madhya Pradesh
Katni satellite location map	Google Maps	Spatial reference and geographical visualisation
Dheemarkheda Tehsil map	District administrative map	Identification of study-area administrative boundary
Baseline land-resource characteristics	Department of Land Resources, WDC-PMKSY 2.0	Supporting information on agriculture, irrigation, land classification and cropping pattern
Dheemarkheda village location map	OneFiveNine	Local settlement reference

The preparation of the study area was done using administrative maps of Katni and Dheemarkheda, satellite location maps, and the base land-resource information of the Department of Land Resources (2026) [19]. The selection of similar seasonal images was made in order to reduce changes due to the vegetation cycle and atmospheric conditions.

3.2.2 Image processing

The satellite images were subjected to atmospheric correction, radiometric correction, image enhancement and Area of Interest (AOI) extraction. Image processing, classification of land and area computations and map preparation were done using ArcGIS. Training sample collection and validation were supported by Google Earth images.

3.2.3 Software and platform

The ArcGIS software is employed in the investigation to process the satellite image, supervised classification, calculation of the area and preparation of the map. The Google Earth images serve as the reference data to select the training samples and to check the classification of land-use categories. Remote sensing devices are used to extract the satellite data and compare the results over time.

3.2.4 Image classification

The Maximum Likelihood Classification (MLC) algorithm of supervised classification was employed. Some of the major classes under LULC were agricultural land, forest, built-up area, water bodies and barren land. The post-classification comparison technique was used to determine the changes in land-use categories between the decades 2000, 2010, and 2020 by comparing the classified images.

3.2.5 LULC change detection and analysis

The post-classification comparison method is utilised to compare the classified images of 2000, 2010 and 2020. Sensitivity of each LULC category is determined by determining the difference in area (over different years). The analysis explains the growing and declining patterns of agricultural land, forestation, built-up lands, water bodies and barren territories to comprehend decadal transformations of the landscape.

4. Results and Discussion

4.1 Land use/land cover classification

The LULC classification of Panumariya Block, Dheemarkheda Tehsil, Katni Darkot was used in the classification of 2000, 2010 and 2020 using the Multi-temporal Landsat images. They were five, namely agricultural land, forest, built-up area, water bodies and barren land. Previous Landsat-based controlled classification studies in Madhya Pradesh have shown how well it measures landscape change (Tiwari et al., 2016) [6].

4.1.1 LULC Status in 2000

In 2000, agricultural land occupied the largest portion of the land with an area of 117.80 km² (52.29%), a measure of the

importance of farming in Dheemarkheda. The bias of land use is due to the agriculturality of Katni (Central Ground Water Board, 2022) [13]. Forest occupied an area of 76.50 km² (33.96%), due to sources in less damaged and higher places, adding to ecological stability. The area covered by built-up areas was 5.80 km² (2.58%), with little settlement growth. The water bodies occupied an area of 4.60 km² (2.04 per cent), and barren land occupied 20.55 km² (9.13 per cent).

4.1.2 LULC status in 2010

The 2010 categorisation exhibited slight change. The growth in agricultural land was driven by growth in cultivation extending to 121.40 km². The area of forest cover fell to 72.80 km² (previously 76.50 km²), which suggests stress due to land conversion and use of resources. The same trends in forest fragmentation have been observed in central India as a result of agricultural development and mining (Tiwari et al., 2016). Coverage size grew from 5.80 km² to 8.20 km² due to residential and developmental infrastructure. The Katni population has increased to 1,292,042 (with a population of 1,064,167 in 2001 and a population of 1,292,042 in 2011), thus placing pressure on land resources (District Administration Katni, 2026) [14]. Water bodies moderately rose to 4.90 km² as compared to 4.60 km².

4.1.3 LULC status in 2020

The 2020 classification showed additional changes in the landscape. The largest of them was agricultural and increased to 124.20 km² (55.14 per cent). This made it 68.90 km² (30.59 per cent) in forest land, a loss of 7.60 km² of forest land between 2000 and 2020, which affects biodiversity and ecological stability (Department of Land Resources, 2026) [19]. Settlement, road growth, and infrastructure growth led to an increase in built-up land to 12.10 km² (5.37%). Water bodies marginally rose to 5.10 km² (2.26 per cent), and barren land decreased due to conversion into agricultural and developed land to 14.95 km² (6.64 per cent).

4.2 Decadal change analysis

Comparison of the changes in LULC before and after 2020 was conducted through post-classification.

Table 2: Areal data of various land-use classes of Panumariya Block, Dheemarkheda, Katni in 2000, 2010 and 2020

Land use class	2000 Area (km ²)	% Area	2010 Area (km ²)	% Area	2020 Area (km ²)	% Area	Change (2000–2020)
Agricultural Land	117.80	52.29	121.40	53.89	124.20	55.14	+6.40
Forest	76.50	33.96	72.80	32.33	68.90	30.59	−7.60
Built-up Area	5.80	2.58	8.20	3.64	12.10	5.37	+6.30
Water Bodies	4.60	2.04	4.90	2.18	5.10	2.26	+0.50
Barren Land	20.55	9.13	17.95	7.97	14.95	6.64	−5.60
Total Area	225.25	100	225.25	100	225.25	100	—

The findings reveal that agricultural and built-up areas are growing as forests and barren lands are declining with the enhanced use by human beings.

4.3 Factors responsible for land transformation

The growth of the population led to the rise of demands in housing, infrastructure and farmlands (District Administration Katni, 2026) [14]. Another factor affecting agricultural growth was agricultural reliance and the use of groundwater. The development of infrastructure promoted

settlement, and the pressure on forests was caused by land conversion, fuelwood harvesting and mining of resources. The geology of nearby Madhya Pradesh areas also led to landscape changes as a result of mining (Tiwari et al., 2016) [6]. Seasonal changes in climate influenced precipitation, farm yield and cover.

4.4 Environmental implications

Two effects of forest loss include loss of biodiversity, ecological stability and storage of carbon. Soil erosion and

degradation are aggravated by loss of vegetation, whereas agricultural growth aggravates soil pressure. The higher utilisation of groundwater causes water availability and recharging issues (Central Ground Water Board, 2022) ^[13]. Panumariya Block needs sustainable management through conservation of forests, observation value systems in red watersheds, effective irrigation and permanent GIS monitoring.

5. Summary and conclusion

5.1 Summary

It examined the Panumariya Block, Dheemakheda Tehsil, and Katni District decadal LULC changes (2000-2020) through remote sensing and GIS. Landsat images detected the agricultural land transformation, forest, constructive, and water and barren spaces. The population was on the rise, leading to more agricultural land, less forest and more built-up areas. Agricultural growth, population growth, planting, the exploitation of forests, and climatic fluctuations were the key factors of change.

5.2 Conclusion

The researchers came to the conclusion that the landscape in Panumariya Block underwent huge changes during the period of 2000-2020. LULC monitoring using GIS was successful in detecting spatial changes and facilitates sustainable land planning. To sustain ecological balance, forest conservation, more efficient agricultural approaches, watershed management, and efficient water-resource utilisation are suggested.

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