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Monitoring Land Use/ Cover Dynamics of Achanakmar Tiger Reserve (ATR), India by Using Multi-Temporal Satellite Data and Future Scenario

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Abstract: The Achanakmar Tiger Reserve (ATR) has experienced various land use changes since 1975. In this study, multi-temporal land-use changes of the ATR from 2000 to 2015 were assessed using IRS-1D and P6, LISS III and Landsat OLI satellite imageries. ERDAS Imagine v 2013 and IGIS v 1.0 software was used to process satellite imageries and assess quantitative data. The maximum likelihood classification algorithm was used to derive a supervised land-use classification of the spring and autumn months for 2000, 2008, 2013 and 2015. Dense forest is the dominant land cover type covering approximately 56% of the area, followed by open forest, scrub land, agricultural land, river bed, built up land and water bodies. During 16-year period, approximately 3.20 and 2.24% of the open forest area had increased during the spring and autumn seasons, and the annual rate of change was 0.20 and 0.14%. Scrub land area has decreased by 3.53 and 2.85% during the spring and autumn seasons during this period. Areas covered under water bodies, river beds and built up lands have also reported increment. Slight variations were observed in areas of dense forest, scrub land and agricultural land. The overall accuracy for supervised images ranged from 91.84 to 94.90%. Projection modeling of ATR area was performed using TerrSet Software (v18.31) for different land use scenario. LULC projection map of 2030 shows that dense forest area will remain the dominant land cover with slight modification in built-up land, agricultural land and water bodies. ATR's land use/ land cover database will help identify the impacts of climate change on forests, water bodies and biodiversity. The results will also be helpful in planning and implementing better management decisions to conserve rich biodiversity of ATR.

Keywords: Achanakmar Tiger Reserve (ATR), Biodiversity, Classification, Accuracy assessment

The Central Indian landscape harbors a globally significant tiger population (Dutta et al 2016). The Achanakmar Tiger Reserve (ATR) is a part of Central Indian Landscape. It is the 32nd tiger reserve of India and third tiger reserve of the state of Chhattisgarh. ATR owes its name to the village called "Achanakmar" (means sudden attack) that lies within the green limits of the Maikal ranges. This protected area has a long history of conservation. In recognition of its uniqueness and richness in biodiversity, Achanakmar was declared as a wildlife sanctuary in 1975 under The Wildlife (Protection) Act, 1972. Later, in 2009 it was declared as a tiger reserve due to the presence of wild tiger population. ATR is also an integral part of Achanakmar Amarkantak Biosphere Reserve (AABR) and is enriched with a rich pool of germplasm. The location of ATR is strategically important for the protection of wildlife biodiversity. It acts as a conduit for movement for tigers from many different tiger reserves and protected areas of the region, thereby promoting genetic exchange and dispersion of wild tiger population. The corridors connect ATR to many important tiger reserves of Central India such as Kanha Tiger Reserve, Pench Tiger Reserve and Bandhavgarh Tiger Reserve (Borah et al 2016, Dutta et al 2016). The ATR is also well connected to the Guru Ghasidas National Park, Phen Wildlife Sanctuary and Bhoramdev Wildlife Sanctuary.

With the advancement of science and technology, application of remote sensing and GIS plays a promising trend in the conservation and management of the environment and natural resources. This technology is widely used by different researchers for habitat assessment of different tiger reserves (Sudeesh & Sudhakar 2012, Salguna et al 2018, Khan et at 2019, Bhardwaj et al 2019). The LULCC is a dynamic and ongoing process (Mondal et al 2016) and changes in different land uses are important for overall environmental monitoring. So far, several studies evaluating floral (Shukla & Singh 2009, Sahu 2011, Singh & Sharma 2017) and faunal biodiversity (Mandal et al 2017, Chandra & Baaz 2018,) have been carried out in the ATR. Few studies have been conducted using geospatial technology of the AABR region (Karwariya et al 2017 and Karwariya & Tripathi 2012). However, little is known about the dynamics of land use/cover change in ATR (Mahato & Singh 2019) and their impact on the surrounding ecosystems. In this study the seasonal variation in land use/cover dynamics of ATR has been examined from 2000 to 2015. Another reason for choosing this period was to study the detailed dynamics of change before and after the declaration of tiger reserve. The present paper also provides the projection of various LULC categories for the year 2030 using geospatial technology.

