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Forest cover change analysis using remote sensing and its impact on forest sustainability at Fasiakhali Wildlife Sanctuary.†

S.M.Sohel Rana *, Syed Hafizur Rahman

Department of Environmental Sciences, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh; hafizsr@juniv.edu (S.H.R.)
* Correspondence: sohel.stu20161@juniv.edu; Tel.: +8801851986530

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Abstract: Anthropogenic activities within and around the protected areas are one of the major reasons for damaging forest cover and threat to the sustainable management of the forest. In Bangladesh, many protected areas are facing constant anthropogenic threats to their biodiversity and forest cover. Fasiakhali Wildlife Sanctuary (FWS) is one of the few protected areas in Bangladesh, the last resort for a few herds of Asian elephants (*Elephas maximus*). The presence of Asian elephants is under constant threat as the forest cover is changing rapidly, leading to exposure to elephant-human conflict. However, there is not enough scientific analysis on forest cover change of Fasiakhali Wildlife Sanctuary. This study was conducted to understand the forest cover change dynamics from 1990-2020 using Landsat 5 TM and Landsat 8 OLI/TIRS images. Landsat 5 TM of 1990 and 2005 and Landsat 8 OLI of 2020 had been used to determine the forest cover change. A supervised classification technique was used for forest cover mapping using a maximum likelihood classification algorithm. The study showed that about 6.8% and 8.6% of forest cover were transformed into non-forest use (e.g., agricultural land and bare land) between 1990-2005 and 2005-2020. Most of the conversion has happened to agricultural land, which was about 200 ha from 1990 to 2020. Primarily, it was found that illegal tree cutting and transforming forest land to the agricultural field were the anthropogenic reasons behind forest cover change. This study could be the essence for a better understanding of habitat fragmentation and monitoring illegal activities inside the Fasiakhali Wildlife Sanctuary for prospects.

Keywords: Forest cover; Remote Sensing; Protected area management; Asian Elephant

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1. Introduction

Protected areas are the essential for the conservation of biodiversity in a region. Forest cover change in the protected forest area is currently a global threat. Globally it is becoming a concern that the forest covers are gradually changing to non-forest usage at an alarming rate. The current global forest cover is 4.06 billion hector which is 31% of total land area [1]. Unlike global condition, forest cover in Bangladesh had also seen declination. Total forest cover in Bangladesh in proportion to total land area is 14.5% in 2019 where it was 14.8% in 2000 [2].

Anthropogenic activities inside protected forest areas such as deforestation, settlement, grazing etc. changes the land use pattern of the forest cover and act as catalyst for forest degradation. Sustainable and efficient land management is required for the conservation of forest areas from depletion and degradation. Hence, this sustainable land area management requires knowledge about 'land use land cover change' (LULCC) of the area. Land use land cover works as an important supporting tools for the decision making process [3]. Land use land cover change is a dynamic and continuous process that requires constant monitoring and research [4]. Synoptic and repetitive data collection capability of satellite sensors makes remote sensing an unique technique to observe spatio-temporal change over particular area. Remote sensing technique have that the unique ability to monitor the land use land cover change with a very low cost and effectively. This kind of approach is very handy for developing countries like Bangladesh [5].

The Fasiakhali Wildlife Sanctuary (FWS) is one of the last resort for few herds of Asian Elephant [6]. But the sanctuary is under constant threat of land use change. Continuous illegal timber trading and human settlements are damaging the forest and creating habitat loss for the Asian Elephant, the flagship species of the forest. Bangladesh Forest Department launched a co-management initiative, but human interventions in the forest are still continuing [6]. The forest requires a new look up at the change dynamics for its land use and land cover.

There are not enough scientific activities regarding the forest cover change dynamics of Fasiakhali Wildlife Sanctuary. This study aimed towards understanding the change dynamics in the sanctuary between 1990 to 2020 and provide a fruitful output for future research and policies.

