A Study on Deforestation in the Protected Forest Areas of the Teknaf Peninsula in Bangladesh

ウラー，シャ，モハッマド，アシック

https://doi.org/10.15017/1931918

出版情報：九州大学, 2017, 博士（芸術工学）, 課程博士
バージョン：
権利関係：

Doctoral Dissertation

A Study on Deforestation in the Protected Forest Areas of the Teknaf Peninsula in Bangladesh

ULLAH SHAH MOHAMMAD ASIK

3DS15005Y

Graduate School of Design

Kyushu University

March 2018

Summary

The main focus of this study was to describe the deforestation status and drivers responsible for deforestation with their impact on the protected forests in the Teknaf Peninsula. Although higher deforestation rate in the tropics, forest degradation and destruction inside the established protected areas in the region has become a concern in the effort to stem deforestation. Teknaf Wildlife Sanctuary (TWS) is a protected forest area established in the southern coast of Bangladesh known as Teknaf Peninsula. TWS is facing high rate of deforestation mainly due to the over dependency of the local people on the forest resources. In this study, deforestation was described considering illegal settlement establishment, agriculture cash crop cultivation (*Paan*) and fuelwood collection as the main drivers responsible for deforestation. The study found that, dense forest areas in the Teknaf Peninsula decrease by 46% in the last two decades with an annual deforestation rate – 2.40. During this study, we identified the factors influencing the deforestation drivers and then described the impact of the drivers on the local forests. For all the deforestation drivers we found that the Union (administrative unit of the local government) they are living and occupation are the common factors influencing the deforestation drivers alongside other socio-economic aspects. If we consider Baharchhara Union, the households there have 87% more chance to cultivate paan, 2.24 times more likelihood to encroach inside the forest and 23% more chance to collect fuelwood from the forest. In case of occupation, farmers have 10 times more chance to cultivate paan and 30% more chance to collect fuelwood from the forest. So we can conclude that people from Baharchhara are more responsible for deforestation than other parts of the peninsula. This study also quantifying the loss of forest resources to draw conclusion on the impacts on forests. Illegal encroachment resulted in 467 ha homestead areas inside the TWS. For paan cultivation, all of the paan borojs in the peninsula required 4530 ton of wood materials for the shading. The most common and visible forest resource was fuelwood for cooking. The demand of fuelwood in the Teknaf was calculated to be 156,520 tons per year. The deforestation drivers described in this study are accountable for 60% to 70% of the total forest products. This is based on the comparison o of the production and total demand. For TWS management, alternative income and energy source with proper zoning should be the most focused area for the policymakers.

Acknowledgement

The author is grateful to all who made contribution to this research work, although it is difficult to mention by all names. First and foremost, the author takes the opportunity to express his deepest sense of gratitude to his honorable supervisor Masakazu Tani Sensei, Professor & Dean, Faculty of Design, Kyushu University for his blessings, inspirations, innovative suggestions, constant guidance, intensive supervision and pragmatic criticism throughout the whole period of the research and writing of the thesis.

The author expresses his profound gratitude to all the members of the supervisory committee for their suggestion and scholastic guidance.

The author expresses special thanks to Mr. Delwar and Mr. Sayed for their constant support and help to collect data and manage the research activities in the Teknaf Peninsula.

Last but not the least, the author expresses his immense indebtedness and thankfulness to his loving wife and son.

The Author

CONTENTS

SUMMARY	i
ACKNOWLEDGEMENT	ii
CONTENTS	iii
LIST OF TABLES	iv
CHAPTER I. INTRODUCTION	1
1.1 Background of the Study	1
1.2 Deforestation in Protected Forest Areas of Bangladesh	3
1.3 Research Framework and Objectives	5
1.4 Limitations of the Study	7
1.5 Thesis Structure	8
CHAPTER II. DEFORESTATION IN TEKNAF WILDLIFE SANCTUARY	11
2.1 Background and Objectives	11
2.2 Methods and Data	11
2.3 Results	16
2.4 Discussion	33
2.5 Conclusion and Summary	35
CHAPTER III. PEOPLE, SETTLEMENT AND DEFORESTATION	36
3.1 Introduction and Objective	36
3.2 Methodology	37
3.3 Results	44
3.4 Discussion	49
3.5 Conclusion	52
CHAPTER IV. AGRICULTURE AND DEFORESTATION	53
4.1 Introduction and Objectives	53
4.2 Data and Methods	54
4.3 Results	57
4.4 Discussion	61
4.5 Conclusion	63
CHAPTER V. FOREST RESOURCE CONSUMPTION AND DEFORESTATION	64
5.1 Introduction	64
5.2 Methodology	65
5.3 Results	68
5.4 Discussion	69
5.5 Conclusion	73
CHAPTER VI. CONCLUSION	75
6.1 Overall Conclusion and Summary	75
6.2 Policy Alternatives and Future Research	78
REFERNCES	80

LIST OF TABLE

Table 1.1	Deforestation in some Asian countries in the tropical area	2
Table 1.2	List of Wildlife Sanctuaries in Bangladesh (Nishorgo, 2008)	4
Table 2.1	Land coverage change in and around TWS from 1989 to 2015	16
Table 2.2	Land cover class plotted with photos	28
Table 2.3	Deforestation rate and land coverage change in the Teknaf Peninsula	32
Table 2.4	Deforestation rate in and around some protected areas of Bangladesh	33
Table 2.5	Deforestation rate in some Asia tropical countries (considering 1990-2015)	34
Table 2.6	Land cover change inside and around TWS (% in 1989 vs % 2015)	35
Table 3.1	Definition of explanatory variables of the Binary logistic model	41
Table 3.2	Union wise socio-economic profile of Teknaf Upazila	44
Table 3.3	Union wise livelihood options in the Teknaf Upazila	45
Table 3.4	Socio-economic profile of people living inside and outside the forest	45
Table 3.5	ANOVA test to compare means between encroachers and non-encroachers	46
Table 3.6	Logistic regression model predicting the likelihood of Encroachment	48
Table 3.7	Union-wise total household	51
Table 4.1	Independent variables of the Logistic Model	56
Table 4.2	Socio-economic status of paan farmers comparing with the Teknaf Upazila	57
Table 4.3	Logistic regression model predicting the likelihood of paan cultivation	59
Table 4.4	Status and extent of Paan Boroj in Teknaf	60
Table 4.5	Wood production usage by paan cultivation	62
Table 5.1	Independent variables of the Logistic Model	67
Table 5.2	Pearson’s product-moment correlations	68
Table 5.3	Logistic regression model predicting the likelihood of fuelwood collection	70
Appendix 1	List of villages in Teknaf Upazila with their socioeconomic parameters	89

CHPATER 1. INTRODUCTION

1.1 Background of the Study

In the twenty first century, development of science and advancement in technologies changed lives and societies around the world towards better living of people. But all of this development will face threat if the human society cannot respond properly to the problem of anthropogenic climate change. Climate change is a serious threat to the world and to mitigate the climate change effects, almost all of the countries signed Paris agreement in 2015 where the main strategy is to limit the global surface temperature rise to below 2ºC (Mander et al., 2016). Temperature rise is very much related to carbon emission; excessive emission leads to the imbalance of carbon in the atmosphere which results in high global temperature. To control the temperature rise it is important to check carbon emission. Among the causes of carbon emission, deforestation accounts for a significant portion of global carbon emissions annually.

Tropical deforestation is one of the most important environmental crisis in the context of climate change mitigation, biodiversity degradation and poverty alleviation. Forest loss has been occurring for a long time but the recent rapid rates of tropical deforestation have become a serious concern. The destruction of tropical forests has received worldwide attention because of the well-known, unique role play in ecological terms, the diversity functions they provide and, above all, the continuing threat to its existence, which directly affects the net carbon emissions derived from deforestation and degradation (Houghton, 2012). Only in the last two decades, tropical deforestation nearly doubled from 5.6 $MHay^{-1}$ to 9.1 $MHay^{-1}$ (FAO and JRC, 2012) and Southeast Asia, the global hotspot for tropical deforestation (Achard et al., 2002; Hansen et al., 2008), lost nearly 195 Mha of forests in the period of 1990 to 2015 (Keenan et al., 2015). As tropical forests cover 44% of the global forests covering nearly 1797 million hectares (Keenan et al., 2015), Southeast Asia's tropical forests cover a significant portion of global forest coverage and play a vital role in providing socioeconomic support for many rural populations and conserving biodiversity conservation. Forest degradation and destruction in the tropical area will not only threat the environment and biodiversity but will be the cause of livelihood loss for many people in dependent on the forests for their living. So tropical deforestation should be considered as a serious problem effecting millions of people's lives as well as a serious threat to biodiversity and environment. Table 1.1 is showing the scenario of tropical deforestation in Asian countries in the tropical areas. Countries like Cambodia and Malaysia lost more than 15% of the forest cover after 2000.

Table 1.1: Deforestation in Asian countries in the tropical area (Butler, 2016)

Country	Forest Coverage (%)	Loss as % of 2009 forest cover	Loss as % of 2004 forest cover	Loss 2001-2014 (1000 ha)
Bangladesh	15.1	1.5	2.8	6.91
Cambodia	49.6	11.5	15.9	1,586
India	12.4	1.1	2.1	1034
Indonesia	85.8	5.1	9.6	18,508
Laos	83.9	4.6	7.4	1,636
Malaysia	89.9	9.0	15.8	5,633
Myanmar	64.6	2.5	4.1	2,030
Philippines	63.6	1.9	3.3	761
Thailand	39.4	2.8	5.2	1,268
Vietnam	51.3	4.9	7.9	1,5085

Source: *https://rainforests.mongabay.com/deforestation_alpha.html*

The establishment and management of protected areas (PAs) is one of the widely practiced strategies being used to combat deforestation. IUCN (1994) defined PAs as “Areas especially dedicated to the protection and maintenance of biological diversity and associated cultural resources, which are managed through legal or other effective means”. PA systems are specially designed to restrict or reduce the anthropogenic pressures in areas of high biological diversity (Venter et al., 2014) and are also efficient in providing important ecosystem services like climate regulation, groundwater recharge, erosion control, pollination, etc. (Sohel et al., 2015 and Mukul, 2014). Considering the wide-ranging benefits including protecting forests, conserving biodiversity and providing ecosystem services, around 15 percent of terrestrial and inland water areas are now covered by protected areas (UNEP-WCMC, 2016). Beside the growing popularity and worldwide spread of PAs, the effectiveness of PAs to mitigate deforestation has become a concern. Several studies have shown that PA can be effective to stem deforestation (Joppa & Pfaff, 2010; Andam et al., 2008 & Sims, 2010) and also have positive impact on socioeconomic attributes of the local people (Andam et al., 2010; Robalino et al., 2012 & Clements et al., 2014). Conversely, other studies also indicated that some protected areas were not significantly effective in reducing forest loss (Campbell et al., 2008 & Naughton et al., 2005). Protected areas are established to reduce deforestation and degradation by restricting land-use change and subsistence activities within their boundaries. Indistinct land ownership rules, conflict of interest with local people, lack of resources and proper management strategies causes the PAs to divert from their purpose resulting to weak and partial restriction and regulations over the conserved area. When regulatory control is particularly weak, protected areas can even exacerbate forest cover change by creating de facto open access regimes (Blackman et al., 2015; Liu et al., 2001; Wittemyer et al., 2008).

Tropical forests cover nearly half of the earths forest coverage and the region is also densely populated with millions of poor people solely dependent on forest resources for their daily livings. Over dependency and excessive demand for forest resources in the tropical areas also leads to a conflict of production and conservation which increases the chance of PAs to fail to meet their objectives. In many tropical countries with high population densities, PAs coexist with people in uneasy, tightly coupled and fractious relationships (Mukul et al., 2012; Nagendra, 2008). Tropical deforestation is a threat and to mitigate the deforestation in the tropics PAs are established but deforestation is also occurring within the PAs. So it is important to understand the rate and extent of deforestation as well as the drivers responsible for this.

1.2 Deforestation in Protected Forest Areas of Bangladesh

Tropical forests in Bangladesh are mainly spread over Chittagong hill tracts, Cox's Bazar and Sylhet totaling 0.67 million hectares which is 4.54% of total landmass of the country and 44% of the national forest land. Despite having high biodiversity, the country has one of the lowest per capita forest land (Mukul and Quazi, 2009) experiencing one of the highest rates of deforestation in south Asia (Poffenberger, 2000). Deforestation is a concerning issue for Bangladesh because of its highly vulnerable to the global climate change impact. As a strategy to stem the deforestation PAs were established in Bangladesh from the 1980's (Chowdhury and Koike, 2010) and currently there are 34 PAs covering nearly 0.27 million hectares of forest land (Mukul et al., 2017). Among the 34 PAs, 17 are national parks and 17 are wildlife sanctuaries (Table 1.2 shows the list of wildlife sanctuaries of Bangladesh). Additionally, there are 5 eco-parks and 2 safari parks in Bangladesh, which also is recognized as protected areas. Alike other PAs in tropical areas, some PAs in Bangladesh are also experiencing deforestation and land cover change within their boundaries (Islam et al., 2017; Alam et al., 2014). On the context of climate change and global deforestation, establishment of PAs are considered as a mean to stem deforestation but deforestation within the PA boundaries is a concerning issue. Identifying and understanding the drivers responsible for deforestation in the tropical area PAs are a very important and concerning issue considering the contemporary global deforestation.

Table 1.2 List of Wildlife Sanctuaries in Bangladesh (Chowdhury and Koike, 2010: Table 3)

Wildlife Sanctuaries	Establishment	Area (ha)	Forest type	Geography
Char Kukri Mukri	December, 1981	40	MNGF	Littoral
Pablakhali	September, 1983	42,087	TMEF	Hilly
Chunati	March, 1986	7,764	TMEF	Hilly
Sundarban East	April, 1996	31,227	MNGF	Littoral
Sundarban West	April, 1996	71,502	MNGF	Littoral
Sundarban South	April, 1996	36,970	MNGF	Littoral
Rema-Kalenga	July, 1996	1,796	TMEF	Hilly
Fashiakhali	April, 2007	1,302	TMEF	Hilly
Teknaf	March, 2010	11,615	TMEF	Hilly
Dudh Pukuria- Dhopachari	April, 2010	4,717	TMEF	Hilly
Hazarikhil	April, 2010	1,178	TMEF	Hilly
Sangu	April, 2010	2,332	TMEF	Hilly
Tengragiri	October, 2010	4,049	MNGF	Littoral
Sonarchar	December, 2011	2,016	MNGF	Littoral
Chadpai	January, 2012	560	MNGF	Littoral
Dhangmari	January, 2012	340	MNGF	Littoral
Dudhmukhi	January, 2012	170	MNGF	Littoral

**MNGF =Mangrove Forest and *TMEF = Tropical Moist Evergreen Forest*

Generating new knowledge and information regarding deforestation issues inside the PAs is essential for policy formulation, conservation planning and land resource management. Deforestation studies in protected areas have been conducted in many parts of the world (e.g. Adhikari et al., 2015; Pfaff et al., 2014; Vuohelainen et al., 2012; Sanchez-Azofeifa et al., 2002). But to understand the deforestation inside the PAs, region specific drivers should be identified with their cause and effects. While there are studies concerning deforestation drivers inside the protected areas in Bangladesh (Islam et al., 2017; Alam et al., 2014; Chowdhury and Izumiyama, 2014), no such studies have been done to describe the factors behind the deforestation drivers with their impact on the local forests.

1.3 Research Framework and Objectives

As described in the previous section, the focus of this study is deforestation within and around the protected forest areas of Bangladesh (Figure 1.1). The study area of deforestation is Teknaf Upazila (Upazila is a unit of administration under District administration) part of the peninsula of the south coastal area of Bangladesh under Cox's Bazar District focusing on the deforestation of Teknaf Wildlife Sanctuary (TWS). This study attempts to elucidate the cause and impact of the deforestation drivers in the tropical protected forest area of Bangladesh.

Deforestation is a complex and multiform process which is difficult to be represented and described precisely by a single approach. In this study, deforestation process will be described using the proximate-underlying approach developed by Geist and Lambin (Geist and Lambin, 2002). According to this approach they summarized 152 sub-national case studies of tropical deforestation into three proximate causes – the expansion of agriculture, wood extraction and infrastructure development; and the five underlying driving forces: demographic, economic, technological, policy & institutional and cultural factors. Proximate causes of deforestation are the human activities that directly affect environment and underlying forces are fundamental forces that underpin the proximate causes. The combination effect of proximate causes and underlying driving forces linked to land use and land cover change have also been conceptualized by others (Meyer and Turner 1992, Turner et al. 1993, Ojima et al. 1994 and Lambin et al. 1999) and the approach developed by Geist and Lambin based on proximate-underlying forces are also been widely used in many tropical deforestation studies (Muller et al. 2012, Petursson et al. 2013) now-a-days.

This thesis will use proximate causes to describe the deforestation process and its impact on forests. Geist and Lambin (Geist and Lambin, 2002) described three major proximate causes in their study i.e. the expansion of agriculture, wood extraction and infrastructure development. Based on those three proximate causes, similar deforestation drivers were seen in Teknaf peninsula. Expansion of agriculture was found in the form of betel leaf (local term: *paan*) cultivation inside and around the protected forest area. The local people of Teknaf Peninsula is solely dependent on fuelwood collected from the forest which represents the wood extraction deforestation driver. Infrastructure development was found in the form of settlement expansion inside the forests. In the Teknaf peninsula, settlement expansion, paan cultivation and fuelwood collection are the most prominent and visible deforestation drivers. In this study deforestation process was described based on these three proximate causes.

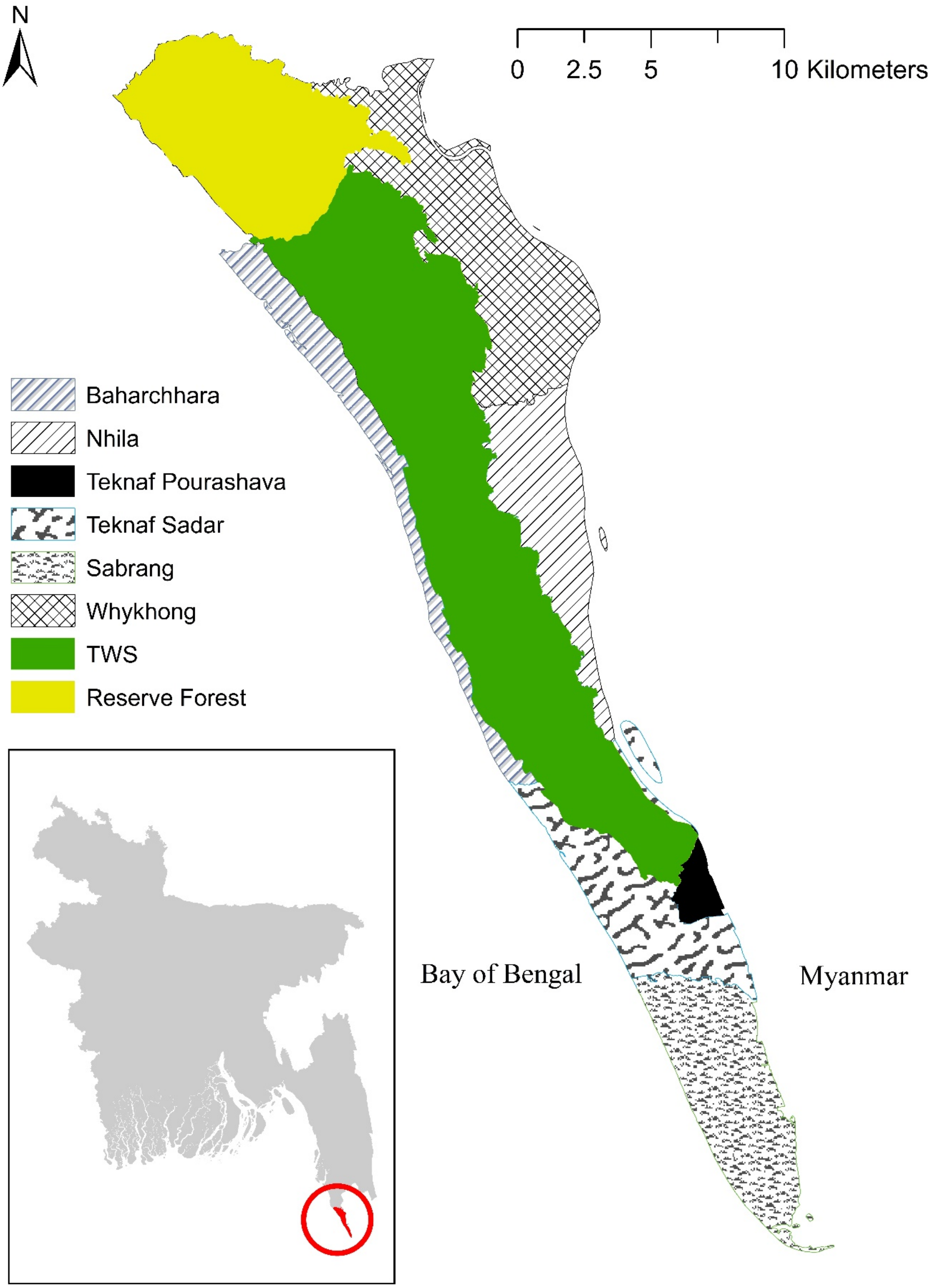


Figure 1.1 Study Area: Teknaf Upazila with the protected forest areas

Over the thesis we will describe the factors responsible for the proximate deforestation drivers and determine their impact on the protected forests. In this study, first the deforestation rate will be calculated and land coverage change will be described by analyzing satellite images obtained from the past 25 years to elucidate the extent of the current scenario of the forest with the deforestation rate. After determining the deforestation rate the deforestation process will be described by the proximate causes of deforestation. This study will investigate the factors having impact on deforestation drivers and also describe the impacts of the drivers on the deforestation process. This study will focus on determining and describing the cause and effect of each deforestation drivers rather than combining the spatial and socio-economic data to perform regression analysis

The key research question of this study is – how the deforestation is occurring in the protected forests of the Teknaf Peninsula? To find the answers to the question the following objectives are set. The objectives are 1) to determine the deforestation rate in the PAs, 2) to understand the factors influencing the deforestation drivers and to describe their impacts on forests and 3) finally to reflect on possible policy recommendation for PA management in Bangladesh.

1.4 Limitations of the Study

. This study was undertaken with a view to have an understanding of the drivers and their effect on deforestation. In order to conduct the research in a meaningful and manageable way it becomes necessary to consider some limitations in regard to certain aspects of the study. Considering the time, money and other resources, the following limitations have been observed throughout the study –

1. The study was confined to Teknaf Upazila in the coastal area of Bangladesh, all the discussions and policy alternatives suggested will be based on the findings in this specific area.
2. Satellite images used to analyze deforestation overtime did not follow certain time intervals rather the images were selected based on the best availability of the pictures. As a result, to analyze deforestation for the we used pictures of 1989, 2004, 2007, 2009 and 2015.
3. Characteristics of the local people are many and varied, but due to limited time and resources it was not possible to consider all socio-economic aspects. Hence basic characters i.e. age, income, education, household size and condition were considered for analysis.

4. During some cases of face to face interview in some cases, due to shyness and reluctance,the respondents did not want to give information of some topic such as age, income and education. But with the help of local researchers we tried to establish proper rapport and overcome this barrier.
5. For developing socio-economic database and village lists we followed the government list provided by the Statistic Bureau but in the field six villages were missing.

1.5 Thesis Structure

The thesis structure is developed based on the objectives. Figure 1.2 illustrates the organization of the thesis.

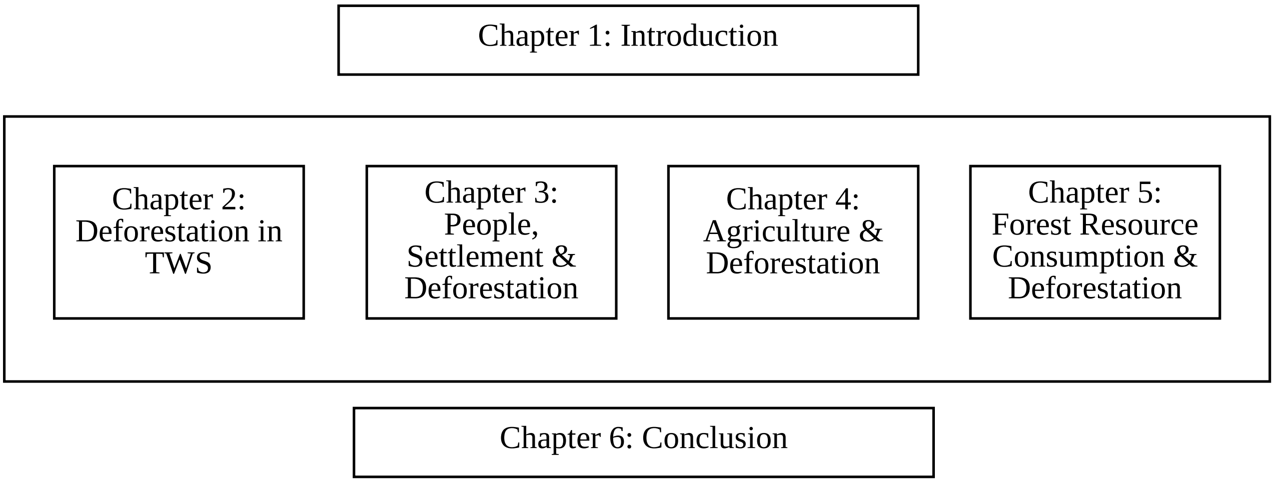


Figure 1.2 Structure of the Thesis

Already described above, the first chapter provides circumstances and background information regarding climate change and tropical deforestation. This chapter provides the importance of the study with background information of the problem and stating the objectives of this study. It describes that tropical deforestation is an important issue in the context of mitigating the effect of global climate change. Establishment of protected areas (PAs) worldwide is a popular mean to prevent deforestation but deforestation is also happening within the boundaries of PAs in tropical areas. More specifically, Bangladesh is also facing deforestation in the PAs which is concerning to the overall deforestation scenario of the country. Considering these circumstances this thesis aims to investigate and overlook the deforestation rate, its cause and impact on the forest in TWS of Bangladesh.

The second chapter focuses on determining the deforestation rate in the study area. This chapter focuses on fulfilling the first objective of the study which is to determine the deforestation rate in the study area. Deforestation means destruction of forest land and degradation means reduction of the forest quality on different aspects. This study will not separately describe deforestation and degradation rather it will refer deforestation as a common term for both degradation and deforestation. Based on the satellite image obtained from 1989, 2004, 2007, 2009 and 2015 deforestation will be calculated considering the NDVI values. Land coverage of the total study area will be categorized by NDVI values and based on the land coverage change from 1989 to 2015 the deforestation rate will be determined. After determining the deforestation rate the study will advance to investigate the drivers of deforestation and their impact on the forests.

The third chapter focuses on settlement and deforestation. Establishment of settlements inside and around the forest is one of the major causes of deforestation. This chapter is a part of fulfilling the second objective stated as - to understand the factors influencing the deforestation drivers and to describe their impacts on forests. In this chapter the settlement around the protected forest is described along the socioeconomic attributes of the local people. Then the land cover change from different distances of the settlement is analyzed to understand the impact of settlement establishment on land cover change over the time period (1989 – 2015). Also logistic regression test is performed to explore the factors influencing the people to encroach inside the forest. This chapter gives an understanding of the encroachment status of the people inside the protected forest area with an overview of the impact of settlements on the forest land change over time.

Fourth chapter deals with agriculture as a deforestation driver. The widely practiced betel leaf cultivation (locally known as *paan*) requires wood materials for shedding materials. These wood materials are mostly collected from the protected forest areas which is a factor for the deforestation of the protected forests. This chapter also deals with the second objective stated previously. In this chapter, the socioeconomic data of the local people cultivating betel leaf are described. The place where betel leaf is cultivated are locally known as *paan boroj*. Every *paan boroj* in the study area was identified and mapped using satellite images. The status and extent of cultivating betel leaf was described with the factors influencing betel leaf cultivation.

The fifth chapter focuses on forest resource consumption. Fuelwood is the most widely consumed forest resources by the local people. Collection of fuelwood from forest is a major deforestation driver in the Teknaf peninsula. To fulfill the second objective, the consumption of the fuelwood by the local people was determined. Also the factors affecting the collection of fuelwood from the protected forests were explored. This chapter gives an idea about the excessive demand of fuelwood by the local people and the impact of fuelwood harvesting on the protected forests.

