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Elephant Habitat Suitability Analysis of Alipurduar District, West Bengal Using Geospatial Technology

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ABSTRACT

In India's Tarai-Dooars region, elephants are the most common wildlife species. The man-wildlife conflict has arisen as a result of forest scarcity, forest fragmentation, global climate change, land use land cover change in the Dooars region, and encroachment into forest life. Although the Wildlife Protection Act of 1972 addressed the conservation of wild animals, the number of wild elephants in West Bengal was constantly changing. The goal of this project is to use geospatial technologies to determine wild elephant habitat suitability zones in West Bengal's Alipurduar area. The first stage in the conservation and management of wild elephants is to determine their habitat suitability. To assess the result, the various habitat suitability factors/parameters of wild elephants were integrated through weighted overlay analysis in the ArcGIS environment. The result shows that the central part of the district - the Buxa forest area, holds the largest suitable environment for elephant habitat. The rest of the study area can be categorized as a medium habitat suitable area excluding some settlements and built-up areas. The authors hope the result will help the proper management and conservation of wild elephants.

INTRODUCTION

The keystone and iconic animal in the forest, the elephant, is an intelligent and herbivore sociable wild mammal that plays a crucial role in maintaining biodiversity and the environment (Puri et al. 2019, Mandal & Chatterjee 2020). South Asian elephant, being the largest terrestrial animal, is adapted in the Dooars' riverine flood plain. Dooars region hosts the largest elephant reserves in West Bengal (99.51 Km^2). Alipurduar district is a tribal dominant district of West Bengal covering 31.54% of forest area including Buxa national park, Jaldapara national park, Buxa wildlife sanctuary, and Chilapata forest area. The Eastern Himalayan region is a biodiversity hotspot region of India (Huang et al. 2019). With increasing population pressure, the natural forests around the world are facing the brunt of anthropogenic activities spelling doom for flora and fauna. With the shrinkage of forest land and changes in land use land cover the bio-reserve of Alipurduar district has been facing man-animal conflict over the years. The study area has been facing the conversion of its natural forests into agricultural land, residential land, road, and industrial land. The development of GIS and remote sensing plays an important role in wildlife conservation, management, and habitat suitability analysis over the world. The habitat suitability index was initially developed by Oldham et al. (2000) for evaluating habitat quantity and quality. Researchers such as Wennink et al. (2018) focused on the habitat suitability of golden jackals in the Netherlands. Catullo et al. (2008) discussed Asian mammals` analysis based on habitat suitability models. Snaith et al. (2002) had done moose habitat suitability analysis in Canada. Purify et al. (2019) worked on Waterbird habitat suitability on an urban coastal wetland in the Lantebung mangrove area. Debeljak et al. (2001) discussed red deer habitat suitability in South-central Slovenia. Khwairakpam et al. (2019) worked on Pengba fish habitat suitability in Loktak Lake and its river basin, Manipur.

Habitat Suitability Index is a numerical knowledge-based index ranging between 0 and 1. A value near 0 indicates unsuitable habitat and a value near 1 represents suitable habitat (Oldham et al. 2000). The purpose of the present study is to identify the habitat suitability index for wild elephants in the Alipurduar district of West Bengal. India has the largest encroachment into forest areas through railway tracks in the form of the Lumding-Guhawati track in Assam; Siliguri-Alipurduar tract in West Bengal; Coimbatore–Thrissur

track in Karnataka and Tamil Nadu, etc. (Roy & Sukumar 2017). A number of roadways also cross through the forest areas of the country. In the study area, NH-317 and SH-16 run through the Buxa forest, while NH-317 has divided the Jaldapara forest area. These hamper the free movement of wild animals and as such are a major problem for the study area. Owing to human encroachment into forest areas owing to the expansion of settlements, elephant encroachment into settlements and destruction of cropland has increased in the recent past triggering man-animal conflict. The present study is focused on habitat suitability zonation and man-elephant collision considering the parameters of land use land cover, NDVI, NDWI, distance to stream, distance to road, and distance to settlement and altitude.

