Doctoral Dissertation

Forest change detection using remote sensing data and conservation through community development in Bangladesh

March, 2017

Mohammad Abdullah Al Faruq

Department of Mountain and Environmental Science

Shinshu University

Table of Contents

List of Figures

List of Tables

Abstract

Bangladesh is a poor, partially forested nation located in South Asia. The forests cover an estimated 17.5% of the land surface area of the nation. Rapid human population expansion has increased wood consumption and resource overexploitation, leading to the degradation of forest reserves. Bangladesh has lost most of its forests during the last 40 years. We mapped and analyzed forest cover change for the period 1972–2014 using Landsat satellite images of the Madhupur Sal forest captured in 1972, 1991, 2010, and 2014. This forest is a tropical deciduous stand within the Bangladeshi Tangail Forest Division. Forest cover changes were identified and approximately delineated on remotely sensed images. We applied a supervised classification approach to the satellite images using ERDAS IMAGINE ver.10 software. The mapping and analyses of five land-use classes were performed with ArcGIS ver.10 software. Thus, we precisely analyzed the trends in forest cover changes over 42 years. The area under natural forest cover was progressively reduced by 7079.4 ha through anthropogenic activities during the period 1972–2010. However, the natural forest area increased by 202.4 ha between 2010 and 2014 due to the implementation of a revegetation program to conserve the forest by improving the livelihoods of people dependent on forest. The maps are very relevant to forest conservation initiatives and will enable a long-term, integrated approach to forest revegetation operated by the forest department in association with local communities. Therefore, we focus on the changing trends in forest conservation and livelihoods in and around forested areas. Community involvement in forest management, a relatively new practice in Bangladesh, was initiated with the dual purpose of limiting

forest degradation and enhancing community development. In Bangladesh, many forestry projects have been introduced to manage forest resources involving local communities, although a few of them became sustain. We conducted a household survey in the forestry project, surveying 200 community forest workers (CFWs). The CFWs were randomly selected and interviewed, and we analyzed human, physical, financial, natural, and social livelihood capitals. The forest conservation program improved the livelihoods of the local community. The perceptions of the community about the general conditions of the forests, and attitudes of the local population about forest conservation, were improved. Dependence on the forests has also noticeably declined during the last few years. An additional outcome of the management program was empowerment and increased dignity of female participants. Such improvements would likely lead to improvements in livelihoods, as well as more sustainable forest management and conservation.

Keywords: Forest cover, Madhupur, remote sensing, rubber plantation, Sal tree, forest conservation, community development, participatory management, Sal forest, Bangladesh

Chapter 1: Introduction

1.3 Objectives and Flow chat of the study

The objectives of the study are the following:

1. To map land use in the Madhupur Sal forest and estimation of the rate of forest-cover change over 4 decades.
2. To examine the impacts of forestry project on forest dependent people's livelihoods, and
3. To investigate the conservation of the Madhupur Sal forest.

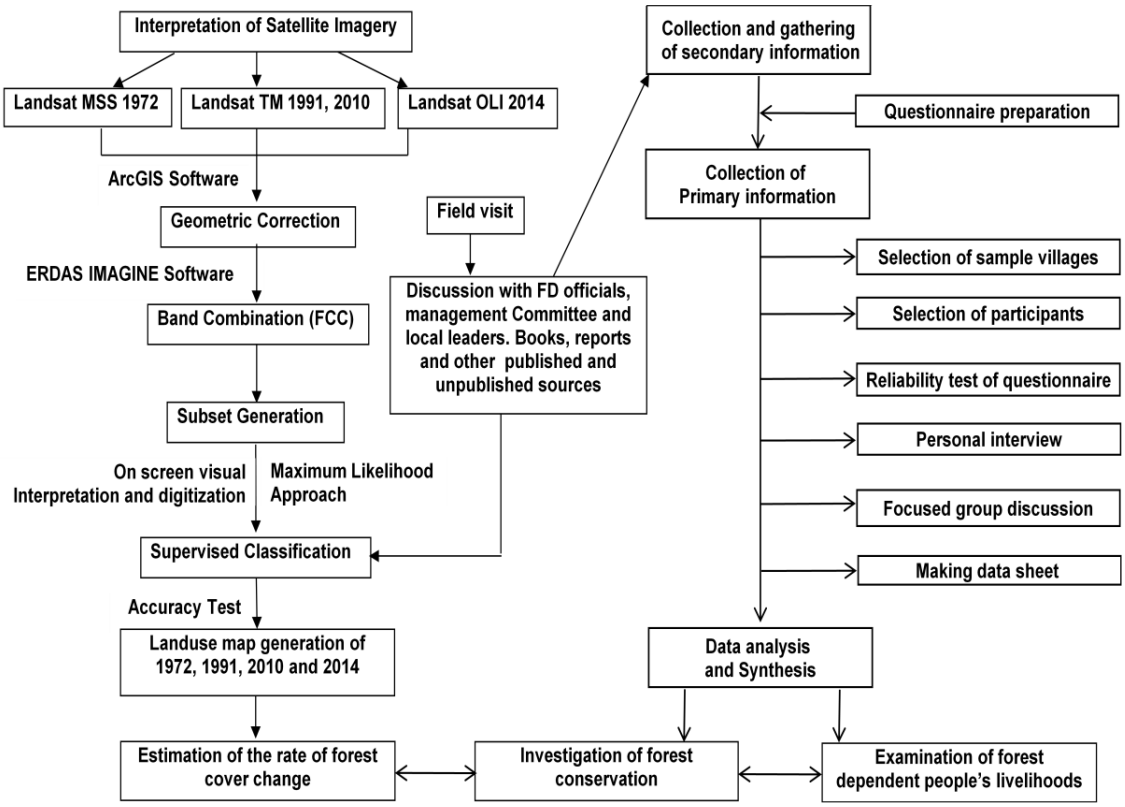

Figure 1. Flow chart of the study

1.4 Analysis of Forest Cover Changes Using Landsat Satellite Imagery

Among natural resources, forests are undoubtedly the most important for sustainable development across the globe. They directly influence local atmospheric cycles and contribute enormously to the diverse needs of forest-dependent and forest-independent peoples as well as to socioeconomic development and environmental stability. Unsustainable management of forest resources coupled with increasing population has resulted in dramatic change of forest cover in tropical countries. Here, change is defined as "an alteration in the surface components of the vegetation cover" (Milne, 1999). Detecting forest conditions and monitoring changes in forest structure lead to improved understanding of forest ecosystem services. Forest change detection is important for updating forest-cover maps and for monitoring and managing forest resources because it provides a quantitative analysis of the spatial distribution of forest density. For a comprehensive understanding of changes in tropical forest conditions, change analyses should span at least several decades (Lambin, 1999). Long-term datasets allow managers to draw meaningful inferences from the information at hand.

Temporal remote sensing data which offers an effective way to monitor gradual forest cover and ecosystem changes are used in many parts of the world. Remotely sensed data relating to land use and its changes over time provide crucial information for a range of diverse applications, such as environmental protection, forestry, hydrology, agriculture, and geology, among others. They

present current conditions and provide digital data acquisition characteristics. Remote sensing is among the most accurate means of measuring the extent and pattern of changes in vegetation cover over a period of time (Miller et al., 1998). It has the potential to provide comprehensive information on diverse criteria for forest management. Data on forest/land-cover changes are required for updating land-cover maps, managing resources effectively, and planning for sustainable development (Alphan, 2003; Muttitanon and Tripathi, 2005). Satellite image quality and availability have greatly improved in recent years. These improvements have enabled progress in image analysis procedures. Although most developed countries have detailed updated information on land use and land cover, the dearth of geospatial databases for many developing countries hampers appropriate development planning.

Bangladesh is a densely populated, South Asian nation that is still in the development stage. Poverty and unemployment rates are very high, and disadvantaged people naturally place great pressure on the country's natural resources as they forage for fuel and food. Deforestation is a major issue in a nation where forest resources are of ecological and economic importance. The estimated per capita consumption of timber and fuel wood is only 0.01 m^3 and 0.07 m^3, and the demand for timber and fuel wood is calculated to be 3.2 and 8.7 million m^3, thus giving an estimated deficit of 62 and 60 percent, respectively (IMF, 2005). The forests contribute significantly to the agricultural income of Bangladesh. It contributed about 1.76% of the country's GDP and 16.77% of the agriculture income in 2012-13 (BBS, 2014). A total forest cover of 25% is

required for the country to maintain ecological balance and environmental stability. Bangladesh has approximately 2.52×10^6 ha of forested land, accounting for *ca*. 17.1% of the national land area (BFD, 2010). In the past 30 years, the area of forest has rapidly decreased. The average annual rate of deforestation is 3–4% (Rasheed, 2008), which can be explained by the high rate of human population growth, commercial land use, the high demand for fuel wood, and extremely heavy use of natural resources (Alam et al. 2008). However, the poor budgetary practices of the national government do not provide extensive information on national forest resources. The scarcity of essential data delays programs aimed at mitigating the effects of deforestation. The development of strategies for estimating forest resources is therefore among the urgent issues required for sustainable forestry in Bangladesh.

The goal of sustainable forest management is to provide a steady flow of resources and income while preserving vegetation cover, biodiversity, and ecosystem integrity (Webb and Sah, 2003). In the early 1990s, the Bangladesh Forest Department and many NGOs participated in several social forestry programs to mitigate the deforestation (Salam and Noguchi, 2006; Alam et al., 2010). The programs contributed importantly by revegetating occupied forest lands with fast-growing plant species, but much less attention was given to sustainable conservation of the Sal forest. Sustainable forest management will require an understanding of the natural characteristics, distribution, quality, suitability, and limitations of the stands in relation to provision of resources to the human population. Most importantly, information on past and present land cover

in the area is crucial for sustainable management (Chaurasia et al., 1996). Few literature sources describe the status of the Sal Forest or changes in its canopy cover over time, although a range of reports provide information on soil quality, biodiversity, social forestry, and agro-forestry. In the face of rapid deforestation and the dearth of information on changes in vegetation cover, we focused on calculations of forest-cover change by using remote sensing technology to classify digital images.

We attempted to map land use in the Madhupur Sal forest over 42 years (1972–2014), focusing primarily on estimation of the rate of forest-cover change. The data that emerged should facilitate dynamic forest management planning. Our work also contributed to the development of remote sensing technology for developing countries, such as Bangladesh, where data gathered by satellite imagery will be especially valuable, as information gathering at ground level is inherently difficult.

Deriving actual land cover statistics and forest cover change information of this area is highly relevant for decision makers and conservation practitioners. An economically and ecologically sound management plan is desirable with minimum disturbance to the forest ecosystem. Proper understanding of the levels of social relations in community based forest management has important welfare implications, especially for livelihood security of forest dependent people. The effective conservation requires the active participation, integration and coordination of every stakeholder. Therefore, priority should be given to conserve this forest with a wide range of ecological and community development.

1.3 Perceptions of Local People toward Community Development and Forest Conservation

Forests serve as important sources of water, food, shelter, medicine, fuel wood, fodder, and timber for local people and adjacent communities. They also provide a wide range of environmental services, including biodiversity conservation, watershed protection, soil protection, and global climate change mitigation (Landell-Mills and Porras, 2002). However, losses of forests and tree diversity have increased globally at unprecedented rates (Kaimowitz and Angelsen, 1998). In developing countries, the degradation of forests has become very severe (Panta et al., 2008, Pelletier et al., 2010).

People in most of the developing world depend on forests for their livelihood. In the case of a developing country such as Bangladesh, the livelihoods of many depend on forests, in terms of direct and indirect income, ecotourism, and the collection and sale of wood and non-wood products. However, in many cases, access to natural resources is not uniform within and between communities (Shackleton et al. 2007). Many local people living in and around forests face high levels of poverty, with limited work opportunities (Shackletom et al. 2007). However, sustainable use of forest resources could provide an opportunity to integrate conservation and social development objectives (Sunderlin et al. 2005).

Review of Sal forest

Among the wooded tracts in Bangladesh, the Sal forest is crucial to the development of appropriate management methods for the country. This vegetation,

which is dominated by the Sal tree (*Shorea robusta*), is the third largest forest ecosystem in Bangladesh (BFD, 2011); the stands are classified as tropical, moist, deciduous forest (UNEP, 2002). Sal forests occupy *ca*. 0.12 million ha, representing 4.7% of the total wooded area of Bangladesh (GOB, 2010). Sal forests are considered environmentally and economically important (Alam et al. 2008). Most of the Sal forest is located in the greater Mymensingh and Tangail districts, also known as Madhupur Grath (Rahman, 2003). The Madhupur Sal forest is considered precious; it is the only forest located in the flood-free central part of the country.

Sal forests are surrounded by dense populations that include ethnic minorities. The Madhupur Sal forest has functioned for centuries as the homeland for ethnic communities such as the Garo and Koch (Ahmed, 2008). The once-biodiversity-rich Madhupur Sal Forest has been degrading since 1950. Thousands of people have become directly and indirectly dependent on the forest, placing it under severe pressure in recent decades through illegal logging, clearing for agriculture and industrialization, and the provision of livelihoods for the poor living around the forest (BFD, 2004). In addition, Sal trees have higher economic potential due to longer durability compared to other tree species. These pressures have caused significant changes to the forest and its associated resources. Encroachment and tree removal have significantly degraded forest ecological functions (Muhammed et. al., 2008). Such overexploitation, combined with inappropriate management, has made forest resource use unsustainable (Iftekhar, 2006). Recently published statistics have shown that only 30.1% of the original Madhupur Sal Forest remains intact (Faruq et al. 2016) (Figure 2).

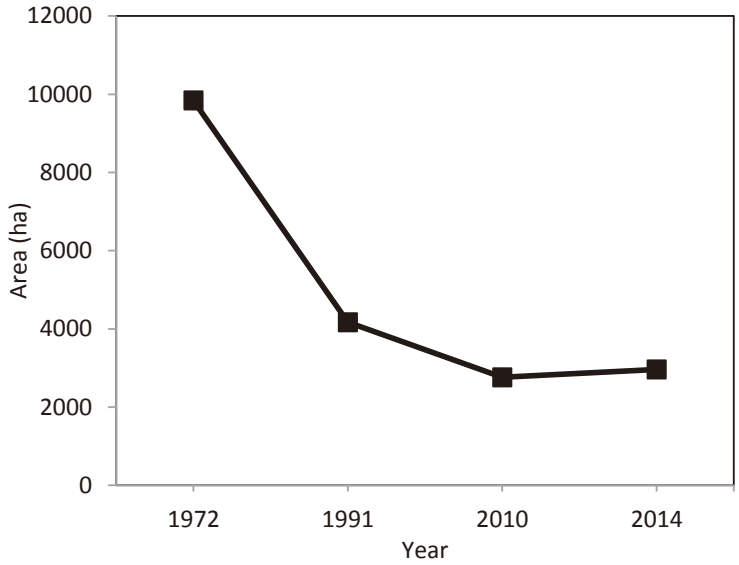

Figure 2. Changes in Sal forest cover over time in Madhupur
(Source: Faruq et al. 2016)

Review of forestry project

In many developing countries, the management of natural resources has gradually become participatory and typically involves a broad range of stakeholders (Turyahabwe et al., 2012). The Forest Department (FD) of Bangladesh started people-oriented forestry programs in the 1980s, when conservation of degraded Sal forests became a top priority (Muhammed et al 2008, GOB 2010). Previous projects failed, due to a shortage of funds and lack of proper implementation plans, as identified by the FD (Nath and Inoue 2008).

In Bangladesh, forest policy established in 1994 provided general direction rather than legislation to regulate realistic issues such as land tenure, sharing benefits, and market processes (Ahmed 2008). The local populations in and around forests have important and long-standing relationships with their forests. Hence, their needs,

aspirations, and attitudes should be considered in forest management; otherwise, the long-term survival of forested areas will be jeopardized (McNeely 1990).

To this end, the FD launched a new project entitled “Revegetation of Madhupur Forest through Rehabilitation of Forest-Dependent Local and Ethnic Communities,” with the broad aim of protecting forests, sharing resource management among forest communities, and ensuring secure livelihoods for those dependent on forests.

The initial 3-year project was initiated in 2010, but was extended to 2015. The FD policy was to identify people who were involved in illegal tree felling, provide motivation and training, and transform the population into guardians of the forest, as CFWs (Community Forest Worker), working in parallel with forest staff. We investigated the conservation of the Madhupur sal forests, the attitudes of the people dependent on them, and the impact of the project on their livelihoods.

Chapter 2: Materials and Methods

2.1 Geographic location and extent of Bangladesh

Bangladesh is a Unitary and sovereign Republic, known as the People's Republic of Bangladesh (Figure 3); it gains its independence on March 26, 1971. Bangladesh occupies a unique geographic location of 20°34'N – 26°38'N latitude to 88°1' E – 92°41'E longitude. The entire country is biogeographically a transition between the Indo-Gangetic plains and the eastern Himalayas and in turn part of the Indo-Chinese sub region of the Oriental realm (IUCN, 2004). It is bordered by the Bay of Bengal on the South and by India on all other sides except for a small south-eastern border with Myanmar. In Bangladesh, much of the land (80%) area does not generally exceed 40m ASL, making the country's landscape the single largest flood-basin in South Asia (Hofer and Messerli, 2006), and the terrace and hill area occupying 8% and 12%, respectively. The 2011 national censuses recorded a population of 142.3 million; a density of 964 persons per sq km. Bangladesh enjoys generally a sub-tropical monsoon climate. Winter begins in November and ends in February. In winter, temperatures fluctuate from minima of 7.22°C – 12.77°C to maxima of 23.88° - 31.11°C. The monsoon starts in July and continues until October. The monsoon accounts for 80% of the total rainfall. Average annual rainfall varies from 1429 mm to 4338 mm (BBS, 2006). Bangladesh, being a tropical country, enjoys a wide range of bio-diversity covering both wild and cultivated land. Of the total area of Bangladesh (147,570 sq. km.), agricultural lands makes up 64%, forest lands account for almost 18%, whilst urban areas are 8% of the area. Water and other land uses account for the remaining 10%.

