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Tracing out of elephant corridors and landscape dynamics of Eastern Assam using geospatial tools: A case study in Tinsukia District of Assam, India

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ABSTARCT

The Asian Elephant (*Elephas maximus*) is listed as endangered in the IUCN Red list as the wild population has declined by at least 50% since the 1930s. Massive deforestation, developmental activities, increased human population have destroyed the age-old corridors of elephant in many parts of Southeast Asia including Assam. This 'corridor' plays a vital role in maintaining population viability across a larger landscape. In the present study status of 4 presently utilized elephant corridors of Tinsukia district of Assam have been assessed on temporal scale for the years 2011 and 2020. The land use and land cover study results show that there was substantial increase in areas of settlement, tea gardens and agricultural land on all the corridors that restrict the free movements of the tuskers and caused conflicts in many parts. Out of the four corridors Takuaoni-Kakojan corridor was found to be least affected by these anthropogenic activities. On the Bagapani corridor besides the pressure of human activities, the National Highway 38 and railway traffic was recognized as the killer of multiple numbers of elephants on its track.

Key words : *Asian Elephant, Corridor, Habitat, GIS, GPS*

Introduction

The world has seen large scale loss and degradation of natural landscapes due to human activities resulting in the reduction and fragmentation of habitat for a myriad of wild species. Such habitat fragmentation and the ensuing interspersion of human habitation and cultivation has brought wildlife into greater contact with humans, leading to an escalation in human animal conflict, particularly in the case of large wide ranging mammal species such as Asian elephant and African elephant (Sukumar, 1994; Hoare, 1999; William, 2001; Madhusudan, 2003; Choudhury, 2004; Sitati, 2006). Increased settlement, cultivation and developmental activities have dramatically encroached the natural habitat resulting in severe conflicts between human and elephant (*Elephas maximus)* (Chodhury, 2004). Mega herbivores like elephants the long ranging species with extensive habitat and nutritional requirements are among the most affected species (Sukumar, 2006). The increased interaction between human

and elephant has caused (Baskaran *et al.*, 1996) damage and death for both the sides. The Asian elephants are threatened throughout their range by a combination of logging, large scale forest conversion and conflict with humans (Rood *et al.*, 2010). Across Southeast Asia, tropical deforestation continues at alarming rates (Santiapillai and Jackson, 1990; Acherd *et al.*, 2007; Hansen *et al.*, 2009; Linkie *et al.*, 2009) and large-bodies mammals like Asian elephant depending on the large areas of suitable habitat to meet their dietary demands, are considered to be particularly vulnerable to the effects of habitat transformation by human (Leimgruber *et al.*, 2003; Shannon *et al.*, 2009) and this situation leads to conflict between human and elephant. In Assam and North East (NE) India the conflict is more serious and has become one of the major conservation issues (Choudhury, 2004). The 'All India Synchronized Elephant Population Estimation' conducted by Government of India enumerated 27,312 elephant population for the nation in 2017 and for Assam it was 5,719 (Govt of India, 2017). The state of Assam is regarded as one of the strongholds of Asian elephant conservation (Santiapillai and Jackson, 1990; Choudhury, 2004). Assam is the major stakeholder state of project elephant having five elephant reserves covering an area of 10,900 km².

Conserving wildlife corridor is increasingly important for maintaining ecological and genetic connectivity in times of unprecedented habitat fragmentation (Ravisankar *et al.*, 2019) and also to manage and mitigate the human elephant conflict (HEC) in India in general and Assam in specific. The elephant corridors are often defined as a narrow strip of land that connects two large habitats. Preservation of these corridors are crucial to reduce animal fatalities due to accidents and to mitigate human elephant conflict. They also serve as breeding ground for elephants in some cases. The increased fragmentation of forests makes it all the more important to protect these migratory corridors. Asian elephants are long ranging species with extensive habitat and nutritional requirements. Furthermore, the population biology and genetics of the species require fairly unhindered gene flows across populations to ensure long-term viability. In fragmented, human transformed landscapes, that typify most elephant habitats in Asia today, corridors thus ensure that nutritional, demographic and genetic needs are met (Venkataraman, 2002). The Tinsukia district is one of the last strongholds of elephant in the state of Assam and according to Tiwari *et al.* (2017) the elephants from Tinsukia district are known to migrate to even to Myanmar through Changlang district of Arunachal Pradesh. But the traditional elephant corridors are blocked by various developmental activities and the rise in tea cultivation in the area has contributed to the rise in human elephant conflicts in the region. Though Tiwari *et al.* (2017) have identified three elephant corridors (viz., Bogapani, Golai and Katha) in Tinsukia district but detail comprehensive mapping of the corridors was lacking behind and the land use/ land cover (LULC) status of those corridors in recent times have changed. During last decades, blockages along these four corridors have pushed the elephants to use new routes to use as corridors in the area and causes HECs in many parts of the region.

