Original Research Article

Land use and land cover change study using RS-GIS and its impact on biodiversity - Study from Arunachal Pradesh (India)

Abstract

This study aims to depict the intricate relationship between biophysical parameters, particularly land surface temperature (LST), and their impact on biodiversity at Itanagar Wildlife Sanctuary in Arunachal Pradesh. Focused on the consequences of anthropogenic activities, our research assesses decadal changes in forest cover using Landsat images from 1990, 2003, and 2019. Utilizing satellite data, calculation of indices such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), Normalized Difference Water Index (NDWI), and LST were performed. Land use land cover (LULC) was determined through supervised classification, achieving accuracies of 75%, 87%, and 83% for 1990, 2003, and 2019, respectively. The analysis highlighted a substantial increase in settlement area from 9.37 km^2 in 1990 to 22.86 km^2 in 2019, indicative of significant urbanization impacts.Our findings reveal a pronounced positive correlation between settlement growth and elevated LST, indicating the influence of urbanization on thermal dynamics. Additionally, positive correlations were observed between LST and NDBI, while a negative correlation existed between LST and NDVI. Questionnaire-based surveys complemented remote sensing data, exposing a gradual decline in wildlife sightings, diminishing populations of rare plant species, and the proliferation of invasive plants within and around the Wildlife Sanctuary since 1990.This research underscores the substantial impact of urbanization on the biodiversity of the Itanagar Wildlife Sanctuary. Positive correlations between settlement growth, LST, and biophysical parameters emphasize the urgency for targeted conservation strategies. The decline in wildlife sightings and the encroachment of invasive species underscore the need for proactive measures to balance biodiversity conservation with the challenges posed by urban development. Our integrated approach, combining remote sensing, survey data, and ecological indices, offers valuable insights for sustainable management and conservation efforts in similar habitats globally.

Key word: LULC, LST, NDIV, NDBI, NDWI, Biodiversity Conservation, RS-GIS.

1. INTRODUCTION

The rapid urbanization has affected the biodiversity, water balance and socio-economic conditions which resulted as change in climate and biosphere [1, 2]. Study based on conservation and management of biodiversity using remote sensing and GIS technology has become more popular because of its effective and fast result compared to conventional methods. In the last two decades, researchers have focused their attentions towards local and regional climate study which are under influences of anthropogenic activities for understanding the various driving factors related to changing climate [3, 4]. The overall affects due to urbanization also contributes to global phenomena such as GHG emission; change in temperature and precipitation and anthropogenic climate change [5, 6, 7].The study on changes of land use land cover and its impact on flora and fauna in the biodiversity hotspot of India have become more popular among the researchers in the country and abroad. The rapid changes on the land use land cover pattern in the Western Ghat, one of the important biodiversity hotspot of India has been studied and reported, the huge transformation due to anthropogenic and natural calamities [8, 9].The monitoring ofland use land cover (LULC) changes along the time series with highly accurate information is very necessaryforbiodiversity conservation and management especially in the youngest mountain ranges i.e.north-eastern Indian Himalaya. Thisinformation will help in understanding the interaction between human activities and environments and its ultimate affects. Furthermore, it will enable to manage the available recourses by utilizing sustainably and maintaining balance environment [10, 11]. Land surface temperature (LST) can be stated as one of the significant parameters for understanding the status of urban environment [12]. Many researches on climate change, urban climate, hydrological cycle, vegetation and environmental research have successfully employed the LST as an important parameter of the study along with indices like NDVI NDBI and NDWI [13, 14, 15, 16]. The mapping of protected areas in Arunachal PradeshusingRS and GIS techniques was found useful for conservation of flora and fauna [17]. The present study has been under taken to quantify and understand the spatio-temporal changes in the region due to urbanization with special reference to effects on biodiversity and conservation.

2. MATERIALS AND METHODS

2.1 Study area:

The Eastern Himalayan region is known for its rich biodiversity and a sophisticated geomorphic history with pervasive topographic features [18]. The present study site is located in the state of Arunachal Pradesh in the north eastern part of the India, which is also the part of eastern Himalayan biodiversity hotspot [19, 20]. The Itanagar Wildlife Sanctuary is situated in the Papumpare districts of Arunachal Pradesh with an area of 140.8km^2. The sanctuary was created on 14/06/1978 vide Govt. Notification No. FOR 118/78 by superseding the Itanagar Reserved Forest as known earlier(Fig: 1). The Wildlife Sanctuary fall under the survey of India (SOI) topo-sheet No. 83E/12 Subansiri. The sanctuary is located adjacent to the state capital Itanagar and is surrounded by three rivers i.e. Poma River in the East, Pachin River in the South and Neorch River in the North West. The vegetation of the study area can be classified as north bank tropical evergreen, tropical semi-evergreen forest and Secondary Forest[21]. The forest can be grouped in sub group2B Northern Tropical Semi Evergreen Forest and Sub group 3C North Indian moist deciduous forest [22]. The sanctuary is home to numbers of diverse mammals, reptiles and birds some notable mammalian like elephants (*Elephas maximus*), tigers (*Panthera* *tigris*), leopards (*Panthera pardus*), clouded leopards (*Neofelisnebulosa*), sambar (*Cervus unicolor*), barking deer (*Muntiacusmuntjak*), dholes (*Cuonalpinus*), wild boars (*Sus scrofa*), jackals (*Canis aureus*), and small cats [23].

