



Land cover change and its impact on human–elephant conflict: a case from Fashiakhali forest reserve in Bangladesh

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Abstract

Changes in land cover are a major driving force behind habitat change, which significantly impacts the distribution of wildlife and ecological systems. However, there is a substantial lack of information on the effects of land cover changes on wildlife habitat and local conservation. Therefore, it is essential to understand how land cover changes may threaten future land cover trends and wildlife habitat loss, especially in protected areas. Landsat satellite imagery uses a geographic information system and remote sensing techniques to determine the spatiotemporal pattern of land cover change and its impact on the human–elephant conflict in the Fashiakhali Wildlife Sanctuary. We found that within the sanctuary (1994–2005), settlements, agricultural land, and bare land increased by 69.8 ha (2.3%), 991.6 ha (32.3%), and 39.5 ha (1.3%), and forest areas and water areas decreased by 1094.1 ha (35.7%) and 6.9 ha (0.2%), respectively. On the other hand (2005–2015), settlements, agricultural land, and water areas increased by 11.7 ha (0.4%), 264.7 ha (8.6%), and 36.2 ha (1.2%), and forest areas and bare land decreased by 308.9 ha (10.1%) and 3.7 ha (0.1%), respectively. Our findings have shown that increased agriculture and settlements have become a severe threat to the ecological sustainability of elephant habitat, resulting in habitat fragmentation and human encroachment of elephant habitats, as well as extreme pressure and competition on resources.

Keywords Fashiakhali forest reserve · Bangladesh · Land cover change · GIS and RS · Human–elephant conflict

1 Introduction

The change in land use/land cover (LULC) is the rapid influence and response of human activities on nature, with significant consequences [1–4]. The rapid changes in land cover, especially in developing countries like Bangladesh, urban sprawl characterized by random and unplanned growth [5, 6], is one of the most anthropogenic causes of the loss of arable land [7–9], habitat destruction [10], and the decline in natural vegetation cover [11]. Besides, land cover changes due to agricultural growth and tourism industry [12], and the conversion of agricultural land into shrimp farming, has changed the soil properties [13],

resulting in vegetation degradation and enormous environmental costs [12, 14]. Local and or regional developments profoundly impact this form of transition—the ecosystem, potentially affecting the global environment.

Bangladesh has strong potential for reforestation as a tropical country that could support an expanded forest area. Since the 1870s, Bangladesh’s forest area has declined [15], and the total forest land is less than 16% or 2.33 million ha [16]. Multiple variables have accounted for a significant deforestation rate ranging from 0.3 to 2% per year over the past 30 years and led to a wide area of degraded forests [17–20]. The world forest contains more than 80% of terrestrial biodiversity and plays a critical role

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in maintaining ecological balance, environmental stability, and biodiversity conservation [21, 22]. Forest cover is a valuable resource for food supply and day-to-day storage; for example, an estimate shows that one million and more than one billion people produce a large part of their lives, such as income, energy, food, from the forest [23, 24]. Therefore, the wildlife corridor that passes through the forest is an essential part of the ecosystem's ecological integrity and long-term endurance [25]. However, forest reserves and wildlife habitats face destruction due to human pressures and settlements that exceed the forest resource's regenerative ability [26–28]. Besides, rising socioeconomic requirements and growing population impose stress on land use/land cover, resulting in unplanned and uncontrolled land use/land cover change [29, 30]. At the local level, land use patterns and land cover changes contribute to systemic consequences, such as climate change, deforestation, land degradation, and environmental change [31–34]. Extensive effects on food security, biodiversity, and humans and communities' vulnerability have already been demonstrated globally [35]. Protected areas have already been designed globally and geographically distinguished and controlled according to the criteria and conservation aspects [36] to conserve the forest and its resources. The creation and management of protected areas depend on people's needs and welfare regarding wildlife's needs and sustainability. Indeed, the biodiversity conservation mechanism has changed quite a bit, notably in the realm of "people and nature," rather than in prior systems, which maintained an apparent dichotomy of the two [37]. Human-wildlife conflicts, however, do not exist in contrast to several other human-nature interactions happening concurrently within the system. The International Union for the Conservation of Nature (IUCN) declared that a human-wildlife conflict exists "when wildlife's requirements overlap with those of human populations, creating costs to residents and wild animals" [38]. This "overlap" may occur in urban and rural areas but is more common in and around protected areas, where wildlife population densities are generally higher [39].

The land cover characterizes the environmental condition and physical features of the land surface area such as water, crops, forests, human structures, shrubs, etc. [31, 40, 41]. Analysis of land use/cover change is an essential tool for estimating land cover changes at different spatial and temporal scales; for instance, it reveals the human behavior in a particular environment [8, 42, 43]. Remote sensing (RS) and Geographic Information System (GIS) may serve as a powerful tool to determine the spatial and temporal dynamics of land use/cover change [11, 44–47]. Scientists are now constantly using Remote Sensing (RS) and Geographic Information systems (GIS) on the broader aspect of land use/cover technology due to the massive

development of satellite-based technologies [48–52]. In addition, the digital archive of remotely sensed data offers an outstanding opportunity to research historical land use/cover change [53]. Landsat satellite image can be a valuable and cost-effective data source with a spatial resolution of 30 m [34] to extract information from a given region and detect changes. Therefore, it is essential to evaluate the forest cover and consider the significant drivers for the change, deforestation, and forest cover degradation [54]. Recent reports have shown a decrease in forests of more than 9000 km² during the 1930s alone, with an annualized rate of deforestation reaching 1% [15]. Most of the remaining areas degraded because of the intensive use for industry, firewood harvesting, and subsistence, including shifting cultivation in hill forests. Many experts differentiate between indirect and direct drivers, and even between degradation and those for deforestation. Indirect drivers were typically the same for deforestation and degradation, particularly poverty, overpopulation, and a community of drivers linked to ineffective governance, including lack of land use planning, corruption, weak management, enforcement power, and ambiguous land tenure. Besides, over-harvesting (excessive and illegal), agriculture or *jhum* (shifting cultivation), and encroachment (including industrial, military, and settlement) are the direct drivers for deforestation [15]. Nationally it is expected that fuelwood harvesting, excessive and illegal logging is responsible for forest degradation are the direct drivers.

Bangladesh is a deltaic country in terms of its unique geographical location, climate, and biodiversity-rich landforms. With a limited priority for protection and restoration, the forest reserve is poorly maintained for plants and animals. Consequently, protected areas with wildlife sanctuary are threatened [55, 56]. The Fashiakhali forest reserve is essential for the ecosystem because of its protected areas, which are assumed to be acknowledged, devoted and managed, by legal or other efficient means to achieve the long-term conservation of nature through associated ecosystem services cultural or intellectual values [57]. Wildlife Sanctuary is an area preserved as an uninterrupted breeding ground for wild fauna. The habitat is sheltered for the inhabitants' constant well-being of migratory fauna [58]. The Fashiakhali Wildlife Sanctuary (FWS) is situated within the Fashiakhali forest range, famed for its Asian elephants (*Elephas maximus*), commonly referred to as a 'keystone' species bordered by 30 villages [59]. The increasing population in the Fashiakhali forest reserve needs to change land use and land cover pattern, which could potentially restore the ecological balance. In comparison, the legal and illegal overexploitation of forest resources makes the matter worse [56]. However, rising human–elephant conflict cases have been recorded

in recent years, and habitat loss due to high population growth and poverty has proven to be the primary cause behind the situation [60]. The human–elephant conflict is alarming for elephants' conservation and protecting human life; for instance, damages of crops, social death, and elephant killing frequently appear [61, 62]. Wild elephants are now protected by the Bangladesh Wildlife Conservation (Amendment) Act of 1974 and are prohibited from being hunted, killed, or captured. Under the act, the Chief Wildlife Warden can declare an elephant as a 'rogue elephant' and issue a special permit to destroy it. The provisions of Wildlife Conservation Act (Draft) 2011, the sentence for killing an elephant shall be a prison of 2–7 years or a fine of Tk 100,000–1,000,000 (US\$ 1420–14,200) or both and a prison term and a fine of Tk 1,200,000 (US\$ 17,140) or both [63].

