

Mapping Trees Outside of Forests Using Remote Sensing

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Abstract- Trees excluded from the forest and other wooded lands are defined as “Trees outside forests (TOF)”. TOF are mostly located on farmlands and built-up areas of rural and urban regions. Remote sensing with its unique capability of synoptic viewing, real time and repetitive nature offers a potential tool for monitoring and evaluation of Earth’s natural resources. Forestry is one of the most important disciplines in which remote sensing technology is being used over a considerably long time period from the early stage of its development. Remote sensing technology has been successfully employed in various studies like forest inventory, monitoring of forest cover changes, forest damage assessment. In the present research a study has been undertaken to develop an operational method for mapping and monitoring trees outside of forests by using the freely available moderate resolution satellite remote sensing data in the Barisal Division of Bangladesh excluding the Jhalokati District. Landsat 8 OLI (Operational Land Imager) data of 2016 and Landsat ETM+ (Extended Thematic Mapper) data of the year 2000 have been used for this purpose. A comparison of TOF has also been done in the five Upazillas of Barguna District between the year 2000 and 2016. Driving forces behind the changes of TOF has also been investigated through GPS (Global Positioning System) based ground verification and interview with the people living in the locality.

Index Terms- ‘Madhupur Sal forest’, Landsat 8 OLI, Spectral Behavior, Data Acquisition Time.

I. INTRODUCTION

Major portions of the woody biomass of Bangladesh are contributed by the large number of “Trees outside forests (TOF)” which are planted in the homestead area or common area in the locality. The world has billions of trees that are not included in the Forest Resource Assessment definitions of forests and other wooded land (FAO 2001). If the TOF are not included in national forest inventories then it would underestimate the country-wide biomass and carbon values. Classification and mapping the TOF are carrying the challenges and some extent showing the difficulties also. TOF may be a significant source of timber and non-wood forest products. TOF play an important ecological role as these planted trees and shrubs help to prevent high surface runoff and thus prevent the soil erosion. It also helps to minimize the flooding and works as fence to protect from strong winds. It has been noticed that the forest resources in the state owned forest land of Bangladesh is decreasing at a significant rate. Good news is that the awareness building activities and campaign raised by the government organizations (GOs) and non government organizations (NGOs) and also the aid agencies working in Bangladesh played a significant role to motivate the people for planting trees around the homesteads and the suitable lands outside of forests. The area under such type of plantations is increasing in the recent years. Along with the segregation of a big family to an additional family a new house is being build and the owners are planting trees around their houses. Thus the homestead forests are mainly belonging to the private properties. The important characteristics of homestead forests are species diversity, high yielding and well organized structure. TOF may be termed by other terminology as ‘village forests’ and ‘rural forests’

which includes trees on homesteads, road sides, common access lands, community lands, premises of educational institutions and places of worship. These trees are not belonging to the forest or other wooded land category but they are TOF (Rawat et al. 2003). Rawat et al. 2003 also mentioned that TOF resources found in Bangladesh are belonging to the following category: Trees grown in homestead gardens, block plantations, agro-forestry plantations and stripe plantations along road and highways, railways, district council and feeder roads. Sylvander (1981) reported on forest cover mapping including TOF for Costa Rica carried out in 1967 and 1977, as part of a forest inventory project. Using FAO (1974) guidelines five classes, based on tree cover and land use were distinguished and mapped (Rawat et al. 2003). Trees those found in isolated patches, in narrow strips, in areas with sparse or predominantly herbaceous vegetation, or in riparian areas are known as TOF and are a great concern on these trees as they may be the habitat of invasive pests such as the emerald ash borer (Andrew et al. 2012).

Therefore the present study has been undertaken with the aim of developing an operational method for mapping and monitoring trees outside of forests by using the freely available moderate resolution satellite remote sensing data. The following objectives would be taken into consideration:

- Identification of the trees outside of forests;
- Study the changes of TOF in and identify the driving forces behind the changes;
- Generation of data set and statistics;

II. MATERIAL AND METHOD

Study area

Study area is located in Barisal Division of Bangladesh excluding the Jhalokati District. There are six districts in Barisal Division and those are Barisal, Bhola, Barguna, Patuakhali, Pirojpur and Jhalokati. Bhola, Patuakhali and Barguna are three coastal districts of Barisal Division. Dhaka Division is in the north, Khula Division is in the west, Chittagong Division is in the east and the Bay of Bengal is in the south of Barisal Division. Barisal Division lies in the Ganges (Padma) River delta on an offshoot of the Arial Khan River (Kirtonkhola). Figure 1 shows the study area. The area extends from N 21° 42' 30.44" to N 23° 06' 36.62" and E 89° 48' 13.43" to E 91° 04' 16.14" and is about 242 km away from the capital city of Dhaka. Relatively low land characterizes landscape of the area. The area is fragmented into small patches and intermingled with the neighboring settlements. The climate of this area is tropical.

