VOLUME 8 (SPL 1) 2022

ISSN 2454-3055

Manuscripts under Special issue are published under the Theme
"ADVANCES IN BIOLOGICAL SCIENCES"

Guest Editor: Dr. S. Mohanasundaram
Assistant Guest Editor: Dr. S.S. Syed Abuthahir

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 8, Spl 1, 29-40 (2022)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Forest Cover Change Detection using Geospatial Technologies in Chandaka National Park, Odisha, India

Joshi K.[1*] and Sethy K.M.[2]

[1]Centre of Environment, Climate Change and Public Health (ECCPH), Utkal University, Bhubaneswar, Odisha, India
[2]Department of Geography, Utkal University, Bhubaneswar, Odisha, India

**Corresponding Author*

Received: 1st December, 2022; **Accepted:** 15th December, 2022; **Published online:** 21st December, 2022

https://doi.org/10.33745/ijzi.2022.v08i0s1.004

Abstract: Forest plays a vital role in carbon sequestration and climate regulation. A crucial tool for managing forest, particularly in protected regions, is keeping track of how the land cover changes in natural places. Using geospatial approaches, such as remote sensing and geographic information system (GIS), the present study has revealed spatio-temporal changes in land use categories and forest cover in the Chandaka National Park of Odisha, India, throughout the period of 1980-2020. The Landsat, LISS III and Sentinel satellite images of the year 1980, 2000 and 2020 were utilized respectively to map five land use land cover categories i.e. deciduous broadleaf forest, crop land, mixed forest, scrub land and water bodies in this preserved area. The satellite images were classified using a Supervised Classification method using Maximum Likelihood algorithm and ground control points (GCPs) were used for the spatial statistical analyses. The overall accuracies of the classification method in land cover categories in year 1980, 2000 and 2020 were 90.45%, 92.76% and 94.68%, respectively. Elsewhere, in order to study land use land cover (LULC) change and loss in forest of the Chandaka National Park, LULC classification, per-pixel scales post classification and self-knowledge on the LULC change process were used. The LULC change detection results showed that deciduous broadleaf forest decreased from 179.01 sq. km (76.66%) in 1980 to 132.75 sq. km (56.85%) in 2020, while mixed forest cover increased by 8.17 sq. km (3.50%) in 1980 to 38.84 sq. km (16.63%) in 2020. Crop land, Scrub land and Water bodies were also increased by 3.34%, 3.27% and 0.07%, respectively. Two significant change processes in the area are the logging activities in several places for timber and the conversion of natural forests with plantation. Agriculture expansion in the forest's periphery is linked to the dramatic decline in forest cover change. The decline in forest cover is also a result of the production of charcoal and lumber exploitation. Overall, our findings indicated that more public awareness and participatory forest management are necessary to preserve Chandaka National Park. This study highlights the use of geospatial technologies in understanding the changes in LULC in the Chandaka National Park.

Keywords: Forest management, Tropical forest, Land use land cover, Remote sensing, Geographic information systems

Citation: Joshi K. and Sethy K.M.: Forest cover change detection using geospatial technologies in Chandaka National Park, Odisha, India. Intern. J. Zool. Invest. 8(Spl 1): 29-40, 2022.

https://doi.org/10.33745/ijzi.2022.v08i0s1.004

This is an Open Access Article licensed under a Creative Commons License: Attribution 4.0 International (CC-BY). It allows unrestricted use of articles in any medium, reproduction and distribution by providing adequate credit to the author (s) and the source of publication.

Introduction

Forests are very important ecosystems that provide material and intangible services to living organisms such as carbon sinks, increased regional biodiversity, environmental services, forest-based economies and functions. Forest plays an important role in climate change regulation, therefore their loss is treated seriously. Intensive and rapid deforestation has heightened global awareness of the need for sustainable forest resource management in recent decades (Geist and Lambin, 2002). Globally, the amount of forest land has decreased by three per cent from 1990 to 2015 (4128 to 3999 million hectares) (Keenan *et al*., 2015). Because of the reduction in ecosystem health, the loss of forest resources poses a substantial danger to the accomplishment of the Millennium Development Goals (MDGs). Given the constant and rapid decline of natural and planted forests, as well as the resulting environmental and health issues, it is critical that this land use change dynamics be properly monitored and assessed (Deng *et al*., 2013). A lot of research has been done to see how much land use land cover (LULC) has altered through time in different countries. Forest is the land cover class most threatened by anthropogenic deforestation among the extant land uses (Fokeng *et al*., 2020). Change detection is a useful technique for determining the range of land use land cover conversion over time. Comprehending of the features, scope and change in land use land cover (LULC) pattern is a critical component of decision-making. Land use change detection has been a more essential consideration for environmental management in recent years (Tsuyuki, 2018). Due to the increasing global population and the development of science and technology, natural resources are being overused in developing countries for the benefit of economic activity. The principal drivers of deforestation are spread of agriculture into forested areas, lumber logging, charcoal making and firewood collecting (Declee *et al*., 2014). For sustenance, small-scale farmers gather fire wood, building production materials, wild edibles and other resources of forest. Forest conversion to agricultural fields is likely to continue (Pellikkaa *et al*., 2018; Nerfa *et al*., 2020).

Change in LULC can have an impact on the availability of ecosystem services and human well-being (Olson *et al*., 2008; Rimal *et al*., 2019). LULC has the prospective to affect biotic processes and ecosystem services. Anthropogenic activities modify significant areas of tropical forests every year (Malhi *et al*., 2014). Tropical forest loss is regarded as the greatest archetypal example of LULC change because of the enormous detrimental effects of forest loss on climate change and ecosystem service provisions (Foley *et al*., 2005). Geographic information systems (GIS) and remote sensing (RS) have shown to be among the most precise methods for determining the scope and pattern of land cover changes over time (Geng *et al*., 2015; Sekela and Manfred, 2019).