Several studies had been conducted in Bangladesh on the land cover changes and their impacts. For example, land cover change was assessed in the Chunati Wildlife Sanctuary (CWS) of Bangladesh using satellite imagery. The study found that the sanctuary had lost a significant amount of high-density forest cover [64]. Earlier, a survey of the Chunati Wildlife Sanctuary residents revealed that 49% were willing to conserve elephants, 16% were undecided, and 35% were against their conservation [65]. Another survey indicates that 388 people in four conservation areas in the Teknaf Game Reserve, Chunati Wildlife Sanctuary, south-east, and north-east Bangladesh, about two-thirds claimed that a wild elephant protected area would not give benefit people, while the remaining acknowledge tourism value and significance of elephant conservation for biodiversity [66]. Another study used a geo-informatics approach to monitor the land-use change for forest fragmentation of Chunati Wildlife Sanctuary in Bangladesh demonstrated that forest fragmentation positively correlated with forest conversion non-forest uses [67]. Besides, land use significantly influences socio-economic and environmental structures' operation with the necessary concession for sustainability [68]. It is also demonstrated that the Chunati Wildlife Sanctuary has been exhibiting a shifting trend since the 1980s and recorded that the forest area has been turned into other land uses. However, there is no scientific monitoring of the forest cover in the Fashiakhali forest reserve area, which is critically important due to its surrounding protected area (Fashiakhali Wildlife Sanctuary). Therefore, this study intended to fill this gap and explore the land cover changes in the Fashiakhali forest reserve in Bangladesh.

The purpose of the study is to examine the spatial and temporal land-cover change in Fashiakhali wildlife sanctuary based on the Remote Sensing (RS) and Geographic Information System (GIS). This paper also explores the relationship between land cover changes on wildlife habitat

and the destruction of human livelihood in the study area. The study focuses on evaluating the following hypotheses: (a) what were the significant changes in land cover in 1994, 2005, and 2015 in the Fashiakhali forest reserve? (b) if there is a relationship between land cover change and human–elephant conflict in the forest reserve areas. The results of this study will provide bases for assessing the sustainability and the management of the wildlife sanctuary and for taking actions to mitigate the degradation of the forest environment.

2 Materials and methods

2.1 Study area

Fashiakhali Wildlife Sanctuary (FWS) is a forest reserve located in Cox's Bazar district of Bangladesh. It lies between 90° 3' 36" E longitude and 21° 43' 53" N latitude to 90° 7' 35" E 21° 4' 51" N and between 92° 7' 3" E 21° 44' 27" N to 92° 6' 6" E 21° 38' 20" N (Fig. 1). The Fashiakhali forest reserve covers an area of approximately 3068.7 ha consisting of the Fashiakhali forest beat. The range of Fashiakhali includes the Dulahazara forest beat under the Cox's Bazar North Forest Division. The study area's elevation ranges from 2 m (meter) to some areas exceeding 60 m in height. The geological structure of the forest reserve and the surrounding area are similar. This structure was built up 25 million years ago during the Pliocene era of the tertiary periods [69] consisting of the Dupitila series of sandstones and shale [69, 70]. The study area experienced a moist tropical maritime climate with 740.8 mm mean annual rainfall where the average annual humidity is 79.3%, and the mean annual temperature is 26.6 °C [70]. Two forest villages with 112 populations were setting up in 1950; however, many Rohingya inhabitants have occupied the sanctuary later [71]. In 2007, it was declared a wildlife sanctuary under the Bangladesh Wildlife Preservation (Amendment) Act of 1947. However, the sanctuary now consists of around 8551 households bordered by 30 villages [59]. The total population of the Fashiakhali union (smallest administrative unit) is 18,945, where 9682 are males and 9263 are females with a population density of 1064 per km² [72]. The area's literacy rate is meager, about 36.53% [72, 73]. The study area is undulating with numerous hill ranges of various heights that cover natural forest, plantation forest, deep bushy vegetation, low valleys, streams, and wetlands [69]. The vegetation of this area has been classified as a tropical rain forest [74]. The flora consists of the Gurjan forests (*Dipterocarpus turbinatus*) and the Dhakijam *Syzygium* species. Take plantation (*Tectona grandis*), the *Eucalyptus* species, and the *Acacia* species