2.2 Forests of Bangladesh

Bangladesh is one of the region's poorest countries in terms of land under forest area. Ecologically the natural forests of Bangladesh covers three major vegetation types occurring in three distinctly different land types of the country, i.e., hill forest (evergreen to semi-evergreen); plain land Sal forest and mangrove forest. In addition to this, there are homestead forests, costal forest and unclassified state forests. Although, once these public forests were remarkably wealthy, but during the last few decades they have been degraded heavily due to various socio-political and management problems. There is a strong link between rural poverty and deforestation in Bangladesh, as both problems are part and parcel of overpopulation, land scarcity, natural disasters, and lack of sufficient policy measures to deal with the problems that include lack of effective management approaches to ensure the participation of forest-adjacent people and to discourage corruption on the part of concerned officials (Biswas & Chowdhury, 2007).Geographically, the country has a large tract of evergreen to semi-evergreen hill forest consists of a mixture of many tropical evergreen and deciduous plant species located in the hilly areas of eastern and south-eastern part; once very rich in biodiversity. The mangrove forests are in the south and south-western deltaic zone of Bangladesh has the largest single tract of mangrove forests of the world. Besides in north-eastern part of the country there are many wetland areas; locally called haors which harbors a huge number of plants, migratory birds (water fowls) and freshwater fish species. The plain land Sal forests is the only available to the greater majority population of the country, mainly consist of Sal

(*Shorea robusta*) trees. The Sal forests are located mostly in the central and northern part of the country.

More than 90% of state owned forest land is concentrated in 12 districts in the eastern and south-eastern region of the country. Other parts of the country depend on homestead and village forests, which contribute more than 80% of national needs of timber and fuel wood. It is argued that the lands under forests are not utilized to their maximum potential. Forest yield are unacceptably low due to over-exploitation of the growing stock and conversion of land for non-forest activities. Homegarden are more fertile and per unit production is higher than state forests. The homestead forestry plays an important role in the economy of the rural households. It provides food, fuelwood, fodder, building material s and other forms of wood. It is one of the renewable resources can play a vital role in the struggle for survival and sustenance of the rural poor.

There are some contradictions about the actual forests coverage of the country. Although, according to FD and some other sources (for example, Mukul *et. al.* 2006 and Hossain, 2005) it is nearly about 2.53 million ha representing approximately 17.5% of the country's total surface area (Figure 3; Table 1) but according to FRA-2005 this figure is only about 0.871 million ha (FAO, 2006 and 2007). Officially, Bangladesh Forest Department manages 1.53 million hectares of forest land of the country.

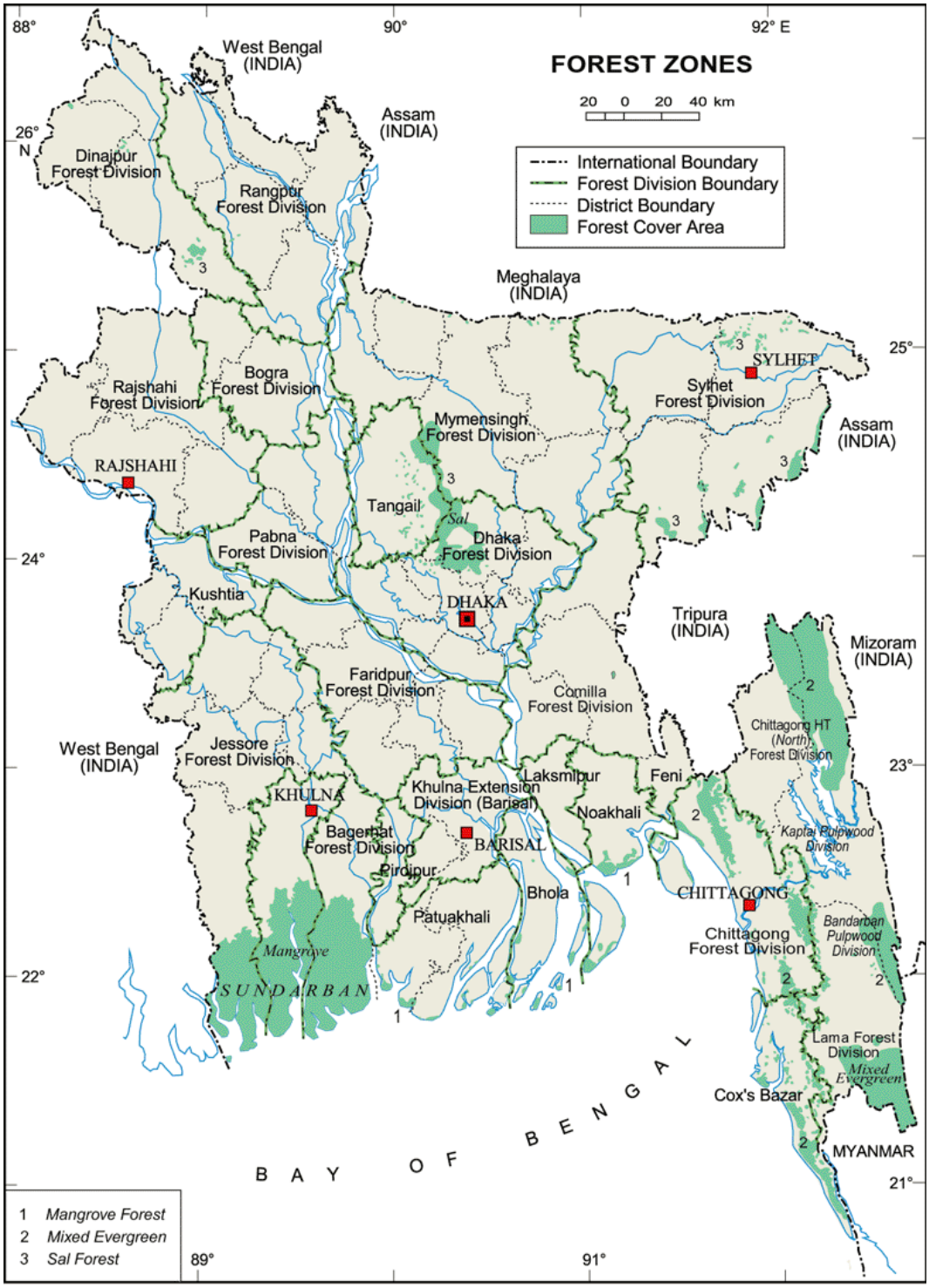

Figure 3. Map showing geographic location and the distribution of forests in Bangladesh

Table 1. Forest type and areas in Bangladesh

Forest type	Location	Area (million ha)	Remarks
Hill forest			
Managed reserved forest (evergreen to semievergreen)	Eastern part of the country (Chittagong, Chittagong Hill Tracts and Sylhet)	0.67	Highly degraded and managed by the Forest Department.
Unclassed state forest (USF)	Chittagong Hill Tracts	0.73	Under the control of district administration and denuded mainly due to faulty management and shifting cultivation. Mainly scrub forest.
Plain land forest			
Tropical moist deciduous forest	Central and north-western region (Dhaka, ymensingh, Tangail etc.)	0.12	Mainly *Sal* forest but now converting to exotic short rotation plantations. Managed by the Forest Department.
Mangrove			
Sundarbans	Southwest (Khulna, Satkhira)	0.57	World's largest continuous mangrove forest and including 0.17 million ha of water.
Coastal forest	Along the shoreline of twelve districts	0.10	World's largest continuous mangrove forest and including 0.17 million ha of water.
Village forest	Homestead forests all over the country	0.27	Diversified productive system. Fulfill majority of country's domestic timber, fuel wood and bamboo requirements
Plantation in tea and rubber gardens	Chittagong hill tracts and Sylhet	0.07	Plantations of various short rotation species (mainly exotics)
Total Forests		**2.53**	17.49% of country's total landmass

Source: Mukul et. al. (2006); Hossain (2005)

2.3 Study Area

Forest is a complex ecosystem consisting mainly of trees that buffer the earth and support a myriad of life forms. In Bangladesh, forest land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent,

or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (FRA, 2015).

The Madhupur deciduous Sal forest (24°32'–24°47'N, 89°59'–90°11'E) covers an area of approximately 25,495.9 ha in 1982 (Islam and Sato, 2012). It is located in the northeastern section of the Tangail Forest Division; a small segment runs along the boundary of the Mymensingh Forest Division (Figure 4). The study site was selected because of the anthropogenic threats facing this stand. Land use in Bangladesh is changing rapidly, and new developments affect the area significantly. The Madhupur Sal stand is the only forest in central Bangladesh. Thousands of ethnic and non-ethnic people depend on its products. The forest is under strong pressure from illegal logging and land encroachment, both of which degrade forest resources. A major portion of the forested area (*ca*. 8,499 ha) has been given "reserve forest" status. The designation was announced in a gazette in 1982, when the reserve was renamed the "Madhupur National Park." Reducing and perhaps reversing the rapid degradation of the stand requires acquisition of robust data on the rates and trends of degradation. Conservation and preservation programs will be enabled by such reliable information.

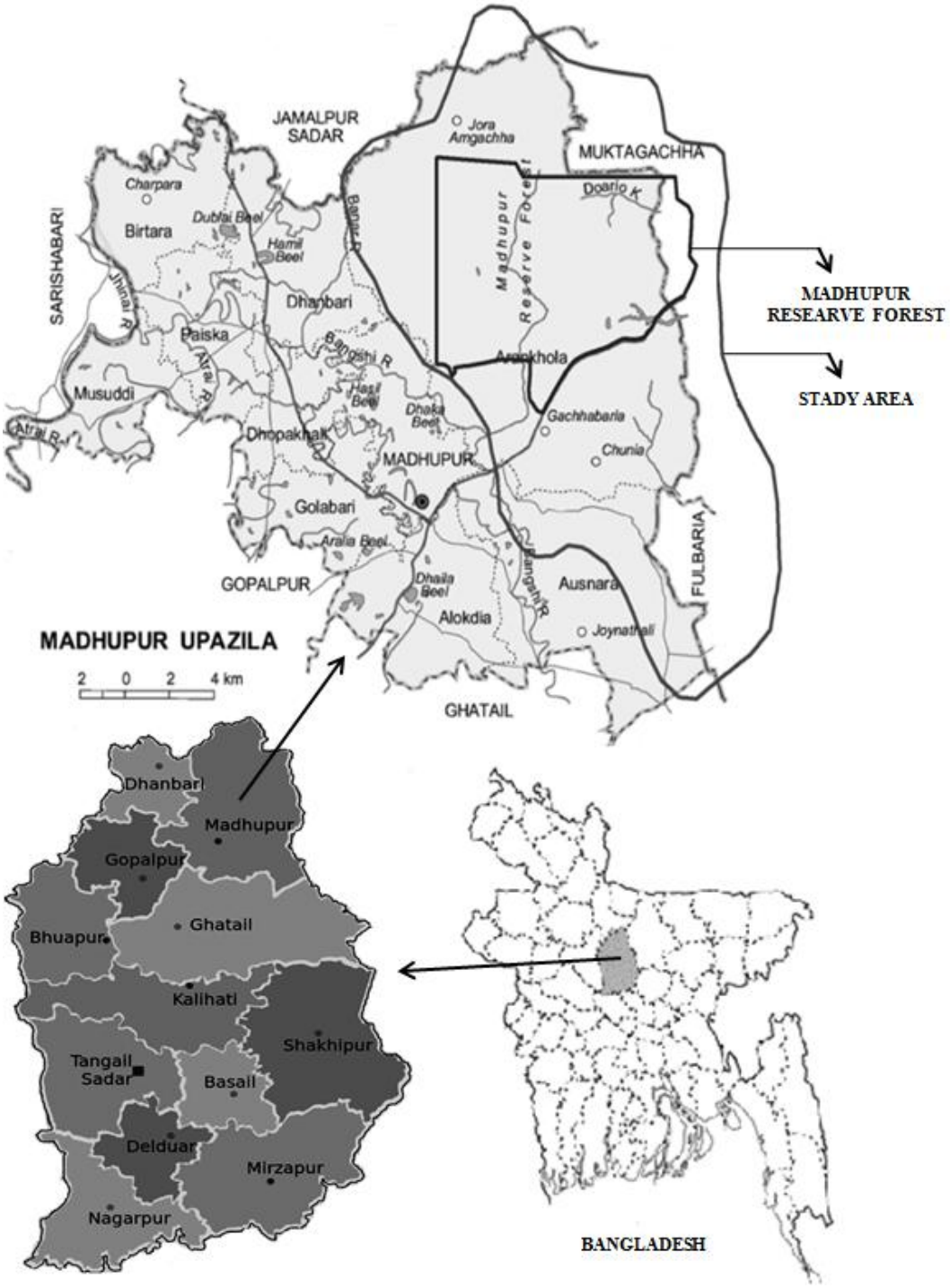

Figure 4. Location of the study area in Madhupur, Bangladesh

The forest is divided into four beats (small administrative units of the Forest Department), namely, Jatyo Uddyan, Dokhola, Aronkhola, and Madhupur. The forest is located *ca*. 20 m above mean sea level. The climate is dominated by monsoon that usually begins in June and ends in October. The rainfall peak occurs from May-September with sometime dry season in January-April. Winter or cold season starts from mid November and lasts until February. High temperature prevails during April-August. The mean annual rainfall is 2,000–2,300 mm, and annual mean temperature is 26.3°C (Rahman, 2003). The soil of Madhupur Sal Forest mixed with yellowish red sandy clay (MSF, 2016). The soil of this forest is very hard in dry season and very loss in rainy season. In rainy season soil are found very fertile and suitable for living plants.

The Madhupur Sal forest area, commonly known as the Madhupur Garh, is on a tract of land *ca*. 1–2 m higher than the surrounding plains. The ridges, known locally as Chala (high lands) was used by the original residents to build their homesteads and for swidden until this cultivation is banned in the early 1950s. These lands are still used by the original residents and the new settlers for homesteads, vegetable gardens, and pineapple plantations. The interior of Chala lands are covered with forest formations and are not continuous. The forest is dense in some parts and sparse in others. Scrub jungle can also be found on the ridges. The baid (low lands in between chala lands) lands were converted by the original residents to wet rice fields after clearing the bushes and these lands are still used for growing wet rice. Parts of deforested slopes between chala and baid lands have also been converted to wet rice

fields by some people, particularly by those who occupy the baid lands adjacent to these slopes.

The Madhupur Sal forest area has been subjected to some degree of exploitation. Many animal species (e.g., tiger, leopard, elephant, sloth bear, and spotted deer) have gone extinct, although much plant diversity still exists (NSP, 2008). The forest canopy height varies between 10 m and 30 m. The dominant species (80–100% of trees) is the commercially profitable Sal tree (*Shorea robusta*), which dominates the upper canopy. It is associated with Ajuli (*Dillenia jpentagyna*), Amlaki (*Phyllanthus emblica*), Koroi (*Albizia procera*), *Terminalia* sp, and Sonalu (*Cassia fistula*), among other taxa. The understory includes *Bambusa* sp., *Alsophila* sp., and several ferns and epiphytes (Feeroz and Islam, 2000). There are 140 species, 19 mammal species, 19 reptile species, and four amphibian species (NSP, 2008).

2.4 Satellite Datasets

We used four multi-temporal satellite images (Landsat MSS 1972, Landsat TM 1991, Landsat TM 2010, and Landsat OLI 2014) to classify land use and to evaluate forest-cover changes in the Madhupur Sal forest area. The images selected spanned temporal changes at intervals of *ca*. two decades prior to the start of a revegetation program in 2009. The images were collected from the Global Land Cover Facility (GLCF) and USGS Global Visualization Viewer (GLCF, 2014) (Table 2). The Landsat Multispectral Scanner (MSS) had four spectral bands with a spatial resolution of 60 m. The Landsat Thematic Mapper (TM) had seven spectral bands with a spatial resolution of 30 m (except band 6, which had 120-m resolution). The Landsat Operational Land Imager (OLI) had nine spectral bands with a spatial

resolution of 30 m (except for band 8, which had a 15-m spatial resolution). Table 3 lists the band specifications of sensors used in the study (USGS, 2014). All of the images were acquired between November and March, during the dry season. The images were clear and cloud free, and had moderate color contrast for land-use mapping and change detection. Our application of satellite images to land-cover mapping and change detection was supported by a number of national and international studies: Naithani (1990), Rosenholm (1993), Quadir et al. (1998), Islam et al. (2006), Islam (2006), Zaman and Katoh (2011), Nath (2014).