Remote sensing data can hastily capture the state of land use land cover and offer a great source of data from which efficient LULC and changes can be composed and evaluated (Pradhan *et al*., 2008). Thus, remote sensing is often utilized to detect and observe land use at different intervals and scales, while GIS gives a versatile framework for gathering, storing, presenting and evaluating digital data required for the land cover change detection (Solefack *et al*., 2018). However, in Chandaka National Park, Odisha, India, there is a general shortage of accurate and current LULC maps, particularly for forest and other natural resources (Gibson *et al*., 2018). This study focuses on the Chandaka Forest in Odisha's Khordha and Cuttack districts. The removal of forest products resulted in fast changes in land cover patterns in these locations (Muhati *et al*., 2018). Rapid population expansion, hunting and timber logging activities all have a complex ecological influence on forest ecosystems, putting this forest under a lot of stress. To discourse the issues of global climate change, the forest ecosystem's vulnerability, resilience and adaptive capacity, as well as improve natural resource management and monitoring, fast, precise and updated LULC change information is necessary (Salghuna *et al*., 2018).

The use of satellite images to evaluate forest change over time is becoming a helpful tool for determining the degree of damage to ecosystems. The use of a digital repository of remotely sensed data to research antique changes in forest cover and narrate the spatiotemporal extent of these changes to different ecological and human causes is a fantastic opportunity (Dewan *et al*., 2012; Mensah *et al*., 2019). Combining the remote sensing and GIS techniques, this study intends to create a forest map for different years in order to detect, measure and analyze land cover changes that have happened in Chandaka Forest Reserve Area in Odisha State, India over the last four decades (1980-2020). The precise objectives are to: (1) detect changes that happened throughout the time period concealed by the satellite images, and (2) calculate the extent and degree of changes that occurred during the research time period.

Materials and Methods

Study area:

The Chandaka National Park differs from other protected area in that it is the state's sole protected area that is adjacent to a metropolis. The sanctuary is located on the outskirts of the state capital, approximately 15 km from the city, and covers an area of 193.39 sq. km, with 7 reserved forest blocks, 6 planned reserved forest blocks, 5 delimited protected forest blocks, private holdings and government waste land/forest land under the Revenue Department administration. Khordha and Cuttack are the two districts that make up the Sanctuary. The Chandaka National Park is located among longitudes 85^0 34' 42" E to 85^0 49' 27" E and latitudes 20^0 12' 29" N to 20^0 26' 18" N, and is concealed by Toposheets No. 73H/11, 12 and 15 of Survey of India. The Chandaka National Park is fragmented of 19 Forest blocks with 5 Reserve forest blocks, 4 undelineated protected forest blocks and 10 Protected forest blocks. Gadjit, a revenue village within the National Park, is made up of five settlements: Dholkath, Nuakua, Behenta Sahi, Dahanigadia and Pithakhai. The forests cover four civil subdivisions and 61 communities in the surrounding area. The forest is divided into the following types based on the composition of species and locations with the most prevalent species: Teak Plantation Forest (TPF), Semi-evergreen Forest (SEF), Moist Bamboo Brakes (MBB), Degraded Thorny Shrubby Forest (DTSF), Northern Secondary Moist Mixed Deciduous Forest (MMDF) and Peninsular Sal Forest (PSF). Mixed tropical moist deciduous and dry deciduous forests dominate the vegetation, with Sunari, Naguari, Kantaikoli, Kochila, Sal, Teak (Plantation) and other species dominating. Elephant, hyena, leopard, wild boar, wild dog, ratel, spotted deer, pangolin, red jungle, pea fowl and other wild creatures thrive in planted teak and bamboo. 120 bird species which include migratory and resident birds, 300 species of plants, 30 mammalian species and 27 species of reptiles use the natural water body and woodlands as a breeding site. The study area located in the map is displayed in Figure 1.

Satellite Data Description:

Three years multi-temporal satellite imageries (Landsat of 1980, LISS III of 2000 and Sentinel imagery of 2020) were used for the study (Table 1). For LULC classification, satellite data were downloaded from the United States Geological Survey (USGS), Global Land Cover Facility (GLCF) and National Remote Sensing Centre (NRSC). Table 1 shows the Satellite data information used in this study. To gather more information, field observations were made. For ground verification, a global positioning system (GPS) and topography maps at a resolution of 1:50,000 were used.

Image Classification Method:

The main aim of the image classification approach is to automatically classify each pixel in the satellite images into different LULC classes in order to extract useful thematic information (Boakye *et al*., 2008). One of the most popular techniques for obtaining thematic data from