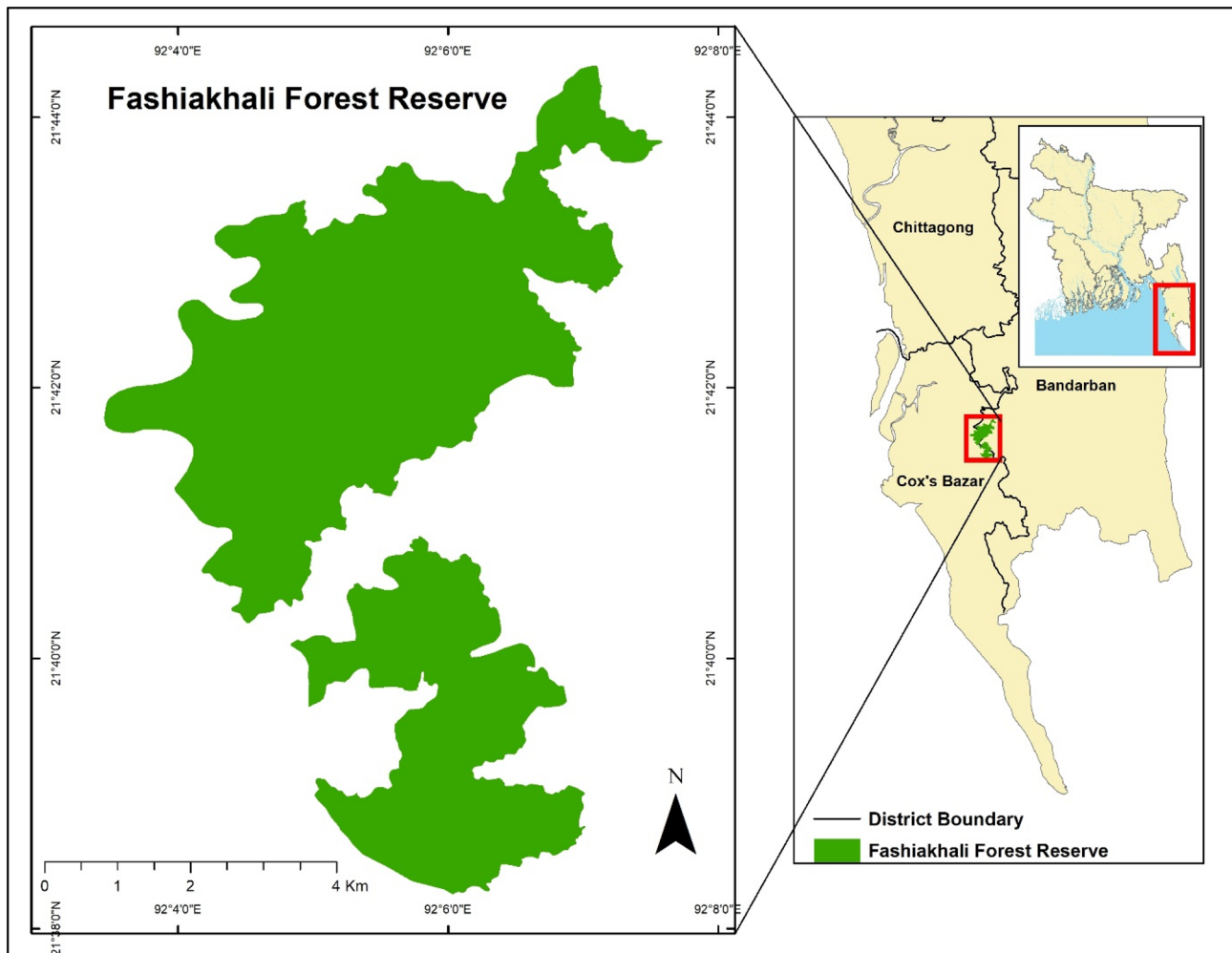


Fig. 1 Study area, Fashiakhali forest reserve, Cox’s Bazar, Bangladesh

are present. This forest reserve is critically important for local biodiversity, especially one of the protected areas of Bangladesh Fashiakhali Wildlife Sanctuary is situated in this forest reserve [56]. The Fashiakhali Wildlife Sanctuary has a wide range of wildlife dependent on mixed evergreen forest, including a herd of Asian Elephants [59].

2.2 Satellite image collection and field data

The Landsat satellite images were obtained from the USGS Global Visualization Viewer (<https://glovis.usgs.gov/>). Landsat TM and Landsat OLI-TIRS (path 136, row 45) were used in this study (Table 1). Other data, e.g., the topographic map (scale: 1:25,000, sheet number: 84C2C, survey year: 2011) from the Survey of Bangladesh, elephant tracks (using GPS) from the field survey in the Fashiakhali forest reserve; location of human–elephant conflict data

Table 1 The characteristics of the Landsat data used in this study

Satellite	Sensor	Path/row	Spatial resolution (m)	Date of acquisition	Sources
Landsat 5	TM	136/44	30	13/12/1994	USGS
Landsat 5	TM	136/44	30	10/02/2005	USGS
Landsat 8	OLI-TIRS	136/44	30	22/02/2015	USGS

was collected from field surveys by random sampling techniques.

2.3 Image processing

Remote sensing data has emerged as one of the most prominent data sources for quantitatively, spatially, and temporally monitoring land-cover change [75–77]. Evaluating the spatial and temporal change in land cover in the

Fashiakhali forest reserve, three Landsat imageries were used and processed by the remote sensing image processing software ENVI 5.3 (Harris Geospatial, Colorado, USA), ERDAS IMAGINE 2014 (Hexagon Geospatial, Madison, US) and ArcGIS 10.3 (ESRI, California, USA). We considered the study area's climate pattern, particularly the monsoon's influence on the image's spatial signature, satellite imagery captured during the dry season between December and February (winter) as less than 10% cloud cover. Open access remote sensing data remains unsystematic error; atmospheric and geometric correction is therefore needed. A relatively high-resolution image from Landsat 8 (sensors: OLI-TIRS) was geo-referenced using ArcGIS 10.3 and ERDAS IMAGINE 2014 software. Other Landsat images were co-registered to perform the geometric correction to the geo-referenced OLI-TIRS image as a reference. In the rectification process, we used about 60 ground control points (GCPs) in the study. Dispersed GCPs yielded a root mean square error (RMSE), which was not more than 0.45 pixels. Later, we performed atmospheric correction for all satellite images in ENVI 5.3. A first-order polynomial fit was applied and used the nearest neighbor method and then resampled to 30 m pixel size. The Bangladesh Transverse Mercator System (BTM), an area-specific standard UTM projection system for Bangladesh, has been applied as the coordinate system [78]. The spectral information sensed by each Landsat-5 TM sensor is stored as an 8-bit digital number (DN) [79] and Landsat-8 OLI-TIRS sensor as a 16-bit DN with 12-bit radiometric resolution [80] in the L1T and L1G products. DNs of each scene were converted to top of atmospheric (TOA) spectral radiance following equations (Eq. 1) adopted by [81] and USGS (Eq. 1 TM images, Eq. 2 OLI-TIRS image) using sensor-specific calibration parameters derived from the image L1T and L1G metadata file. The radiance of each scene's reflective bands was then converted to the TOA reflectance using the standard equations (Eq. 3 for TM images, Eq. 4 for OLI-TIRS image) formulated by [82] and USGS.

$$L_{\lambda} = \frac{(L_{\max} - L_{\min})}{(QCAL_{\max} - QCAL_{\min})} * (QCAL - QCAL_{\min}) + L_{\min} \quad (1)$$

$$L_{\lambda} = \frac{M_L * QCAL + A_L}{\Pi * L_{\lambda} * d^2} \quad (2)$$

$$p_{\lambda} = ESUN_{\lambda} * \cos \theta_s \quad (3)$$

$$p_{\lambda} = M_p * QCAL + A_p \quad (4)$$

In the above equations, L_{λ} is the TOA spectral radiance ($W m^{-2} sr^{-1} \mu m^{-1}$), $QCAL_{\max}$ and $QCAL_{\min}$ are maximum and minimum quantized calibrated pixel values typically

as 255 and 1, QCAL is the DN values, L_{\max} and L_{\min} are spectral radiances scaled to $QCAL_{\max}$ and $QCAL_{\min}$, M_L and A_L are band-specific multiplicative and additive radiance rescaling factors obtained from the image L1T and L1G metadata file, P_{λ} is the unitless TOA reflectance, d is the earth-sun distance in astronomical units, $ESUN_{\lambda}$ is the mean solar exoatmospheric irradiances ($W m^{-2} \mu m^{-1}$), $\cos \theta_s$ is the solar zenith angle (radians) calculated from the solar elevation angle stored in the image L1T and L1G metadata file, P_{λ} is the TOA spectral reflectance, M_p and A_p are band-specific multiplicative and additive reflectance rescaling factors obtained from the image L1T and L1G metadata file. The $ESUN_{\lambda}$ and d values were applied from [81].

2.4 Image classification scheme and algorithms

Land use/cover thematic mapping is often done using a variety of image classification techniques [83]. To assess the Fashiakhali forest reserve's land cover changes, we used a moderation of the Anderson scheme Level-I method [84]. Before classifying the land cover, all satellite data was revised to obtain the digital numbers (DNs) of different land cover categories using spectral and spatial profiles. The classification scheme was established based on ancillary information from a field survey conducted in 2015 in the Fashiakhali forest reserve, visual image interpretation, and local knowledge of the study area. Five land cover types—settlement, water, agriculture/grassland, forest, and bare land were classified. The description of each category of land cover considered in this study is shown in Table 2. In our land cover classified scheme, we assimilated the agricultural land and grassland into a single class because during the dry season in Bangladesh, due to scarcity of rainfall, no agricultural crop is cultivated and huge amount of agricultural land is likely to reduce and is converted into grassland [85, 86].

