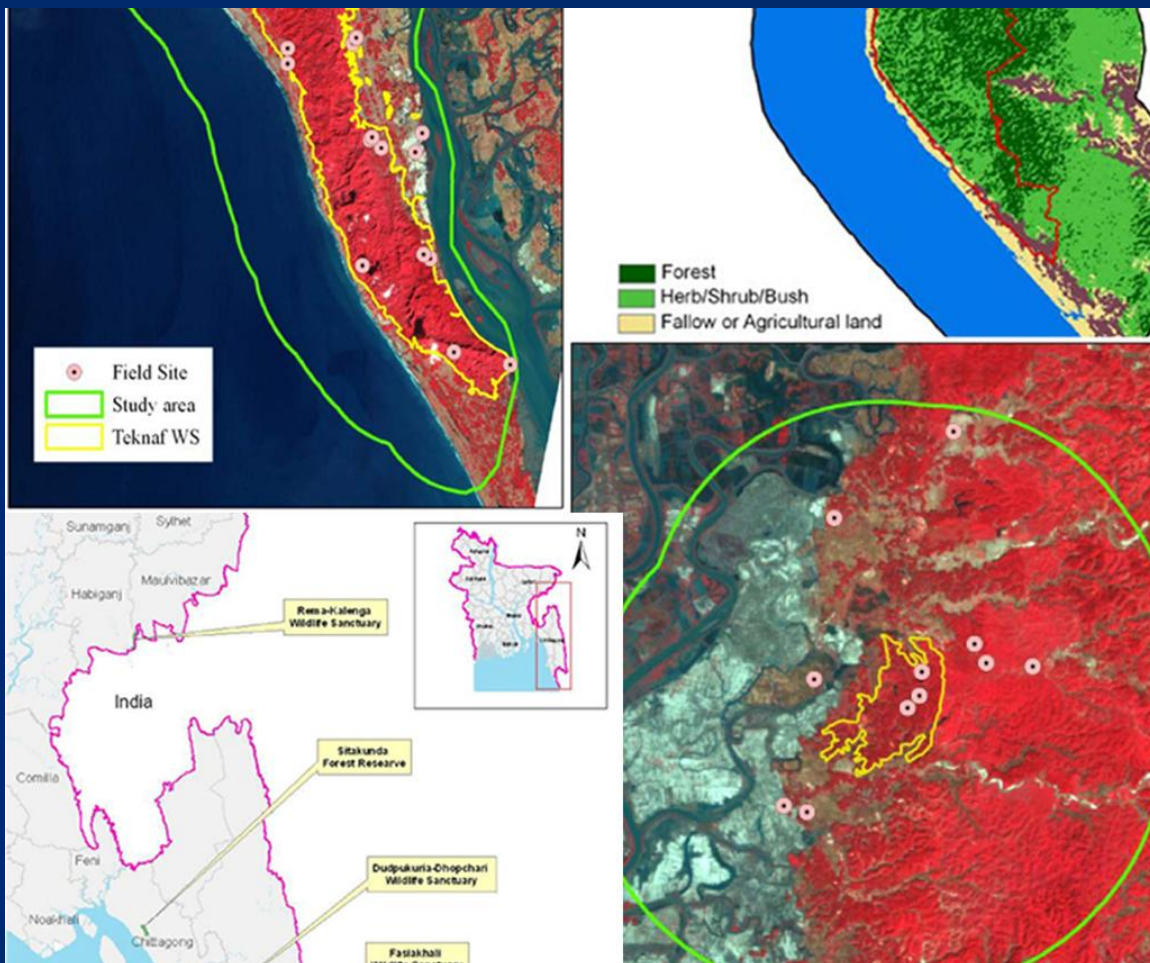# INTEGRATED PROTECTED AREA CO-MANAGEMENT (IPAC)

LANDUSE CHANGE TREND ANALYSIS IN SEVEN PROTECTED AREAS IN BANGLADESH UNDER IPAC THROUGH APPLICATION OF LANDSAT IMAGERIES

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Abbreviations

ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BTM	Bangladesh Transverse Mercator System
CEGIS	Center for Environmental and Geographic Information Services
CHT	Chittagong Hill Tracts
DGPS	Differential Global Positioning System
ECA	Ecologically Critical area
ETM	Enhanced Thematic Mapper
GCP	Ground Control Points
GIS	Geographic Information Services
GPS	Global Positioning System
GT	Ground Truth Data
IPAC	Integrated protected area
IRG	International Resources Group
IRS	Indian Remote Sensing Satellite
ISODATA	Iterative Self-Organizing Data Analysis
NP	National Park
PA	Protected area
RF	Reserve Forest
RMS	Root mean square
RS	Remote Sensing
TM	Thematic mapper
USAID	United States Agency for International Development
WS	Wild life Sanctuary

Executive Summary

The Bangladesh Forest Department manages 1.53 million ha of forest land mainly under the legal categories of 'Reserved Forest' and 'Protected Forest'. Presently there are 28 notified Protected Areas (PAs) under the management of the Forest Department, covering an area of 261,891.50 ha under protected area categories. The Nishorgo Network is a platform for collaborative management of forest and wetland protected areas with multiple local stakeholders whereby a paradigm shift has been introduced from traditional command-and-control approach of forest management.. For preserving the forest protected areas , wetlands and Ecologically Critical Areas (ECAs), the IPAC project is being implemented over the period of June 2008-May 2013 under the framework of the Nishorgo Network with the Ministry of Environment and Forests and Ministry of Fisheries and Livestock and financial support from the USAID. One of the initiatives of the project is to develop a bundled carbon-project for 7 forest protected areas and consequent time series landuse analysis based on Landsat satellite imageries.

Landuse change trend analysis is studied using remote sensing and GIS tools. In this study images of 3 different stages (1990, 2000 and 2010) of the study areas were processed and analyzed. The study revealed that forest area in a few study areas had decreased gradually within the PA boundary from 1990 to 2010 (Teknaf WS, Inani-Bangabondhu NP, Medhakachapia NP and Rema-Kalenga WS).The decreasing rate from 1989 to 2009 is alarming for Teknaf WS and Inani-Bangabondhu NP (proposed) which was 46% for both areas. The decreasing rates are 20% and 16% respectively for the Medhakachapia NP and Rema-kalenga WS. In the case of Dudpukuria-Dhopachari WS, the forest had increased at the rate of 11% from 1989 to 2009. The Sitakunda RF area had also increased gradually from 1990 to 2010 at the rate of 94%. In Fasiakhali WS, the forest cover had increased from 1989 to 2009 at the rate of 0.3%.

Table 1: Forest cover changes over 1989-2009 for 7 protected areas.

Sl No.	Land Uses/Covers	Year					
		1989		1997/2000		2009	
		Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
1	Teknaf WS: Forest	3,304	28.4	2,812	24.2	1,794	15.4
2	Inani-Bangabandhu NP (proposed): Forest	4,161	58.7	3,280	46.3	2,249	31.7
3	Medhakachapia NP: Forest	140	35.3	114	28.7	112	28.2
4	Fasiakhali WS: Forest	300	23.0	392	30.1	301	23.1
5	Dudpukuria-Dhopachari WS: Forest	2,398	50.8	2,632	55.8	2,653	56.2
6	Sitakunda RF: Forest	1269	15.4	1525	18.6	2461	29.9
7	Rema-Kalenga WS: Forest	1570	87.4	1339	74.6	1317	73.2

In this context, the time series analyses of 7 protected areas provide a total scenario which can be used for developing a bundled carbon project for these PAs.

Chapter 1
Introduction

1.1   Background

The Nishorgo Network has been established by the Government of Bangladesh (GoB) to benefit local communities through conservation of forest and wetland biodiversity with support from USAID's Integrated Protected Area Co-Management Project (IPAC). Recognizing the need to conserve the most productive ecosystems of the country, the GoB materialized its concerns by establishing the Nishorgo Network comprising of forests, wetland Protected Areas (PAs) and Ecologically Critical Areas (ECAs) by which local communities are empowered through various biodiversity conservation efforts.

Over the period of June 2008 to May 2013, the IPAC Project will be working in protected landscapes of 25 forests, wetlands and ECAs for promotion of collaborative management under the framework of the Nishorgo Network. As a part of the project initiatives, IPAC intends to develop a time series landuse database based on satellite imageries in seven protected forest landscapes of Bangladesh.

The International Resources Group (IRG) has given CEGIS the responsibility for conducting trend analysis of landuse change in the seven protected areas using free available Landsat satellite imageries (30 m spatial resolution). The contract agreement between the IRG and CEGIS was signed on 22 November 2010.

1.2   Objectives of the study

The main objective of the study is to conduct trend analysis of landuse change in the protected forest landscapes.

1.3   Study area

The study area includes seven protected forest landscapes. The names of the protected forest landscapes are given below:

i.   Teknaf Wildlife Sanctuary, Cox's Bazaar

ii.   Inani-Bangabondhu Natinal Park (Proposed), Cox's Bazaar

iii.   Medhakachapia National Park, Cox's Bazaar

iv.   Fasiakhali Wildlife Sanctuary, Cox's Bazaar

v.   Sitakunda Forest Reserve, Chittagong

vi.   Dudpukuria-Dhopachari Wildlife Sanctuary, Chittagong and

vii.   Rema-Kalenga Wildlife Sanctuary, Habiganj
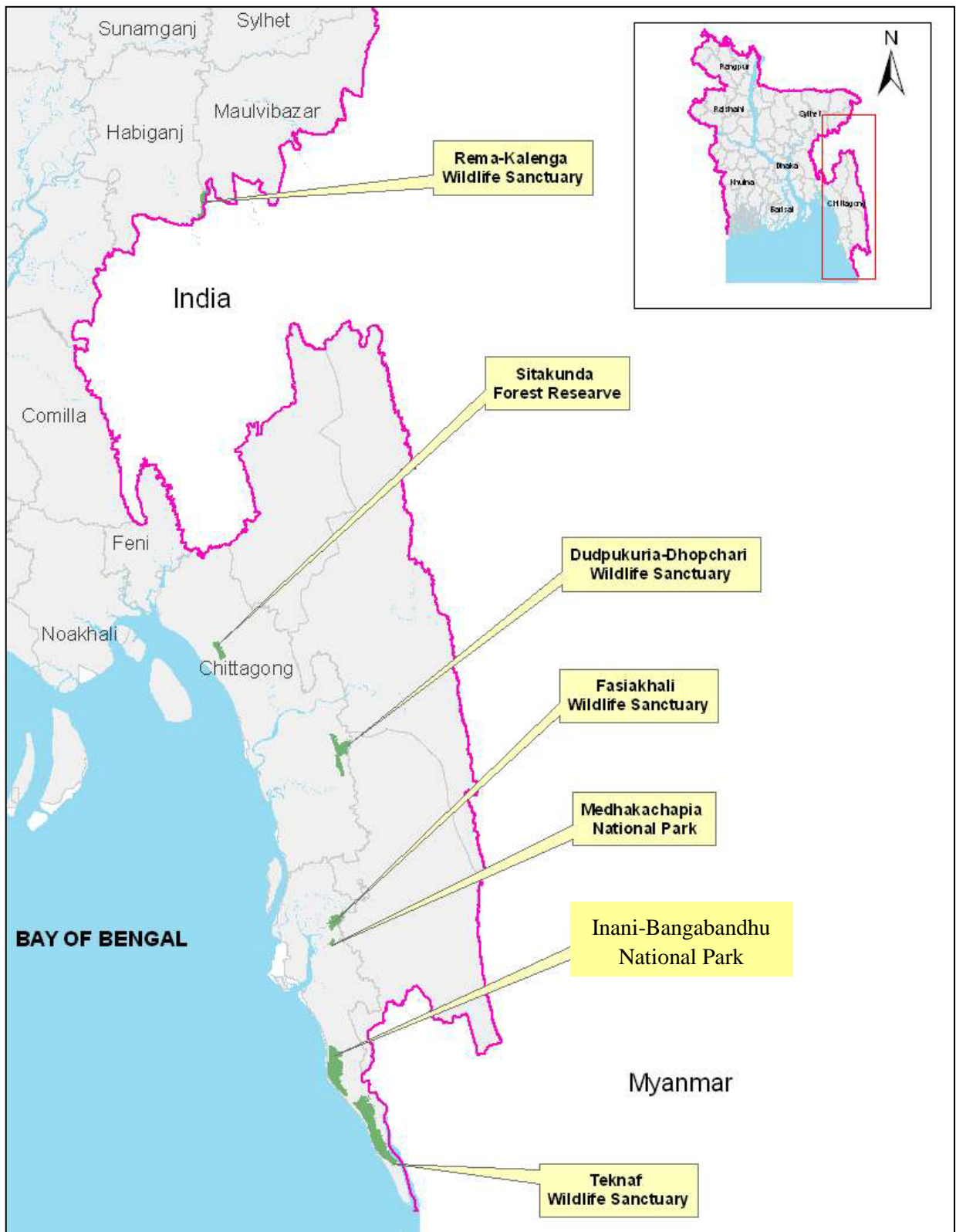
Figure 1.1: Geo-spatial locations of the seven protected forest landscapes

1.4   Deliverables

The following deliverables will be provided after completion of the assignment:

 i.   Time series of georeferenced Landsat 5 TM satellite images of the seven selected protected forest landscapes (digital format, CD).

ii.   Time series of classified Landsat 5 TM images for the seven selected forest landscapes with landuse class names and calculated area (digital format, CD).

iii. A final report (in 5 hard copies) containing detailed description of the satellite images, field survey, methodology of the classification and trend analysis, and accuracy level methodology and key activities.