MATERIAL AND METHODS

Study area: The geographical extent of the Achanakmar Tiger Reserve (ATR) lies between 22°17' and 22°38' North latitudes and 81°31' and 81°57' East longitude (Fig. 1). It covers an area of 914.017 km^2, of which 626.195 km^2 belongs to core zone (critical tiger habitat) and 287.822 km^2 to the buffer zone. It is a hilly-dominated area and its elevation range varies from 305-1080 m above mean sea level (Mahato & Singh 2022). Champion & Seth (1968) categorized forest vegetation into Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous Forest (Roychoudhary 2013). Sal (*Shorea robusta*) is the dominant forest type in the region, followed by Sal mixed forest which includes tree species such as Saja (*Terminalia tomentosa),* Tendu (*Diospyros melanoxylum),* Haldu (*Adina cordifolia),* Bijasal (*Pterocarpus marsupium),* Mahua (*Madhuca indica),* Dhawda *(Anogeissus latifolia),* Teak (*Tectona grandis* (plantation). Bamboo (*Dendrocalamus strictus*) is also found in higher and lower slopes with miscellaneous tree species (Mandal et al 2017). The Maniyari river which originates from Sihawal sagar inside the core zone of ATR, is its lifeline. ATR is the home of Bengal tiger, leopard, striped hyena, Indian gaur and many other endangered mammals. Few indigenous tribal groups of Baiga, Kol, Munda are the inhabitants of the study area.

Data used: Multi-date cloud free satellite data acquired by the Indian Remote Sensing (IRS) satellites 1D and P6 and LANDSAT 8 data (Table 1) were used for visual interpretation, land use/cover identification and classification. Achanakmar

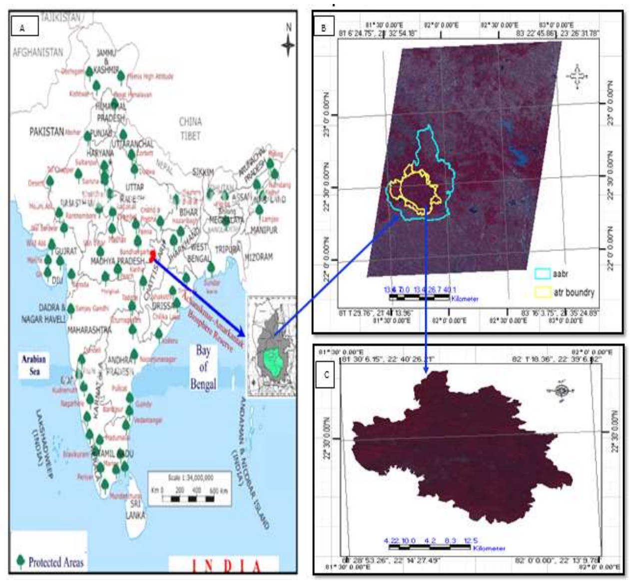


Fig. 1. Location map of ATR A-Protected Areas of India, B-Location of AABR and ATR in IRS LISS III image, C-False Colour Composite image of Achanakmar Tiger Reserve Area

Table 1. Specification of the analyzed satellite data

Satellite	Sensor	Path/row	Month and year of acquisition	Spectral bands (µm)	Spatial resolution (m)	Data source
IRS 1D	LISS 3	102/56	February 2000	0.52-0.59	23.5	NRSC
			October 2000	0.62-0.68		
				0.77-0.86	70.5	
				1.55-1.70		
IRS P6	LISS 3	102/56	March 2008			
			October 2008			
			February 2013			
			December 2013			
LANDSAT 8	OLI	142/44,	February 2015	0.435-0.451		USGS
		142/45	November 2015	0.452-0.512		(https://earthexplorer.usgs.gov)
				0.533-0.590		
				0.636-0.673		
				0.851-0.879		
				1.566-1.651	30	
				2.107-2.294		
				0.503-0.676	15	
				1.363-1.384	30	
				10.60-11.19	100*30	
				11.50-12.51	100*30	
		143/44	February 2015			
		143/45	November 2015			

LISS III- Linear Imaging and Self Scanning, OLI- Operational Land Imager, m-meter, NRSC-National Remote Sensing Centre, USGS-United States Geological Survey

Tiger Reserve boundary has been obtained from the Chhattisgarh Forest Department. The preliminary interpretation of the study area is based on topographical sheets. The Survey of India (SOI) topographic maps of 64F10, 64F11, 64 F14 and 64F15 at a scale of 1:50,000 published by SOI, Dehradun have been used for digitalization.