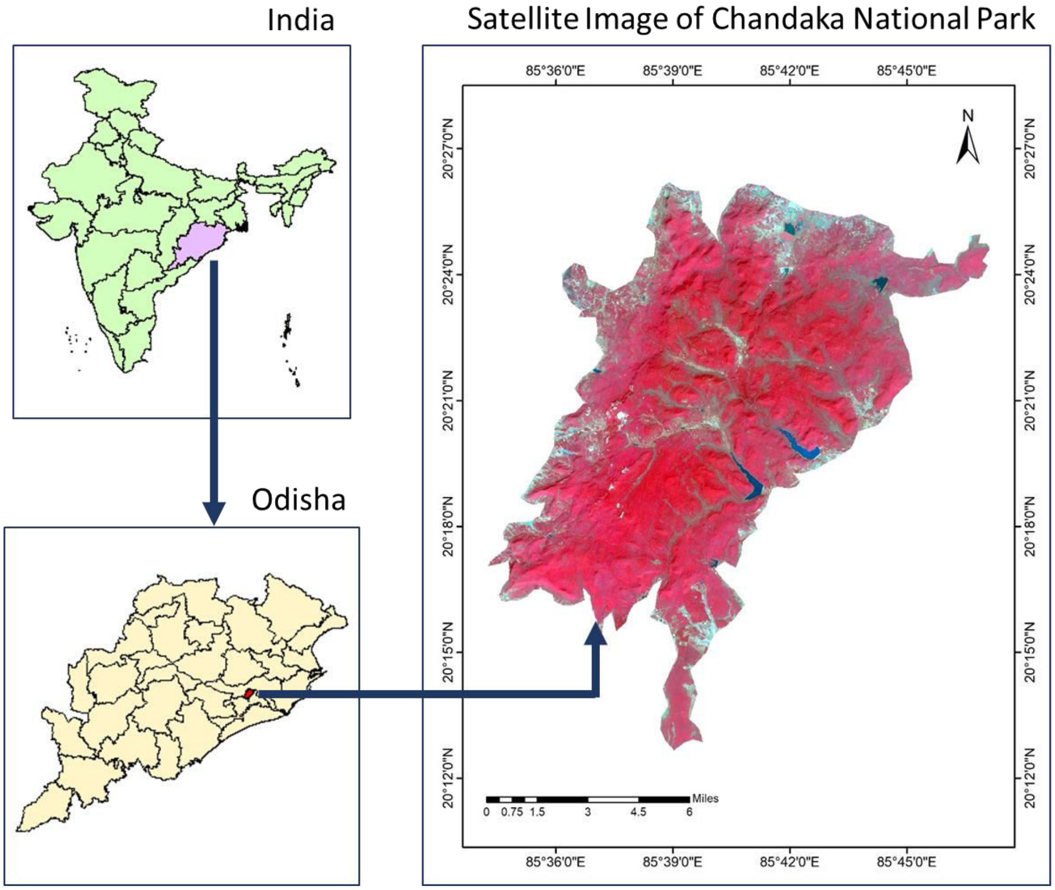

Fig. 1: Map of the Study Area Chandaka National Park.

Table 1: Satellite data information

Type of Data	Date of Acquisition	Spatial Resolution	Source
Landsat	18/03/1980	30 m	GLCF
LISS-III	12/03/2000	23.5 m	NRSC
Sentinel	25/03/2020	10 m	USGS

satellite images is multi-spectral image classification method (Sarma *et al*., 2008). Image pre-processing with band ratio, haze reduction i.e. radiometric correction, geometric correction and post-classification of 1980, LISS III of 2000 and Sentinel imagery approach were conducted to rectify the characteristics of surface features reflectance. Then, the classified LULC maps were developed from Landsat of 2020.

The classification of images was done using a hybrid classification strategy that combined supervised and unsupervised methods. The hybrid classification mode was selected for the image classification because it increases classification efficiency and accuracy which includes feature identification using spatial and spectral pattern recognition (Lillesand and Kiefer, 2000). From various image classification algorithms,

Table 2: Land use land cover classification scheme

Land Use Land Cover Class	Description
Deciduous Broadleaf Forest	Areas primarily covered by mature broad-leaved trees that shed all their leaves during one season, shrubby plants and other plants growing close together
Crop Land	Areas allotted to rain fed and irrigated cultivation, including fallow plots, cultivated land mixed with some bushes, trees and the scattered rural settlements included within the cultivated fields
Mixed Forest	Areas covered by trees forming closed or nearly closed canopies; Forest; Plantation forest
Scrub Land	Land covered by small trees, bushes, and shrubs, in some cases mixed with grasses; less dense than forests
Water bodies	Areas covered by manmade small dams, seasonal water bodies and permanent water bodies

supervised classification approach using maximum likelihood was used by taking 100 sample training area for five major land use classes (20 sample points for each land use class). Interpretation of expert visualization approach was also followed to classify the satellite images in various land use classes.

The LULC classes include deciduous broadleaf forest, crop land, scrub land, mixed forest and water bodies (Table 2). The processing of satellite images and LULC changes analyses were performed using ArcGIS 10.5 and ERDAS Imagine 2016 software.

Trend analysis was done to determine the area's rate of change (area covered or area in which changes occur over the period of time for the study).

Trend Analysis: $\Delta LULC = L2 - L1$ ....(1)

Where L2 = final year; L1 = initial year

For each LULC class, the rate of change was computed using the formula given below:

Rate of Change = $\left(\frac{(L2-L1)}{t}\right) \times 100$ ....(2)

Where t = time; L2 = final year; L1 = initial year

Post-Classification:

Accuracy assessment was done for the post classification. The accuracy assessment is crucial because it informs us of how accurately the associated classified image reflects the reality on the ground. In order to generate quantitative assessments of the LULC maps' classification accuracy, sample areas from each output representing various LULC categories were chosen at random. An error matrix or confusion matrix was utilized to express the classification accuracy for each dataset and classifier, and it was from this the overall accuracy, producer's accuracy, user's accuracy and Kappa statistics were obtained. In this study, the integrated approach provided better accuracy for the image classification (Olofsson *et al*., 2013; Jeon *et al*., 2014).

The overall accuracy was calculated using the division of the total correctly classified pixels and the total sample points (Total reference pixels) (Rogan *et al*., 2002). The Kappa coefficient, which was defined as a statistical extent of accuracy and has a range between 0 to 1, deals with the image classification is how much better compared to randomly assigned class values for each pixel (Miller and Yool, 2002).