In the last chapter, thesis ends with summary of all results and discussions, final conclusion, recommendation for further studies and policy alternatives to mitigate deforestation in the PAs. This chapter deals with the objective to reflect on possible policy recommendation for PA management in Bangladesh. In this chapter all the findings from the above chapters are linked together to generate a better understanding of the overall deforestation process and situation in the Teknaf Peninsula. The chapter ends with some policy recommendation to mitigate the deforestation and ensure sustainable forest management.

CHAPTER 2. DEFORESTATION IN TEKNAF WILDLIFE SANCTUARY

2.1 Background and Objectives

Deforestation in the tropical areas, specifically in the PAs are the main focus of this study. Chapter 2 will deal with determining deforestation rates using analyses of satellite images. Specific information on forest coverage and deforestation can assists the governments, non-governmental organizations and commercial sectors making decisions on policies and investments. Also determining deforestation rate is important to scientific communities for further research to understand the forest area change. Deforestation rate can vary due to different methodologies, calculation formula, time consideration and place. Although defining an exact deforestation rate and its extent is quite difficult and the variation of deforestation rates determined by following different methodologies make it more complex but at least a deforestation rate gives an idea about the forest loss and helps to draw a quantifiable conclusion. Estimation by the Food and Agriculture Organization of the United Nations (FAO, 2011) showed a net global deforestation of 0.20%, 0.12% and 0.14% respectively from 1990 to 2000, 2000 to 2005, and 2005 to 2010, aggregating a net loss of 5.2 million hectares from the year 2000 to 2010. In a different estimation, Hansen et al. (2010) indicated a rate of 0.6% of annual forest loss and estimated 101.1 million ha loss of global forest area between 2000 and 2005. Keenan et al. (2015) showed a comparison between forest area change rates estimated in different studies analyzing satellite images of pan-tropical areas during 2000-2010. The study showed three different forest area changes i.e. - 6.6 M ha/y (FAO, 2015), - 8.5 M ha/y (Hansen et al., 2013) and - 7.6 M Ha/y (Achard et al., 2014).

Considering the complexity and widely used different methodologies in case of calculation forest area change, this chapter pursues its objectives as follows, 1) describing the land coverage change in the last two decades of the study area and 2) determining the deforestation rates in the protected forest area known as TWS.

2.2 Methods and Data

2.2.1 Study Area

The study was conducted in Teknaf Upazila (20° 51′ 56″ N and 92° 17′ 43″ E) which is situated 48 kilometers south from Cox’s Bazar District (Upazila is an administrative unit consisting several Unions under District administration in Bangladesh). The 388.68 km^2 study area is bordered by the Bay of Bengal from west to south, the Naf river to the east and Ukhia Upazila to the north. Because three sides of this Upazila is bordered by waterbodies, it is also known as Teknaf Peninsula. In Teknaf Upazila a total of 14,602 ha land is covered by forest of which 11,615 ha protected forest area is known as Teknaf Wildlife Sanctuary (TWS) and this TWS is the main focus of this deforestation study. The dimensions of TWS are roughly 28 km from north to south and 3-5 km from east to west. The forested areas in the southern half of the Teknaf peninsula became a reserve forest in 1907 (Belal 2013). The same area was declared as the Teknaf Game Reserve (TGR) in 1983 under the Bangladesh Wildlife Act of 1974 (Alam et al. 2012) and its status was changed to the Teknaf Wildlife Sanctuary (TWS) in 2010 (BFD 2014). The boundary of TWS was considered to determine deforestation inside the protected forest areas and for inside and around the protected forest the study area is shown in Figure 2.1. Based on the availability of picture and exclusion of the beach areas from the analysis a total of 20,577.11 ha areas were considered for the analysis and termed as study area.

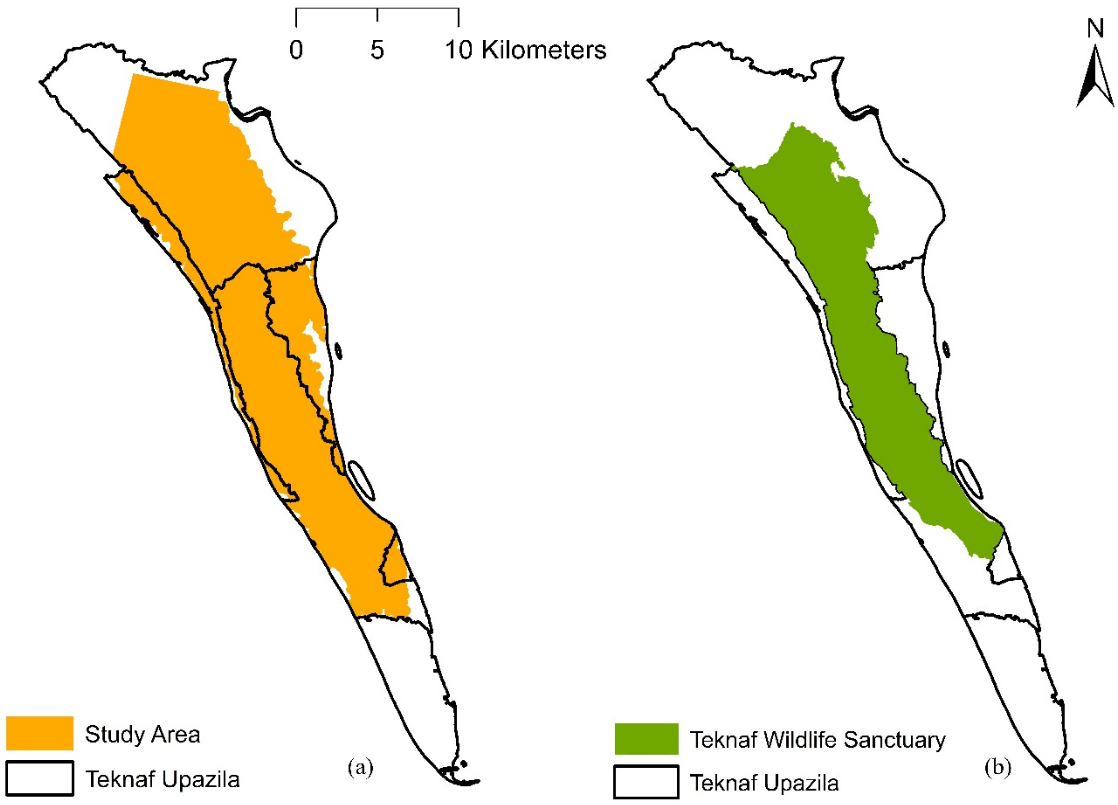


Figure 2.1 a) study area considered for deforestation and b) boundary of the TWS

2.2.2 Methods and Data

2.2.2.1 Satellite Image Analysis

To investigate the land cover change in the forest area analyzing Landsat images is the most widely used scientific method by the researchers. In this study Landsat images of 1989, 2004, 2007, 2009 and 2015 will be used because of the best available pictures of our particular study area. A Landsat image consists of 30 x 30 m cells. Each cell is assigned with values measured by multiple sensors. Landsat image cells within the study area were processed and categorized according to the values of the Normalized Difference Vegetation Index (NDVI). NDVI has been extensively applied in forest-related analyses based on remote sensing data (e.g., Justice et al. 1985). NDVI is an index of the density of green plants on a patch of land, and is calculated based on the difference in values between the visible red and the near-infrared sensors. NDVI value ranges from +1, highest active green to -1.

In case of this study, Landsat cells that having less than 0.4 NDVI were first eliminated from the analysis because poor vegetation coverage and termed as Class 0. The remaining cells were classified by changes in NDVI during the dry season of a particular year. For this study, cells were clustered using the Iterative Self-Organizing Data Analysis Technique (ISODATA) based on a series of NDVI values obtained for every month from the beginning of the dry season (November) to its conclusion (March–April) during any one year. As a result, three classes of cells were identified, of which Class 3 cells, which entailed the highest NDVI value, were postulated to contain mature trees or forest. However, ground truth data collected at 63 locations classified as Class 3 indicated that these cells did not necessarily contain mature trees. This is because the presence of grassy plants and shrubs could also result in a high NDVI value. Therefore, a second step in the analysis is conducted on Class 3 cells entailed segregating these cells into those with trees and those with only a few trees. For this step, one satellite image for a year was selected for analysis. The timing of the image was as close as possible to the end of the dry season, when the majority of grassy plants were likely to have died, so that the NDVI value reflected the presence of perennial trees. Each cell belonging to Class 3 within this selected image was analyzed, focusing on three types of spectral characteristics: NDVI, Normalized Difference Water Index (NDWI), and Green-Red Vegetation Index (GRVI). This analysis yielded three new clusters (3, 4, and 5) produced out of the former Class 3, resulting in a total of five classes. The presence of trees within the locations of the three new classes was verified using high-resolution satellite images and the ground truth method, confirming that cells within Classes 4 and 5 had trees.

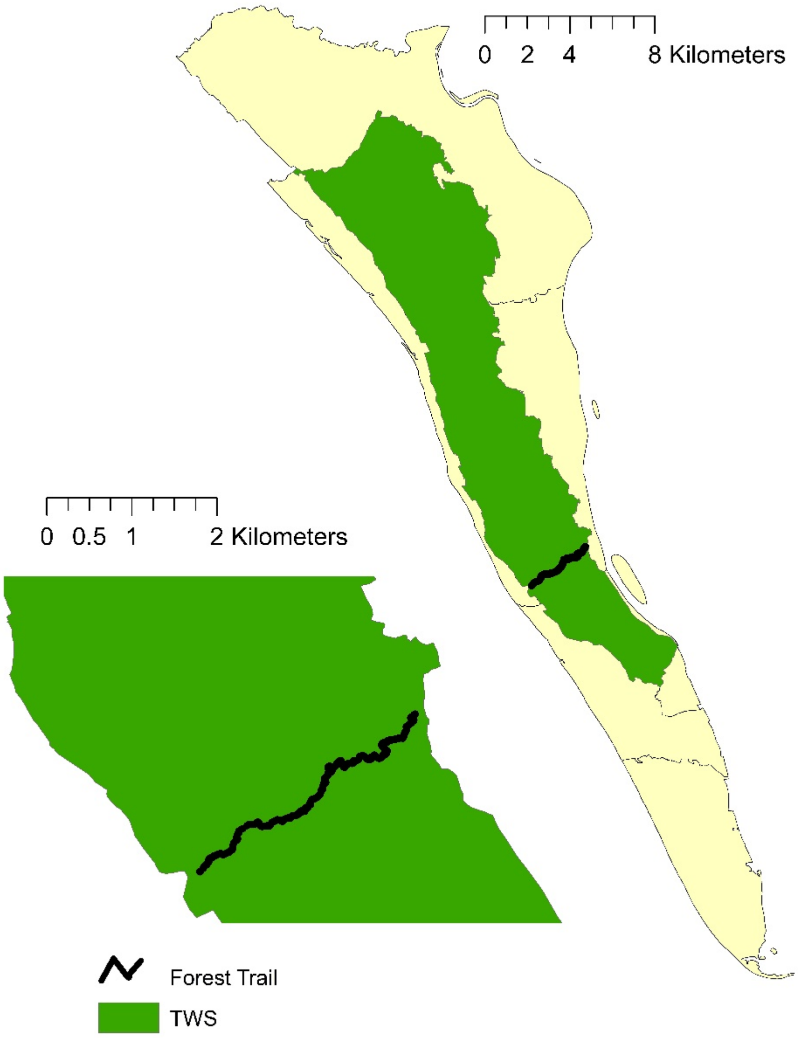


Figure 2.2 Forest trail inside TWS

To croos-check the findings of Landsat image analysis and to obtain clearer understating of forest land cover, nearly a 3 km long tracking was done from west to east inside the forest trails taking 515 photos of different Landsat cell classes. From the photos each Landsat class was investigated and described for better understanding. The photos have GPS information and the photo location are compared with the NDVI class location. The photos are visually judged based on the vegetation and each photo was classified into the following types

a) Grass land with small bushes
b) Short bush
c) Tall bush
d) Bush area with tree coverage less than 10%
e) Lean forest (tree coverage less than 40%)
f) Dense forest (tree coverage more than 40%)

The different land classes based on NDVI were described using the above category photos. The percentage of different photos in different land classes are investigated and based on that percentage the land classes are defined (Table 2.2). For example, photos covering land class 5 were 97% from dense forest category, so this land class can be labelled as dense forest area.

2.2.2.2 Determining Deforestation Rate

Different authors use different formulas to calculate the annual rate of deforestation based on the methods and types of data. Also different terms are used to describe the rate of deforestation. In this study the formula developed by Puyravaud (2003) is used to calculate the mean annual deforestation rate. This formula is selected because it uses the forest area data and considers time to calculate a standardized deforestation rate (r) which can be expressed in terms of percentage of forest area loss per year. Also it is simple to calculate and+ highly accepted by other researchers. The formula is -

$$r = \frac{1}{(t_1 - t_2)} . ln\left(\frac{A_2}{A_1}\right).100$$

Here,

r = Deforestation rate (standardized mean forest lost percentage per year)

A_1 = Forest area in hectares in the years of t_1

A_2 = Forest area in hectares in the years of t_2

t_1 = First year of the considered deforestation period

t_2 = Last year of the considered deforestation period

In this study this formula will be used to calculate deforestation. Also this formula will be used to calculate the land coverage change rate of different land classes defined from Landsat image analysis. Among the Landsat image classes based on NDVI calculation, Class 4 & 5 are considered as forest area and the rest are mainly bush, settlements and crop fields. But the same formula will be used to determine the land coverage change rate over the period of time. So, the same formula will be used but in case of forest area or class it is termed as deforestation rate and in case of other areas than forest it is termed as land coverage change rate. Also sometimes the deforestation rate is confused with forest area lost. Deforestation rate is the mean loss of forest area annually over a period of time whereas, forest area lost is the total forest area destroyed. A large area can have a relatively less deforestation rate.

2. 3 Results

2.3.1 Land Cover Change in the Teknaf Peninsula

2.3.1.1 Land Coverage Change in the study area

The study area considered for land coverage change was 20577.11 ha including the TWS. Table 2.1 shows the land coverage change of each land class based on NDVI. Figure 2.3 to 2.7 shows graphical representation and percentage of land cover change from 1989 to 2015. Class 0 includes the area having NDVI value less than 0.4 which is not shown in the maps in Figure 2.3. During 1989, Class 5, considered to be forest area was 3734.24 ha and decreased to 1999.62 ha within 2015. Significant increase was observed in case of Class 2, which increased from 22% to 34% during the last two decades and covering 6898.93 ha areas in 2015.

Table 2.1 Land coverage change in the study area from 1989 to 2015

Land Class based on NDVI		1989 (ha)	2004 (ha)	2007 (ha)	2009 (ha)	2015 (ha)
TWS	0	706.26	821.98	982.20	855.15	765.26
	1	448.49	753.98	505.76	551.26	699.97
	2	3230.95	5131.76	4982.77	4876.20	4851.46
	3	2074.25	2231.30	1782.09	2183.27	2129.80
	4	2501.99	1805.92	1217.15	2126.54	2216.35
	5	2653.06	870.06	2145.03	1022.58	952.17
Study area	0	4143.12	4030.80	4417.92	3751.19	2844.96
	1	2731.30	3070.24	2463.94	2686.76	3195.80
	2	4624.33	6778.54	6785.53	6839.33	6898.93
	3	2216.09	2494.06	1939.75	2432.92	2481.91
	4	3128.03	2406.52	2204.84	2894.24	3155.89
	5	3734.24	1796.95	2765.14	1972.68	1999.62

2.3.1.2 Land Coverage Change Inside the TWS

Table 2.1 and Figure 2.8 to 2.12 shows the land coverage change from 1989 to 2015 inside the TWS. The forest area (Class 5) inside the TWS was 2653.06 and decreased nearly 64% to cover only 952.17 ha areas in 2015. Inside the TWS except land Class 4 and 5, other land class increased their coverage. Among the increased land classes, class 2 increased to 42% land coverage in 2015.

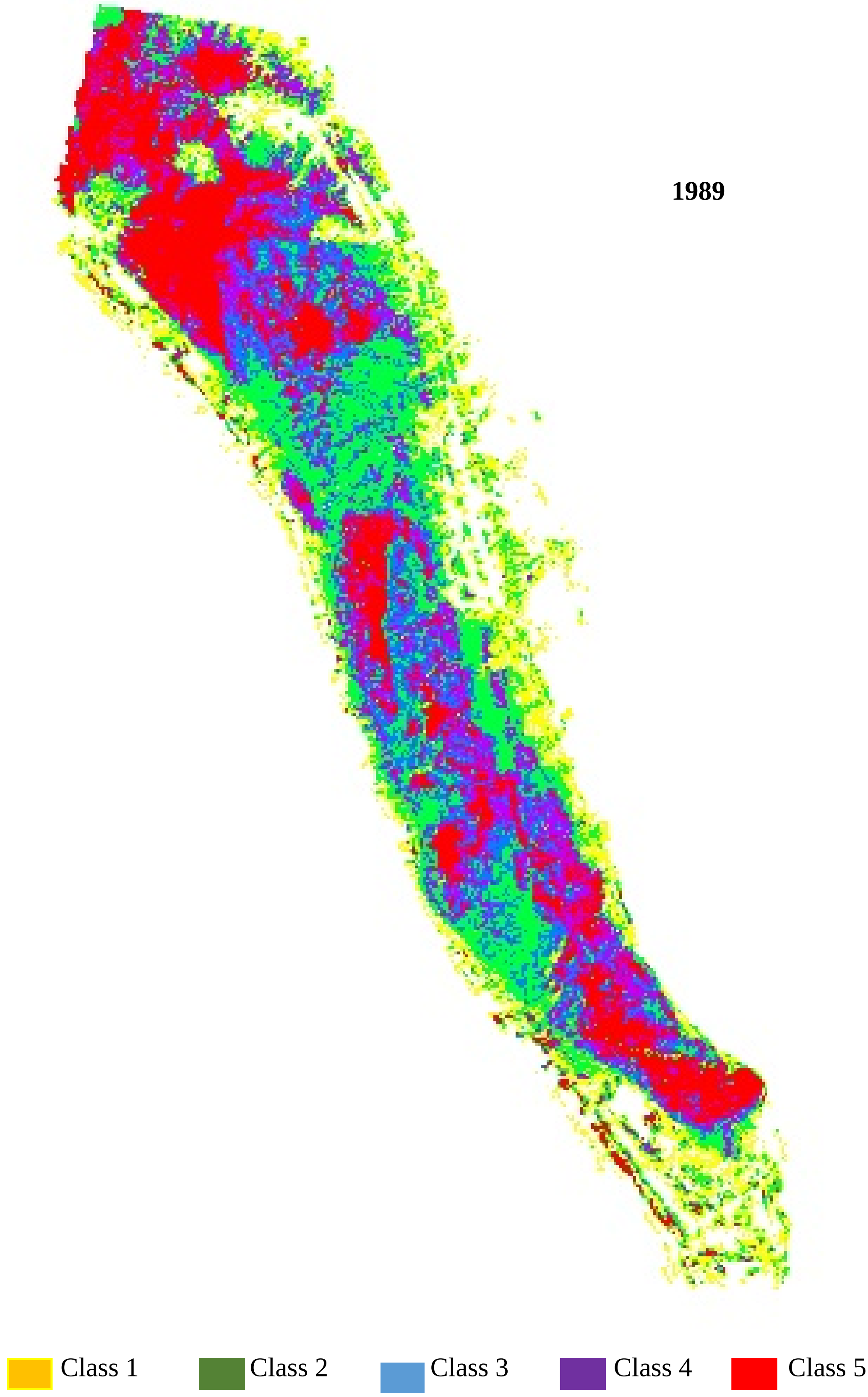
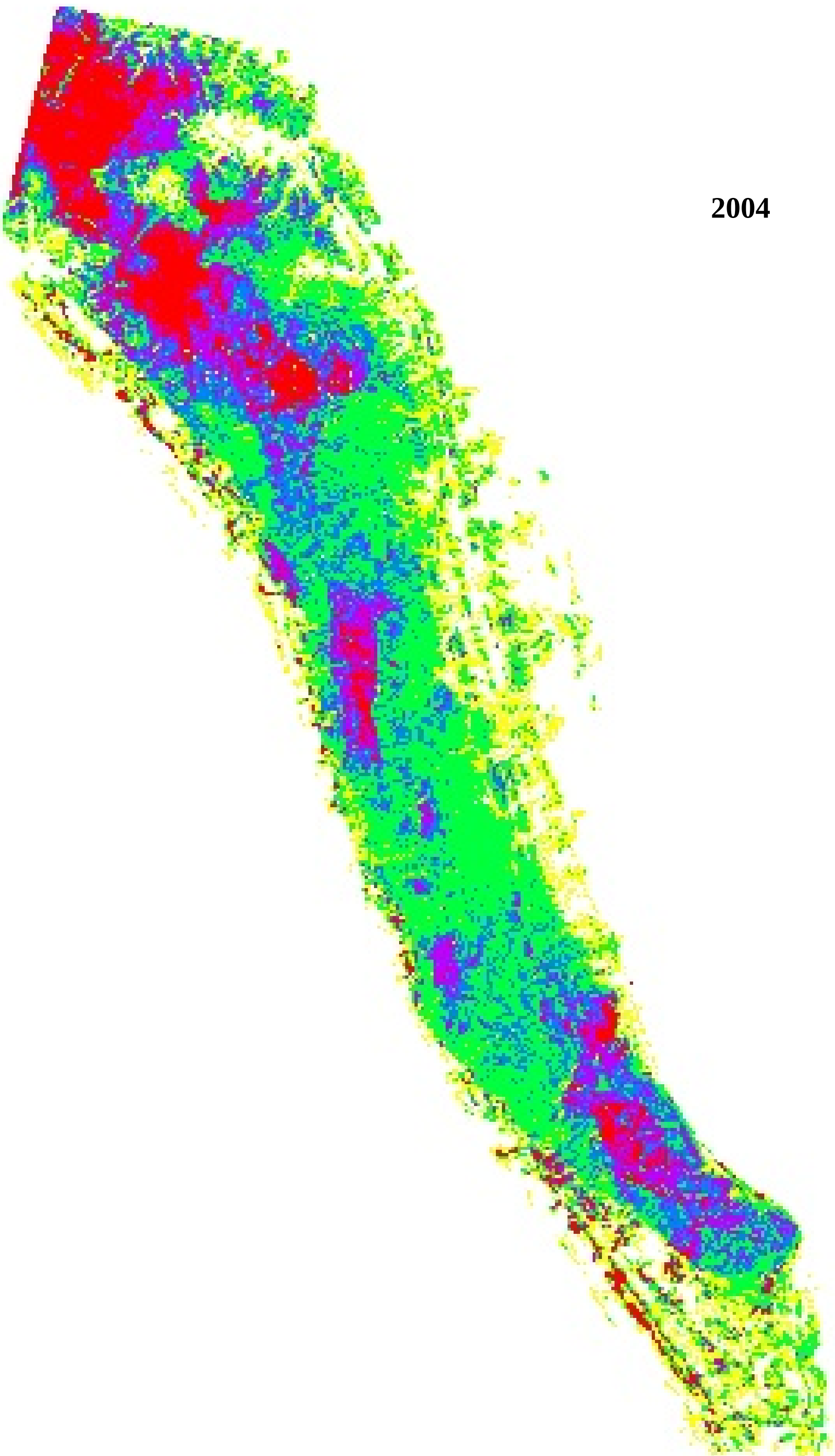