The imageries obtained were registered in the Universal Transverse Mercator (UTM) map projection with the WGS-84 datum, zone 43 N. Before classifying the imageries, the satellite data were reprojected into the Projected Coordinate System (PCS) to maintain consistency within the generated database. Observations made from satellite data were verified with ground thruthing and surveys in the study area. IGIS software version 1.0 was used for image pre-processing (layer stack, subset of the study area and image enhancement) and ERDAS IMAGINE version 2013 software has been used for image classification and accuracy assessment of the classified images. TerrSet software v18.31 was used for projection modelling.

Climate: The ATR area experiences tropical climate. The hottest month is May, when the maximum temperature raise to 46.7°C and drops to as low as 2°C in the winter months. The average annual precipitation of ATR is above 1200 mm and maximum precipitation falls in the month of July, August and September

Pre-processing of satellite data: The cloud free data of spring and autumn seasons have been used for the present study (Table 1). The satellite imageries acquired on different dates with path 102 and row 56 contain the spectral bands in separate files in Geo Tiff format. The files of required bands are stacked into one image using layer stacking option of the IGIS software. LANDSAT images downloaded from USGS websites having path-row 142-44, 142-45, 143-44 and 143-45 were mosaicked in GIS software. The clipping of the study area was performed from satellite imageries using the image subset function. All imageries were subjected to geometric rectification, radiometric calibration and atmospheric correction. Visual interpretations of imageries were performed on False Color Composites (FCC) using image elements such as tone, texture, pattern and location.

Image processing: Image processing and performing supervised image classification help extract information from imageries (Islam et al 2018). In present study, spring and autumn seasons were chosen to map and monitor the seasonal and temporal variation in different land use/ cover classes. Supervised classification of imageries was performed in ERDAS software v 2013 using a maximum likelihood classifier followed by accuracy assessment. A total of seven classes were identified: Dense Forest, Open Forest, Scrub Land, Agricultural Land, Built-up Land, Water Bodies and River Bed. About 100 ground locations were randomly selected in the classified imageries and accuracy assessment of the supervised imageries was performed using the Google earth synchronization tool. It includes the assessment of the overall accuracy, kappa statistics, producer's accuracy and user's accuracy of the LULC classes for the supervised imageries for years 2000, 2008, 2013 and 2015 respectively. An error matrix and kappa statistics were generated from the reference and classified data from the reports section of the software.

Change detection: For each LULC categories, the magnitude of change was assessed by subtracting the area covered in the second year from the initial year as illustrated in the equation (1)

Magnitude of change = magnitude of new year – magnitude of previous year (1)

The annual rate of change for each LULC categories was evaluated by subtracting the final year to initial year, which was further divided by number of study year i.e. 2000-2008, 2008-2013, 2013-2015 and 2000-2015 respectively using the equation (2)

$$\text{Annual rate of change} = \frac{\text{Final year} - \text{initial year}}{\text{Number of years}} \quad (2)$$

Projection modeling: Projection modeling of ATR area was performed to assess the impact of land use change on the study area. The modeling was done with the Land Change Modeler (LCM) of the TerrSet Software (Version 18.31) for different land use scenarios. The generated LULC maps were used to predict the future LULC projection map for the year 2030.