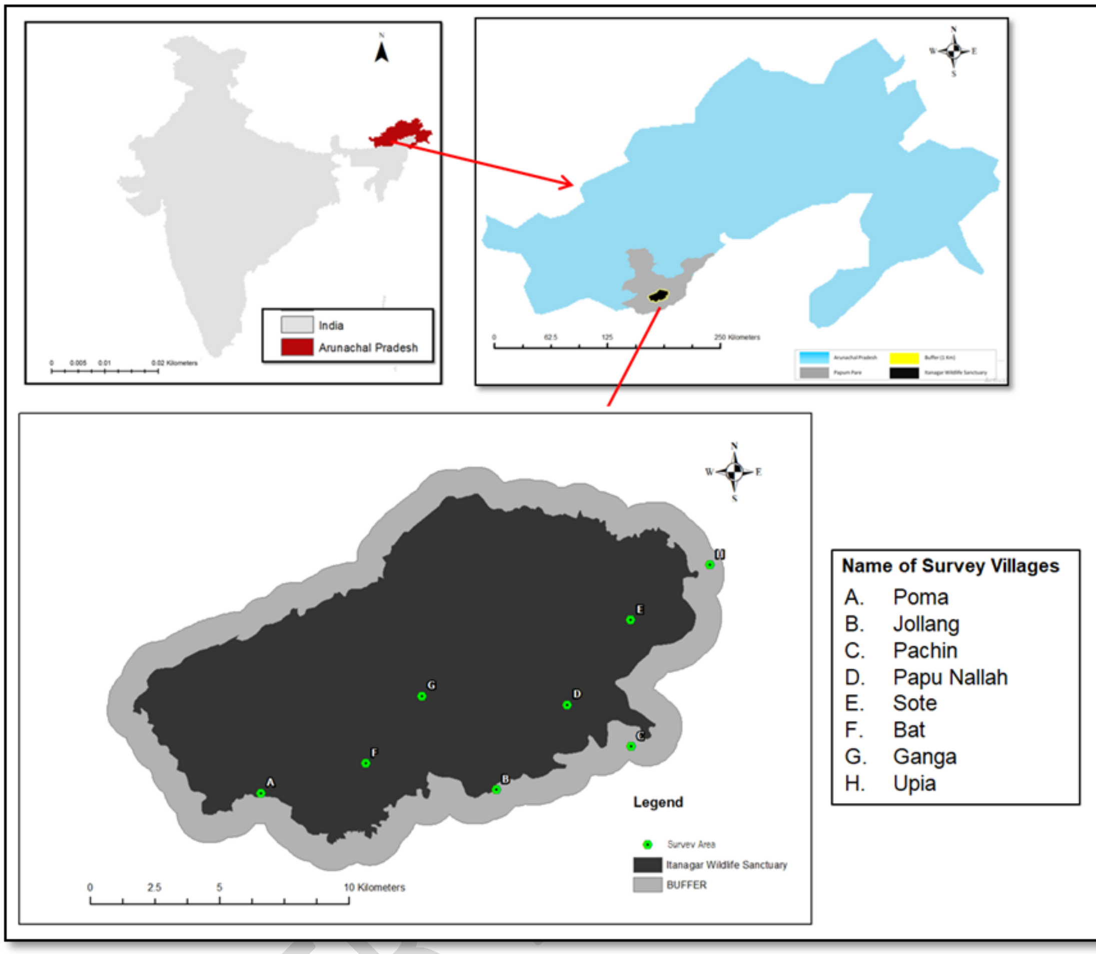

Figure 1: Study site.

2.2 Satellite Data

The LANDSAT image data are the most widely use satellite data in the world for observation of environmental changes because of its large repository of continuous spatial data with longer time periods [24]. The boundary of the selected wildlife sanctuary was obtained from Department of Environment and Forest, Govt. of Arunachal Pradesh in a PDF file format. After obtaining the boundary of the sanctuary a 1 km. buffer was created in Arc-GIS 10 for the study (Fig 1). LANDSAT satellite images were also acquired (Path/row: 135/41) from USGS earth explorer website for the study. Based on the availability of imageries with less than 10% cloud cover, three set at different time scales(1990, 2003, 2019) were downloaded in GEOTIFF format which are in UTM Zone 46N of WGS 84 datum (Table 1).

Table 1: Characteristics of the satellite data used in the study.

Date	Path/Row	Satellite	Sensor	No. of Band	Spatial Resolution
1990/05/17	135/41	Landsat 5	TM	7	Thermal= 30x30 Reflective= 30x30
2003/03/10	135/41	Landsat 7	ETM	8	Thermal= 30x30 Reflective= 30x30 Panchromatic= 15x15
2019/04/06	135/41	Landsat 8	OLI_TIRS	11	Thermal= 30x30 Reflective= 30x30 Panchromatic= 15x15

2.3 Estimation of Indices and LST

The pre-processing of the satellite images i.e.geometric, atmospheric correction and data analysis were performed in the ERDAS Imagine 14 and Arc-GIS 10 software. The derivations of normalized indices NDVI, NDBI, NDWI were performed by computing the band ratios. These indices were used to understand the relation with various biophysical parameters like greenness, built-up intensity and wetness with respect to thermal responses of the concern environment.The red band (RED)(0.63-0.69mm) and near-infrared (NIR) band (0.76-0.9mm) were processed for normalized difference vegetation index (NDVI) analysis[25]. Normalized difference built-up index (NDBI) is used in detecting the built-up areas as it has higher reflectance of short-wave infrared wavelength (1.55-1.75mm), so it is calculated with NIR[26]. The normalized difference water index (NDWI) which is also known as leaf area water-absent index. NDWI measure the liquid water molecules in vegetation that interact with solar radiation. NDWI is computed using the green band and the near-infrared band[27]. The thermal infrared band (10.4-12.5mm) was used in retrieving the land surface temperature (LST) of the study area [28, 29].