As the accuracy in land cover classification is fundamentally significant for remote sensing analysis, several studies evaluated the support vector machine (SVM), maximum likelihood classifier (MLC), decision tree (DT), and ensembles classifier such as Random Forest (RF) for monitoring land-cover change and these algorithms have shown a quantum increase in current times [87]. In particular, SVM [88] and Random Forest [89] have recently received considerable attention in remote sensing image classification, RF have been applied relatively extensively, offer suitable levels of accuracy [90, 91], and both are supervised, non-parametric statistical learning techniques [92, 93]. However, the images of the study were classified using a supervised maximum likelihood classification (MLC) algorithm [90], and the most practical algorithms for parametric classification rule [75, 94, 95] usually been proven to achieve

Table 2 Land cover classification scheme

Class	Description
Settlement	Residential, commercial, transportation, industrial, utilities, mixed and other urban
Water	Rivers, ponds, reservoirs
Agriculture/grassland	Cropland, herb, and shrub
Forest	High vegetation, mixed forest lands, reserved forest, non-reserved forests, settlement under tree cover, homestead vegetation
Bare land	Fallow land, exposed soils, bare soil

the best results if each class of the remotely sensed data has a Gaussian distribution [11, 96]. MLC is self-evident and still used because this algorithm significantly decreases the data necessities and providing a potential to extract comprehensive information [87, 97–99]. Based on the visual analysis of the locations on Google Earth and the image itself, 50 polygons were digitized for each category.

2.5 Change detection and accuracy assessment

The change detection and the classified maps have been produced using the pixel-by-pixel method [100]. In the classified land cover images derived from the MLC algorithm, some technical errors were found between the agriculture and forest due to their similar spectral features. Next, to recover the classification's accuracy, a simple and efficient method called post-classification refinement was used [11, 101, 102]. Then, to remove the salt-and-pepper effect on the classified land covers, a 3 * 3 majority filter was applied [103]. After that, to determine the land cover changes, a post comparison of changes was executed [5, 11, 102, 104].

For the accuracy assessment of this study's land cover classification, field data, topographic maps, and geographical features on land cover maps were used. To assess the accuracy of land cover maps obtained from Landsat data, a total of 225 stratified random sample points (i.e., 45 for each class) for 1994, 2005, and 2015 land cover maps were selected. For the accuracy evaluation of the 2015 land cover map, a high-resolution Google earth image was also used. To calculate the classification precision, a nonparametric Kappa test following the equation (Eq. 5) was performed [11, 105].

$$K = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r (x_{i+})(x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+})(x_{+i})} \quad (5)$$

where r is the row number in the matrix, is the number of observations in row- i and column- i (the diagonal elements), $+$ and $+$ are the marginal totals of row- r and column- i , respectively, and N is the number of the observations.

2.6 Human–elephant conflict risk hot spot

The elephant's routes and their movement throughout the study areas were observed and identified by any elephant signs (e.g., footprints, dung, and broken trees) were recorded on GPS. The plotted GPS data of elephant signs revealed the elephant movement routes, corridor, and entry point to settlement or crop fields. In the survey process, local people were guided to find the elephant routes accurately. Here two crucial pieces of evidence or features that precisely locate elephants' presence are elephant's footprints and dung piles. The human–elephant conflict (HEC) zone and elephant hot spots were visualized in the map (Figs. 5, 7) using ArcGIS10.3 software. The risk hot spot map is derived from Kernel density estimation and hot spot mapping. The data includes information on the households' location affected and damaged, e.g., homestead garden agricultural field, and social death. From the respondents' interviews, the participants were asked to name and locate the areas where most conflicts occur within the study areas.

3 Results

3.1 Accuracy assessment

We found the total accuracy of the Landsat-derived classified images was 95%, 92%, and 96%, with the result of kappa coefficient of about 0.90, 0.86, and 0.93 for 1994, 2005, and 2015 respectively (Table 3). The product is similar to the standard land cover mapping accuracy of 85–90%, as suggested [84].

This study's accuracy assessment confirmed an accuracy level is closer to another survey conducted in nearby regions for forest cover change in Teknaf in Bangladesh for the years 2016/2017 [106]. That study obtained an overall classification accuracy of 94.53 and 95.14% for 2016 and 2017 land cover maps, respectively, with general Kappa statistics of 0.93 and 0.94. The producer and user accuracy

Table 3 Overall accuracy and kappa coefficient of land cover classification

Year	Class	User accuracy	Producer accuracy	Overall accuracy	Kappa coefficient
1994	Settlement	76	81	95	0.90
	Agriculture/grassland	86	90		
	Forest	93	88		
	Water	80	100		
	Bare land	91	71		
2005	Settlement	76	76	92	0.86
	Agriculture/grassland	78	82		
	Forest	73	79		
	Water	100	100		
	Bare land	73	54		
2015	Settlement	89	93	96	0.93
	Agriculture/grassland	88	88		
	Forest	89	87		
	Water	100	100		
	Bare land	91	72		

for forest cover ranged between 92.98 and 98.21% and 96.49–92.98%, respectively.

3.2 Land cover classification

The land cover classification results are summarized for 1994, 2005, and 2015 in Table 4 and the land cover classification is represented in Fig. 2. From 1994 to 2005, settlement, agricultural areas, and bare land increased by 69.8 ha (2.3%), 991.6 ha (32.3%), and 39.5 ha (1.3%), respectively, but forest areas and water areas and decreased by 1094.1 ha (35.7%) and 6.9 ha (0.2%), respectively. From 2005 to 2015, settlement, agricultural areas, and water areas increased by 11.7 ha (0.4%), 264.7 ha (8.6%), and 36.2 ha (1.2%), respectively. Besides,

land forest areas and bare land decreased by 308.9 ha (10.1%) and 3.7 ha (0.1%), respectively.

Therefore, the total amount of decreased forest areas is 1402.9 ha from 2006.4 ha (1994) to 603.5 ha (2015), which is 45.7% of the total areas of land. The changes in forested areas over time are meant by the changes in wildlife movement in 21 years. As shown in Table 5, the areas well qualified for agriculture or grassland area was 582.2 ha in 1994; this number increased by 40.9% and became 1838.5 ha in 2015. These given data (Table 5) expressly state that the increase in agricultural areas/grassland mostly results in deforestation, which means some forest areas were removed and converted into household agriculture. The transitions of land cover types are represented in Fig. 3.

Table 4 Summary of Landsat classification area statistics for 1994, 2005, and 2015

Land cover types	1994		2005		2015	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Settlement	37.7	1.2	107.6	3.5	119.3	3.9
Agriculture/grassland	582.2	19.0	1573.8	51.3	1838.5	59.9
Forest	2006.4	65.4	912.3	29.7	603.5	19.7
Water	94.2	3.1	87.3	2.8	123.5	4.0
Bare land	348.1	11.3	387.6	12.6	383.9	12.5
Total	3068.7	100.0	3068.7	100.0	3068.7	100.0