Figure 2.3 Land Coverage of the study area in 1989



Class 1 Class 2 Class 3 Class 4 Class 5

Figure 2.4 Land Coverage of the study area in 2004

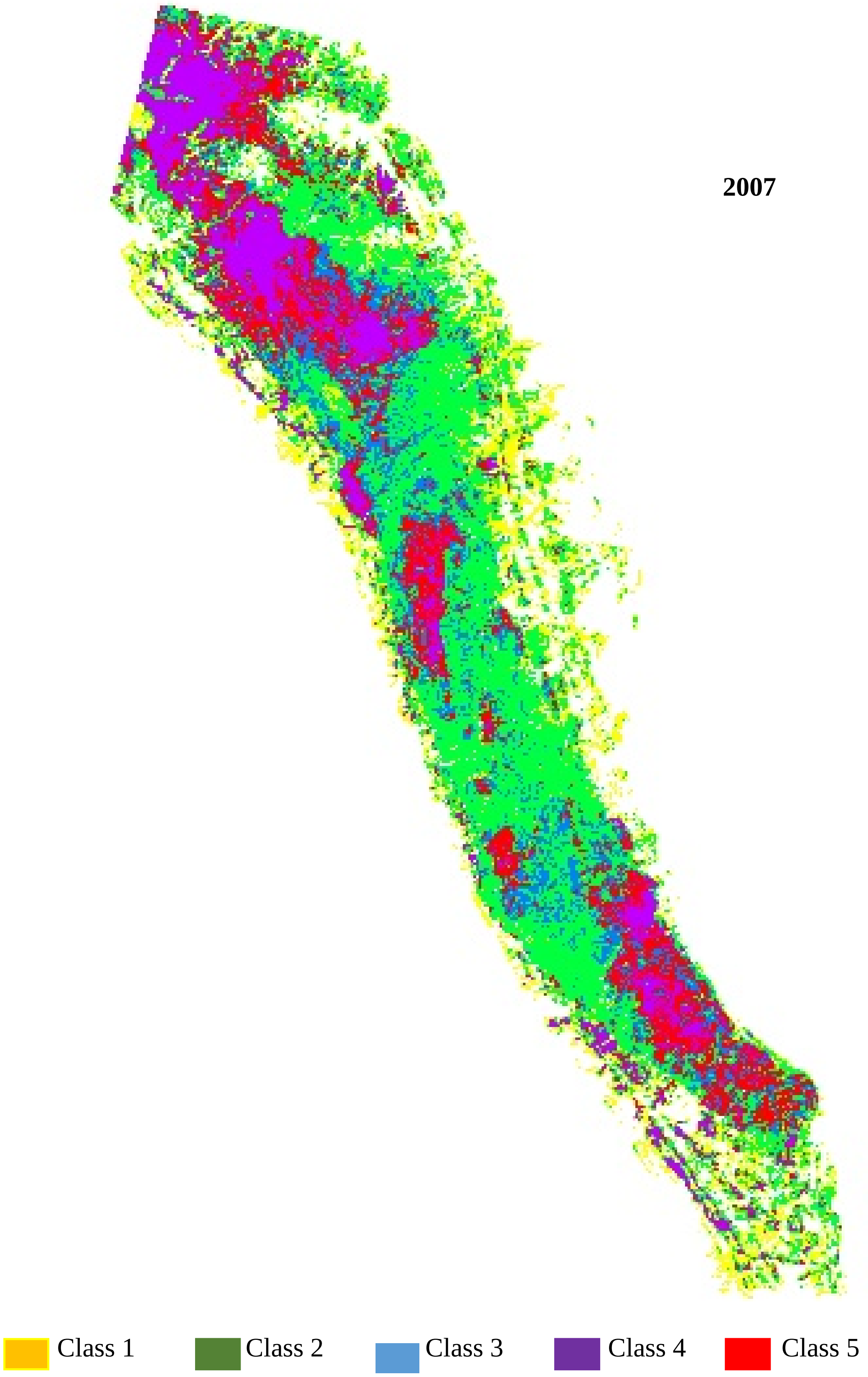


Figure 2.5 Land Coverage of the study area in 2007

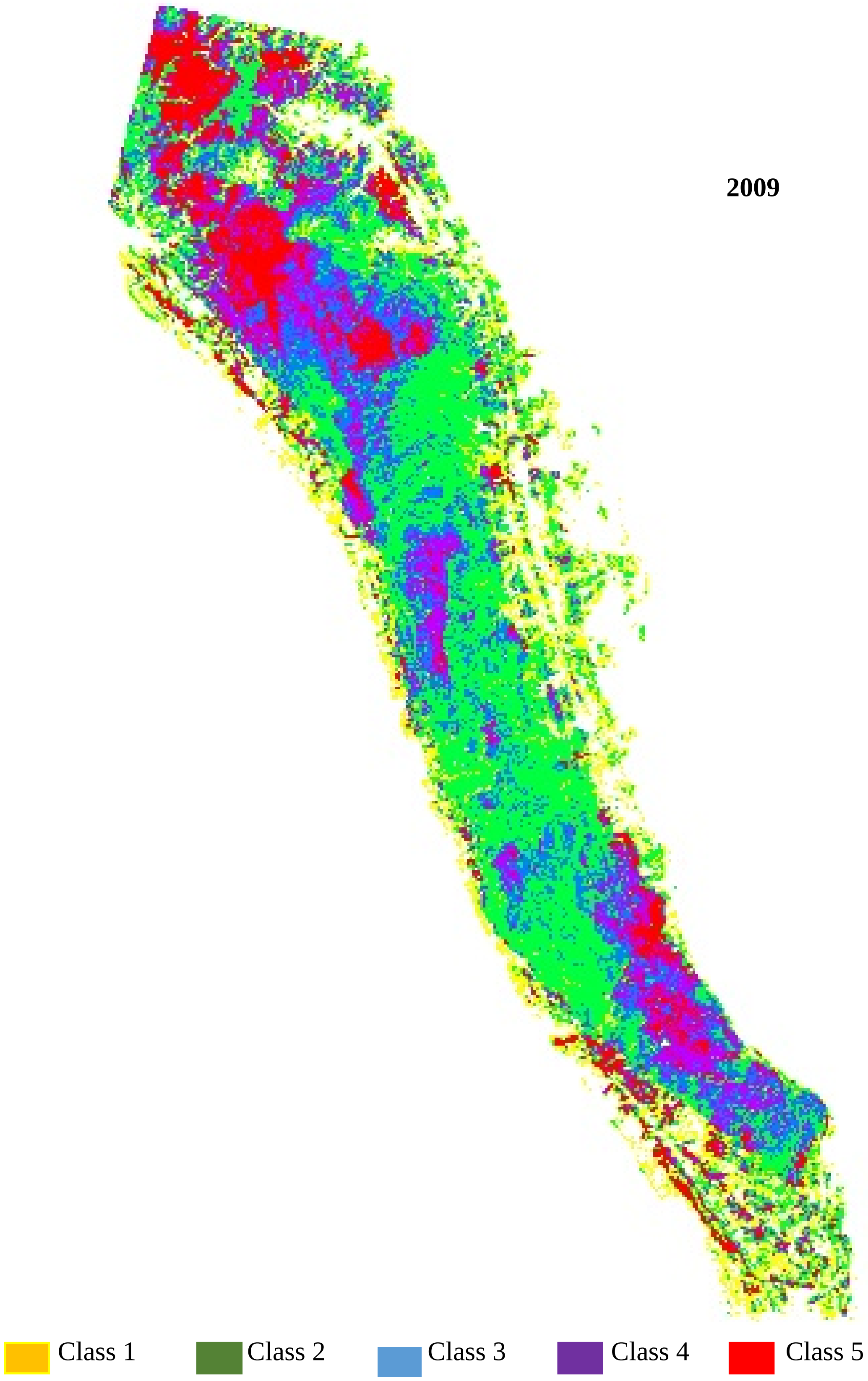


Figure 2.6 Land Coverage of the study area in 2009

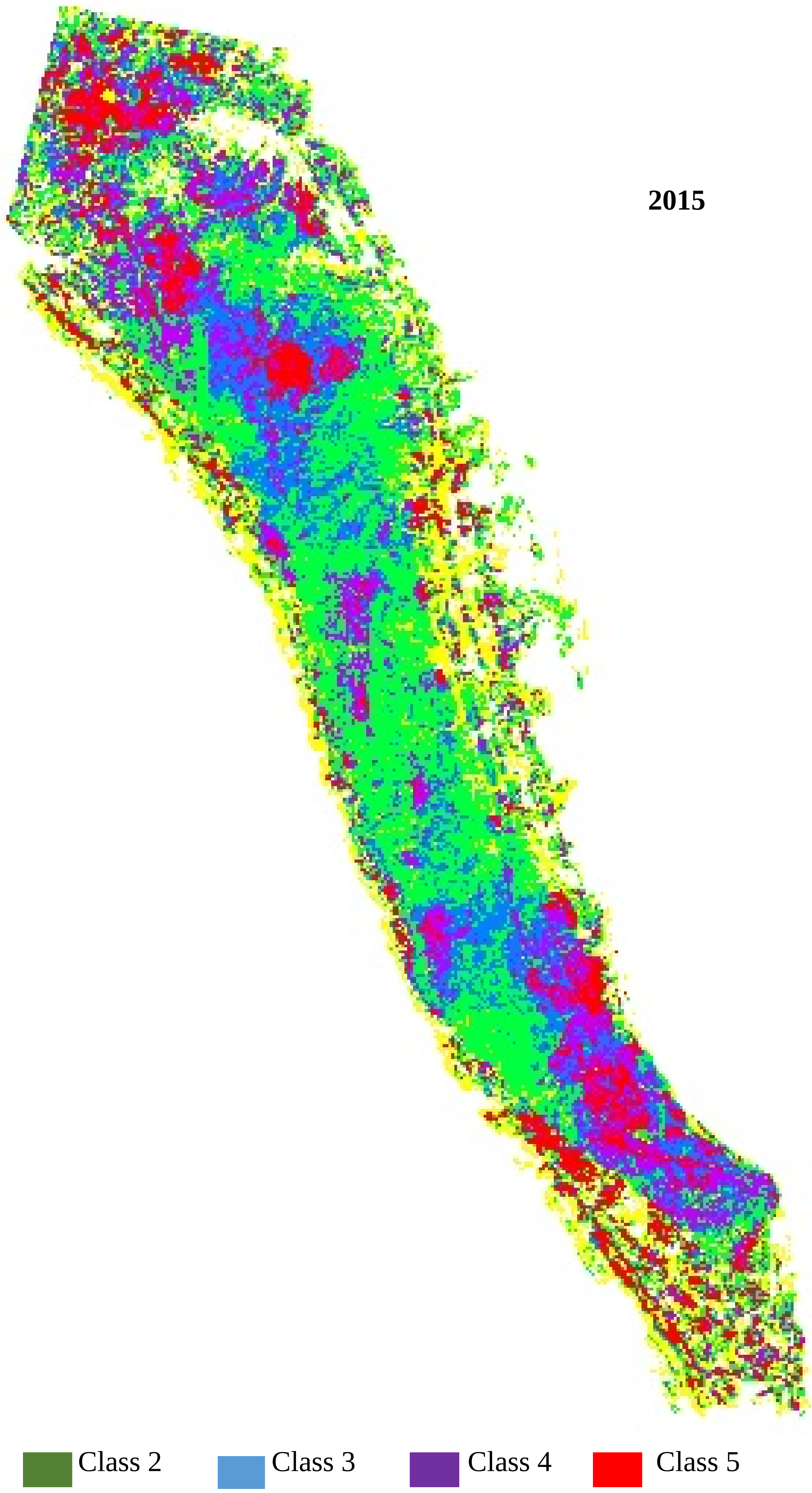


Figure 2.7 Land Coverage of the study area in 2015

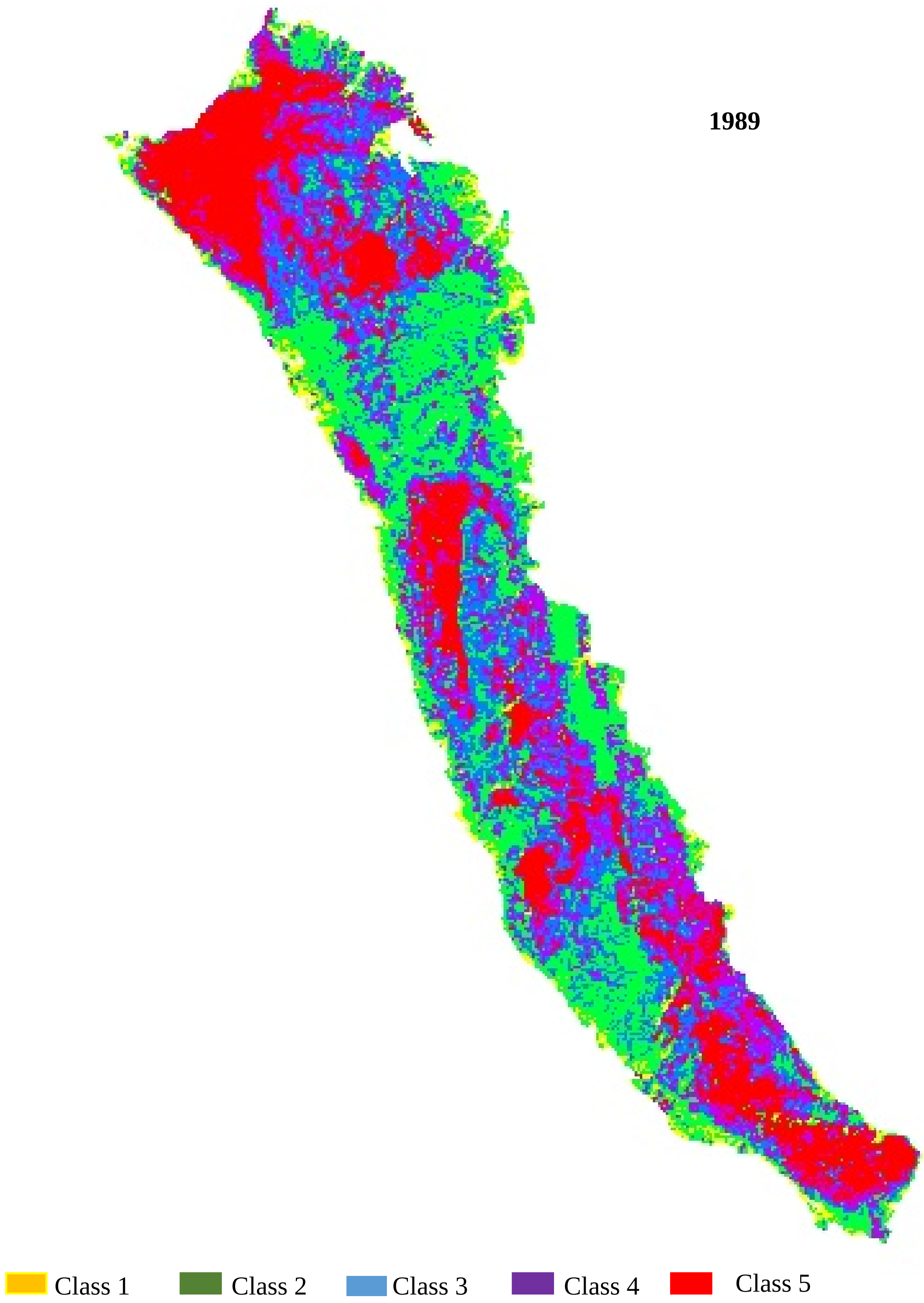


Figure 2.8 Land Coverage of the TWS in 1989

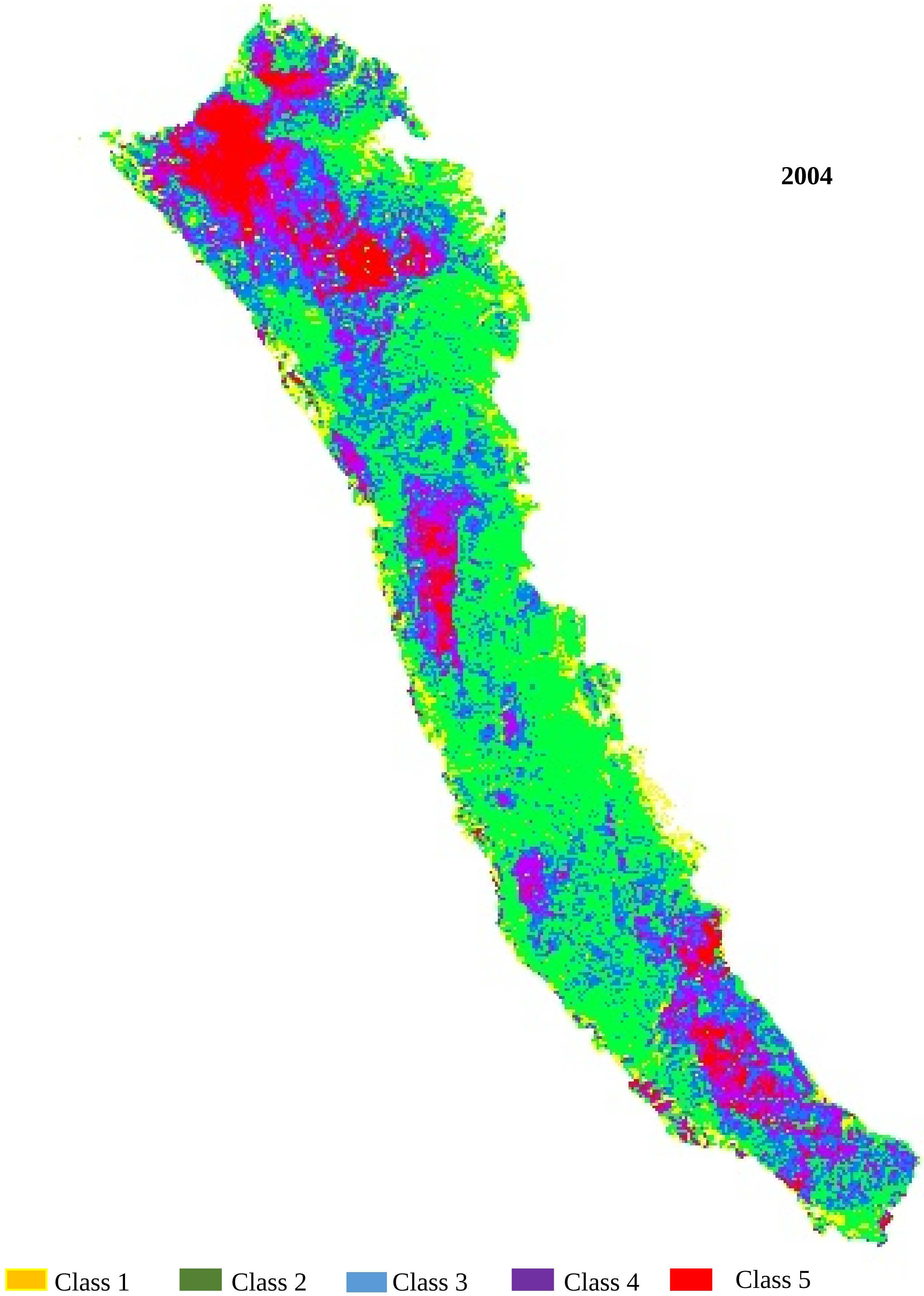


Figure 2.9 Land Coverage of the TWS in 2004

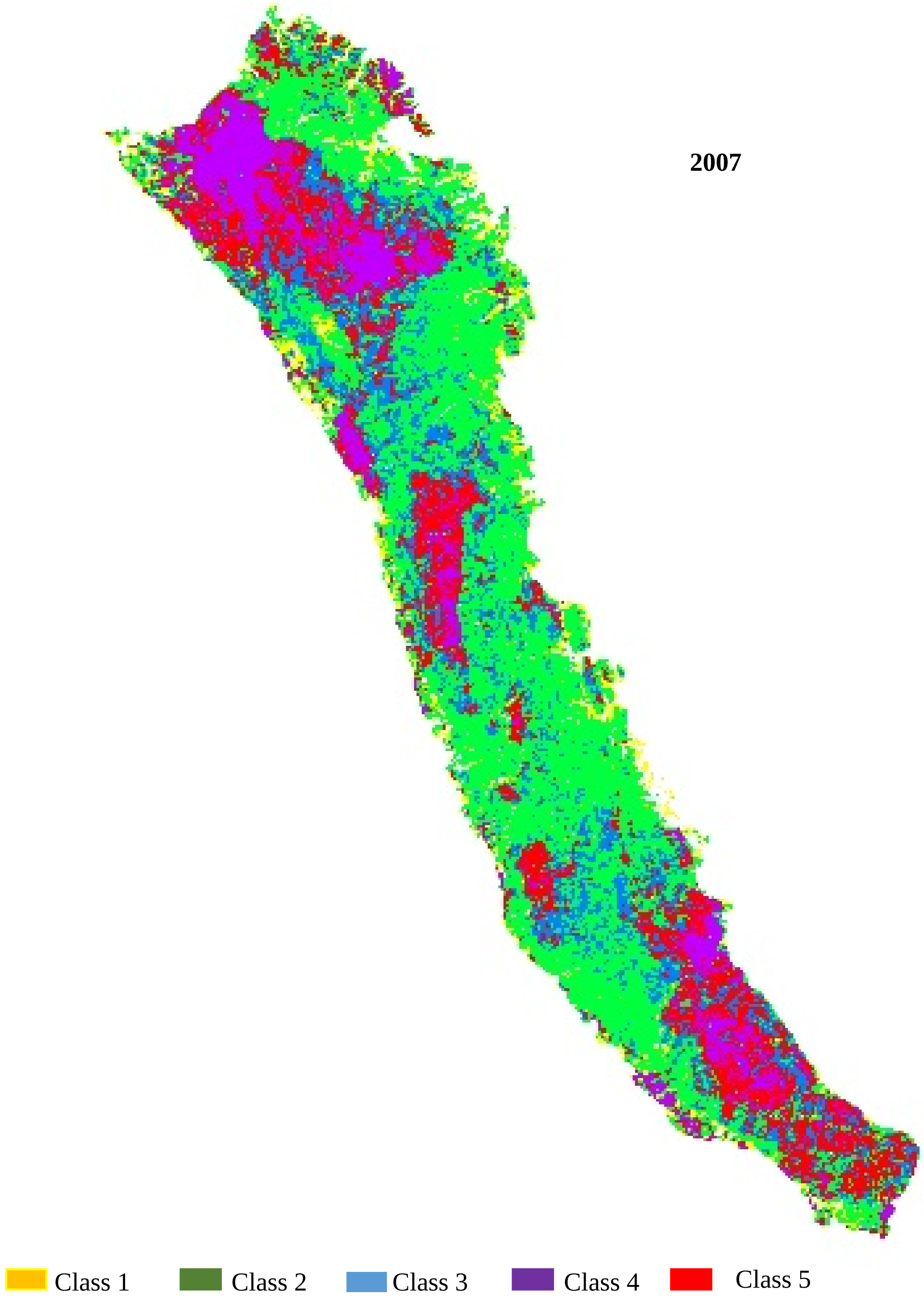


Figure 2.10 Land Coverage of the TWS in 2007

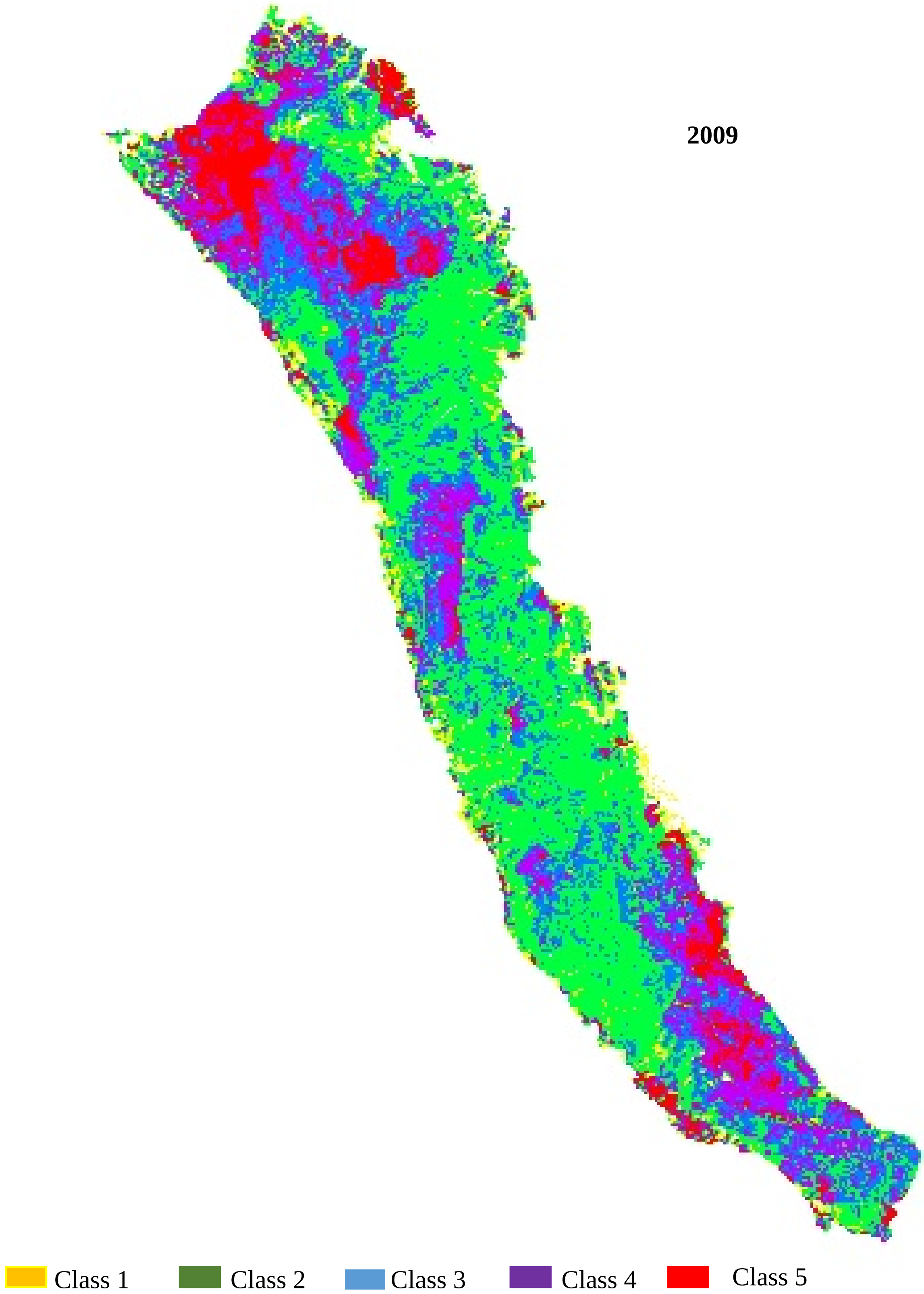


Figure 2.11 Land Coverage of the TWS in 2009

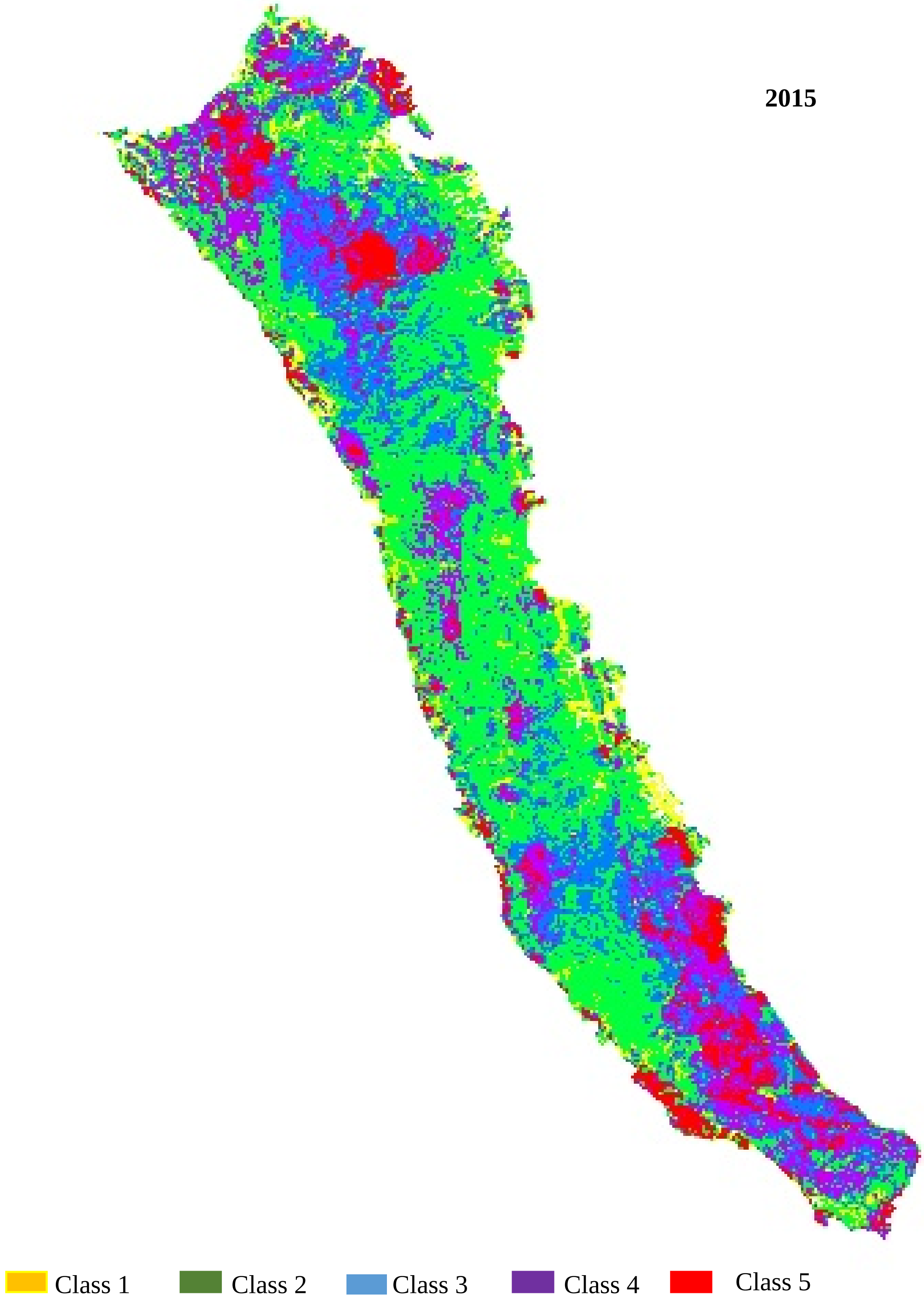
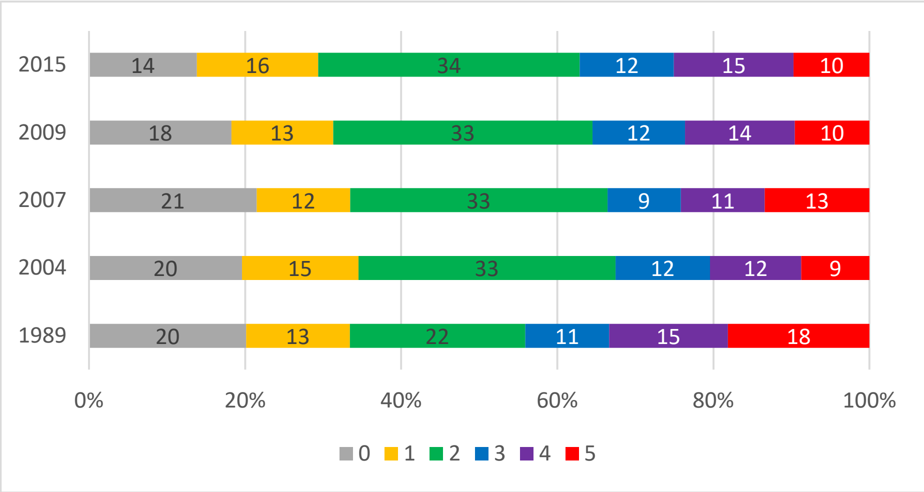
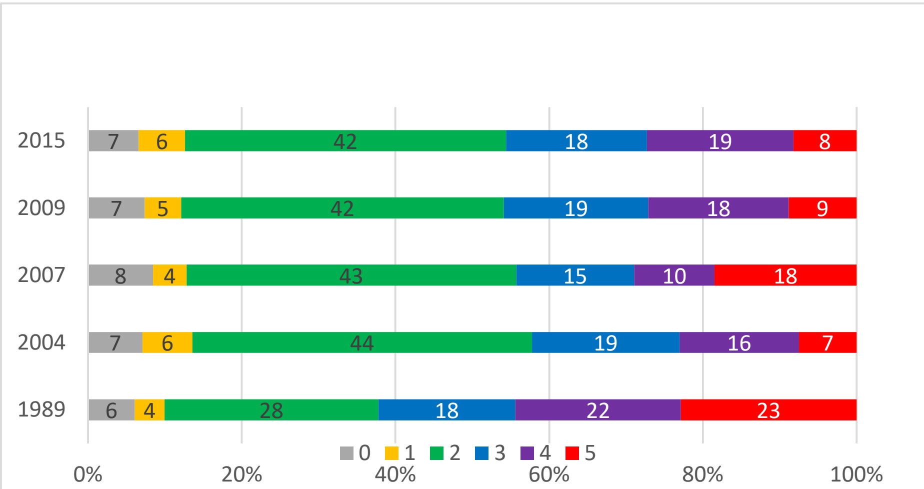


Figure 2.12 Land Coverage of the TWS in 2015



Land Coverage Change in the study area



Land Coverage Change Inside the TWS

Class 1 Class 2 Class 3 Class 4 Class 5

Figure 2.13 Land Coverage change in percentage of the study area and TWS (1989-2015)

2.3.2 Land Cover Classes and Ground Photos

The photos taken while walking through the trail are categorized into 6 groups (described is methodology section) based on the visual judgement. Each photo has GPS information and based on that GPS information the photos are plotted against the land classes based on NDVI. This allows to have a clearer vision of the forest land cover change in the study area. Based on the Table 2.2 the NDVI classes are defined.