Table 2. List of satellite images selected

Satellite data	Date	Spatial resolution	Bands
MSS (WRS-1, Path 148, Row 43)	23/11/1972	60 m	4,3,2 (NIR, R, G)
TM (WRS-2, Path 137, Row 43)	26/11/1991	30 m	4,3,2 (NIR, R, G)
TM (WRS-2, Path 137, Row 43)	30/1/2010	30 m	4,3,2 (NIR, R, G)
OLI (WRS-2, Path 137, Row 43)	30/3/2014	30 m	5,4,3 (NIR, R, G)

NIR, near infrared: R, red; G, green. MSS, Landsat Multispectral Scanner; TM, Landsat Thematic Mapper; OLI, Landsat Operational Land Imager

Table 3. Major specifications of MSS, TM, and OLI

MSS		TM		OLI	
Observed band	Wave range (μm)	Observed band	Wave range (μm)	Observed band	Wave range (μm)
Band 4	0.5 to 0.6	Band 2	0.52 to 0.60	Band 3	0.53 to 0.59
Band 5	0.6 to 0.7	Band 3	0.63 to 0.69	Band 4	0.64 to 0.67
Band 6	0.7 to 0.8	Band 4	0.75 to 0.90	Band 5	0.85 to 0.88

MSS, Landsat Multispectral Scanner; TM, Landsat Thematic Mapper; OLI, Landsat Operational Land Imager

2.5 Field Survey Data

A field survey was carried out among the CFWs of the forestry project during January and February 2016. Both the quantitative and qualitative data on

socioeconomic, demographic, and cultural variables were collected by using structured questionnaire. The questionnaire is attached in appendix of the thesis.

Chapter 3: Analysis of Forest Cover Changes Using Landsat Satellite Imagery

3.1 Methods

3.1.1 Data processing and analysis

The flow chart in Figure 5 depicts the sequence used in our research. Multi-temporal sets of remote sensing data were used to categorize land-use classes. The image processing software package ERDAS IMAGINE ver.10 (ERDAS, Inc., Atlanta, GA, USA) and the vector data manipulation software ArcGIS ver.10 (ESRI, Redlands, CA, USA) were used to process, analyze, and integrate spatial data. To make the images comparable, the digital image data were first transformed to a uniform ground coordinate system. Geometric correction was required to avoid geometric distortions; thus, we established an image coordinate system relationship. We first performed image rectification on the Landsat TM 2010 image using the World Geodetic System (WGS) 1984 datum, zone 46 north, which is derived from the Universal Transverse Mercator (UTM) coordinate system. We used 15 well-distributed ground control points (GCPs). Finally, Landsat TM 2010 was rectified to 0.25 pixels (7.5 m) using the nearest-neighborhood method with root square mean errors. Landsat MSS 1972, Landsat TM 1991, and Landsat OLI 2014 images were subsequently rectified to Landsat TM 2010 using image-to-image rectification, and resampled to 30-m pixels using the nearest-neighborhood method. We subsequently generated a false color composite combination of infrared, red, and green to facilitate vegetation recognition; chlorophyll in plants strongly reflects the near infrared. We then generated subset, and selected the areas of interest at the study site.

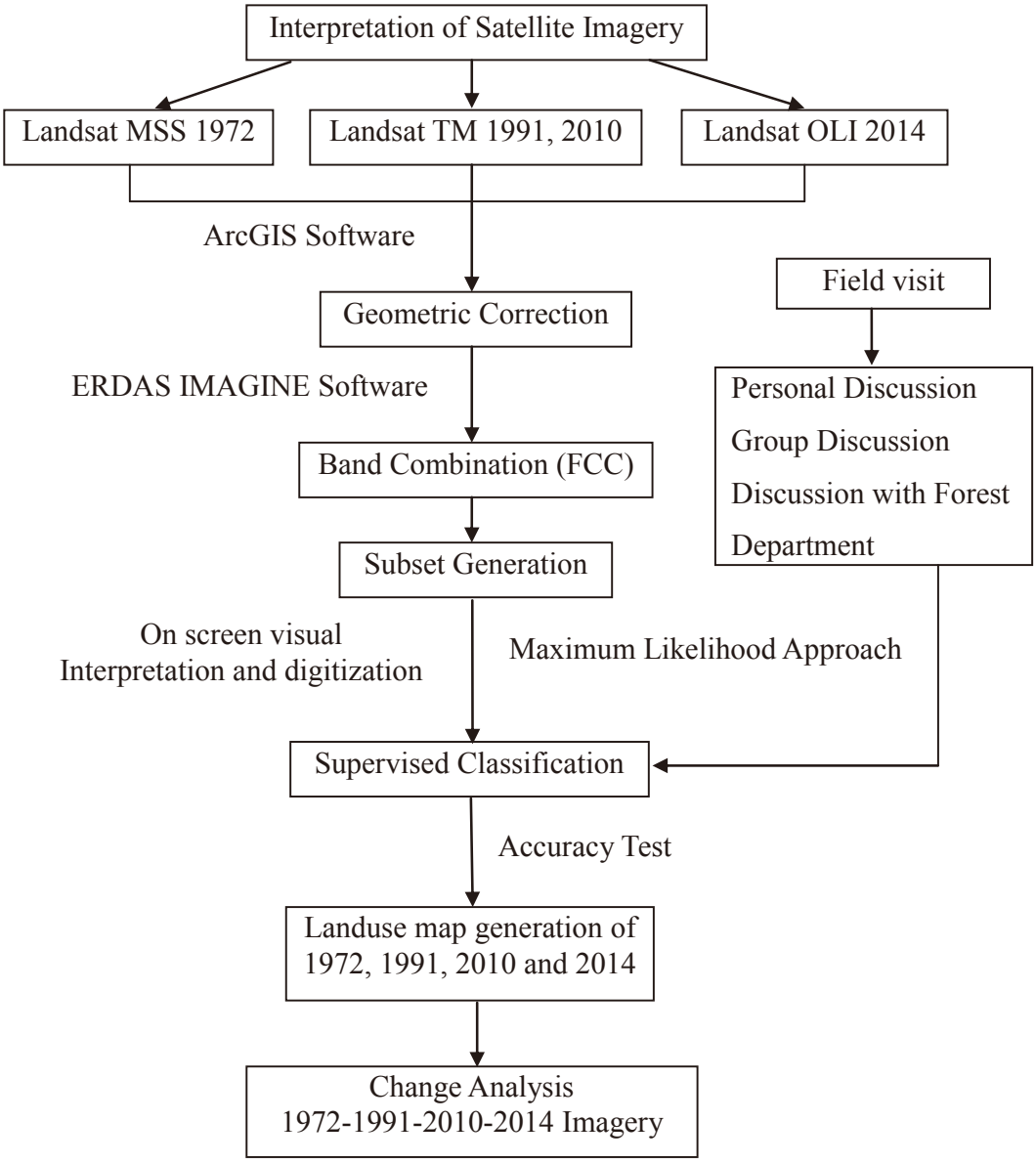

Figure 5. Flow chart depicting the sequence of procedures used in the study

Finally, we categorized the images using the maximum likelihood classification (MLC) technique of supervised classification approaches; five land-use classes were identified: natural forest, rubber plantation, woodlot plantation, water

bodies, and settlements/croplands/other uses. The supervised classification procedure requires training areas for each of the classes identified. These training areas were used to define spectral reflectance patterns/signatures of each land-use category. The signatures were then used by classifiers to group the pixels into a selected category consistent with the spectral patterns. We selected 15 homogeneous training areas for each land-use class and used an interpretation key for classification. The interpretation key was created with the aid of visual analysis of the images using displays of red/green/blue (RGB) combinations. The classification was also supported by reference data and ancillary information. The reference data, which were collected from digital forest-cover maps for 1963, 1977, 1991, 2003, and 2008, together with visual interpretations of the images, were used to validate the classified images. The ancillary information was obtained from the digital land-use map, forest-cover maps, Google Earth (Google Inc., Googleplex, Mountain view, California, USA), and the author's prior knowledge of the study area obtained by visiting the site. A 3 × 3 majority filter was finally was applied to smooth the classified images. The land use descriptions were as follows:

- Natural forest: Most of the trees in natural forests were indigenous and had recruited naturally. The stands were capable of producing timber or other wood products.
- Rubber plantation: Areas covered with rubber trees (*Hevea brasilensis*).
- Woodlot plantation: Areas covered with native and exotic timber-producing tree species.
- Water bodies: Rivers, lakes, ponds, irrigation lines, and seasonal standing water.

- Settlements/croplands/other uses: Agricultural lands used to produce human food, and bare land devoid of vegetation, such as sand dunes and exposed soil. Settlements were mostly rural housing with homestead vegetation. Other uses included roads, and an air force live bombing ground.

We produced land-use maps for 1972, 1991, 2010, and 2014. The general land use of an area conveyed information on the overall area-based utilization of both natural and cultural resources.

Accuracy assessment was the next step in image classification. It is very important for interpreting and application of the results. We used this procedure to evaluate the quality of each thematic map from a satellite image. The software we used contained an accuracy assessment tool; overall accuracy and kappa statistics were computed. Finally, using the ERDAS IMAGINE attribute table, we calculated the area statistics (in ha) of each land-use category and then compared different classes of land use among years. Thus, we examined changes in forest cover and other land use within the Madhupur Sal forest at decadal intervals over 42 years (1972–1991–2010–2014). Statistically significant differences were detected using Microsoft Excel 2003 software (Microsoft Corporation, Redmond, WA, USA).

3.1.2 Interpretation key

The criterion set by interpretation elements that we used for identification of an object was termed an interpretation key. The key is a set of guidelines used to assist interpreters in rapid identification of features on a remote sensing image. The six primary elements of visual interpretation were tone (or color), size, shape, texture, shadow, and pattern. We developed an interpretation key for the study years by cross-

comparing existing maps of the forest cover and the tonal characteristics of false color composite (FCC) imagery. Tone refers to the relative brightness or color of objects captured in an image. Texture is the frequency of tonal change on the image; it determines the overall visual smoothness or coarseness of an image's features. We interpreted images using ERDAS IMAGINE ver. 10 software, with additional information provided by (i) maps made available by Google Earth, (ii) a land-cover map of the Madhupur Reserve Sal forest, and (ii) site visits (site visits included discussions with Forest Department and local people, as well as the authors' personal examination of the forest). Table 4 lists the land-cover characteristics and interpretative remarks.

Table 4. Interpretation key for MSS, TM, and OLI images.

Landsat imagery	Feature	Physical characteristics	Feature color in the images
MSS	Natural forest	Tropical moist deciduous forest	Dark red with smooth texture
	Rubber plantation	Rubber tree plantation	-
	Woodlot plantation	Native/exotic tree species	-
	Water bodies	River, pond, canal	Dark green with smooth texture
	Settlements/croplands/ other uses	Crop/bare land, rural houses with homestead gardens, roads etc.	Light green, whitish, cyan with medium texture
TM	Natural forest	Tropical moist deciduous forest	Dark to pinkish red with smooth texture
	Rubber plantation	Rubber tree plantation	Light red with smooth texture
	Woodlot plantation	Native/exotic tree species	Dark red with medium texture
	Water bodies	River, pond, canal	Dark blue with smooth texture
	Settlements/croplands/ other uses	Crop/bare land, rural houses with homestead gardens, roads etc.	Light green, whitish, cyan, red with medium texture
OLI	Natural forest	Tropical Moist deciduous forest	Pinkish red with smooth texture
	Rubber plantation	Rubber tree plantation	Light red with smooth texture
	Woodlot plantation	Native/exotic tree species	Dark red with medium texture
	Water bodies	River, pond, cannels	Dark blue with smooth texture
	Settlements/croplands/ other uses	Crop/bare land, rural houses with homestead gardens, roads etc.	Whitish, cyan, red with medium texture

MSS, Landsat Multispectral Scanner; TM, Landsat Thematic Mapper; OLI, Landsat Operational Land Imager

3.2 Results

3.2.1 Land-use classification

The study area was categorized into five land-use classes: natural forest, rubber plantation, woodlot plantation, water bodies, and the "settlements/croplands/other uses." The land use maps for 1972, 1991, 2010, and 2014 are depicted in Figure 6. Table 5 lists the areas occupied by each land-use category. The settlements/croplands/other uses category occupied the largest proportion of the area throughout the study period, reaching a maximum of 23,684.6 ha in 2014. Natural forest was the second largest category. It occupied 9,840.3 ha in 1972, declining to 2,760.9 ha in 2010. Rubber and woodlot plantations first appeared in 1991 and gradually increased thereafter. The area of the water bodies peaked (at 2,145.9 ha) in 2010, and fell dramatically in 2014.

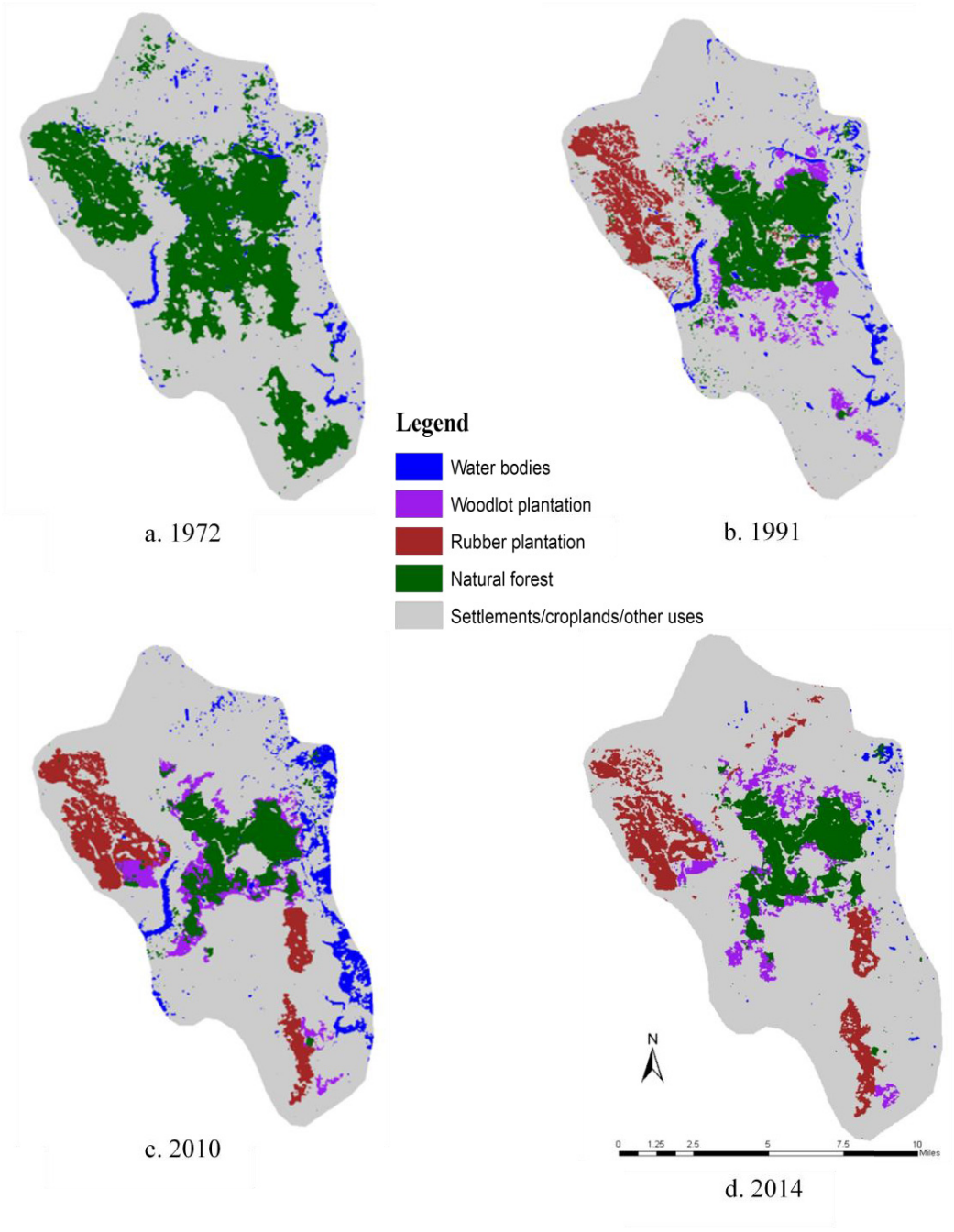

Figure 6. Classified image maps of the Madhupur Sal Forest area

Table 5. Land areas (ha) and their proportions (%) of the total calculated from maps of different land uses in the Madhupur Sal forest area

Year	Natural forest		Rubber plantation		Woodlot plantation		Water bodies		Settlements/crop lands/other uses		Total area
	(ha)	%	(ha)	%	(ha)	%	(ha)	%	(ha)	%	(ha)
1972	9840.3	31.5	-	-	-	-	1114.8	3.4	20267.5	64.9	31222.6
1991	4168.4	13.4	2201.0	7.1	1435.8	4.6	1211.9	3.9	22205.6	71.1	31222.6
2010	2760.9	8.8	2924.4	9.4	1519.0	4.9	2146.9	6.9	21871.4	70.1	31222.6
2014	2963.3	9.5	2778.3	8.9	1537.3	4.9	259.1	0.8	23684.6	75.9	31222.6

3.2.2 Accuracy assessment of the classification

Overall classification accuracies and overall kappa statistics obtained for the classified images are listed in Table 6. Kappa coefficient values were aggregated into three groups: (i) values >80%, representing strong agreement; (ii) values of 40–80%, representing moderate agreement; and (iii) values <40%, representing poor agreement (Rahman et. al., 2004). The kappa statistics for the year 1972, for example, indicated that our classification system produced a map in which ≥97% of pixels were correctly classified (more than would be expected by random assignment).