2.4 Classification of land use and land cover (LULC)

The land use and land cover (LULC) classification is the expression of the earth surface utilized by human and its observation of the earth surface [30]. The analysis of LULC is becoming an important tool for interpreting the rapid changes of the environment over the course of time[31, 32]. The supervised classification method was applied using the maximum likelihood (ML) algorithm, which is one of the extensively used algorithms in remote sensing for its robustness [33]. Six LULC classes were identifiedfor Itanagar wildlife sanctuary. The LULC includes (i) Forest; (ii) Jhum land; (iii) Barren land; (vi) Agriculture land; (v) Built-up and (vi) water body/ river. The overall methodology followed for the analysis are represented as flowchart (Fig. 2).

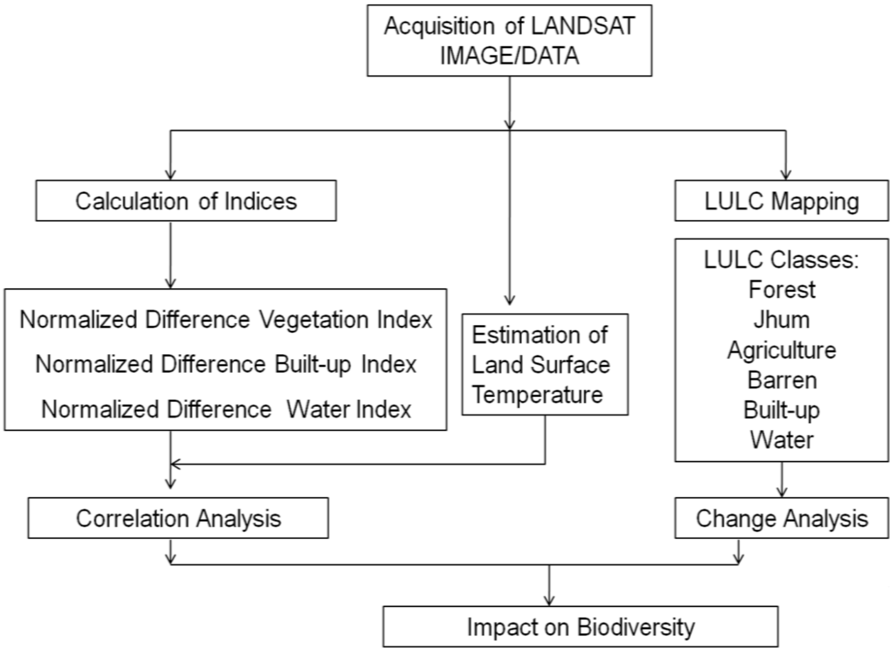

Figure 2: Flowchart of the methods.

2.5Collection of ground truth data and field survey

The study on flora diversity and faunal interaction with the local community was conducted in the 8 villages (Table 2 and Fig 1). A total of 82 respondents were selected within the age group of 30-55 for formal and informal interviews. The data on sighting of wildlife in and around the village and conflict related to wildlife with the villagers in the past three decades were recorded. The floral diversity of the study area was also recorded by conducting extensive field survey in forest area near the survey villages. The identification of the faunal diversity in the field was done with field guide book [34]. Plant species were identified by following taxonomic literatures and consultation with the experts of regional herbaria (ASSAM and ARUN) of Botanical Survey of India (BSI), Govt. of India.A total of 100 random GPS point samples was collected in the study area describingeachLULCclasses (Fig 2). Gramintrex 30 devices were used to collect the location data.

Table 2: List of surveyed villages in Papum Pare district (Arunachal Pradesh).

Sl. No	Village	Dominant Tribal community	Number of Household	Number of respondents
1	Poma	*Nyshi*	26	15
2	Bat	*Nyshi*	37	6
3	Ganga	*Nyshi*	86	15
4	Jollang	*Nyshi*	71	8
5	Papu nallah	*Nyshi*	77	10
6	Upia	*Nyshi*	21	10
7	Sote	*Nyshi*	40	10

8	Pachin	*Nyshi*	27	8

2.6 Accuracy assessment and quantitative analysis of LST with biophysical parameters

The accuracy assessment of the LULC was performed by using 100 randomly collected GPS points which covers all the classes. Additionally, the calculation of producer's accuracy, user accuracy, overall accuracy and Kappa co-efficient was also done using standard methods[35]. However, to understand the dynamics relationship of LST and the biophysical parameters (NDVI, NDBI, NDWI)a total of 100 point were randomly generated in GIS platform which are well distributed in all the classes of LULC. The random points were then used to extract the values of biophysical parameters and LST of all the studied images. The correlation and regression analysis are used to understand how the environments responds to urbanization and its impact of urbanization on biodiversity.