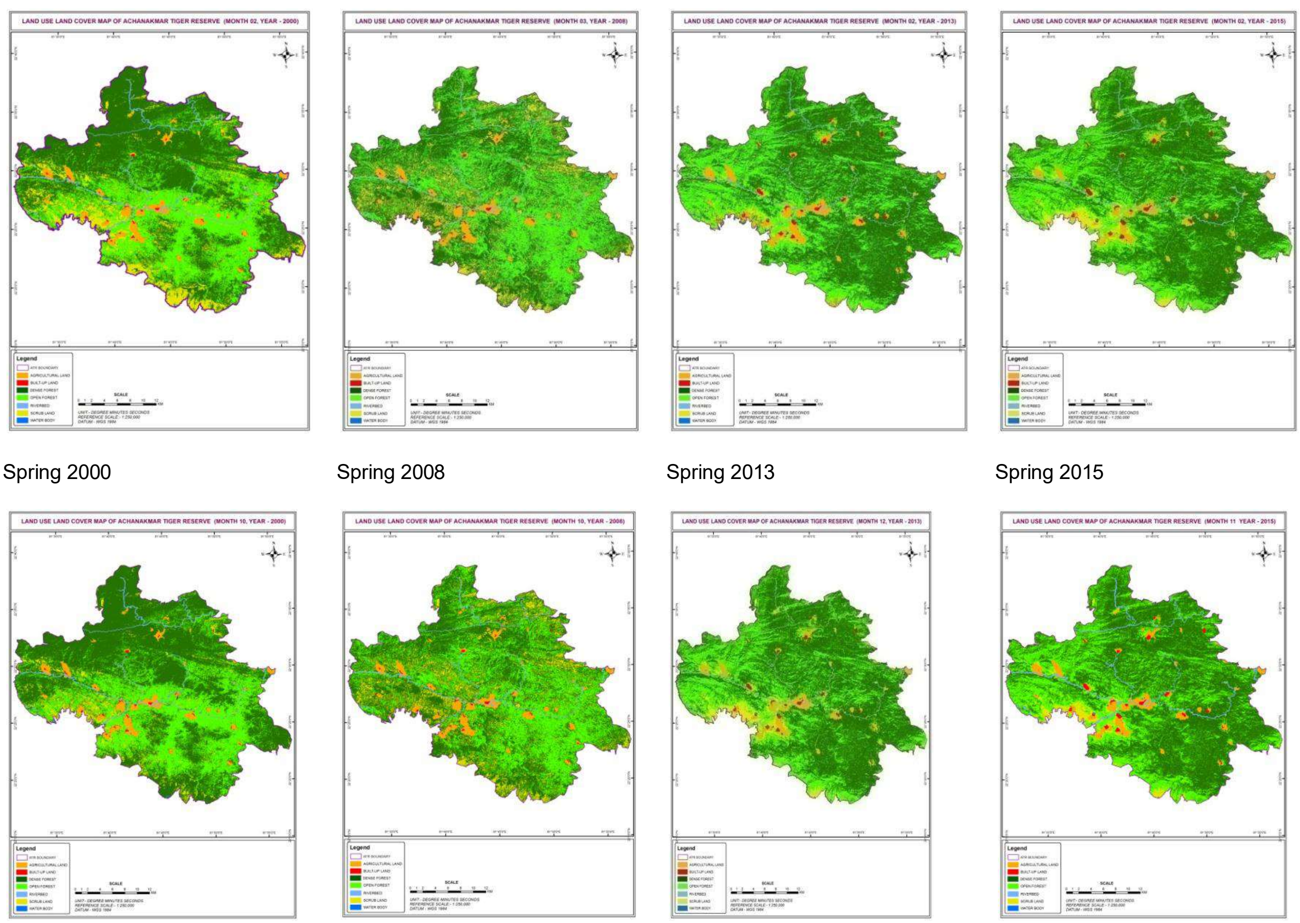
RESULTS AND DISCUSSION

LULC dynamics of ATR during spring season: The overall change assessment from 2000 to 2015 shows changes in the areas covered by different LULC classes (Table 2). The year 2000 is considered as a base year for the change detection and analysis. The main changes over the 16 year period are the 3.53 % reduction in scrub land, which has been converted to open forest cover by 3.20 % between 2000 and 2015. Slight decline in dense forest cover by 0.49 % and agricultural land area by 0.01% has been recorded during this time. Another positive change accounts from the increase in built-up area by 0.38 %. The areas covered under water bodies during spring season increased by 0.12% compared to 2000, which is due to good rainfall and increased conservation measures during recent years. The dense forest area was highest during 2000. The data also coincides with extreme climate variables in 2008 that led to the reduction in dense forest area in 2008, which also reversed in 2013.