Table 6. Accuracy assessment of the classified images

Reference Year	Classified image	Overall classification accuracy (%)	Overall kappa statistics
1972	Landsat MSS	98.3	0.97
1991	Landsat TM	86.4	0.76
2010	Landsat TM	93.2	0.89
2014	Landsat OLI	91.9	0.89

MSS, Multispectral Scanner; TM, Thematic Mapper; OLI, Operational Land Imager

3.2.3 Land use changes between 1972 and 1991

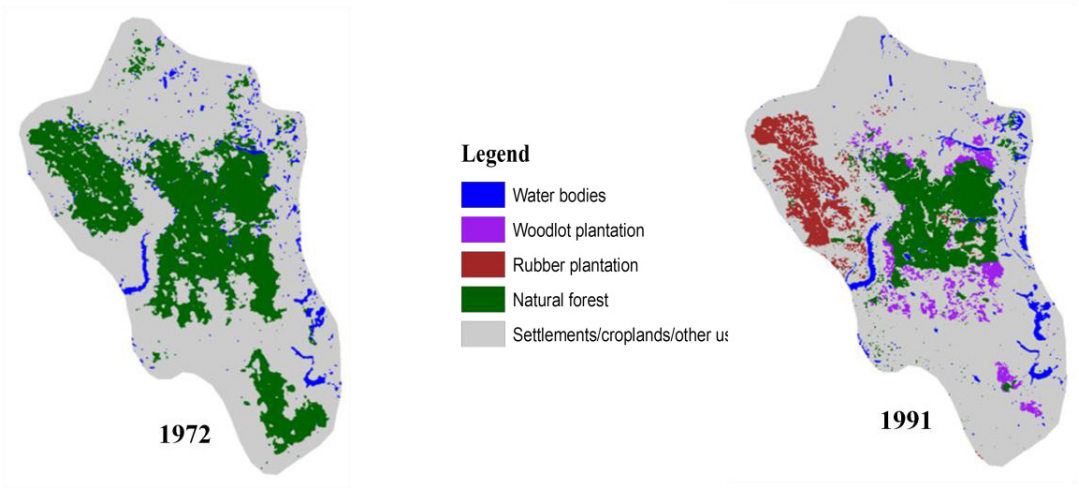

Figure 7. Land use maps of 1972 and 1991 of Madhupur Sal forest area

Figure 7 showing land use classes occupied area in 1972 and 1991. The forest cover occupied 9,840.3 ha in 1972, dramatically declined to 4,168.4 ha in 1991. There was no rubber and woodlot plantations in 1972 but appeared in 1991 at 2201.1 ha and 1435.8 ha, respectively. Water body extent increased slowly from 1972 to 1991 and reached at 1211.9 ha in 1991. Settlements/croplands/other uses occupied 20267.5 ha in 1972 and increased up to 1991 at 22205.6 ha. The absolute and relative changes in land use classes from 1972 to 1991are summarized in Table 5.

3.2.4 Land use changes between 1991 and 2010

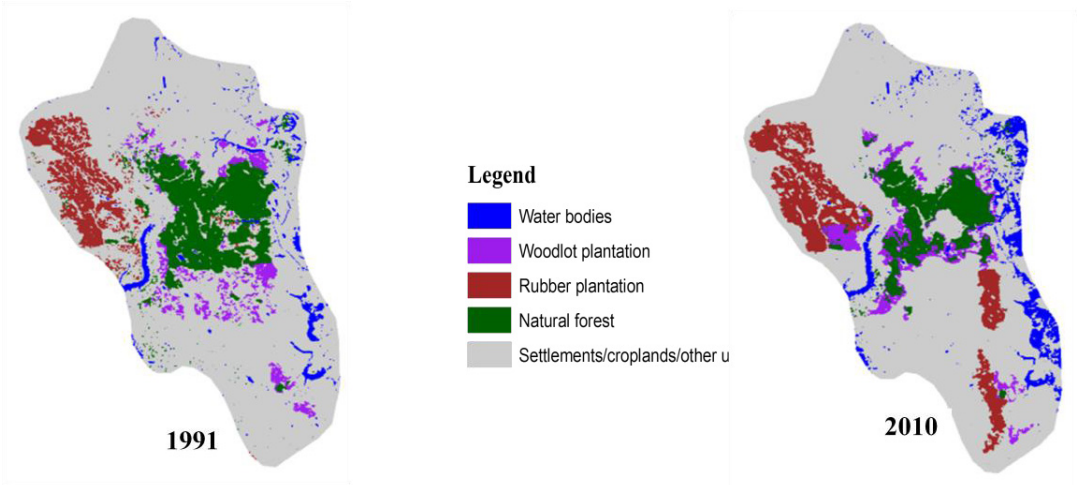

Figure 8. Land use maps of 1991 and 2010 of Madhupur Sal forest area

Figure 8 showing land use classes hold area in 1991 and 2010. The forest cover decreased slowly from 1991 and reached at 2760.9 ha at 2010. Rubber and woodlot plantations increased from 1991, and reached at 2924.4 ha and 1519.0 ha in 2010, respectively. Water bodies increased radically from 1991 and reached at peak in 2010 at 2146.9 ha. On the other hand, settlements/croplands/other uses reached at 21871.4 ha by slowly decreasing from 1991. Table 5 summarizes absolute changes in the land use area from 1991 to 2010 through the study period.

3.2.5 Land use changes between 2010 and 2014

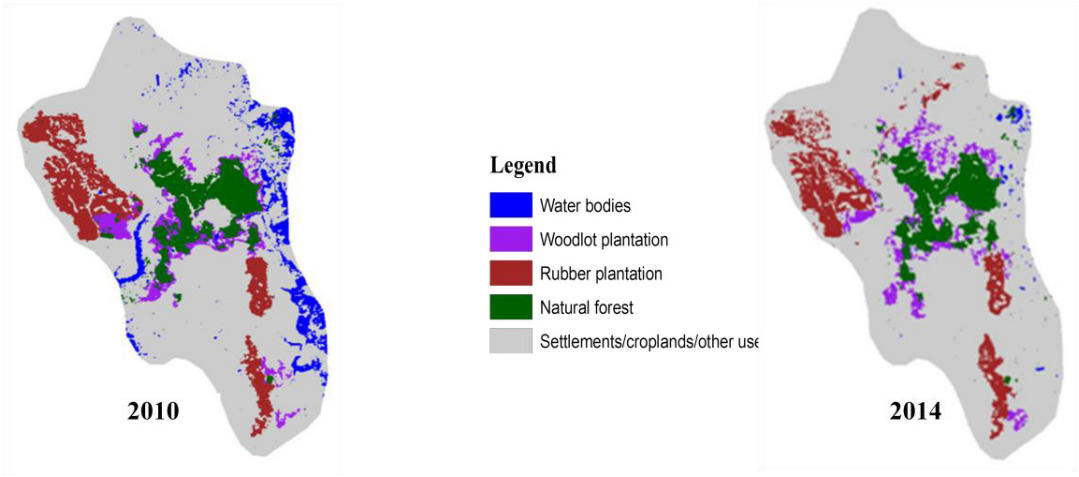

Figure 9. Land use maps of 2010 and 2014 of Madhupur Sal forest area

Figure 9 showing land use classes engaged area in 2010 and 2014. The forest cover finally increased from 2010 and reached at 2963.3 ha in 2014. The rubber plantation was maximum in 2010 at 2924.4 ha but decreased in 2014 at 2778.3 ha. There was an increasing trend in woodlot plantations. The plantations appeared at peak in 2014 at 1537.3 ha. Water body extent was peak in 2010 at 2146.9 ha but decreased dramatically in 2014 at 259.1 ha. The settlements/croplands/other uses increased from 2010 and finally reached at peak of 23,684.6 ha in 2014. Details of areal expansion of these land use categories between 2010 and 2014 are listed in Table 5.

3.2.6 Forest-cover change

The land-use change statistics for the study area are depicted in Figure 10. Natural forest cover decreased by 18.2% from 1972 to 1991 and by 4.5% from 1991 to 2010, but increased by 0.7% from 2010 to 2014. The absolute and relative changes in natural forest area are summarized in Table 5. In total, 6,877 ha of natural forest cover were lost to other land uses through the study period.

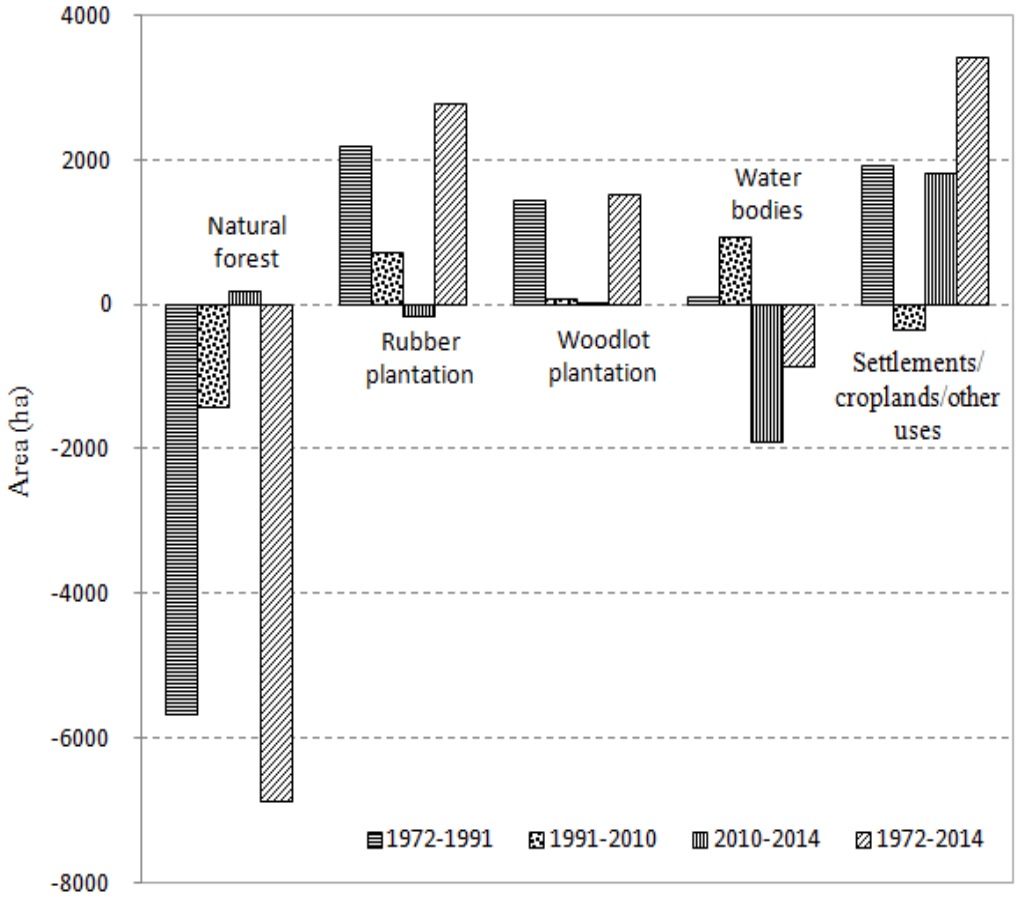

Figure 10. Land-use change in the periods 1972–1991, 1991–2010, 2010–2014, and 1972–2014

3.2.7 Rubber and woodlot plantation areal changes

The trends in areal occupancy by rubber and woodlot plantations were the reverse of those for natural forest cover. Rubber plantations occurred in the northwestern and southern sectors of the natural forest. Woodlots were located around and within the natural forest. Table 5 summarizes absolute changes in the area occupied by rubber plantations and woodlots through the study period.

3.2.8 Water bodies and settlements/croplands/other uses categories

Most of the water bodies were located in the eastern and western sectors of the natural forest. Their areal extent increased slowly from 1972 to 1991 and more rapidly between 1991 and 2010. Water body area decreased dramatically in 2014 as the areas of natural forest, woodlot plantation, and settlements/croplands/other uses increased. The areas occupied by the settlements/croplands/other uses category were distributed around and within natural forest. Details of areal expansion of this land use category are listed in Table 5.

3.3 Discussions

3.3.1 Trend in forest covers changes

The destruction of natural Sal forest began at the periphery of the stand and moved inward over time. The spatial distribution of damage was variable, with most occurring in northern, northwestern, and southern sectors of the forest. The northwestern sector was clear-cut, and most of the logged tract was converted to a rubber plantation in the period 1972–1991 (Figure 6b). A heavily deforested area in the southern sector was used as woodlot plantation and possibly for other purposes in the period 1972–1991. Between 1991 and 2010, this area was logged over for rubber tree planting. Commercial monoculture rubber planting was introduced in the Madhupur Sal forest area in 1985 (Gain, 1998). Additional extensive damage was caused in and around the natural forest, likely through human population growth, establishment of settlements, firewood shortages, domestic consumption, poor forest management policies, local-level corruption, land encroachment, illegal felling, conversion of forest land for industrialization, and commercial crop cultivation. Islam and Sato (2012) showed that illegal logging and forest land conversion were the ultimate causes of losses in the Sal forests of Bangladesh. They also indicated that illegal logging is a complex phenomenon promoted by local syndicates; they demonstrated that land conversion to diverse commercial activities directly influenced national policies and prevailing attitudes in the country. Settlements, road networks, and other infrastructure for the burgeoning population in the area had negative impacts on the forest and its wildlife, while continually degrading forest resources. Over the past 20 years, both the human population in the area adjacent to

the park and the number of illegal houses inside the forest have doubled; most of the people in this increasing population depend on the forest for their livelihoods (Islam and Sato, 2012). The Forest Department has identified at least 5000 households in the Madhupur Sal forest area (GOB, 2010). Some of the department's personnel and a few members of the local elite are indirectly responsible for illegal logging in the Sal forests. Corruption in the department has strongly promoted forest conversion (Gain, 2002). Ineffectual and bureaucratic forest management approaches have had immense negative impacts on most state forests in Bangladesh (Ahmed, 2008). The market demand for timber in the overpopulated nation is among the causes contributing to the depletion of forest resources, including losses to illegal logging. People with inadequate incomes covet the wooden furniture seen in television images or in furniture company advertisements (Ahmed, 2008). Additionally, the live firing range of the Bangladesh Air Force (BFA) occupied a significant area (405 ha) after clear cutting began from the southern perimeter of natural forest, causing losses of canopy cover (Gain, 2005).

To reduce the pressure exerted by local forest-dependent people on the natural forests and to improve the general understanding of forest resource conservation, Bangladesh has introduced a number of forestry management approaches, including agro-forestry plantations, social or participatory forestry, woodlot plantations, Sal coppice management, and buffer zone management. These approaches may have reduced the rate of deforestation in this area after 1991. Participatory, people-oriented forestry activities have operated in the Tangail forest area since 1987 (Muhammed et al., 2008). The woodlot plantation and agro-forestry programs have operated

satisfactorily, but the Sal coppice and buffer zone management efforts were total failures (GOB, 2010), and the areas set aside for these projects were occupied by members of the local elite for commercial agriculture enterprises.

Forest cover increased markedly from 2010 through 2014. This is the most optimistic finding of our study. Zaman and Katoh (2011) reported significant increases in forest cover in areas protected by local governments and private owners. They also observed conversion of some croplands into closed forest and open forest tracts in the Thakurgaon forest, located in northern Bangladesh.

A co-management procedure was introduced after 2009 for reforestation by rehabilitation of forest-dependent local and ethnic communities. Conservation measures included the provision of guards, a participatory plantation program in the encroached forest land, and a program to encourage forest-dependent people to seek alternative sources of income. The reductions in external pressures probably promoted natural regeneration on the forest floor, which increased canopy cover. Bangladesh government is committed to increase overall forest cover under many forestry management programs which funded by developed countries. In Madhupur Sal forest, the participatory plantation of adjacent and inside encroached land may be added to the natural forest canopy, which also increased overall tree cover. These are the most likely explanations for increases in forest coverage between 2010 and 2014, postulates that are supported by current literature. Revegetation activities have proceeded apace, even as authorities have ignored many of the illegal activities of forest-dependent people and protected their encroachments; despite this inconsistency, the net effect has been a significant improvement in the vegetation (Islam et al., 2013).

3.3.2 Trends in rubber and woodlot plantations

No rubber or woodlot plantations operated in the Madhupur Sal forest area in 1972. These enterprises began in the 1980s (Figure 6). Rubber production is an important land-use issue because large tracts of land have been converted from their original natural forest state. At the initiative of the Bangladesh Forest Industries Development Corporation (BFICD), the area under rubber trees increased between 1991 and 2010. Between 2010 and 2014, this area decreased (Table 5), perhaps through encroachment by local people who converted plantations to cropland, mismanagement by authorities charged with plantation protection, or natural calamities. BFIDC (2014) reported that rubber plantations were created in the Madhupur Sal forest in the periods 1987–1989 (2,138.4 ha) and 2001–2002 (1,072.4 ha). Woodlot plantations were established within and around degraded and denuded forest land under the auspices of a reforestation program. This program, which represented an important participatory activity involving local people, was initiated by the Bangladesh Forest Department in 1989 to reduce the anthropogenic pressure on natural forests exerted by the collection of fuel wood, timber, and other resources. GOB (2010) reported that the woodlot plantation enterprise is a dominant operating program among the different participatory management approaches in the Madhupur Sal forest area. Plantation production is a continuous process involving logging and replanting. Spatial and temporal variation in these activities causes variability in the area of land under woodlot cover.

3.3.3 Trends in water body and settlements/croplands/other use categories

The area under water bodies increased slowly through 1991 and then more

rapidly until 2010. These changes resulted from continued encroachment into the natural forest. A number of brick kilns built through this period were fired with illegally cut trees. Clay from nearby land was consumed in brick making, and the excavation process may have reduced the topographic elevation. The low-lying tracts contained large volumes of seasonal water in the late rainy and early winter seasons of 2010. On the other hand, as agriculture based country, rice is the major crop in Bangladesh. The only season of high yielding rice production is winter and it starts in January-February. Lot of water as flood irrigation is needed for rice field preparation. Probably, the irrigation water increased the total water volume in 2010.