Chapter 2

Data used for the study

2.1 Satellite Image Data

Landsat 5 TM satellite images were used for land use/cover mapping of the protected forest landscapes. The Landsat 5 TM imagery is acquired in seven spectral bands. The TM is a scanning optical mechanical sensor that records energy in the visible, reflective infrared, middle infrared and thermal infrared regions of the electromagnetic spectrum. It has a 30 m ground resolution for all bands except band-6, which has a 120 m resolution. Its ground swath is 185 kilometers. Table 2.1 shows the characteristics of the LANDSAT 5 TM sensor.

Table 2.1: Characteristics of Landsat 5 TM satellite sensor

Satellite	Sensor	Swath width	Resolution	Band
Landsat 5	TM (Thematic Mapper)	185 km	30 m	0.45 – 0.52 µm 0.52 – 0.60 µm 0.63 – 0.69 µm 0.75 – 0.90 µm 1.55 – 1.75 µm 2.08 – 2.35 µm
			120 m	10.40 – 12.50 µm

In the analysis, the TM bands are chosen over the multi spectral scanner for their value in water penetration, discrimination of vegetation type and vigor, plant and soil moisture measurement, differentiation of clouds, snow, and ice and identification of hydrothermal alteration in certain rock types. Vegetation absorbs much of the incident blue and red radiation for photosynthetic purposes. It reflects approximately half of the incident near-infrared radiation, causing it to appear bright in the band 4 (near infrared) image. Bands 5 and 7 both provide more detail in the wetland as they are sensitive to soil and plant moisture conditions.

Table 2.2 shows the acquisition dates of the LANDSAT 5 TM images. Depending on the availability of data for PA areas three years were selected for trend analysis of the land use/cover of the protected forest landscapes. The years that were selected are: 1989, 2000 and 2009. For Sitakunda and Rema-kalenga, LANDSAT 5 TM images of 2010 were used instead of images of 2009. Satellite images of 1997 were used as the Teknaf Wildlife Sanctuary is not fully covered by the satellite images of 2000. The acquisition period of all available images is the dry period. Figure 2.1 shows the path, row and extent of Landsat 5 TM images covering the study area.

Table 2.2: Acquisition dates of Landsat 5 TM images

Protected Areas	Acquisition Dates		
Teknaf Wildlife Sanctuary	22 February 1989	12 Jan 2000 & 28 Jan1997	6 December 2009
Inani-Bangabondhu NP (Proposed)	22 February 1989	12 Jan 2000	6 December 2009
Medhakachapia National Park	22 February 1989	12 Jan 2000	6 December 2009
Fasiakhali Wildlife Sanctuary	22 February 1989	12 Jan 2000	6 December 2009
Sitakunda Forest Reserve	22 February 1990	12 Jan 2000	8 February 2010
Dudpukuria-Dhopachari Wildlife Sanctuary	22 February 1989	12 Jan 2000	6 December 2009
Rema-Kalenga Wildlife Sanctuary	5 January 1989	30 March 1999	8 February 2010

2.2   Ground-Truth Data

Ground truth data were collected for supporting digital classification and accuracy assessment. For this study, a field survey was carried out at the Teknaf Wildlife Sanctuary, Inani-Bangabondhu NP (Proposed), Medhakachapia, Fasiakhali, Sitakunda, Dudpukuria-Dhopachari and Rema-Kalenga between 6 and 15 January 2011. Table 2.3 shows the number of field survey sites visited within the core area and 5 km buffer of the core area.

Table 2.3: Number of field survey sites

Protected Areas	Number of Visited Sites
Teknaf Wildlife Sanctuary	17
Inani-Bangabondhu Natinal Park (Proposed)	12
Medhakachapia National Park	11
Fasiakhali Wildlife Sanctuary	15
Sitakunda Forest Reserve	13
Dudpukuria-Dhopachari Wildlife Sanctuary	15
Rema-Kalenga Wildlife Sanctuary	28
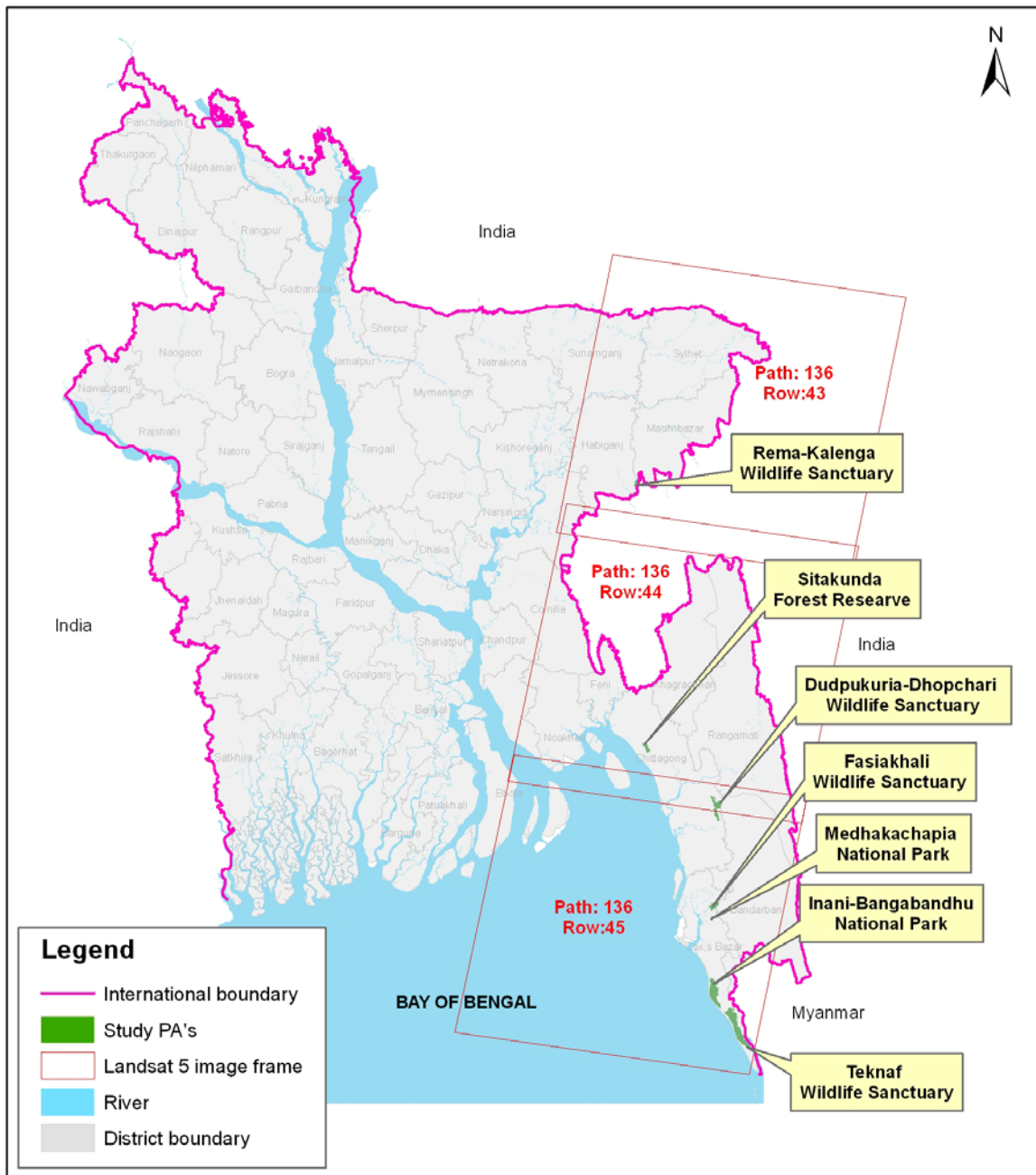
Figure 2.1: Path, rows and extent of Landsat 5 TM images

The ground truth data were used for supporting digital classification. Before going to the field, different unknown spectral patterns were identified and marked on the multispectral images as field survey site. A field survey map was prepared to facilitate the survey work and to locate the field survey sites on the ground. During field survey land use/cover information, latitude and longitude and photographs were taken for each PA. The pink dots in Figure 2.2 (a), (b), (c), (d) and in Figure 2.3 (a), (b) and (c) show the visited sites within each PA.

(a) Teknaf Wildlife Sanctuary

(b) Inani-Bangabondhu NP (Proposed)

(c) Medhakachapia National Park

(d) Fasiakhali Wildlife Sanctuary
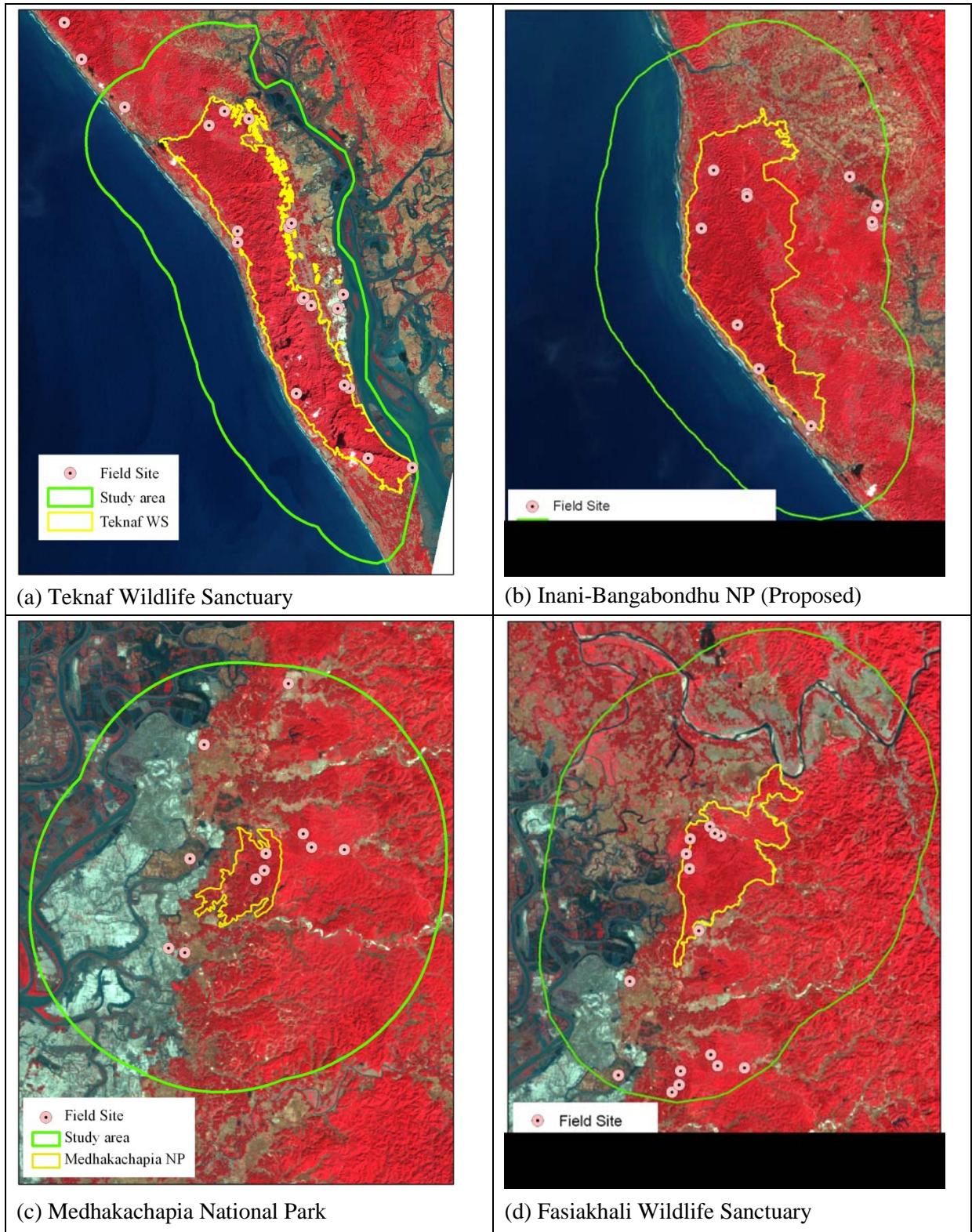
Figure 2.2: Locations of field survey sites in Teknaf Wildlife Sanctuary, Inani-Bangabondhu NP (Proposed), Medhakachapia National Park, and Fasiakhali Wildlife Sanctuary