Change Detection Analysis:

After calculations and analyses of the land use land cover classes from 1980 to 2020 images have been completed, the process of change detection in land use land cover classification is carried out. A LULC change matrix, which represents the level of land cover change from one land use class to the other, was constructed by using a cross-tabulation module detection approach to identify LULC change in ArcGIS (Quan *et al*., 2019). The

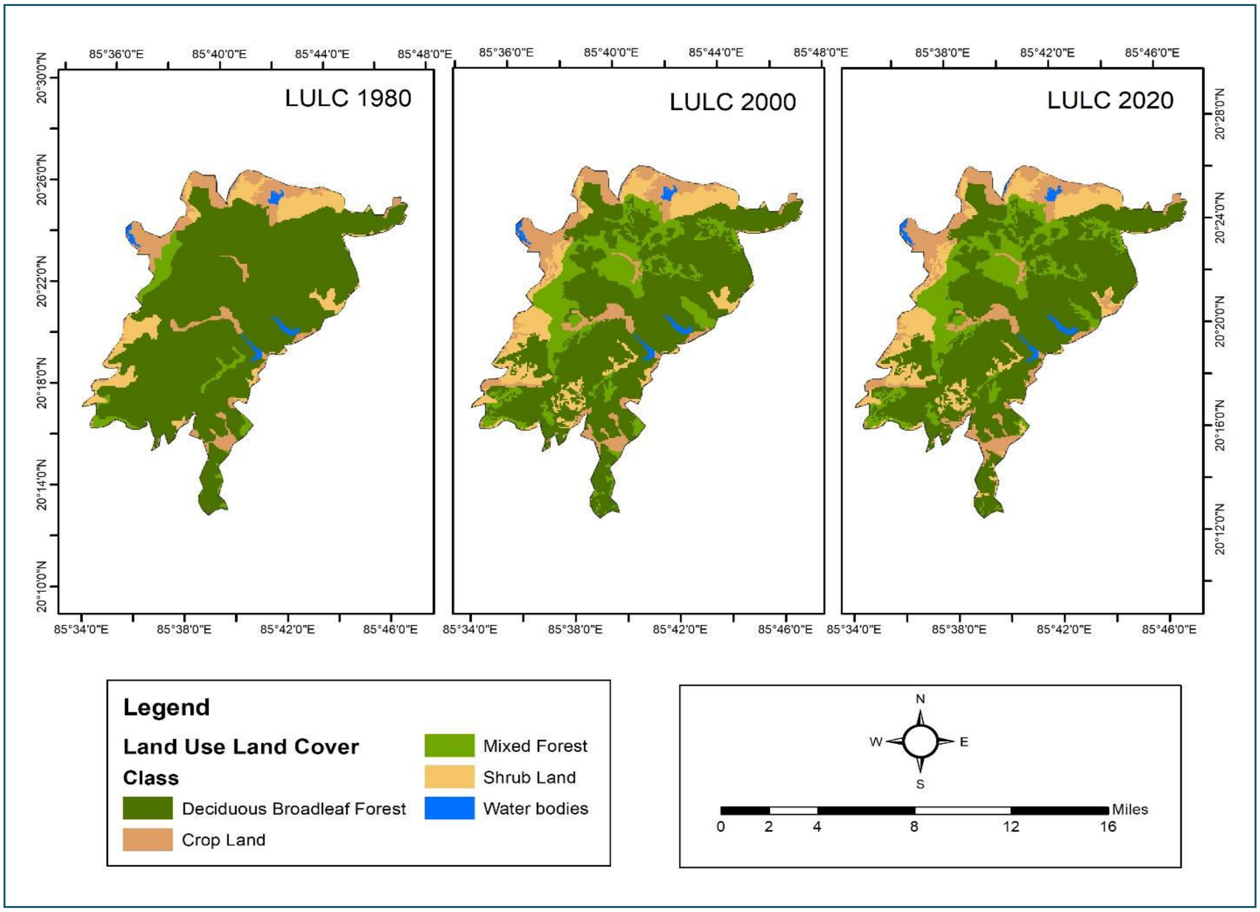

Fig. 2: Classified images of Chandaka National Park for 1980, 2000 and 2020 years.

differences between two images of 1980 and 2020 for all the five land use and land cover class were calculated. This matrix offers crucial details regarding the spatial distribution and nature of land use change. The primary types of change or directions in the research area are enabled by a change matrix.

Results and Discussion

The satellite image of the Chandaka National Park is shown in Figure 1. Figure 2 shows the Chandaka National Park's classified image for year 1980, 2000 and 2020. The accuracy evaluation is extremely important because it indicated how accurately the corresponding classified image reflects the reality. The total number of correctly classified pixels divided by the total pixels was used to calculate the overall classification accuracy of the image. The Landsat image of 1980 had the overall accuracy of 90.45 per cent with Kappa statistics of 0.91, whereas the LISS III image of 2000 and Sentinel image of 2020 had overall accuracies of 92.76 per cent and 94.68 per cent with Kappa statistics of 0.93 and 0.95, respectively. The overall accuracy attained in this study is satisfactory and Kappa coefficient is nearer to one. Overall, these showed excellent classifications.