3. RESULT AND DISCUSSION

3.1 Land used land cover Change analysis

The temporal LULC map of the Itanagar Wildlife sanctuary was prepared for three different time periods 1990, 2003, 2019 to understand the changes in LULC due to urbanization (Fig 3). A total of six classes of LULC were classified which includes i) Forest- it includes all the forest covers including bamboo mixed forest; ii) Jhumland (shifting agriculture)- it includes all types of mixed cultivation with few sparsely distributed trees, Fallow land with shrubby dominance; iii) Agriculture- this includes mostly the areas under monoculture of paddy specially the wet rice cultivation; iv) Barren- it includes the area with no vegetation or exposed soil either naturally through landslide or by anthropogenic influence; v) Builtup area- this represents the settlements in the area; vi) Water- it includes river and lake. The distributions of LULC classes along the time line (1990, 2003 and 2019) are clearly showing continuous changeswith rapid growth in built-up areas (Table 3).The Forest cover of the study area was found to be decreasing gradually as it represents a total of 181. 48 sq. Km (77.88%) in 1990 while it was reduced to 163.98 sq. Km (70.37%) by 2019. However, an opposite trend of gradual increase was found in Jhum with 15.52 sq. Km in 1990, 20.63 sq. Km in 2003 and 22.86 sq. Km in 2019. Moreover,Built-up classes werealso observed with similar trend, with 9.37 sq. Km, 10.59 sq. Km, and 22.86 sq. Km in 1990, 2003, 2019 respectively. The rural-urban migration in the study area has influence the expansion of built-up areas. According to population census 1991 and 2011, the population hasincreased from16, 550 to 59,490[36]. The increase in population in the area can be attributed to movement of from rural to urban areas for quality life and opportunities. A similar type of example of LULC changes has been observed in the twin cities of Minnesota (USA), where the forest and agriculture land decreased gradually andBuilt-up areas expanded with the time [37]. The accuracy assessment on LULC classes reveals that the overall accuracy was 75, 87, and 83% for the maps of 1990, 2003 and 2019 respectively while, kappa co-efficient for 1990, 2003 and 2019 are 0.70, 0.84 and 0.79 respectively (Table 4). Moreover, the result on LULC of the study area was found reasonableas it rangesunder good or satisfying agreements which are sufficient for analyzing the changes along the 3-decadetime span[38].

Table 3: Land use land cover (LULC) distribution of Itanagar Wildlife Sanctuary.

LULC Classes	1990		2003		2019	
	Area (sq.Km)	Area (%)	Area (sq.Km)	Area (%)	Area (sq.Km)	Area (%)
Forest	181.48	77.88	168.77	72.43	163.98	70.37
Jhum (Shifting agriculture)	15.52	6.66	20.63	8.85	22.64	9.72
Agriculture	13.21	5.67	8.97	3.85	9.62	4.13
Barren	10.45	4.49	20.74	8.90	9.65	4.14
Built-up	9.37	4.02	10.59	4.54	22.86	9.81
Water	3.00	1.29	3.39	1.46	4.27	1.83

