Long-term monitoring of land-use/land-cover change in Morena district, Madhya Pradesh, India, using EO satellite data

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Knowledge on land-use/land-cover (LULC) patterns plays an important role in the development plan of any area. In addition, the information on change in LULC is important in studying the type and magnitude of land conversion and the associated land and environmental degradation taking place in a given area. In the present study, we map and monitor the LULC change that has taken place in Morena district, Madhya Pradesh, India during the past 25 years (1994–2018). Multi-season satellite data have been analysed along with ancillary information to prepare LULC maps at 1 : 50,000 scale for 1994 and 2018. These maps reveal that the area under built-up land has increased from 23.19 to 57.69 sq. km, mainly due to population growth. Double-cropped area has increased from 608.05 to 2050.08 sq. km due to reclamation of ravines. Ravine area in the district has decreased by about 22% during the above-mentioned period, indicating that the land reclamation measures taken by the people and the concerned government department have been effective in combating land degradation. The area under dense forest has decreased from 235.47 to 143.47 sq. km due to deforestation and forest degradation.

Keywords: Change detection, deforestation, land use, land cover, ravines, satellite data.

SPATIAL data on the present land use/land cover (LULC) and its change with time are important for any area development plan and policy formulation[1]. Land is the most important natural capital on which humans depend for their survival and well-being. The different types of land are subject to various forms of utilization. Often people consider land use and land cover as synonyms; however, these are two different factors. Land use refers to the use of land by people for different purposes to meet their own requirements – production of food, fodder, fibre, energy, provision of shelter, extraction and processing of materials and recreation, etc. Thus, land uses are usually under the influence of the following two broad factors: human requirements and environmental processes. Land cover refers to the biophysical state of the earth's surface. It basically represents land surface and subsurface features[2]. It may include vegetation/forest, mountains, wetlands, etc.[3,4]. Land cover deals with the amount and type of vegetation, water and earth materials[5], i.e. man-made construction (buildings, etc.), type of materials used in housing structures, etc.[6]. When we discuss vegetation as a land cover, it also includes the different aspects of the physical environment such as soil biota, biodiversity, surface water, groundwater, etc.[4]. Sometimes, natural disasters like landslides, droughts, floods and earthquakes can lead to change in land use and land cover[7]. Anthropogenic factors are also responsible for LULC change. Our understanding regarding LULC has also changed with time. Earlier, LULC change studies mostly considered the physical aspects of the change, but with time, the global environment change has become an integral part of such studies. LULC change not only impacts biological productivity of the land and state of the environment, but also influences the land surface processes and energy balance, thereby affecting the regional climate[8,9]. In addition to degrading the land, LULC change also impacts the goods and services offered by the terrestrial ecosystems[10,11].

Modifying or changing LULC by humans is not new; it has been taking place since the invention of agriculture, may be about more than 6000 years ago. Humans have been converting forest land into agricultural land to meet the growing demand for food and fodder. However, the rate of land conversion and LULC change has increased during the past century. This can be mainly attributed to increase in population and the resultant demand for food, fibre, fodder and energy[12]. Presently, monitoring and mitigating the adverse impact of LULC change has become a major priority for the researchers and governments, across the world[13]. As mentioned earlier, LULC change also impacts the quantity and quality of water[14]. LULC change on a large scale can transform the terrestrial

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biosphere into anthropogenic biomes[15–17]. Often land use influences the land cover and changes in land cover affect land use. However, a change in either is not necessarily the result of the other. Often, LULC change leads to land degradation as well decline in the ecosystem functions. Land cover change through change in land use need not necessarily lead to land degradation. Sometimes, LULC change may lead to land improvement, e.g. conversion of marginal agriculture land into plantation. However, as mentioned earlier, changes in LULC may lead to changes in surface albedo and energy exchange at the land surface, thereby influencing the climate and biosphere[18,19]. Land conversion (forest to agriculture, pasture to built-up, grassland to built-up/agriculture, etc.) and LULC change taking place across the world are driven by the need to meet the growing demand for food, fodder, energy, shelter, etc.[5,12,20].

The developments in space-based imaging and sophisticated image processing techniques during the past four decades have revolutionized the field of cartography and mapping[21]. Remote-sensing images from a variety of satellites, including Landsat and IRS, have been a major source of information for LULC mapping and change analysis[22].

Morena district, Madhya Pradesh (MP), India, has witnessed remarkable expansion and growth in urban built-up area, roads and other infrastructure development during the past few decades, which has led to land conversion and LULC change. It has also led to deforestation, mainly for agriculture expansion. There have been positive changes as well, e.g. reclamation of ravines for agricultural uses. Therefore, it is imperative to study the changes in LULC and their possible impact on the land, environment and socio-economic conditions of the people. In the present study, we have prepared LULC maps at 1 : 50,000 scale to monitor the changes in land-use patterns in Morena district, MP, during the past 25 years (1994–2018) using multi-date satellite data and GIS technology.