Dynamics of land use/cover of ATR during autumn season: The overall assessment of change from 2000-2015 depicts that the dense forest area remained the dominant cover type with around 56% of the area (Fig. 2). During the autumn season, dense forest area increased by 0.09 %. The open forest area covered 32.11 % (293.49 km^2) in 2000 and increased to 34.31 % (313.96 km^2) during 2015. Scrub land area decreased by 2.85%. The built-up land area, which was 1.92 km^2 (0.21 %) in 2000, gradually increased to 2.10 km^2 (0.23 %), 4.11 km^2 (0.45 %) and 5.39 km^2 (0.59%) during the year 2008, 2013 and 2015. Utilized agricultural land area decreased by 0.03 % over a period of 16 years. The areas covered by water bodies and riverbeds showed variations depending on the precipitation received in the study area.

The general dynamics of change in the land use/ cover pattern of ATR was assessed based on the data presented in the Table 2 and magnitude of change and annual rate of change is illustrated in Table 3. The relative changes showed an irregular pattern in this study area from 2000-2015. Land use change from 2000-2008 showed slight negative changes in dense forest, scrub land and water bodies. This scenario showed a better trend in the period 2008-2013. Scrub land area had decreased by about 3.53 and 2.85% during spring and autumn between 2000 and 2015. The built-up land area covered 0.21% in 2000, increased to 0.59 % by 2015. The extent of change in area covered by water bodies varies from year to year due to variation in temperature and precipitation in the region. Riverbed area also showed fluctuation depending on the precipitation and surface runoff of the region.

Accuracy assessment: The highest accuracy for supervised imageries was reported for the autumn season (94.90% accuracy) for 2013 and the lowest for the same year during spring season (91.84% accuracy) (Table 4). The Kappa coefficient of > 0.90 for all seasons and years indicates that an observed classification of the order of 90%



Spring 2000 Spring 2008 Spring 2013 Spring 2015

Autumn 2000 Autumn 2008 Autumn 2013 Autumn 2015

Fig. 2. LULC map of ATR derived from satellite imageries for the year 2000, 2008, 2013 and 2015 during spring and autumn season

agrees almost perfectly. User accuracy of the dense forest and open forest classes was consistently high, ranging from 71.43 % to 100%. The producer's accuracy for the same ranged from 83.33 to 100%. The analysis shows that the classes such as dense forest, open forest, agricultural land and riverbeds were mapped unambiguously due to their distinct pattern and compactness. While the classes like scrub land and water bodies showed a slight ambiguity in classification. Factors contributing to misclassification include similar spectral information, spatial resolution of the satellite imagery, class ranges smaller than the spatial resolution of IRS P6-LISS III data etc. (Kar et al 2018).

Projected land use/ land cover map for the year 2030: The projected LU/LC for the year 2030 (Fig. 3) was generated

Table 2. Category wise LULC distribution of ATR during spring and autumn based on time frame data (2000-2015)

LULC classes	Season	2000		2008		2013		2015	
		Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Dense forest	Spring	518.51	56.73	507.73	55.55	516.14	56.47	514.03	56.24
	Autumn	514.22	56.26	508.55	55.64	513.12	56.14	515.04	56.35
Open forest	Spring	283.80	31.05	310.94	34.02	312.13	34.15	313.05	34.25
	Autumn	293.49	32.11	308.84	33.79	313.59	34.31	313.96	34.35
Scrub land	Spring	62.33	6.82	44.88	4.91	31.81	3.48	30.07	3.29
	Autumn	54.02	5.91	44.51	4.87	35.01	3.83	27.97	3.06
Agricultural land	Spring	31.35	3.43	31.90	3.49	31.08	3.40	31.26	3.42
	Autumn	31.72	3.47	31.90	3.49	31.17	3.41	31.44	3.44
Built-up land	Spring	1.92	0.21	2.10	0.23	4.11	0.45	5.39	0.59
	Autumn	1.92	0.21	2.10	0.23	4.11	0.45	5.39	0.59
Water body	Spring	1.92	0.21	1.10	0.12	3.56	0.39	3.02	0.33
	Autumn	2.38	0.26	1.10	0.12	3.38	0.37	3.20	0.35
River bed	Spring	14.17	1.55	15.36	1.68	15.17	1.66	17.18	1.88
	Autumn	16.27	1.78	17.00	1.86	13.62	1.49	17.00	1.86