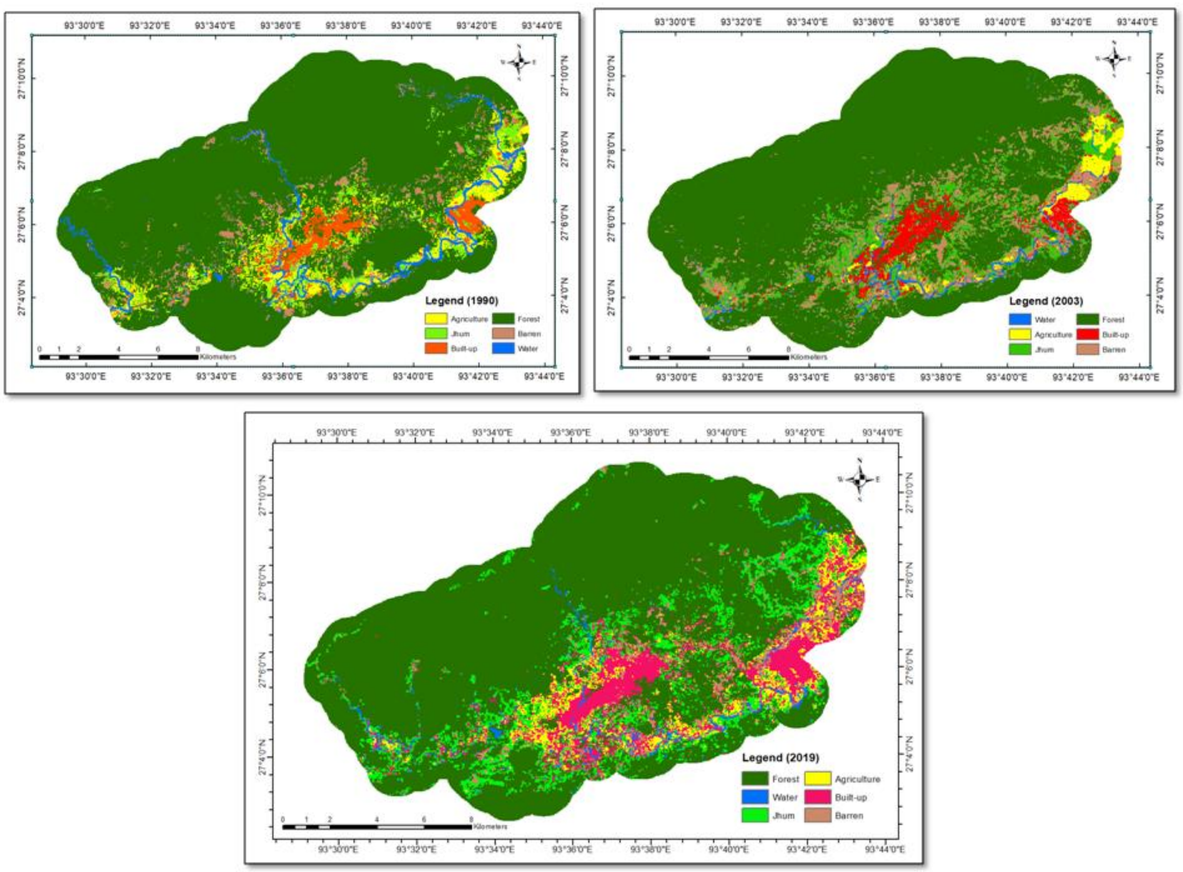

Figure 3: LULC of Itanagar Wildlife Sanctuary in 1990, 2003 and 2019.

Table 4: Accuracy assessment LULC classification for 1990, 2003 and 2019.

Class	1990		2003		2019	
	PA	**UA**	**PA**	**UA**	**PA**	**UA**
Forest	0.94	0.80	0.93	0.79	0.87	0.81
Jhum	0.73	0.73	0.80	0.85	0.87	0.81
Agriculture	0.53	0.47	0.87	1	0.87	0.93
Barren	0.78	0.73	0.90	0.78	0.70	0.82
Built-up	0.68	0.73	0.90	0.90	0.95	0.76
Water	0.85	0.90	0.73	1	0.67	0.90
Overall Accuracy %	75		87		83	
Kappa coefficient	0.70		0.84		0.79	

3.2 Impact of urbanization on Biodiversity

The rapid urbanization in the world has resulted in the growth of myriad form of structures which modified the energy and water balance by changing the dynamics of air and surface temperature [39, 40]. The analysis on the Land surface temperature (LST) has reveals the thermal changes in the study area during 1990, 2003 and 2019 (Fig 4). It was estimated that the highest surface temperature in Itanagar and Naharlagun area were 28.83^{o}C, 29.21^{o}C and 30.21^{o}C for 1990, 2003 and 2019 respectively. The urban heat island (UHI) can be attributed by the energy transformation in the cities; decrease of evapotranspiration and production of anthropogenic energy [41]. It was observed that the temperature class of 24-30 ^{o}C was spreading in almost all the area of the Itanagar city in year 2019 depicting an urban heat island (UHI). However, there were very less area of UHI with the same temperature class (24-30^{o}C) in 1990 (Fig 4).The increasing built-up area in Itanagar city and deforestation around the sanctuary has resulted in rise of temperature.

The three biophysical parameters NDVI, NDBI and NDWI for the year 1990, 2003 and 2019 are present in Figure 5.The NDVI map for different time periods 1990, 2003 and 2019 clearly indicates the effect of urbanization on vegetation cover in the study area. The mean index values of NDVI are 0.41, 0.41 and 0.22 for 1990, 2003 and 2019 respectively. However, the mean NDBI values are found increasing i.e. -0.01, -0.11 and -0.13 for 1990, 2003, 2019 respectively.Correlation coefficient analysis of LST with NDVI, NDBI and NDWIwere found comparatively acceptable (Table 5). The NDVI-LST and NDVI-NDBI were found negatively correlated for the years 1990, 2003, 2019 with the values of -0.42, -0.48, -0.45 and -0.79, -0.68, -0.86 respectively (Table 5). The resulthas also supported the statement that increasing built-up has influence on vegetation and temperature in the urban areas.