Elephant Habitat Preference in the Alipurduar District

Alipurduar district is situated in the foothills of the Siwalik Himalaya. The northern part of the district is hilly with a moderate slope. Elephants do not prefer high altitudes and steep slopes and extended winter with snowfall (Giannatos 2004). The study area is devoid of a steep slope and long-term snow cover, favoring elephant habitation. Generally, elephants prefer large forests with dense vegetation near water sources. They sometimes use forest corridors in search of food within the forest or any other nearby location. The forest variability within this district takes care of the fodder and camouflages their existence along with taking care of other needs. There are a lot of rivers flowing from Bhutan hills that go through this district serving as a water source for the elephants.

The study's key objective is to elucidate elephant habitat suitability evaluation. The current study investigates the relationship between the performance of the elephant habitat in the study area and the forest ecosystem in addition to other parameters. Thus favorable factors like terrain, climate, water availability, food availability, and forest cover along with other encouraging factors have made the Alipurduar district a preferable place for elephant habitat.

MATERIALS AND METHODS

Study Area

Alipurduar district is one of the newly formed districts of West Bengal, extending between 26˚23′50″N to 26˚51′56″N latitude and 89˚2′58″E to 89˚53′40″E longitude having an elevation ranging from 60m to 350m above mean sea level (Fig. 1). It is bounded by Bhutan in the North, Assam in the east, Jalpaiguri in the West, and Cooch Behar in the South. River Raidak, Sankosh, Torsa, Jayanti, Checko, Hollong, Gadadhar, Basra, Kalikhola, etc., flow through the Alipurduar district. The area is characterized by high rainfall (350-650cm) and the forest comprises dry deciduous, moist deciduous, semi-evergreen, and evergreen types of Sal (Shorea Robusta) and its associated form of vegetation. Wild elephant (*Elephant maximus*), Gour (*Bos gouras*), and one-horned Rhinoceros (*Rhinoceros unicornis*) are the most abundant species of Jaldapara, Buxa, and Chilapata forest area. The forest area of this district is fragmented and interspersed with tea gardens and villages. Since 1947 over 20% of the forest area has been converted into tea garden plantations and other anthropogenic activities of economic importance. People in the study area are mainly engaged in agriculture and tea gardens while industrial activities are almost absent. The population density in the study area varies from 300 per Km^2 to 500 per Km^2 as per the Census of India, 2011 which is more than the national average population density.

Methodology

The present study was done by following steps: (1) Sentinel-2 satellite data was downloaded from the USGS portal (https://earthexplorer.usgs.gov/); (2) Road, settlement position, and stream shapefile were downloaded from (https://extract.bbbike.org/). (3) SRTM Digital elevation model (DEM) was downloaded from USGS portal (https://earthexplorer.usgs.gov/). All the imageries and shapefile were georeferenced in WGS-1984 UTM zone 45N. Landsat satellite imageries were analyzed in the ArcGIS environment for preparing the land use and land cover identification. The interactive supervised image classification system was used for land use land cover layer preparation and classified into seven subclasses as- water body, agricultural land, dense vegetation cover, grassland, settlement, sparse vegetation, and barren land. NDVI is a significant method for vegetation quantification, where a value near +1 indicates dense vegetation on the other hand value near -1 indicates a water body. NDVI was calculated from Sentinel -2 using band 4 and band 8 with the help of Pettorelli et al. (2005) by following equation (1)-

$$\text{NDVI}=\frac{(NIR-RED)}{(NIR+RED)} \quad \ldots(1)$$

NDWI is another method to predict the moisture content of vegetation that reflects the possibility of a forest fire. NDWI values near +1 indicate much moisture content and value near -1 indicate low water content. NDWI was calculated from Sentinel 2 using band 4 and band 12 with the help of the McFeeters (1996) by the equation (2).