Considering these aspects an attempt has been made in this research paper to assess the impacts of changing land use land cover LULC along the important elephant corridors of Tinsukia district of upper Assam using geospatial tools and extensive ground base survey. The findings of this study would help the authorities to manage and mitigate the HECs in the region.

Study Area

Tinsukia district of Assam, the northeastern state of India is situated in the eastern most part of the state covering a geographical area of 3790 km². The geographical extension of the district is between 27°12'52.8''N to 27°58'57.7'' N latitudes and 95°58'51.3''E to 95°13' 53.0''E longitudes. The district is one of the major strongholds of Asian elephant population in the state. The Dibru-Saikhowa National Park, Dihing Patkai Wildlife Sanctuary, Digboi and Doom Dooma Forest Divisions and the foothill regions along the boundary of the Assam and the state of Arunachal Pradesh are the prime habitats of elephant in the district. The Dihing Patkai Wildlife sanctuary (111.19 km²) is a part of Dihing Patkai Elephant Reserve (937 km²) under the project elephant initiative by Ministry of Environment and Forest, Government of India (Fig. 1). The region falls under the Assam valley tropical wet evergreen forests and forms the remaining patches of rain forests in Assam. The reserve supports a healthy population of more than 300 elephants (Das *et al.*, 2019). There are three designated elephant cor-

ridors in the district (Tiwari *et al.*, 2017) connecting one habitat to another, but clearing large tracts of elephant habitat for mining and tea estates, resettlement of farmers displaced by floods and erosion of the Brahmaputra, and land conversion by politically motivated transmigration of farmers from within and outside the state as well as neighboring countries, have rapidly dwindled the forests, and wild elephant herds are becoming homeless in their own abode (Sarma, 2007, Nath, 2013). Hence, HEC in Tinsukia district is gradually on the rise.

Material and Methods

Extensive field visits were carried out during August and October of 2019 to assess the status of elephant corridors of the district which were already demarcated in 2005 by Wildlife Trust of India with the help of the local communities and Forest Department, Govt. of Assam. Different migratory routes and corridors of elephant of the district were delineated using GPS device for Bogapani elephant corridor, Upper Dihing east-west corridor, Kotha – Burhidihing corridor and Kakojan – Takuaoni elephant corridor. For mapping the recent land use land cover along the corridors and the respective buffer areas, high resolution satellite imagery (Digital Globe) of 2020 was used which is available in open source Google Earth Pro platform. IRS 1D LISS III imagery of November, 2011 was utilized as the base year for change detection. Onscreen image interpretation technique was applied to delineate different land use land cover in GIS platform for both the years. For delineating the routes and corridors of elephant Arc GIS conservation extension tool (Hawath's Analysis Tool) of integrated spatial analysis was executed. Sufficient field verifications and Google Earth Pro platform were used to validate and correlate the collected data and also for accuracy assessment of the LULC classes.

To check the classification accuracy of LULC type reference template from the margining data have been applied. With fifty randomly selected samples on Google Earth Pro imagery of 2020, overall accuracy, user's accuracy, producer's accuracy and Kappa statistics were derived (Lillesand *et al.*, 2004). The Kappa statistics was derived from the statistical equation:

$$K\hat{} = \frac{\text{Observed accuracy} - \text{Chance agreement}}{1 - \text{Chance agreement}}$$

Results and Discussion

Four new corridors in Tinsukia district have been evolved due to the blockage of the traditional routes of the elephants due to various developmental activities took place during the last couples of decades. Along these four new corridors viz., Bogapani, Upper Dihingeast - west, Takuaoni-Kakojan and Koth - Burhidihing, there are recurring incidents of HECs. The detail of these corridors is described herewith (Fig. 1).