Over the entire study period, lands in the settlements/croplands/other use category occupied the largest area within the park and continued growing through the time span of the study as the natural forest decreased. The area under seasonal water decreased after 2010, leaving open land, whose area peaked in 2014

3.3.4 Shortcomings

The settlements/croplands/other uses and woodlot plantation categories may have been confused in the analysis due to the plantation patterns. A typical rural settlement consisted of native and exotic tree plantations known as homestead gardens. In some cases, the homestead garden may have been classified as woodlot plantations. The areas of water bodies may have been overestimated due to mixed pixel effects. The extent of marshland varied among seasons depending on the water regime in the area. Furthermore, the minimum mapping unit size that we used precluded the detection of small changes.

3.4 Conclusions

Forest-cover change through deforestation is a major environmental problem in the Bangladeshi Madhupur Sal forest. In this study, we tracked the recent history of forest cover change in the region. Five classes of land use were extracted from satellite images of the park. The extent of forest cover changed markedly between 1972 and 2014, with radical decreases from 1972 to 2010. The areas of forested lands declined by 5,672.0 ha in the period 1972–1991; they fell by 1,407.4 ha in the period 1991–2010. We observed expansions of rubber plantations, woodlot plantations, agricultural lands, and areas in the settlements/croplands/other use category as the forest cover declined. Across the whole area, 9,840.3 ha of land were covered with forest in 1972, but this value declined to 2,760.9 ha in 2010. This decrease resulted from anthropogenic changes in the study area, but we did not investigate the activities that led to these changes. Forest coverage dramatically increased from 2010 to 2014, reaching 2,963.3 ha. This increase resulted from co-management practice procedures operated jointly by the Bangladesh Forest Department and local forest-dependent ethnic and non-ethnic peoples.

Therefore, to prevent further destruction of forest resources:

- Local people should be encouraged to plant fast-growing trees within their farm boundaries, on their homesteads, and on degraded lands instead of cutting trees in the existing forest.
- Forest-cover monitoring is required to alert authorities to forest changes; forest maps should be well organized and accurate in location and extent.

- Awareness of the forest conservation system should be promoted among local people by the authorities to support the regeneration of the Sal forest.

Most importantly, it is necessary to find out, why and how the forest cover increased from 2010 to 2014. The co-management forestry project should be investigated, so that, its success might be a model for Bangladesh's forestry sector. On the other hand, the results might have potential implications for the broader context of forest management in Bangladesh and other developing countries.

Chapter 4: Perceptions of Local People toward Community Development and Forest Conservation

4.1 Methodology

4.1.1 Project description

The project, called the Bangladesh Climate Change Trust, was started in the Madhupur Sal Forest area in June 2010 (FD, 2012). It was implemented with an integrated and holistic approach, under direct supervision of the local forest office of the Madhupur Forest Range. The project was initially launched for 3 years, but was extended for another 2 years, ending in June 2015.

The project has involved forest resource users, ethnic communities, Bengali communities and different organizations acting together to develop conservation and social development activities for sustainable forest management. The local forest office identified a total of 700 forest-dependent individuals from the Madhupur forest area, and trained them in different income-generating initiatives. Among the participants, 500 illegal loggers were listed, according to the records of FD offenses, and another 200 poor forest dependents (income less than 1 US dollar/day/person) were selected for training. The participants received 2 months of intensive training. The training included growing trees in nurseries and reforestation, mushroom cultivation, medicinal plant cultivation, fisheries, poultry rearing, cattle fattening, apiculture, pisiculture, vegetable gardening, compost preparation, jam and jelly production, forest fire protection, and motivation to change attitudes. During the training period, every participant was given 4500 Taka (78 Taka = 1 US dollar) per month as a training allowance. The trainers were also given uniforms, identity cards,

and training materials. Trainers included public representatives, political leaders, journalists, government officials, NGO representatives, and academicians. After being trained, the participants were treated as CFWs, participating in the development of activities and helping the forest guard to protect the forests.

All CFWs received a 15-day refresher training organized by the FD 3 months after the main training. Every CFW received 800 Taka per month as a wage after the training. Each forest range office was responsible for monitoring the activities of the CFWs. Under each range, there was a representative committee of CFWs nominated by the general CFWs. All CFWs met monthly in the Madhupur forest office.

In addition, another 5500 families dependent on the forest were selected. These families, together with 700 CFWs, received incentives totaling 11,000 Taka. The families planted 200 saplings, including 50 fruit trees, 50 timber trees, and 100 fuel wood species, to gradually reduce dependence on forests and secure their livelihoods. The project also rejuvenated forests that were disturbed and/or depleted by other locals. During the project period, 1000 ha of degraded forest was replanted, mostly with native tree species in different forest beats.

4.1.2 Questionnaire and data collection

A survey was conducted during January and February 2016 among the CFWs of the forestry project. Before the data collection a discussion was carried out with the FD officials, members of management committee and local leaders. An experienced middle aged person of the local community was selected who worked with the research team (headed by the first author) during the survey. The flow chart in Figure 11 provides an overview of the data collection methods. A structured questionnaire

was used for household survey. The questionnaire was prepared in English and translated into the Bangla language in order to make understandable to both enumerator and respondents. Both quantitative and qualitative data were collected. Before conducting the survey, the questionnaire was pre-tested for reliability of information from the field. Reliability of the questionnaire using a pilot test was carried out on 30 participants. We got similar results when repeated our questionnaire soon. The questionnaire was designed to gather information on socioeconomic, demographic, cultural variables, and their perceptions on forest conservation. The sample population was selected from 12 villages in the area, consisting of 186 males and 14 females of various ages (20–75 years old). The participants responded to the questionnaire with the help of other family members, as necessary (Figure 12). In addition to the questionnaire, informal meetings were held in each household. A focus group discussion was arranged in each village to gain a more complete understanding of community perceptions and to cross-check the validity of the data recorded during the interviews.

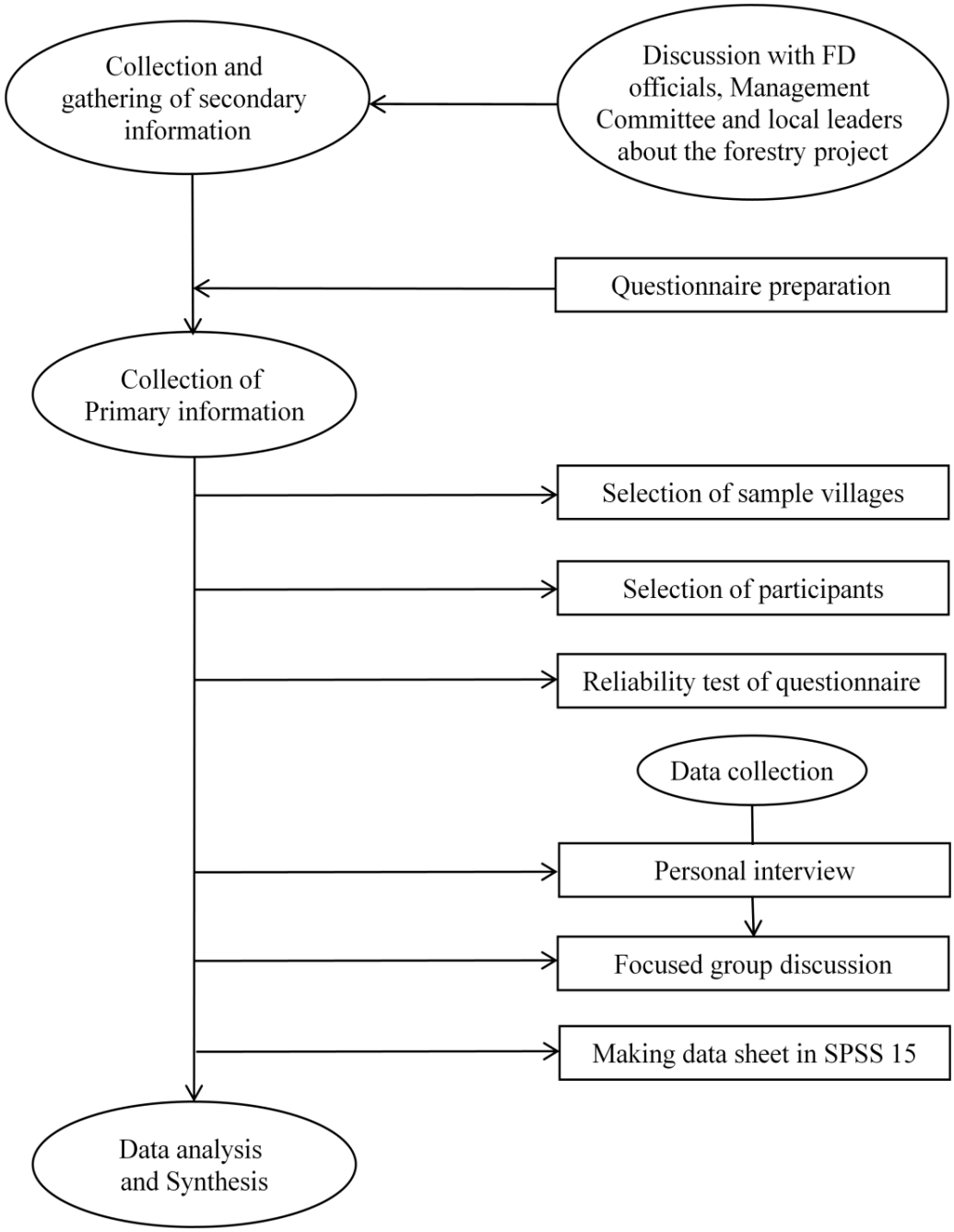

Figure 11. Flow chart depicting the data collection procedures used in the study

Figure 12. Interview with participants

4.1.3 Livelihood analysis

Livelihood is a complex concept and it is constantly discussed and reformulated, but the definition, mostly used by policy makers "livelihood comprises the capabilities, assets (including both materials and social resources) and activities required for a means of living" (Carney, 1998). Livelihoods were viewed in a sustainable livelihood framework, to analyze and understand the complexity of rural development and its balance with forest conservation. This is a tool that provides new ways to examine how, in different contexts; sustainable livelihoods are achieved through access to a range of livelihood capitals. We explored human, physical, financial, natural, and social livelihood capitals The framework is useful for explaining the inter-relationships among various livelihood capitals and their utilization in diversifying livelihood strategies to attain desired outcomes (e.g. increased income and stable natural resource base) in the available enabling environment (Nath and Inoue, 2010). Quantitative data were analyzed using SPSS 15.

4.2 Results

4.2.1 Demographic characteristics

The characteristics of participants are listed in Table 7. Briefly, the average age of respondents was 44 years, and most were middle-aged. There were similar numbers of ethnic and non-ethnic respondents, and 97.5% of participants were married. The literacy rate was 51%. The average family size was 4.64, slightly above the national average of 4.50 (BBS, 2011). The average farm size was 0.59 ha, lower than the national average of 0.67 ha Krishi Dairy, 2012). The religion of all ethnic respondents was Christianity, whereas the majority of non-ethnic respondents (97%) were Islamic. Before the forestry program was started, the main source of income was illegal tree harvesting (80.5%); after the program, the major occupation was farming (65%).

Table 7. Distribution of participants according to demographic characteristics (n=200)

Variables	Frequency	Percentages (%)
Gender		
Male	184	92
Female	16	8
Ethnicity		
Banglee (Non ethnic)	114	57
Garo (Ethnic)	86	43
Age (Year)		
(Young age) up to 30	70	35
(Middle age) 31-50	89	44.5
(Old age) > 50	41	20.5
Marital status		
Married	195	97.5
Unmarried	3	1.5
Widow	1	0.5
Widower	1	0.5
Distribution of respondents by religion		
Muslim	112	56.0
Hindu	3	1.5
Christian	85	42.5
Family Size (Member)		
Small (<5)	77	38.5
Medium (6-8)	106	53.0
Large (>8)	17	8.5
Education		
Illiterate (No schooling)	98	49.0
Primary (1-5)	57	28.5
Secondary (6 -10)	35	17.5
Higher secondary (college and university)	10	5.0
Farm size (Hectare)		
Landless (<0.02)	8	4.0
Marginal (0.02-0.2)	79	39.5
Small (0.2-1)	94	47.0
Medium (1-3	17	8.5
Large (>3)	-	-

4.2.2 Livelihood capital

We assessed multiple forms of livelihood capital, as detailed below.

4.2.3 Human capital

Human capital represents the skills, knowledge, health, and ability to pursue

different livelihood strategies and achieve objectives (Roberts and Yang, 2003). To enhance knowledge and skills related to community development and forest management, the FD conducted 2 months of intensive training (requiring 15% of the project budget) (FD 2012). Such training can improve human capital, leading to improved household income (Islam *et al*. 2010). After the training, 15 days of refresher courses were arranged for all of the participants. To understand the skills and improvement of the areas of the training program, we evaluated participant's skills according to five areas of training programs. We found that 96% of the participants able to explain in the area of vegetable gardening training program, compared to 85%, 83%, 78%, and 74% in areas of nursery raising, Cattle fattening, Compost preparation, and Poultry rearing, respectively (Table 8). The training programs helped to build strong networks, enabling participants to work together as a team. In addition, illiterate participants were given more attention during the training sessions. All participants reported enhanced skills after the program.

Table 8. Assessing participants' performance on major training programs

Area of Training	Key objectives	Participant capable of explanation (%)	Skill evaluation
Nursery raising	Nursery establishment, rising income	85	Very good
Vegetable gardening	Meet household demand, additional income	96	Excellent
Compost preparation	Soil health improvement, additional income	78	Good
Poultry rearing	improve their own nutrition, rising income	74	Good
Cattle fattening	Technology adaptation, fast income	83	Very good

4.2.4 Physical capital

Physical capital comprises the basic infrastructure and goods required to

support a livelihood (Jonathan, 2000). All project participants received incentive money to improve house and developed their household with guidance from project staff (Table 9).

Housing is obviously an important family asset. Prior to the project, participants owned mud houses with tin roofing (75%), houses with bamboo-matt walls and tin or straw roofs (22%), or brick houses with tin roofs (3%). After the program, the proportions of each type of housing were 77%, 18.5%, and 4.5%, respectively. Houses consisted of 3–4 rooms, compared to 2–3 rooms before the project. In addition, 47.5% of participants had tube wells and 36% had toilets before the project, whereas 98.5% and 87.5%, respectively, had these basic utilities after the program.

Prior to the project, most participants (91.5%) possessed various livestock, including cows, buffalos, goats, pigs, chickens, and ducks. Every participant bought a cow, goat, or pig after receiving the project incentive of Taka 5000. Approximately 75% of the participants raised poultry (chicken and duck) after the project, which was 13% higher than prior to the project. Participants also tended to raise more cows but fewer goats, pigs, and buffalos after the project.

Use of expensive appliances (e.g., TV, CD player, motor bike, power tiller, irrigation pump) increased among the participants after joining the program. Moreover, 32% and 35% of the participants used solar panel power and electricity, respectively, whereas only 12% of the participants used electricity before the program.

Table 9. Incentive provided by the project to the participants and forest dependent local people

Taka (money) (73 Taka = 1 dallar)	Purpose
3000.00	House infrastructure improvement
5000.00	Buying ruminant (eg. Cow, goat, pig)
1000.00	200 seedlings planting in household premises
1000.00	Vegetable cultivation
1000.00	Compost preparation
Free	Eco-friendly burner (one per family)
Total = 11000.00 Taka	

4.2.5 Natural capital

Natural capital is the term used for natural resource stocks from which resource flow and services that are useful for livelihoods are derived (Goldman, 2000). Land is important natural capital and the participants were categorized as either landless (<0.02 ha), or having marginal (0.02–0.2 ha), small (0.2–1 ha), medium (1–3 ha), or large (>3 ha) holdings (DAE, 1999). Land provided by the FD for community forestry was not included in the measurement of each participant's holdings. The majority of respondents were marginal (44.7%) to small farm holders (47%). There were no large farm holder.

The land provided for community forestry (mentioned above) was a 1 ha plot given to each participant and on which they were allowed to practice agro-forestry by planting local timber, fuel wood, fodder, and fruit species. Agro-forestry systems offer multiple alternatives and opportunities for farmers, with a view to improve farm production and income, and also provide productive and protective functions for the ecosystems (Sharma et al. 2007). Moreover, participants planted about 1,100,000 tree

species (fruit, timber, and firewood species) on homestead premises.

Most participants (65%) who engaged in agriculture reported that they planted high-yielding crops. Only a few (8.5%) of the households reported collecting non-wood forest products (NWFPs) from the forest to supplement their livelihoods. The intensity of NWFP collection was highest among very poor people living in the forest.

Finally, 96% of informants reported that they had stopped illegal cutting after the program. Changes in energy use, shifting from forest products to alternative fuel sources, were reported by 91.5% of the participants. More specifically, all of the participants started using improved stoves provided by the project, and 63% of the participants stated that the stoves saved 30–40% fuel compared to traditional stoves (Table 10).

Table 10. Fuel saved by using improved stove

Fuel saving category (%)	Participants' opinion	
	Frequency	Percent
10-20	15	7.5
21-30	47	23.5
31-40	57	28.5
41-50	77	38.5
>50	4	2.0

4.2.6 Financial capital

Financial capital represents the monetary resources that people use to achieve livelihood objectives (Lasse, 2001). Financial capital includes two main sources: available stock (e.g., savings, cash, liquid assets) and regular flow of money (e.g., wages, pension, sale of agriculture products). A remarkable change in the respondents' primary means of securing a livelihood was noticed in the community.

Before joining the project, illegal tree cutting was the primary source of income for 80.5% of the participants, followed by farming (10.5%), and forest product collection (5.0%). After initiating co-management activities, the majority of participants (65%) reported farming (crop cultivation, vegetable gardening, fruit cultivation, etc.) as their primary source of income/livelihood (Table 11). Illegal cutting and selling of trees was another livelihood that almost stopped during the project period, being replaced with alternative livelihoods.