Objectives

The main objective of this study was to prepare LULC maps at 1 : 50,000 scale and monitor the changes in LULC classes, such as built-up land, agricultural land, forest, wastelands, ravines and water bodies during 1994–2018 using multi-date and multi-season satellite data, ancillary information and GIS technology.

Study area

Morena district, MP, is located between 25°55′N–26°52′N lat. and 77°10′E–78°42′E long. (Figure 1). Total geographical area of the district is 4992 sq. km, and it comprises of 489 Gram Panchayat and 782 villages. It is bounded by Kota district in the southwest, Sawai Madhapur and Bharatpur districts of Rajasthan in the northwest, Agra district of Uttar Pradesh in the north, Bhind district in the east and Gwalior and Shivpuri districts in the southeast. Its northern boundary is formed by the Chambal river and northwest boundary by the Parvati river. Total population of the district according to the 2011 Census is 1,965,970 persons, of which 1,068,417 are males (54.35%) and 897,553 females (45.65%). Rural population of the district is 1,495,508 persons (815,218 males and 680,290 females) and urban population is 470,462 persons (253,199 males and 217,263 females)[23]. Morena district comprises of six tehsils and seven community development blocks, namely Sabalgarh, Kailaras, Joura, Morena, Ambah, Porsa and Pahadgarh. Physiographically, Morena district is divided into the five divisions, viz. (i) Chambal ravines, (ii) Karhal Plateau, (iii) Sabalgarh–Imlia forests (iv) Peach–Morena–Joura plains and (v) Kulaith-Baldia forests. Bamurbasa, Kulaith, Thatipara and Baldia are the main forest trees in the district. The trees are mostly of tropical deciduous type. The district is drained by Chambal, Kunwari, Kunu, Asan, Parvati, Sip and Sank rivers. Climatically, Morena district is hot during summer and often remains dry for the whole year, except during monsoon season. The annual rainfall of this district is 753.7 mm, which is experienced between June and September. The minimum temperature of 7°C is observed in January, while maximum temperature of 42°C is experienced in May. The maximum wind velocity of 11.3 km/h is observed in June, while minimum wind velocity of 3.1 km/h is experienced in November. Morena district is situated at an altitude of 165 m amsl and has a gentle slope towards north. Geologically, Morena district comprises of sandstone and shale and alluvium type of rocks which belong to the Vindhyan Super Group. Mainly alluvial soil is found in Morena district, which consists of unconsolidated to consolidated yellowish-brown sand silt and clay with gravels and pebbles. The thickness of the alluvium ranges from 1 m to 180 m. *Rabi* crops grown in Morena district are wheat, gram and mustard, while *kharif* crops are jowar, bajra, rice, tuar, urad and moong[24].

Data used

Table 1 provides details of satellite data and ancillary information used in the preparation of LULC maps of Morena district, MP.

Methodology

Figure 2 is a flowchart providing detailed steps used in preparation of LULC maps using satellite data. Preparation of LULC maps involves visual or digital analysis of multi-season satellite data. In visual analysis technique, tone, texture, shape, pattern, size, location, association and shadow, as depicted on the satellite images, are used