Table 2.2 Land cover class plotted with photos

NDVI Class	**Ground Photo Numbers by Different Categories**						
	Grass Land with small bushes	*Short Bush*	*Tall Bushes*	*Bush area with Low tree coverage*	*Lean Forest*	*Dense Forest*	*Total*
1	12 *(50%)*	7 *(30%)*	3 *(13%)*	2 *(7%)*	-	-	24
2	56 *(22%)*	77 *(31%)*	89 *(36%)*	28 *(11%)*	-	-	250
3	13 *(16%)*	6 *(8%)*	16 *(20%)*	32 *(40%)*	13 *(16%)*		80
4	5 *(7%)*	5 *(7%)*	5 *(7%)*	4 *(6%)*	42 *(67%)*	4 *(6%)*	65
5	-	-	-	-	2 *(3%)*	94 *(97%)*	96
Total	86	95	113	66	57	98	515

Table 2.2 provides better understanding about the NDVI land classes. In case of Class 5, it contains 97% dense forests and 3% lean forests. Where Class 4 contains 73% forest areas. Class 3 is dominated by bush areas with very low coverage of trees (40%) following tall bush areas (20%). Class 2 is mainly composed of bush areas covering 66% photos of bush. Class 1 is dominated by small bushes and grass land. From the results presented in Table 2.2, five NDVI classes are defined the and use the new terms in the further part of the study. The classes can be defined as –

Figure 2.13 Grass land with small bushes

Figure 2.14 Short bushes

Figure 2.15 Tall bushes

Figure 2.16 Bushes with trees

Figure 2.17 Lean forest

Figure 2.18 Dense forest

a) Class 1: Farm & Grass land area
b) Class 2: Mixed area of Grass, Bush and low tree coverage
c) Class 3: Bush with low tree cover area
d) Class 4: Lean forest area
e) Class 5: Dense forest area

As, NDVI value less than 0.4 was in the class 0 categories in the analysis, this class will be termed as barren land area. But the barren land area can contain roads, small water bodies and large building compounds.

2.3.3 Deforestation Rate in Teknaf

Determining deforestation rate in the TWS is the main focus of this study. The following table represents the status of deforestation rate and land coverage change.

Table 2.3 Deforestation rate and land coverage change in the Teknaf Peninsula

Land Class		Deforestation rate/ land coverage change rate (%/year)	Land coverage change from 1989 – 2015 (%)
Study area	Class 0 (Barren)	-1.45	-31
	Class 1 (Farm & Grass Land)	0.60	17
	Class 2 (Mixed area)	1.54	49
	Class 3 (Bush with low tree)	0.44	12
	Class 4 (Lean Forest)	0.03	1
	Class 5 (Dense Forest)	-2.40	-46
TWS	Class 0 (Barren)	0.31	8
	Class 1 (Farm & Grass Land)	1.71	56
	Class 2 (Mixed area)	1.56	50
	Class 3 (Bush with low tree)	0.10	3
	Class 4 (Lean Forest)	-0.47	-11
	Class 5 (Dense Forest)	-3.94	-64

In Table 2.3, deforestation rate inside the TWS is -3.94 which is higher while considering the total study area (-2.40). From the period of time, 1989-2015, dense forest land (Class 5) decreased 64% inside the protected forest area and considering the total study area it decreased

46%. Mixed area increased nearly around 50% of both study areas. The land use change rate of Farm & Grass land was 1.71 inside the TWS, increasing by 56% from 1989 to 2015. While considering the total study area highest increase was found in mixed area (land coverage change rate 1.54) and inside the TWS highest increase was found in case of Farm& Grass land.

2.4 Discussion

Change in land coverage of the study area is very important considering the deforestation problem inside the protected forests of the tropical areas. From 1989 to 2015, dense forest area decreased 46% at a rate of -2.40 and considering the TWS only, dense forest decreased 64% at a higher rate of -3.94. Considering decrease pattern (figure 2.13), after 2004 there was an increase of forest area considering both inside TWS and total study area. This is due to the introduction of social forestry in the region and plantation of betel nuts. Similar study was done by CGEIS in 2011, where satellite images were analyzed from 1989 -2009 to determine deforestation around and inside the Teknaf Wildlife Sanctuary. Comparing with the previous findings, the CGEIS (2011) reported deforestation rate - 3.05 (calculated by Puyravaud equation using CGEIS, 2011 report) inside the TWS and our study found a slight higher rate of deforestation (-3.94) considering dense forest areas. Reducing the dense forest area by 64% inside a protected forest in the last two decades is a clear threat to the existence of the protected forest area. Also the establishment of PAs to stem the deforestation is clearly not working in this region. Deforestation inside the protected areas are common in Bangladesh. Deforestation rate in and around some PAs are presented below based on the data from a report published by CGESI, 2011.

Table 2.4 Deforestation rate in and around some protected areas of Bangladesh

Protected Areas	**Deforestation Rate (%/year)**	
	Inside PA	**Around PA**
Inani Bangabondhu NP	-3.07	-5.06
Medhakachapia NP	-1.12	2.20
Rema-Kalenga WS	-0.81	-1.13
Fasia Khali WS	0.02	-3.65
Sitakundu RF	3.31	1.34
TWS (Findings of the study)	***-3.94***	***-2.40***

NP = National Park, WS = Wildlife Sanctuary, RF = Reserve Forest (Source CGEIS, 2011)

Table 2.4 shows that Inani-Bangabandhu, Medhakachapia and Rema-Kelannga PAs are also losing forests inside the protected areas but in case of TWS the rate is higher than other protected areas. Also there is a trend, when deforestation occurs around the PAs also deforestation happens inside the PAs (Fasia Khali WS is showing opposite but the rate of forest change is very low, 0.02). Among the PAs presented in Table 2.4 Sitakundu RF is working properly with a positive rate of forest area change. Not only inside and around the PAs, according to FAO (2015) the deforestation rate of Bangladesh is -0.18.

Table 2.5 Deforestation rate in some Asia tropical countries (considering 1990-2015)

Country	**Deforestation Rate (%/Year)**
Bangladesh	-0.18
Cambodia	-1.26
Indonesia	-1.06
Malaysia	-0.03
Myanmar	-1.15

Source: FAO, 2015: Calculated using, Puyravaud (2003) formula

Not only the country, the deforestation rate inside the TWS is also higher than other Asian tropical countries. Table 2.5 presents deforestation rate of some Asian tropical countries where the highest deforestation rate was recorded in Cambodia (-1.26). From the above discussion it is clear that the deforestation rate inside and around the TWS significantly higher than other PAs in Bangladesh and also comparing with other tropical countries it is quite higher.

Land coverage changed inside the TWS noticeably between 1989 to 2015. Table 2.6 shows that land coverage percentage significantly changed in case of dense forest considering both inside and around the protected area. The high deforestation rate is the main cause of this deforestation. Another significant change was seen in mixed area, 14% inside the TWS and 12% around the TWS. Mixed area is mainly bush and shrub areas with very few trees. From the land coverage change pattern, the total scenario can be generalized to a point that forest lands are converting to bush and shrub lands. Also the high rate of deforestation indicates that very few areas were under afforestation. Also - 6 % change in barren area in and around the TWS indicates the increase of anthropogenic activities in the Peninsula which is very much related to the high deforestation rate, which will be investigated in the further chapters.

Table 2.6 Land cover change inside and around TWS (% in 1989 vs % 2015)

Land Class	Land coverage Change (% in 1989 vs % 2015)	
	Inside TWS	In & Around TWS
Class 0 (Barren)	-1 %	-6 %
Class 1 (Farm & Grass Land)	+2 %	+3 %
Class 2 (Mixed area)	+14 %	+12 %
Class 3 (Bush with low tree)	0 %	+1 %
Class 4 (Lean Forest)	-3 %	0 %
Class 5 (Dense Forest)	-15 %	- 8 %

2.5 Conclusion & Summary

The aim of this chapter was to the describe the land coverage change pattern and determine the deforestation rate in the protected forest area called Teknaf Wildlife Sanctuary in the coastal region of Bangladesh generally known as the Teknaf Peninsula. The deforestation rate was found -2.40 in & around the protected area and a higher deforestation rate of -3.94 was found inside the protected forest area. The deforestation rate found inside the TWS was higher than the nation deforestation rate and also greater than other Asian tropical country deforestation. The reflection of high deforestation rate was also visible in land coverage change. Dense forest area inside the TWS decreased 64 % compared to the forest area in 1989, mixed area increased 50% and, Grass and Farm land increased 56% inside the TWS from 1989 to 2015. The next chapters will deal with the drivers of deforestation in aim to investigate the causes of deforestation in the Teknaf Peninsula.

CHPATER 3. PEOPLE, SETTLEMENT AND DEFORESTATION

3.1 Introduction and Objectives

Proximate causes for deforestation are commonly grouped into three categories and the expansion of infrastructure is one of them (Lambin 1994; Kaimowitz and Angelsen 1998; Contreras-Hermosilla 2000). The expansion of infrastructure includes settlement expansion (Geist and Lambin, 2001) containing urban settlements and rural settlements expansion. Settlement expansion is one of the major causes of deforestation in the Teknaf Peninsula. Settlement and homestead vegetation area (land coverage type containing settlement areas with homestead gardens) coverage has increased 53% from 1989 inside the TWS (CGEIS 2011). This chapter will deal with the settlement expansion as a deforestation driver in Teknaf. The population in Teknaf is increasing and also people are migrating from other areas to Teknaf to meet their livelihood. Although deforestation causes are time and site specific, population growth is a principal factor leading to deforestation in some cases (e.g. Tekle and Hedlund 2000; Zeleke and Hurni 2000; Dessie and Carl 2008; Bishaw 2009). In Teknaf Upazila, increased population is resulting in settlement expansion which is causing deforestation. Our survey conducted in 2015 found 5195 households inside the protected forest areas in Teknaf.

This chapter aims to describe the expansion of settlement as a proximate cause of deforestation. In Teknaf Upazila there are many households inside the forest. During the British colonization, the Government gave permission to some local people to live inside the forest and they are known as forest villagers. But now-a-days due to poor regulation and lack of man power in the forest department many local people are building new houses inside the forest. Also people from outside Teknaf are coming here to build houses inside the forest. To describe and explore the settlement and its impact on forest it is important to understand the people and the causes of their encroachment. Considering the above circumstances this chapter pursues its objectives as follows-

a) To describe the socio-economic profile of the encroaches and explore the differences with between encroachers and non-encroachers
b) To explore the factors responsible for the encroachment of the people
c) To investigate the impact of encroachment on the forests

3.2 Methodology

3.2.1 Study Area

The previous chapter focused on the location of Teknaf Peninsula and the protected forest area known as TWS. This section is dealing with the Teknaf Upazila unit and its people. From the previous chapter it is stated that, Teknaf upazila (an upazila is an administrative unit of local government in Bangladesh) is located in Cox`s Bazaar District in the southeastern part of Bangladesh.

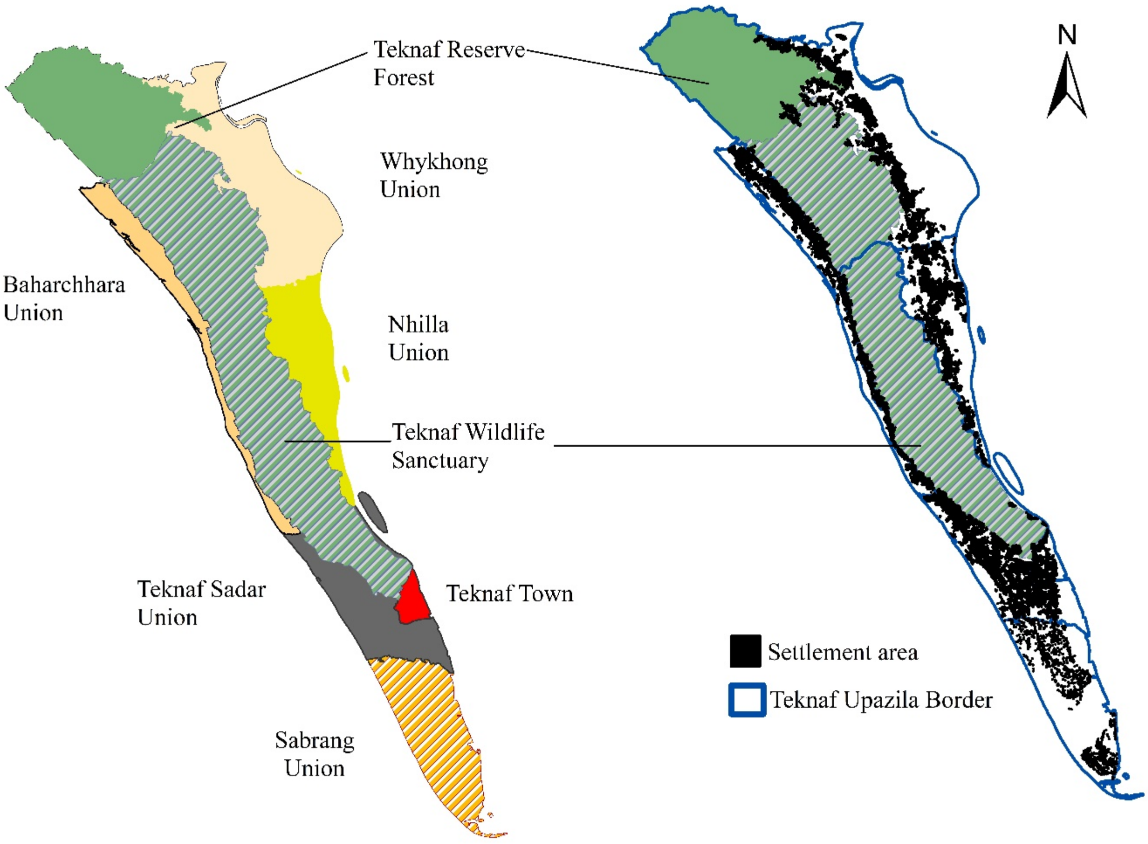


Figure 3.1: Teknaf Upazila: Forest and settlements

Teknaf Upazila and Teknaf Peninsula are considered to be generally the same place, where the peninsula is indicating the entire area and the upazila is an administrative unit. Teknaf Upazila comprises six unions, 12 mouzas (several villages typically form a single mouza), and one pourashava (pourashava is the town or center of the upazila and termed as Teknaf town also) comprising 147 villages. Among the six unions, one is a small island known as St. Martin which is not considered as part of the study area. As a result, the study area contains five Unions (Baharchhara, Nhila, Teknaf sadar, Whykhong and Sabrang) and Teknaf Pourashava also known as Teknaf town (Figure 3.1). Based on the objectives, some part of the study area is excluded to perform analysis more purposefully i.e. Sabrang union is far from forest without any encroachers there, so Sabrang is excluded from analysis while considering encroachment issues. The total forest area of Teknaf peninsula is nearly 15,000 ha but among that forest area 11,615 are known as TWS and the remain 3000-5000 ha forest area is documented as government forest but that area is not under the TWS. In this study when refering the term TWS or protected forest area, it means the protected forest area listed as Teknaf Wildlife Sanctuary but when the term local forests or Teknaf Peninsula forests is referred, it means the total 15,000 ha forest area. While analyzing encroachers or deforestation study the forest boundary of 15,000 ha is considered rather than only considering the TWS. But when discussing about the protected areas it is referred to TWS.

Teknaf Upazila has a population of 265,717 distributed over an area of 388.68 km.^{2} The literacy rate in this area is 19.72%, which is well below the national average (51.8%). The area exhibits diverse land types, with wet, forested, hilly, coastal, and flat land found together within a narrow stretch of land. The two main agricultural crops cultivated in the area are the *Aman* rice variety and betel leaf. A locality's climate is one of the factors determining the type and density of vegetation. This area is in subtropical climate characterized by a relatively high amount of annual rainfall (more than 4000 mm) and an average temperature of 25.5 ºC (BBS, 2011). The physiographic and climatic conditions of the area are conducive to the growth of forests. At one time, forests were dominant. However, although 41% of the area comprises forests, these are highly degraded as a result of extensive anthropogenic activities, as well as natural phenomena. The area is also characterized by cultural variability with settlements of Bengalis, Chakmas, and Rohingyas living in Teknaf upazila. Collection of forest resources, fishing, farming, business, and labor are the main livelihood activities in the area.

3.2.2 Data and Methods

3.2.2.1 Teknaf Upazila: People and Settlement

Data are compiled from a recent survey conducted in Teknaf upazila by the research team from Kyushu University with the help of local research assistants, which also profiled the population of the study area. The survey included counting and collecting the locational information of all the households of Teknaf upazila (except the island under Teknaf upazila named St. Martin, because the mainland area is considered for the study). The village lists were obtained from the Bangladesh Bureau of Statistics (BBS), which is the centralized official bureau responsible for collecting and disseminating demographic, economic, and other relevant statistics about the country was considered as the primary database to follow. The present study also includes the direct interviews conducted with 10% of the households to obtain socioeconomic data of the local people. A systematic sampling approach was applied, selecting every tenth household to be interviewed while counting all households in Teknaf Upazila with GPS devices. According to a report released by the BBS (2011), there are 153 villages, with a total of nearly 46,000 households in Teknaf upazila. During the survey conducted from December 2015 to May 2016, 147 villages (Appendix 1) were idenfied comprising 57,404 households. Locational data on households were collected using Garmin GPSMAP 62 and 64 devices. Household heads were interviewed using a structured interview schedule containing questions on topics such as age, annual income, family size, education, and fuelwood use. After managing and compiling all the data, a database called Teknaf Database was developed. This study uses this Teknaf Database further to describe the socio economic profiles of different categories of people, identifying and describing the encroachers and also developing statistical models to explore the factors having impact on different deforestation drivers. Mean comparison will be done between the socio-economic profile of the people living inside and outside the forest by performing one-way ANOVA test.

3.2.2.2 Factors Impacting Deforestation Drivers

In order to assess the significance of the socioeconomic determinants to deforestation drivers (this chapter, it is forest encroachment), a binary logistic regression model is developed using the entry procedure. This logistic regression model is applied to examine a range of socio-economic factors that is considered to potentially influence the likelihood of a deforestation driver to occur. Encroachment inside the forest in this study is modeled as a binary decision whereby a household either located inside or outside the forest. In this case of binary decision, the dependent variable is a discrete dummy variable (Forest encroachment =1; and living outside the forest = 0). The choice of the model is based on its ability to perform better with discrete choice studies (McFadden, 1974 and Judge, et al, 1985). Logistic regression model has been used successfully in land use change and deforestation studies (Ludeke et al., 1990; Mertens and Lambin, 2000; Serneels and Lambin, 2001; Etter et al., 2006; Ellis and Porter-Bolland, 2008). Logistic regression allows to evaluate the odds/probability of membership in one of the groups based on the combination of the independent variables (Tabachnick and Fidell, 2007).

The logistic model predicts the logit of the response variable (Y, forest encroachment) from the explanatory variables (X, socioeconomic factors). The logit is the natural logarithm (ln) of odds of Y, and odds are ratios of probabilities (pi) of Y happening to probabilities (1−pi) of Y not happening. The logistic model is specified as:

$$Pi = \frac{e^{(b0+b1x1+\cdots bvxv)}}{1+e^{(b0+b1x1+\cdots bvxv)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

The equation used to estimate the coefficients is

$$\text{In (odds)} = \text{In } [\frac{pi}{1-pi}] = b_0 + b_1x_1 + \ldots b_v\, x_v \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where Pi is the predicted probability of the event which is coded with 1 (forest encroachment) rather than with 0 (no forest encroachment), 1- Pi is the predicted probability of no forest encroachment, and the X's are predictor variables while the b's represent the coefficients. The quantity $P_i/ (1 – P_i)$ is the odds ratio. In fact, equation 2 expresses the logit (log odds) as a linear function of the independent factors (X_s). Equation 2 allows for the interpretation of the logit weights for variables in the same way as in linear regressions. For example, the variable weights refer to the degree to which the probability of encroaching would change with a one-year change in schooling year of the respondent.

The model contains 12 explanatory variables which are presented in Table 3.1. Dichotomous explanatory variables (gender and paan farming status) were coded by assigning 0 to one case and 1 to the other. For multinomial explanatory variables, coding was done by assigning 1 to the lowest number of cases and sequentially higher values for others. Before performing the logistic regression, multivariate correlation analysis was applied to check for co-linearity between the explanatory variables. High collinearity between the independent variables poses a statistical problem in logistic regression models (Hosmer and Lemeshow, 2000) and the collinearity between the independent variables were checked before the statistical analysis. The dependent variable is encroachment. Every homestead inside the forest boundary is considered as encroacher. Despite the forest department has given permission to some homestead to live inside the forest (locally known as forest villager), all households including forest villagers are considered as encroachers.

Table3.1: Definition of explanatory variables of the Binary logistic model

Variables (x_i)	**Unit of account (Definition)**
Age	Years in number (Age of household head)
Education	Years in number (Schooling year of the household head)
Family Size	Number of family members
Household Area	Decimals of hectares in number
Length of residence	Years in number (Years of the members living in the house)
Union [a]	1 - Baharchhara, 2 – Nhila, 3 – Teknaf Sadar, 4 - Whykhong
House Type [b]	1 – Kacha (including Jhupri and Mud house), 2- Paka (Brick buildings)
Occupation [c]	1 – Abroad, 2 – Business, 3 – Farming, 4 – Fishing, 5 - Labor
Pan farming status	1 – Yes, 0 - No
Annual income	Thousand BDT in Number
Collecting fuelwood	1 – Yes, 0 – No
Fuelwood expense	% of Total income in terms of fuelwood value

[a] *For the variable Union, Teknaf PS was considered the reference category*
[b] *For the variable House type, others was considered as the reference category*
[c] *For the variable Occupation, others was considered as the reference category*

For interpreting the model, the odds ratios of significant parameters were used (Serneels and Lambin, 2001). Odds ratios >1 indicate increased and <1 indicate decreased likelihood of the occurrence of the event, which is forest encroachment for this model (Tabachnick and Fidell, 2007). Hosmer and Lemeshow goodness-of-fit test, Cox & Snell value and Nagelkerke value were used to determine the significance level of the model. In this statistical model, five Unions containing of Teknaf Upazila namely Baharchhara, Nhila, Whykhong, Tekanf sadar and Teknaf PS covering 101 villages and 4622 households were considered as the data set. The same model will be used to analyze other deforestation drivers i.e. agricultural expansion and wood resource extraction (in chapter 4 & 5 receptively).

3.2.2.3 Settlement and Deforestation

Chapter 2, analyzed the land coverage change from 1989 to 2015 in Teknaf Peninsula. In this chapter the impact of settlements on the forest is described by using the land coverage change data of chapter 2. From Teknaf database (described above) the location information of every household in the Teknaf Upazila is obtained.

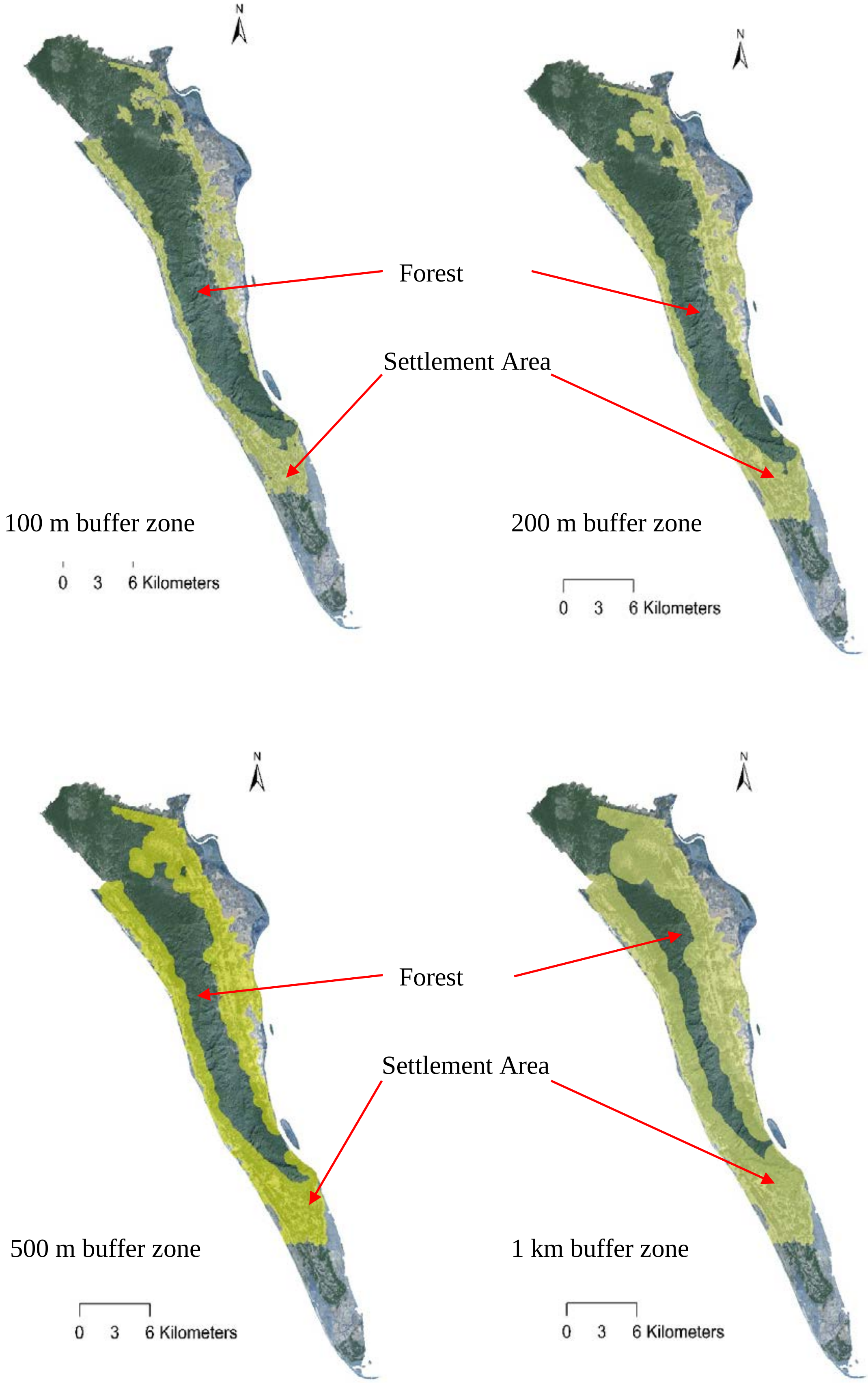


Figure 3.2: Impact of settlement on Forests

Using the location information of all homesteads in the considered study area, buffer zones of different diameters i.e. 100 m, 200m, 500m and 1 km is created using ArcGIS software and will describe the land coverage change inside and outside the buffer zones. Here buffer zone refers to the area which is created by using the buffer program of ArcGIS which shows a calculated area created by considering a center point (here homestead) and a given diameter. The term buffer zone is similar as the conventional term "Buffer Area" in forest management but due to the outcome of the program called buffer, the designated area was termed as buffer zone and more specifically Arcmap buffer zone. Figure 3.2 is showing the different Arcmap buffer zones. The area inside the Arcmap buffer zone (yellow color) is termed as settlement area and area remaining is known as forest area. When the Arcmap buffer zone becomes bigger the settlement area increases and the forest area decreases. In case of 1 km buffer zone, the settlement area is 15,698 ha and the forest area is 4879 ha. On contrary, considering 50 m Arcmap buffer zone, forest area is 15655 ha and buffer area is 4922 ha. While considering the Arcmap buffer zone, the protected forest boundary is not considered to determine the forest area. Forest area is described as the remaining area outside the Arcmap buffer zone. The land coverage change is described considering the same study area presented in figure 2.1 where the beaches, rivers and salt fields were excluded from the study. The total area of analysis is 20, 511 ha areas.

By analyzing the land cover change in forest area and settlement area considering different Arcmap buffer zones the difference of the land cover change in the respective area is described. While the settlement area increases with the increase of Arcmap buffer zone, the land decreases in the forest area. All the findings are described based on the percentage of the respective area. If there are any different trends visible in the land coverage change from 1989 to 2015 in different land classes considering different Arcmap buffer zone in settlement and forest area than it can be described by the impact of settlements on land coverage change. For example, while increasing the Acrmap buffer zone for settlement area if the land coverage percentage in the forest land class is in a decreasing trend then it is clear that near the households, deforestation is not happening. This study analyzed all the land classes and their changes considering different Arcmap buffer zones in order to understand and describe the effect of settlements on deforestation.