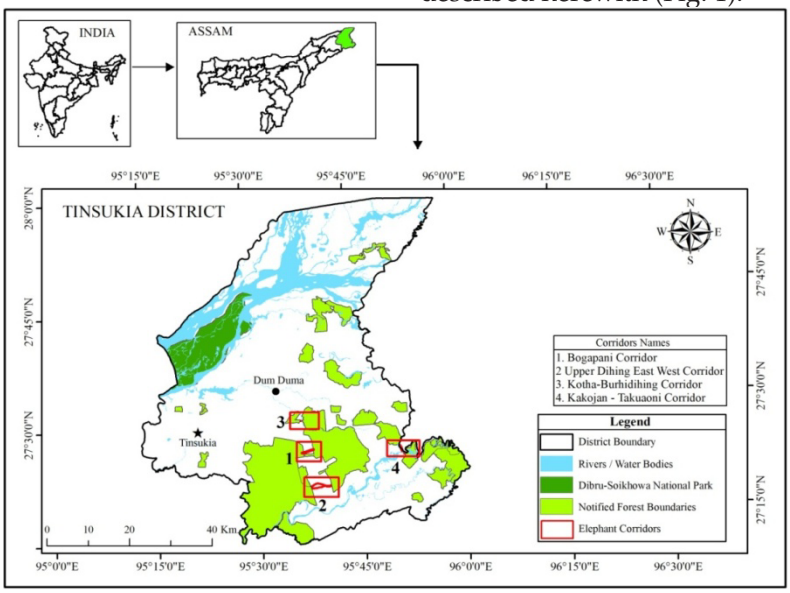

Fig. 1. Study area location

Bogapani Elephant Corridor

This corridor connects the forest areas of Upper Dehing East and Upper Dehing West blocks at Bogapani. The total length of this corridor is 3 km. The corridor extends from 27°25'23.49″ N to 27°25'46.25'' N latitudes and 95°36'31.3'' E to 95°38'12.90'' E longitudes. The major obstacles here are the National Highway 38 and a railway track between Digboi and Tinsukia that pass through this corridor. The elephants have to cross these obstacles to move from either side. The railway track has caused the death of seven elephants in a single accident in 2001 (Tiwari *et al.,* 2005). The intersection point of the corridor and the railway line is considered as the riskiest zone for elephant (27°25'23.23″ N and 95°36'34.81'' E). The buffer zone of this corridor is 500 meters of the either sides of the corridor and the area covered by the buffer is 661.38 acres (Table 1). Agriplantation, tea gardens, human settlement (mainly tea laborers) are the major land use pattern in the buffer zone of the corridor (Fig. 2). Construction of house, paddy cultivation and extension of tea gardens has led down a serious problem for the elephants in this corridor in last couple of years. Sometimes the elephant unable to cross the corridor and remain on Upper Dehing east side causing a serious human elephant conflicts (HEC) in the area.

Upper Dihing East–West Corridor

This corridor also connects Upper Dihing East – West blocks but the sight is 10 km away from the Bogapani. There are two strips of corridor available in this area. The total length of the corridor is 6.30 km and the buffer of the corridor is 200 meter in either sides of the corridor. The corridor extends from 27°20'24.76'' N to 27°20'55.28'' N latitude and 95°37'17.22″ E to 95°40'41.64'' E longitudes. Recent constructions of an oil terminus by Indian Oil Corporation Ltd. near the corridor and new settlements have drastically changed the area's geo-environmental condition. Another major obstacle of the corridor is the National Highway 38 which intersects with the corridor (Fig. 3). Here in this corridor a major portion passes through tea gardens and agricultural land and it creates HECs in the area in recent time. The total area of the buffer zone of the corridor is 1024.5 acres (Table 1).