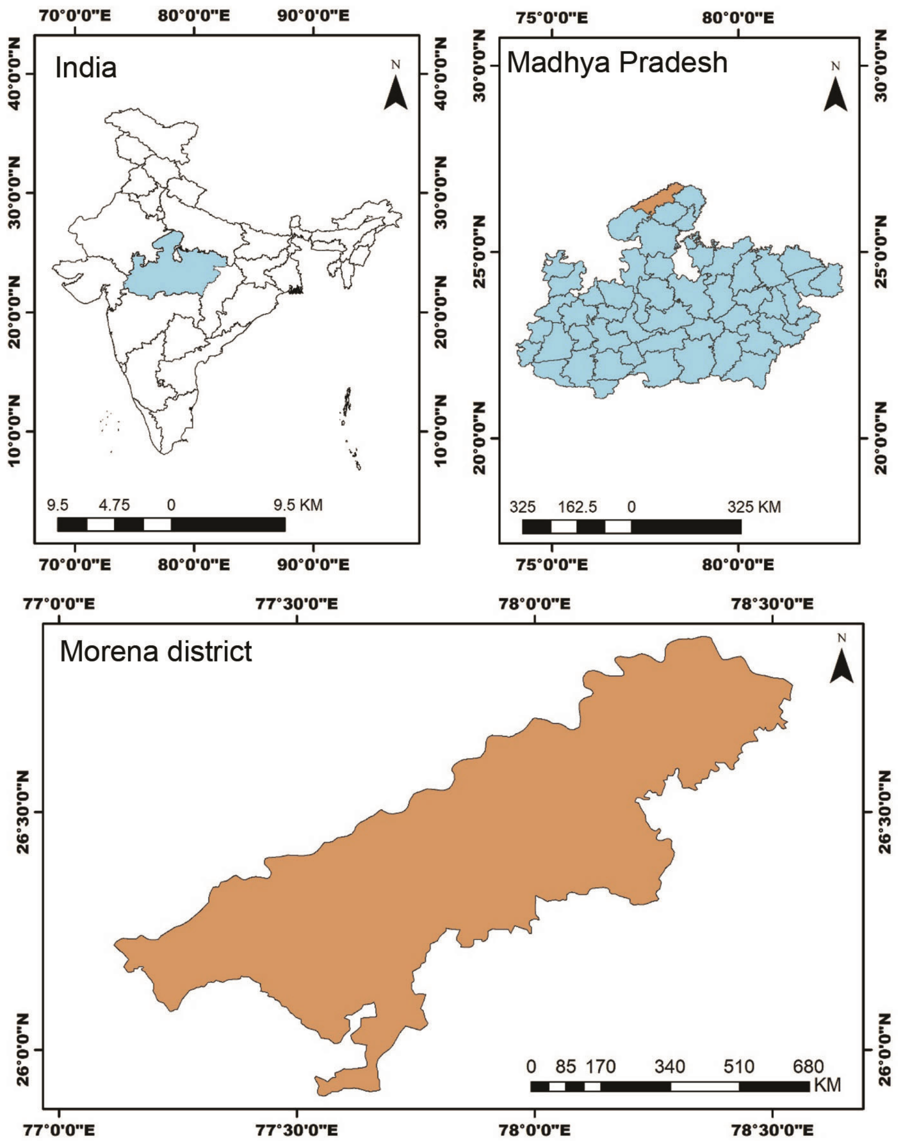

Figure 1. Location map of the study area – Morena district, Madhya Pradesh, India.

Table 1. Satellite data, ancillary information and collateral data used in the study

Data	Specification	Source	Date
Satellite data	30 m resolution	Landsat-5, TM	30 September 1994
			9 October 1994
			17 January 1994
			26 January 1994
	30 m resolution	Landsat-8, OLI	29 September 2017
			8 October 2017
			12 January 2018
			19 January 2018
Ancillary information	Topographical maps on 1 : 50,000 scale	Survey of India	
Collateral data	Population	Census (2011)	

to interpret, identify and delineate various land features. A ground-truth survey was conducted in the study area. Information collected during the field survey about different LULC features was used to prepare the interpretation key as well as for LULC mapping. First, an interpretation key was prepared using the ground-truth data on various land objects and the manner in which these objects are depicted on the satellite image in terms of tone, texture, shape, pattern, size, location, association and shadow. The interpretation key was then used for identification, delineation and mapping of different objects/land-use classes on the satellite image. While interpreting various LULC classes from the satellite image, on-screen digitization of the polygon features pertaining to different LULC classes was carried out and stored in GIS environment to create a spatial layer for them. Before on-screen interpretation of satellite images, a base map of the study area was prepared using topographical maps on 1 : 50,000 scale. The base map contains features like major towns, major rivers, forest boundaries, major water bodies, etc. It was kept as a layer in the background while interpreting the satellite data. The map thus prepared was the preliminary or pre-field LULC map. Once the preliminary map was prepared, ground-truth information was used to finalize the map. Basically any confusion or ambiguity in the mapped classes was resolved using ground-truth data and the map is corrected at this stage. The resulting map was the final map. Using the above steps, LULC maps for 1994 and 2018 were prepared for Morena district, MP. Accuracy assessment of LULC maps was carried out using ground truth data. LULC change analysis was carried out using the maps of 1994 and 2018, and finally a LULC change map and change matrix were generated. Standard LULC classification system was adopted for LULC category mapping using satellite data[25]. Table 2 gives the LULC classification system (up to level-II) used in the present study.

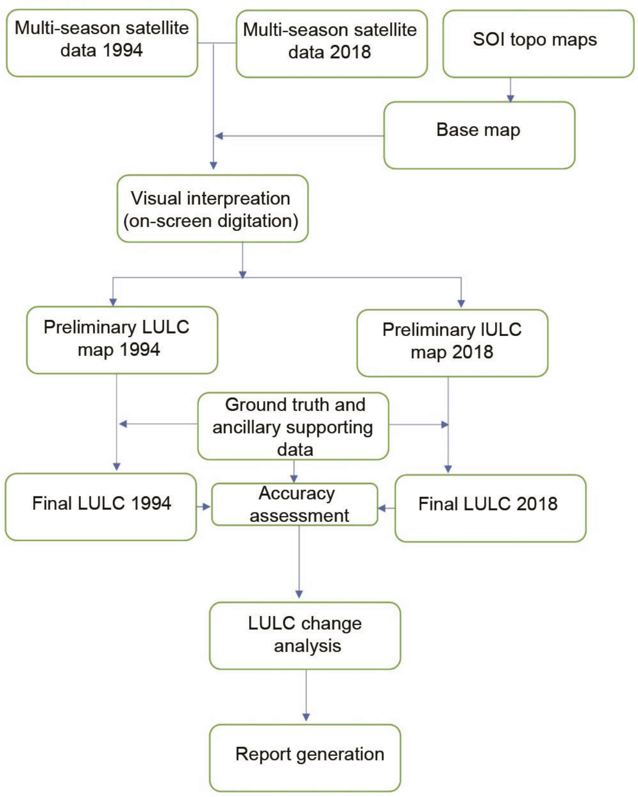

Figure 2. Flow chart for land-use/land-cover (LULC) mapping and change analysis.