3.3 Results

3.3.1 Settlement and Forest

This section of the chapter mainly describes the people and settlement around the forest. Table 3.2 is showing the socio economic profile of the people of Teknaf Upazila. From here it is stated that the average family size in Teknaf Upazila is 6.2 and Baharchhara Union has the highest family size of 6.5 and Teknaf pourashava has the lowest of 5.9. The average schooling year is 1.9 years. The mean duration of settlements are 26 years with an average of 0.12 ha of land properties per household.

Table 3.2 Union wise socio-economic profile of Teknaf Upazila

	Baharchhara	Nhilla	Whykhong	Teknaf Sadar	Teknaf town	Sabrang	Teknaf upazila
Number of houses	8674	10605	12185	11010	3622	11308	57404
Mean duration of settlement (year)	21	25	19	31	28	28	26
Mean age of household head (year)	40	41	41	40	40	39	40
Mean family size (2016)	6.5	6.1	6.0	6.1	5.9	6.2	6.1
Mean education (Schooling year)	1.7	2.5	2.2	2.0	2.0	1.2	1.9
Average annual income (000 BDT)	236	206	200	170	153	186	195
Mean land property (decimal of ha)	0.20	0.10	0.13	0.11	0.02	0.08	0.12

From the household survey, which also covered livelihood options, it is found that household members are engaged in several livelihood activities. However, the respondents were asked to specify their main livelihood activities and household annual incomes. Table 3.3 shows the numbers of households within each union engaged in different livelihood activities. The five main livelihood options in Teknaf is found to be farming, *pan* farming (*pan* is the local term for betel leaf), fishing, employment abroad, and business. Other livelihood options include services, fuelwood collection, and jobs like teaching and salesmen. Table 3.3 shows that incomes derived from employment abroad and business are higher than those derived from natural resource-based livelihoods such as farming and fishing.

Table 3.3 Union wise livelihood options in the Teknaf Upazila

Number of households (Avg. Income in 000 BDT)	Baharchhara	Nhilla	Whykhong	Teknaf Sadar	Teknaf pourashava	Sabrang	Teknaf upazila
Farming (Avg. income 119)	52	129	218	53	0	68	520
Betel leaf farming (Avg. income 130)	163	2	1	126	1	81	374
Fishing (Avg. income 138)	154	48	30	153	10	231	626
Abroad (Avg. income 292)	110	127	126	100	32	207	702
Business (Avg. income 174)	160	216	202	211	127	200	1116
Others (Avg. income 154)	89	285	201	235	118	171	1117

The comparison between the people living inside and outside the forest also gives an idea about the impact of forest on the local peoples' lives. Table 3.4 shows the socio-economic profile of the encroachers and non-encroachers. Table 3.4 shows that in the forest there are 623 households and all these households are encroachers.

Table 3.4 Socio-economic profile of people living inside and outside the forest

	Encroacher	Non-Encroacher	Teknaf upazila
Number of houses	623	5146	57404
Mean duration of settlement (year)	21	28	26
Mean age of household head (year)	40	40	40
Mean family size (2016)	6.1	6.2	6.1
Mean education (Schooling year)	1.6	2.0	1.9
Average annual income (000 BDT)	163	199	195
Mean land property (ha)	0.15	0.11	0.12
Mean homestead area (ha)	0.09	0.06	0.06

Among these households few are legal (forest villagers) and the rest are illegal taking the advantage of loose restriction from the authority. More interestingly, the homestead size and land property area both are larger inside the forest comparing the households outside the forest. To compare the means of encroachers and non-encroachers, one-way ANOVA test is done and the results are presented in Table 3.5.

Table 3.5 ANOVA test to compare means between encroachers and non-encroachers

	F - Value	P value
Mean duration of settlement (year)	49.842	0.000**
Mean age of household head (year)	2.328	0.126
Mean family size (2016)	1.073	0.300
Mean education (Schooling year)	6.737	0.009**
Average annual income (000 BDT)	13.595	0.000**
Mean land property (ha)	7.332	0.007**
Mean homestead area (ha)	81.711	0.000**

** 1% level of significance

Table 3.5 shows that there is significant difference in major socio-economic aspects except age of household head and family size. Apart from these two, significant difference between encroachers and non-encroachers are seen in other aspects. The encroachers have comparatively lower means in the case of education, income and settlement duration, and higher means in homestead area, land property comparing to the non-encroachers.

3.3.2 Factors Effecting Encroachment

A binary logistic regression model is developed to explore the key determinants of the likelihood of the households of Teknaf Peninsula to encroach the forests. Overall assessment of the model was significant ($p < 0.001$) and the Hosmer & Lemeshow goodness-to-fit test showed adequate fit of the model to the data, with an overall 86.9% correct prediction. The determinant factors of encroachment is found to be duration of living, union of living, house type, occupation, fuelwood collection and use, and *paan* cultivation (Table 3.6). The logistic regression model showes that the duration of living is significantly correlated with the likelihood of encroachment ($p < 0.01$; Table 3.6). One unit (year) increase in the duration of living decreases the odds (Odds Ratio 0.887) of encroachment by approximately 11%. According to the model, the people living in Baharchhara have 2.2 times more likelihood to live inside the forest and people living in Nhila have 75% less chance to live inside the forest. House type also influences the encroachment, when living in a Kacha house there are 2.3 times more possibility to encroach inside the forest. Among the occupations, fishermen have 50% less chance to encroach the forest while labors have 22% more chance to live inside the forest.

Paan farmers and fuelwood collectors have 2.2 and 3.7 times more likelihood to encroach the forest. Also fuelwood usage has impact on the encroachment, with each unit increase of fuelwood usage, the chance of encroachment increased by nearly 3%.

3.3.3 Settlement impact on Forest

Here the impact of settlements on the forest is described. From chapter 2, the forests of Teknaf Peninsula were categorized into six land classes namely; Barren, Farm & Grass, Mixed, Bush with low trees, Lean forest and Dense forest. Arcmap buffer zones of different diameters is created and based on the Arcmap buffer zone the study area is divided into forest area and settlement area. While considering the different Arcmap buffer zones, the area coverage of different land classes changed from 1989 to 2015 both in the settlement area and forest area. Describing the land class change trend of settlement area and forest area considering different Arcmap buffer zones the impact of settlement on forests is described. From figure 3.3, in case of forest area, forest land class (Class 5 in figure 3.3) change from 1989 to 2015 remains almost the same. Specific trend is observed in case of Farm & grass land class (Class 1) and Mixed class (Class 2). In each of the cases they had specific relationship with different Arcmap buffer zones, i.e. with the decrease of the Arcmap buffer zone (considering 1km to 100 meter) the land change percentage also decreased. So, in the dense forest area grass land and mosaic land increased. But, in the case of settlement area, with the decrease of Arcmap buffer zone, the % of forest land increased meaning considering more near areas of the settlement the percentage of forest increases. From the above discussion, it can be concluded that, inside the dense forest, the forest degradation happened to be the same regardless the distance from the settlement and that’s why the grass and mixed areas are increasing. But surprisingly the forest land class coverage increases while considering more near to the settlement while grass and mosaic area decreases.

Table 3.6 Logistic regression model predicting the likelihood of Encroachment

	B	S.E.	Wald	*d.f.*	Sig.	Odds Ratio (eB)	95.0% C.I.for EXP(B)	
							Lower	Upper
Age	-0.005	0.004	1.285	1	0.257	0.995	0.987	1.003
Education	0.013	0.017	.591	1	0.442	1.013	0.980	1.046
Family Size	-0.025	0.022	1.323	1	0.250	0.975	0.934	1.018
Household Area	0.043	0.314	1.773	1	0.547	1.009	0.884	1.078
Duration of living	-0.196	0.348	3.583	1	0.003	0.887	0.653	1.115
Union			150.838	4	0.000			
Baharchhara	0.806	0.130	38.301	1	0.000	2.239	1.735	2.891
Nhila	-1.377	0.195	50.045	1	0.000	0.252	0.172	.369
Teknaf Sadar	0.877	0.195	0.198	1	0.341	2.404	1.640	3.525
Whykhong	0.016	0.135	.014	1	0.906	1.016	0.780	1.324
House Type			33.729	2	0.000			
Kacha	0.865	0.158	29.916	1	0.000	2.374	1.741	3.236
Paka	-0.047	0.355	.018	1	0.894	0.954	0.476	1.911
Occupation			22.294	5	0.000			
Abroad	0.379	0.191	3.923	1	0.148	1.461	1.004	2.125
Business	0.009	0.164	0.003	1	0.957	1.009	0.732	1.391
Farmer	-0.017	0.188	0.008	1	0.927	0.983	0.680	1.421
Fishermen	-0.698	0.209	11.185	1	0.001	0.497	0.330	.749
Labor	0.020	0.149	0.018	1	0.021	1.216	0.761	1.368
Annual Income	0.201	0.459	0.268	1	0.604	1.301	1.053	1.863
Fuelwood Usage	0.026	0.011	5.712	1	0.003	1.031	1.005	1.178
***Paan* Farming**	0.794	0.176	20.349	1	0.000	2.213	1.567	3.125
Fuelwood Collector	1.294	0.106	148.038	1	0.000	3.646	2.960	4.491
Constant	-3.269	0.297	121.201	1	0.000	0.038		

Hosmer & Lemeshow Test: Chi Square = 16.45, d.f. = 9, p = 0.036
-2 Log likelihood = 3130.538,
Cox & Snell $R^2 = 0.107$
Nagelkerke $R^2 = 0.196$
Overall percentage of right prediction = 86.9%

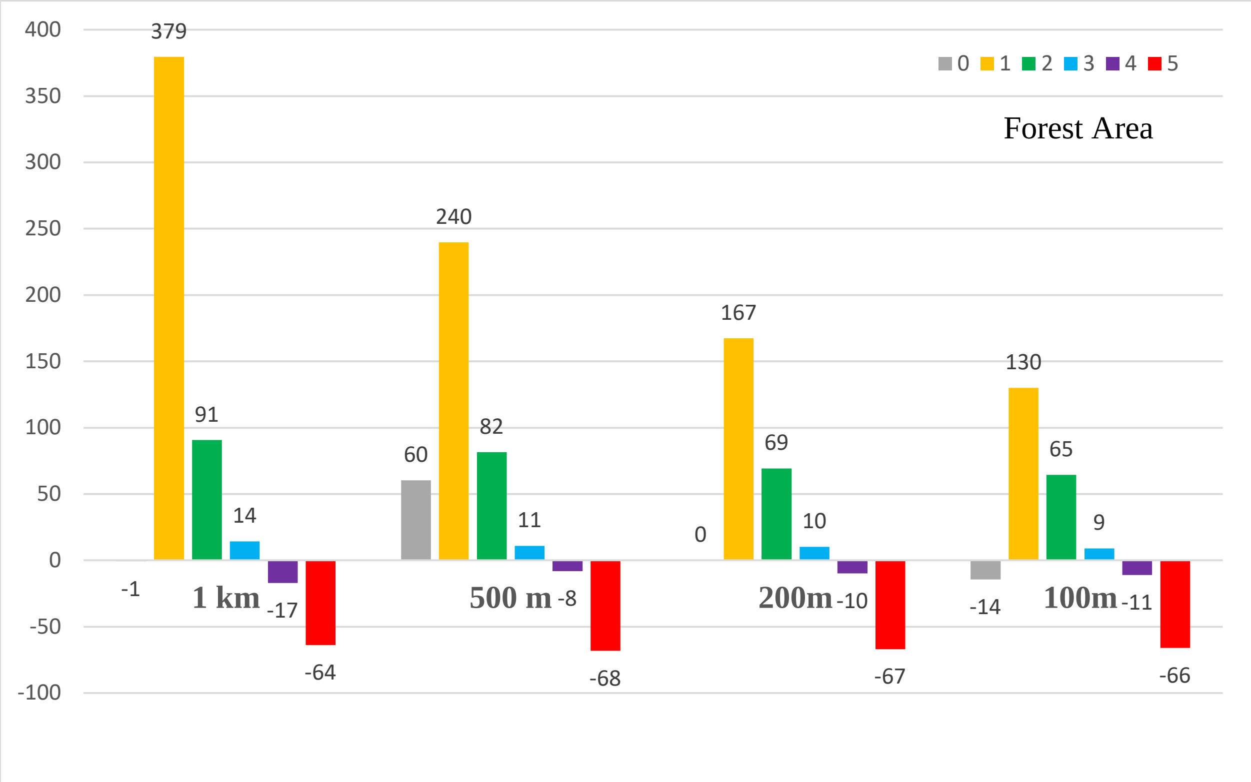
3.4 Discussion

The main focus of this study is to explore encroachment as a deforestation driver. This section will discuss the factors having impact on encroachment (why people live inside the forest?) and the impact of encroachment on the forest (how settlement affects the forest?).

3.4.1 Impact on Encroachment

People living inside the protected forest area is legally prohibited and not good for the forests facing high deforestation rates. To investigate the causes of why people are encroaching the difference in the socio-economic profile of the people living inside and outside the forest is explored. From the analysis it is found that difference in duration of living, education, income, homestead size and land property is significant. The encroachers have comparatively new settlements than outsiders with low education and low income. But their homestead and land properties are bigger than the outsiders. Similar results were also found by Tani et. al., (2013), where encroachers had low income and relatively new homesteads. Basically poor people have more likelihood to move inside the forest because of the free land and limited other options. From the logistic model, it is found that, people living in new houses have 11% more chances to be an encroacher. Among the Unions, Baharchhara people have high possibilities to encroach, this is due to the narrow shape of the Union bordering the forest area and the people depending much higher on the forest for natural resources. If the house type is Kacha then there are higher chance of the people living in this type of houses to be an encroacher.

Occupation also impacts the choice of encroachment. Fishermen have less chance and farmers have higher chance to encroach inside the forest. Fishermen are dependent on the sea for their livelihood so they live beside the sea, this factor limits their choices to encroach inside the forest. On the other hand, labors are poor and most of them are engaged in agricultural labors which includes *paan* farming. As *paan* farmers have very high chance to encroach the labors also have higher chances comparing to other occupations. Fuelwood collection and fuelwood use have impact on encroachment. If a person collects fuelwood and the household fuelwood consumption is higher than the likelihood of the house to encroach is high. Fuelwood collection and consumption is very much related with the forests. If a person collects fuelwood from the forest and consumes higher than others it is easily predictable that the person will have a likelihood to live near or inside the forest. Lastly it can be concluded that encroachers can be profiled as relatively poor people, with less education and high fuelwood dependency.



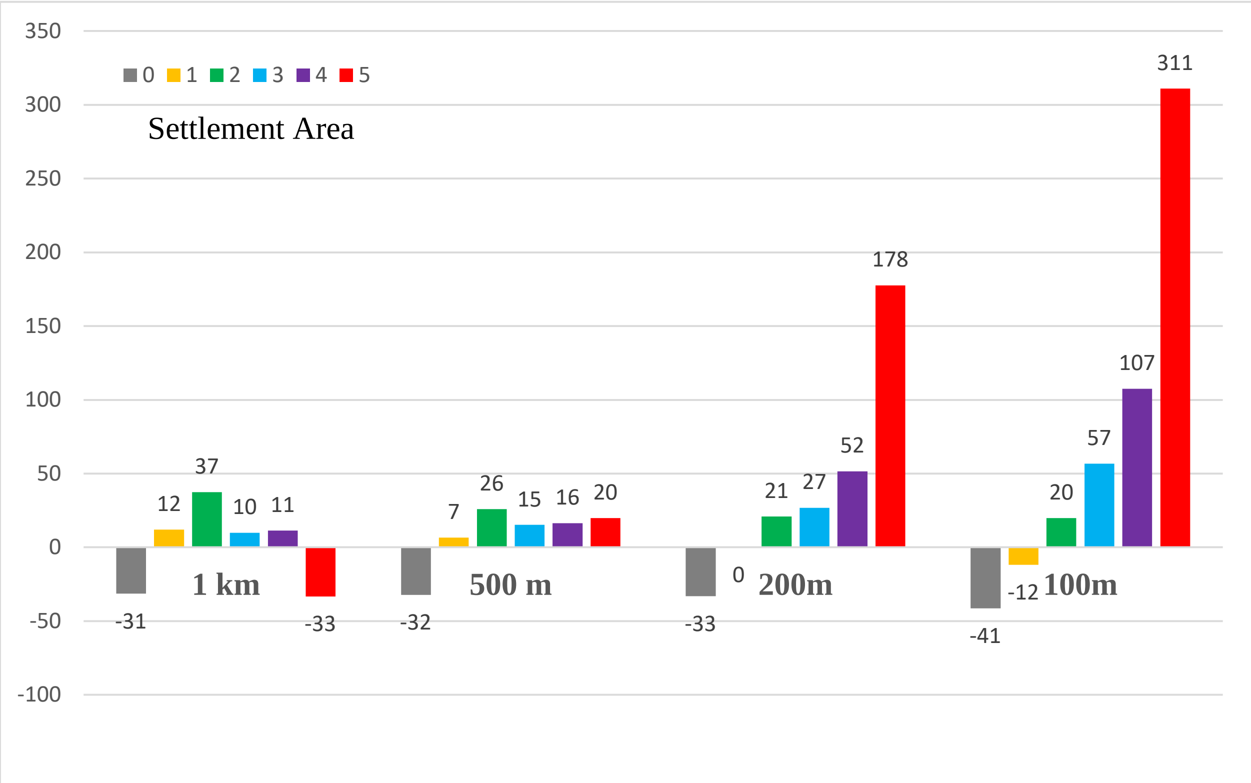


Figure 3.3 Land class change in Settlement area and buffer area

3.4.2 Impact of Encroachment

Figure 3.3 shows the land class change from 1989 to 2015 of forest area and settlement area considering different Arcmap buffer zones. Here, the trend of forest land class change is interesting. The forest land loss in the forest area remains almost same in case of different Accmap buffer zones. The bigger the Acrmap buffer zone becomes the forest area tends to limit more inside way i.e. far from the settlements. So, while considering 100 meter Arcmap buffer zone, the forest area starts from the edge of the settlements and while Arcmap buffer zone increases the forest area concentrates more far from the settlements. Different Arcmap buffer zones are resulting almost same forest land change indicates that settlements distance to the forest area have no impact on the forest destruction. But when considering the settlement area, the closer area to the settlements, the forest land increases more. This can be described as, people are destroying the natural forests ether it is far or near, they depend on forest resources which is resulting to forest loss but around the settlements people are replacing the natural tree coverage by planting tree species for homestead income. The most visible example is Betel nut trees. People are clearing forest and planting Betel nut trees. So, satellite images are showing tree coverage but it is not the natural forest. To summarize the effect of settlements on forest it can be stated that, deforestation is happening on a constant rate either far or near from the settlements. But the increased forest land class near the settlements are also in a sense a deforestation considering that endogenous species are the best option for forests, other species can give short term benefit and increase forest land coverage but considering the total forest ecosystem for long term it is not a good option.

Table 3.7 Union-wise total household

Union	Inside Forest	Outside Forest	Total
Baharchhara	2364	6310	8674
Nhilla	338	10267	10605
Sabrang	0	11308	11308
Teknaf Pourashava	497	3125	3622
Teknaf Sadar	1397	9613	11010
Whykhong	599	11586	12185
Total	**5195**	**52209**	**57404**

Table 3.7 shows the total households in Teknaf Upazila with the encroachment numbers. There are 5195 households inside the forest in Teknaf. The average homestead size inside the

forest is 0.09 ha. Considering this homestead size, the total encroached area inside the TWS forest occupied by the households are 467.55 ha. This is only the homestead area and if the total land property is included the number will increase more. Each household migrating inside the forest results in 0.09 ha area of forest land clearing in terms of homestead area which is increasing day by day.

3.5 Conclusion

The aim of this chapter was to describe the people inside the forest, explore the factors of their encroachment and determine the impact of encroachment on the forest. The encroacher inside the forest are comparatively poor and less educated than the people living outside the forest. Duration of living, which Union people live, type of household, occupation, fuelwood collection and consumption are found to impact the likelihood of encroachment inside the forest. The settlements had impact on the forests. Around the settlements, forest land class was increasing due to plantation of income generating tree species but inside the core forest the deforestation remained the same.

CHAPTER 4. AGRICULTURE AND DEFORESTATION

4.1 Introduction and Objectives

Agricultural expansion is one of the most cited deforestation drivers currently found in the forest loss related studies (Gibbs et al., 2010). The reflection of the most cited forest driver loss is also seen to play a role in the deforestation in the Teknaf Peninsula. This chapter deals with agricultural expansion as a deforestation driver in the Teknaf Peninsula reserve forests. Forests in Teknaf are mainly in the hilly areas and rice cultivation following the widely practiced methods are suitable for plain land and cultivating rice on the hilly areas is difficult and non-profitable. Also the cropping intensity in Teknaf is 136%, which is much lower than the national average cropping intensity of 196% (AIS, 2017) indicating amount of cultivating other crops and vegetable are also below normal. The unique agricultural practice in Teknaf is betel leaf cultivation. Betel leaf is very popular in the south and south east Asia countries and it is chewed with betel nuts for its stimulant and psychoactive effects (Song et al., 2013). Betel leaf, scientific name *Piper betle L.* under the family Piperaceae, locally known as *paan* and the place where it is grown is known as *paan boroj* (Figure 4.2). Cultivating *paan* requires shading and forests can be the source of shading materials. Due to capabilities to grow on hilly areas, availability of shading materials from the forests and higher net income, *paan* is a major cash crop in the Teknaf Peninsula, as it is in many other areas (Ghosh and Maiti, 2011).

Paan cultivation is a prominent deforestation driver in the Teknaf Peninsula. Based on the previous studies (Tsuruta et al., 2012; Alam et al., 2014; Tani, 2017), group discussion with local people and experts, and observation of nearly 5 years we found that *paan* cultivation is one of the causes for high rate of deforestation in the region. *Paan* requires a lot of shading materials which causes the destruction of forests and some cases *paan* is cultivated inside the forest clearing the existing vegetation which is also affecting the deforestation and degradation in the Teknaf Peninsula. The objective of this chapter is to describe the extent of *paan* cultivation and the impact on the forests alongside the socio-economic factors effecting the *paan* cultivation. This chapter first describes the socio-economic status of the *paan* farmers and determines the factors effecting *paan* cultivation. Then the status and extent of *paan* cultivation in the Peninsula is described. Finally, the impact of *paan* cultivation on the local reserve forests and climate change is discussed.

4.2 Data and Methods

The Teknaf Upazila is considered for the study area. *Paan boroj* from all Unions namely Teknaf Sadar, Baharchhara, Nhila, Whykhong and Sabrang is identified and analyzed by using satellite images. Teknaf Pourashava is an urban area where no *paan boroj* was found.

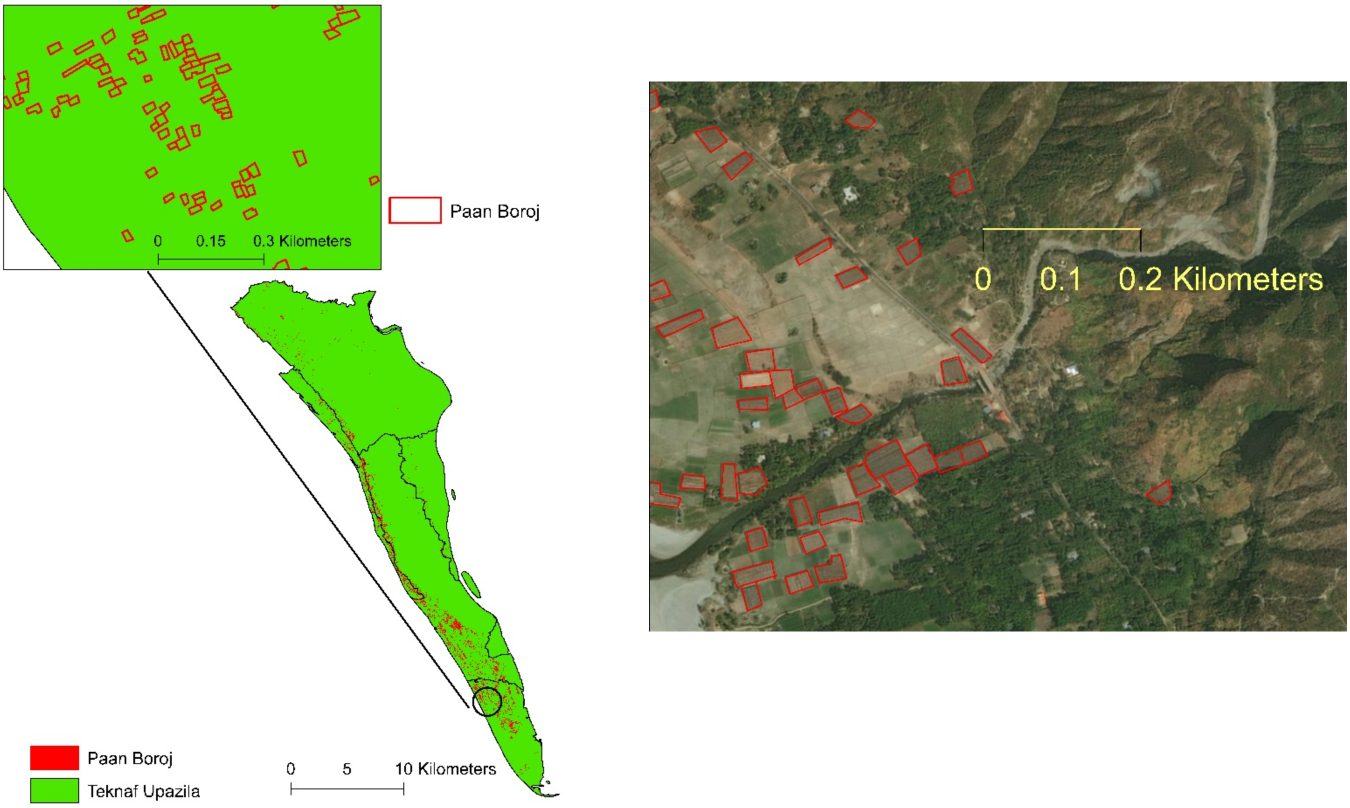


Figure 4.1 *Paan boroj* in the Teknaf Peninsula

4.2.1 Socio-economic Characteristics of the Farmers

One of the objective of the study is to describe the socio-economic attributes of *paan* farmers. Among the socio-economic attributes age, family size, education, annual income, cultivation practice is the main focus. To understand about *paan* farming in the Teknaf Peninsula it is important to know about the people cultivating *paan*. The dataset used in this analysis coveres 10% of the total population of the Teknaf Upazila (5769 households) collected by following a systematic sampling procedure. Data sampling and collection procedure was described briefly in Chapter 3 (section 3.2) and termed as Teknaf Database. Descriptive statistics including mean and percentage is used to analyze the socio-economic characteristics of *paan* farmers.

(a)

(b) (c)

Figure 4.2 *Paan boroj* in the Teknaf Peninsula: (a) outside & (b,c) inside

4.2.2 Factors Effecting *Paan* Cultivation

In order to assess the significance of the socioeconomic determinants to the *paan* cultivation, a binary logistic regression model is used following the entry procedure. *Paan* cultivation in this study is modeled as a binary decision by the household either they cultivate *paan* or not. Given this case of binary decision, the dependent variable is a discrete dummy variable (*paan* cultivation =1; and not cultivation = 0). The dataset and parameters used to develop this model are similar as the logistic model described in Chapter 3 (section 3.2) with the change in the dependent variable. Shortly, five Unions containing of Teknaf Upazila namely Baharchhara, Nhila, Whykhong, Tekanf sadar and Teknaf PS covering 101 villages and 4622 households. The independent variables used in this model are presented in Table 4.1.

Table 4.1 Independent variables of the Logistic Model

Variables (x_i)	**Unit of account (Definition)**
Age	Years in number (Age of household head)
Education	Years in number (Schooling year of the household head)
Family Size	Number of family members
Household Area	Decimals of hectares in number
Length of residence	Years in number (Years of the members living in the house)
Union [a]	1 - Baharchhara, 2 – Nhila, 3 – Teknaf Sadar, 4 - Whykhong
House Type [b]	1 – Kacha (including Jhupri and Mud house), 2- Paka (Brick buildings)
Occupation [c]	1 – Abroad, 2 – Business, 3 – Farming, 4 – Fishing, 5 - Labor
Fuelwood Collection	1 – Yes, 0 - No
Annual income	Thousand BDT in Number
Living inside the forest	1 – Yes, 0 – No
Fuelwood expense	% of Total income in terms of fuelwood value

[a] *For the variable Union, Teknaf PS was considered the reference category*

[b] *For the variable House type, others was considered as the reference category*

[c] *For the variable Occupation, others was considered as the reference category*

This logistic model determines the socio-economic factors influencing *paan* cultivation in the Peninsula which provides a better understanding of the deforestation driver.