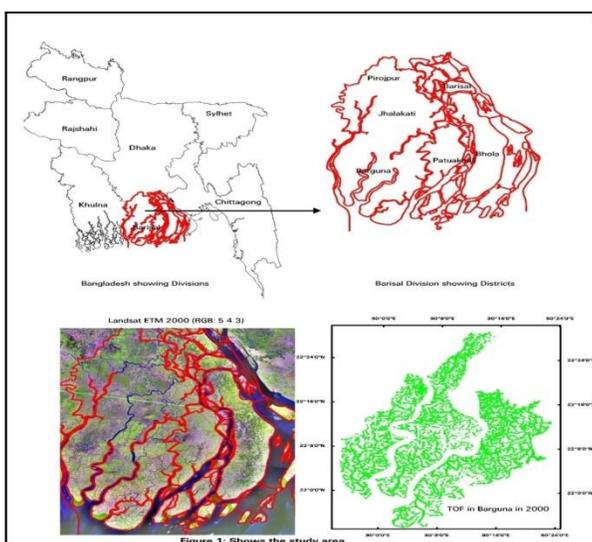


Figure 1: Location map of the study area.

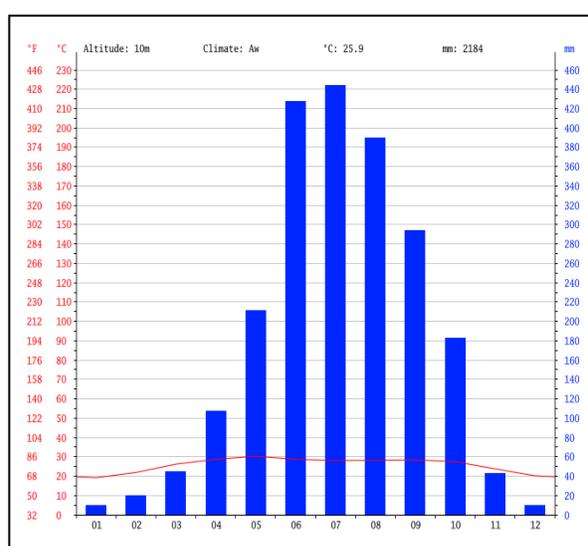


Figure 2: Temperature and rainfall graph of Barisal.

In Barisal, the average annual temperature is 25.9 °C and the average annual rainfall is 2184 mm (Figure 2). The driest month is January, with 10 mm of rainfall. With an average of 444 mm, the most precipitation falls in July. The warmest month of the year is May, with an average temperature of 30.3 °C. January has the lowest average temperature of the year. The difference in precipitation between the driest month and the wettest month is 444 mm. During the year, the average temperatures vary by 11.1 °C (<https://en.climate-data.org/location/31711/>).

Data and software used

Various types of data have been used for the present study. Table 1 provides a list of the satellite data and ancillary data that have been used for the present study.

Table 1: List of satellite data and ancillary data used for the study

Satellite/Sensor	Acquisition Dates	Ancillary data
Landsat 7 ETM+	28 February, 2000	As ancillary data, high resolution data from Google Earth and SPARRSO archive, administrative boundary from Survey of Bangladesh were used.
Landsat 8 OLI	15 January, 2016	

Besides these, historical maps and insitu data of this area have also been used. Field photographs acquired by digital camera have also been used. ERDAS IMAGINE and Arc/Info software has been used for data generation and vector layer analysis and management.

Methodology

Cloud-free Landsat 7 ETM+ data of 28 February 2000 has been downloaded form United States Geological Survey (USGS) website. Extraction of different bands data has been done and then layer stacking of has been conducted for making the multi bands images. Bands 1 to 6 were considered for layer stacking. Landsat 7 ETM+ observation of the study area displaying Band 5, 4 and 3 (R, G, B) on 28 February 2000 has been shown in Figure 3. Cloud-free Landsat 8 OLI data of 15 January 2016 has been downloaded form United States Geological Survey (USGS) website. Extraction of different bands data has been done and then layer stacking of has been conducted for making the multi bands images. Bands 2 to 7 were considered for layer stacking. Landsat 8 OLI observation of the study area displaying Band 6, 5 and 4 (R, G, B) on 15 January, 2016 has been shown in Figure 4.