Land use/land cover classes

Details of each LULC category are discussed below.

Built-up land: This is the area with settlements and it is put to non-agricultural use. It has a cover of buildings and infrastructure, including transport, communication, utilities in association with water, vegetation and vacant land.

Agricultural land: This refers to the land which is put to use for farming for the production of food, fibre, as well as commercial and horticultural crops. It includes land under crops (irrigated and unirrigated), fallow and horticulture/plantations.

Forest: This refers to the area which lies within the limits of reserve and protected forests (RF and PF), and has a thick cover of trees and shrubs. It is capable of producing wood and also acts as a habitat for wildlife and livestock[26]. Any area under forests having crown density more than 40% is known as dense forest and that having crown density ranging from 20% to 40% is termed as open forest. The area having the crown density less than 10% is known as degraded forest. 'Crops within forests' is an area where crops are grown under forests. 'Ravines in forests' is the gully eroded area within the forest boundary.

Wastelands: This refers to the land which is degraded and can be rehabilitated by implementing sustainable land

Table 2. Land-use/land-cover (LULC) classification system

Level-I	Level-II
Built-up land	Built-up land
Agricultural land	*Kharif* crops
	Rabi crops
	Double crops
Forest	Crops within forests
	Dense forest
	Open forest
	Degraded forest
	Ravines in forests
Wastelands	Ravines
	Quarries
	Stone quarries
	Limestone quarries
	Barren/rocky area
	Land with/without scrub
Waterbodies	Rivers/canals
	Pond/lake/reservoirs
Others	

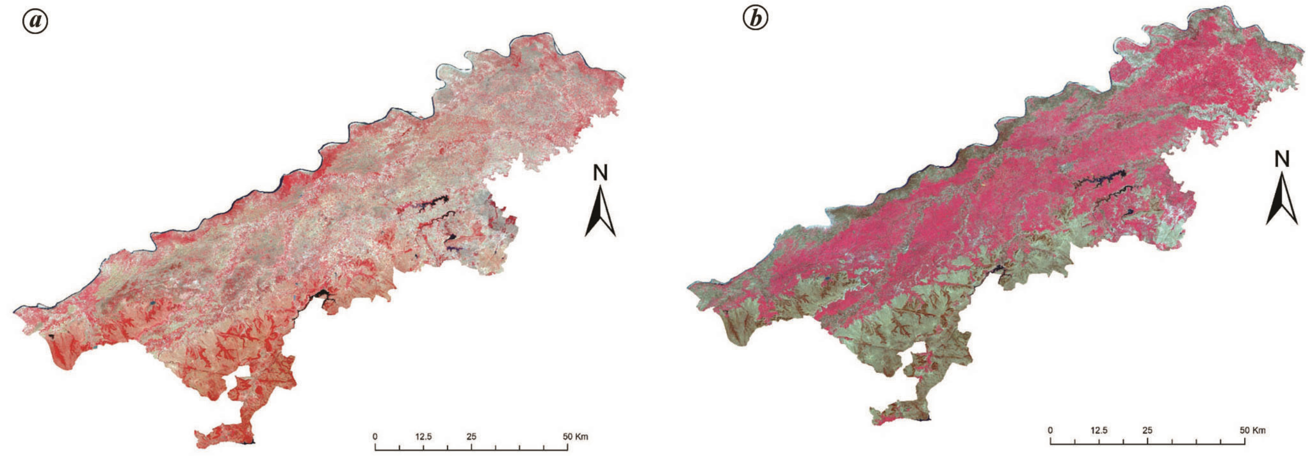

Figure 3. Landsat 5 TM false colour composite (FCC) image of Morena district, MP, for (***a***) *kharif* and (***b***) *rabi* season in 1994.