4.2.3 Status and Extent of *Paan* Farming

The status and extent of *paan* farming is described by identifying, counting and measuring all the *paan boroj*s in the Teknaf peninsula. *Paan boroj* is the place where the *paan* is cultivated. Shading materials, fence and supporting poles are used to make a *paan boroj*. *Paan boroj* is visible from the satellite image and can be considered as an unit of *paan* cultivation. ArcGIS 10.3 software is used to identify and measure all the *paan boroj*s. A basemap available in ArcGIS is used as the source of satellite images from where the *paan borojs* were identified. The basemap in ArcGIS is basically satellite images of the world and during the analysis photos taken in 2016 is used. Using the basemap *paan borojs* are identified (Figure 4.1) and the area of each *paan boroj* is measured in hectares. Finally, the total area coverage under *paan* cultivation, number of *paan boroj*, average size and maximum size are calculated to describe the status and extent of *paan* cultivation in the Peninsula.

4.3 Results

4.3.1 *Paan* Farmers' Socio-economic Attributes

To understand *paan* cultivation as a deforestation driver it is necessary to know about the people who are cultivating *paan*. Table 4.2 presents some major socio-economic attributes of the *paan* farmers. Based on thedataset of 10% of the total Teknaf population, there were 506 households cultivating *paan*. Among the unions there are the highest *paan* farmers in Baharchhara (228 households engaged in *paan* farming) followed by Teknaf sadar (157 households) with the fewest in Whykhong (21 households). According to Table 4.2 the average age of household head is found to be 44.47 with average schooling year of 1.28. The family size is found to be bigger than the average family size in Teknaf Upazila.

Table 4.2 Socio-economic status of *paan* farmers comparing with the Teknaf Upazila

Socio-economic Status	*Paan* Farmers (Mean)	Total (Mean)
Age of Households (Years)	44.5	40.0
Family Size (Members)	6.9	6.1
Education (Schooling year)	1.28	1.93
Duration of Settlement (Year)	33	26
Annual Income (000 BDT)	213	195
Land Property (hectare)	0.22	0.12

The duration of *paan* farmers' settlement is 33 years, indicating slightly higher than the average in the study area. Annual income and the average land property (0.22 ha) of *paan* cultivators is also higher comparing the average in the study area. From the socio-economic attributes it can be concluded that, *paan* farmers have more income with large family and big land property with less education comparing within the Teknaf Peninsula.

4.3.2 Factors effecting *Paan* Cultivation

As described above, a binary logistic regression model was developed to explore the key determinants of the likelihood of the households of Teknaf Peninsula to cultivate *paan*. Overall assessment of the model for cultivating *paan* was significant (p <0.001) and the Hosmer & Lemeshow goodness-to-fit test showed adequate fit of the model to the data, with an overall 95.4% correct prediction. The determinant factors of the *paan* farmers' characteristics for cultivating *paan* were found to be family size, which union they are living and their occupation (Table 4.3).

Family size (*P* = 0.006) was found to be significantly having impact on the likelihood of *paan* farming. Increase of 1 person in the family results in increasing the chance of cultivating *paan* by nearly 9% (Odds ratio 1.092). The bigger the family size is, the more people likely cultivate *paan*. As described above, the distribution of *paan* farmers are not even. Baharchhara and Teknaf sadar have higher *paan* cultivators than the other regions and the same findings are seen in the logistic regression model. From Table 4.3 Baharchhara, Nhila, Teknaf sadar and Whykhong all have significant impact, though Baharchhara and Teknaf sadar have positive and other have negative effect. More clearly, in case of Baharchhara and Teknaf sadar, farmers living here have respectively 87% (Odds ratio = 1.875) & 17% (Odds ratio 1.173) more chance to cultivate *paan*. On contrary, Nhila and Whykhong has 29% (Odds ratio = 0.714) and 36% (Odds ratio = 0.640) less likelihood to cultivate *paan* respectively. Occupation is also found to effect the likelihood of cultivating *paan* in the Teknaf Peninsula. In case of business, farmer and labor they have 2.23, 10.94 and 3.085 times more chances of cultivating *paan*. Among them farmers have 10 times (Odds ratio = 10.94) more chance to cultivate *paan* which is very high comparing to other factors. Encroachment inside the forest is also having impact on the *paan* cultivation. People living inside the forest have 2.3 times more likelihood of cultivating *paan* than the people living outside. Fuelwood usage and collection has no impact on *paan* cultivation. Based on the Odds ratio of we rank the factors impacting the likelihood of cultivation *paan*, then they are first, the occupation of the farmers followed by which area they live in and lastly, the family size.

Table 4.3 Logistic regression model predicting the likelihood of *paan* cultivation

	B	S.E.	Wald	df	Sig.	Odds Ratio(eB)	95.0% C.I. for EXP(B)	
							Lower	Upper
Age	-0.021	0.007	10.156	1	0.151	0.979	0.966	.992
Education	0.012	0.027	0.180	1	0.671	1.012	0.959	1.068
Family Size	0.087	0.031	7.641	1	0.006	1.091	1.026	1.160
Household Area	0.062	0.584	2.136	1	0.752	0.898	0.613	1.126
Duration of living	-0.056	0.217	1.749	1	0.508	0.991	0.815	1.107
Union			269.675	4	0.000			
Baharchhara	0.629	0.170	13.741	1	0.000	1.875	1.345	2.615
Nhila	-4.236	0.524	65.471	1	0.000	0.714	1.005	.540
Teknaf Sadar	-0.138	0.720	1.459	1	0.022	1.173	0.056	.320
Whykhong	-3.221	0.268	144.096	1	0.000	0.640	1.024	0.468
House Type			0.911	2	0.634			
Kacha	-0.019	0.201	0.009	1	0.925	0.981	0.662	1.455
Paka	-.368	0.394	0.874	1	0.350	0.692	0.320	1.497
Occupation			505.938	5	0.000			
Abroad	-0.139	0.471	0.087	1	0.768	0.870	0.346	2.190
Business	0.805	0.360	4.994	1	0.025	2.236	1.104	4.529
Farmer	4.634	0.345	180.191	1	0.000	10.942	52.328	202.511
Fishermen	-0.199	0.464	0.185	1	0.667	0.819	0.330	2.034
Labor	1.127	0.371	9.230	1	0.002	3.085	1.492	6.382
Annual Income	0.251	0.076	1.925	1	0.265	1.005	0.998	1.029
Fuelwood Usage	-0.023	0.251	0.043	1	0.073	0.965	0.768	0.998
Encroachment	0.851	0.192	19.685	1	0.000	2.343	1.608	3.412
Fuelwood Collector	-0.268	0.166	2.611	1	0.106	0.765	0.553	1.059
Constant	-3.476	0.479	52.603	1	0.000	0.031		

Hosmer & Lemeshow Test: Chi Square = 4.551, d.f. = 9, p = 0.113
-2 Log likelihood = 1244.371
Cox & Snell $R^2 = 0.281$
Nagelkerke $R^2 = 0.623$
Overall percentage of right prediction = 95.4%

4.3.3 Status and Extent of *Paan*

This section of the chapter describes the current status of *paan* cultivation in the Teknaf peninsula. *Paan* is cultivated using shading materials and the place with shading materials where *paan* is cultivated is known as *paan boroj*. From the satellite image all the *paan borojs* are counted and mapped with the size (Figure 4.1). In the Teknaf Peninsula 4273 *paan boroj* is identified covering 250.74 ha areas (Table 4.4). Among the *paan boroj*s 1264 *paan boroj* is located inside the protected forest area covering 59.76 ha area.

Table 4.4 Status and extent of *Paan Boroj* in Teknaf

Place	**Number of *Paan Boroj* (ha)**	**Average Size of *Paan Boroj***	**Total Land Coverage (ha)**
Teknaf Sadar	2026	0.06	122.85
Sabrang	879	0.07	63.45
Baharchhara	730	0.05	38.02
Whykhong	473	0.04	20.67
Nhila	165	0.03	5.75
Inside TWS	1264	0.05	59.76
Teknaf Upazila	4273	0.06	250.74

The average size of *paan boroj* is 0.05 ha and the size range of the *paan boroj* is 0.35 ha to nearly 10 m^2. According to Table 4.4, nearly half (2026) *paan borojs* are located in Teknaf sadar. But among the Teknaf sadar *paan boroj* there are many farmers who live in Baharchhara but they establish *paan boroj* in Teknaf sadar (figure 4.3). This is due to the boundary of the TWS on the eastern side of Baharchhara is also the boundary of Teknaf sadar. So, the illegal encroachment from Baharchhara inside the forest officially is situated in Teknaf sadar area. That’s the reason for high number of *paan boroj* in Teknaf sadar and conversely high number of *paan* farmers in Baharchhara. Considering the number of *paan* farmers, *paan boroj* inside the forest which are cultivated by Baharchhara farmers and the density of *paan boroj* Baharchhara is the main focal area where the *paan borojs* are concentrated.

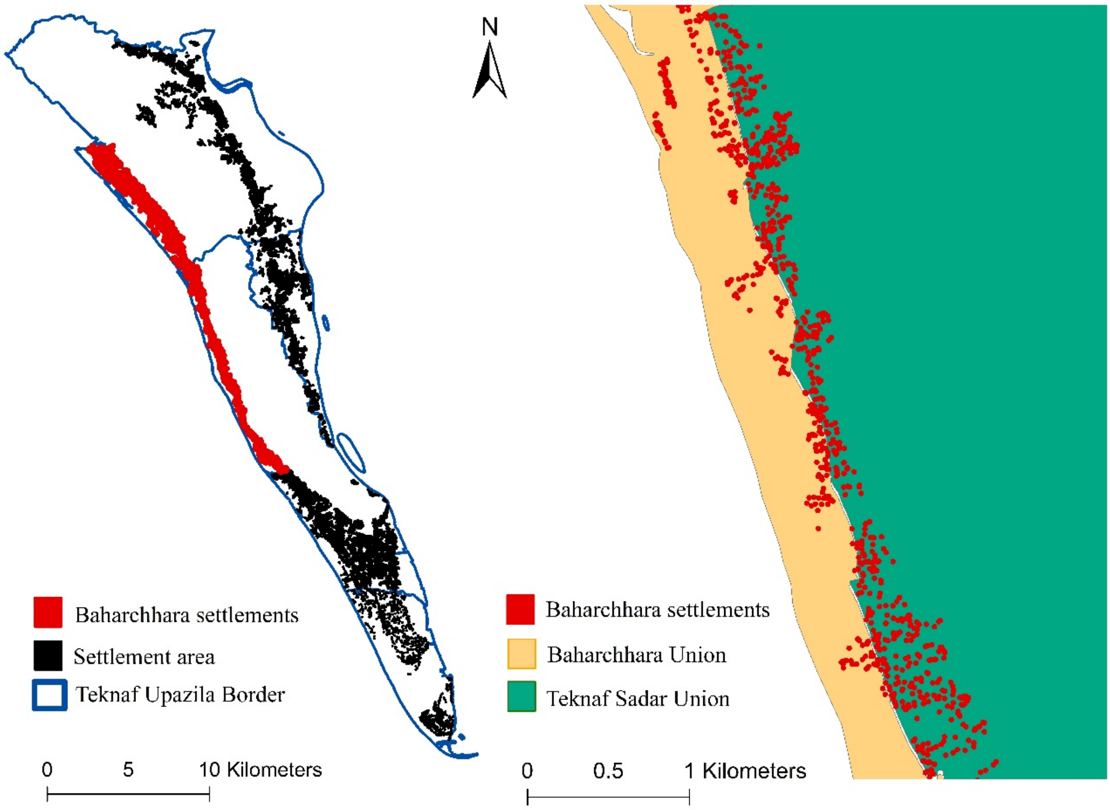


Figure 4.3 *Paan boroj* in Baharchhara

4.4 Discussion

4.4.1 Factors Effecting *Paan* Cultivation

Paan cultivation is one of the major deforestation drivers in the Teknaf Peninsula. This section discusses the factors affecting *paan* cultivation. From the socio-economic profile of the *paan* farmers described above (section 4.3.1) it is clear that *paan* farmers have relatively low education comparing the total study area. Also land property and family size are also bigger comparing the average of the study area. Family size is found to have impact on *paan* cultivation from the logistic model also. Bigger family has the opportunity to have more labor force which is necessary for *paan* cultivation. *Paan* requires more labors to prepare land and intercultural operations (weeding, irrigation and fencing) are also laborious. Harvesting of *paan* continues for long time which also requires more labors. So, big families have the benefit to cultivate more *paan*. From the survey and mapping of *paan* it was clear that the western side of the peninsula is more prospective for growing *paan* than the eastern side, specially Baharchhara union is the hotspot of *paan* cultivation. The main reason of this can be related to easy access of forest resources. In Baharchhara, the settlements are very close to the forest and also the road goes inside the settlement. Roads and forest boundaries are less than 500 meters apart in some cases of Baharchhara. High access to communication, availability of shading materials from the forest and very few restrictions to encroach inside the forest results in the high density of *paan boroj* in Baharchhara. This was also supported by the analysis where people living in Baharchhara have 87% of more chance to cultivate *paan*. Occupation is also found to effect the *paan* cultivation. Farmers were about 10 times more likely to cultivate *paan*. This is understandable that farmers will cultivate *paan* and also other crops. Encroachment is seen to influence the *paan* cultivation. Living inside the forest makes it easier to access to forest resource materials for *paan* cultivation. Finally, it can be concluded that encroachers living in Baharchhara have the highest likelihood to cultivate *paan*.

4.4.2 *Paan* cultivation affecting deforestation

This section of the chapter describes the impact of *paan* cultivation on the protected forests of Teknaf Peninsula. A study conducted to estimate the impact of betel leaf cultivation in Teknaf found that the average size *paan boroj* is 0.062 and an average size of *paan boroj* requires 1.12 tons of wooden poles (Tani, 2017). Using this figure to determine the effect of *paan* farming, the total consumption of wood for *paan* cultivation sums up to 4529.50 tons. The forest productivity of the tropical forests in Thailand was recorded 28.6 ton/ha (Tsuruta et al., 2012). Considering this productivity, the total production of 11,615 ha area of the TWS is expected to be 334,512 tons wooden materials annually. Comparing the wood amount required for *paan* cultivation with the production it reveals that 1.35% wood production is used by *paan* cultivation. But this estimation is based on that 11,615 ha forest area will be productive but practically it is not possible in the current state of the condition of the TWS. In chapter 2 the land coverage was described and considering that the lean and dense forest area are capable of wood production only, the findings are presented in Table 4.5

Table 4.5 Wood production usage by *paan* cultivation

Year	% of lean & dense forest of TWS	% of wood used of total production in *paan* cultivation
1989	45%	3.01%
2004	23%	5.89%
2007	28%	4.84%
2009	27%	5.02%
2015	27%	5.02%

From Table 4.5, considering the forest condition in 1989 only it would require 3.01% of its wood production and in the current condition *paan* cultivation requires 5.02% of the total wood production of the forest. As time proceeds, if the *paan* cultivation remains same then the percentage of wood used of total production will increase. This is the visible and predictable scenario of *paan* cultivation impact on forest but there is another type of impact of *paan* cultivation on forest. While building a *paan boroj*, small poles are made of saplings inside the forest, which has a devastating impact on forest regeneration. If every *paan boroj* uses only 10 saplings (but actual requirement is quite higher around 50-100 based on the size of *paan boroj*), nearly 40,000 trees are destroyed yearly hampering the chance of regeneration of the forest. Also when the *paan boroj* is built inside the forest it clears the vegetation also impacting the deforestation and forest regeneration. So it can be concluded that, if the deforestation continues then the *paan* cultivation will affect the protected forests even more in the future.

4.5 Conclusion

The aim of this chapter is to describe *paan* cultivation as a deforestation driver with its impact on the protected forests. Firstly, the socio-economic attributes are described of the *paan* farmers were *paan* farmers found to have relatively high income, more land properties and less education comparing with the Teknaf Upazila. Family size, location of living and occupation is found to impact the *paan* cultivation. The impact of *paan* cultivation is described as *paan* cultivation requires 1.35% of the total wood production. But considering the current state of the forest, the percentage can increase up to 5.02%. *Paan* cultivation is an integral part of the livelihood of the local people and the only source of income for many people. So *paan* cultivation cannot be replaced immediately by other income generating actives but the local people should try to cultivate *paan* leading to sustainable use of forest resources.

5.1 Introduction

Forest products are the main sources of food, energy, medicine, animal feed, construction materials, furniture, agricultural implements, and utensils for many people around the world. Of these forest products, fuelwood, a non-timber forest product, which is the primary source of energy for many households, especially for the rural poor people is the main focus of this chapter. Its consumption as an energy source, constituting 9% of the total global energy consumption (Lauri et al. 2014), accounts for one of the main uses of forests and woodlands. Developing countries account for nearly 90% of the fuelwood that is produced and consumed worldwide (Dovie et al. 2004; Naughton-Treves et al. 2007). In South Asia alone, the demand for fuelwood is projected to reach 361.5 million cubic meters by 2020 (Arnold and Persson 2003), and in countries like Bangladesh, demands are apparently pressing up against limitations in supplies. Environmental damage from fuelwood harvesting can be significant if too many people depend on too few forested areas. Many hotspots of biodiversity in the tropics (Bouget et al. 2012, Myers et al. 2000) represent such a scenario, with numerous human populations relying on vanishing, reducing and fragmenting forests to meet their demand for fuelwood, land for agriculture and ingestion of animal protein (Peres et al. 2010, Ruger et al. 2008).

The impact of fuelwood harvesting on forests is still a point of contention. Some studies have reported that there is a direct connection between fuelwood extraction and “severe deforestation” (e.g. Pang et al. 2013; Singh et al. 2010) or “forest degradation” (e.g., Ahrends et al. 2010; Cantarello et al. 2014; Moroni and Musk 2014; Orozumbekov et al. 2015; Ryan et al. 2012; Specht et al. 2015). On contrary, other studies have suggested that fuelwood demands have limited impacts on forest cover (e.g., Hansfort and Mertz 2011; Shrestha et al. 2013). However, broad generalizations on fuelwood harvesting and deforestation are intrinsically misrepresentative. The effects of fuelwood collection on forests depend on various factors such as patterns of fuelwood supply and demand (Ghilardi et al. 2007; Wangchuk et al. 2014), type of usage as subsistence fuelwood or commercial charcoal (Naughton-Treves et al. 2007), vegetation responses to disturbances, changing species preference, extraction sites, and volumes extracted (He et al. 2009; Jagger and Shively 2014; Ruger et al. 2008). Fuelwood harvesting in Teknaf is the most commonly used mean of forest resources and also is one of the main causes for deforestation in the TWS. For proper forest management, fuelwood harvesting will be one of the most critical issue to deal with. Almost every household uses fuelwood from the forest as their cooking fuel with very few alternative sources of energy available in the peninsula. Understanding the consumption and demand of fuelwood from the forests and the factors having impact of fuelwood collection will be resourceful for developing sustainable forest management strategies. The objectives of this chapter are- 1) to determine the consumption of fuelwood from the local forests, 2) to explore the factors having impact on fuelwood collection and consumption and 3) to describe the impact of fuelwood collection on local forests.

5.2 Methodology

5.2.1 Study area

Different datasets are used to perform different analysis. The fuelwood consumption survey was done in three villages namely – Marishbania, Mathabhanga and Uttar Shilkhali under Baharchhara Union. The Teknaf Database (Chapter 3, sub-section 3.2) is used for analyzing factors impacting the fuelwood collection and respondents of Baharchhara, Teknaf Sadar, Teknaf PS, Nhila and Whykhong were considered for this analysis.

5.2.2 Fuelwood Consumption and Factors Impacting Consumptions

Fuelwood consumption survey was done in three villages covering 174 households selected by systematic sampling procedure covering 10% of the total households. To estimate fuelwood consumption, sample HHs were asked to show stacked fuelwood bundles for HH cooking. From the bundles, based on the family size, 3–5 bundles were weighed and separated from the rest of the fuelwood (Figure 5.1). Then the respondents were requested to cook for the HH from the weighed bundles for the next 3 days. After 3 days, the remaining bundles were weighed again. After physically weighing of fuelwood, it was divided by family size to determine per capita consumption. This was done two times to cover both rainy season (March to September) and dry season (October – February). Data were collected in July- August, 2016 (to cover rainy season) and January-February, 2017 (to cover dry season). The family size, education level, homestead area, annual income and duration of resident were recorded by face to face interview with the household members. Annual income of each HH was separately recorded in different categories such as farming, fishing labor, abroad and business. Pearson's product-moment correlations were used to identify influencing the fuelwood consumption.

(a)

(b)

Figure 5.1 Fuelwood bundles: (a) from market & (b) from fuelwood collectors

5.2.3 Factors Effecting Fuelwood Collection

In order to assess the significance of socioeconomic determinants to the fuelwood collection, a binary logistic regression model is used following the entry procedure. Fuelwood collection in this study is modeled as a binary decision by the household either collect fuelwood from forest or not. Given this case of binary decision, the dependent variable is a discrete dummy variable (fuelwood collection =1; and not collection = 0). The dataset and parameters used to develop this model are similar as the logistic model described in Chapter 3 (section 3.2) with the change in the dependent variable. Shortly, five Unions containing of Teknaf Upazila namely Baharchhara, Nhila, Whykhong, Tekanf sadar and Teknaf PS covering 101 villages and 4622 households. The independent variables used in this model are presented in Table 5.1.

Table 5.1 Independent variables of the Logistic Model

Variables (x_i)	**Unit of account (Definition)**
Age	Years in number (Age of household head)
Education	Years in number (Schooling year of the household head)
Family Size	Number of family members
Household Area	Decimals of hectares in number
Length of residence	Years in number (Years of the members living in the house)
Union [a]	1 - Baharchhara, 2 – Nhila, 3 – Teknaf Sadar, 4 - Whykhong
House Type [b]	1 – Kacha (including Jhupri and Mud house), 2- Paka (Brick buildings)
Occupation [c]	1 – Abroad, 2 – Business, 3 – Farming, 4 – Fishing, 5 - Labor
Paan collection	1 – Yes, 0 - No
Annual income	Thousand BDT in Number
Living inside the forest	1 – Yes, 0 – No
Fuelwood expense	% of Total income in terms of fuelwood value

[a] *For the variable Union, Teknaf PS was considered the reference category*

[b] *For the variable House type, others was considered as the reference category*

[c] *For the variable Occupation, others was considered as the reference category*

This logistic model determine the socio-economic factors influencing fuelwood collection in the Peninsula which will help to have a better understanding of the deforestation driver.

5.3 Results

5.3.1 Fuelwood Consumption and Factors Impacting Consumption

All 174 assessed HHs reported using fuelwood regularly as their main source of cooking fuel with 11 HH reporting the usage of alternative fuels i.e. LP gas besides fuelwood. The mean fuelwood consumption of HHs were found to be 1.65 kg/person/day which sums up to 602.25 kg annual fuelwood consumption per capita. The maximum per capita daily fuelwood consumption was found to be 8.29 kg. Difference was found in the fuelwood consumption between two seasons. In case of rainy season, the mean per capita daily fuelwood consumption was 1.52 kg and during the winter season it was 1.82 kg.

Table 5.2 Pearson's product-moment correlations

	Variables	**Pearson's product-moment correlation coefficient (r)**
Per capita daily fuelwood consumption	Family Size	-0.675**
	Education level	-0.386**
	Homestead Area	-0.183*
	Annual Income	-0.013
	Fuelwood cost	-0.401**
	Duration of Residence	0.255

** 1% and *5% level of significance

Table 5.2 presents the socio-economic aspects of the households impacting the fuelwood consumption. Family size, education level, homestead area and fuelwood cost are significantly correlated with per capita daily fuelwood consumption. Family size refers to the total members of the family. With the increase of the family member's per capita fuelwood decreases and this correlation had less than 1% level of significance. Education level is the total schooling year of all the members of the household and have negative correlation with the per capita fuelwood consumption. With the increase of the education level of the household the fuelwood consumption decreases. Homestead and fuelwood cost has also negative correlation with per capita fuelwood consumption resulting decrease in fuelwood consumption with the increase of homestead area and fuelwood consumption cost.

5.3.2 Factors Effecting Fuelwood Consumption

As described above, a binary logistic regression model is developed to explore the key determinants of the likelihood of the households of Teknaf Peninsula to collect fuelwood. Here collection of fuelwood means that either people go inside the forest to collect fuelwood or they decide to buy fuelwood and totally not go for fuelwood collection inside the forest. Overall assessment of the model for fuelwood collection is significant ($p < 0.001$) and the Hosmer & Lemeshow goodness-to-fit test showing adequate fitness of the model to the data, with an overall 67% correct prediction. The determinant factors for fuelwood collection were found to be education, family size, which union they are living, their occupation, fuelwood usage, encroachment status (Table 5.3).

Education level ($P = 0.003$) and Family size ($P = 0.005$) are found to be significantly having impact on the likelihood of fuelwood collection. Increase in one year of education decreases the chance of 3% to collect fuelwood. An increase of one family member results in the increase of the chance of collecting fuelwood by nearly 9% (Odds ratio 1.092). The bigger the family size is; the more people are likely to collect fuelwood from forest. Baharchhara and Teknaf sadar has opposite impacts on fuelwood collection. Households in Baharchhara have nearly 30% chance to collect fuelwood where in case of Teknaf sadar there are 95% chance of people not collecting fuelwood. Kacha houses have 68% more chance to collect fuelwood. The type of occupation is found also to effect the likelihood of fuelwood collection in the Teknaf Peninsula. In case of abroad and business, there were less chance of collecting fuelwood and farmers had higher chance of collecting fuelwood. With the increase of one-unit fuelwood usage the chance of collecting fuelwood increased nearly 3%. Households inside the forest had 3.4 times more chance to collect fuelwood than houses outside the forest boundary. Paan farmer were found to have 1.6 times more likelihood to collect fuelwood.

5.4 Discussion

5.4.1 Fuelwood Consumption

The mean of daily fuelwood consumption per capita was found 1.65 kg (602 kg/person/year). A study conducted in seven locations in the northern Brazilian Atlantic Forest found fuelwood consumption of 961 (±778) kg/person/year for people exclusively depending on fuelwood for cooking (Specht 2015); and in rural hilly areas in Karnataka, India, fuelwood consumption was 744 kg/person/year (Ranganathan, 1993).

Table 5.3 Logistic regression model predicting the likelihood of fuelwood collection

	B	**S.E.**	**Wald**	**df**	**Sig.**	**Odds Ratio(eB)**	**95.0% C.I.for EXP(B)**	
							Lower	**Upper**
Age	-0.153	0.312	4.127	1	0.445	0.894	0.783	0.992
Education	-0.027	0.011	6.135	1	0.003	0.973	0.953	0.994
Family Size	0.125	0.046	7.409	1	0.005	1.133	1.036	1.240
Household Area	0.023	0.045	1.379	1	0.246	1.265	0.853	1.442
Duration of living	-0.026	0.033	1.468	1	0.314	0.907	0.881	1.004
Union			125.322	4	0.000			
Baharchhara	0.206	0.107	3.738	1	0.043	1.229	0.997	1.514
Nhila	-0.020	0.091	0.048	1	0.827	0.980	0.820	1.172
Teknaf Sadar	-3.004	0.285	110.964	1	0.000	0.050	0.028	0.087
Whykhong	-0.098	0.096	1.041	1	0.308	0.906	0.750	1.095
House Type			38.650	2	0.000			
Kacha	0.520	0.096	29.214	1	0.000	1.682	1.393	2.031
Paka	-0.279	0.212	1.729	1	0.189	0.757	0.500	1.146
Occupation			119.164	5	0.000			
Abroad	-0.755	0.173	19.154	1	0.000	0.470	0.335	0.659
Business	-0.833	0.156	28.443	1	0.000	0.435	0.320	0.590
Farmer	0.180	0.170	1.119	1	0.004	1.297	0.858	1.771
Fishermen	0.078	0.167	0.218	1	0.640	1.081	0.779	1.501
Labor	-0.019	0.152	0.015	1	0.902	.981	0.728	1.322
Annual Income	0.018	0.112	0.765	1	0.433	1.018	0.986	1.109
Fuelwood Usage	0.025	0.008	9.475	1	0.002	1.025	1.009	1.342
Encroachment	1.237	0.106	137.119	1	0.001	3.445	2.801	4.237
Paan Farming	0.293	0.106	14.382	1	0.000	1.653	1.007	1.751
Constant	-0.649	0.200	10.568	1	0.001	0.523		

Hosmer & Lemeshow Test: Chi Square = 6.702, d.f. = 9, p = 0.091
-2 Log likelihood = 5369.357
Cox & Snell $R^2 = 0.179$
Nagelkerke $R^2 = 0.241$
Overall percentage of right prediction = 67.2%

Fuelwood consumption in Teknaf peninsula is lower than other studies where people are exclusively dependent on forest fuelwood. The lower consumption rate is due to the supplement of cooking fuel from the homestead trees. Settlements of the Teknaf Peninsula are scattered in and around the local forests and the officially protected forest area is practically open for small-scale activities such as fuelwood collection. Since local people have no alternative sources of energy for cooking, most are directly dependent on forests. Cow dung, charcoal and jute sticks are widely used in other rural areas in Bangladesh for cooking fuel but not commonly in Teknaf. Liquid petroleum gas and electric heaters are too costly for these people and seen in very few households. As a result, due to poverty, the lack of alternative fuels and ample availability of fuelwood inside the nearby forest, the local people have no other fuel choice than fuelwood from the forest. Fuelwood is mainly collected from the forests by the local people themselves, and it is very common for people in Teknaf to enter the forest and cut trees for fuelwood. Some poor people in the locality sell harvested fuelwood as their means of livelihood. As a result, even when people buy fuelwood from the local markets, it actually comes from the protected forest area. This excessive consumption is putting pressure on the forests.