Figure 3: Landsat 7 ETM+ observation of the study area displaying Band 5, 4 and 3 (R, G, B) on 28 February 2000.



Figure 4: Landsat 8 OLI observation of the study area displaying Band 6, 5 and 4 (R, G, B) on 15 January, 2016.

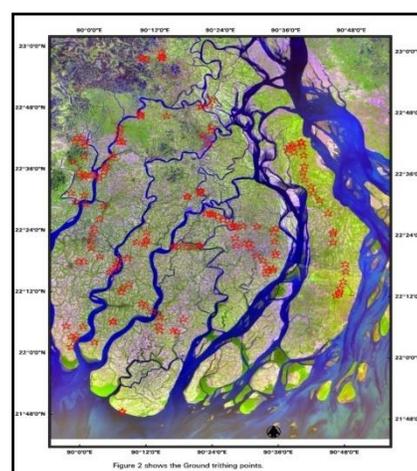


Figure 5: GPS base ground truthing and data collection.

The main target of this study was to mapping trees outside of forest (TOF). On screen digitization has been performed to delineate the TOF and different land cover classes. Global Positioning System (GPS) based ground verification (Figure 5) has also been conducted in different land cover classes to delineate accurately the land cover classes in the study area (Figure 6). Ground photographs have also been taken during ground truthing. The whole methodology of the study has been shown in figure 7.



Figure 6: Shows the colour composite of Landsat 8 OLI image of 15 January 2016 where the location of different land cover classes has been shown.

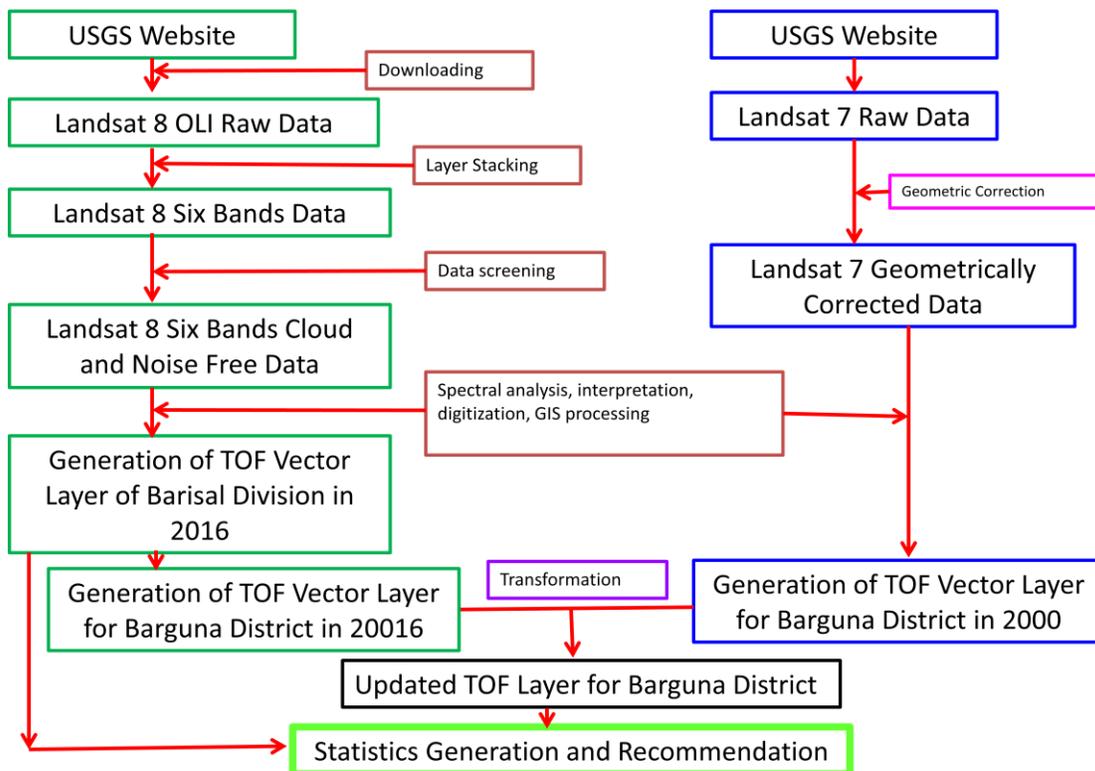


Figure 7: Shows the whole methodology of the research.