Table 3. Magnitude and annual rate of change of LULC classes (2000-2015)

LULC classes	Season	Magnitude of change				Annual rate of change			
		2000-2008	2008-2013	2013-2015	2000-2015	2000-2008	2008-2013	2013-2015	2000-2015
		Area (%)	Area %)	Area (%)	Area (%)	Area (%)	Area (%)	Area (%)	Area (%)
DF	Spring	(-)1.18	(+)0.92	(-)0.23	(-)0.49	(-)0.131	(+)0.153	(-)0.077	(-)0.031
	Autumn	(-)0.62	(+)0.50	(+)0.21	(+)0.09	(-)0.069	(+)0.083	(+)0.070	(+)0.006
OF	Spring	(+)2.97	(+)0.13	(+)0.10	(+)3.20	(+)0.330	(+)0.022	(+)0.033	(+)0.200
	Autumn	(+)1.68	(+)0.52	(+)0.04	(+)2.24	(+)0.187	(+)0.087	(+)0.013	(+)0.140
SL	Spring	(-)1.91	(-)1.43	(-)0.19	(-)3.53	(-)0.212	(-)0.238	(-)0.063	(-)0.221
	Autumn	(-)1.04	(-)1.04	(-)0.77	(-)2.85	(-)0.116	(-)0.173	(-)0.257	(-)0.178
AL	Spring	(+)0.06	(-)0.09	(+)0.02	(-)0.01	(+)0.007	(-)0.015	(+)0.007	(-)0.001
	Autumn	(+)0.02	(-)0.08	(+)0.03	(-)0.03	(+)0.002	(-)0.013	(+)0.010	(-)0.002
BL	Spring	(+)0.02	(+)0.22	(+)0.14	(+)0.38	(+)0.002	(+)0.037	(+)0.047	(+)0.024
	Autumn	(+)0.02	(+)0.22	(+)0.14	(+)0.38	(+)0.002	(+)0.037	(+)0.047	(+)0.024
WB	Spring	(-)0.09	(+)0.27	(-)0.06	(+)0.12	(-)0.010	(+)0.045	(-)0.020	(+)0.008
	Autumn	(-)0.14	(+)0.25	(-)0.02	(+)0.09	(-)0.016	(+)0.042	(-)0.007	(+)0.006
RB	Spring	(+)0.13	(-)0.02	(+)0.22	(+)0.33	(+)0.014	(-)0.003	(+)0.073	(+)0.021
	Autumn	(+)0.08	(-)0.37	(+)0.37	(+)0.08	(+)0.009	(-)0.062	(+)0.123	(+)0.005

DF-Dense Forest, OF-Open Forest, SL-Scrub Land, AL-Agricultural Land, BL- Built up Land, WB- Water bodies, RB- River Beds, PA- Producer's Accuracy, UA- User's Accuracy, (+) sign denotes increase and (-) sign denotes decrease of change area (%) between 2000-2015 using previous supervised imageries. The projected LULC map shows that the dense forest area will cover 55.89 % (510.86 km^2). The Open Forest area will occupied 34.37 % (314.1 km^2), followed by agricultural land (3.93 %), scrub land (3.55 %), river bed (1.36 %), built up land (0.52%) and water body (0.37%). The transition probability of LULC changes in 2030 is presented in Table 5.

In the present study, spatio-temporal dynamics of LULC pattern of ATR for the years 2000, 2008, 2013 and 2015 were assessed using remote sensing and GIS technology. Rathore et al (2012) reported that land use and land cover changes are important variable factors in tiger movement as they affect the distribution of prey species, particularly when moving through a human-dominated matrix. The ATR area is predominantly covered by dense forest, followed by open forest, scrub land, agricultural land, river beds, built-up land and water bodies. Dense forest land occupied more than half of the reserve area and a slight reduction in this category was observed. Similar findings have been reported in the Kanha Tiger Reserve (Devi et al 2018) and the Pench-Satpura wildlife corridor (Banerjee et al 2020). Open forest cover was the second most common land cover type in the ATR and showed an increasing trend over a 16-year period. This is due to conversion from scrub land to open forest area, which is due to the gradual succession and changing climatic variables of ATR. Bhardwaj et al (2019) also observed that