$$\text{NDWI}=\frac{(NIR-SWIR)}{(NIR+SWIR)} \quad \ldots(2)$$

Distance to the road, distance to stream, and distance to settlement layers were prepared according to the Euclidean distance method in the ArcGIS environment (Fig. 2). Elevation was extracted from SRTM 1 (Fig. 2). All the thematic

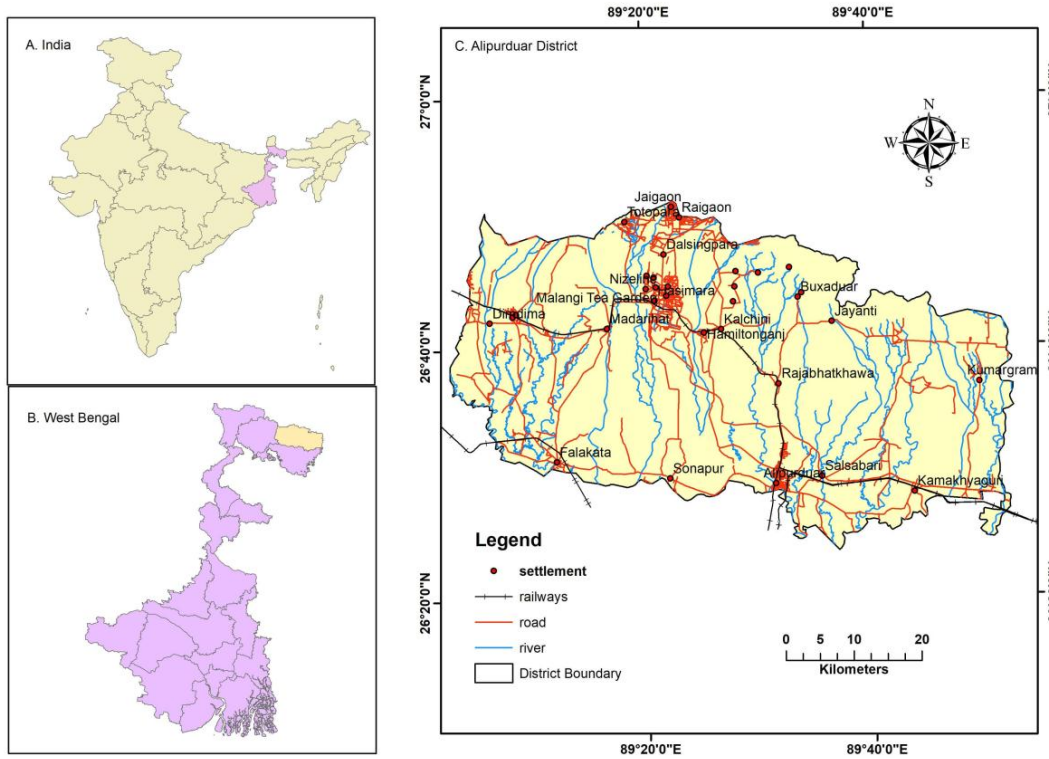

Fig. 1: Study area.

layers were then reclassified and suitable weights were given (Goparaju et al. 2017) using ArcGIS extension weighted overlay (Table 1).

The final habitat suitability map was categorized into three classes- highly suitable areas, medium suitable, and low suitable areas.