III. RESEARCH FINDINGS AND DISCUSSIONS

Mapping trees outside forests in study area

The map of trees outside of forest (TOF) of the study area has been shown in figure 8. Mangroove and water have also been shown in the map. Statistics has been generated from the analyzed images of the study area and it has been found that the TOF area were 259571.4 ha in 2016 in Barisal Division excluding Jhalokati District. This area is 20 % of total study area. Comparisons with total study area in ha and in percentage (%) have been shown in figure 9 & 10 respectively.

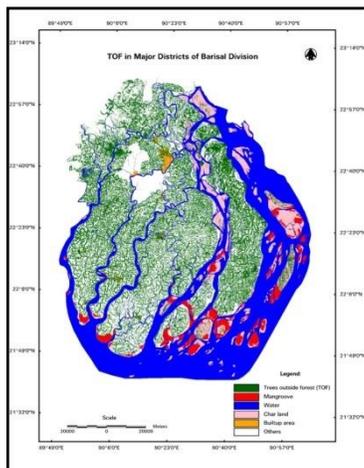


Figure 8: Shows the trees outside of forest (TOF) in the study area in 2016.

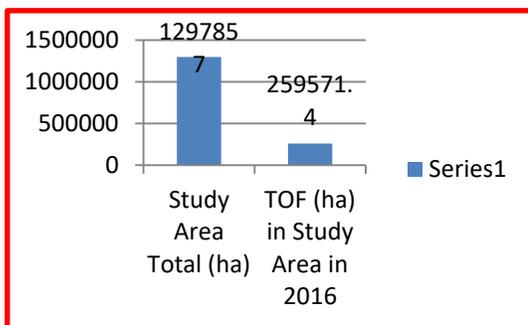


Figure 9: Shows the trees outside forest (TOF) comparison with total study area in ha in 2016.

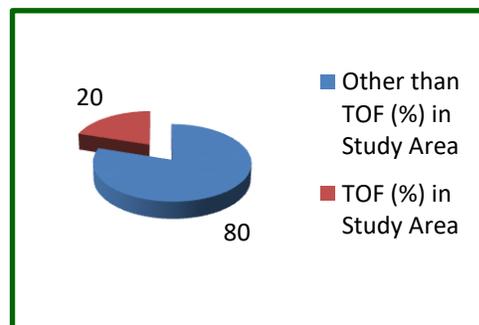


Figure 10: Shows the trees outside forest (TOF) comparison with total study area in percentage (%) in 2016.

Changes of tree outside forest (TOF) in Barguna District between 2000 & 2016

The map of trees outside of forest (TOF) in Barguna District has been mapped for the year 2000. Then the comparison has been made between the year 2000 and 2016 (Figure 11 & 12). The area of Trees outside Forests (TOF) area was 18325.90 ha in 2000 in Barguna District. This area is 10.02 % of Barguna District area study area in 2000. The area of Trees outside Forests (TOF) area was 37043.90 ha in 2016 in Barguna District. This area is 20.25 % of Barguna District area study area in 2016. The total coverage of TOF in the Barguna District increased between 2000 and 2016 is 18325.9 ha to 37043.9 ha and 10.02 % to 20.25 % (Figure 13 & 14).

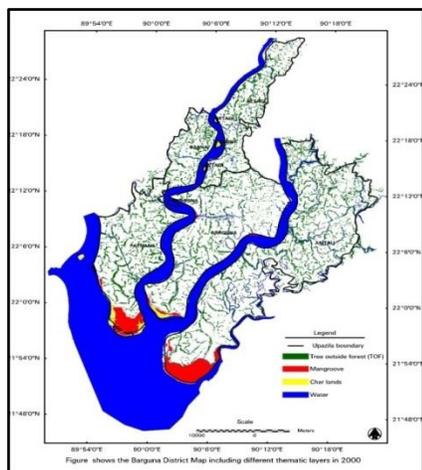


Figure 11: Shows the trees outside forest (TOF) and other land cover map of Barguna District in 2000.

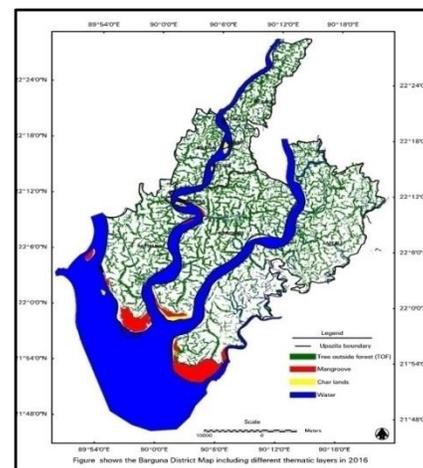


Figure 12: Shows the trees outside forest (TOF) and other land cover map of Barguna District in 2016.