The project supplied wages to the participants to guard the forest and sale of trained participant's (16.5%) labor to agriculture and commercial farms to sustain their livelihood. In some cases, such as family financial crisis, participants were forced to sell their trees, cattle, and goats for money. A remarkable number of participants (71.5%) received loans from NGOs, relatives, neighbors, or local banks for crop cultivation, livestock rearing, small businesses, and other purposes. An increase in the average monthly income was observed in the community. The lowest-income group was reduced from 35.8% before the project to 19.4% after it (Figure 8).

Table 11. Changing pattern in the participants' occupation for sustainable livelihoods in the study area

Period	Occupations	Relative frequency (%)
Before joining the project	Illegal wood cutting	80.5
	Agriculture farming	10.5
	Forest product collection	5.0
	Day labor	2.5
	Others	1.5
After joining the project	Agriculture farming	65.0
	Day labor (agric. and non agric.)	16.5
	Small Business	7.0
	Poultry Rearing	5.0
	Livestock rearing	3.5
	Others	3.0

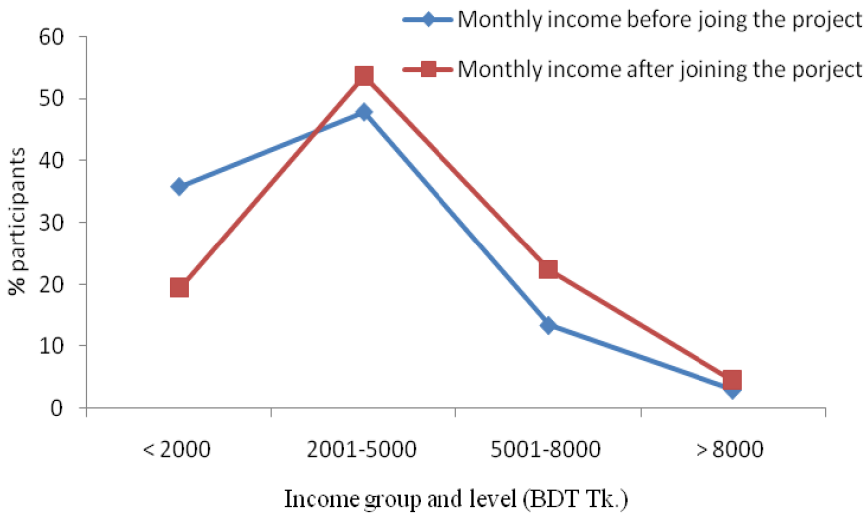

Figure 13. Comparative monthly income of participants before and after joining the project

4.2.7 Social capital

There is much debate about what exactly is meant by the term *social capital* (DFID, 1999). Social capital refers to the social resources that people draw on to make a living, including relationships with more powerful people (vertical connections) and others such as themselves (horizontal connections), as well as memberships to groups or organizations. We analyzed relationships between participants and FD staff as well as the general community (Table 12). Among participants, 40.5% indicated that they felt that they had good relations with FD staff; only 1% indicated that they did not. In addition, 48.5% and 54.0% of the participants felt that they received more respect after the program from FD staff and from their family members, respectively. About 49.5% of the participants reported that, since joining the project, they received more invitations to social ceremonies such as weddings, religious activities, and other social events. The same percentage reported

receiving more help from neighbors during emergencies.

Female participants were asked three specific questions: Has there been a reduction in discrimination by others when you go outside the home? Has there been a reduction in abuse by your husband? Has there been a reduction in demand for dowry by your husband or husband's family? A remarkable reduction was reported for all three situations.

Table 12. Improvement of Participants in term of social parameters in the study area

Parameters	Participants' opinion (%)				
	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Do you feel good relations with FD staffs?	40.5	37.5	11.5	9.5	1.0
Do you feel more respected by the FD staffs?	48.5	37.5	12.0	2.0	-
Do you feel more respected by the family members?	54.0	38.0	6.0	2.0	-
Do you get more invitations to social ceremonies?	53.5	35.0	8.0	3.5	-
Do you get more help from neighbors in emergency?	49.5	32.0	15.0	2.5	1.0
Do you think that you have gathered knowledge?	50.5	35.0	12.5	2.0	-
Do you think that your skill has been developed?	46.5	30.5	15.0	8.0	-
Do you take decision in consultation with spouse or family members?	36.0	42.0	15.5	6.5	-

4.2.8 Forest conservation

Forest conservation refers to the successful protection, improvement, and/or creation of specific forests and/or specific forest functions and services (Sunderlin et al. 2005). Forest conservation can provide the motivation to protect, improve, and/or create functions and services that benefit people living in or near a given forest or far

from them. In this study, participants were highly inspired in response to the training program that focused on conserving Sal forest. They guarded the forest rotationally to protect anthropogenic intervention (Figure 14).

Figure 14. Forest patrolling by CFWs

The FD initiated a revegetation project as part of their program. The FD included 1000 ha of encroached forest land, to be planted with local tree species of timber, fruit, fodder, and so on (Figure 15; Table 13). The participants would received 45% of the income generated from the project for 10 years (the FD would also receive 45% and the remaining 10% would go toward future tree farm management funds). To reduce dependency on forests for fuel wood, timber, and other resources, the project supplied 200 tree species (e.g., timber, firewood and fruit species) to every participant and 5500 forest-dependent families. They planted these trees in their homestead premises (Figure16). The study observed that about 52.5% trees have survived after 5 years in their homestead premises, when the participants started benefiting. Most of the participants collected firewood, either from their homestead or market, rather than from the forest.

Figure 15. Re-vegetation with native tree species in degraded forest land

Table 13. Re-vegetation scheme of Madhupur Sal Forest area

Year	Species	Area (ha)	Tree Number	Name of tree species
1st	Native timber, fuel wood and fruit species	150	375000	Black Berry (*Sytzygium cumini*), Bohera (*Terminalia belerica*),
	Native fodder species	10	16000	Chickrosi (*Chukrassia tabularis*),
2nd	Native timber, fuel wood and fruit species	600	1500000	Dhakijam (*Syzygium grande*), Gamar (*Gmelina arborea*),
3rd	Native timber, fuel wood and fruit species	250	625000	Garjan (*Dipterocarpus turbinatus*), Jackfruit (*Artocarpus heterophyllus*),
	Native fodder species	10	16000	Kadom (*Neolamarckia cadamba*),
1st & 2nd	Local fruit, timber and fuel wood species to every rehabilitee family	Homestead	1100000	Mahogani (*Swietenia macrophylla*), Neem (*Azadirachta indica*), Sal (*Shorea robusta*), Star Apple (*Syzygium samarengense*)

Figure 16. Tree plantation in participant's homestead premises

The real causes of destruction of Madhupur forest have not been rightly diagnosed in the past. Only those who felled trees in the forest have been blamed for the forest destruction. Huge cases have been filed in court against them. The new policy has been able to lessen the gap between local ethnic and non ethnic community and build up confidence. Positive attitude has been developed among people of Madhupur. As a result, forest offenses such as illegal logging, land encroachment and other illegal activities were gradually reduced during the project period. In 2008–2009 and 2009–2010, there were 361 and 376 offenses, respectively. In 2010–2011, there were only 23. There were no offenses in 2011–2012, 2012–2013, or 2013–2014 (Figure 17). Forest disturbances by anthropogenic activities had decreased due to decrease in forest offences, cattle grazing, and forest product collection. The absence of anthropogenic disturbances has had an important impact on the natural regeneration of the forest floor. A number of young tree species of timber, fruit, medicinal, shrub, climber etc. were found naturally regenerated in the forest floor opined by participants (Table 14). In addition, they also put their opinion about wildlife increases (Table 15). More than 50% participants were agreed with raises of deer, cock and monkey in compare with the period of program launched.

Finally, we asked participants about their willingness to extend the project. All respondents expressed a firm intention to continue with the project. When asked why, most cited economic benefits and protection of the forest, and very few did not respond.

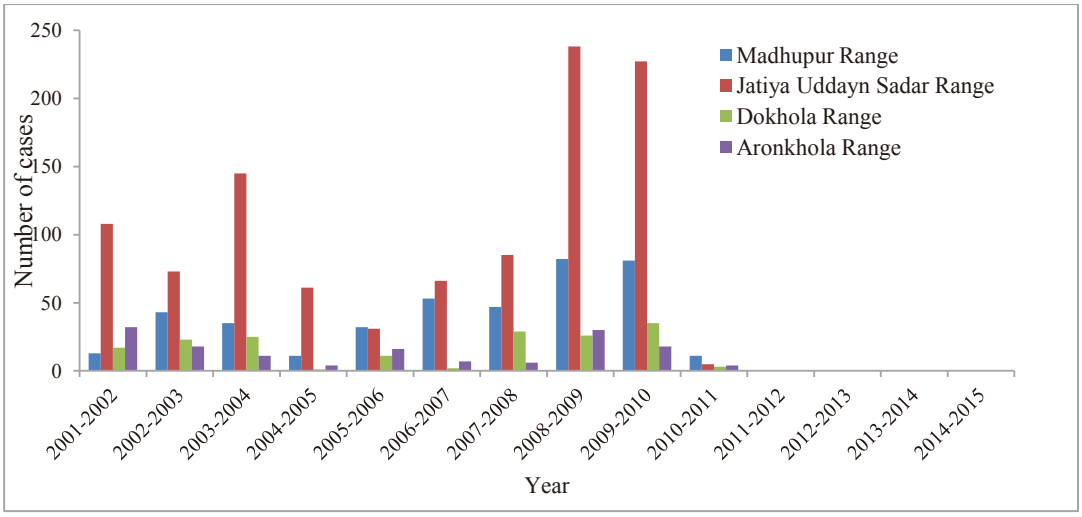

Figure 17. Trend of offences in Madhupur Sal forest over time (Source: FD, 2016)

Table 14. Tree species naturally regenerated in forest floor opined by participants

Unit	Frequency	Percent
Timber Trees		
Sal (*Shorea robusta*)	98	49.0
Gandhi gajari (*Miliusa velutina*)	78	39.0
Koroi (*Albigia procera*)	62	31.0
Ajuli (*Dillenia pentagyna*)	42	21.0
Shida (*Lagerstroemia parvifloraRoxb*)	29	14.5
Kaika (*Adima cordifolia*)	17	8.5
Shiris (*Albiria sp.*)	16	8.0
Segun (*Tectona grandis)*	15	7.5
Giza (*Odina Older*)	12	6.0
Others (Jarul, Arjun, Bot, Sonalu etc.)	34	17.0
Fruit trees		
Black berry (*Syzygium cumini*)	143	71.5
Anaigota (*Ziziphus rugosa*)	104	52.0
Ban Alu (*Dioscorea bulbifera*)	48	24.0
Pahari banana (*Musa textilis*)	32	16.0
Neor (*Bursera serrata*)	27	13.5
Jaina (*Schleichera oleosa*)	42	21.0
Medicinal Plants		
Amloki (*Phyllanthus emblica*)	108	54.0
Bohera (*Tenninalia arjuna*)	103	51.5
Haritaki (*Terminalia belerica*)	53	26.5
Undergrowth and climbers		
Bet (*Calamus spp.*)	18	9.0
Monkata (*Randia dumentorum*)	15	7.5

Table 15. Increased wildlife's availability in the forest opined by participants

Unit	Frequency	Percent
Deer	165	82.5
Cock	155	77.5
Monkey	116	58.0
Birds	96	48.0
Mukhpora Hanuman	51	25.1
Pig	42	21.0
Snake	38	17.0
Cat	29	14.5
Porcupine	27	13.5
Fox	23	11.5
Rabbit	21	10.5

4.3 Discussions

The present study attempted to highlight protecting forests, sharing resource management and ensuring secure livelihoods for those dependent on forest through a forestry project. Participation in this project "Revegetation of Madhupur Forest through Rehabilitation of Forest-Dependent Local and Ethnic Communities," had a positive influence on livelihood development and forestry management. The development program was built around a vision for human empowerment, advancement, and welfare, with the fullest range of available natural resources being available (Mbie et al 2005). Our results revealed the existence of strong relationships among FD staff and participants, despite the fact that most participants were illegal loggers before the project was initiated.

The participants knew each other quite well and a strong, collaborative attitude was built among them. Previously, most of the participants were dependent on the forest for their livelihoods. They earned subsistence money, either by engaging in illegal logging activities or collecting forest products, thus accelerating forest degradation. After starting the project, however, they stopped stealing timber from the forests and became crop producers or engaged in other income-generating activities.

The success of the FD program involved people radically departing from their roles of tree destroyers to forest protectors. They benefited from their participation in the project, which discouraged them from further involvement in activities destructive to the forest and encouraged them to engage in the conservation process. The intensive training and motivation, as well as the monetary incentives, changed the

attitudes of the community.

Ezebilo (2011) reported that local people residing in the vicinity of the Cross River National Park in Nigeria highly preferred collaborative management of local resources that combined biodiversity, conservation, and community development. Islam et al. (2013) reported that a rehabilitation project for Sal forest dependents in Bangladesh resulted in a high participation rate among encroachers and forest dependents, resulting in capacity building, social relationship development, and the use of natural assets and human capital through alternative livelihood strategies that have provided security and improved livelihoods. According to Yadav et al. 2003, natural resources in most regions of Nepal deteriorated before the introduction of community forestry, but the forests improved where community forestry was well-established.

4.3.1 Shortcomings

In the present study, we also observed some shortcomings of the project. For example, the FD made most decisions regarding project implementation; hence, while participants were empowered by the project they were not in control of most aspects. Most of the participants were fallen in forest offence cases before starting the project. Their request of cases dismissal was not possible due to bureaucratic problems. Regular attendances to court lose their money and time, and sometimes faced in awkward situation in the community which has partially hampered their daily duty of forest patrolling. We also found that while participants protected the forest, some owners of saw mill and brick field tried to influence them and created pressure to cut trees illegally. Finally, after the project concluded, and wages and incentives from the

FD were terminated, the participants again considered pursuing illegal logging.

4.3.2 Improved human capital

The development of human capital improved the capability of individuals to secure their well-being. In this study, human capital included training, as well as refresher courses. Specialized training was also built on awareness of these issues in the community. Training could enhance skills, which might have a significant impact on the participants' attitudes, as well as on forest conservation (Islam et al. 2012). Moreover, acquired skills and knowledge affect social capital, such as building relationships and encouraging self-sufficiency within participating groups.

An important finding from this study was the change in attitude of the FD staff toward the participants and local people. Muhammad et al. (2008) claimed that, as for the implementing agency of any project, the staff included in his study played a role in the failure of the project. They did not seek active participation of genuinely poor people and other direct stakeholders in the forestry projects. Tole (2010) also mentioned that state officials entrusted with the design and implementation of co-management projects in many developing countries often have negative attitudes about community empowerment, which impedes the full realization of the project goals. This did not occur in our study.

4.3.3 Improved physical capital

Most participants improved their houses after being involved in the project. In a case study in Bangladesh, Islam and Sato (2012) found a similar trend for non-ethnic groups but ethnic participants showed negative attitudes after being involved in a participatory forestry program.

Animal husbandry is an important livelihood activity in the study area. Animals are reared for milk, manure, meat, and farming activities. All of the participants were given a ruminant from the project, but in general the average number of livestock decreased due to a lack of grazing land and shortage of fodder in the study area. A similar trend was reported by Islam and Sato (2012).

The participants had previously allowed open grazing of their livestock in the forest. After the project, open grazing was restricted and human entrance as well. Good communication and transportation is a prerequisite for community development. However, improvements to roads and other public goods were beyond the scope of this project. We did find that access to and use of some expensive appliances such as televisions, CD players, and solar panels increased among the participants after the project.

4.3.4 Improved natural capital

Natural capital was one of the main income sources for participants. Most participants produced crops that generated income. Moreover, agro-forestry practices in the participatory forestry plots provided additional income. Muhammad et al. (2008) also identified agro-forestry as being the most beneficial practice among different land-use patterns for public-oriented forestry in the Tangail Forest Division of Bangladesh.

Participants used their financial capital to cover household expenses and partially sustain their livelihoods. Livelihoods and natural resources are closely interrelated, where the decline of one puts additional pressure on the other (Rigg, 2006). Community forests are natural capital. Access to forest resources, particularly

firewood, was restricted. In the study area, wood was the main energy source for cooking. Before the project, the majority of participants were dependent on forests as a source of firewood. The project helped to minimize their firewood demand, by establishing homestead forestry, but some of the local poor people still depend on the forests for this resource.

4.3.5 Improved financial capital

Financial assets denote disposable income from various sources. Adequate financial resources help to overcome external risks. The major source of cash income of the participants was associated with farming. The trained participants worked on farms, which provided a good source of seasonal income. The participants received wages from the project as well, which provided regular income. Moreover, loans from different sources were obtained to support their livelihoods.

Participants spent their money on household items, appliances, and agricultural inputs. Some also invested in education and health care for their children. Hence, the extra financial capital helped to partially sustain their livelihoods. In the event of family crises, the sale of natural resources such as trees and livestock generated enough to meet their emergency financial needs. Therefore, the project helped to boost their financial capital, but their livelihoods depended on all types of capital.

4.3.6 Improved social capital

Social capital plays an important role in the management of natural resources and improvement of livelihoods, particularly in remote, rural areas (Nath and Inoue, 2010). The benefits of the creation of social capital depend on the participation of

households and individuals in local institutions and enhanced knowledge of rights and duties involved in securing a livelihood. Knowledge, skills, and motivation have a strong impact on social capital, which builds positive relationships and capabilities.