2. Materials and Methods

2.1. Study Area

The study was conducted at Fasiakhali Wildlife Sanctuary (FWS), Bangladesh. Fasiakhali Wildlife Sanctuary is a tropical evergreen and semi-evergreen forest which lies at Chakaria upazilla of Cox's Bazar district [7]. Fasiakhali Wildlife Sanctuary was declared as a wildlife sanctuary in 2007 [6]. The area is almost flat with some undulated and dissected hilly areas with elevation less than 100m.[8] The extend of the sanctuary is between 21045' to 21040' N and 9204' to 9208' E. Total area of FWS is about 1302 hector. The sanctuary consists of two forest beat named Dulahazra and Fasiakhali under Fasiakhali range administrative unit of Bangladesh Forest Department [7].

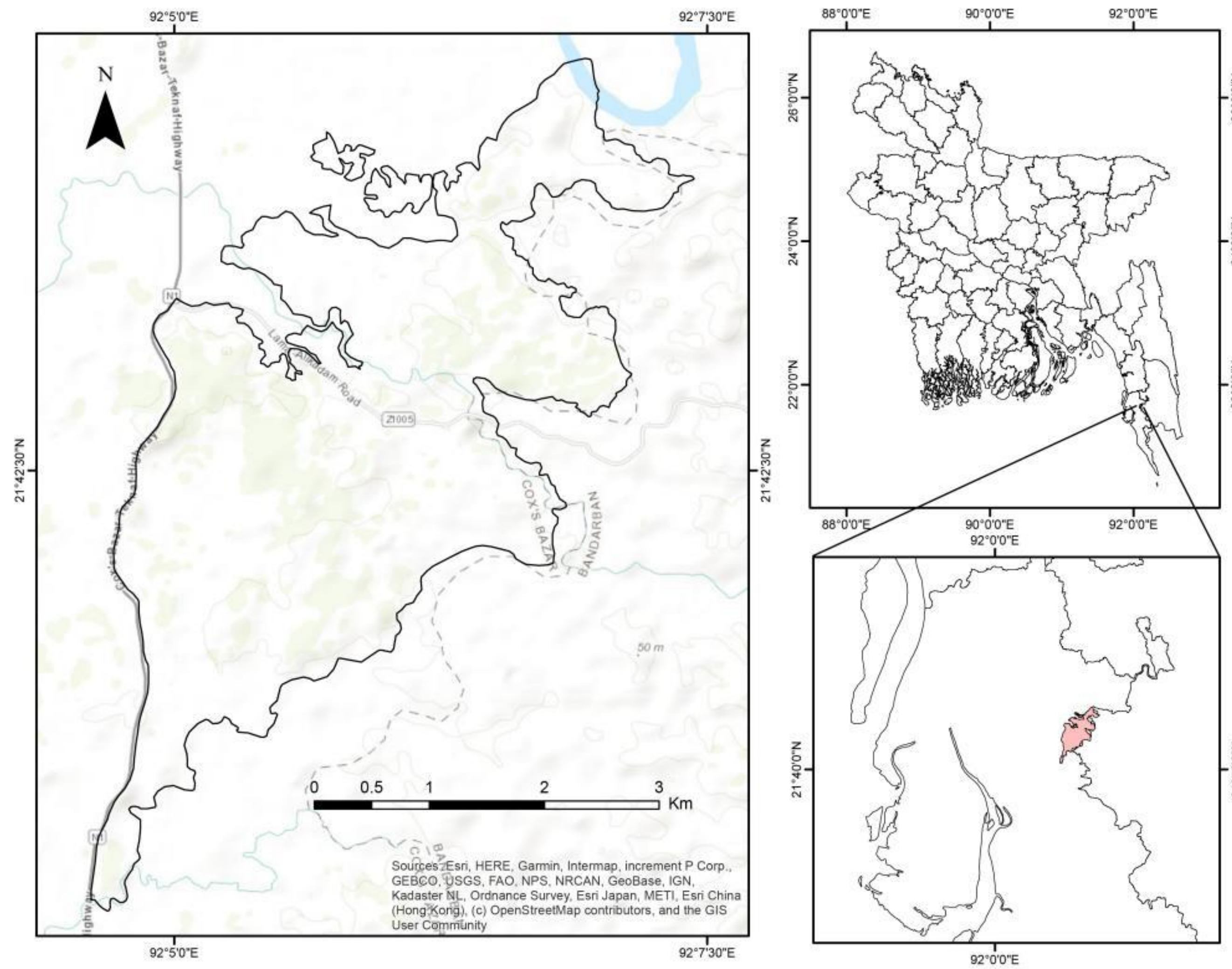


Figure 1. Study area showing the position of FWS in Bangladesh map.

2.2. Data acquisition and Image processing

Landsat 5 TM and Landsat 8 OLI/TIRS satellite data was used for the study. Landsat 5 TM image for 1990 and 2005 as well as Landsat 8 OLI image for 2020 had been used for the study. Satellite images were downloaded from the USGS website. The images were collected for the winter season with no cloud coverage. All satellite images had been obtained from Landsat Level 1T. That means, the images were already geometrically corrected and rectified [9]. ArcGIS 10.6 software was used to analyze the satellite images. WPS Office was used for the generation of charts for analysis. Table 1 shows the key characteristics of satellite data used for the study.

Table 1. Key characteristics of satellite data used for the study.

Year	Satellite & Sensor	Acquisition date	Resolution
1990	Landsat 5 TM	2020-11-18	30m
2005	Landsat 5 TM	2005-11-25	30m
2020	Landsat 8 OLI/TIRS	1990-01-03	30m