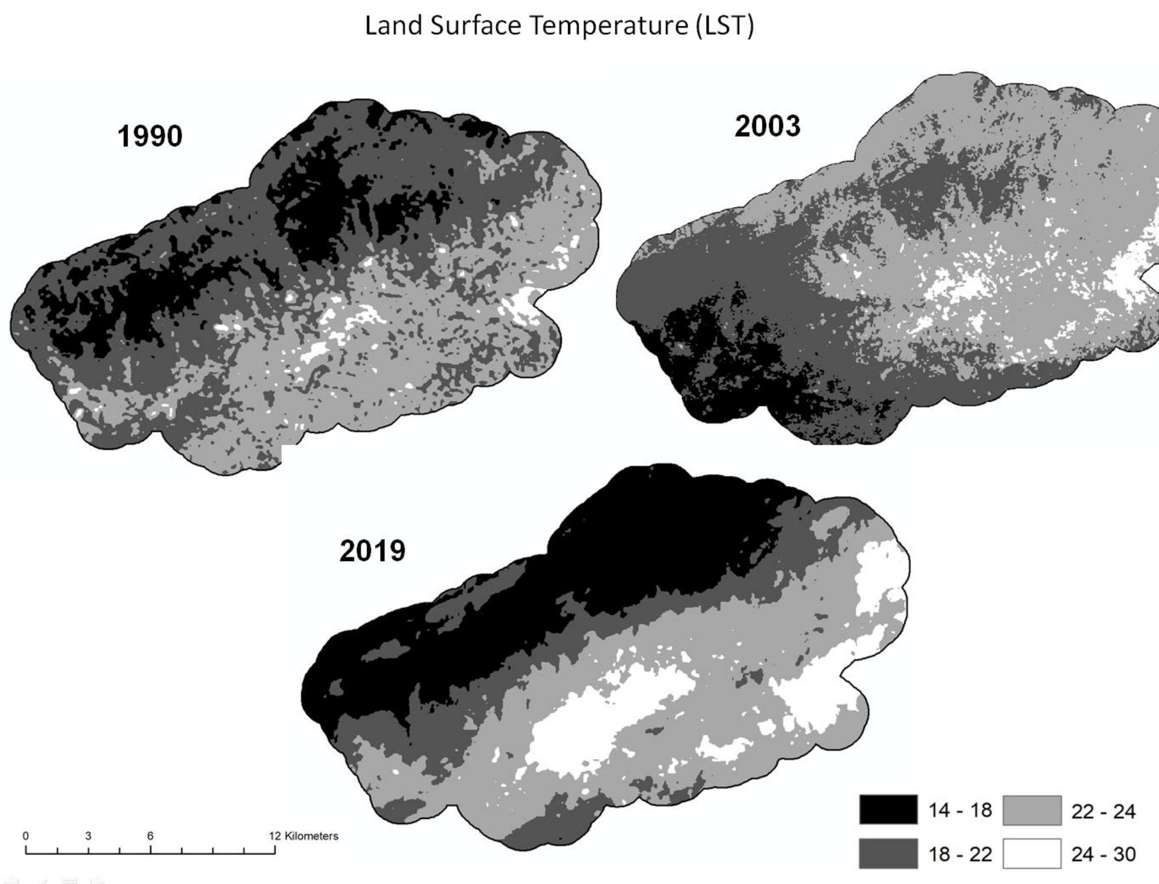

Figure 4: Land surface temperature (LST) of Itanagar wildlife sanctuary in 1990, 2003 and 2019.

Table 5: Correlation coefficient between the biophysical parameters in the year 1990, 2003 and 2019.

Environmental Indices	1990	2003	2019
NDVI:LST	-0.42	-0.48	-0.45
NDBI:LST	0.65	0.83	0.69
NDWI:LST	0.30	0.33	0.41
NDVI:NDBI	-0.79	-0.68	-0.86
NDVI:NDWI	-0.98	-0.97	-0.99
NDBI:NDWI	0.68	0.53	0.81

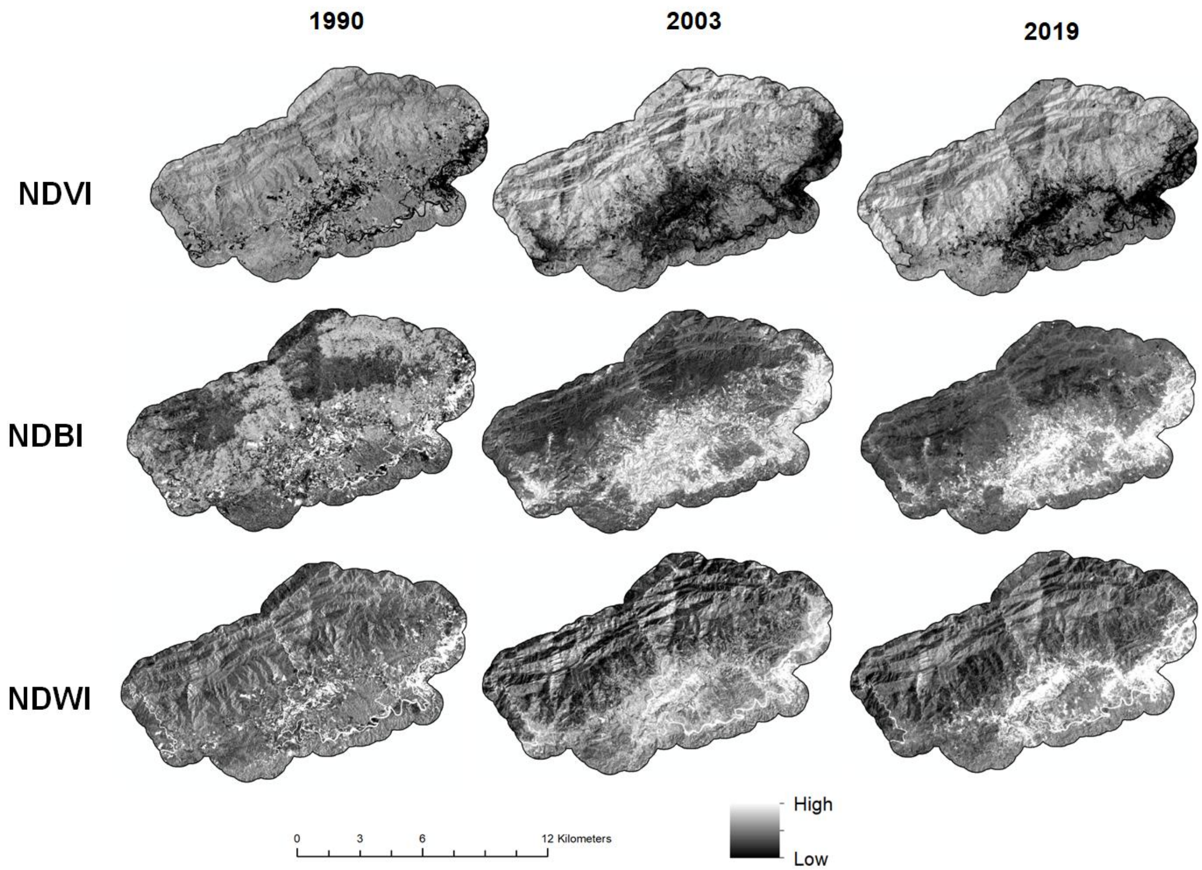

Figure 5: Biophysical parameters (NDVI, NDBI, and NDWI) in 1990, 2003 and 2019.