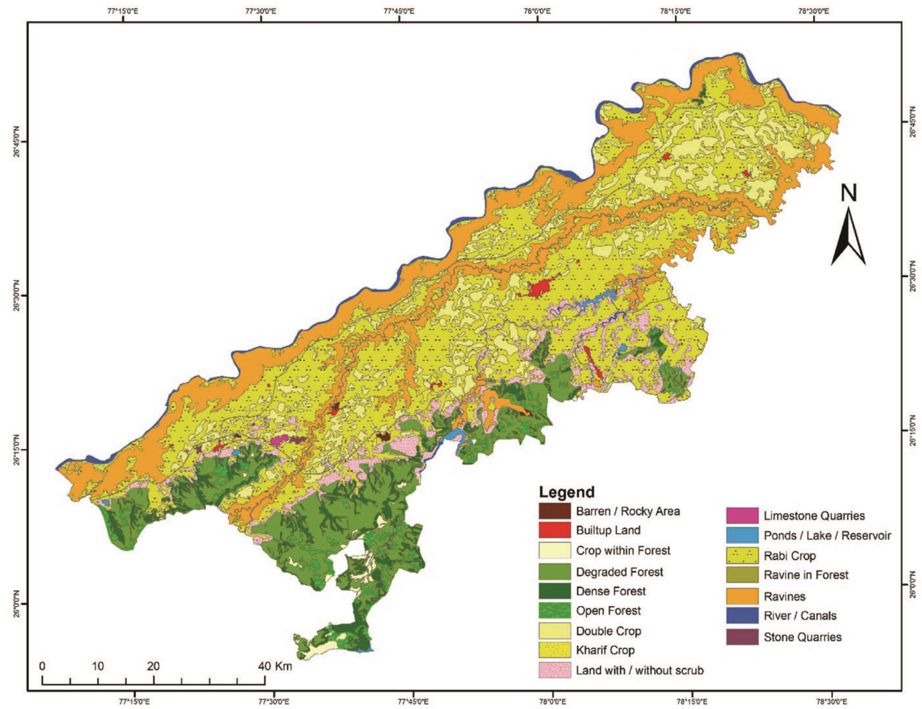

Figure 4. LULC map of Morena district, MP in 1994.

management (SLM) practices, and suitable land and water conservation measures[27]. Ravines are unique landscapes under wasteland category, and are the most dominant class under wastelands in Morena district, MP. Generally, the wide gullies in India are known as ravines. For operational convenience, ravines can be classified as shallow (3–6 m), medium (6–9 m) and deep (>9 m).

Water bodies: This refers to areas/structures where water is impounded/stored during monsoon. For example, reservoirs/lakes/tanks/canals, besides natural lakes, rivers/streams and creeks.

Others: Any LULC class or land feature present in the study area and not pertaining to the above five classes is included in the class 'Others'.

Multi-season Landsat satellite data of Morena district, MP, pertaining to *kharif* and *rabi* seasons for 1994 and 2018 were used to prepare LULC maps for the two-time-periods using the above methodology. Figure 3 *a* and *b* show the *kharif* and *rabi* season Landsat images (false colour composite, FCC) for 1994 respectively. Figure 4 shows LULC map for 1994. Figure 5 *a* and *b* show the corresponding images respectively, for 2018. These images have been interpreted on screen, and digitized to

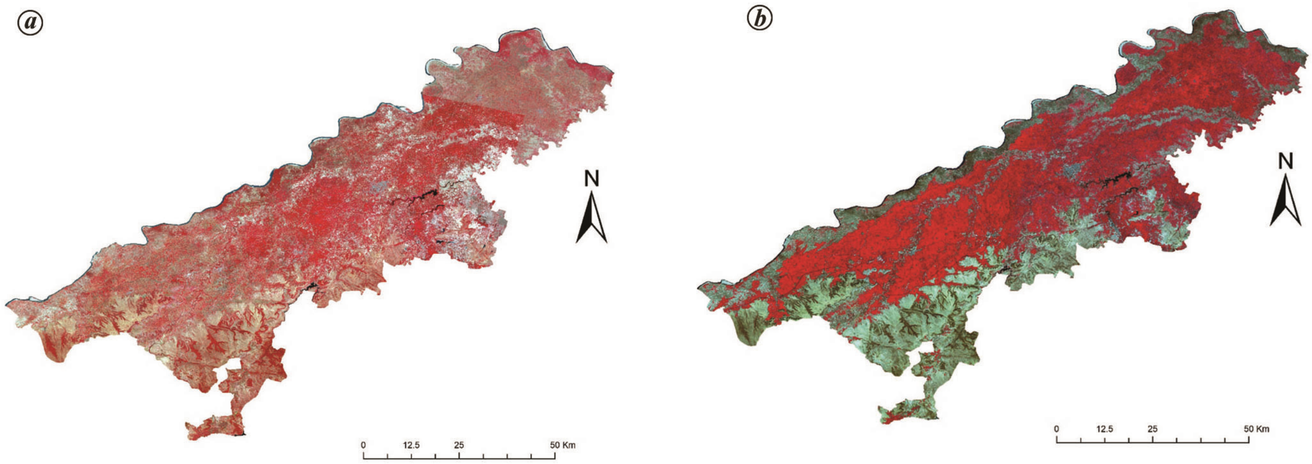

Figure 5. Landsat 8 OLI FCC image of Morena district, MP, for (***a***) *kharif* and (***b***) *rabi* season in 2018.