The forest cover classification was carried out using supervised classification method employed by the maximum likelihood classification approach. Maximum likelihood approach is most widely used well known parametric classifier for land use land cover change analysis [9].

Band 1, 2, 3 and 4 for Landsat 5 TM and Band 2, 3, 4 and 5 for Landsat 8 OLI/TIRS images had been stacked and then the study area was clipped. Then training samples were created by analyzing the images with various band combination. Further by using the training samples and maximum likelihood algorithm approach, the forest cover map was generated. The accuracy of the classification was carried out using Google Earth Pro historic images.

The forest covers are classified into three classes such as Dense Forest, Degraded forest and Non-forest. Degraded forest includes forest cover that has not yet transformed into non-forest use rather it is low vegetation area with patches. Non-forest cover includes water body, agricultural land, barren land and settlements.

3. Results & Discussion

3.1. Accuracy assessment

The accuracy of the forest cover change classification was evaluated using overall accuracy, kappa index and class-specific user and producer confusion matrix [10]. Total 90 points were produced using stratified random sampling in ArcGIS respectively for 1990, 2005 and 2020 supervised images. These points had the classification value and were used as reference data for accuracy analysis. For each selected pixel, the true forest-change type was determined by visual comparison of the Landsat series against high-resolution images from Google Earth [10]. Table 2 presents the result of the accuracy assessment for all the classification images.

Table 2. Accuracy assessment of forest cover classification of FWS.