(a) Dudpukuria-Dhopachari Wildlife Sanctuary

(b) Sitakunda Forest Reserve

(c) Rema-Kalenga Wildlife Sanctuary
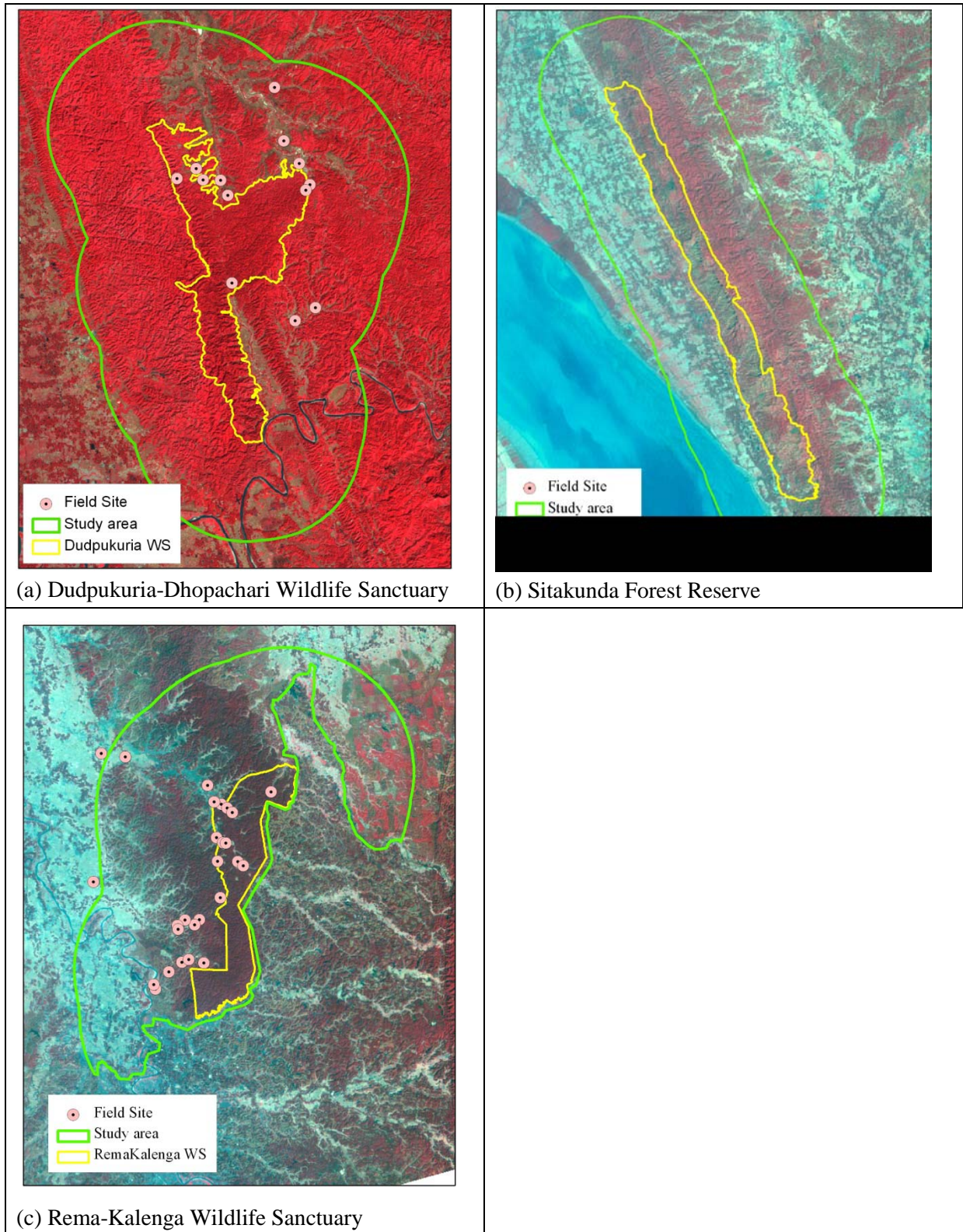
Figure 2.3: Locations of field survey sites in Dudpukuria-Dhopachari Wildlife Sanctuary, Sitakunda Forest Reserve and Rema-Kalenga Wildlife Sanctuary

At present most of the areas of the Teknaf Wildlife Sanctuary are barren with only grass, bush and herb-shrubs. A few plantations are observed within the boundary of the PA area. Local people reported that the forest area is degrading day by day. Large quantities of trees were uprooted by the cyclones of 1991, 1994 and 1997. There is a large garjan forest in the western side of the PA. The main trees within the PA area are Teak, mahogany, telshur, chapalish, acacia, black berry, shimul, jarul, civit, and gamar etc. Figure 2.4 shows the photographs taken at Teknaf Wildlife Sanctuary.

(a) Garjan Forest

(b) Acacia plantation

(c) Forest in Teknaf Game Reserve
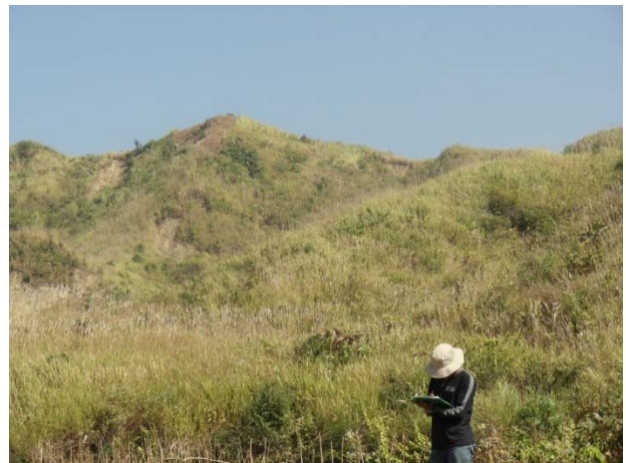
(d) Bush Covered Hill

Figure 2.4: Photographs from Teknaf Wildlife Sanctuary

Within the Inani-Bangabondhu NP (Proposed), the major trees are Teak, telshur, gamar, civit, acacia, chapalish, jarul etc. Herbs, shrubs and bushes dominate in the buffer zone. The eastern side of the PA forest cover was damaged several times by cyclones. However, some areas of forest cover have been restored through social aforestation. Figure 2.5 shows the photographs taken at Inani-Bangabondhu NP (Proposed).

(a) Acacia plantation

(b) Social forest

(c) Natural forest

(d) Garjan forest

Figure 2.5: Photographs from Inani-Bangabondhu NP (Proposed).

The major trees within Medhakachapia National Park is Garjan,. Some social forestry plantation and Teak copies were observed in the buffer area of the PA. Herbs, shrubs and bushes cover the rest of the area. Figure 2.6 shows some photographs taken at Medhakachapia National Park.

The major trees in the Fasiakhali Wildlife Sanctuary are garjan, bailam, telshur, bet, black berry, chapalish, champa, and gamar etc. Herbs, shrubs and bushes cover the rest of the area. Social forestry plantation of acacia, which was started in 2007, was observed in Paglir beel within the buffer area. Teak copies were found in the buffer area of the PA, which used to be a dense forest before 1996. Agar plantation was observed on the northern side outside the PA.

(a) Forest with bushes

(b) Social forest

(c) Garjan and acacia plantation

(d) Bushes

(e) Teak copies with bushes

(f) Acacia plantation

Figure 2.6: Photographs of Fasiakhali Wildlife Sanctuary

The major trees in Dudpukuria-Dhopachari Wildlife Sanctuary are garjan, agar, acacia, jarul, amoloki, bohera, bailam, telshur, chapalish, champa, and gamar etc. Herbs, shrubs and bushes are also observed in the PA area.

Most of the areas of Sitakunda Reserved Forest are barren with only grass, herbs, and shrubs. Only a few areas are covered with tree plantations. The major trees in this area are mahogany, chapalish,

bahadi, neem, acacia, bhadi, bon-shonalu, eucalyptus, shimul, chatil, and sheora. There are some trees like arjun, neem, amoloki, bohera, and horitoki in the Sitakunda Eco-Park area. Social plantations are observed in the foothills of the PA.

The major trees within Rema-Kalenga Wildlife Sanctuary are Teak, chapalish, malakana, mengium, acacia, koroi, shimul, civit, garjan, jarul, and gamar etc. Social plantation of Teak, sal, garjan, chapalish were found in the western part outside the PA. Tea gardens are located in the periphery of the study area.

Chapter 3
Satellite Image Analysis

3.1 Introduction

Under this study, trend analysis of the land use/cover of seven PAs was done using Landsat 5 TM satellite imageries. Figure 3.1 shows the overall methodology followed for this study.
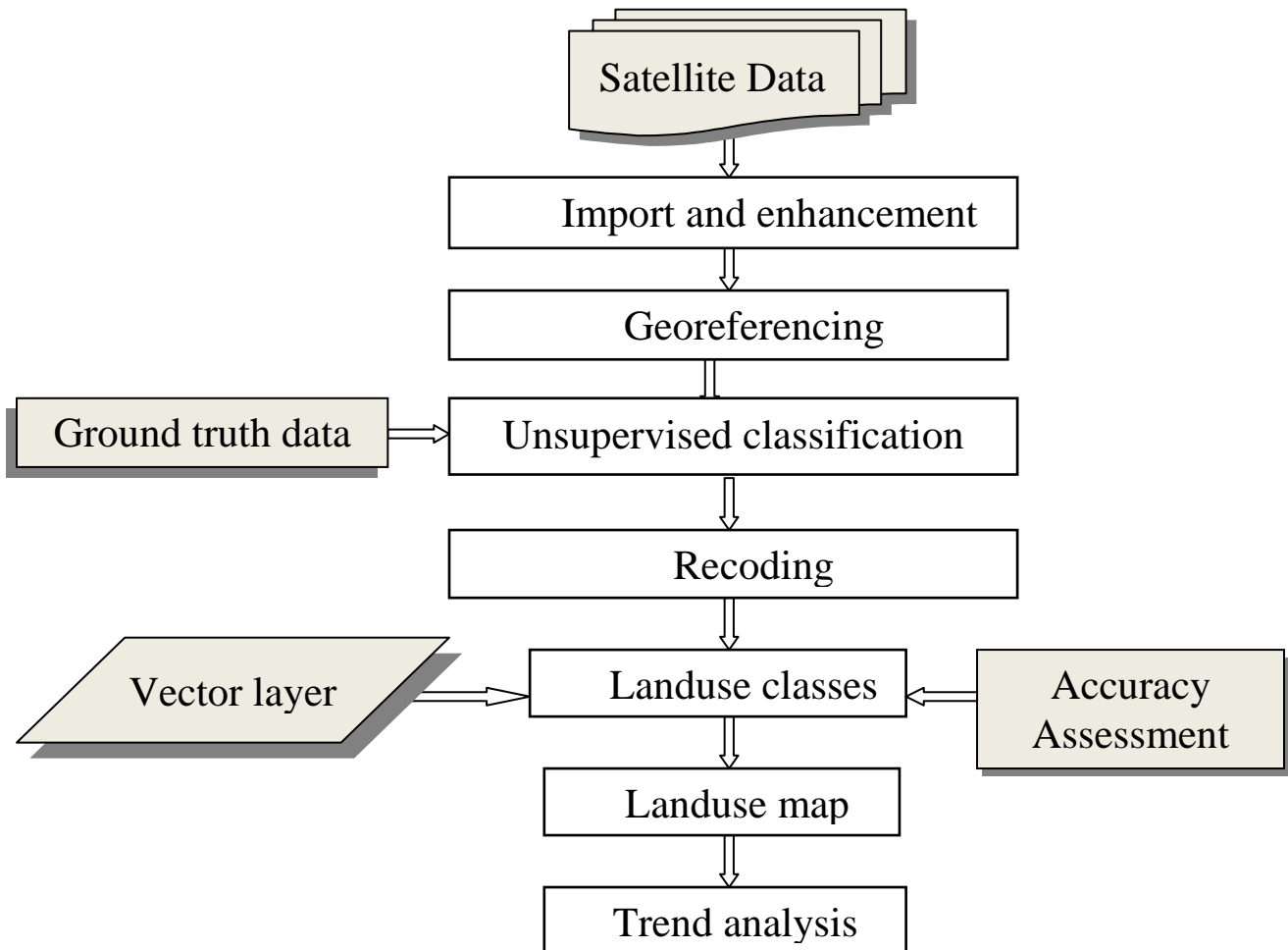
Figure 3.1: Methodology of the study