Takuaoni-Kakojan Elephant Corridor

This corridor connects Kakojan Reserve Forest and Takauni Reserve Forest. The total length of this corridor is 1 km and the buffer area of the corridor is 200 meter of the either sides of the corridor. The corridor is extends from 27°29'37.45'' N to 27°29'39.79'' N latitudes and 95°36'18.09'' E to 95°36'44.65'' E longitudes. The total buffer area is 61.09 acres (Table 1). The corridor passes through a substantial area of agricultural land (Fig. 4) and again it creates HECs in the area.

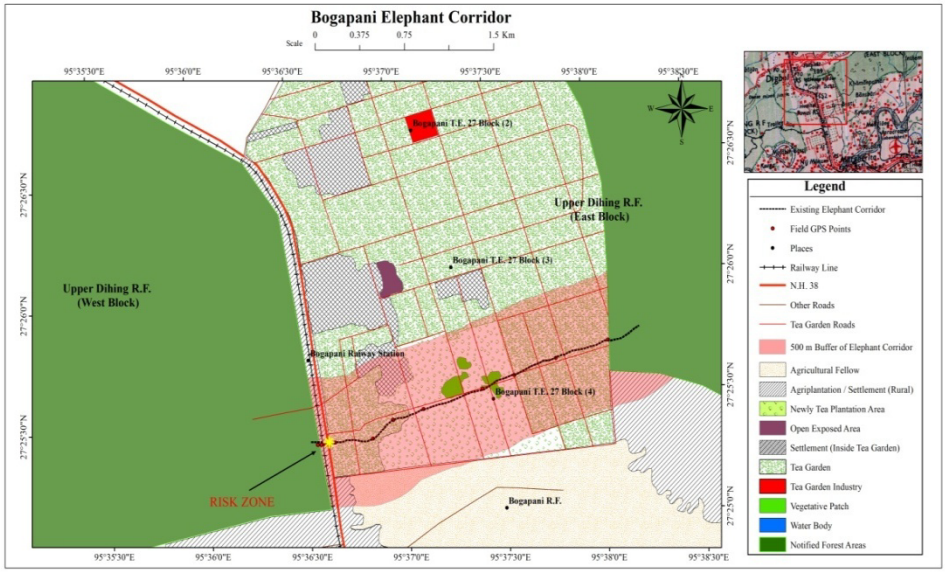

Fig. 2. Bogapani Corridor and its surrounding area

Table 1. Land Use / Land Cover status of the elephant corridors and its buffer areas.

Land Use Classes	Bogapani Corridor	Upper Dihing East-West Corridor	Takauni-Kakojan Corridor	Kotha-Burhidihing Corridor
		(Area in Acres)		
Agriplantation/ Settlement (Rural)	53.38	26.77	****	268.69
Agricultural Land	****	****	25.54	203.87
Agricultural Fellow	38.22	299.27	****	2.5
New Tea Plantation Area	230.16	****	****	****
Settlement (inside tea garden)	26.28	****	****	****
Tea Garden	275	486.28	12.28	****
Forest Outside Notified Area	13.34	27.73	17.01	124.51
Township	****	58.62	****	****
Barren Land/ Wasteland	25	***	2.42	****
Ox Bow Lake / Low Land/ Low-lying Area	****	42.24	****	74.36
Scrub Forest	****	****	****	44.33
River Sand	****	****	****	64.04
River	****	****	4.84	66.96
Water Body	****	83.59	****	1.17
Total Area	661.38	1024.5	62.09	850.43