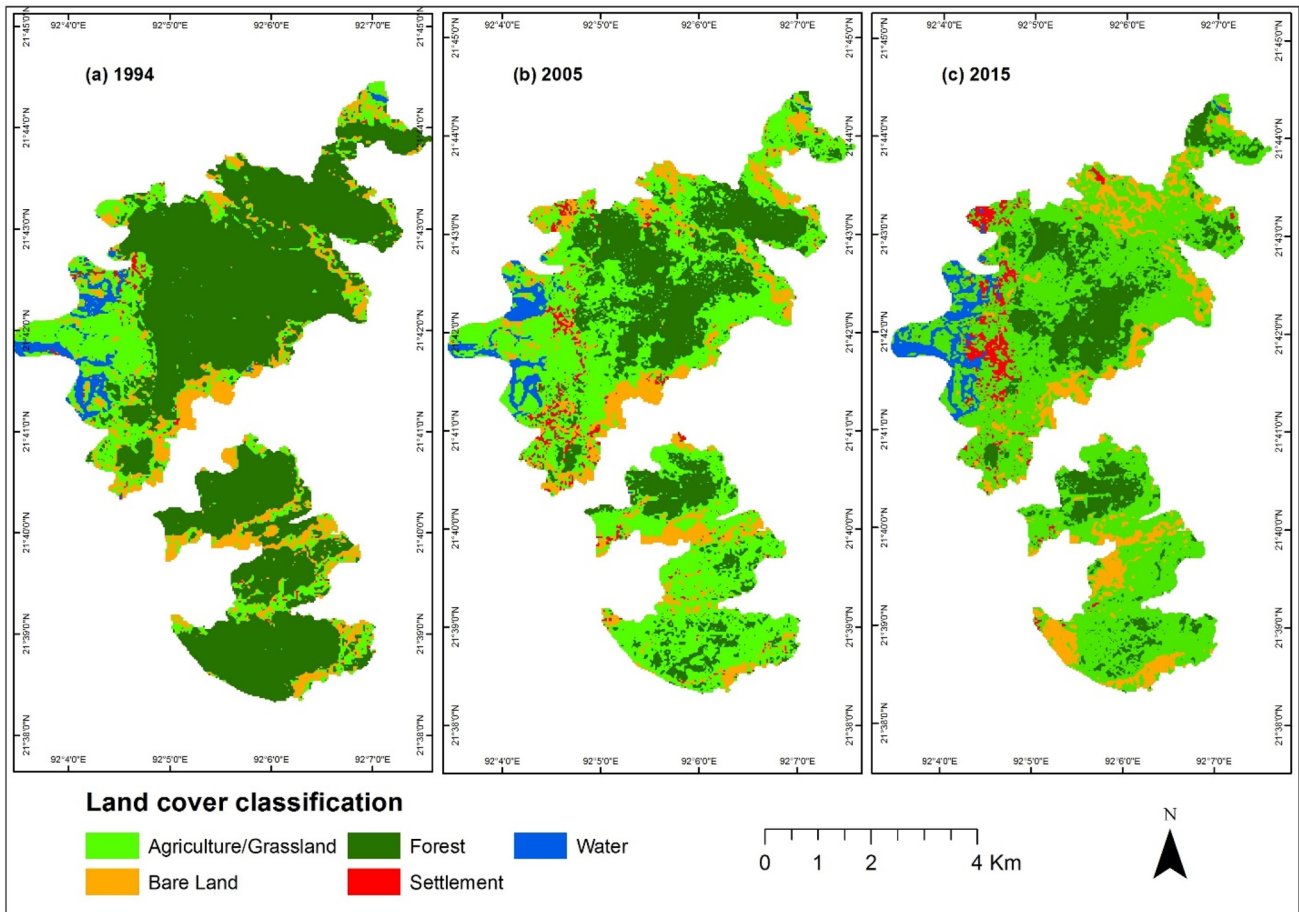


Fig. 2 Land cover classification of Fashiakhali forest reserve

Table 5 Relative changes of land cover types from 1994 to 2015

Land cover types	Relative changes					
	1994–2005		2005–2015		1994–2015	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Settlement	69.8	2.3	11.7	0.4	81.5	2.7
Agriculture/grassland	991.6	32.3	264.7	8.6	1256.3	40.9
Forest	– 1094.1	– 35.7	– 308.9	– 10.1	– 1402.9	– 45.7
Water	– 6.9	– 0.2	36.2	1.2	29.3	1.0
Bare land	39.5	1.3	– 3.7	– 0.1	35.8	1.2

*Note: (–) sign indicates a decrease of change

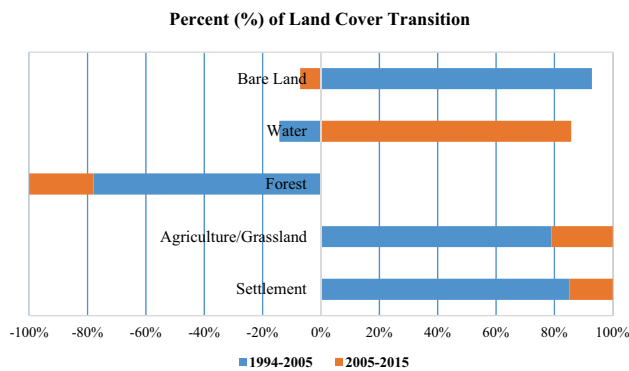


Fig. 3 Transition of land cover types

Table 6 Significant land cover transitions from 1994 to 2015

From class	1994–2005 area (ha)	2005–2015 area (ha)	To class
Settlement	22.7	38.9	Agriculture
Agriculture/grassland	58	278.4	Settlement
	20.2	68.3	Water
	124.7	230.3	Bare land
Forest	1132.4	363.2	Agriculture
	45.3	38.6	Settlement
	73.1	42.2	Bare land
Water	28.4	10	Agriculture
Bare land	151	111	Agriculture
	12.2	100.7	Settlement
No Change	1400.5	1787.3	

3.3 Land cover change detection

The change detection analysis for each land cover is summarized in Table 6; Fig. 4. Significant transitions between 1994 and 2015 are found, particularly the conversion from forest to agricultural land shows a remarkable change from 1994 to 2005 (1132.4 ha) and between 2005 and 2015 (363.2 ha). The increased agricultural activity that replaced the forested areas indicated the human necessity for alternative food production, e.g., small vegetation adjacent to the household. Significant changes have been seen in agriculture to bare land in both periods 1994–2005 (124.7 ha) and 2005–2015 (230.3 ha).

3.4 Land cover and forest change impacts on human–elephant conflict

The survey was taken in 2015 (Fig. 5) shows the wild elephant route distribution and depicts the number of respondents who observed the conflict between human livelihood and wildlife (e.g., elephant) and shared their

experiences from recent to past few years. We conducted 50 interviews with the village households adjacent to the Fashiakhali forest range. Villagers were asked in these villages if they thought the human–elephant conflict was increasing in the area, and 98% of respondents thought it was for several types of damages they observed. 82% of village people mentioned that they were affected by elephants and destroyed their fields' fences and crops. Wild elephant route distribution and their proximity to human settlement are represented in Fig. 5.

3.5 Human–elephant conflict risk hot spot

We used the human–elephant conflict data collected through field surveys in Fashiakhali forest reserve areas in 2015. The participants were asked to name and locate the places where most conflicts occur within the study areas from the respondents' interviews. The sites were marked and located on a map of human–elephant conflicts (Fig. 7). The map shows the human–elephant conflicts hot spots (or areas where a lot of conflicts occur). The hot spots are located inside the Fashiakhali forest reserve and Fashiakhali Wildlife Sanctuary. Our survey found out that 82% of the respondents claimed that the conflict areas were the household's adjacent agricultural fields (Fig. 6).