Table 4. Accuracy and kappa statistics for 2000, 2008, 2013 and 2015 supervised imageries

LULC classes	Year	2000		2008		2013		2015	
	Season	S	A	S	A	S	A	S	A
DF	PA (%)	93.75	100.00	100.00	100.00	100.00	92.31	86.67	90.91
	UA (%)	96.77	100.00	100.00	100.00	71.43	85.71	92.86	71.43
OF	PA (%)	100.00	100.00	100.00	100.00	83.33	84.62	76.92	83.33
	UA (%)	95.45	100.00	100.00	100.00	71.43	78.57	71.43	71.43
SL	PA (%)	76.92	100.00	81.25	90.91	70.00	87.50	85.71	73.68
	UA (%)	90.91	57.14	92.86	71.43	100.00	100.00	85.71	100.00
AL	PA (%)	100.00	100.00	92.86	77.78	100.00	100.00	100.00	100.00
	UA (%)	77.78	100.00	92.86	100.00	100.00	100.00	100.00	100.00
BL	PA (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	UA (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
WB	PA (%)	100.00	57.14	100.00	100.00	100.00	100.00	100.00	100.00
	UA (%)	100.00	66.67	92.86	100.00	100.00	100.00	100.00	100.00
RB	PA (%)	100.00	100.00	91.67	92.31	100.00	100.00	100.00	100.00
	UA (%)	100.00	100.00	78.57	85.71	100.00	100.00	100.00	100.00
Overall accuracy	Spring	94.57%		94.90 %		91.84 %		92.86%	
	Autumn	94.57%		93.88%		94.90%		0.9167	
Overall Kappa statistics	Spring	0.9312		0.9405		0.9048		91.84%	
	Autumn	0.9314		0.9286		0.9405		0.9048	

DF-Dense Forest, OF-Open Forest, SL-Scrub Land, AL-Agricultural Land, BL- Built up Land, WB- Water bodies, RB- River Beds, PA- Producer's Accuracy, UA-User's Accuracy

Table 5. Transition probability of LULC changes in 2030

LU/LC classes	Scrub land	River beds	Dense forest	Built up land	Open forest	Agriculture land	Water body
Scrub land	0.6782	0.0155	0.0825	0.0257	0.1356	0.0560	0.0064
Riverbeds	0.2930	0.1432	0.2710	0.0209	0.2124	0.0518	0.0077
Dense forest	0.0997	0.0048	0.8695	0.0039	0.0107	0.0094	0.0020
Built up land	0.0110	0.0081	0.0044	0.8737	0.0021	0.0678	0.0327
Open forest	0.0014	0.0038	0.0011	0.0058	0.9738	0.0135	0.0006
Agriculture land	0.0269	0.0244	0.0125	0.1950	0.0067	0.6699	0.0644
Water body	0.3683	0.0082	0.1105	0.01	0.0366	0.0211	0.4454