Post-classification change statistics between 1980, 2000 and 2020 gives the total area concealed by the various land use classes and the change detected. The area of all LULC categories in hectares for 1980, 2000 and 2020 years are given in Table 3. Figure 3 displays the area of each land use and land cover (LULC) class for the year 1980, 2000 and 2020. The category wise LULC change from year 1980 to 2020 is represented in Table 4. Figure 4 shows the change observed in various LULC classes from year 1980 to 2020. Figure 5

Table 3: Area of LULC classes in Chandaka National Park

Land Use Land Cover Class	1980		2000		2020	
	Ha	%	Ha	%	Ha	%
Deciduous Broadleaf Forest	17901	76.66	13292	56.92	13275	56.85
Crop Land	2224	9.52	2725	11.70	3003	12.86
Mixed Forest	817	3.50	4093	17.53	3884	16.63
Shrub Land	2161	9.25	2993	12.82	2924	12.52
Water bodies	249	1.07	249	1.07	266	1.14
	23352	100	23352	100	23352	100

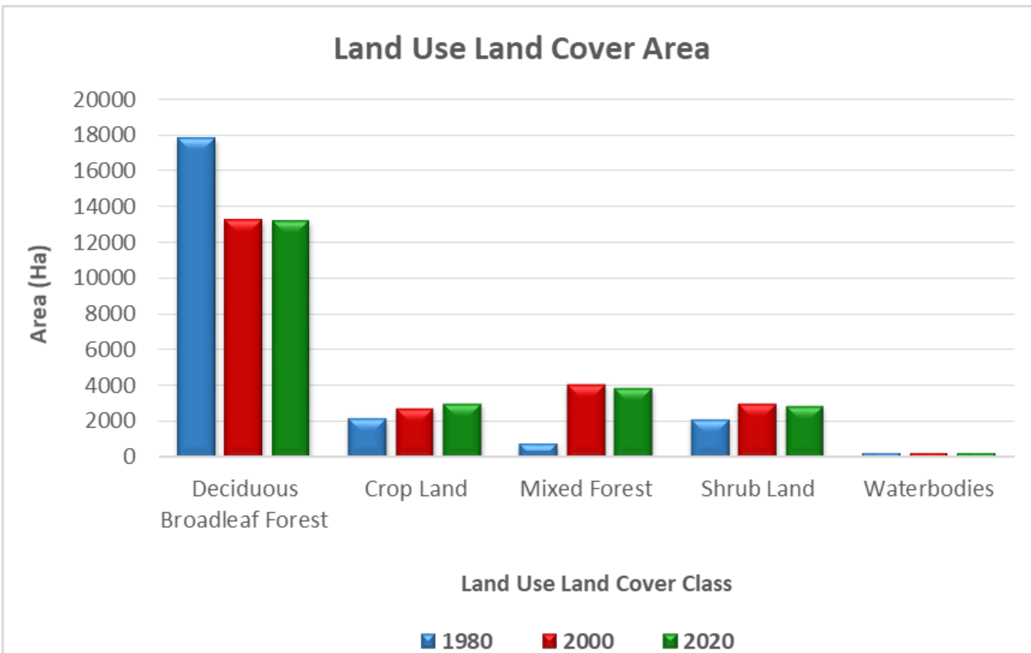

Fig. 3: Area of each Land Use Land Cover (LULC) Class.

Table 4: LULC Change in Chandaka National Park

Land Use Land Cover Class	1980-2000		2000-2020		1980-2020	
	Ha	%	Ha	%	Ha	%
Deciduous Broadleaf Forest	-4609	-19.74	-17	-0.07	-4626	-19.81
Crop Land	501	2.15	278	1.19	779	3.34
Mixed Forest	3276	14.03	-209	-0.89	3067	13.13
Shrub Land	832	3.56	-69	-0.30	763	3.27
Water bodies	0	0	17	0.07	17	0.07

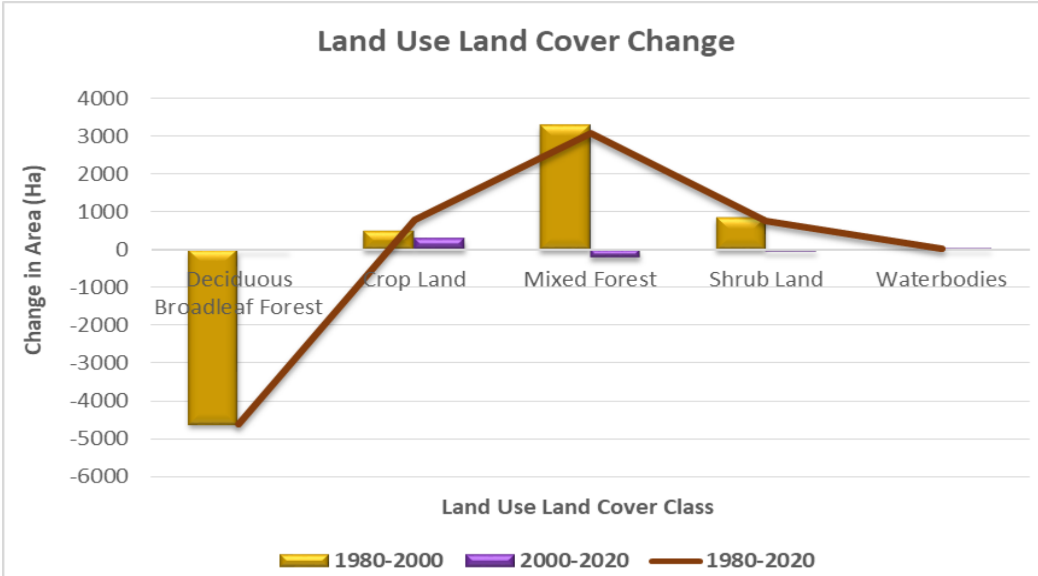

Fig. 4: Change in different LULC classes from year 1980 to 2020.