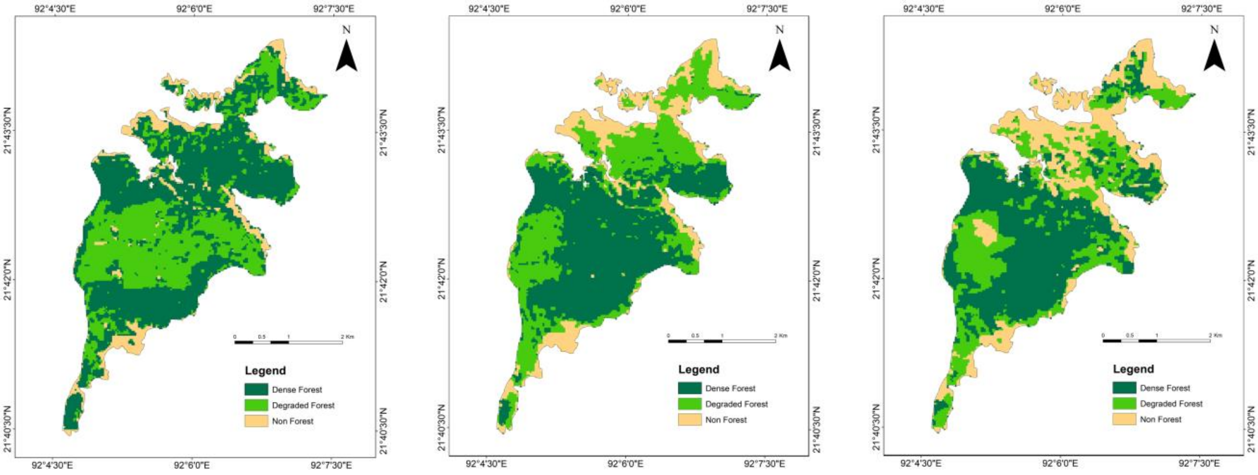
Forest cover class	1990		2005		2020	
	Producer's	User's	Producer's	User's	Producer's	User's
Dense Forest	88.64%	90.69%	95%	97.43%	96.67%	93.54%
Degraded Forest	83.87%	83.87%	92.59%	92.59%	83.33%	100%
Non-forest	86.67%	81.25%	95.65%	91.67%	100%	88.24%
Overall accuracy	86.67 %	86.67 %	94.44 %	94.44 %	93.33 %	93.33 %
Kappa Index	0.78	0.78	0.91	0.91	0.92	0.92

The overall accuracy was 86.67%, 94.44% and 93.33% respectively to 1990, 2005 and 2020. The accuracies were satisfying and acceptable for the study area [11].

3.2. Forest cover loss analysis

Satellite image analysis of three date shows some dominant changes in the landscapes. From 1990 to 2005, about 6.8% of total forest cover had been experienced transformation from forest cover to non-forest such as conversion to agricultural land, left as bare land, settlement and water-bodies. About 91.08 ha of forest area had been turned into agricultural land or kept as bare land in that period. It had been observed that dense forest had decreased from 711.63 ha to 624.24 ha between 1990-2005. Degraded forest area had been decreased from 490.14 ha to 486.9 ha. The area that converted into non-forest was about 134.82 ha to 225.9 ha.

In the 2005-2020 period, non-forest area had been increased from 225.9 ha to 341.1 ha. About 8.6% of total forest cover had been experienced the conversion of forest cover to non-forest cover change. Dense forest had declined from 624.24 ha to 584.19 ha in between this period. Degraded forest had been decreased from 486.9 ha to 412.11 ha. The forest cover change map derived from Landsat images are shown in figure 2.



(**a**) (**b**) (**c**)

Figure 2. Forest cover change of Fasiakhali Wildlife Sanctuary in the year (a) 1990; (b) 2005; (c) 2020.

The rate of conversion from forest cover to non-forest use is seen very high in period between 2005-2020. Increasing agricultural land and settlement causes the conversion from forest to non-forest cover. Every year, on average about 6.072 ha of land had been changed to non-forest in between 1990-2005 period. The rate had been increased to 7.68 ha per year in the period of 2005-2020. Figure 3 shows the overall comparison of forest cover class between three periods.