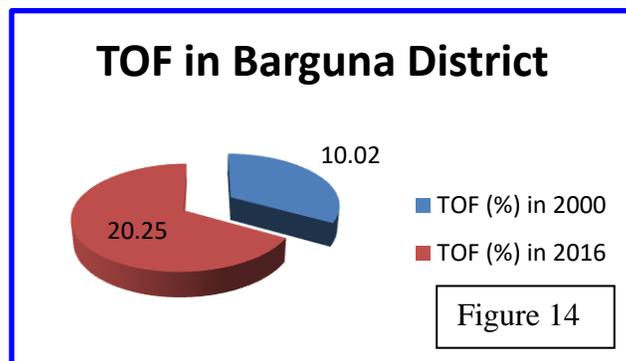
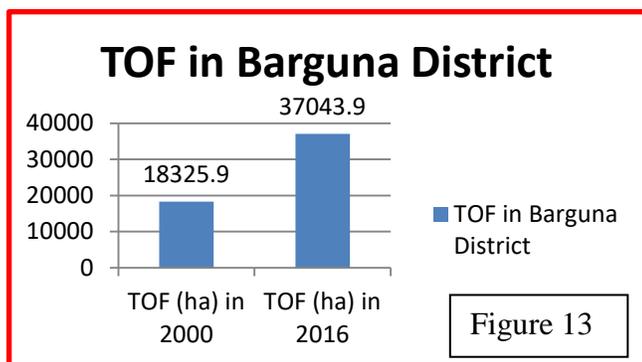


Figure 13&14: Shows the trees outside forests (TOF) changes in Barguna District between 2000 & 2016.

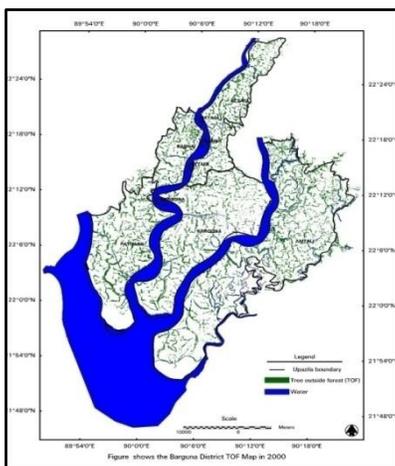


Figure 15: Shows the trees of outside forests (TOF) in Barguna District in 2000.

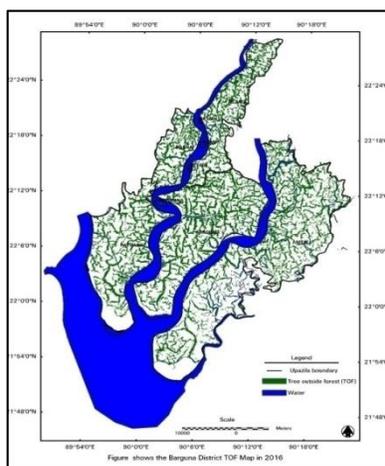


Figure 16: Shows the trees of outside forests (TOF) in Barguna District in 2016.

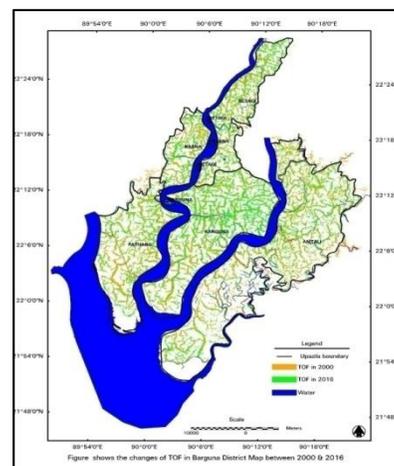


Figure 17: Shows the changes of outside forests (TOF) in Barguna District between 2000 & 2016.

Changes of tree outside forest (TOF) in different Upazillas of Barguna District between 2000 & 2016

Summary of the changes of TOF in different Upazillas of Barguna district shown in table 2. TOF in 2000 and 2016 and their changes in Barguna Sadar Upazilla between 2000 & 2016 have been shown in figure 18, 19 & 20 respectively.