4 Discussion

4.1 Land cover classification

Based on the classification of multiple temporal satellite imageries, our study's findings revealed significant differences in different land cover types over different years, particularly the enormous changes and differences among the forest cover areas. The obtained data from our findings and Landsat image classification expressly state that the increase in agricultural areas/grassland mostly results in deforestation, which means some forest areas were removed and might be converted to household agriculture. The causes might be attributed to a lack of frequent surveillance by the forest department and substantial encroachment and rapid destruction of a natural resource from Fashiakhali. There are 16 villages inside the sanctuary with 3300 people are highly reliant on their subsistence services. *Rohingya* refugees have already occupied a substantial portion of the forest resource, and their illegal logging is simultaneously responsible for the land-use change in Fashiakhali [59, 71]. Like our study area, the land cover change of Chunati Wildlife Sanctuary in Chittagong in Bangladesh was analyzed. They showed nearly 76% of the total land area (8258 ha) was covered by vegetation during 2005; and reduced to 61% (6637 ha) in 2015, 15% declined from 2005, and vacant land coverage increased from nearly

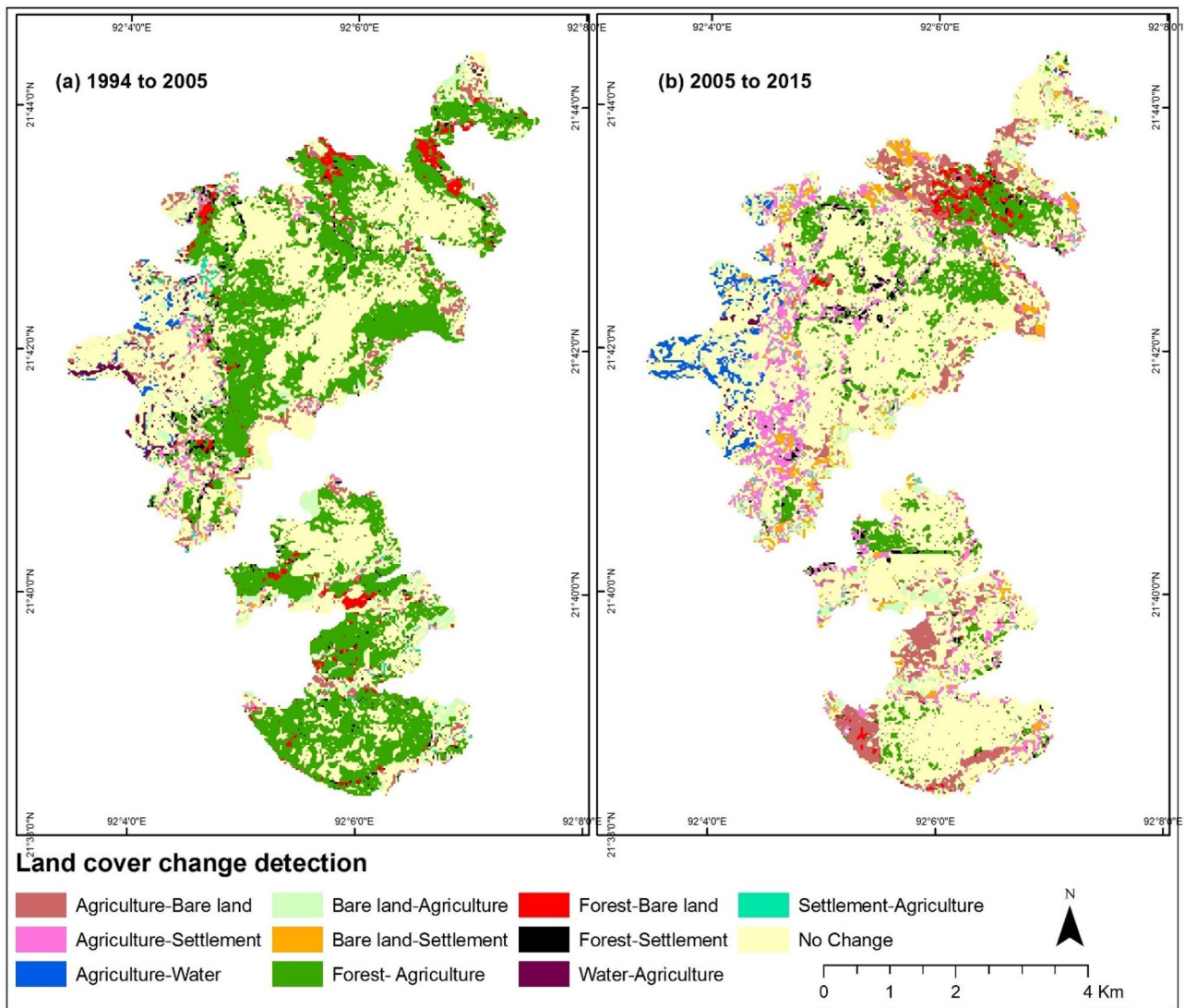


Fig. 4 Land cover change detection of Fashiakhali forest reserve

10% in 2005 to 22% in 2015 [107]. The changes are observed because of land grabbing, which has become the primary problem, especially in Bangladesh’s protected forest areas during the last two decades [108]. Our study’s change detection analysis suggests that changes in observed behaviour can indicate the destruction of crops due to wildlife habitat displacement and movement (e.g., occurred by elephant) or removing the agricultural field and replacing the settlements.

Among other transition events, forest to bare land to agriculture showed significant alteration between these two transition periods. Apart from land cover change detection in Bangladesh, the significant land-use changes for India’s northeastern part from 2008 to 2018 were analyzed using satellite imagery [109]. It is found that the forest area had increased by 446 km² within the last 10 years (2008–2018), and the annual rate of change was

12%. It is also demonstrated that the area under agriculture had reduced by 128 km² with an annual decline rate of change of 2.5%. The area under tea plantation declined by 307 km² with an annual decline rate of 12%, whereas the area under human settlements increased by 61 km² with an annual decline rate of 44% [109].

There are some other factors responsible for the land cover change, for instance, shifting cultivation, which is a traditional agricultural land use (*Jhum* cultivation) in the Chittagong Hill Tracts (CHT) in Bangladesh. This changes over time under the influence of several internal and external pressures (e.g., intensive land-use systems, a steady increase of population, migration, the encroachment of reserve forests, etc. [75, 110]. However, it is indicated that the fundamental causes of the shrinking forest cover in the Hill Forests in Bangladesh are: (a) own conflict among