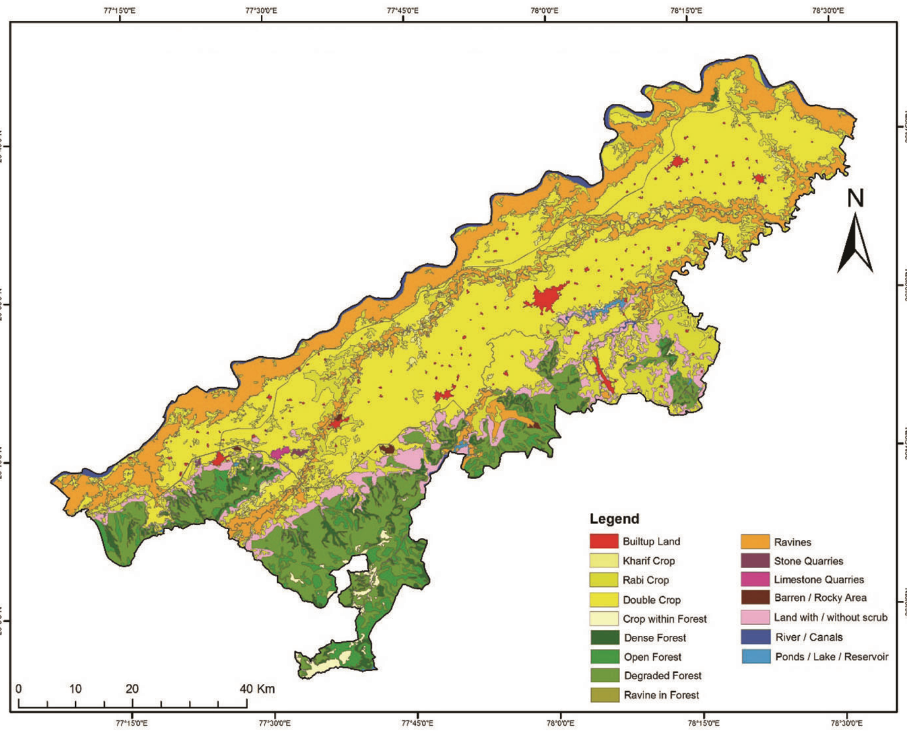

Figure 6. LULC map of Morena district, MP in 2018.

prepare LULC maps at scale of 1 : 50,000 for 1994 (Figure 4) and 2018 (Figure 6). The LULC layers pertaining to 1994 and 2018 were analysed in the GIS environment to prepare LULC change map (1994–2018) for Morena district, MP (Figure 7). Table 3 gives the LULC statistics for 1994 and 2018.

Results and discussion

The LULC maps of Morena district, MP for 1994 and 2018, prepared using the above methodology (Figure 2), are given in Figures 4 and 6 respectively. In these maps, green colour represents forested area, yellow agriculture, red built-up land, blue water bodies, orange ravines, purple waste land and brown stony area. Perusal of the LULC statistics for 1994 and 2018 reveals that the area under various categories of LULC in Morena district, MP, has changed significantly (Table 3). It can be clearly seen from Figures 4 and 6 that built-up land has significantly increased during the period 1994–2018. This is attributed to increase in the population of Morena district, MP. Whereas ravine area has decreased significantly