Table 5: Class wise Area of LULC Transformation from 1980 - 2020

Land Use Land Cover Class	**Area Change (Ha)**
Crop Land - Crop Land	2091
Crop Land - Deciduous Broadleaf Forest	54
Crop Land - Mixed Forest	31
Crop Land - Scrub Land	31
Crop Land - Water bodies	17
Deciduous Broadleaf Forest - Crop Land	419
Deciduous Broadleaf Forest - Deciduous Broadleaf Forest	13054
Deciduous Broadleaf Forest - Mixed Forest	3669
Deciduous Broadleaf Forest - Scrub Land	746
Deciduous Broadleaf Forest - Water bodies	13
Mixed Forest - Crop Land	154
Mixed Forest - Deciduous Broadleaf Forest	82
Mixed Forest - Mixed Forest	182
Mixed Forest - Scrub Land	399
Scrub Land - Crop Land	332
Scrub Land - Deciduous Broadleaf Forest	77
Scrub Land - Mixed Forest	2
Scrub Land - Scrub Land	1748
Scrub Land - Water bodies	2
Water bodies - Crop Land	7
Water bodies - Deciduous Broadleaf Forest	8
Water bodies - Water bodies	234

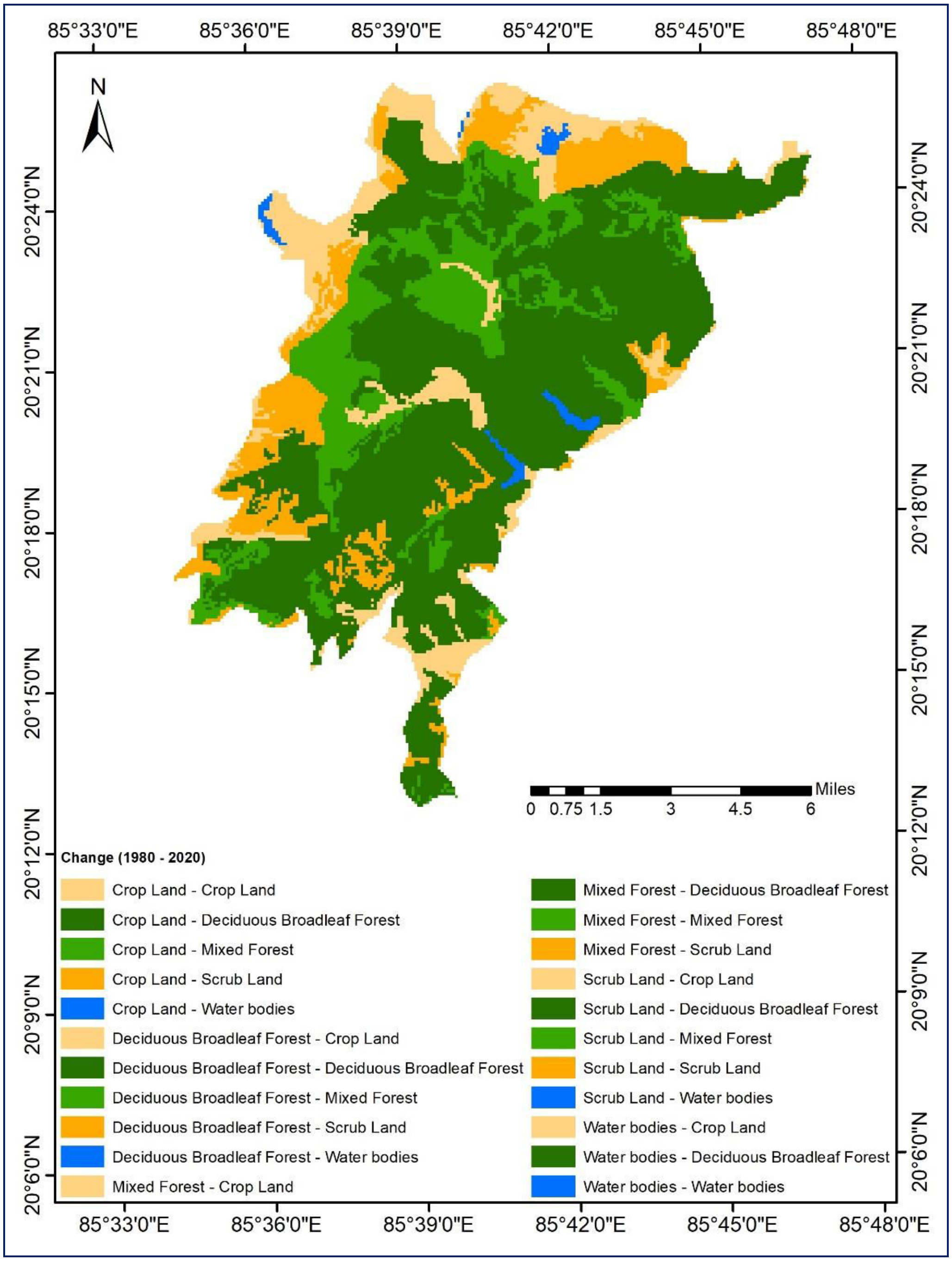

Fig. 5: Map of LULC Transformation in different classes.

represents the Chandaka National Park's LULC change map from 1980 to 2020. It explains which land use type was transformed to which. Table 5 gives the area calculation for the LULC class conversion from each class to another class since four decades. Figure 6 depicts change area in each class to another class for the last forty years.