3.3 Changes in the Phyto-diversity Status

The study on floral diversityof the sanctuary has reveals that the forest represents heterogeneous mixtures of species from semi-evergreen to evergreen forest. Among the tree species *Dipterocarpus macrocarpus*,*Artocarpus chama*,*Magnolia sp.*, *Aglaia spectabilis*, *Castonopsis indica*, *Schimawallichii*, *Duabanga grandiflora*, *Parkiatimoriana*, *Toona ciliate*, *Sapindusmurkorossii* represent the higher canopy layers. While, the understory tree layers were *Lagerstroemia speciosa*, *Macaranga denticulata*,*Bauhinia purpurea*,*Mallotussp.*, *Dysoxylumgobara*, *Actephilaexcelsa*, *Callicarpa arborea*, *Musa sp*, *Cyathea sp.* The shrub layers in the area includes*Buddleja asiatica*, *Sterculia hamiltonii*, *Pinangagracilis*, *Phryniumpubinerve*, *Croton caudatus*, *Angiopterisevecta*, *Sambucus hookeri*, *Calamus tenuis*, *Phryniumrheedei*, *Leea indica*, *Phlogocanthuscurvifolius*, *Urena lobata*species.The herbaceous layers were represented by species like*Begonia roxburghii*, *Pteris sp*, *Diplaziumdilatatum*, *Aolocasia acuminate*, *Curcuma sp*, *Floscopa scandens*, *Euphorbia hirta*, *Amomum sp*, *Galinsoga parviflora*, *Ipomoea batatas*, *Equisetum debile*, *Ageratum conyzoides*, *Acmella oleracea*, *Asparagus racemosus*. Apart from these compositions of species the sanctuary also represents with some large patch of bamboo mixed forest randomly distributed in most of the areas. Some of the dominant bamboo's species found in the sanctuary are *Dendrocalamushamiltonii* and *Bambusa pallida*.The practice of shifting cultivation (popularly known as *Jhum cultivation*in the region) has been an integral part of culture and traditions of the local people which is also the major source of vegetables and other food crops. During the field survey,presence of invasive species like *Mikania micrantha, Chromolaena odorata, Lantana camara, Parthenium hysterophorus*was observed in the fallow jhum land.*Chromolaena odorata* and *Parthenium hysterophorus* are also commonly observed along the roads. The occurrence of invasive species in the study areas indicates that the forests are getting disturbed and fragmented,similar other studies conducted earlier for the same study area has also madesimilar statements [42, 43].The invasive plant species poses serious threats to the native plant community and its ecosystem properties [44]. The extensive field survey conducted in the sanctuaryhas also observed some rare, threatened and medicinally important species which are distributed with very less population (Table 6).Thefactors responsible forthreatening the rare flora and fauna in the study site are the forest degradation caused by encroachment of forest land for cultivation, building infrastructure and roads.The practice of shorter rotation periods (3-5 years instead of 10-12 years) of Jhum cultivation might have affected the soil nutrient balance and species composition.This also aggravates therisk of soil erosion and frequent landslides in the monsoon season causing habitat fragmentation. The observation of threats on flora and fauna were also found similar with the findings of others reports [45, 46]. The concernsover conservation and sustainable utilization of the resources like medicinal plantswere also express by other studies in the state [47, 48].

3.4 Anthropogenic affects on wildlife

The result on faunal diversity and its interacting with local community was recorded through formal and informal interviews followed by documentation of the events. Among the 8 survey villages only 5 have reported with interaction and conflict with the wildlife.The respondents in Poma village have reported the highest numbers (14 nos.) of interaction and conflict with wildlifefollowed by Pachin (12 nos.). The reports on human-wildlife conflict were only recoded with Wild Dog, Elephant and King Cobra in Poma, Pachin and Sote villages. Moreover, italso reveals that only5 species i.e.Monitor Lizard, King Cobra, Mongoose, Wild pig, Jungle cat were the mostfrequently observed by the local communities during 1990-2019 (Table 7), these species are reported to be seen regularly in the Jhum land and the nearby forest. However, species like Tiger, Common Leopard, Asiatic Black Bear and Chinese Pangolin were reported to be encountered onlyduring 1990-2000.There was a gradual decrease in interaction of big animals like Tiger, common leopard, wild dog, Asiatic black bear and Elephant according to villagers. One of the villagers in Poma has reported that most of the wild animals were rarely seen at the northern side of the Sanctuary. However, in April, 2020 three individuals from Pachin village have made the headlines in national news for killing a large adult King Cobra.In July, 2020 the King Cobra again made news headline in Itanagar with different ending. An adult King Cobra with a length of 10 feet weighing around 10 kilograms was sighted in the residential area of Itanagar, later it was rescue by the forest department.The regular interaction of wildlife with the local community has been a regular event in and around the Sanctuary. This type of conventional events, are the results of encroachment of forest land for anthropogenic activity causing habitat loss and fragmentation.