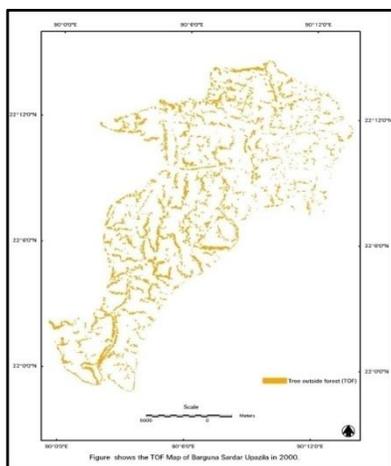


Figure 18: Shows the trees outside forest (TOF) in Barguna Sadar Upazilla in 2000.

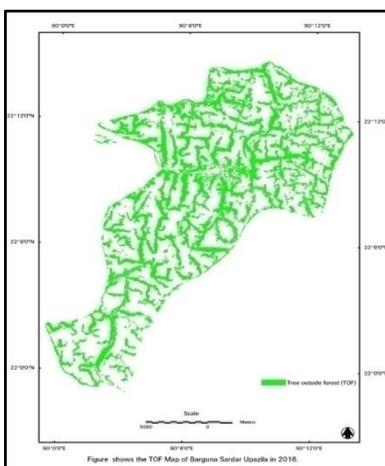


Figure 19: Shows the trees outside forest (TOF) in Barguna Sadar Upazilla in 2016.

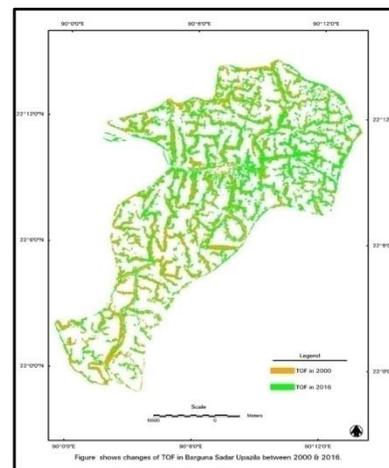


Figure 20: Shows the changes of trees outside forest (TOF) in Barguna Sadar Upazilla between 2000 & 2016.

Trees outside forests (TOF) in 2000 and 2016 and their changes in Betagi Upazilla between 2000 & 2016 have been shown in figure 21, 22 & 23 respectively.

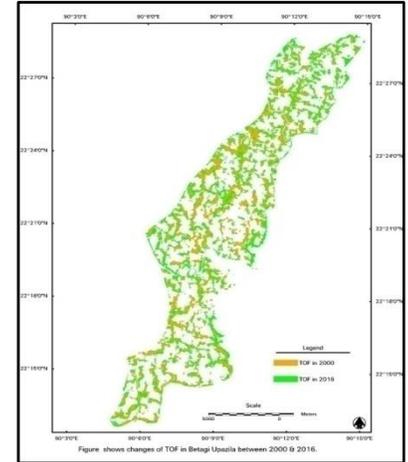
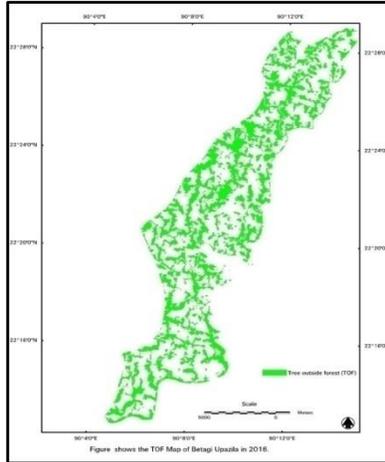
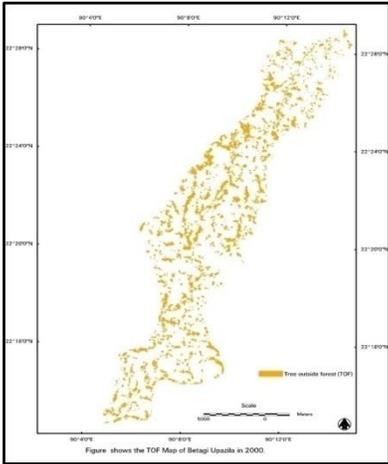


Figure 21: Shows the trees outside forest (TOF) in Betagi Upazilla in 2000.

Figure 22: Shows the trees outside forest (TOF) in Betagi Upazilla in 2016.

Figure 23: Shows the changes of trees outside forest (TOF) in Betagi Upazilla between 2000 & 2016.

Trees outside forests (TOF) in 2000 and 2016 and their changes in Pathorghata Upazilla between 2000 & 2016 have been shown in figure 24, 25 & 26 respectively.