In our study, intensive training and CFW activities helped to create good social networks. Participants developed social relationships among themselves and with the project staff and neighbors. In the past, locals had not been satisfied with the FD or their own community. These relationships improved throughout the project. Muhammad et al. 2008 reported similar results.

The project also improved most participants' satisfaction with their annual diet, clothing, health care, education, and entertainment (Table 16).

Progress related to women's rights were also improved. In rural Bangladesh, women are usually deprived of their status and respect, both in the family and in society (Subhani, 2008), although it is generally recognized that women play an important role in resource management because of their knowledge, skills, and experience. In this study, officials encouraged women to actively participate in the project activities and this reduced mental and physical harassment and also improved their empowerment both in the family and in society. Subhani, 2008 also reported improvements in skills, knowledge, decision-making power, and respect in females who participated in co-management projects in Lawachara National Park, Bangladesh.

Table 16. Improvement of Participants in terms of household expenditure

Unit	Participants' opinion (%)							
	Before joining the project				After joining of the project			
	Highly Satisfied	Satisfied	Less satisfied	Not satisfied	Highly Satisfied	Satisfied	Less satisfied	Not satisfied
Food	-	34.3	65.7	-	11.9	83.6	4.5	-
Cloths	1.5	26.9	58.2	13.4	14.9	62.7	22.4	-
Health	-	13.4	79.1	7.5	11.9	71.6	16.4	-
Education	3.0	12.1	80.3	4.5	16.7	72.7	10.6	-
Amusement	-	7.6	59.1	33.3	9.1	36.4	42.4	12.1

4.3.7 Improved forest condition

The project reduced dependency on forest resources and thus improved the forest conservation and the socioeconomic development of the local communities. The community-based projects improved the living conditions of local residents, alleviated pressures on resources, and reduced conflicts between community members and forest managers (Blaint, 2006).

Sawhney et al. 2007 reported that participation in such projects improves when adequate incentives are offered and the roles of participants are clearly defined. The Sal project achieved these objectives, and both the community and the forest benefited.

Figure 18. Degraded forest land plantation (end of the project)

More specifically, incentives for livelihood improvement and inspirational development of various socio-cultural parameters of the community were the basis for sound forest management. The participants became highly motivated during training and were committed to conserving the forest. They attempted to resuscitate degraded forest (Figure 18) lands but also opposed human intervention to keep the forest undisturbed. This was achieved through protection (patrolling by CFWs) of forests from illegal tree felling, livestock grazing outside of the forest, and a reduction in the extraction of forest products. These reductions in external pressures probably promoted the natural regeneration of the forest floor, which increased canopy cover. The natural regeneration of vegetation is a dynamic process by which life recolonises land when the vegetation has been partially or totally destroyed. Life recovers the lost ground through the mechanism of the succession of species. The most evident way to restore vegetative cover is to protect it from the causes for degradation mostly exploitation which can spread naturally, but the process is often slow. The species

were naturally regenerated because seeds were fallen from surrounding trees to forest floor of stumped sprouts and root suckers developed from them, but it is necessary to understand the strategy for survival of each tree species (Figure 19). Jayakumar and Nair (2013) reported that tree regeneration was higher in species rich vegetation type with no sign of human disturbances. On the other hand, the vegetation is providing important resources for nesting, food and protection for a variety of wildlife, resulting, and their increases in the forest (Figure 20). Saara et. at. (2003) reported that changes in tropical forest structure and species composition that occur during regeneration following land abandonment may have important consequences for wildlife populations.

Figure 19. Natural regeneration in forest floor

Figure 20. Wildlife in the forest

In addition, the plots given out for planting trees adjacent to the Madhupur Sal Forest may eventually become a part of the natural forest canopy, increasing overall tree cover. Faruq et al. 2016 reported an increase in natural forest cover of Madhupur Sal forests in Bangladesh. Zaman and Katoh (2011) found significant increases in forest cover in areas protected by local governments and private owners. They also observed conversion of some croplands into closed and opened forest tracts in the Thakurgaon Forest in northern Bangladesh. Islam et al. 2013 reported that re-vegetation activities have proceeded in Sal forest area of Bangladesh, even as authorities ignore many of the illegal activities of forest-dependent people. The net effect is that there has been a significant improvement in the vegetation.

In our study, at the start of the program, participants who were most dependent on the forest were in conflict with the program, particularly in the initial stages. Firewood sellers, in particular, complained bitterly about the restrictions on collecting firewood, although their firewood needs were still accommodated, at least to some extent. They were also encouraged to pursue other alternative income-

generating activities, including farming, nursery production, and the rearing of livestock and poultry. These alternatives eventually contributed considerably to their family incomes and also reduced their dependency on forest for resource collection. Mukul and Quazi, 2008 also reported a collaborative management project that combined biodiversity conservation and community development and the project almost eliminated illegal logging and the use of forest trees for firewood. Shubani (2008) also reported that a majority of female members involved in a similar project in Satchari National Park, Bangladesh abandoned firewood collection to become involved in more sustainable activities.

For people dependent on forests, it is difficult to reduce the collection of forest trees for firewood, especially for cooking. In this situation it is important to take measures for the reduction in collection in a variety of way. In the study area, participants adopted other alternative fuel like agricultural residues, cow-dong, tree leaves and so on. But it can create debate about the flow of organic nutrients addition in the agriculture. So, there is no other alternative than increasing plant resources by planting more trees when almost all the people in the community use traditional mud stoves that do not support using other fuels (Chowdhury et al. 2011). Thus, in the study area, to reduce dependence on the forest for timber and firewood, all participants were provided different tree species to cultivate in their homestead premises and in plots given to them for this purpose (Figure 21). The participants were also given improved cooking stoves to save firewood and they were experienced to save fuel using the stove (Figure 22). IAP, 2008 reported that a one mouth portable improved cocking stove can save 50% of fuel and 25% more effective compare with a

traditional mud stove.

Figure 21. Homestead premises plantation (end of the project)

Figure 22. Using improved cocking stove in homestead

4.4 Conclusions

In this study, co-management of a Sal forest in Bangladesh greatly improved the livelihoods of the people dependent on the forest and enhanced the forest's conservation. Recognizing the interrelationships between community livelihoods and forest resource conservation, the rehabilitation project involved both the local community and local government officials. This project might be a model for Bangladesh's forestry sector.

The results of this study have potential implications for the broader context of co-management in Bangladesh and other developing countries. Among other factors, social capital played an important role in achieving project objectives. The project developed good relationships between local communities and the FD.

The program enhanced various types of livelihood capital, and improved access to livelihood opportunities. The project properly addressed community needs and problems, and developed capacity building through intensive training and by providing alternatives for new occupations. The project reduced illegal logging and encouraged the planting of native species by project participants. Therefore, attempts to conserve the Sal forest were successful.

To prevent further destruction of this forest, and further develop the livelihoods of those who depend it, the FD should consider continued conservation and livelihood strategies for locals; the forest should be protected through coordination among the FD, police, and the justice department; and all brick fields and sawmills in the forest area should be monitored and their owners strongly motivated to not use Sal timber illegally.

Chapter 5: Overall Conclusions

Land cover classification is a primary requirement for proper management and planning of various resources. Land use change and habitat degradation must be monitored and measured in order to identify risks and to plan for conservation in the context of increasing population and development pressures. Rapid population growth and its demand for agricultural land and forest products such as firewood, fodder, timber etc. have accelerated deforestation processes in many developing countries. There is a need for a comprehensive methodology to understand and value forest cover present condition, change and degradation from ecosystem services perspectives for subsistence economy, poor people and forest dwellers depending on ecosystem services for daily needs. Bangladesh has a substantial experience on ground based forest inventory which has established considerable data sources on forest stock. The methods used are aerial photographs, field inventory and satellite images analysis by Remote Sensing and GIS

Forest cover change through deforestation is a major environmental problem in the Bangladeshi Madhupur Sal forest. In this study, we used multi temporal Landsat satellite images to detect forest cover changes in the area. Satellite based remote sensors can obtain accurate data over vast areas, and various software packages facilitate land cover classification and change assessment. This approach enables detection of spatial and temporal changes over time. This technique is useful for studying land use in a developing country such as Bangladesh where data and monitoring are lacking. From the study it may concluded that the Sal forest of

Madhupur is in a remnant condition due to expansions of rubber plantations, woodlot plantations, agricultural lands, and areas in the settlements/croplands/other use category. The extent of forest cover changed markedly between 1972 and 2014, with radical decreases from 1972 to 2010. Across the whole area, 9,840.3 ha of land were covered with forest in 1972, but this value declined to 2,760.9 ha in 2010. This decrease resulted from anthropogenic changes in the study area, but the study did not investigate the activities that led to these changes.

However, this forest is extremely rich in plant diversity, even after disturbance occurrence by grazing, extraction of economical or medicinal species and lack of management practice. Therefore, priority should be given to conserve this forest which is facing pressure from increasing population and their demand. Deriving actual land cover statistics and land cover change information is highly relevant for decision makers and conservation practitioners. In order to maintain the complexity of this forest an economically and ecologically sound management plan is desirable with minimum disturbance to forest ecosystem. Proper understanding of the levels of social relations in community based forest management has important welfare implications, especially for livelihood security of forest dependent people. The immediate attention on people's participation is most essential for effective conservation. The effective conservation requires the active participation, integration and coordination of every stakeholder, from planning to implementation. Therefore, forests are managed for a wide variety of ecological, economic, and social benefits. A government-initiated forestry project in co-management was conducted in the Madhupur Sal forest area. The study also focused on changing trends of attitudes

toward forest conservation by members of local communities living in and around the forest and the impact of the project on their livelihoods.

In this study, co-management of a Sal forest in Bangladesh greatly improved the livelihoods of the people dependent on the forest and enhanced the forest's conservation. Recognizing the interrelationships between community livelihoods and forest resource conservation, the project involved both the local community and local government officials. This project might be a model for Bangladesh's forestry sector.

The history of scientific forest management in Bangladesh dates back to the nineteenth century with defined forest policies and laws. Due to various socio-economic and socio-political factors, forest cover of the country was reduced drastically and all policy initiatives to stop the decline proved ineffective. Although traditional forest management objectives covered a wide range from economic benefit to ecological stability, these have never been attained fully. Huge population and increase limited land area obligated policy makers to think about alternatives to traditional forest management. While traditional forest management resulted in a net loss of forest resource cover, the co-management forestry project on the other hand, has played a vital role in the expansion of forest cover. Results showed that forest coverage dramatically increased from 2010 to 2014, reaching 2,963.3 ha.

The project properly addressed community needs and problems, and developed capacity building through intensive training and by providing alternatives for new occupations. The program enhanced various types of livelihood capital and reduced illegal logging, and encouraged the planting of native species. Therefore, attempts to conserve the Sal forest were successful. The results of this study have

potential implications for the broader context of co-management in Bangladesh and other developing countries.

Therefore, to prevent further destruction of forest resources, and further develop the livelihoods of those who depend it:

- The planners should think about forest-cover monitoring with well organized and accurate forest maps.
- Government should be implement strong low enforcement for protect illegal logging.
- Government and Non Government organizations can support for extra income generation for forest dependent households by creating scope for alternative income generating activities.
- Development of sustainable eco-tourism and ensuring the local community involvement and benefit from eco-tourism.
- Empowerment of women and support aid for their income generating i.e. establishment of small trade, tailoring, handicraft and poultry rearing.
- Local people should be encouraged to plant fast-growing trees within their farm boundaries, on their homesteads, and on degraded lands instead of cutting trees in the existing forest.
- Forest dependent communities can make own cooperative society for their unity.

- Government and Non Government organizations should support for Setup bio gas plant and solar energy reducing pressure on forest wood consumption and availability of energy use.
- Motivation and awareness campaign will be conducted in the schools, colleges, and other public gathering places in adjacent villages in order to inform people about the importance of forest conservation by the authorities to support the regeneration of the Sal forest and better livelihood for the local people.
- Government should support for educating the forest dependency family through free education and set up programs for forest dependency community education.
- It should be ensuring effective management system of Sal forest resources management that will be well-being of local communities and community participation approach and involving them in decision making process.
- The FD should consider continued conservation and livelihood strategies for locals.

References

Ahmed, A.I.M.U. (2008) Underlying causes of deforestation and forest degradation in Bangladesh. Global forest coalition (GFC), Netherlands. Available from: http://www.globalforestcoalition.org (Accessed on January 10, 2015)

Alam, M., Furukawa, Y. and Harada, K. (2010) Agroforestry as a sustainable land use option in degraded tropical forests: a study from Bangladesh. Environ. Dev. Sustain. **2**: 147–158

Alam, M., Furukawa, Y., Sarkar, S.K. and Ahmed, R. (2008) Sustainability of Sal (*Shorea robusta*) forest in Bangladesh: past, present and future actions. Int. Forestry Rev. **10**: 29–37

Alphan, H. (2003) Land use change and urbanization in Adana, Turkey. Land Degrad. Dev. **14**: 575–586

BBS (2006) Ministry of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, pp 12-35

BBS (2011) Bangladesh Bureau of Statistics. Statistical Yearbook of Bangladesh. Ministry of Planning, Government of the people's Republic of Bangladesh. Available from: http://www.bbs.gov.bd/ (accessed on April 20, 2015)

BBS (2014) Bangladesh Bureau of Statistics. Statistics & Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Available from: http://www.bbs.gov.bd/ (accessed on April 20, 2015)

BFD (2004) Participatory Forestry Newsletter. Bulletin 3, December 2004. Bangladesh Forestry Department, Government of the People's Republic of Bangladesh.

BFD (2010) Bangladesh Forest Department Homepage, Ministry of Environment and Forest, Government of the People's Republic of Bangladesh. Available from: http://www.bforest.gov.bd (accessed on October 16, 2014)

BFD (2011) Forest Type: Tropical Moist Deciduous Forests. Bangladesh Forestry Department, Government of the People's Republic of Bangladesh. Available from: http://bforest.gov.bd/index-category/tropical-moist-dediduous-forest (accessed on August 20, 2014)

BFD (2016) Bangladesh Forest Department. Land and forest area of Bangladesh. Available from: https://www.bforest.gov.bd (accessed on April 5, 2016)

BFIDC (2014) Bangladesh Forest Industries Development Corporation. Available from: http://bdedure.blogspot.jp/2012/06/rubber-plantation-in-bangladesh.html (accessed on October 15, 2014)

Blaint, P. J. (2006) Improving community based conservation near protected areas: the importance of development variables. Environ. Manag. **38**: 137-148

Biswas, S. & Choudhury, J.K. (2007). Forests and forest management practices in Bangladesh: the question of sustainability. Int. Forestry Review. **9**: 627- 640.

Carney, D. 1998. Implementing the sustainable rural livelihoods approach. In: Sustainable rural livelihoods, what contribution can we make? Papers presented at the Department of International Development's Natural Resources Adviser's' Conference, London, DFID, pp. 2-26

Chaurasia, R., Closhali, D.C., Dhaliwal, S.S., Sharma, P.K.M., Kudrat, M. and Tiwari, A.K., (1996) Landuse change analysis for agricultural management: a study of Tehsil Tal-wandi Sabo, Punjap. J. Indian Soc. Remote Sens. **24**: 115–123

Chowdhury, M.S.H.; Koike, M.; Akther, S. and Miah, M.D. 2011. Biomass fuel use, burning technique and reasons for the denial of improved cooking stoves by forest user groups of Rema Kalenga Wildlife Sanctuary, Bangladesh. Int. J. Sust. Dev. World Ecol. **18**: 88-97

DAE (1999) Department of Agricultural Extension. Agricultural Extension Manual, Govt. of the People's Republic of Bangladesh, Ministry of Agriculture. P. 1- 175

DFID (1999) Sustainable Livelihoods Guidance Sheets. Department for International Development, London. Available from: http://www.eldis.org/vfile/upload/1/document/ 0901/section2.pdf (Accessed on June 14, 2016)

Ezebilo, E. E. (2011) Local participation in forest and biodiversity conservation in a Nigerian rain forest. Int. J. Sust. Dev. World Ecol. **18**: 42-47

FAO (2006) Global Forest Resource Assessment 2005: Progress towards sustainable forest management. FAO Forestry Paper 147, FAO, Rome, Italy. 320 pp.

FAO (2007) State of the World's Forest 2007. FAO, Rome, Italy. 144 pp.

Faruq. M. A. A., Zaman, S. and Katoh, M. (2016) Analysis of Forest Cover Changes Using Landsat Satellite Imagery: A Case Study of the Madhupur Sal Forest in Bangladesh. J. For. Plann. **21**: 29-38

Feeroz, M.M. and Islam, M.A. (2000) Primates of West Bhanugach Forest Reserve: major threats and management plan. In: Ahmed, M. F. (ed) Bangladesh Environment 2000. BAPA Bangladesh Poribesh Andolon, Maulvibazar. 239–253 pp

FRA (2015) Forest Resources Assessment, country report Bangladesh, 2015. Available from: http://www.fao.org/3/a-az161e.pdf (Accessed on September 5, 2015)

Gain, P. (2002) The last forests of Bangladesh. Society for Environment and Human Development (SHED), Dhaka, Bangladesh, 224 pp

Gain, P. (2005) Bangladesher Biponno Bon. Society for Environment and Human Development (SHED), Dhaka, Bangladesh, 276 pp

GLCF (2014) Global Land Cover Facility. Available from: http://glcf.umd.edu and http://glovis.usgs.gov (accessed on March, 2014)

GOB (2010) Forest department official website. Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. Available from: http//www.bforest.gov.bd/land.php (accessed on October 20, 2014)

Goldman, I. (2000) Sustainable Livelihoods Approaches: Progress and Possibilities for Change. Available from: http://www.eldis.org/vfile/upload/1/document/0812/LA_Progress.pdf. (accessed on April 20, 2016)

Hofer, T. and Messerli, B. (2006) Floods in Bangladesh: History, dynamics and rethinking the role of the Himalayas. United Nations University Press, Tokyo. 468 pp.