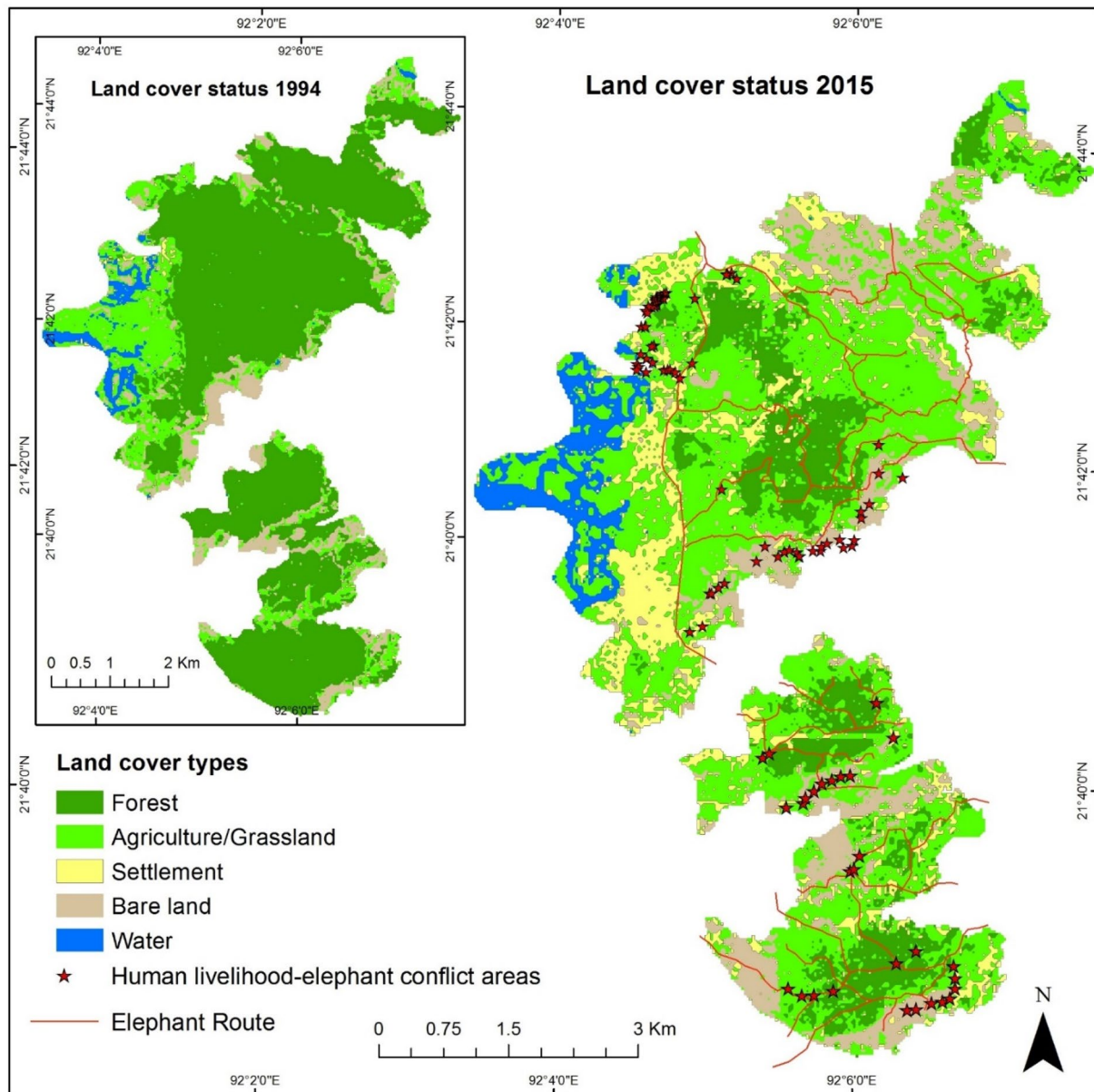


Fig. 5 Wild elephant routes

indigenous forest dwellers, (b) migrants move toward the forests, (c) unwillingness in implementing the suitable policy by forest authority are the significant causes of forest loss [61]. The improvement of the forest department's capability to operate forests sustainability remains a concern requiring a much greater government commitment. The forest department needs good cooperation from local people and the government to regulate illegal or legal cutting, over-harvesting, and encroachment, which is the most direct deforestation driver. Population migration, lack of satisfaction, aggressive behavior of the indigenous/ethnic people, challenging working situation, unsettled land tenure issue, fear apprehension from

foresters, insufficient staffing, and low opportunity for foresters are the local driving factors associated with forest fragmentation, deforestation, and forest conservation and restoration. It is essential to keep in mind that individual drivers' effect on a global to local scale can change over time. For example, it is unlikely that forests in a country with internal political instability would be under the same drivers' control.

4.2 Human–elephant conflict

In Bangladesh, particularly in the Cox's Bazar region, humans and elephant conflict are frequent incidents [111].

Fig. 6 Type of affected areas by elephant observed by respondents (total number of respondents: 50) Type of affected areas by elephant observed by respondents (total number of respondents: 50)

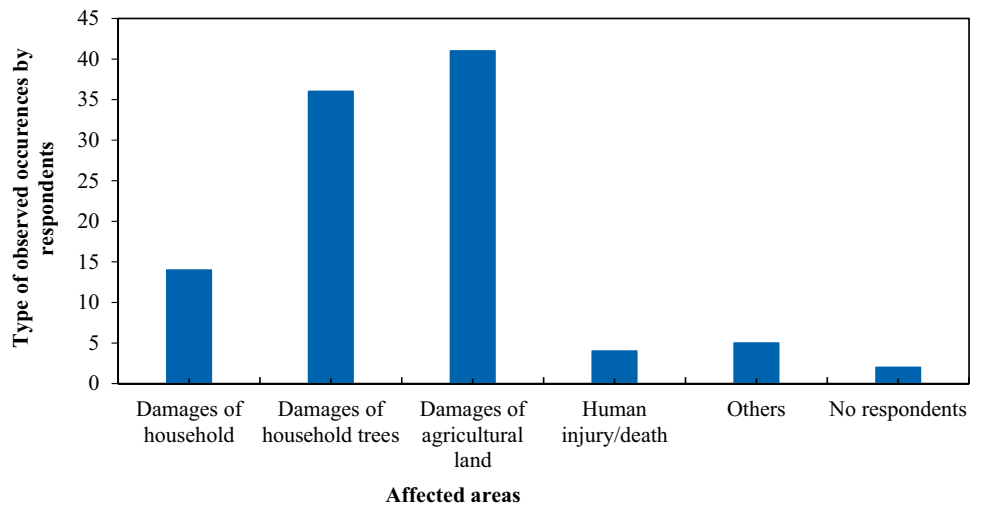
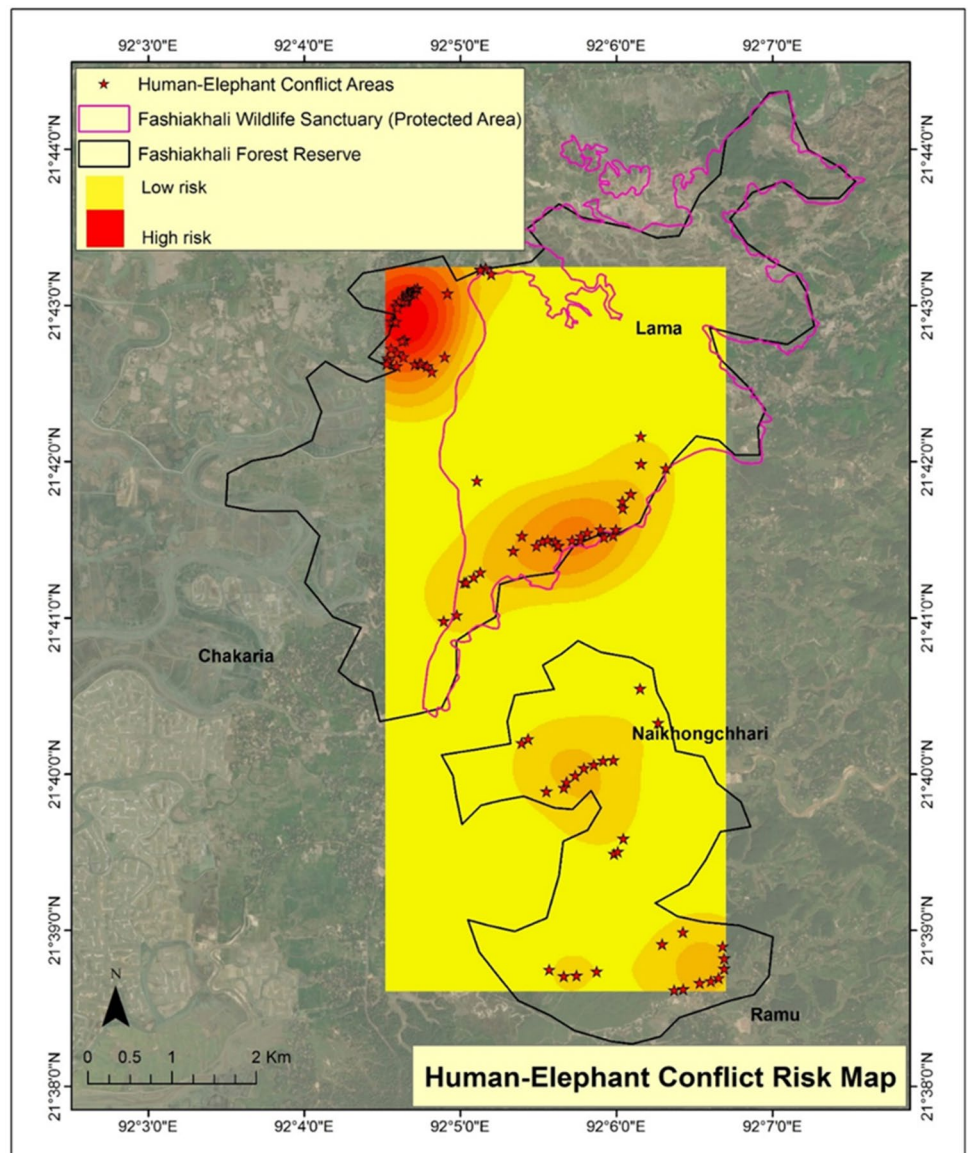