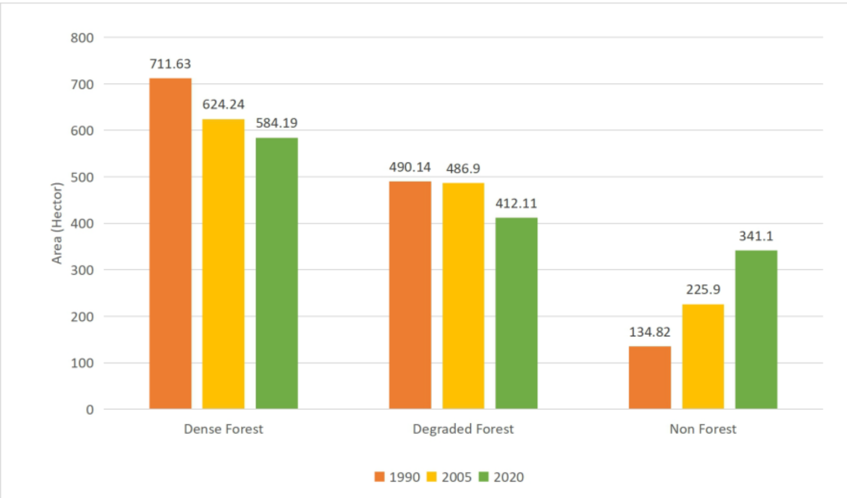


Figure 3. Overall comparison of forest cover class of FWS in three time period.

Overall observation shows the declination of dense forest cover and increase of non-forest land use.

3.3. Sustainability of FWS

The unregulated land encroachment in the Fasiakhali Wildlife Sanctuary is a key concern for the sustainability of the sanctuary. Initially, people were given settlement in that area to protect the sanctuary. Besides, migrants from coastal off shores and other areas had taken shelter besides the sanctuary [6]. However, the dependency for livelihood and fuel, these settlers had cut down many trees since their settlement. Also, rich and influential elites are involved in the illegal deforestation and land encroachment [6].

From the current study, it was found that between 1990 to 2020, the rate of settlement and increase in the conversion of forest cover to agricultural land had increased significantly from 2005-2020 which is an alarm for the forest. Figure 4 shows the trend of land conversion to non-forest usage especially agricultural use.

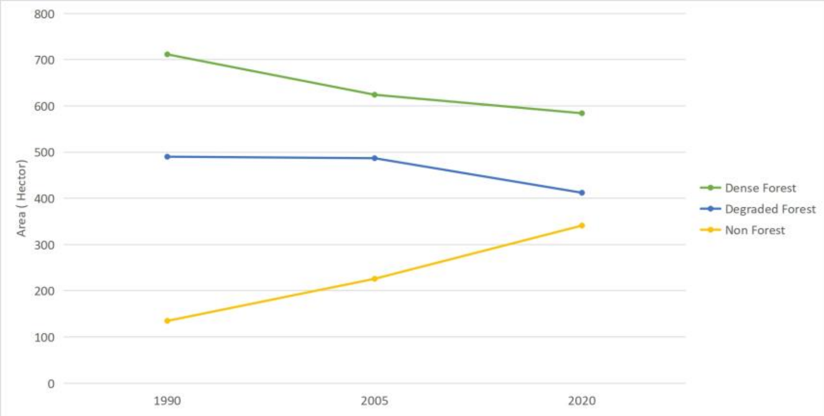


Figure 4. Trend of forest cover area of FWS in three time period.

Bangladesh forest department along with the Nishorgo network took initiative on co-management in 2009. Co-Management was established in FWS on 23 December 2009 following a Ministry of Environment and Forests order published in November 2009 [12]. However, the threats and issues for forest sustainability addressed at that time are still the reason for the forest cover loss. Illegal logging, land encroachment etc. was the major issues addressed during the field survey in 2009. The issues are still remained uncontrolled. These major issues are currently imposing a threat to the sustainability of the FWS.

4. Conclusions

The study shows that in the last 30 years, the forest had undergone with continuous and significant decline of its cover. This increased destruction of forest cover had altered the habitat and created a tension of human-elephant conflict in the area. The current condition threatens the presence of species lived there especially the Asian Elephants. Subsequently, this disturbance in the forest causing the forest unsustainable regarding ecosystem services and functions.

The study faced problem during the ground validation of 1990 classified image as Google Earth does not have high resolution for such old images. This caused some problem of mismatching the class area between dense forest and degraded forest. Besides, high resolution satellite images such as RapidEye, QuickBird etc. can be used to create detail map of the land use land cover of the area for further and in-depth analysis. The study shows an indication on the current status of the FWS comparing with the previous condition. Further, it shows that the activities of Forest Department needs rethinking to control the ongoing declination of forest cover in the Fasiakhali Wildlife Sanctuary.

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