Hossain, M. K. (2005) Conversion of dipterocarps-dominant natural forests to short rotation plantations- an unrecoverable threat to the native dipterocarps in Bangladesh. Available from :http://www.apafri.org/8thdip/Session%204/S4_Hossain.doc

Iftekhar, M.S. (2006) Forestry in Bangladesh, an Overview. J. Forest. **104**: 148–153

IMF (2005) Bangladesh: Poverty Reduction Strategy Paper. Int. Monitory Fund (IMF) country report No. 05/410. Washington, D.C. 180 pp

Islam, J., Ahmed, A.N., Hossain, M.A., Rashid, M.M. and Atauzzaman, M. (2006) Deforestation study of Dinajpur Sal Forest using GIS and remote sensing techniques. J. Subtrop. Agric. Res. Dev. **4**: 47–54

Islam, K. K. and Sato, N. (2012) Participatory forestry in Bangladesh: has it helped to increase the livelihoods of Sal forests dependent people. J. Forest Sci. **74**: 89-101

Islam, K. K., Sato, N. and Hoogstra, M. (2010) Poverty alleviation in Bangladesh: the case of the participatory agroforestry program. Int. Forestry Rev. **12**: 412-415

Islam, K.K. and Sato, N. (2012) Deforestation, land conversion and illegal logging in Bangladesh: the case of the Sal (*Shorea robusta*) forests. iForest—Biogeosci. For. **5**: 171–178

Islam, K.K., Rahman, G.M., Fujiwara, T. and Sato, N. (2013) People's participation in forest conservation and livelihoods improvement: experience from a forestry project in Bangladesh. Int. J. Biodiver. Sci. **9**: 30–43

Islam, S.T. (2006) Resource Assessment of Deciduous Forests in Bangladesh. PhD theses, Durham University. Available at Durham E-theses online: http://etheses.dur.ac.uk/3889/ (Accessed on September 15, 2014)

IUCN (2004) National Biodiversity Strategy and Action Plan, Government of the People's Republic of Bangladesh (2nd Draft). Ministry of Environment and Forests (MoEF) and IUCN Bangladesh Country Office, Dhaka. 74 pp. Available from: http://www.iucnbd.org/download/nbsap/Draft_NBSAP_(All).htm.

IUCN (2014) The IUCN red list of threatened species. International Union for Conservation of Nature. Bangladesh Country office. Available from: https://books.google.co.jp/books?isbn=9843383648 (accessed on May 10, 2016)

Jonathan, G. (2000) Sustainable livelihoods. Int.Social Sci. J. **17**: 77–86

Kamiowitz, D. & Angelsen, A. (1998) Economic models of tropical deforestation a review. Center for International Forestry Research, Bogor, Indonesia. 153pp 17

Krishi Dairy (2012) Agricultural information Service, Ministry of Agriculture, Government of the People's Republic of Bangladesh.

Lambin, E.F. (1999) Monitoring forest degradation in tropical regions by remote sensing: some methodological issues. Global Ecol. Biogeogr. **8**: 191–198

Landell-Mills, N. & Porras, T. I. (2002) Silver bullet or fools' gold? A global review of markets for forest environmental services and their impact on the poor. Instruments for sustainable private sector forestry series. International Institute for Environment and Development, London. 249pp 23

Lasse K, (2001) The Sustainable Livelihood Approach to Poverty Reduction. International Development Cooperation Agency, Sweden. Available from: http://www.forestry.umn.edu/prod/groups/cfans/@pub/@cfans/@forestry/documents/asset/cfans_asset_202603.pdf. (accessed on May 14, 2016)

Mbie, P., Vabi, M., Meboka, M., Okon, D., Arrey-Mbo, J., Nkongho, F. and Ebong, E. (2005) Linking management and lihelihood in environmental conservation: case of the Korup National Park Cameroon. J. Environ. Manag. **76**: 1-13

McNeely, J. A. (1990) The future of national parks. Environment. Sci. Pol. Sustain. Dev. **32**: 16-20

Miller, A.B., Bryant, E.S. and Birnie, R.W. (1998) An analysis of land cover changes in the northern forest of New England using multi-temporal Landsat MSS data. Int. J. Remote Sens. **19**: 215–265

Milne, M. (1999) Change direction analysis using imagery: a review of methodology. Proceedings of IGARSS'88 Symposium. Edinburgh, Scotland, 541–544 pp

MSF (2016) Report on Madhupur Sal Forests. Available from: https://ronzusgreenworld.wordpress.com/eco-tourism-spots-in-bd/madhupur-sal-forest-msf/ (Accessed on October, 10, 2016)

Muhammed, N., Koike, M., Hauqe, F. and Miah, M.D. (2008) Quantitative assessment of people-oriented forestry in Bangladesh: a case study in the Tangail forest division. J. Environ. Manage. **88**: 83–92

Mukul, S. A. and Quazi, S. A. (2008) Communities in conservation: protected area management and enhanced conservation in Bangladesh. In: Robin N. Leslie (eds) The future of Forests in Asia and the Pacific: Outlook for 2020, Edition: RAP Publication: 2008/03. Publisher: Food and Agriculture Organization, Regional Office for Asia and the 11 Pacific, p. 143-159

Mukul, S. A., Uddin, M. B. and Tito, M. R. (2006) Study on the status and various uses of invasive alien species in and around Satchari National Park, Sylhet, Bangladesh. Tigerpaper. **33**: 28-32.

Muttitanon, W and Tripathi, N.K. (2005) Land use/cover changes in the coastal zone of Bay Don Bay, Thailand using Landsat 5 TM data. Int. J. Remote Sens. **20**: 9–20

Naithani, K.K. (1990) Can satellite images replace aerial photographs? A photogrammetrist's view. ITC J. **1**: 29–31

Nath T.K. and Inoue, M. 2008. How does local governance affect project outcomes? Experience from a participatory forestry project in Bangladesh. Int. J. Agric. Resour. Governance Ecol. **7**: 491-506

Nath, B. (2014) Quantitative assessment of forest cover change of a part of Bandarban Hill tracts using NDVI techniques. J. Geosci. Geomet. **2**: 21–27

Nath, T. K. and Inoue, M. (2010) Impacts of participatory forestry on livelihoods of ethnic people: experience from Bangladesh. Soc. Nat. Resour. **23**: 1093-1107

NSP (2008) Framework management plan for Madhupur National Park, Nishorgo Support project, Bangladesh. Available from: http//www.nishorgo.org/nishorgo2/pdf/reports/GENERAL%20REPORTS/1.MNP_Framework_ManagementPlan/ (accessed on May 15, 2016)

Panta, M., Kim, K. and Joshi, C. (2008) Temporal mapping of deforestation and forest degradation I Nepal: Applications to forest conservation. Forest Eco. Manage. **256**: 1587-1595

Pelletier, J., Kirby, K. R. and Potvin, C. (2010) Significance of carbon stock uncertainties on emission reductions from deforestation and forest degradation in developing countries. Forest Pol. Econ. **12**: 497-504

Quadir, D.A., Rahman, A., Haque, F., Ahmed, I.U. and Runkel, M. (1998) Monitoring of forest cover in Chittagong forest division of Bangladesh using remote sensing and GIS techniques. J. Remote Sens. Environ. **2**: 1–18

Rahman, M.M. (2003) Sal forest. In: Islam, S., Miah, S. (eds.) Banglapedia: National Encyclopedia of Bangladesh. Asiatic Society of Bangladesh, Dhaka. **9**: 28–29

Rahman, M.M., Csaolovics, E., Koch, B. and Kohl, M. (2004) Interpretation of tropical vegetation using Landsat ETM+Imagery. Available from: http://www.isprs.org/proceedings/XXXV/congress/yf/papers/951.pdf (Accessed on August 16, 2015)

Rasheed, K.B.S. (2008) Bangladesh—Resource and Environmental Profile. A H Development Publishing House. Dhaka, 103 pp

Rigg, J. K. (2006) Forests, marketization, livelihoods and the poor in the Lao RDR. Land Degra. Dev. **17**: 123-133

Roberts, M. G, and Yang, G. A. (2003) The international progress of sustainable development research: A comparison of vulnerability analysis and the sustainable livelihoods approach. Adv. Earth Sci. **22**: 11–21

Rosenholm, D. (1993) Land use and vegetation cover mapping by satellite: SSC Satellite experiences. ITC J. **3**: 251–260

Salam, M.A. and Noguchi, T. (2006) Evaluating capacity development for participatory forest management in Bangladesh Sal forests based on stakeholder analysis. For. Policy Econ. **8**: 785–796

Sawhney, P., Kobayashi, M., Takahashi, M., King, P. N. and Mori, H. (2007) Participation of civil society in management of natural resources. Int. Rev. Environ. Strategies. **7**: 117-132

Shackleton C. M., Shackleton, S. E., Buiten, E. and Bird, N. (2007) The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. Forest Pol. Econ. **9**: 558-577

Sharma, R., Xu, J. and Sharma, G. (2007) Traditional agroforestry in the eastern Himalayan region: Land management system supporting ecosystem services. Int. Society Trop. Econ. **48**: 297-307

Subhani, R. (2008) Impacts of co-management activities on women members of forest user group in Satchari National Park. In: fox, j., Bushley, B. R., Dutt. S., Quazi, S. A. (eds) Connecting communities and conservation: collaborative management of protected areas in Bangladesh. United States Agency for International Development (USAID). P. 231-250

Sunderlin W. D., Anglsen, A., Belcher, B., Burgers, P., Nasi, R., Santos, L. and Wunder, S. (2005) Livelihoods, forests and conservation in developing countries: an overview. World Vev. **33**: 1383-1402

Tole, L. (2010) Reforms from the ground up: a review of community based forest management in tropical developing countires. Environ. Manag. **45**: 1312-1331

Turyahabwe, N., Agea, J. G., Tweheyo, M. and Tumwebaze, S. B. (2012) Collaborative Forest Management in Uganda: Benefits, Implementation Challenges and Future Directions. Sustainable Forest Management - Case Studies, Dr. Julio J. Diez (Ed.), ISBN: 978-953-51-0511-4, InTech, Available from: http://www.intechopen.com/books/sustainable-forest-management-case-studies/collaborativeforest-management-in-uganda-benefits-implementation-challenges-and-future-directions. (accessed on March 10, 2016)

UNEP (2002) Bangladesh State of the Environment 2001. United Nations Environment Programme, Regional Resource Centre for Asia and the Pacific (UNEP RRCAP), Pathumthani 12120. Thailand, 17 pp

USGS (2014) U.S. Geological Survey—Band Designations for the Landsat Satellites. Available from: http://landsat.usgs.gov/best_spectral_bands_to_use.php. (Accessed on March 20, 2014)

Webb, E.L. and Sah, R.N. (2003) Structure and diversity of natural and managed Sal (*Shorea robusta*) forest in the Terai of Nepal. For. Ecol. Manage. **176**: 337–353

Yadav, N. P., Dev, O. P., Springate-Baginski, O. and Soussan, J. 2003. Forst management and utilization under community forestry. J. For. Livelihood. **3**: 37-50

Zaman, S. and Katoh, M. (2011) Assessment of forest covers change in tropical moist deciduous forest in Thakurgaon, Bangladesh using ALOS data. J. For. Plann. **16**: 285–292

Appendix

Questionnaire used in household survey

Date:

Household General Information

1. **Name of the participant:**

2. **Sex:**
   a. Male b. Female

3. **Age:**

4. **Name of village:**

5. **Educational status:**
   a. Illiterate b. Primary c. Secondary d. Higher secondary e. Graduate
   f. Others ( )

6. **Marital status:**
   a. Married b. Unmarried c. Widow d. Widower e. Separated

7. **Ethnicity:**
   a. Bangali b. Garo c. Others ( )

8. **Religious:**
   a. Islam b. Hindu c.Christian d. Budhist e. Other ( )

9. **Family size:**
   a. Male …… b. Female…….

10. **Occupation:** a. Before starting the project ( )
    b. After starting the project ( )

11. **Farm size:**

Land type	Ownership patterns			Condition of lease
	Self-owned	Lease	Others	
Homestead				
Agriculture				
Others				

12. Animal resources in the homestead:

Types	Before starting the project			After ending the project		
	Ownership patterns	Quantity	Use	Ownership patterns	Quantity	Use
Cattle						
Buffalo						
Goat						
Pig						
Chicken						
Duck						

13. Housing condition:

Types	Before starting the project	After ending the project
Mud house with tin roofing		
Bamboo-matt walls and tin or straw roofs		
Brick houses with tin roofs		
Number of rooms		

14. Household assets:

Types	Before starting the project	After ending the project
Radio		
Tape recorder		
TV		
CD player		
Computer		
Bicycle/Motorbike		
Rickshaw/Van		
Sewing machine		
Power tiller		
Irrigation pump		
Electricity		
Solar power		

15. Source of drinking water

Types	Before starting the project	After ending the project
Tube well		
Well		
River		
Pond		
Others		

16. Source of irrigation water

Types	Before starting the project	After ending the project
Rain		
Deep tube well		
Shallow tube well		
River		
Pond		
Others		

17. Use of latrine

Types	Before starting the project	After ending the project
Traditional		
Sanitary		
Others		

18. Use of cocking stove

Types	Before starting the project	After ending the project
Traditional mud stove		
Improved stove		
Kerosene stove		
Bio-gas		
Natural gas		

19. What percent (%) of fuel is saved by using Improved Cocking stove:

…….

20. Do you cultivate high yielding variety of crops?

a. Yes b. No c. Neutral

If yes, why? ……..

21. Financial status

Types	Before starting the project	After ending the project
Monthly income		
Monthly expenditure		
Access to borrow money (Bank/NGO/Rice people/Relatives/Others)		

22. Satisfaction level of family Expenditure

Item of expenditure	Before starting the project				After ending the project			
	Highly satisfied	Satisfied	Less satisfied	Not satisfied	Highly satisfied	Satisfied	Less satisfied	Not satisfied
Food								
Cloth								
Medical								
Education								
Entertainment								

Household livelihoods, forest dependency and forest conservation

23. Terms of access in the forest:

Access terms	Before starting the project	After ending the project
No access		
Free access		
Conditional		
Sharing agreement		
Others ( )		

24. Resource used by the household members from forest:

Types	Before starting the project	After ending the project
Fodder		
Fuel wood		
Timber		
Leaf litter		
Fruit		
NTFP		
Medicinal plants		
Honey		
Animal hunting		
Grazing for cattle		
Forest land for personal use		
Others ( )		

25. Adaptation with the changed availability of forest resources

Resource type	Alternative source				Reason
	Forest	Homestead	Agriculture field	Market	
Fodder					
Fuel wood					
Timber					
Leaf litter					
Fruit					
NTFP					
Medicinal plants					
Honey					
Grazing for cattle					

26. Major activities related to forest management that contributed to adapt better forest condition

Adaptation measures	Ranking
Guard the forest to protect illegal felling	
Participatory plantation in encroached forest land	
Restriction of forest product harvesting	
Control of grazing	
Distribution of sapling for homestead plantation	
Distribution of fuel saving improved cocking stove	
Provided training	
Motivation to change attitude	
Create Income generating activities	

27. What do you know about the subject matter of the training which you revived?

Major trainings	Excellent	Very good	Good	Fair	Poor
Nursery raising					
Vegetable gardening					
Compost preparation					
Poultry rearing					
Cattle fattening					

28. Do you think illegal logging has been stopped?

a. Yes b. No c. Neutral

29. Do you find any changes inside the forest?

Unit	Yes	No
Forest is anthropogenic disturbance free		
Species regeneration in forest floor		
Wildlife food source increased		
Wildlife increased		
Human food source increased		
Existing tree growing fast		
No changes		

30. Do you think tree species naturally regenerated in forest floor?

a. Yes b. No c. Neutral

If yes mention the name.

Type	Name of trees
Timber trees	
Fruit trees	
Medicinal plants	
Undergrowth and climbers	

31. Do you think wildlife increased in the forest?

a. Yes b. No c. Neutral

If yes, mention the name.

Type	Name of wildlife
Animal	
Birds	
Others	

32. What is the survival rate of homestead tree plantation: ……%

33. Do you getting benefit from homestead tree plantation?

a. Yes b. No c. Neutral

34. Changing attitude of participants after starting the project

Activities	Increased	As usual	Decreased
Illegal felling			
Encroachment			
Willing to receive training			
Willing to conserve the forest			
Women involvement in decision making			

35. Perceptions of participants being a member of the project

Type	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Do you feel that you have good relations with FD staff?					
Do you feel more respected by the FD staff?					
Do you feel more respected by family members?					
Do you get more invitations to social ceremonies?					
Do you get more help from neighbors in emergencies?					
Do you think that your skills have been developed?					
Do you make decisions in consultation with your spouse or other family members?					

36. Do you face any problem being a member of the project?

a. Yes b. No c. Neutral

If yes, mention the problems.

……

37. For women participants

Specific questions	Increase	Decrease	As usual
Has there been a reduction in discrimination by others when you go outside the home?			
Has there been a reduction in abuse by your husband?			
Has there been a reduction in demand for dowry by your husband or husband's family?			

38. Do you think the project should be continued?

a. Yes b. No c. Neutral

If yes, why do you think so? ……

39. Do you have any suggestions about the project?

a. Yes b. No c. Neutral

If yes, please mention. ……....