Multispectral time series satellite images were collected, imported and enhanced and georeferenced. After georeferencing all images were classified using the ISODATA clustering technique. Using ground truth data and expert knowledge of the Forest Department employees and CEGIS employees time series land use\cover maps of each PA were prepared. After preparation of the land use /cover maps, time series analysis were carried out to identify changes of land use/cover within the PA boundary including the 5 km buffer.

3.2   Satellite Data Import and Enhancement

All satellite images were imported into raster format (.img) using the image-processing software ERDAS IMAGINE. It is an easy-to-use, raster-based software designed specifically for extracting information from satellite images. After importing the images, statistics were calculated for all images. Enhancement techniques were applied for better understanding and visualization of the images.

3.3   Georeferenced Satellite Images

The GCPs in the imagery were identified in the first step of georeferencing. During selection of the GCPs, preference was given to clearly visible points and permanent features such as road intersections; end of a bridge over a river; and corner of ponds. The source coordinates of each GCP were taken from the satellite images selected for this study. The corresponding reference coordinates of each GCP were collected from DGPS corrected IRS 1D/1C panchromatic satellite images available in the CEGIS archives. During the identification of GCPs, the RMS (Root Mean Square) error for each GCP and the total RMS error in both x and y were examined. Within reason, the locations of the GCPs were adjusted in the imagery to achieve optimal positioning and distortion-free rectification.

A set of coefficients (Transformation Matrix) were computed from these GCPs, and used in polynomial equations to transform coordinates from pixel to the Bangladesh Transverse Mercator system. First order polynomial transformation was used to reduce distortion in the final image, particularly at scene edges or over large water bodies. After georeferencing, an accuracy assessment of the georeferenced images was done with respect to reference images. Georeferencing accuracy was found to be ±30 m (1 pixel) with respect to DGPS corrected satellite images. After georeferencing, coregistration was done for time series images for each PA.

3.4   Satellite Image Classification

After visual interpretation, a digital unsupervised classification was done to derive different land use/cover information from satellite images. Unsupervised classification (commonly referred to as clustering) is one of the methods of image classification. It is an effective method of partitioning remote sensor image data in multispectral feature space and extracting land-cover information. Pixels with similar spectral characteristics are grouped into unique clusters according to some statistically determined criteria. Then re-labeling and combining the spectral clusters into information classes using ground truth data and expert knowledge results in the land use/cover map.

Under this study, all images were classified into 100 spectral classes using the Iterative Self-Organizing Data Analysis Technique (ISODATA) algorithm to perform an unsupervised classification. The ISODATA represents a comprehensive set of heuristic (rule of thumb) procedures that have been incorporated into an iterative classification algorithm. The ISODATA clustering method uses the minimum spectral distance formula to form clusters. It begins with either arbitrary cluster means or means of an existing signature set and each time the clustering repeats, the means of this cluster are shifted. The new cluster means are used in the next iteration. ISODATA is self-organizing because it requires relatively little human input.

The different land uses extracted from the analysis of the images were 'Forest', 'Herb\Shrub\Bush', and 'Fallow or Agriculture Land', and 'Water'. 'Forest' is defined as broadleaved semi-evergreen and sometimes deciduous forests; mainly plantations of long and short rotation species.

'Herb\Shrub\Bush' has been defined in this study as degraded patches of semi-evergreen forests with vegetation of low height. 'Fallow or Agriculture Land' is defined as land which are used for agricultural purposes or barren land. The 'Settlement with Homestead Vegetation' class is defined as land with settlements and surrounded by vegetation.'Tea garden'is defined as perennial shrub trees surrounding forest reserves and crops on gentle sloping ground. .'Water' class is defined as rivers, ponds, water logged areas and other water bodies

These classified schemes were confirmed in a meeting by the professionals of the Forest Department, CEGIS and IPAC. In hilly regions, it is difficult to identify settlements using 30-meter Landsat 5 satellite images. The 'Settlement with Homestead Vegetation' layer was available in the CEGIS archives. This layer was extracted from IRS Panchromatic images of 5.8 m resolution satellite images (2002-2004). It was integrated with the land use/cover map of 1999/2000. This layer was updated under the study using high-resolution satellite images available in Google Maps and integrated with land use/cover map of 2009/2010. For 1989/1990 the 'Settlement with Homestead Vegetation' layer was digitized from Landsat Images of 1989/1990 as much as possible using the visual interpretation technique. Finally, it was integrated with the land use/cover map of 1989/1990.

There were limitations to identifying semi-ever green forests using dry season images (February and March). In such cases, high-resolution Google earth imageries, available alternative dates of imagery and expert opinions of Forest Department professionals were considered to delineate deciduous forest areas. The hill shade areas associated with 'Forest' and 'Herb/Shrub/Bush' classes were classified as 'Forest' and 'Herb/Shrub/Bush' respectively. Figures 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, and 3.8 show the land use and land cover maps of Teknaf Wildlife Sanctuary, Inani-Bangabondhu NP (Proposed), Medhakachapia, Fasiakhali, Sitakunda, Dudpukuria-Dhopachari and Rema-Kalenga respectively.

(a) Landuse/landcover map 0f 1989

(b) Landuse/landcover map 0f 1997 and 2000

(c) Landuse/landcover map 0f 2009
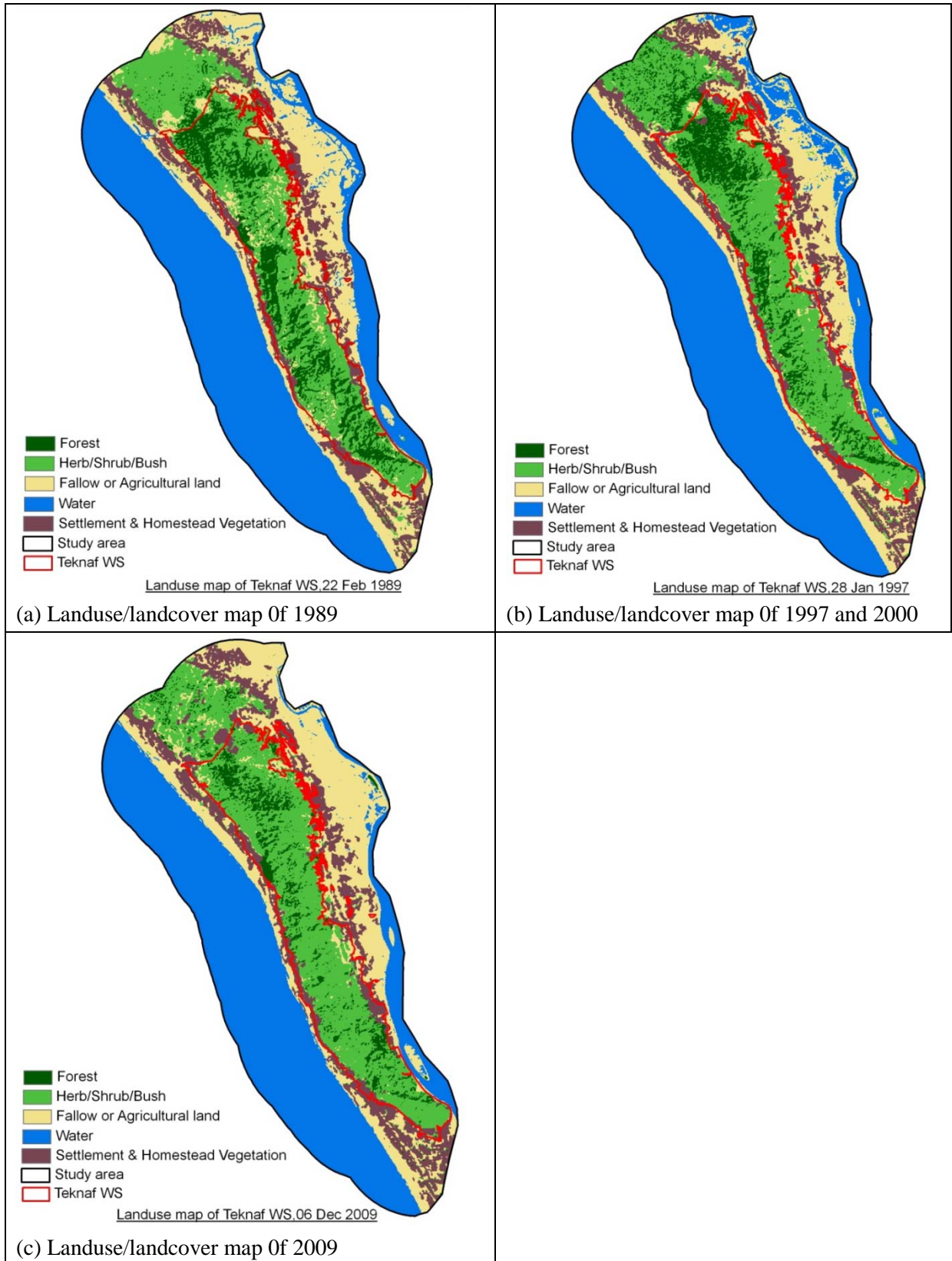
Figure 3.2 Time series landuse/landcover maps of Teknaf Wild life Sanctuary