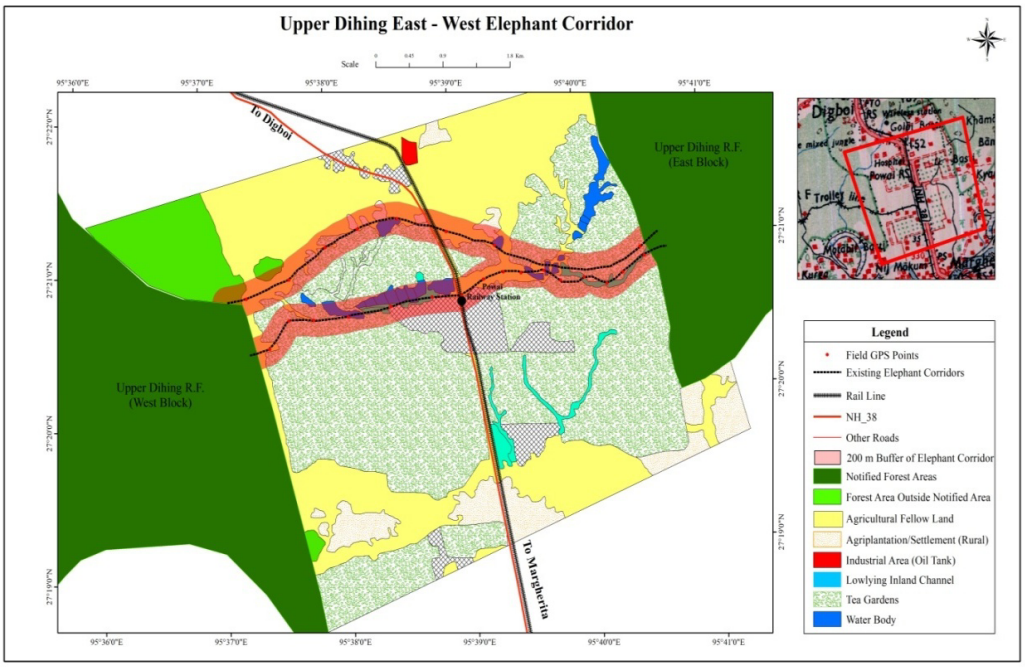

Fig. 3. Upper Dihing East West Corridor and its surrounding area

Koth-Burhidihing Elephant Corridor

This corridor connects the Kotha Reserve Forest of Digboi Forest Division with the Burhidihing Reserve Forest facilitating the movement of elephant populations to Changlang district of Arunachal Pradesh (Tiwari *et al.,* 2005). The total length of this corridor is 5.29 km and the buffer zone of the corridor is 300 meters from either side of the corridor. The total area of the buffer zone is 850.43 acres (Table 1). The corridor extends from 27°24'22.67''N to 27°25'55.45'' N latitudes and 95°50'34.52''E to 95°52'34.52''E longitudes. The resettlement in these areas has led a serious problem both for the elephants as well as human beings (Fig. 5).

Changes in LULC along the elephant corridors

Information on land use / land cover in the form of maps and statistical data is very vital for spatial planning, management and utilization of land resources (Chopra *et al.*, 1997). Currently, with the growing population pressure, changing human population-land ratio and increasing land degradation, the need for optimum utilization of land as-