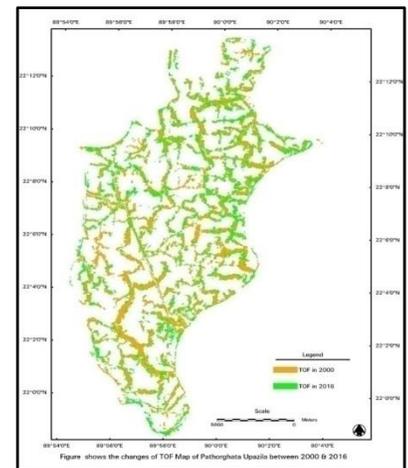
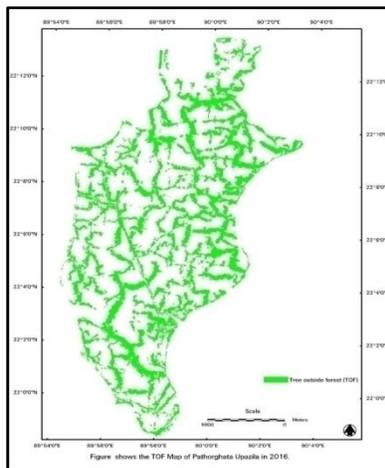
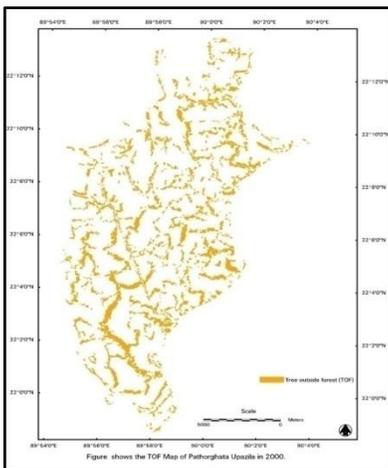


Figure 24: Shows the trees outside forest (TOF) in Pathorghata Upazilla in 2000.

Figure 25: Shows the trees outside forest (TOF) in Pathorghata Upazilla in 2016.

Figure 26: Shows the changes of trees outside forest (TOF) in Pathorghata Upazilla between 2000 & 2016.

Trees outside forests (TOF) in 2000 and 2016 and their changes in Amtali Upazilla between 2000 & 2016 have been shown in figure 27, 28 & 29 respectively.

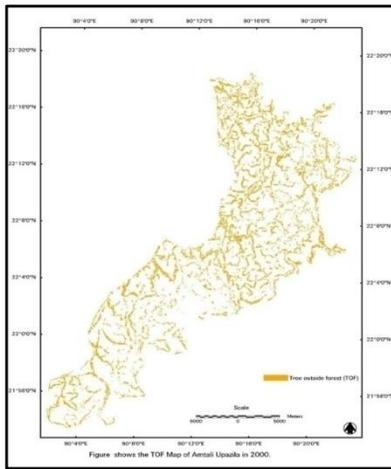


Figure 27: Shows the trees outside forest (TOF) in Amtali Upazilla in 2000.

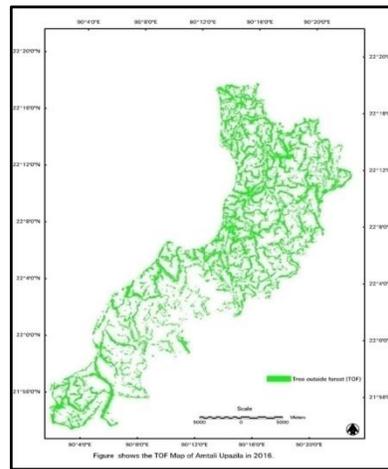


Figure 28: Shows the trees outside forest (TOF) in Amtali Upazilla in 2016.

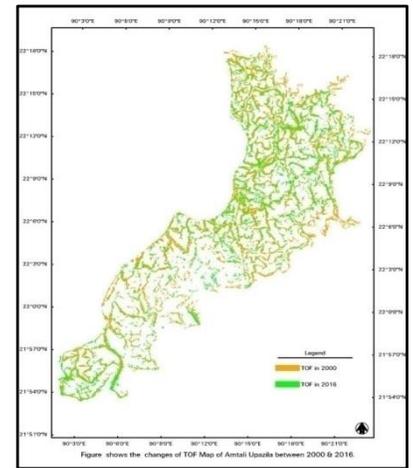


Figure 29: Shows the changes of trees outside forest (TOF) in Amtali Upazilla between 2000 & 2016.

Trees outside forests (TOF) in 2000 and 2016 and their changes in Bamna Upazilla between 2000 & 2016 have been shown in figure 30, 31 & 32 respectively.