(a) Landuse/landcover map 0f 1989

(b) Landuse/landcover map 0f 2000

(c) Landuse/Landcover map 0f 2009
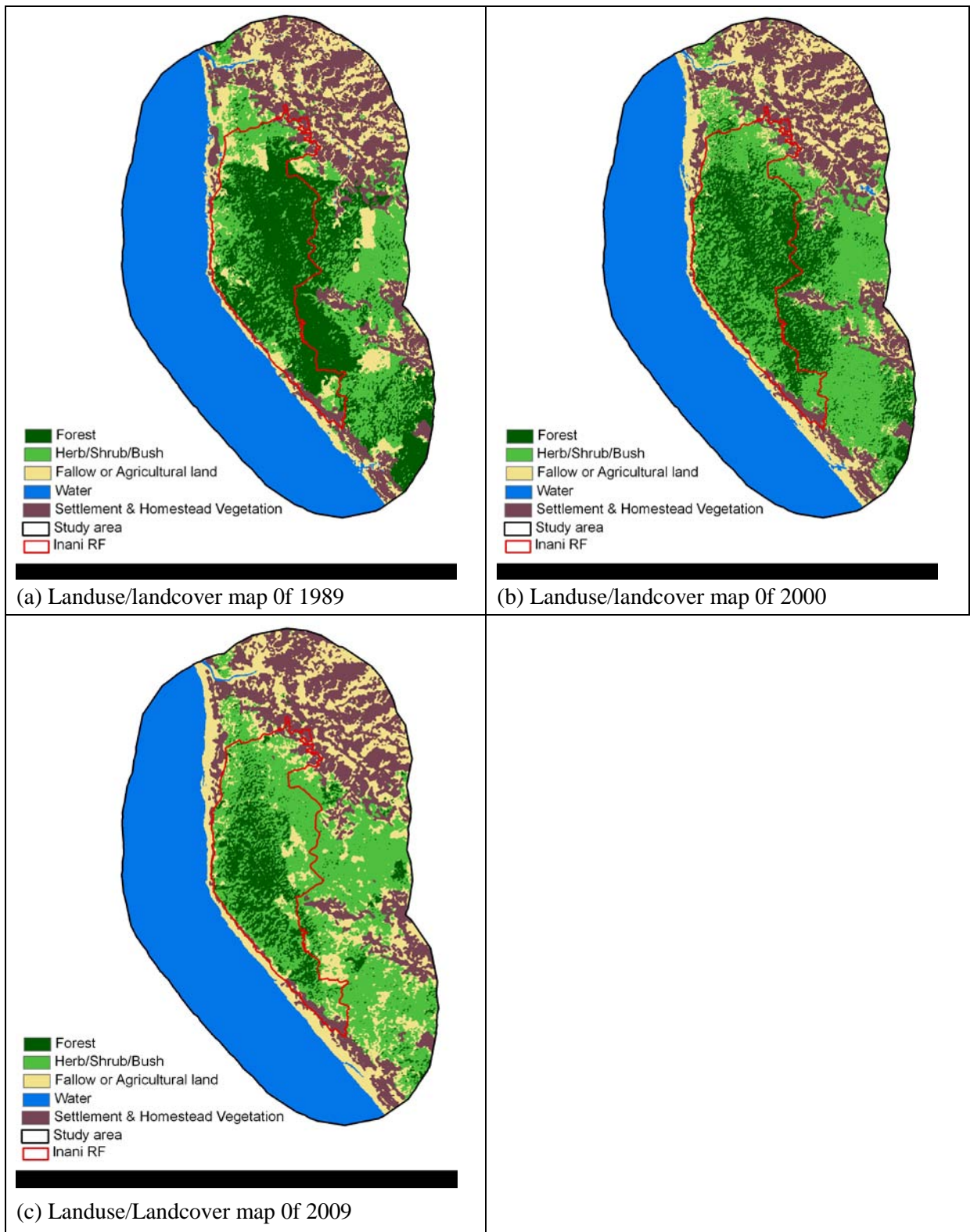
Figure 3.3 Time series landuse/landcover map of Inani-Bangabondhu NP (Proposed)

(a) Landuse/landcover map 0f 1989

(b) Landuse/landcover map 0f 2000

(c) Landuse/landcover map 0f 2009
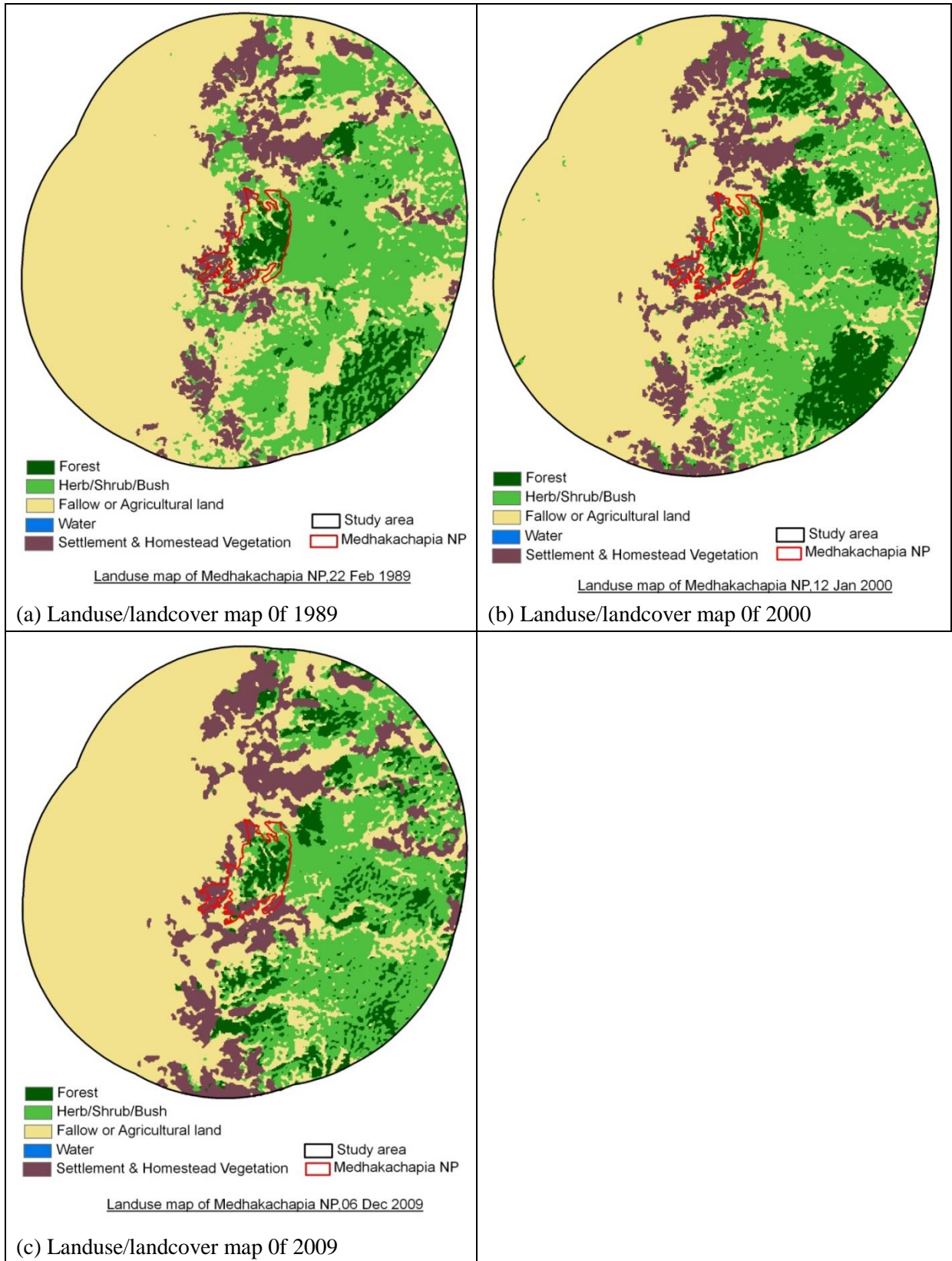
Figure 3.4 Time series landuse/landcover map of Medhakachapia National Park

(a) Landuse/landcover map 0f 1989

(b) Landuse/landcover map 0f 2000

(c) Landuse/landcover map 0f 2009
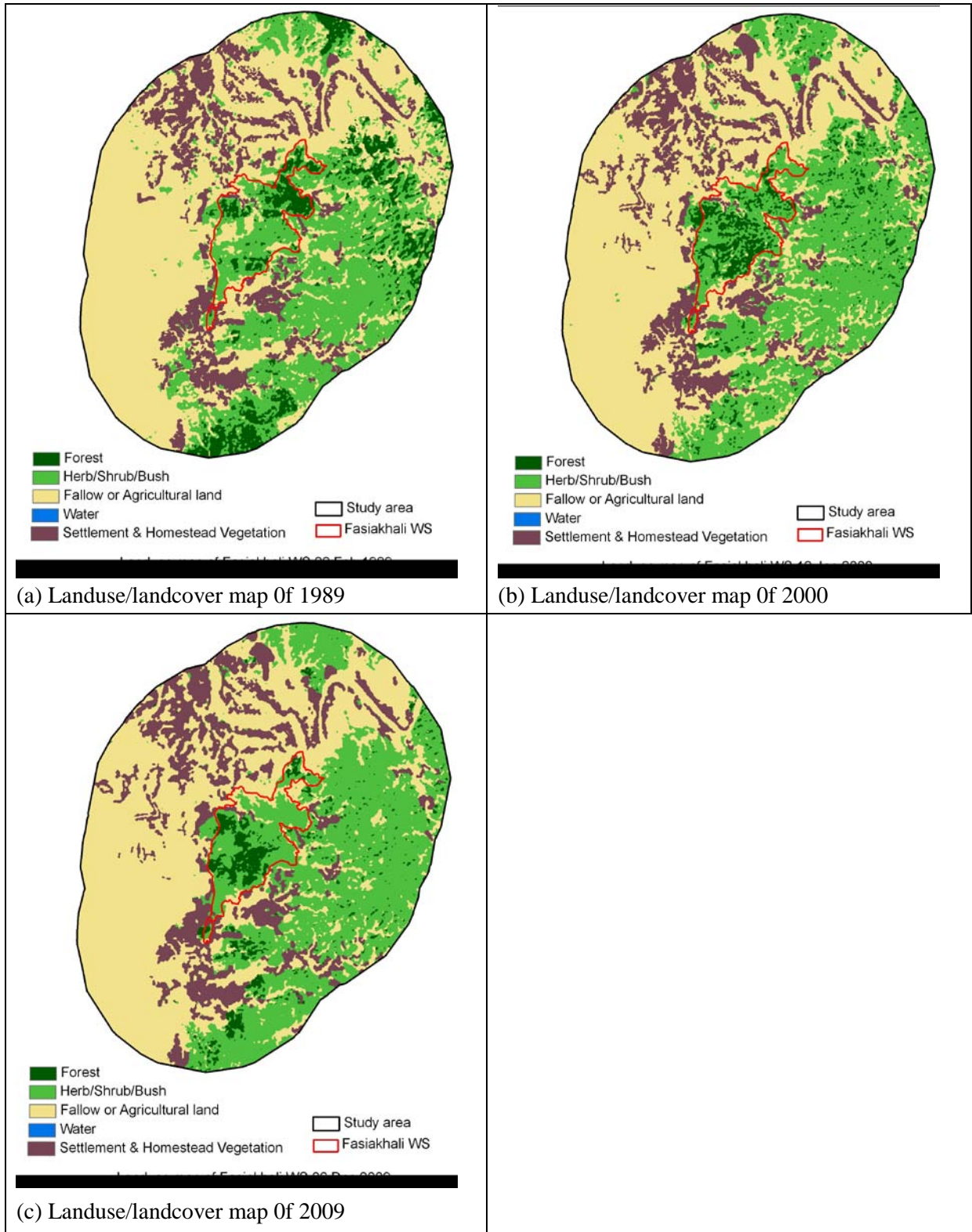
Figure 3.5 Time series landuse/landcover map of Fasiakhali Wild life Sanctuary