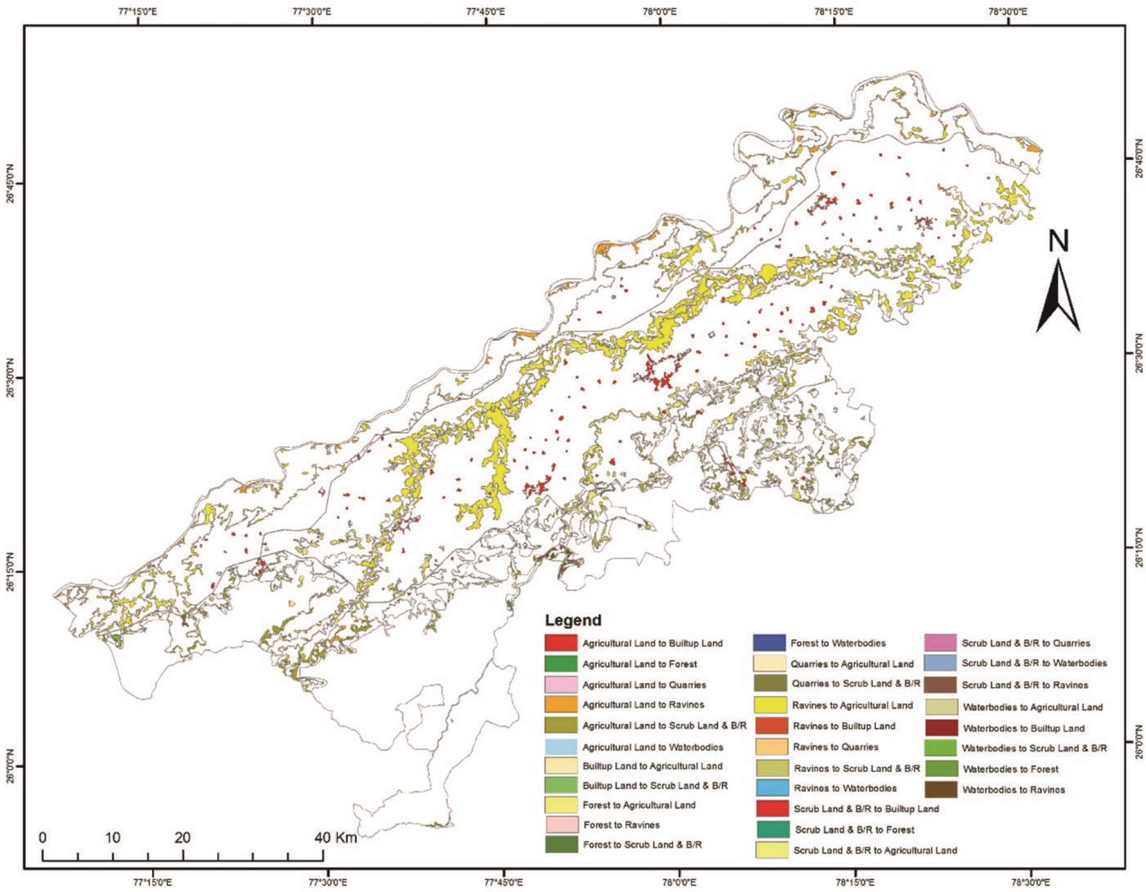

Figure 7. LULC change map (1994–2018) for Morena district, MP.

Table 3. Area under various LULC classes between 1994 and 2018

	1994		2018	
LULC class	Area (sq. km)	% GA	Area (sq. km)	% GA
Built-up land	23.19	0.46	57.69	1.16
Kharif crops	28.63	0.57	70.40	1.41
Rabi crops	1933.86	38.74	667.55	13.37
Double crops	608.05	12.18	2050.08	41.07
Crops within forests	39.81	0.80	38.39	0.77
Dense forests	235.47	4.72	143.47	2.87
Open forests	163.81	3.28	230.00	4.61
Degraded forests	517.99	10.38	543.59	10.89
Ravines in forests	0.84	0.02	0.84	0.02
Ravines	1038.20	20.80	813.88	16.30
Stone quarries	3.70	0.07	3.04	0.06
Limestone quarries	3.86	0.08	4.04	0.08
Barren/rocky area	6.10	0.12	6.11	0.12
Land with/without scrub	265.14	5.31	249.62	5.00
Rivers/canals	102.81	2.06	101.15	2.03
Ponds/lakes/reservoirs	20.69	0.41	12.28	0.25
Total area (sq. km)	4992.15	100.00	4992.15	100.00

GA, Geographic Area.

(about 22%) during the above period. The area under built-up land has increased from 23.19 sq. km in 1994 to 57.69 sq. km in 2018. The area under agricultural crop-land has increased due to land utilization and reclamation of ravines. The double-cropped area has increased from 608.05 to 2050.08 sq. km. Significant area under ravines

Table 4. Land conversion matrix for Morena district, Madhya Pradesh, India (1994–2018)

LULC 1994/2018	Built-up land	*Kharif* crops	*Rabi* crops	Double crops	Crops within forests	Dense forest	Open forest	Degraded forest	Ravines in forests	Ravines	Stone quarries	Limestone quarries	Barren/rocky area	Land with/ without scrub	Rivers/canals	Ponds/lake/ reservoirs	Total area (sq. km)
Built-up land	22.85	0.02	0.05	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	23.19
Kharif crop	0.41	3.57	5.89	13.23	0.00	0.00	0.00	0.00	0.00	2.74	0.00	0.03	0.00	2.75	0.00	0.00	28.63
Rabi crop	22.65	24.42	426.33	1386.92	0.35	0.23	0.00	1.07	0.00	35.56	0.02	0.20	0.18	35.93	0.00	0.00	1933.86
Double crop	8.44	5.21	47.64	542.23	0.00	0.00	0.00	0.00	0.00	2.96	0.00	0.00	0.02	1.54	0.00	0.00	608.04
Crop within forest	0.00	1.15	0.54	0.00	29.51	0.00	0.03	7.28	0.00	0.47	0.00	0.00	0.00	0.70	0.00	0.13	39.81
Dense forest	0.00	0.05	0.46	0.00	3.50	140.13	63.36	27.91	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	235.47
Open forest	0.00	0.16	0.38	0.00	2.51	1.88	149.09	9.75	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	163.81
Degraded forest	0.00	0.10	0.08	0.00	2.47	1.16	16.74	497.41	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	517.99
Ravine in forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84
Ravines	0.74	27.82	152.51	87.66	0.00	0.00	0.00	0.00	0.00	766.32	0.02	0.00	0.35	2.76	0.03	0.00	1038.20
Stone quarries	0.00	0.07	0.36	0.02	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.26	0.00	0.00	3.70
Limestone quarries	0.00	0.01	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.80	0.00	0.00	0.00	0.00	3.86
Barren/rocky area	0.19	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	5.56	0.00	0.00	0.00	6.10
Land with/without scrub	2.38	7.73	30.45	19.66	0.05	0.06	0.00	0.02	0.00	1.96	0.00	0.00	0.00	202.81	0.02	0.01	265.14
Rivers/canals	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.52	101.09	0.00	102.81
Ponds/lake/reservoir	0.02	0.07	2.09	0.13	0.00	0.02	0.78	0.16	0.00	3.10	0.00	0.00	0.00	2.20	0.01	12.11	20.69
Total area (sq. km)	57.69	70.40	667.55	2050.08	38.39	143.47	230.00	543.59	0.84	813.88	3.04	4.02	6.11	249.62	101.15	12.28	4992.14