Fig. 7 Human–elephant conflict risk map in Fashiakhali forest reserve, Cox’s Bazar. (Image source: Google Earth 2019)



Generally, the land cover changes have more significant consequences on wild animal distribution, routes and corridors, and natural habitats, mainly known as biophysical resources [25]. Land cover changes also influence the animal's movement, e.g., obstruction of routes with the corridor. IUCN has identified Asian elephants (*Elephas maximus*) as endangered due to loss of habitat, elephant poaching, and human–elephant conflict [112]. Similarly, our study's land cover changes showed the impacts on the wildlife route/passage, natural habitat, and the accessibility of feeding resources for wildlife. We found a significant amount of land cover changes of the Fashiakhali forest reserve from our geospatial analysis. These land cover changes suggest an aggregate of human settlement and explain the 1994 to 2015 periods' changing situation. The land cover changes trigger the loss of wide ranges of wildlife or elephant habitat and damages of human belongings, e.g., household, trees, and agricultural fields, even social death [109]. Information acquired from the neighboring village people of Fashiakhali forest reserve also supports the argument that there is currently a higher concentration of elephant aggression on household premises. It is a clear indication of deforestation in that forested environments, and indeed, the relationship between humans and wildlife is worsening. A study from the northeastern part of India tried to show the relationship between the land-use changes and human–elephant conflicts. It demonstrated that conflicts have mostly occurred in the protected areas, tea plantations zone, and along major riverine corridors [109]. The study also revealed that the local community is often chased and stressed by the elephants in agriculture fields and at their own houses [109]. Investigating the relationship between human–wildlife and land-use change, a study conducted in Kenya, showed that agriculture expansion is considered more advantageous than pastoralism or conservation [113]. The household people around the Fashiakhali forest reserve area usually rely on the sanctuary for resources like fuelwood, grass, bamboo, and medicinal plants. Due to settlement development for refugees in the Fashiakhali, the vegetation or forested land has been diminishing. Hence, these areas are likely to become uninhabitable for elephants [114]. Besides, human actions inside and around the wildlife sanctuary result in ecosystem degradation and illegal logging in the sanctuary area [114].

4.3 Human–wildlife conflict area analysis

Forest protected, and the human settlements and farms usually separate reserved area boundaries from natural ecosystems people have no ecological sense to wildlife animals [115]. Consequently, the settled areas are surrounded by protected areas once inhabited by wildlife, leading to conflicts

between people and wild animals [25]. From (Fig. 3), it seems that expansion of settlement and replacement of agricultural land instead of forest adjacent the protected areas increase the probability of human–elephant conflict. This map provides a scenario for the sizes needed for the management to avoid conflict. It is demonstrated that increasing agricultural land uses in the boundaries of the protected area might be the causes of this conflict reveals a similar assumption with our study [116]. Human settlements increased around every protected area, potentially increasing human activity along the edges of protected areas and threatening their ecological integrity. There is possible evidence of deforestation and shrub encroachment throughout the hot spot [116]. The conflict between humans and wildlife has been observed at several places for various human activities; for instance, evidence has been found in the Amboseli–Kilimanjaro ecosystem that has reported increased recent agricultural activities [25]. The study also demonstrated that land use for crops growing and wild and domestic animals has been reducing, setting the competition and conflict between wildlife and livestock for water forage as they live nearby [25]. Eventually, this led to wildlife predation on livestock and humans and the destruction of ranch structures by wild animals [117]. Another study observed that the human–elephant conflict is related to the land-use changes from grazing to farms and settlements. However, the changes reduce animal dispersal and migration areas and block migration routes [25].

5 Conclusions

This paper investigates land cover changes in Fashiakhali forest reserves in Bangladesh from 1994 to 2015 using remote sensing and GIS techniques. This study found that agricultural land and grassland are mostly affected and lost due to the increase in the settlement area by approximately 1337.9 ha. Moreover, the forest area was decreased around 1402.9 ha, which is 45.7% of the total in the study area, since it was assumed that whether there is any relationship with the biodiversity or wildlife habitats (e.g., elephant) and their impacts on the areas of human settlement and agriculture land due to changes in forested areas. The study established that there has been an expansion of agriculture and settlements into the wildlife grazing and dispersal areas. Also, human–wildlife conflicts have increased due to land use incompatibility. However, wildlife habitats are expected to further decrease significantly due to agricultural expansion. The area is well known for having elephant habitats, and the wildlife sanctuary is also crucial for biodiversity. Indeed, the evolution of human settlement adjacent to the forest areas and deforestation are the leading causes of wildlife habitat disturbances. Consequently, damages to local houses, homestead gardens,

agricultural lands, and even social death have frequently occurred for the last few years.

Habitat destruction and fragmentation have had a significant effect on Bangladesh's wild elephant population [65]. The lack of opportunities for forest reliance on livelihoods has further exacerbated deforestation and degradation. In addition, as far as land tenure is concerned, women do not usually have land possession [118] and do not have sufficient institutional power over land even if they have access to and use many goods (e.g., firewood, non-timber forest products). Women's activities, such as conventional reforestation programs and tree plantation, can help recognize sustainable forest conservation or wildlife habitat obstacles. It may contribute to formulating appropriate and relevant governance strategies at the national and local levels. Local people and ethnic groups, particularly women and young communities, can be an insightful source of knowledge in identifying deforestation and forest destruction drivers around their communities and a platform for suitable solutions. Hence, forest management must also acknowledge the importance of inter-departmental coordination, land use planning, the significance of environmental services, and transparent land tenancy regimes to prevent forest transition, but at the same time creating a sound ecological forest management framework and not tolerating corruption within the forest. Therefore, any measures to curb this deforestation must be based on the dynamic social, political, and infrastructural changes of the rural community surrounding the forest reserve.

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Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

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