(a) Landuse/landcover map 0f 1990

(b) Landuse/landcover map 0f 2000

(c) Landuse/landcover map 0f 2010
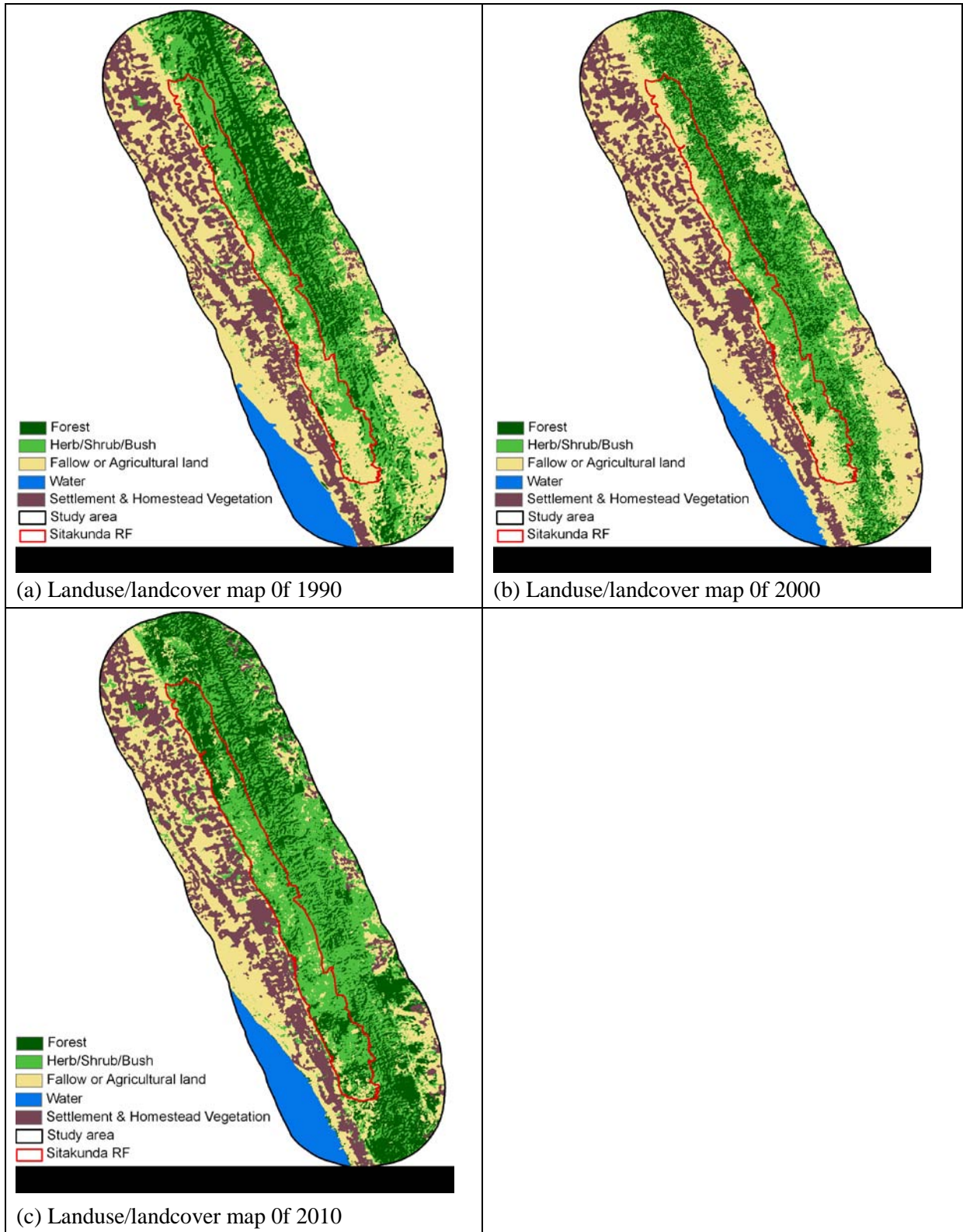
Figure 3.6 Time series landuse/landcover map of Sitakunda Reserve Forest

(a) Landuse/landcover map 0f 1989

(b) Landuse/landcover map 0f 2000

(c) Landuse/landcover map 0f 2009
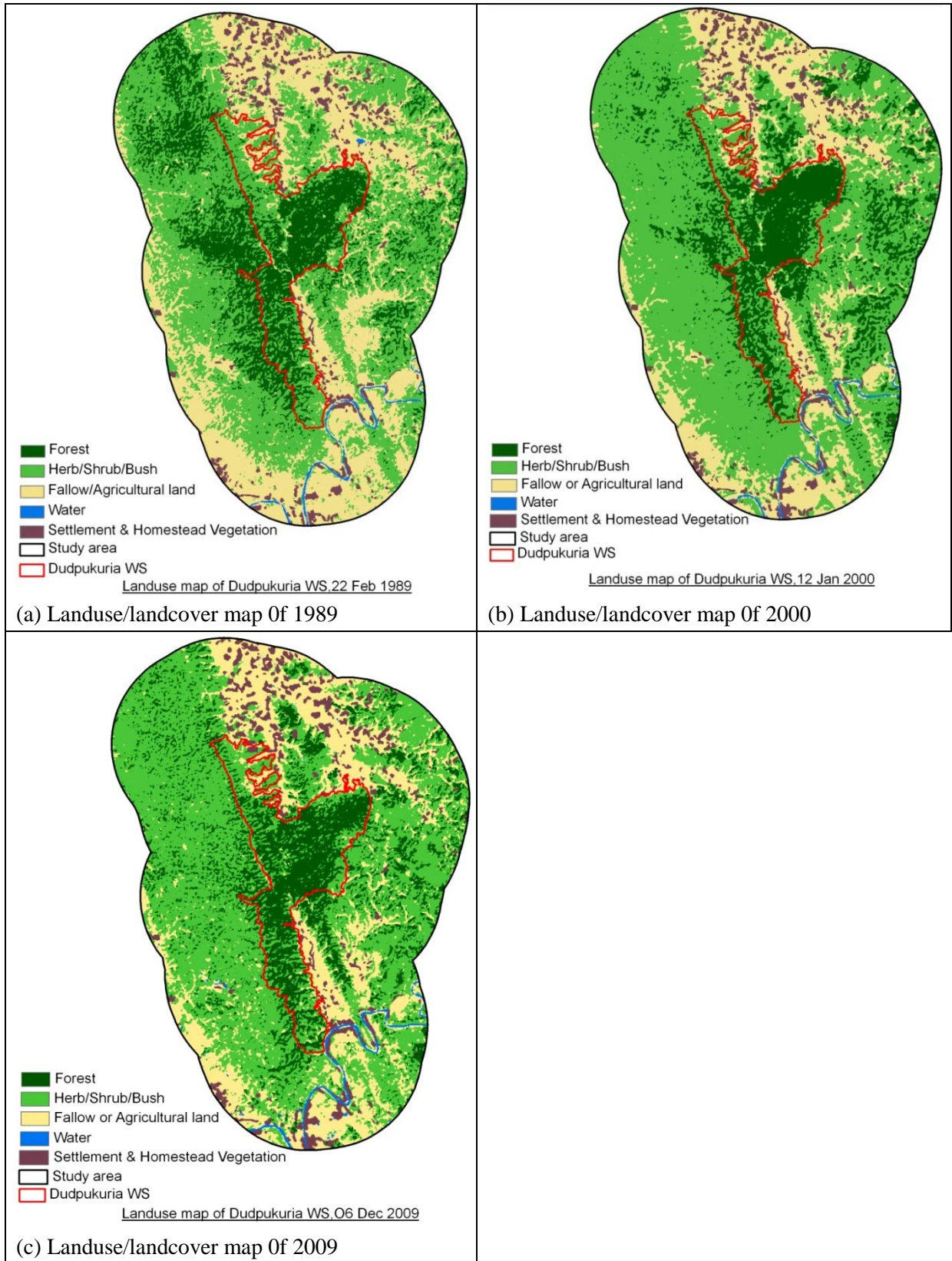
Figure 3.7 Time series landuse/landcover map of Dudpukuria-Dhopachari Wildlife Sanctuary

(a) Landuse/landcover map 0f 1989

(b) Landuse/landcover map 0f 1999

(c) Landuse/landcover map 0f 2010
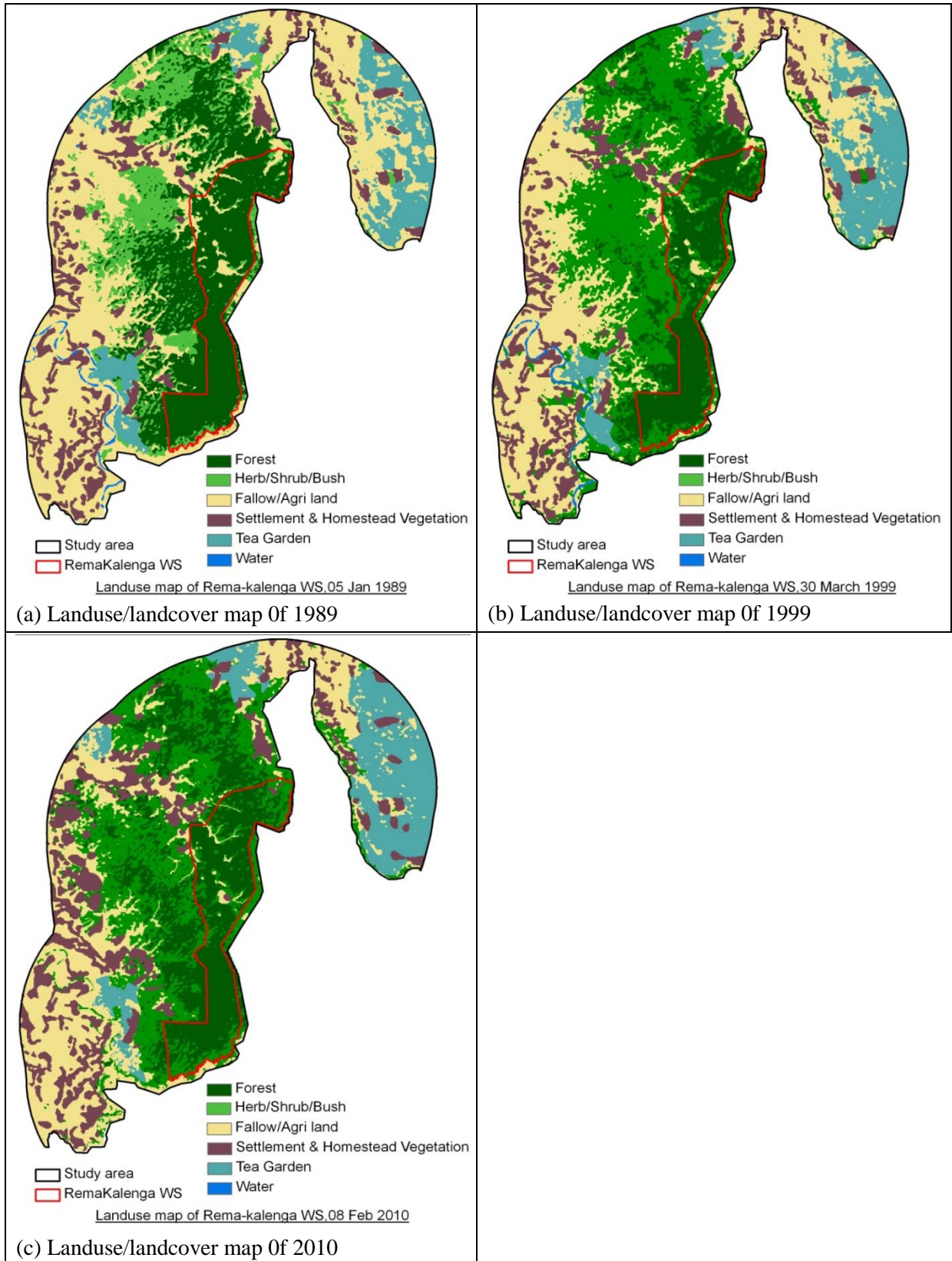
Figure 3.8 Time series landuse/landcover map of Rema-Kalenga Wild life Sanctuary

Chapter 4

Trend Analysis

4.1   Introduction

After classification, the area statistics of land use/cover were generated for each PA to understand the land use/cover change trend within the protected areas. The area coverage of each land use/cover was measured in hectares. The area coverage of each land use/cover was calculated both for core area and within 5 km buffer area around the PA.

4.2   Teknaf Wildlife Sanctuary

The land use/cover statistics of Teknaf Wildlife Sanctuary (within PA) are given in Table 4.1. The table shows that the 'Forest' area coverage within the Teknaf Wildlife Sanctuary is decreasing gradually. It was about 3,304 hectare (28.4%) in 1989; 2,812 hectare (24.2%) in 1997/2000; and 1,794 hectare (15.4%) in 2009. From 1989 to 2009 it was reduced by 45.7% of the forest area. The 'Herb/Shrub/Bush' area was found to be 6,263 hectare (53.9%) in 1989. It had increased to 6,994 hectare (60.2%) in 1997/2000 and 7,824 hectare (67.4%) in 2009. From 1989 to 2009, it had increased by 24.9% of the 'Herb/Shrub/Bush' area. Fallow or agriculture land within the PA boundary was reduced by 49.5% of the 'Fallow or Agricultural Land'. The settlement and homestead vegetation within the PA boundary was increased by 52.6% of the 'Settlement and Homestead Vegetation' area.