Table 6: List of important plant species with conservation concern

Sl. No	Scientific Name	Uses	Population Status
1	*Abroma augusta*	Medicinal Properties: menstrual disorders and gonorrhoea.	Stable
2	*Alsophila spinulosa*	NA	Decreasing
3	*Angiopteris crassipes*	NA	Decreasing
4	*Aquillariaagallocha*	Essential oil is used in cosmetic and perfume industry.	Threatened**
5	*Callicarpa arborea*	Medicinal Properties: Stomachache, boils and piles	Decreasing
6	*Clerodendrumcolebrookianum*	Medicinal Properties: antioxidant and antimicrobial	Decreasing
7	*Costusspeciosus*	Medicinal Properties: Urinary problem, stimulant and astringent.	Threatened**
8	*Dioscorea pentaphylla*		Decreasing
9	*Dipteriswallichii*	NA	Decreasing
10	*Dipterocarpus gracilis*	Medicinal properties: antiseptic for gonorrhoea and urinary disease	Vulnerable***
11	*Gynocordia odorata*	Medicinal properties: Diarrhea	Threatened**
12	*Hedychium spicatum*	Medicinal properties: Anti-inflammatoru. Antispasmodic, and antifungal and antifungal	Threatened**
13	*Homalomenaaromatica*	Essential oil is used in cosmetic and perfume industry.	Threatened **
14	*Hydrocotylejavanica*	Medicinal properties: Stomachache, dysentery and antibacterial properties.	Decreasing
15	*Livistonajenkinsiana*	Traditional housing roof	Decreasing
16	*Oroxylum indicum*	Medicinal Properties: Stomachache, rheumatism, diarrhoea	Decreasing
17	*Piper mullesua*	Medicinal Properties: Cough, bronchitis problem and Stomachache	Decreasing
18	*Piper pedicellatum*	Eaten as vegetables by the locals	Threatened **
19	*Terminalia chebula*	Medicinal Properties: Dehydration and contipation	Stable
20	*Terminalia myriocarpa*	Medicinal Properties: Chest pain	Decreasing

Note: **threatened in regional (Ved et al., 2005); ***threatened as per IUCN RED List

Table 7: List of faunal diversity encounter by the local community in and around the wildlife Sanctuary.

Sl No.	Name of Identified species	Scientific Name and IUCN threatened category	Name of the village/ area	Sighting Year		
				1990-2000	2001-2010	2011-2019
1	Elephant	*Elephas maximus****	A, E, C	■	■	
2	Tiger	*Panthera tigris****	A	■		
3	Common Leopard	*Panthera pardus***	A	■		
4	Asiatic black bear	*Ursus thibetanus***	A,D	■		
5	Clouded leopard	*Neofelisnebulosa***	A,B, C	■	■	
6	Wild dog	*Cuonalpines****	A,B, C	■	■	
7	Jungle cat	*Felis chaus*	A, B, C, D, E	■	■	■
8	Barking deer	*Muntiacusmunjak*	A, B, C, D, E	■	■	
9	Wild pig	*Sus scrofa*	A, B, C	■	■	■
10	Chinese Pangolin	*Manis pentadactyla****	C	■		
11	Mongoose	*Herpestes sp.*	A, B, C, D, E	■	■	■
12	Indian Porcupine	*Hystrix indica*	A, B, C,	■	■	
13	Monitor Lizard	*Varanus bengalensis*	A, B, C, D, E	■	■	■
14	King Cobra	*Ophiophagus Hannah***	A, B, C, D, E	■	■	■
15	Small Indian Civet	*Viverricula indica*	A, B, C,	■	■	

Note: A- Poma; B- Jollang; C- Pachin; D-Papu Nallah; E-Sote, ***Endangered; **Vulnerable;

4 CONCLUSIONS

The application of Remote Sensing (RS) and Geographic Information System (GIS) techniques for assessing changes in land use and land cover in protected areas has proven to be an efficient and invaluable tool. The current study successfully monitored the gradual transformation of land cover into various forms. It revealed a rapid decline in the forest cover of the Itanagar Wildlife Sanctuary from 1990 (77.88%) to 2019 (70.37%), impacting a total area of 17.5 sq. km. Additionally, the built-up area exhibited a substantial increase from 1990 to 2019, measuring 9.37 sq. km, 10.37 sq. km, and 22.86 sq. km, respectively. The research emphasized a correlation between the rise in land surface temperature (LST) and expanding built-up areas, indicative of the formation of an urban heat island (UHI). Correlation analysis further supported a positive correlation between LST and Normalized Difference Built-Up Index (NDBI) throughout the study years (Table 5).

The study underscored those anthropogenic activities, including Jhum cultivation, forest land encroachment, human-wildlife conflict, rapid invasive species spread, and uncoordinated infrastructure development around the Sanctuary, have significantly impacted biodiversity. Despite Itanagar being the state capital, sustaining economic growth poses a challenge for the Sanctuary. However, achieving a balance between biodiversity conservation and economic development is not unattainable. Both can coexist by promoting sustainable development that prioritizes the restoration and maintenance of ecosystem services. Proposed measures for the Sanctuary encompass habitat evaluation, regular monitoring of wildlife populations and habitats, and the rehabilitation of rare, threatened, and important plants through in-situ and ex-situ conservation. Sensitization programs aimed at local communities, including awareness and training initiatives, can contribute to effective biodiversity conservation. Furthermore, ecotourism activities such as bird watching, nature walks, and camping can provide livelihood opportunities for the local community. The success of these activities hinges on collaborative efforts involving government departments, research institutes, NGOs, village councils, and other stakeholders, culminating in the formulation of a comprehensive strategy that adheres to the principles outlined above.

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