From 1980 to 2020, there are significant changes in the LULC categories. The area of deciduous broadleaf forest decreased from 17901 ha (76.66%) in 1980 to 13275 ha (65.85%) in 2020 demonstrating the decrease by 4626 ha (19.81%). Mostly the Deciduous Broadleaf Forest found altered into either mixed forest or crop land or scrub land area might be as a result of increase in human population and urbanization. Crop Land, Mixed Forest, Scrub Land and Water bodies increased from 1980 to 2020. Crop Land is

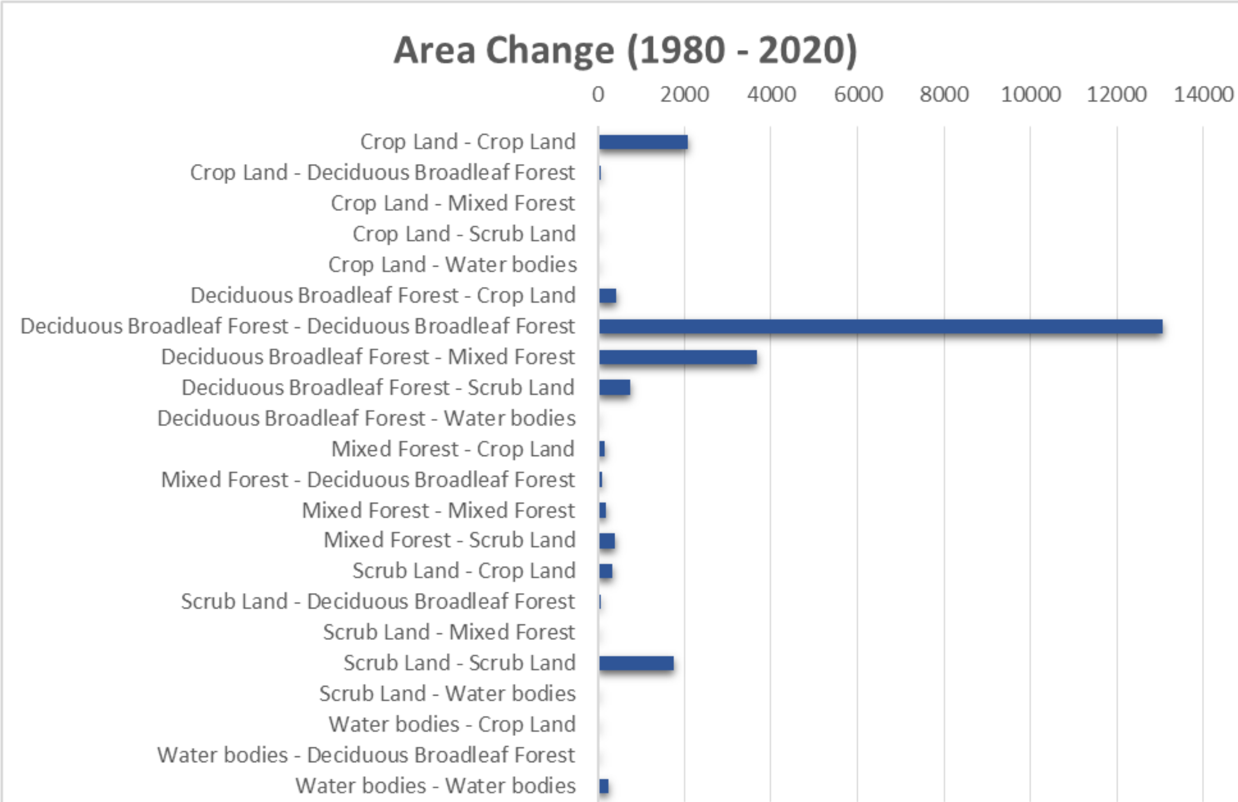

Fig. 6: Class wise LULC Transformation from 1980 – 2020.

measured from 2224 ha (9.52%) in 1980 to 3003 ha (12.86%) in 2020 indicating the increase by 779 ha (3.34%). Mixed Forest is measured from 817 ha (3.50%) in 1980 to 3884 ha (16.63%) in 2020 indicating the increase by 3067 ha (13.13%). Scrub Land is measured from 2161 ha (9.25%) in 1980 to 2924 ha (12.52%) in 2020 indicating the increase by 763 ha (3.27%). Water bodies is measured from 249 ha (1.07%) in 1980 to 266 ha (1.14%) in 2020 indicating the increase by 17 ha (0.07%). The findings indicated that periodic monitoring of LULC changes is necessary in order to effectively develop a land use strategy that will promote sustainable development.

Conclusion

This study has provided insight into how land use and land cover have changed in forest area of the Chandaka National Park in the past forty years. This study has efficiently demonstrated that Deciduous Broadleaf Forest, which has significantly declined during the 1980 to 2020, has undergone the greatest shift in land use and land cover in the Chandaka National Park. The study showed increase in Crop Land, Mixed Forest, Scrub land and Water bodies in the study are from 1980 to 2020. The main factors inducing the change in land use during the past forty years have been urbanization, population growth and underuse of available land. Policy makers, resource managers and scientists can effectively map and monitor the forest area with the help of digital image processing, change detection combined with spatial analysis techniques.

Acknowledgements

The authors thank to National Remote Sensing Centre (NRSC), United States Geological Survey (USGS) and Global Land Cover Facility (GLCF) for providing required satellite data to fulfill this research. Thanks are also due to the authorities of Utkal University, Bhubaneswar, Odisha, India for providing the necessary facilities for the research work. Rashtriya Uchchatar Shiksha Abhiyan (RUSA) scheme of Department of Higher Education, Government of India is also duly acknowledged for providing the necessary support to Centre of Environment, Climate Change and Public Health (ECCPH).

References

Boakye E, Odai SN, Adjei KA and Annor FO. (2008) Landsat images for assessment of the impact of land use and land cover changes on the Barekese catchment in Ghana. European J Sci Res. 22(2): 269-278.

Declee B, Mayaux PH, Hansen M, Amani PL, Sannier C, Mertens B, Hausler T, Siwe RN, Poilive H, Gond V, Rahm M, Haarpaintner J and Lubamba JPK. (2014) Evolution of forest cover at a national and regional scale and drivers of change. In: Forest of Congo Basin-State of the forest 2013, (eds.)De Wasseige C., Flynn J., Louppe D., Hoil F. and Mayaux P.H., Weyrich, Belgium, pp. 21-46.