Table 4.1: Land use/cover statistics of Teknaf Wildlife Sanctuary within the PA boundary

Sl No.	Land Uses/Covers	Year					
		1989		1997/2000		2009	
		Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
1	Forest	3,304	28.4	2,812	24.2	1,794	15.4
2	Herb/Shrub/Bush	6,263	53.9	6,994	60.2	7,824	67.4
3	Fallow or Agricultural Land	1,106	9.5	635	5.4	558	4.8
4	Settlement and Homestead Vegetation	942	8.2	1,174	10.2	1,438	12.4
	Total area	**11,615**	**100**	**11,615**	**100**	**11,615**	**100**

Percentage of total PA area
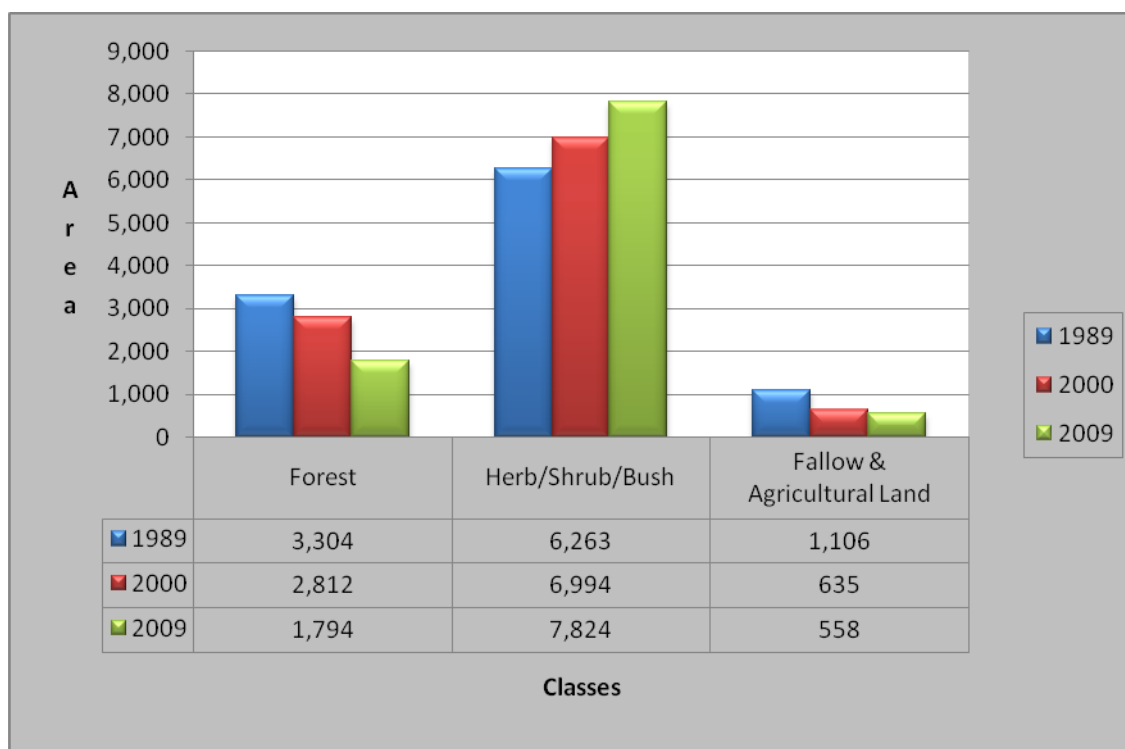
Figure 4.1 Bar diagram shows the area coverage of each class in Teknaf WS

Table 4.2 shows the land use/cover statistics within the 5 km buffer area of the Teknaf WS. It shows that the forest area had reduced by 39% of the 'Forest' area within the 5km buffer area of the PA since 1989 to 2009. During this period the herb/shrub/bush area had increased by 13% of the 'Herb/Shrub/Bush area'. The 'Fallow or Agricultural Land' had increased very little from 1989 to 2009. During this period the settlement and homestead vegetation had increased by 26% of the 'Settlement and Homestead Vegetation'.

Table 4.2: Land use/cover statistics of Teknaf Wildlife Sanctuary within the 5 km buffer of the PA boundary

Land Uses/Covers	Year					
	1989		1997/2000		2009	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	3,406	7.9	3,392	7.9	2,089	5.0
Herb/Shrub/Bush	8,722	20.5	9,277	21.7	9,864	23.1
Fallow or Agricultural Land	8,730	20.6	7,790	18.3	8,749	20.5
Settlement and Homestead Vegetation	4,672	10.9	4,995	11.8	5,884	13.8
Water	17,082	40.1	17,158	40.3	16,026	37.6
Total area	**42,612**	**100**	**42,612**	**100**	**42,612**	**100**

*Percentage of total PA area

4.3   Inani-Bangabondhu Natinal Park (Proposed)

The land use/cover statistics of the Inani-Bangabondhu NP (Proposed) are given in Table 4.3. Forest area coverage within the Inani-Bangabondhu NP is also decreasing gradually. The table shows that the 'Forest' area was 4,161 hectare (58.7%) in 1989 and it reduced to 3,280 hectare (46.3%) in 2000 and 2,249 hactare (31.7%) in 2009. During this period (1989 to 2009) it was reduced by 45.9% of the forets area within the PA boundary. In 1989 the 'Herb/Shrub/Bush' area coverage was 1,885 hectare (26.6%) within the PA area. It was increased to 3,119 hectare (44%) in 2000 and 3,683 hectare (51.9%) in 2009. Within the PA boundary the fallow or agricultural land was increased by 13.7% of the 'Fallow or Agricultural Land' from 1989 to 2009. During this period the settlement and homestead vegetation was increased by 6.4% of the 'Settlement and Homestead Vegetation'.

Table 4.3: Land use/cover statistics of Inani-Bangabondhu NP (Proposed) within the PA boundary:

Land Uses/Covers	Year					
	1989		2000		2009	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	4,161	58.7	3,280	46.3	2,249	31.7
Herb/Shrub/Bush	1,885	26.6	3,119	44.0	3,683	51.9
Fallow or Agricultural Land	636	9.0	280	3.9	723	10.2
Settlement and Homestead Vegetation	411	5.8	413	5.8	437	6.2
Total area	**7,092**	**100**	**7,092**	**100**	**7,092**	**100**

Percentage of total PA area

Classes	1989	Herb/Shrub/Bush	Fallow & Agricultural Land
1989	4,161	1,885	636
2000	3,280	3,119	280
2009	2,249	3,683	723

Figure 4.2 Bar diagram shows the area coverage of each class in Inani-Bangabondhu NP (Proposed)

Table 4.4 shows the land use/cover statistics within the 5 km buffer area of the Inani-Bangabondhu NP (Proposed). It shows that the forest area had also decreased by 63.6% of the 'Forest' area within the 5 km buffer area of the PA from 1989 to 2009. The herb/shrub/bush area was increased by 51.8% of the 'Herb/Shrub/Bush' area during this period. Within the buffer area the fallow & agricultural land was increased by 37.4% of the 'Fallow & Agricultural Land' and the settlement and homestead vegetation was increased by 6.7% of the 'Settlement and Homestead Vegetation' from 1989 to 2009.

Table 4.4: Land use/cover statistics of Inani-Bangabondhu NP (Proposed) within the 5 km buffer of the PA boundary

Land Uses/Covers	Year					
	1989		2000		2009	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	7,508	18.8	5,293	13.2	2,728	6.8
Herb/Shrub/Bush	6,119	15.3	8,796	22.0	9,290	23.3
Fallow & Agricultural Land	4,800	12.0	4,661	11.7	6,600	16.5
Settlement and Homestead Vegetation	5,986	15.0	6,144	15.4	6,392	16.0
Water	12,930	32.4	12,459	31.2	12,339	30.9
Total area	**39,955**	**100**	**39,955**	**100**	**39,955**	**100**

*Percentage of total PA area

4.4   Medhakachapia National Park

The land use/cover statistics of Medhakachapia NP is given in Table 4.5. In 1989, the 'Forest' area was 140 hectare (35.3%) within the PA boundary. The area was reduced to 114 hectare in 2000 and 112 hectare in 2009. From 1989 to 2009 the forest area coverage was reduced by 20% of the forest area within the PA boundary. The 'Herb/Shrub/Bush' area was 91 hectare (22.9%) in 1989, 115 hectare (29%) in 2000 and 95 hectare (23.9%) in 2009. During this period it was increased by 4.3% of the 'Herb/Shrub/Bush' area. The 'Fallow or Agricultural Land' was 82 hectare in 1989 and decreased to 75 hectare in 2000. After 2000, it increased to 82 hectare. The settlement and homestead vegetation increased by 28.5% of the 'Settlement and Homestead Vegetation' between 1989 and 2009.

Table 4.5: Land use/cover statistics of Medhakachapia NP within the PA boundary:

Land Uses/Covers	Year					
	1989		2000		2009	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	140	35.3	114	28.7	112	28.2
Herb/Shrub/Bush	91	22.9	115	29.0	95	23.9
Fallow or Agricultural Land	82	20.7	75	18.9	82	20.7
Settlement and Homestead Vegetation	84	21.2	93	23.4	108	27.2
Total area	**397**	**100**	**397**	**100**	**397**	**100**

Percentage of total PA area

Classes	1989	2000	2009
Forest	140	114	112
Herb/Shrub/Bush	91	115	95
Fallow & Agricultural Land	82	75	82
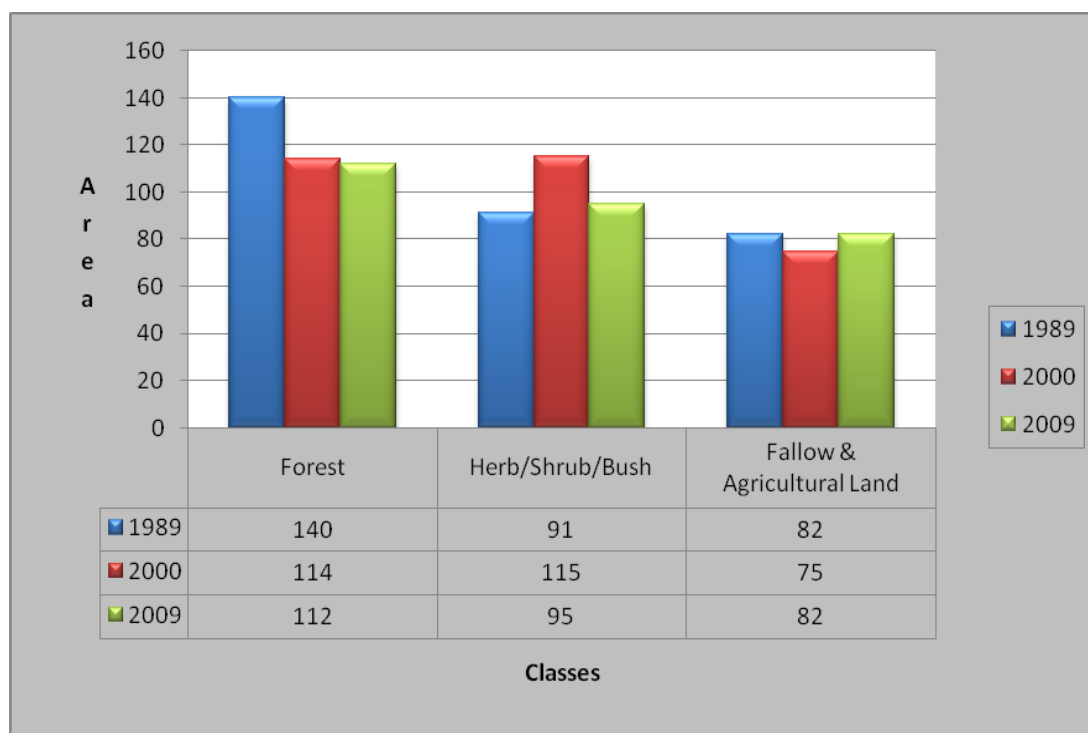
Figure 4.3 Bar diagram shows the area coverage of each class in Medhakachapia NP

Table 4.6 shows the area coverage of land use\cover within the 5 km buffer boundary of the PA. It shows that the forest area had increased by 55% of the 'Forest' area between 1989 and 2009. Conversely, the 'Herb/Shrub/Bush' was decreased by 16% within the buffer area of the PA. Fallow & agricultural land had decreased by 3% of the 'Fallow & Agricultural Land' between 1989 and 2009. During this period the settlement and homestead vegetation was increased by 34% of the 'Settlement and Homestead Vegetation' area.