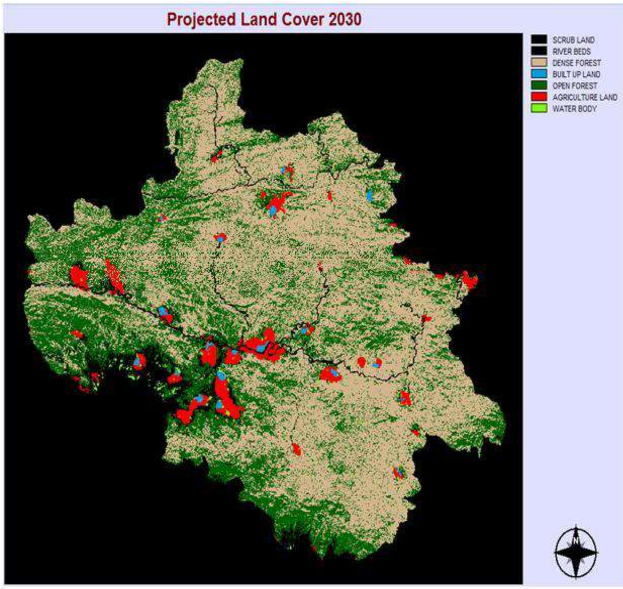


Fig. 3. Projected LU/LC map for 2030

open forest area increased by 5.76% and dense forest area decreased by 3.83% over a ten-year period (2007-2016) in Sariska Tiger Reserve, Rajasthan. Kumari et al (2020) also reported similar findings from the non-forested area of the Palamau Tiger Reserve increased by 10.40% between 1975 and 2015 due to anthropogenic impacts. In ATR, the agricultural area covered an area of approximately 3%, a similar study was reported from Nagarjunasagar-Srisailam Tiger Reserve, Andhra Pradesh, India, where the agricultural area covered 4.21% (Sudeesh & Sudhakar 2012). The area in this category was larger in the autumn months than in the spring because rainfed agriculture is practiced in the region. The slight decline in agricultural land may also be due to the relocation of six core villages from ATR that may be involved in agricultural activities. Because a very small percentage of the ATR area has agricultural land, conservation efforts may not be directly hampered. Damania et al (2003) reported that land use for agricultural purposes has negative impacts on tiger conservation.

The built-up land area witnessed a slight increase. Hund et al (2013) and Prasad et al (2012) reported that the rate of population growth and its needs, along with its natural and economic drivers, affect the conversion of land cover to land use in an area. Salghuna et al (2018) observed that in Kondapalli Reserve Forest (KRF), Andhra Pradesh, where the built-up land area increased from 1.11% in 1990 to 16.84% in 2017. This drastic increase in built-up areas near KRF is due to population growth, urban expansion and other developmental activities. The region's indigenous flora and fauna is threatened by the sprouting of built-up and inhabited areas in and around the forest (Ye et al 2015). The area covered by water bodies in ATR increased by 0.12 % in spring and by 0.09% in autumn during the 16-year period. This is due to the construction of various waterholes, anicuts etc. to conserve and capture water. The river bed occupies an area of about 1.5 % and its area varies with the rainfall in the region. In contrast, the water body in Sariska Tiger Reserve covered an area of 0.93% in 2007, which decreased to 0.32% by 2016 (Bhardwaj et al 2019).Conservation and protection of the tiger requires that its habitat be protected so viable populations can thrive and reproduce. Significant changes in the LULC through core village shifts and grassland development can create favorable habitat for ungulate species from ATR, thereby increasing the prey population for large carnivorous mammals such as tigers and leopards (Mahato & Singh 2019). Therefore, relocation of core villages, stringent restrictions on traffic and tourist movement in the core zone, regulation of developmental projects along corridors connecting other tiger reserves, and involvement of buffer and transition zone residents may be helpful in achieving the conservation goals of ATR.

CONCLUSION

ATR is recognized as one of the regions with the greatest potential for in situ conservation of tigers. Dense forests are the predominant type of land cover, followed by open forests, scrub land, agricultural land, river beds, built-up areas and water bodies. A slight variation in temporal and seasonal LULC classes was observed at ATR. The season and climate play a very important role in reflecting properties of the earth's surface, which are crucial for remote sensing applications. The present study demonstrates the potential of satellite-based temporal data and GIS techniques in analyzing the spatio-temporal dynamics of the ATR region for the management of land resources on a sustainable basis. The dynamics of LULC changes and their consequences are essential for better study and implementation planning for development projects, as well as for the sustainable survival of the biodiversity and hydrology of the area. The information gained from LULC change detection will help provide better options for effectively managing land and water resources. ATR's supervised classification depicts that dense forest is the dominant land cover type, covering approximately 56% of the area, followed by open forest, scrub land, agricultural land, river bed, built up areas and water bodies. Overall, the scrub land area decreased which are likely to be converted into open forest. The built-up land area has also increased in the period of 16 years. During the study period, water bodies have increased and require more conservation measures as the ATR area faces water shortages during the dry summer months due to the seasonal nature of the river Maniyari and its tributaries.

The ATR projection model for 2030 shows that dense forest area will cover 55.89% followed by open forest area (34.37%). This study has direct application to the conservation not only of ungulates but implicitly of large carnivores as well. The present research may provide a database of land use/ cover on spatio-temporal basis and contribute to the improvement of conservation and management plans in the near future.

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