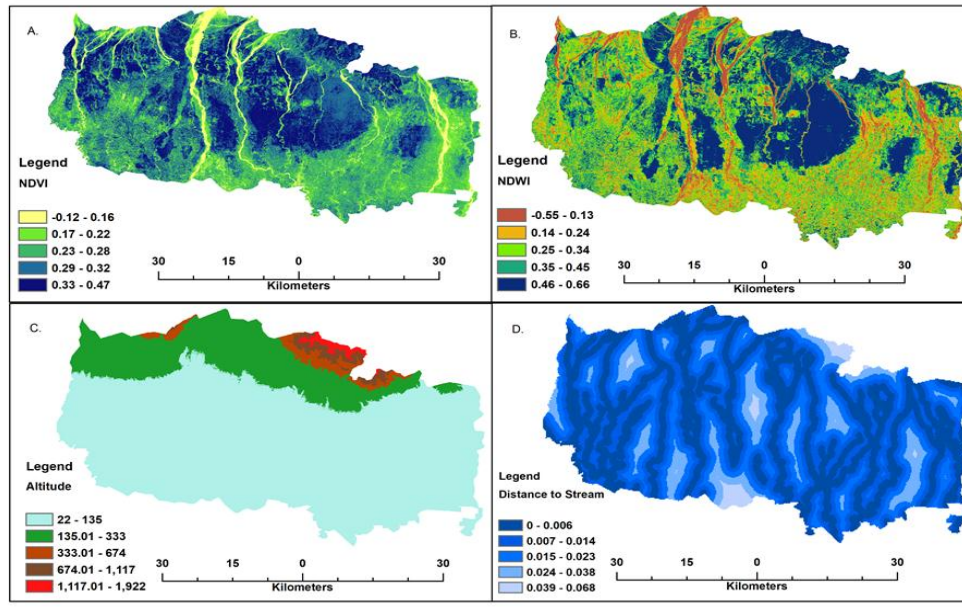

Fig. 2a: (A) NDVI (B) NDWI (C) Altitude (D) Distance from the stream.

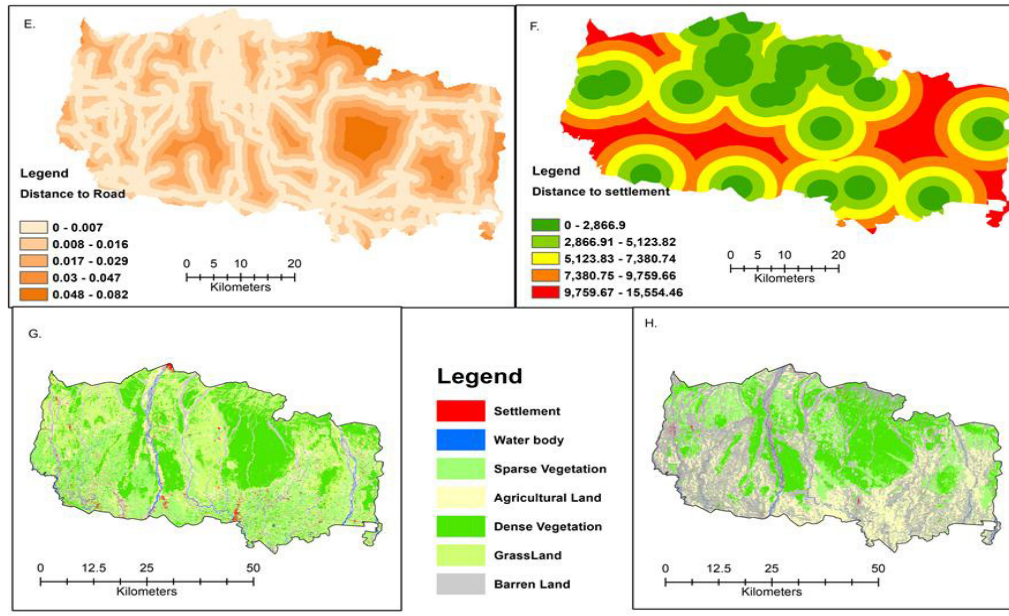

Fig. 2b: (E) Distance to road (F) Distance to settlement (G) LULC, 2020 (H.) LULC, 1990.