has been reclaimed during the past 25 years; it has decreased from 1038.20 to 813.88 sq. km. The area under dense forest has decreased from 235.47 to 143.47 sq. km due to deforestation.

Stone quarries have shown a slight change from 3.70 sq. km in 1994 to 3.04 sq. km in 2018. There is a minor increase in the area under limestone quarries; it has increased from 3.86 to 4.04 sq. km. Expanse under barren/rocky area has remained almost unchanged during the period.

The present study on LULC change in Morena district, MP, has revealed that there is about two and a half times increase in area under built-up class. Such increase in built-up land is at the cost of agriculture and scrub/pasture land. Urbanization is one of the major processes leading to land and environmental degradation. Significant deforestation has taken place during the past 25 years. Forest land has been encroached for agriculture, which will ultimately lead to land and environmental degradation. Limestone quarrying taking place in the forest/scrubland in some parts of the district, is another type of LULC change which is degrading the land and the environment. Another important LULC change which has taken place in Morena district, MP, is the reclamation of ravines for the purpose of agriculture. About 22% of the area under ravines has been reclaimed during the period 1994–2018 for agriculture. This is a positive change and will lead to improvement in environmental conditions, increase in the agricultural production and thus improvement in the socio-economic conditions of people living in the area. It also shows the positive impact of measures taken by the local people and the concerned government authorities towards combating land degradation. However, its impact on the floral and faunal diversity needs to be studied.

For accuracy assessment, a field survey was carried out in the *rabi* season of 2018. Eighty-five points pertaining to various LULC classes were randomly selected for field checks during the ground-truth survey and used for accuracy assessment of the LULC map of 2018 (ref. 28). Out of the total 85 points verified in the field, 77 were found to be correctly classified, providing a mapping accuracy of 90.59%. Table 4 shows a LULC class conversion matrix. It provides details on whether a LULC class in 1994 has changed to another LULC class or remains the same. Thus, it helps in understanding the LULC dynamics and land conversion that has taken place in Morena district, MP, during the past 25 years.

Conclusion

LULC monitoring and change analysis are important in the assessment of type and magnitude of land conversion and the associated environmental and land degradation. In addition, information on LULC and its change is a prerequisite for the preparation of area development plans. In the present study, multi-season satellite data of 1994 and 2018, along with ancillary information, have been analysed to prepare LULC maps (on 1 : 50,000 scale) for the two-time frames to monitor the LULC change for Morena district, MP. The LULC maps prepared based on the analysis of satellite data reveal that the area under built-up land has increased by two and a half times, from 23.19 sq. km in 1994 to 57.69 sq. km in 2018. This is mainly due to the growth in population and infrastructure development in the district. Double-cropped area has increased from 608.05 to 2050.08 sq. km during the past 25 years, mainly due to reclamation of ravines and expansion of agriculture. A significant area under ravines (224.32 sq. km) has been reclaimed for agricultural use during the above period. Area under dense forest has decreased from 235.47 to 143.47 sq. km due to deforestation and forest degradation. This is mainly due to conversion of forest land for agriculture. The overall classification accuracy of the LULC maps has been found to be 90.59%.

Conflict of interest: The authors declare no conflict of interest.

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ACKNOWLEDGEMENTS. We thank the Visualization of Earth observation Data and Archival System (VEDAS) Research Group for providing the necessary training facilities and the scientists at Space Applications Centre (ISRO), Ahmedabad for their continuous support for this work. No fund/grant has been provided for this study.

Received 29 June 2021; revised accepted 2 October 2021

doi: 10.18520/cs/v121/i12/1584-1593