Family size, education level, homestead area and fuelwood cost has influence on fuelwood consumption. The relationship between poverty and fuelwood dependency has been documented in Brazil and other countries at local scales (Hiemstra 2009; Matsika 2013; Top 2006). Medrios et al. (2012) found that socioeconomic characteristics of rural communities in the same region explained up to 31% of fuelwood consumption, with monthly income the most important. This study shows that, socioeconomic characteristics (i.e. family size, education level and homestead area) are related to fuelwood consumption. With the increase of family size, the per capita fuelwood consumption decreases because of cooking for more members together decreases the amount of per capita fuelwood consumption. Increase in education level associates with awareness and better management of resources which leads to decrease in fuelwood consumption. When the homestead area increases the source of fuelwood from the homestead area also increases which lowers the consumption of forest fuelwood. Fuelwood cost is calculated by calculating the economic value of the fuelwood consumed by the household. With the increase in the fuelwood value the consumption decreases. Understanding the factors influencing the fuelwood consumption is important for developing management strategies for sustainable forest resource usage.

5.4.2 Fuelwood Collection

Fuelwood collection is one of the major deforestation drivers in Teknaf peninsula. This section discusses the factors influencing the fuelwood collection from the forests. Education level and family size impacts the likelihood of fuelwood collection. When the education increases the chance of fuelwood collection decreases because higher education results in alternative income sources which leads to less chance of fuelwood collection. Family size has positive impact on fuelwood collection. When the family size increases the fuelwood consumption for household increases due to cooking extra food for more family members. Also extra family members can help in fuelwood collection which results in more likelihood to collect fuelwood. Among the Unions, people in Baharchhara have more likelihood to collect fuelwood from the forests. In Baharchhara, the forest boundary is very near to the seaside giving a comparatively narrow space for settlements which results in more households inside or along the forest boundary. Also in Baharchhara, paan farmers are concentrated. These factors influence the people to collect fuelwood from the forests leading to more likelihood of fuelwood collection. Among the house type, kacha houses have more likelihood to collect fuelwood from the forests. Kacha houses belong to relatively poor people with no alternative cooking fuel choice than fuelwood. Also they do not have the capability to purchase the fuelwood. These factors are supported by the logistic regression analysis resulting in 68% more likelihood to collect fuelwood from the forests than other type of households. Type of occupation is found to have impact on the fuelwood collection choice. Households whose main occupation are abroad and business seems to have less chance of fuelwood collection than the farmers. Households whose main occupation are broad and business have more mean income comparing with farming and other occupations causing them to be capable of purchasing fuelwood rather than collecting. Encroachment and *paan* farming also influences fuelwood collection. Encroachment means living inside the forest illegally. When a family lives inside the forest the option for buying fuelwood from the market has less priority because they have an easy access to fuelwood collected from the nearby forest area. So encroachers always will have the high likelihood to collect fuelwood from forests. In case of paan farmers, for collecting the shading materials they have to collect woods from the forests. When collecting wood from forests for shading materials becomes foreseeable, collecting fuelwood from forest also becomes the most convenient choice for cooking fuel. So all the paan farmers have high likelihood to collect fuelwood. Exploring the factors influencing the fuelwood collection is very important for the control of fuelwood collection. To stem the deforestation inside the protected area of TWS it is important to identify and realize the factors influencing the deforestation drivers.

5.4.3 Fuelwood and Deforestation

In case of Teknaf reserve forests, large scale disturbance i.e. forest land clearing for industry or pastures and tree harvesting for wood industry. But the small scale disturbance such as fuelwood harvesting has become a threat to the future existence to the forest. Fuelwood is used by almost every household in Teknaf and not only the source of cooking energy, fuelwood selling and distribution is the mean of living for many poor people in the peninsula. But the over dependency on fuelwood is exerting pressure on the forests. This study found that 602 kg fuelwood is required annually for one person, considering the total population 0.26 million the total demand for fuelwood in the Teknaf Peninsula is 156,520 tons of fuelwood. Considering the total forest product 334,512 annually (chapter 4), fuelwood alone accounts for 47% of the total forest production. Besides this, during the harvest of fuelwood sometimes the collectors cut the saplings and young trees totally to increase the amount of fuelwood. Cutting the saplings and young trees hampers the natural regeneration of the forests. Limiting the collection of fuelwood from the forest area is necessary to stem the deforestation in the protected forest area. Considering the above issues, forest management strategies have to include alternative fuel option and sustainable collection of forest products.

5.5 Conclusion

The focus of this chapter is to determine the fuelwood consumption in the Teknaf peninsula and explore the factors influencing the consumption and collection of fuelwood. The per capita annual consumption of fuelwood is found 602 kg. During the winter season the consumption is higher (1.82 kg/person/day) than the rainy season (1.52 kg/person/day). Family size, education level, homestead area and fuelwood cost has influence on the fuelwood consumption. Beside the fuelwood consumption, the factors influencing the fuelwood collection are described. Education, family size, place of living, house type, occupation, encroachment status and paan cultivation are found to impact the fuelwood collection. Fuelwood harvesting and consumption has impact on the forests. Fuelwood consumption is responsible for the 47% forest product annually. Fuelwood is an important issue in the context of deforestation inside the protected forests of Teknaf. Immediate restriction of fuelwood collection will not be possible due to the over dependency on fuelwood by the local people but the policy makers should focus on alternative sources of energy than fuelwood and sustainable forest resource management. Alternative energy source will reduce pressure on fuelwood dependency leading towards less fuelwood harvest. Less fuelwood harvest can play a vital role to stem the deforestation in the Teknaf peninsula.

CHAPTER 6. CONCLUSION

6.1 General Conclusion

This study mainly focuses on the deforestation drivers and their impact on a protected forest area known as Teknaf Wildlife Sanctuary. To stem deforestation, establishing PAs are commonly practiced but deforestation within the PAs has become a concern. Deforestation rate in Bangladesh is nearly -0.18 (FAO, 2015) but in some PAs, deforestation rate is even higher within the forest boundaries. Deforestation within and around the boundaries of protected forests is a major concern for the forest management strategies. Deforestation is one of the concerning environmental crises (Ludeke et al. 1990), which is responsible for a significant part of GHG emissions (IPCC 2007; Vieilledent et al. 2013) and biodiversity loss (Gibson et al. 2011), and leads to further environmental crises, desertification (Geist 2005). In recent decades, deforestation has mostly occurred tropical developing countries, where their rate had been declining, but their trend has overturned (Budiharta et al. 2014). Halting deforestation is a global political commitment and one of the main mitigation actions in climate change issues. Deforestation has been recognized an anthropogenic issue (IPCC 2007), within which various and dynamic proximate and underlying factors are interconnected (Angelsen and Kaimowitz 1999; Geist and Lambin 2002). Understanding those factors should be put in a certain context and circumstance, in order to improve our better understanding, as well as to bridge further discussion for policy examinations.

6.1 Overall Conclusion and Summary

The main objective of the study was to elucidate the deforestation drives and to describe their impact on the forests in Teknaf Peninsula. Chapters 3 - 5 mainly describes the deforestation drivers. For this study, settlement expansion, paan cultivation and fuelwood collection are considered as the main three proximate drivers responsible for the deforestation in the Teknaf Peninsula. Figure 6.1 represents a summary of the cause and effect of the deforestation drivers. During this study, the factors influencing the deforestation drivers were identified and then the impact of the drivers were described on the local forests. For all the deforestation drivers the Union they are living and occupation are the common factors influencing the deforestation drivers alongside other socio-economic aspects. In case of Baharchhara, the households there have 87% more chance to cultivate paan, 2.24 times more likelihood to encroach inside the forest and 23% more chance to collect fuelwood from forests.

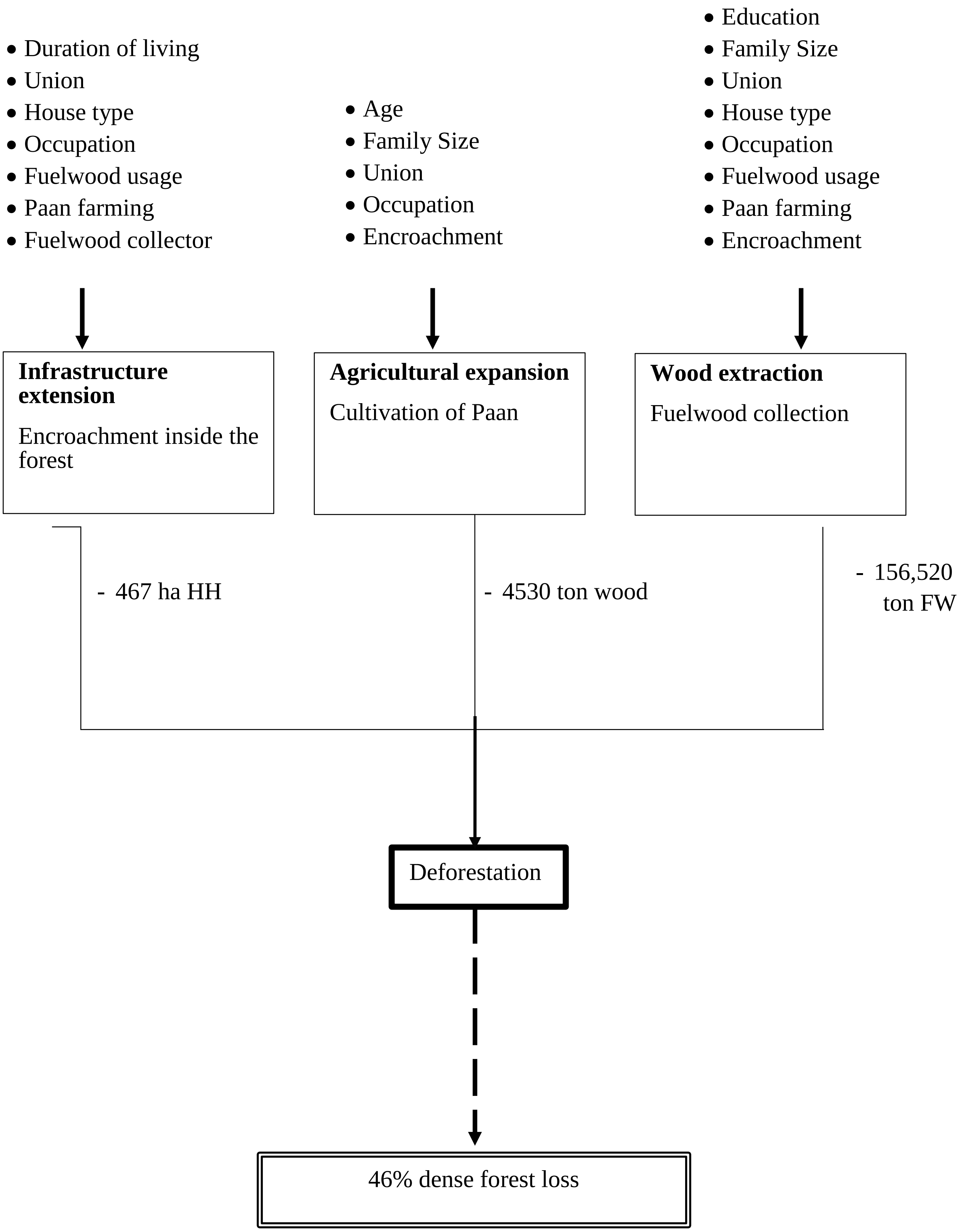


Figure 6.1 Cause and effect of deforestation drivers in the Teknaf Peninsula

So, while developing forest management strategies, these points should be considered. Baharchhara is a Union of Teknaf Upazila but the location and position of the Union can be used in future studies. Baharchhara Union is a narrow strip between the sea and forest barely 1 km in width. People have easy access to forest comparing to other Unions. When the settlements are very near the forest and natural barrier locks the borders, people have very few choices other than depending on the forest. Establishing settlements near the forest makes people more dependent on the forest resources. Same scenario is presented in Baharchhara. The local people of Baharchhara lives in a close proximity to the forest and west side is blocked by the Bay of Bengal which makes them more dependent on forests than other Unions.

In case of occupation, farmers have 10 times more chance to cultivate paan and 30% more chance to collect fuelwood from the forest. Understanding the factors having impact on deforestation drivers is necessary for developing forest management strategies. From this study it can be concluded that people from Baharchhara are more responsible for deforestation than other parts of the peninsula and also farmers are directly depending more on forests comparing the other occupations. The impact of these deforestation drivers are devastation. During the last 25 years (1989-2015) dense forest area (mainly Class 5) decreased 46% and if considering just inside the TWS boundary then the loss is up to 66%. This study focused on quantifying the loss of forest resources to draw conclusion on the impacts on forests. It is found that illegal encroachment resulted in 467 ha homestead areas inside the TWS. This is only the homestead area but the agriculture land clearing the forest area can show more clear picture of deforestation but that was not possible to quantify in this study. In case of paan cultivation all of the paan borojs in the peninsula required 4530 ton of wood materials for the shading. The most common and visible forest resource was fuelwood for cooking. The demand of fuelwood in the Teknaf was calculated to be 156,520 tons per year.

The impact of the deforestation drivers on the local forests were prominent but the exact quantification is a very complicated procedure. Also the lack of forest productivity data of the specific region made it more difficult to determine. Considering the forest productivity in Thailand (28.6 ton/ha, Tsurutal et.al., 2012) and the highest recorded AGWP in Asia (23.6 Mg/ha/year, Paoli & Curran 2007), the deforestation drivers described in this study are accountable for 60% to 70% forest products. This is based on the comparison of the of the production and total demand. But the actual scenario of deforestation has more dimensions than production and consumption. The clearing of forest coverage for settlements and agriculture have immense impact on the deforestation. Also while harvesting forest products cutting saplings hampers the regeneration of the forests. The impact of the deforestation drivers is becoming more threatening day by day due to the high rate of deforestation. The demand of people is putting more pressure on the forests and the existence of the forest is in threat. Without proper forest management strategies taking account of the deforestation drivers, the future of the forests will not change. The immense pressure of the deforestation drivers will lead the Teknaf Wildlife Sanctuary towards total forest land destruction and degradation.

6.2 Policy Alternatives and Future Research

Establishment of protected areas itself is a widely practiced policy to stem deforestation. But this approach is not working properly in the Teknaf peninsula. PA may work in other regions, with different environment and population dynamics but in case of TWS the approach needs to be revised and rectified. In case of TWS, the local people are dependent on the forest much more than other protected forests. So, restricting the forest area with poor regulation may lead to deforestation rather than stopping it. For TWS, alternative income sources and alternative energy sources should be the most focused area for the policy makers. Some polict alternative aspects is described below-

a. Alternative Income Generation

   In the current situation, local people are dependent on protected forests for their livelihood. Collection of fuelwood, *paan boroj* inside forest, cultivation inside forest and homestead garden are the most common mean od forest dependency generating income from the forest or forest resources. The more people depending on forest will lead to more deforestation. Alternative income sources i.e. crafting, poultry, cultivating high value agricultural products and small industry like fish feed can be explored for alternative income sources.

b. Alternative Energy Sources

   Almost every household in Teknaf peninsula uses fuelwood for cooking. Some houses use LP gas but the number is not significant. Fuelwood is the most widely used forest resource. As big trees decreased in the region now people collect fuelwood from the long bushes and even young saplings. This process is leading towards deforestation by hampering the regeneration process. Alternative energy source, best option is LP gas for Teknaf should be used by more people. Comparing the cost, LP gas has high initial cost but latterly the cost of fuel is almost similar comparing the price of fuelwood. But the main point is fuelwood is free and LP gas needs to be paid. But creating awareness among the local people of the benefit of LP gas and if possible incentive from the government will make people adapt to LP gas use in large scale. Introduction of LP gas in a large scale among the local people will have immediate impact on forest regeneration and also stem deforestation.

c. Zoning

Zoning the forest area is a common practice around the world. Also PA is a kind of zoning lands. In case of Teknaf, zoning will be very difficult because local people are very much dependent on forests and restricting them to enter the forests will be impossible. But creating a zone around the forest boundary and declaring the area for forest resource use can help to stem deforestation. Currently the total area is restricted officially but people are exploiting the forest resources. Declaring a buffer area around the forest boundary which can be used for forest resource consumption and restricting the dense forest areas will decrease the land under strict supervision. Also at the same time forest area can be freely used by the local people to meet their livelihoods. The point of zoning is managing the illegal use of forest area and bringing it under a sustainable management process allowing the dense forest area to maintain a stricter protection. This will allow the forest to regenerate and in the future can supply enough forest resources to decrease the pressure on the buffer zone created around the forest boundary. Executing zoning in Teknaf will require more planning, accurate mapping of forest resources and strict protection support from the government and other concerning organizations.

Further advance studies are required for developing proper forest management strategies. Future possible studies can be as follows -1) accurate mapping of the forest area for proper mapping, 2) comprehensive evaluation of the on-going strategies taken by government and non-government organizations, 3) further research on the possibilities to reduce the dependency of the local people on the forests.

References

Achard, F., Beuchle, R., Mayaux, P., Stibig, H.-J., Bodart, C., Brink, A., Donnay, F., Lupi, A., Carboni, S., Desclee, B., Donnay, F., Eva, H.D., Lupi, A., Rasi, R., Seliher, R., Simonetti, D., 2014. Determination of tropical deforestation rates and related carbon losses from 1990 to 2010. Global Change of Biology, 20, pp 2540–2554

Achard, F., Eva, H.D. Stibig, H.T., Mayaux, P., Gallego, J., Richards, T., Malingreau, T.P. 2002. Determination of deforestation rates of the world's humid tropical forests Science, 297, pp. 999-1002

Adhikari, S., Southworth, J., & Nagendra, H. (2015). Understanding forest loss and recovery: A spatiotemporal analysis of land change in and around Bannerghatta national park, India. Journal of Land Use Science, 10(4), pp 402-424

Agresti, A. 1996. An introduction to categorical data analysis John Wiley & Sons, Inc., New York, pp 290

Ahrends A, Burgess ND, Milledge SAH, Bulling MT, Fisher B, Smart JCR, Clarke GP, Mhoro BE, Lewis SL. 2010. Predictable waves of sequential forest degradation and biodiversity loss spreading from an African city. Proc. Natl. Acad. Sci. USA 107 (33): 14556–14561

AIS. 2017. Agriculture information service. Ministry of Agriculture, Government of the People's Republic of Bangladesh, Dhaka

Alam MF, Uddin MZ, Hasan MA. 2012. Evaluation of Plant Biodiversity in Teknaf Wildlife Sanctuary, Bangladesh. LAP LAMBERT Academic Publishing. Germany

Alam, S., Misbahuzzaman, k., Rahman, M. A., Kabir, M.H. 2014. Threats to the Teknaf Wildlife Sanctuary of Bangladesh. Journal of Environmental Science and Natural Resources, 7 (1), pp 233-239

Andam, K., Ferraro, P., Pfaff, A., Sanchez-Azofeifa, A., & Robalino, J. 2008. Measuring the effectiveness of protected area networks in reducing deforestation. Proceedings of the National Academy of Sciences, 105(42), pp 16089–16094

Andam, K., Ferraro, P., Sims, K., Healy, A., Holland, M. 2010. Protected areas reduced poverty in Costa Rica and Thailand. Proceedings of the National Academy of Sciences, 107(22), pp 9996 – 10001

Arnold M, Persson R. 2003. Reassessing the fuel wood situation in developing countries. International Forestry Review 5(4): 379

Belal MAH. 2013. Effectiveness of Co-management Committees in Teknaf Wildlife Sanctuary. In: Fox J, Mustafa MG, Bushley Brennan SM, Durand L. Connecting Communities and Conservation: Co-management Initiatives Implemented by IPAC in Wetland and Forests of Bangladesh. USAID-Nishorgo Network: Dhaka, Bangladesh

BFD. 2014. Wildlife Sanctuary: Protected Areas of Bangladesh. Bangladesh Forest Department. [updated 2011 Dec 15; cited 2014 December 03]. Available from: http://www.bforest.gov.bd/index.php/protected-areas

Blackman, A. 2015. Strict versus mixed use protected areas: Guatemala's Maya Biosphere Reserve. Ecological Economics, 112, pp 14 – 24

Bouget C, Lassauce A, Jonsell M (2012) Effects of fuelwood harvesting on biodiversity—a review focused on the situation in Europe Can J Forest Res, 42, pp. 1421–1432

Budiharta, S., Meijaard, E., Erskine, P. D., Rondinini, C., Pacifici, M. and Wilson, K. A. 2014. Restoring degraded tropical forests for carbon and biodiversity. Environmental Research Letters 9 (11)

Butler R. 2016. Tropical Deforestation Tables. Mongabay.com, 11, January, 2016. rainforests.mongabay.com/deforestation_alpha.html.

Campbell, A., Clark, S., Coad, L., Miles, L., Bolt, K., & Roe, D. 2008. Protecting the future: Carbon, forests, protected areas and local livelihoods. Biodiversity, 9 (3-4), pp117-122

Cantarello E, Lovegrove A, Orozumbekov A, Birch J, Brouwers N, Newton AC. 2014. Human impacts on forest biodiversity in protected Walnut-Fruit Forests in Kyrgyzstan. J. Sustain. For. 33(5): 454–481

CEGIS. 2011. Land use Change Trend Analysis in Seven Protected Areas in Bangladesh under IPAC Through Application of Landsat Imageries. USAID's Integrated Protected Area Co-Management (IPAC) Project. USAID/Bangladesh

Chowdhury, M.S.H., Izumiyama, S. 2014. Potential Threats, Their Patterns and Extend to the Protected Areas of Bangladesh: A Red Flag of Biodiversity Conservation Efforts. Forest Conservation in Protected Areas of Bangladesh. Chapter 11, pp 231-250

Chowdhury, M.S.H., Koike, M. 2010. An overview on the protected area system for forest conservation in Bangladesh. Journal of Forestry Research, 21, pp 111-118

Clements, T., Suon, S., Wilkie, D., & Milner-Gulland, E. J. 2014. Impacts of protected areas on local livelihoods in Cambodia. World Development, 64(S1), pp 125-134

Contreras-Hermosilla, A. 2000. The Underlying Causes of Forest Decline. Bogor (Indonesia): Center for International Forestry Research

Coulibaly-Lingani, P., Tigabu, M., Savadogo, P., Oden, P.C., Ouadba, J.M. 2009. Determinants of access to forest products in Southern Burkina Faso. Forest Policy and Economics, 11, pp 516-524

Dovie DBK, Witkowski ETF, Shackelton CM (2004) The fuelwood crisis in Southern Africa – relating fuelwood use to livelihoods in a rural village. GeoJournal 60(2):123–133

Ellis, E.A., Porter–Bolland, L. 2008. Is community-based forest management more effective than protected areas? A comparison of land use/land cover change in two neighboring study areas of the Central Yucatan Peninsula, Mexico. Forest and Ecological Management 256, pp1971–1983

Etter, A., McAlpine, C., Wilson, K., Phinn, S., Possingham, H. 2006. Regional patterns of agricultural land use and deforestation in Colombia. Agricultural Ecosystem and Environment, 114, pp 369-386

FAO, 2015. Global Forest Resources Assessment 2015. FAO Forestry Paper No. 1. UN Food and Agriculture Organization, Rome

FAO, JRC Global forest land-use change 1990–2005. Lindquist, E.J., Annunzio, R. D., Gerrand, A., MacDicken, K., Achard, F., Beuchle, A., Brink, A., Eva, H.D., Mayaux, P., San-Miguel-Ayanz, J., Stibig, H.J. (Eds.). 2012. FAO Forestry Paper No. 169, Food and Agriculture Organization of the United Nations and European Commission Joint Research Centre, FAO, Rome

Food and Agriculture Organization of the United Nations (FAO), 2011. State of the World's Forests. (Chapter 2)

Geist, H.J., Lambin E.F. 2002. Proximate causes and underlying driving forces of tropical deforestation. Bio. Sci., 520 (2), pp 143-150

Ghilardi A, Guerrero G, Masera O. 2007. Spatial analysis of residential fuelwood supply and demand patterns in Mexico using the WISDOM approach. Biomass Bioenergy 31(7): 475-491

Ghosh, S., Maiti, A. 2011. Betel leaf cultivation – A Potential Crop for Sustainable Income. An In-depth Study on Economy of Betel Leaf Cultivation and Marketing with reference to Nadia District, West Bengal, India. Pp 120

Gibbs, H.K., Ruesch, A.S., Achard, F., Clayton, M.K., Holmgren, P., Ramankutty, N., Foley, J.A. 2010. Tropical Forests Were the Primary Source of New Agriculture Land in the 1980 and 1990. Proceedings of Natural Academy of Science in U.S.A, 107, 16732 – 16737

Hansen, C.M., Krylov, A., Tyukavina, A., Potapov, P.V., Turubanova, S., Zutta, B., Ifo, S., Margono, B., Stolle, F., Moore R. 2016. Humid tropical forest disturbance alters using landset data. Environmental Research Letter. 11(3)

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G., 2013. High-resolution global maps of 21st-century forest cover change. Science 342, pp 850- 853

Hansen, M.C., Stehman, S.V., Potapov, P.V., 2010. Quantification of global forest cover loss. Proc. Natl. Acad. Sci. USA 107, 8650–8655

Hansen, M.C., Stehman, S.V., Potapov, P.V., Loveland, T.R., Townshend, J.R.G., DeFries, R.S., Pittman, K.W., Arunarwati, B., Stolle, F., Steininger, M.K., Carroll, M., Di Miceli,

C. 2008 Humid tropical forest clearing from 2000 to 2005 quantified by using multitemporal and multiresolution remotely sensed data. PNAS, 105, pp 9439-9444

Hansfort SL, Mertz O. 2011. Challenging the woodfuel crisis in West African woodlands. Hum. Ecol. 39(5): 583-595

He G, Chen XD, Bearer S, Colunga M, Mertig A, An, Zhou SQ, Linderman M, Ouyang ZY, Gage S, Li S., Liu JG. 2009. Spatial and temporal patterns of fuelwood collection in Wolong Nature Reserve: implications for panda conservation. Landsc. Urban Plan. 93(1): 92

Hiemstra van der Horst G, Hovorka AJ (2009) Fuelwood: the "other" renewable energy source for Africa? Biomass Bioenerg, 33, pp. 1605–1616

Hosmer, D.W., Lemeshow, S. 2000. Applied Logistic Regression, second ed. John Wiley and Sons, New York

Houghton, R. 2012. Carbon Emissions and the Drivers of the Deforestation and Forest Degradation in the Tropics. Current Opinion in Environmental Sustainability, 4, pp 597-603

IPCC 2014. Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press

Islam, K., Mohammed, J., Biswajit, N., Tapan, K. N. 2017. Land use classification and change detection by using multi-temporal remotely sensed imagery: The case of Chunati wildlife sanctuary, Bangladesh, The Egyptian Journal of Remote Sensing and Space Science, 2017, ISSN 1110-9823, http://dx.doi.org/10.1016/j.ejrs.2016.12.005

Jagge P, Shively G. 2014. Land use change, fuel use and respiratory health in Uganda. Energy Policy, 67, pp 713-726

Joppa, L., Pfaff, A. 2010. Global protected area impacts. Proceedings of the Royal Society, 278(1712), pp 1633–1638

Judge, G. G., Hill, R. C., Griffiths, W. E., Lűtkepohl, H., Lee, T.C. 1985. Theory and practice of econometrics. John Wiley and Sons, New York

Kaimowitz, D. and Angelsen, A. 1998. Economic Models of Tropical Deforestation: A review. Center for International Forestry Research

Keenan, R. J., Reams, G. A., Achard, F., de Freitas, J. V., Grainger, A., & Lindquist, E. 2015. Dynamics of global forest area: Results from the FAO global forest resources assessment. Forest Ecology and Management, 352, pp 9-20

Lambin, E.F. 1994. Modelling Deforestation Processes: A Review. Luxembourg: European Commission, Directorate-General XIII. Report no. EUR-15744-EN. (Available from Office of Official Publications of the European Community, Luxembourg.)