RESULTS AND DISCUSSION

Growth and reduction in a wildlife population are generally triggered by changes in population density and available resources. Forest areas help them hide, provide shelter, and fodder, and maintain their body metabolism. Forest fragmentation and existing local vegetation impact the colonization of elephants in a variety of environments (Kumar et al. 2010). For Suitability zoning, all the conditioning thematic raster has been superimposed in a weighted overlay GIS environment and categorized into three high groups, medium, and low suitability (Fig. 3)

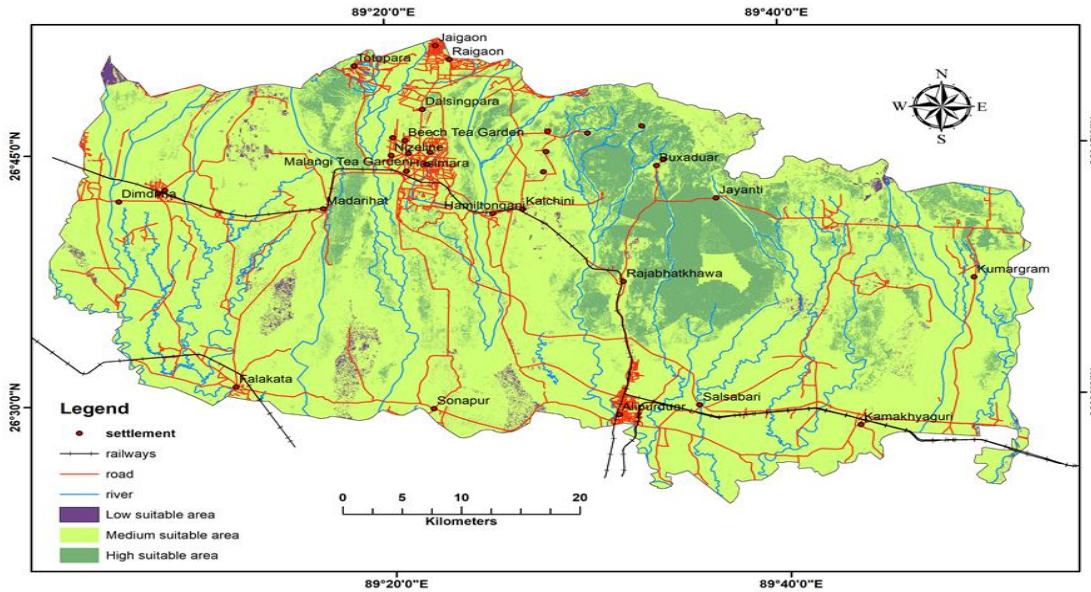

Fig. 3: Elephant habitat suitability zones.

Table 1: Weight of each parameter.

Parameters	Classes	Influence	Scale value
Distance to Road	0 to 0.007 m	5	1
	0.008 to 0.016 m		2
	0.017 to 0.029 m		3
	0.03 to 0.047 m		3
	0.048 to 0.082 m		5
Distance to Settlement	0 to 2866.9 m	15	1
	2866.91 to 5123.82 m		2
	5123.83 to 7380.74 m		3
	7380.75 to 9759.66 m		4
	9759.67 to 15554.46 m		5
Land use / Land cover	Water Body	25	3
	Agricultural Land		2
	Dense Vegetation Cover		7
	Grass Land		5
	Built-up Area		1
	Tea Garden		4
	Vacuum land		1
Distance to Stream	0 to 0.006 m	25	1
	0.007 to 0.014 m		2
	0.015 to 0.023 m		3
	0.024 to 0.038 m		4
	0.039 to 0.068 m		5
Altitude	22 to 135 m	5	2
	135.01 to 333 m		1
	333.01 to 674 m		1
	674.01 to 1117 m		1
	1117.01 to 1922 m		1
NDVI	-0.12 to 0.16	15	1
	0.17 to 0.22		2
	0.23 to 0.28		3
	0.29 to 0.32		4
	0.33 to 0.47		5
NDWI	-0.55 to 0.13	10	5
	0.14 to 0.24		3
	0.25 to 0.34		3
	0.35 to 0.45		1
	0.46 to 0.66		1

Wild elephant habitat suitability using weighted overlay geospatial technology in the Alipurduar district resulted in only 14.48 % of the area (Table 2) being under highly suitable area, 83.63 % area under medium suitable, and only 1.89 % being under low suitability area (Fig. 4). Result reveals that most of the area comes under medium suitable conditions. Areas coming under highly suitable areas have been rapidly getting converted to medium suitable areas