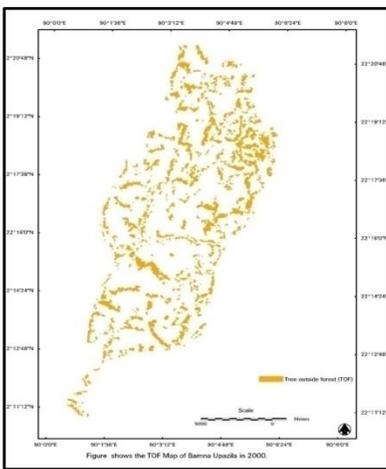


Figure 30: Shows the trees outside forest (TOF) in Bamna Upazilla in 2000.

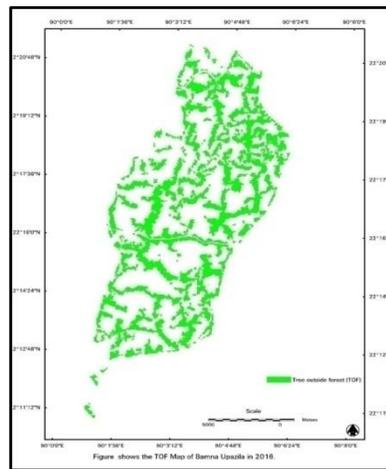


Figure 31: Shows the trees outside forest (TOF) in Bamna Upazilla in 2016.

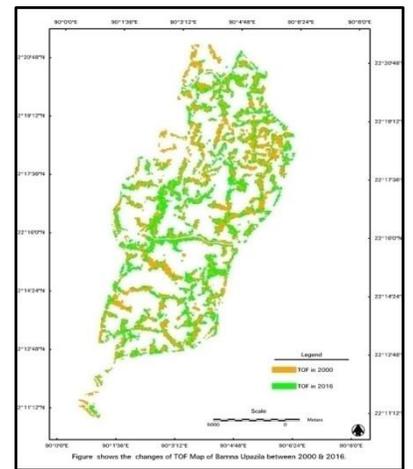


Figure 32: Shows the changes of trees outside forest (TOF) in Bamna Upazilla between 2000 & 2016.

Table 2: Shows the changes of trees outside forests (TOF) in different Upazillas of Barguna District between 2000 & 2016.

Name of Upazila in Barguna	Total area (ha)	TOF (2000)		TOF (2016)		TOF changes in 2000-2016	
		Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Barguna Sadar	45400	3489.39	7.69	10029.55	22.09	6540.16	187.43
Betagi	16700	2357.79	14.12	5496.44	32.91	3138.65	133.12
Pathorghata	38700	3323.60	8.59	6118.81	15.81	2795.21	84.10
Amtali	72000	7734.17	10.74	12519.42	17.39	4785.25	61.87
Bamna	10100	1420.95	14.07	2879.68	28.51	1458.73	102.66
Total	182900	18325.90	10.02	37043.90	20.25	18718.00	102.14

Driving forces for tree outside of forest (TOF) expansion in different Upazillas of Barguna District between 2000 & 2016

An attempt has been made to identify the driving forces behind the trees outside of forest (TOF) expansion in different Upazillas of Barguna District. Individual survey and focused group discussion had been conducted during ground truthing. People from different profession, age, sex, literacy, habitat (urban, sub-urban) etc. were considered for addressing the representative sampling. The following tree species were found in the study area namely Rain tree, Coconut, Mahogany, Acacia, Eucalyptus, Mango, Guava etc. The location of TOF were mainly in the homestead, farmland, bund of farmland, roadside, canal side, dam & bund side, community area (school, mosque, temple, church)

- The major drivers of these changes were population growth and household expansion,
- Higher financial returns from forests and forest products compared to alternative land uses,
- Initiatives related to social forestry programs,
- Awareness to the environmental issues and
- Fencing for protecting from natural disasters.

IV. CONCLUSION

Trees outside of forest (TOF) in the study area have been increased as a significant amount of area during 2000 to 2016. The main reason was the population growth and as a result fragmentation of joint family and turned in to new families with their new settlements. Although the cropping land is under tremendous pressure through building the new settlements but the green vegetations are increasing a lot and the equilibrium point is still unknown. An operational methodology for mapping of TOF and generating statistics in this research based on Landsat data. "Trees outside of forest" is a challenging vegetation layer while working on the crop monitoring and landuse mapping. The output of this research may be helpful for the other researcher in those regards.

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