Lambin, E.F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E.F., Rindfuss, R.R., Sato, Y., Skole, D., Turner, B.L., Vogel, C. (1999): Land-Use and Land-Cover Change (LUCC) – Implementation Strategy. A core project of the International Geosphere-Biosphere Programme and the International Human Dimensions Programme on Global Environmental Change (= IGBP Report; 48/IHDP Report; 10). – IGBP Secretariat: Stockholm & IHDP Secretariat: Bonn

Lauri P, Havlı KP, Kindermann G, Forsell N, Bo ̈ttcher H, Obersteiner M (2014) Woody biomass energy potential in 2050. Energy Policy, 66, pp 19–31

Liu, J., Linderman, M., Ouyang, Z., An, L., Yang, J., & Zhang, H. 2001. Ecological degradation in protected areas: The case of Wolong Nature Reserve for giant pandas. Science, 292, pp 98 – 101

Ludeke, A.K., Maggio, R.C., Reid, L.M.1990. An analysis of anthropogenic deforestation using logistic regression and GIS. Journal of Environment and Management, 31, pp 247-259

Mander S., Kevin A., Alice L., Clair G., Naomi V. 2016. The Role of Bio-energy with Carbon Capture and Storage in meeting the Climate Mitigation Challenge: A Whole System Perspective. 13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November, Lausanne. Switzerland

Matsika R, Erasmus BFN, Twine WC (2013) A tale of two villages: assessing the dynamics of fuelwood supply in communal landscape in South Africa Environ Conserv, 40, pp. 71–83

McFadden, D. 1974. Conditional logit analysis of qualitative choice behaviour. In: Zarembka P (ed), Economic Theory and Mathematical Economics. Academic Press, New York

Mederios PM, da Silva TC, de Almeida ALS, de Albuqueraque UP (2012) Socio-economic predictors of domestic wood use in an Atlantic forest area (north-east Brazil): a tool for directing conservation efforts Int J Sust Dev World, 19, pp. 189–195

Meyer, W.B., Turner, B.L. 1992. Human population growth and global land use/ land-cover change. - Annual Review of Ecology and Systematics,Vol. 23, pp 39-61

Moroni MT, Musk RA. 2014. Domestic Timber Harvesting Affects Wood Quantities in Tasmanian Dry Eucalypt Forests. Australian Forestry

Mukul, S. A., Rashid, A. Z. M. M., Khan, N. A. 2017. Forest protected area systems and biodiversity conservation in Bangladesh. In: Mukul, S. A., Rashid, A. Z. M. M. (eds.), Protected Areas: Policies, Management and Future Directions, pp 161. Nova Science Publishers, US

Mukul, S.A. 2014. Biodiversity conservation and ecosystem functions of traditional agroforestry systems: case study from three tribal communities in and around Lawachara National Park. In: Chowdhury, M.S.H. (ed.). Forest conservation in protected areas of

Bangladesh: policy and community development perspectives. Switzerland: Springer. pp 171-179

Mukul, S.A., Quazi, S.A. 2009. Communities in Conservation: Changing protected area management and enhanced conservation in Bangladesh. In: Leslie, R.N. (ed.), The Future of Forests in Asia and the Pacific: Outlook for 2020. Food and Agriculture Organization of the United Nations, Bangkok, Thailand (FAO-RAP Publication no 2008/3), pp 143-159

Mukul, S.A., Rashid, A.Z.M.M., Quazi, S.A., Uddin, M.B., Fox, J., 2012. Local peoples' response to co-management in protected areas: a case study from Satchari National Park, Bangladesh. For. Trees Livelihoods 21, 16–29

Muller, R., Muller, D., Schierhorn, F., Gerold, G. and Pacheo, P. 2012. Proximate Causes of Deforestation in Bolivian Lowlands: An Analysis of Spatial Dynamics. Regional Environmental Change, 12, pp 445-459

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities Nature, 403, pp. 853–858

Nagendra, H., 2008. Do parks work? Impact of protected areas on land cover clearing. Ambio 37(5), pp 330–337

Naughton-Treves L, Kammen DM, Chapman C (2007) Burning biodiversity: woody biomass use by commercial and subsistence groups in western Uganda's forests. Biol Conserv 134:232–241

Naughton-Treves, L., Holland, M. B., Brandon, K. 2005. The role of protected areas in conserving biodiversity and sustaining local livelihoods Annual Review of Environment and Resources, 30, pp 219-252

Ojima, D.S., Galvin, K.A., Turner, B.L. 1994.The Global Impact of Land-use Change. – BioScience. Vol. 44 (5), pp. 300-304

Orozumbekov A, Cantarello E, Newton AC. 2015. Status, distribution and use of threatened tree species in the walnut-fruit forests of Kyrgyzstan. For. Trees Livelihoods 24 (1)

Pang C, Yu H, He J, Xu J. 2013. Deforestation and changes in landscape patterns from 1979 to 2006 in Suan County, DPR Korea. Forests 4(4), pp 968-983

Paoli, O.L., Curran, L. M. 2007. Soil nutrients limit fine litter production and tree growth in mature lowland forest of southwestern Borneo Ecosystem, 10, pp 503-518

Peng, C.Y.J., Lee, K.L., Ingersoll, G.M. 2002. An introduction to logistic regression analysis and reporting The Journal of Education Research, 96 (1), pp 3-14

Peres CA, Gardner TA, Barlow J, Zuanon J, Michalski F, Lees AC, Vieira ICG, Moreira FMS, Feeley KJ (2010) Biodiversity conservation in human modified Amazonian forest landscapes Biol Conserv, 143, pp. 2314–2327

Petursson, J.G., Vedeld, P. and Sassen, M. 2013. An Institutional Analysis of Deforestation Process in Protected Areas: The Case of the Transboundary Mt. Elgon, Uganda and Kenya

Pfaff, A., Robalino, J., Lima, E., Sandoval, C., & Herrera, L. D. 2014. Governance, location and avoided deforestation from protected areas: Greater restrictions can have lower impact, due to differences in location. World Development, 55, pp 7-20

Poffenberger, M. 2000. Communities and forest management in South Asia. IUCN, DFID, and Asia Forest Network, Philippines

Puyravaud, J.P., 2003. Standardizing the calculation of the annual rate of deforestation. For. Ecol. Manage. 177, 593–596. http://dx.doi.org/10.1016/S0378-1127(02) 00335-3

Ranganathan V, Subba SR, Praddu GS (1993) Demand and supply of fuelwood in Karnataka (unpublished) For the Forest Department, Government of Karnataka. Indian Institute of Management (II M), Bangalore. Pp 187

Robalino, J., Villalobos, L., Blackman, A., & Pfaff, A. 2012. Impacts of protected areas on population growth, inequality, and marginalization in Mexico Working paper. Turialba, Costa Rica: Centro Agrono´mico Tropical de Investigacio´n y Ensen˜anza (CATIE)

Ruger N, Williams-Linera G, Kissling WD, Huth A (2008) Long-term impacts of fuelwood extraction on a tropical montane cloud forest Ecosystems, 11, pp. 868–881

Ryan CM, Hill T, Woollen E, Ghee C, Mitchard E, Cassells G, Grace J, Woodhouse IH, Williams M. 2012. Quantifying small-scale deforestation and forest degradation in African woodlands using radar imagery. Glob. Change Biol. 18(1): 243-257

Sanchez-Azofeifa, G. A., Rivard, B., Calvo, J., & Moorthy, I. 2002. Dynamics of tropical deforestation around national parks: Remote sensing of forest change on the Osa Peninsula of Costa Rica. Mountain Research and Development, 22(4), pp 352-358

Serneels, S., Lambin, E.F. 2001. Proximate causes of land-use change in Narok District, Kenya, A spatial statistical model. Agricultural Ecosystem and Environment, 85, pp 65-81

Shrestha S, Karky BS, Gurung A, Bista R, Vetaas OR. 2013. Assessment of carbon balance in community forests in Dolakha, Nepal. Small-scale For. 12(4): 507-517

Sims, K. 2010. Conservation and development: Evidence from Thai protected areas. Journal of Environmental Economics and Management, 60(2), pp 94-114

Singh G, Rawat GS, Verma D. 2010. Comparative study of fuelwood consumption by villagers and seasonal “Dhaba owners“ in the tourist affected regions of Garhwal Himalaya, India. Energy Policy 38(4): 1895-1899

Sohel, M.S.I., Mukul, S.A., Burkhard, B. 2015. Landscape’s capacities to supply ecosystem services in Bangladesh: A mapping assessment for Lawachara National Park. Ecosystem Services, 12 pp 128-135

Song, H., Wan, Y., Xu, Y.Y. 2013. Betel Quid Chewing Without Tobacco - A Meta-analysis of Carcinogenic & Precarcinogenic Effects. Asia Pasific Journal of Public Health. doi:10.11 77/1010539513486921

Specht MJ, Ribeiro PSR, Albuqueque UP, Tabarelli M, Melo Felipe PL. 2015. Burning biodiversity: fuelwood harvesting causes forest degradation in human-dominated tropical landscapes. Glob. Ecol. Conserv. 3: 200-209

Stibig, H.J., Achard, F., Carboni, S., Raši, R., Miettinen, J. 2013. Change in tropical forest cover of Southeast Asia from 1990 to 2010. Biogeosci. Discuss., 10, pp 12625-12653

Tabachnick, B.G., Fidell, L.S. 2007. Using Multivariate Statistics, fifth ed. Allyn & Bacon, Boston

Tani, M. 2017. Impact of Betel Leaf Cultivation. Deforestation in the Teknaf Peninsula of Bangladesh: A study of Political Ecology. Chapter 3. pp 43-56

Tani, M., Rahman, M.Z., Moslehuddin, A.Z., Asahiro, K., Tsuruta, H., 2013. The Characterization of Dwellers in the Reserve Forest of Teknaf Wildlife Sanctuary, Bangladesh. Proceedings of 4th International Conference on Environmental Aspects of Bangladesh. ICEAB 2012. August 24-26

Top N, Mizoue N, Ito S, Kai S, Nakao T, Ty S (2006) Re-assessment of woodfuel supply and demand relationship in Kampong Thom Province, Cambodia Biomass Bioenerg, 30, pp. 134–143

Tsuruta, H., Tani, M., Rahman, M.Z. 2012. The study on the impact of betel leaf cultivation on the local forest in the Teknaf Peninsula. Proceedings of 3rd International Conference on Environmental Aspects of Bangladesh. ICEAB 2012. October 12-14

Turner, B.L., Moss, R.H., Skole, D.M. 1993. Relating land use and global land-cover change. A proposal for IGBP-HDP core project (IGBP Report; 24/HDP Report; 5)

UNEP-WCMC. 2016. The world database on protected areas (WDPA) [On-line]. Cambridge, UK: UNEP-WCMC. Available online at: www. protectedplanet.net

Venter, O., Fuller, R.A., Segan, D.B., Carwardine, J., Brooks, T., Butchart, S.H.M., Marco, M.D., Iwamura, T., Joseph, L., O'Grady, D., Possingham, H.P., Rondinini, C., Smith, R.J., Venter, M., Watson, J.E.M. 2014. Targeting global protected area expansion for imperiled biodiversity. PLoS Biology, 12

Vieilledent, G., Grinand, C. and Vaudry, R. 2013. Forecasting deforestation and carbon emissions in tropical developing countries facing demographic expansion: A case study in Madagascar. Ecology and Evolution 3 (6), pp 1702-1716

Vuohelainen, A. J., Coad, L., Marthews, T. R., Malhi, Y., Killeen, T. J. 2012. The effectiveness of contrasting protected areas in preventing deforestation in Madre de Dios, Peru. Environmental Management, 50(4), pp 645-663

Wangchuk S, Siebert S, Belsky J. 2014. Fuelwood use and availability in Bhutan: implications for national policy and local forest management. Hum. Ecol. 42(1): 127-135

Wittemyer, G., Elsen, P., Bean, W., Coleman, A., Burton, O., & Brashares, J. 2008. Accelerated human population growth at protected area edges. Science, 321(5885), pp 123-126

Yang, X., Skidmore, A.K., Melick, D.R., Zhou, Z., Xu, J. 2006. Mapping non-wood forest product (matsutake mushrooms) using logistic regression and a GIS expert system. Ecological Modelling, 198, pp 208-218

Appendix I

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	No. of Houses	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
1	Teknaf Pourashova	Kaikkali Para	45	10.0	36.3	7.5	0.0	105750.0	3.8
2	Teknaf Pourashova	Naittong Para	801	20.9	39.3	6.2	1.3	158890.0	7.7
3	Teknaf Pourashova	Puran Pollan Para	622	26.5	36.3	6.0	2.7	167861.5	7.8
4	Teknaf Pourashova	Kaikal Para	171	30.4	39.1	6.2	0.7	143666.7	2.9
5	Teknaf Pourashova	Islamabad	235	17.9	38.9	5.3	1.0	178125.0	4.6
6	Teknaf Pourashova	Oilabad	71	24.8	46.7	6.6	4.6	13200.0	6.0
7	Teknaf Pourashova	Oilabad	240	27.1	44.6	5.6	3.9	155857.1	8.2
8	Teknaf Pourashova	Dalipara	72	17.3	44.3	6.6	2.9	217000.0	3.6
9	Teknaf Pourashova	Kulal Para	290	26.4	36.8	5.5	3.5	134321.7	4.0
10	Teknaf Pourashova	Chowdhury Para	93	48.9	32.2	6.1	3.3	131666.7	3.7
11	Teknaf Pourashova	Uttar Jalia Para	386	38.6	40.1	5.6	0.8	117955.6	3.5
12	Teknaf Pourashova	Bazar Para	63	20.3	45.3	6.7	2.0	100285.7	3.4
13	Teknaf Pourashova	Madhya Jalia Para	121	47.9	46.3	6.3	1.3	146500.0	4.4
14	Teknaf Pourashova	Dakhin Jalia Para	229	48.5	44.0	5.9	1.4	153230.8	4.8
15	Teknaf Pourashova	Hungar Para	22	25.0	48.8	11.0	2.0	423750.0	8.3
16	Teknaf Pourashova	Kulal Para	161	26.4	36.8	5.5	3.5	134321.7	4.0
17	Baharchhara	Hajam Para	376	14.0	38.0	6.7	1.5	116878.4	29.9
18	Baharchhara	Mathabhanga	227	24.0	35.9	6.1	3.7	200145.5	104.2

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	No. of Houses	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
19	Baharchhara	Bara Dail	309	44.9	38.5	7.3	2.6	196206.7	51.8
20	Baharchhara	Kachapia	408	51.5	39.5	7.1	1.9	221920.0	60.9
21	Baharchhara	Noakhali	684	37.7	36.3	5.9	1.3	185991.0	43.2
22	Baharchhara	Marish Bania	252	22.7	43.2	5.4	2.3	194000.0	56.8
23	Baharchhara	Uttar Shilkhali	1276	19.3	39.9	6.6	1.9	291442.5	50.6
24	Baharchhara	Shamlapur	3320	12.5	40.9	6.2	1.2	248715.2	43.9
25	Baharchhara	Jahajpura	678	22.3	37.5	7.3	2.3	297633.3	55.8
26	Baharchhara	Halbania	237	17.5	39.9	7.3	1.3	185956.5	30.1
27	Baharchhara	Dakshin Shilkhali	907	24.9	41.0	6.6	2.1	205391.1	59.6
28	Nhilla	Naikhangkhali	891	25.9	43.7	5.9	2.2	239093.0	16.4
29	Nhilla	Hoabrang	354	16.2	40.9	6.2	2.0	234733.3	16.8
30	Nhilla	Pankhali	1186	30.8	42.1	6.0	3.8	199099.2	28.4
31	Nhilla	Sikdar Para	1032	15.9	38.6	6.0	2.8	187267.3	20.8
32	Nhilla	Lechuaprang	239	35.5	38.8	6.4	0.0	160033.3	38.8
33	Nhilla	Ulochamari	675	15.9	41.1	6.0	1.0	212991.2	32.0
34	Nhilla	Nhilla Mogpara	405	19.0	36.9	5.8	4.2	383523.8	31.1
35	Nhilla	Nhilla Bazar (Bazar Para)	209	26.0	41.6	5.7	4.7	272285.7	21.9
36	Nhilla	Fullerdail	542	18.7	39.2	5.9	2.9	314840.0	28.9
37	Nhilla	Nath Murapara	302	39.1	40.0	6.5	3.5	184541.9	9.9

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	No. of Houses	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
38	Nhilla	Kona Para	107	24.2	40.2	6.5	0.5	166681.8	39.9
39	Nhilla	Chowdhury Para	111	45.4	49.8	6.4	3.2	296400.0	28.1
40	Nhilla	Purba Rangikhali	276	36.1	42.8	6.1	1.8	115178.6	29.2
41	Nhilla	Paschim Rangikhali	214	39.9	35.7	6.5	2.3	160363.6	45.7
42	Nhilla	Jumma Para	150	20.8	41.1	5.7	0.0	128053.3	18.2
43	Nhilla	Alikhali	826	22.6	41.3	6.5	0.7	154855.4	45.5
44	Nhilla	Puchinga Para	48	23.0	35.8	5.8	0.8	175200.0	11.2
45	Nhilla	Leda Para	802	26.9	39.9	6.6	2.6	187157.5	14.3
46	Nhilla	Muchani Para	170	31.7	40.8	6.1	4.8	219058.8	12.0
47	Nhilla	Naya Para	270	24.3	42.9	6.5	1.9	154888.9	12.3
48	Nhilla	Jadimura	461	26.9	40.3	6.1	3.5	164446.8	14.2
49	Nhilla	Dumdumia	281	32.7	40.4	7.1	3.6	130867.9	25.0
50	Nhilla	Huakya Para	58	22.4	45.8	5.7	0.5	166500.0	5.5
51	Nhilla	Marichaghona	229	26.8	44.9	6.0	1.6	178950.4	15.7
52	Nhilla	Rojarghona	263	21.3	37.6	5.3	2.2	168959.3	19.9
53	Nhilla	Ali Akbar Para	504	30.2	40.0	5.7	2.5	206109.1	44.5
54	Sabrang	Baharchhara	110	20.8	36.8	5.3	0.0	178545.5	11.7
55	Sabrang	Chanduli Para	230	19.0	38.5	6.4	0.0	157256.5	19.7
56	Sabrang	Uttar Nayapara	97	51.1	42.0	6.9	1.0	146400.0	47.2

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	Number of Households	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
57	Sabrang	Kyurabuja Para	196	28.8	38.1	6.5	1.1	140750.0	16.5
58	Sabrang	Fathe Ali Para	94	23.5	39.8	4.6	1.1	131018.2	27.7
59	Sabrang	Hariakhali	342	38.8	42.6	6.6	1.1	144676.5	31.3
60	Sabrang	Hadurchhara	108	31.5	46.7	6.9	1.3	279062.5	21.8
61	Sabrang	Mundar Dail	667	31.7	38.2	5.8	0.6	186820.9	26.4
62	Sabrang	Mondal Para	264	63.9	42.0	7.1	3.6	243955.6	17.0
63	Sabrang	Sikdar Para	243	77.6	43.3	5.5	1.4	160416.7	28.4
64	Sabrang	Mogpara	49	5.7	50.0	5.1	2.0	113571.4	10.9
65	Sabrang	Panchhari Para	207	52.9	46.4	7.3	2.7	213954.5	13.9
66	Sabrang	Benga Para	113	22.1	43.8	5.1	0.3	120333.3	55.0
67	Sabrang	Acharbania	150	38.4	46.0	6.6	3.5	162760.0	14.2
68	Sabrang	Lezir Para	89	47.4	45.8	6.4	2.8	208300.0	13.0
69	Sabrang	Koanchhari Para	426	22.6	41.8	5.7	0.6	220516.3	37.8
70	Sabrang	Deguliar Bil	231	35.1	44.9	5.6	2.1	146695.7	25.3
71	Sabrang	Dail Para	136	38.1	36.9	6.5	1.6	137984.7	5.3
72	Sabrang	Dakshin Nayapara	627	28.2	37.8	5.5	1.3	211593.8	29.8
73	Sabrang	Puran Para	309	24.4	42.4	6.3	2.2	193718.8	16.8
74	Sabrang	Katabania	310	21.7	38.9	5.2	2.5	216806.5	26.7
75	Sabrang	Kachubania	397	53.1	44.0	6.5	0.9	279175.0	23.7

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	Number of Households	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
76	Sabrang	Lafarghona	117	24.3	35.8	6.2	0.7	116363.6	9.3
77	Sabrang	Zinnah Para	127	35.6	46.3	5.9	2.3	170457.1	15.4
78	Sabrang	Pendal Para	169	23.6	37.4	5.8	2.4	169352.9	12.4
79	Sabrang	Alirdeil Para	387	17.4	40.9	5.5	0.5	140578.9	34.7
80	Sabrang	Kurer Mukh	133	24.7	35.6	5.7	2.6	186071.4	25.6
81	Sabrang	Guchha Gram	100	24.2	38.7	5.2	4.2	140700.0	21.8
82	Sabrang	Rullher Depa	143	18.8	36.5	6.2	2.9	205000.0	17.6
83	Sabrang	Karachi Para	70	24.6	46.3	6.4	1.4	54000.0	15.7
84	Sabrang	Khairtipara	69	23.6	42.7	7.0	4.7	312142.9	13.4
85	Sabrang	Mistry Para	410	23.1	45.0	6.6	1.3	280956.1	36.0
86	Sabrang	Purba Uttar Para	243	18.3	35.4	6.3	1.5	150500.0	10.9
87	Sabrang	Golapara	40	48.8	35.8	11.5	0.0	108000.0	7.3
88	Sabrang	Dakshinpara	441	22.9	40.2	6.5	0.2	157568.2	9.5
89	Sabrang	Hajir Para	107	17.0	32.1	6.3	1.2	193636.4	12.0
90	Sabrang	Paschim Uttar Para	464	27.5	36.5	6.6	1.3	199574.5	9.0
91	Sabrang	Bazar Para	290	33.4	37.1	7.3	2.4	172462.1	53.4
94	Sabrang	Majher Para	773	17.1	38.5	6.1	0.5	150067.6	8.5
95	Sabrang	Jalia Para	441	18.9	38.2	5.8	0.3	155281.8	3.5
97	Sabrang	Majer Dail	165	15.6	38.8	6.2	0.0	154447.1	3.9

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	Number of Households	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
98	Sabrang	Dangor Para	561	14.3	33.9	5.8	0.3	175514.8	10.5
99	Sabrang	Dail Para	188	77.0	39.9	6.2	1.4	130142.9	12.78
100	Sabrang	Karachi Para	180	13.5	8.4	6.7	0.8	222600	11.6
102	Teknaf Sadar	Razarchhara	420	44.7	40.6	6.1	2.0	135785.7	43.1
103	Teknaf Sadar	Habibchhara	424	17.8	37.7	5.8	1.6	108804.8	26.4
104	Teknaf Sadar	Mitta Panirchhara	539	42.2	39.2	6.1	2.3	154638.9	29.4
105	Teknaf Sadar	Dargachhara	203	15.4	39.8	6.3	2.4	135980.0	18.9
106	Teknaf Sadar	Tulatali	195	15.8	44.7	6.7	2.3	152552.6	43.7
107	Teknaf Sadar	Lambori	980	40.1	39.4	6.0	2.2	214521.3	16.1
108	Teknaf Sadar	Hatiarghona	467	38.6	42.5	6.0	0.0	162095.7	35.0
109	Teknaf Sadar	Lengurbil	726	20.0	40.8	6.0	2.9	188769.4	49.5
110	Teknaf Sadar	Jahalia Para	540	20.4	39.0	6.2	1.9	185685.2	28.1
113	Teknaf Sadar	Kerantali	215	9.7	37.5	6.0	1.8	136085.7	6.2
114	Teknaf Sadar	Baraitali	152	22.7	37.5	5.5	0.0	198400.0	16.8
116	Teknaf Sadar	Natun Pallan Para	1195	13.5	41.9	6.0	2.8	235653.4	25.9
117	Teknaf Sadar	Shilbania Para(Part)	128	36.0	40.4	6.6	0.4	240666.7	6.0
118	Teknaf Sadar	Goder Bil	972	17.5	37.0	5.9	1.9	149177.1	34.1
119	Teknaf Sadar	Dail Para (Part)	491	28.8	39.6	5.5	0.6	148029.2	15.4
120	Teknaf Sadar	Mohish Khalia Para	784	31.9	37.2	6.1	1.8	126682.1	19.1

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	Number of Households	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
121	Teknaf Sadar	Khonkar Para	355	50.3	36.5	5.8	3.0	91794.3	25.7
122	Teknaf Sadar	Kachubunia	288	46.3	41.2	6.8	3.1	149088.0	20.1
123	Teknaf Sadar	Hankar Para (Part)	220	18.2	39.6	7.4	4.3	150561.9	40.1
124	Teknaf Sadar	Moulvi Para	309	20.8	41.5	5.4	2.5	226257.1	42.4
125	Teknaf Sadar	Nazir Para	366	33.9	43.1	6.9	1.1	171777.8	29.0
126	Teknaf Sadar	Chhota Habib Para	413	21.3	42.7	6.4	2.0	174204.9	10.9
127	Teknaf Sadar	Bara Habib Para	500	46.8	44.1	5.9	2.7	211568.2	19.3
128	Teknaf Sadar	Hajam Para	128	10.7	38.1	6.3	0.0	97250.0	16.5
129	Whykhong	Unsiprang	397	37.1	43.0	6.9	3.9	268904.8	14.8
130	Whykhong	Kutubdia Para	179	24.6	39.8	6.3	1.9	171944.4	35.6
131	Whykhong	Karachi Para	207	24.1	41.8	7.2	0.2	124830.0	34.9
132	Whykhong	Naya Para	810	15.9	41.0	6.0	3.1	225743.9	43.9
133	Whykhong	Jimangkhali	1234	19.5	40.8	5.7	2.4	241599.2	28.2
134	Whykhong	Satgharia Para	933	21.8	39.9	5.6	2.3	205620.4	31.0
135	Whykhong	Mahishakhalia Para	908	14.2	42.0	5.7	2.3	246473.5	6.3
136	Whykhong	Rojarghona	95	17.5	40.9	5.4	0.3	164995.0	11.4
137	Whykhong	Nasor Para	312	11.1	42.1	6.1	4.1	245685.7	6.1
138	Whykhong	Kharang Khali	65	33.2	51.2	6.3	6.2	400100.0	9.2
139	Whykhong	Komkania Para	338	17.8	34.5	5.6	2.3	221687.7	28.4

Table 1: List of villages in Teknaf Upazila with their socioeconomic parameters

No.	Union	Village	Number of Households	Duration of Settlements (Year)	Age (Year)	Family size (Members)	Education (Schooling Year)	Annual Income (000 BDT)	Land Property (Decimal)
140	Whykhong	Kanjer Para	1094	12.8	41.9	6.0	1.6	160897.5	42.4
141	Whykhong	Keruntali	665	22.2	40.5	6.0	2.8	221716.4	30.0
142	Whykhong	Ghilatali	285	21.0	38.4	6.3	2.2	210483.9	11.8
143	Whykhong	Katakhali	516	27.1	41.4	6.9	2.8	202909.1	11.3
144	Whykhong	Balukhali	425	3.0	42.0	6.1	2.0	152134.9	56.6
145	Whykhong	Uhulubania	554	21.4	41.5	5.9	2.4	176578.6	38.2
146	Whykhong	Daingakara	432	18.3	42.6	6.6	1.6	259295.1	56.2
147	Whykhong	Harikhola	222	11.5	42.9	5.0	2.4	107956.5	167.2
148	Whykhong	Laturikhola	177	17.4	39.8	5.9	0.6	161527.8	31.3
149	Whykhong	Whykong	672	5.9	35.7	5.8	2.7	165709.4	21.8
150	Whykhong	Lambabil	679	23.2	42.4	6.4	1.7	148216.4	26.2
151	Whykhong	Amtali	413	13.8	42.3	6.3	2.4	152432.6	36.5
152	Whykhong	Raikong	455	17.8	42.8	6.3	0.9	200017.4	17.2
153	Whykhong	Lambaghona	118	22.7	43.0	7.4	1.3	146058.3	12.4