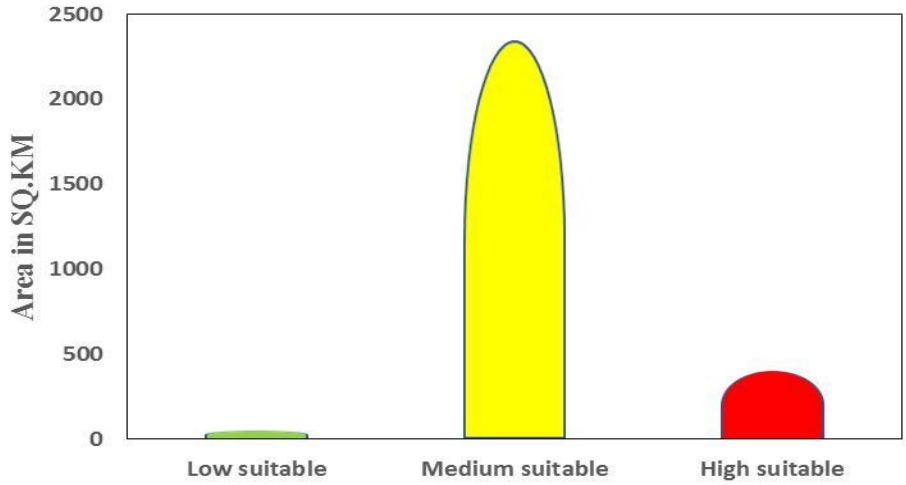

Fig. 4: Areal extension of suitability zones.

due to rapid deforestation, fragmentation of forest areas, encroachment, etc.

A Lorenz curve was done to assess the inequality of the number of elephants in north Bengal from the period 2002 to 2017 (Fig. 5). The man-elephant conflict has been an important issue for several decades in the Alipurduar district along with the entire Dooars region. Different analyses were performed to identify Man-elephant conflict management (Neupane et al. 2018). The management of Man-elephant conflict varies according to different social, financial, and environmental conditions. In the Alipurduar district, the human-elephant conflict has been increasing with every passing day. A comparative analysis of the land use between 1990 and 2020 (Fig. 2), revealed that settlement area has increased by 1.62%, thereby reducing dense vegetation areas by 11.4% during the same time. This change has spelled doom for the free movement and habitation of wild animals in the study area. During the same time, there has been a reduction in the number and areal extent of tea gardens which erstwhile played the role of an elephant corridor. Riverbank soil erosion is a major problem in the Dooars region. There has been a reduction of 22% in the water bodies of the study area due to riverbank erosion (Table 3).

Besides human interference, change in the natural environment is another important cause behind human-elephant conflict in this area. Elephants were mainly sighted by the authors in two seasons in the study area - the winter season and the rainy season. Dooars region has wet deciduous natural vegetation that becomes leafless in the winter season creating a food crisis within the forest area forcing the elephants to come out of the forest towards localities. The rainy season is their breeding season, hence forcing them to come out of forests to local residential areas in search of food (Fig. 6). In the absence of any buffer zone between the forests and settlements, encroachment into settlements triggers man-elephant conflict. Many times such conflict results in loss of life on both sides. Damage to life, property, and crops has become a persistent problem in the study area owing to man-elephant conflict.

Table 2: Areal extension of suitability classes.

Suitability Classes	Area in SQ.KM	[%]
Low suitable	52.9664	1.89
Medium suitable	2344.736	83.63
High suitable	406.0052	14.48