Deng X, Li Z, Huang J, Shi Q and Li Y. (2013) A revisit to the impacts of land use changes on the human wellbeing via altering the ecosystem provisioning services. Adv Meteorol. 2013: 907367.

Dewan AM, Yamaguchi Y and Rahman Z. (2012) Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh. Geo J. 77(3): 315-330.

Fokeng RM, Forje WG, Meli VM and Bodzemo BN. (2020) Multi-temporal forest cover change detection in the Metchie - Ngoum protection forest reserve, West Region of Cameroon. Egyptian J Remote Sensing Space Sci. 23(1): 113-124.

Foley JA, Defries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N and Snyder PK. (2005) Global consequences of land use. Science 309(5734): 570-574.

Geist HJ and Lambin EF. (2002) Proximate causes and underlying driving forces of tropical deforestation tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. Bio Sci. 52(2): 143-150.

Geng X, Wang X, Yan H, Zhang Q anf Jin G. (2015) Land use/land cover change induced impacts on water supply service in the upper reach of Heihe River Basin. Sustainability 7: 366-383.

Gibson L, Munch Z, Palmer A and Mantel S. (2018) Future land cover change scenarios in South African grassland-implications of altered biophysical drivers on land management. Helyiyon 4: e00693.

Jeon SB, Olofsson P and Woodcock CE. (2014) Land use change in New England: A reversal of the forest transition. J Land Use Sci. 9(1): 105-130.

Keenan RJ, Reams GA, Achard F, de Freitas JV, Grainger A and Lindquist E. (2015) Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015. Forest Ecol Managem. 352: 9-20.

Lillesand TM and Kiefer RW. (2000) Remote Sensing and Image Interpretation. John Wiley and Sons Inc, New York.

Malhi Y, Gardner TA, Goldsmith GR, Silman MR and Zelazowski P. (2014) Tropical forests in the Anthropocene. Annual Rev Environ Resour. 39: 125-159.

Mensah AA, Sarfo DA and Partey ST. (2019) Assessment of vegetation dynamics using remote sensing and GIS: a case of Bosomtwe Range Forest Reserve, Ghana. Egypt J Remote Sens Space Sci. (TSI) 22(2): 145-154.

Miller JD and Yool SR. (2002) Mapping forest post-fire canopy consumption in several overstory types using multi-temporal Landsat TM and ETM data. Remote Sensing Environ. 82(2-3): 481-496.

Muhati GL, Olago D and Olaka L. (2018) Land use and land cover changes in a subhumid Montane forest in an arid setting: a case study of the Marsabit forest reserve in northern Kenya. Glob Ecol Conserv. 16: e00512.

Nerfa L, Rhemtulla JM and Zerriffi H. (2020) Forest dependence is more than forest income: development of a new index of forest product collection and livelihood resources. World Dev. 125: 104689.

Olofsson P, Foody GM, Stehman SV and Woodcock CE. (2013) Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. Remote Sensing Environ. 129: 122-131.

Olson JM, Alagarswamy G, Andresen JA, Campbell DJ, Davis AY, Ge J, Huebner M, Lofgren BM, Lusch DP, Moore NJ, Pijanowski BC, Qi J, Thornton PK, Torbick NM and Wang J. (2008) Integrating diverse methods to understand climate and interactions in East Africa. Geoforum 39: 898-911.

Pellikkaa PKE, Heikineimo V, Hieanen J, Schafer E, Siljander M and Heiskanern J. (2018) Impact of land cover change on aboveground carbon stocks in Afromontane landscape in Kenya. Appl Geogr. 94: 178-189.

Pradhan B, Lee S, Mansor S, Buchroithner M, Jamaluddin N and Khujaimah Z. (2008) Utilization of optical remote sensing data and geographic information system tools for regional landslide hazard analysis by using binomial logistic regression model. J Appl Remote Sens. 2(1): 1-11.

Quan B, Pontius Jr RG and Song H. (2019) Intensity analysis to communicate land change during three time intervals in two regions of Quanzhou City, China. GIScience Remote Sensing 57(1): 21-36.

Rimal B, Sharma R, Kunwar R, Keshtkar H, Stork NE, Rijal S, Rahman SA and Baral H. (2019) Effects of land use and land cover change on ecosystem services in the Koshi River Basin, Eastern Nepal. Ecosyst Serv. 38: 100963.

Rogan J, Franklin J and Roberts DA. (2002) A comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery. Remote Sensing Environ. 80(1): 143-156.

Salghuna NN, Prasad PRC and Kumari JA. (2018) Assessing the impact of land use and land cover changes on the remnant patches of Kondapalli reserve forest of the Eastern Ghats, Andhra Pradesh, India. Egyptian J Remote Sensing Space Sci. 31(3): 419-429.

Sarma PK, Lahkar BP, Ghosh S, Rabha A, Das JP, Nath NK, Dey S and Brahma N. (2008) Land-use and land-cover change and future implication analysis in Manas National Park, India using multi-temporal satellite data. Curr Sci. 95(2): 223-227.

Sekela T and Manfred FB. (2019) Land-use and land-cover (LULC) change detection in Wami River Basin, Tanzania. Land 8(9): 136.

Solefack MC, Njouonkouo AL, Temgoua LF, Djouda Zangmene R, Wouokoue Taffo JB and Ntoukpa M. (2018) Land use/land cover change and anthropogenic causes around Koupa - Matapit gallery forest, West-Cameroon. J Geogr Geol. 10: 56.

Tsuyuki S. (2018) Completing yearly land cover maps for accurately describing annual changes of tropical landscapes. Global Ecol Conserv. 13: e00384.