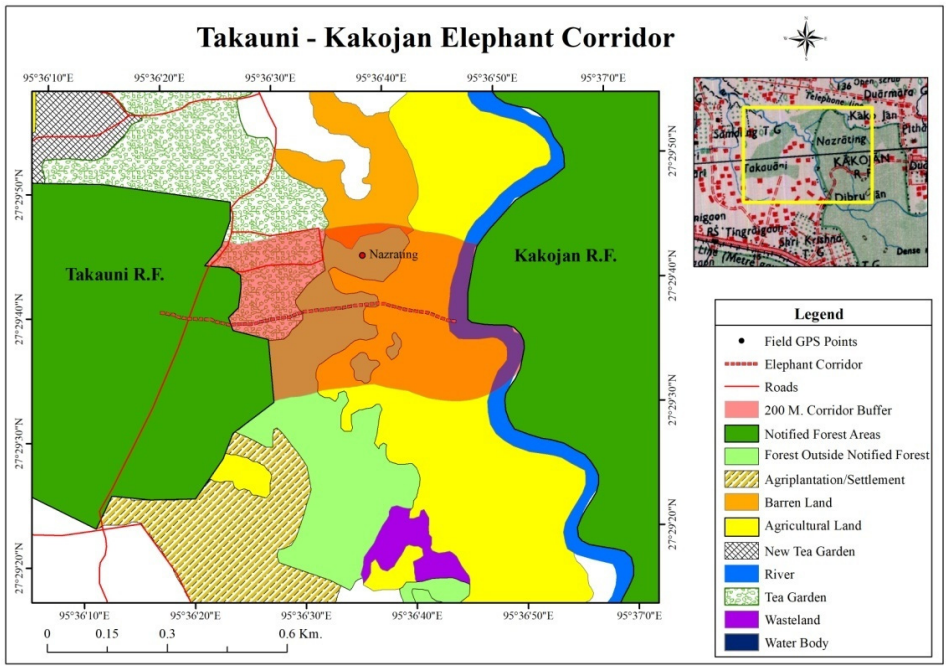

Fig. 4. Takauni-Kakojan Elephant Corridor and its Surrounding area

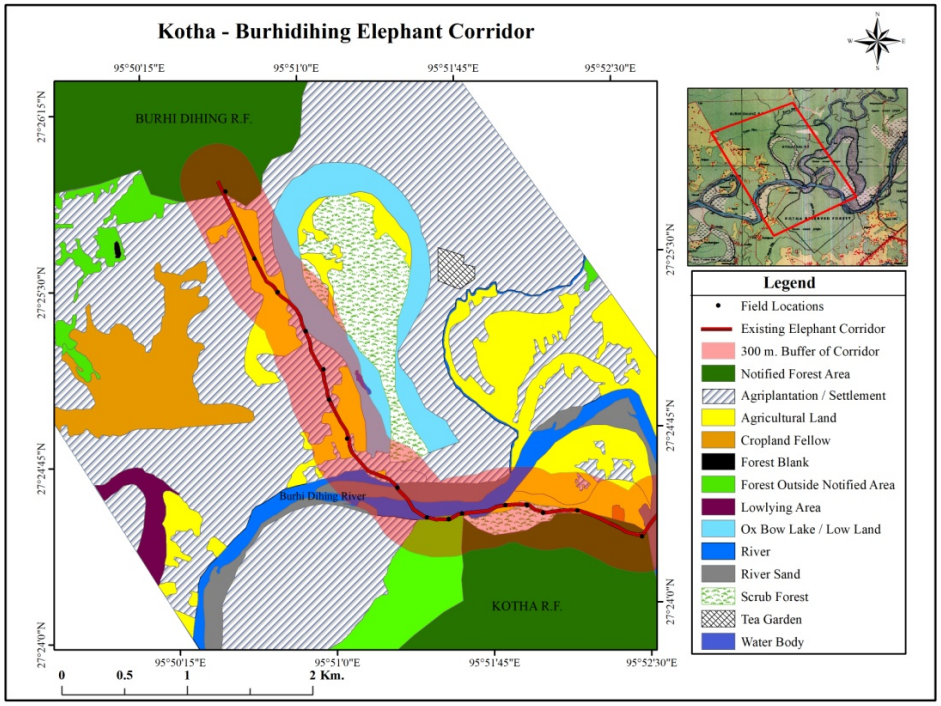

Fig. 5. Kotha-Burhidihing elephant corridor and its surrounding area

sumes much greater relevance. Anthropogenic changes in land use and land cover are being increasingly recognized as critical factor influencing global change. While land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface, while land use is often shaped by human, socio-economic and political influences on the land (Nagendra *et al.*, 2004). Change detection of land use / land cover is the process of identifying differences in the state of the object or phenomenon by observing it at different times. Essentially, it includes the ability to quantify changes using multi-temporal data sets. The following results show the changes of LULC along the four elephant corridors and its respective buffer areas using multi temporal satellite images of 2011 and 2020.

LULC Changes in Bagapani Corridor

The LULC changes in Bagapani elephant corridor shows that there is a substantial increase of agriplantation and settlement areas along the corridor from 2011 to 2020 but the agricultural fallow land has decreased from 149 acres in the year 2011 to 38.22 acres in the year 2020. These decreases are mainly due to the increase in settlement and tea garden in the area. Tea gardens of the area have increased from 261 acres in 2011 to 275 acres in 2020. This indicates that the buffer area of the corridor is not well protected from the increased settlement and tea gardens (Table 2).

LULC changes in Upper Dihing East-West Corridor

In this elephant corridor the increased area of tea garden is a major concern. Tea garden has increased from 479.54 acres to 486.28 acres from 2011 to 2020. The agriplantation and settlement along this corridor has also increased from 24.98 acres in the year 2011 to 26.77 acres in the year 2020. Remarkably the agricultural fellow land of this area has decreased from 304.99 acres to 299.27 acres. This decrease is mainly due to the expansion of tea garden in the area. Another important observation along this corridor is the increase of township area; it increased from 57.12 acres to 58.62 acres from 2011 to 2020. This indicates that there are several disturbance factors like tea gardens, human settlement, township, etc for free movement of elephant along this corridor and its buffer area (Table 2).