The study area lacks indigenous measures to curb the conflict. Mwamidi et al. (2012) mentioned the Taita community`s indigenous knowledge to protect wildlife. After seeding they return home without looking back, believing that God Mlungu would protect their crop and restrain from harvesting the crops until the wild animals consume a substantial part. Su et al. (2020) also mentioned that the Bulang community of China protects Banyan trees believing that the species help them maintain their vitality and keeps them alive longer owing to their divinity. Certain communities have also used various agricultural-based deterrents, like chili, to curb the encroachment of elephants into settlements (Hedges & Gunaryadi 2010). The technique of combining often damaged crops with crops that are less appealing or palatable to elephants is another agriculture-based deterrent (Gross et al. 2016). The alternative crops, which include coriander, mint, ginger, onion, garlic, lemongrass, and citrus trees, can aid farmers economically by compensating for the reduced production of major crops (Shaffer et al. 2019). New research in Africa has shown promising results employing bio-acoustic

measures/deterrents to prevent elephants, such as beehive fences, which also provide an additional economic benefit to pollinators and honey (King et al. 2017).

CONCLUSION

Among the districts of West Bengal state of India, Alipurduar district ranks fourth in terms of forest cover (31.54%) closely followed by the districts of South 24 Parganas, Darjeeling and Kalimpong. Major forest areas in the district, such as the Buxa forest, Jaldapara forest, and Chilapata forest, have been dwindling and experiencing encroachment as a result of both natural (rivers) and anthropogenic (roads, railway

Table 3: Land use land cover changes (1990-2020).

Class name	Area in SQ.KM (1990)	Area in SQ.KM (2020)	Change [%]	Trend
Settlement	14.0286	59.5173	1.62	Increased
Grassland	182.159	49.1463	4.74	Decreased
Waterbody	15.7624	638.018	22.19	Increased
Dense vegetation	703.785	391.36	11.14	Decreased
Sparse vegetation	355.201	805.484	16.06	Increased
Vacuum land	980.949	693.369	10.26	Decreased
Agricultural land	551.811	166.813	13.73	Decreased

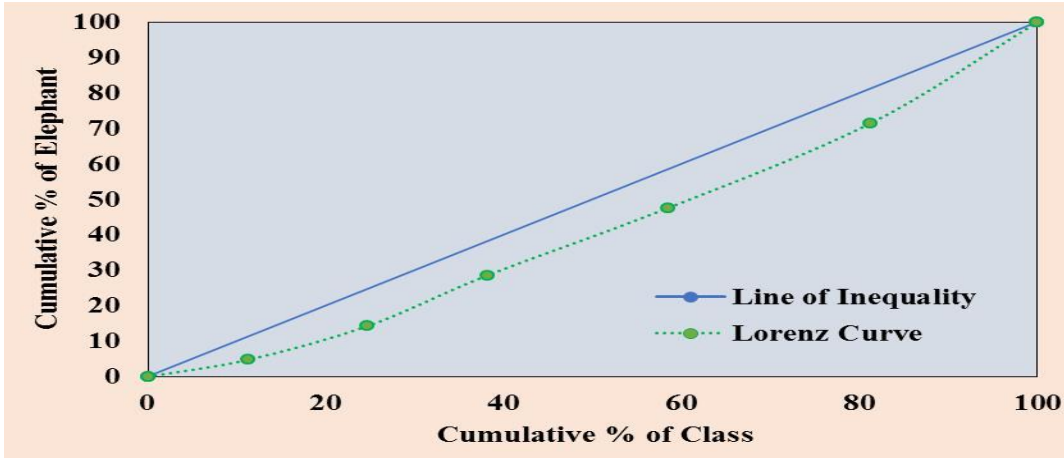

Fig. 5: Inequality of the number of elephants in North Bengal from the period 2002 to 2017.

Fig. 6: Elephant outing at night.

tracks, and settlement) causes. The study area has a high potential for elephant conservation as well as biodiversity management. It is the home to a host of tribal indigenous people. Ethnic knowledge plays a vital role in conserving and managing biodiversity and wildlife. Various management techniques like ensuring fodder for the animals in their natural habitat throughout the year, identification of alternative railway tracks outside the jungles, creation of buffer zones, expansion of ecological corridors, prevention of forest land encroachment, creation of biodiversity awareness among locals, development of various deterrents, etc along with promoting indigenous knowledge-based management techniques will help the reduction of man-animal conflict and support the protection and conservation of wild elephants.

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