Table 2. LULC changes along the elephant corridor and its buffer area of 4 elephant corridors of Tinsukia district of Assam

LULC Categories	Elephant Corridors							
	Bagapani Corridor		Upper Dihing East-West Corridor		Kakojan-Takauni Corridor		Kotha-Burhi Dihing	
	Area in Acres							
	2011	2020	2011	2020	2011	2020	2011	2020
Agriplantation / Settlement (Rural)	49.06	53.38	24.98	26.77	***	***	254.98	268.69
Agricultural Land	***	***	***	***	27.54	25.54	209.67	203.87
Agricultural Fellow	149	38.22	304.09	299.27	***		2.51	2.5
New Tea Plantation Area	136	230.16	***	***	***	***	***	***
Settlement (inside tea garden)	21	26.28	***	***	***	***	***	***
Tea Garden	262	275	479.54	486.28	12.29	12.28	***	***
Vegetative Patch(Forest Outside Notified Area)	13.32	13.34	29.98	27.73	17.12	17.01	124.51	124.51
Township	***	***	57.12	58.62	***	***	***	***
Barren Land / Wasteland	31	25	***	***	0.29	2.42	***	***
Ox Bow Lake/Low Land/ Low-lying Area	***	***	43.23	42.24	***	***	70.36	74.36
Scrub Forest	***	***	***	***	***	***	56.33	44.33
River Sand	***	***	***	***	***	***	68.44	64.04
River	***	***	***	***	4.85	4.84	61.96	66.96
Water Body	***	***	85.56	83.59	***	***	1.67	1.17
Total Area	661.38	661.38	1024.5	1024.5	62.09	62.09	850.43	850.43

LULC changes in Kakojan-Takauni Corridor

The Kakojan-Takauni corridor is the only corridor among these four, where there is no drastic change in LULC. The agricultural land of this area has decline from 27.54 acres to 25.54 acres from 2011 to 2020. This change is because of increase of barren land caused by flood and siltation in recent time(Table 2).

LULC changes in Kotha-Burhidihing Corridor

The agriplantation and settlement along this corridor has increased from 254.98 acres to 268.69 acres but the agricultural land has decreased from 209.67 acres to 203.87 acres during the decade. This decrease of agricultural land is mainly due to the increase of human settlement and agriplantation along the corridor. The river channel area also increased from 61.96 acres to 66.96 acres from 2011 to 2020. River bank line erosion is the main cause of this expansion of river area. Another important change has observed regarding the scrub forest cover. Scrub forest has decreased from 56.33 acres to 44.33 acres. Increase of human settlement is the root cause of this decline. This indicates that human settlement is gradually increasing along the corridor and it has created problem to free movement of elephant in the area (Table 2).

Accuracy Assessment of LULC change

The overall accuracy of the classification was 94 percent and the overall kappa (K^) statistics was 0.9099.

Conclusion and Recommendations

Based on the results in the present study the following few recommendations could be useful for preserving the existing elephant corridors and reduce the conflicts between elephant and human.

a) The corridors and buffer zones should be notified as restricted area by the concern authorities as early as possible to get an obstacle free movement of elephants from one habitat to another.
b) Plantation along the corridors should be done immediately to provide an ecological connectivity of the species in the area.
c) Developmental activities and human habitation should be avoided in the corridors and buffer zones.
d) Expansion of tea garden along the corridor should be regulated.
e) The intersection points of elephant corridors, railway line and national highways should be notified as risk zone for elephant and measures should be taken to minimize the causality of elephant in those areas.
f) Mass awareness in the fringe villages regarding biodiversity conservation and elephant habitat conservation is utmost necessity to mitigate human elephant conflict in the area. Conservation agencies like Department of Environment and Forest, Government of Assam, NGOs, educational institutions, etc. should take proper attention for such awareness drives in the area.
g) Analysis of remotely sensed data on temporal scale could be an effective tool to monitor the status of these corridors on regular basis.

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