Table 4.6: Land use/cover statistics of Medhakachapia NP within 5 km buffer of the PA boundary

Land Uses/Covers	Year					
	1989		2000		2009	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	651	5	1,132	8.7	1,011	7.9
Herb/Shrub/Bush	3,704	28.6	3,182	24.5	3,116	24
Fallow or Agricultural Land	7,262	56.2	7,045	54.6	7,048	54.5
Settlement and Homestead Vegetation	1,313	10.2	1,571	12.2	1,755	13.6
Total area	**12,930**	**100**	**12,930**	**100**	**12,930**	**100**

Percentage of total PA area

4.5   Fasiakhali WS

The land use/cover statistics of Fasiakhali WS is given in Table 4.7. Between 1989 and 2000 the 'Forest' area had increased but decreased between 2000 and 2009. In 1989, the 'Forest' area was 300 (23%) hectares and was increased to 392 (30.1%) hectares in 2000. After 2000, the area coverage of

the 'Forest' was reduced from 392 hectares to 301 hectares between 2000 and 2009. The 'Herb/Shrub/Bush' area was 692 hectare (53.1%) in 1989, 695 hectare (53.3%) in 2000 and 767 hectare (58.9%) in 2009. From 1989 to 2009, the coverage of the herb/shrub/bush area was increased by 10.8% of the 'Herb/Shrub/Bush' area. Within the PA boundary the fallow or agricultural land had decreased by 30.1% of the 'Fallow or Agricultural Land' between 1989 and 2009 and the settlement and homestead vegetation increased by 15.3% of the 'Settlement and Homestead Vegetation' during the same period.

Table 4.7: Land use/cover statistics of Fasiakhali WS within the PA boundary:

| Land Uses/Covers | Year | | | | | |
| | 1989 | | 2000 | | 2009 | |
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	300	23.0	392	30.1	301	23.1
Herb/Shrub/Bush	692	53.1	695	53.3	767	58.9
Fallow or Agricultural Land	272	20.9	175	13.4	190	14.6
Settlement and Homestead Vegetation	39	3.0	41	3.1	45	3.5
Total area	**1,303**	**100**	**1,303**	**100**	**1,303**	**100**

Percentage of total PA area

	Forest	Herb/Shrub/Bush	Fallow & Agricultural Land
1989	300	692	272
2000	392	695	175
2009	301	767	190
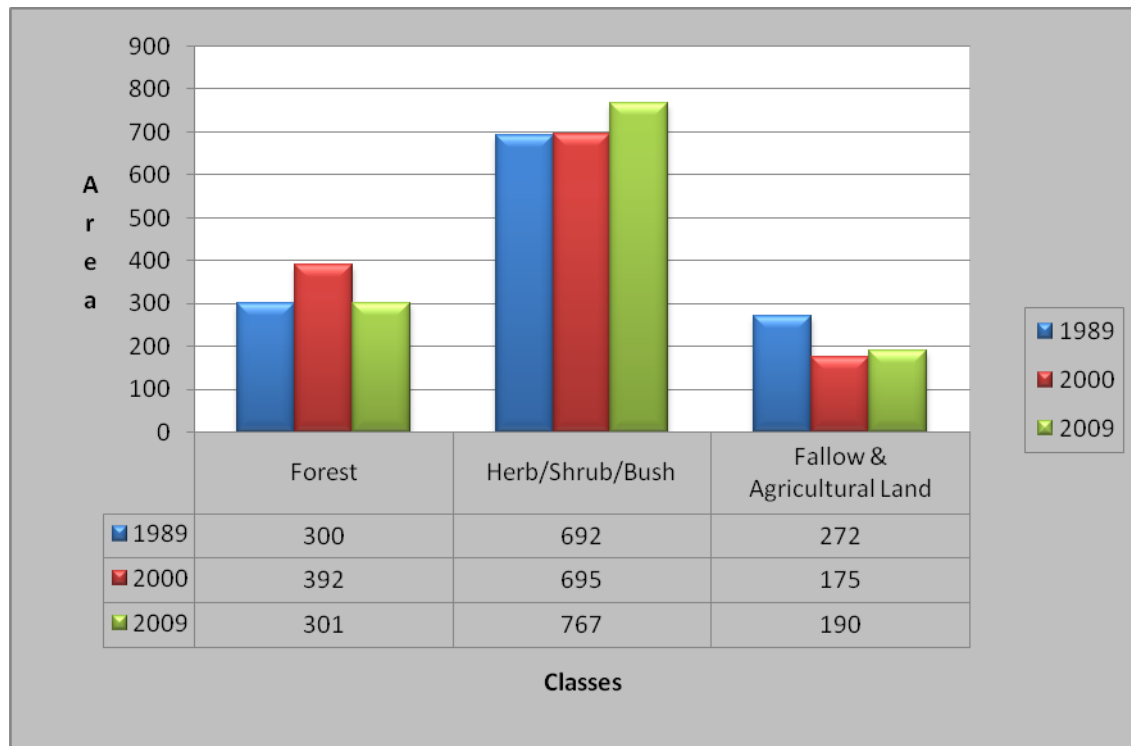
Figure 4.4 Bar diagram shows the area coverage of each class in Fasiakhali WS

Table 4.8 shows the land use/cover statistics within the 5 km buffer area of the Fasiakhali WS. It shows that the forest area had decreased by 51.9% of the 'Forest' area from 1989 to 2009. During this period the herb/shrub/bush area was increased by 19.2% of the 'Herb/Shrub/Bush' area. The fallow or agricultural land within the buffer area of the PA was decreased by 7.2% of the 'Fallow or

Agricultural Land' between 1989 and 2009. The settlement and homestead vegetation within the buffer area was increased by 15.1% of the 'Settlement and Homestead Vegetation'.

Table 4.8: Land use/cover statistics of Fasiakhali WS within the 5 km buffer of the PA boundary

| Land Uses/Covers | Year | | | | | |
| | 1989 | | 2000 | | 2009 | |
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	1,402	7.4	833	4	675	4
Herb/Shrub/Bush	5,202	27.3	5,907	31	6,202	33
Fallow or Agricultural Land	9,632	50.6	9,267	49	8,940	47
Settlement and Homestead Vegetation	2,788	14.7	3,018	16	3,208	17
Total area	**19,025**	**100.0**	**19,025**	**100**	**19,025**	**100**

Percentage of total PA area

4.6 Dudpukuria-Dhopachari Wildlife Sanctuary

The forest coverage in the Dudpukuria-Dhopachari WS is increasing gradually. In 1989, the forest coverage within the Dudpukuria-Dhopachari WS was 2,398 hectare (50.8%). It was increased to 2,632 hectare in 2000 and 2,653 hectare (56.2%) in 2009. It was increased by 10.6% of the Forest area within the PA boundary between 1989 and 2009. Within the PA boundary the 'Herb/Shrub/Bush' was 1,943 hectare (41.2%) in 1989, 1,803 hectare (38.2%) in 2000 and 1,751hectare (37.1%) in 2009. During this period the herb/shrub/bush coverage was decreased by 9.8% of the 'Herb/Shrub/Bush' area. The fallow or agricultural land was decreased by 24.4% of the 'Fallow or Agricultural Land'. The settlement and homestead vegetation was increased by 95.8% of the 'Settlement and Homestead Vegetation'.

Table 4.9: Land use/cover statistics of Dudpukuria-Dhopachari Wildlife Sanctuary within the PA boundary:

| Land Uses/Covers | Year | | | | | |
| | 1989 | | 2000 | | 2009 | |
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	2,398	50.8	2,632	55.8	2,653	56.2
Herb/Shrub/Bush	1,943	41.2	1,803	38.2	1,751	37.1
Fallow or Agricultural Land	352	7.5	254	5.4	266	5.7
Settlement and Homestead Vegetation	24	0.5	28	0.6	47	1
Total area	**4,717**	**100**	**4,717**	**100**	**4,717**	**100**

Percentage of total PA area

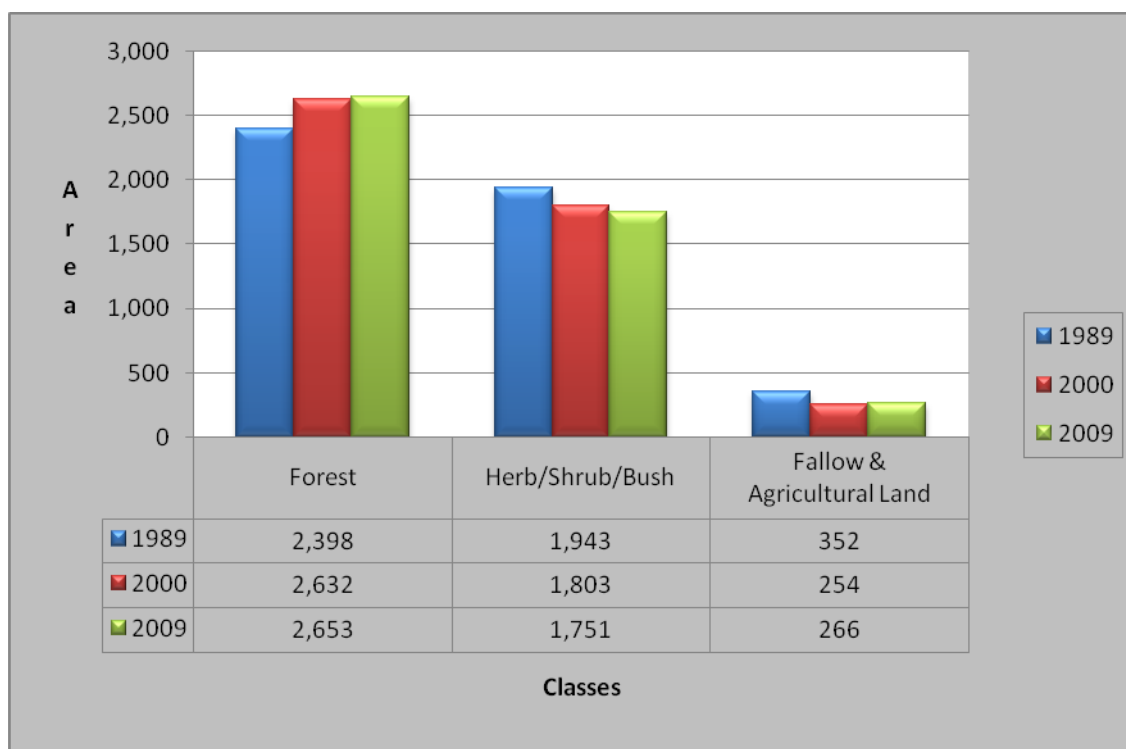|	Forest	Herb/Shrub/Bush	Fallow & Agricultural Land
1989	2,398	1,943	352
2000	2,632	1,803	254
2009	2,653	1,751	266

Figure 4.5 Bar diagram shows the area coverage of each class in Dudpukuria-Dhopachari Wildlife Sanctuary

Table 4.10 shows the land use/cover statistics within the 5 km buffer area of the Dudpukuria-Dhopachari WS. Within the buffer area of the Dudpukuria-Dhopachari WS, the 'Forest' area was decreased by 1% of the Forest area since 1989 and 2009. The herb/shrub/bush area was increased by 18% of the 'Herb/Shrub/Bush' area between 1989 and 2009. The fallow or agricultural land was decrased by 29% of the 'Fallow or Agricultural Land' within the buffer area. The settlement and homestead vegetation within the buffer area was incrased by 21% of the 'Settlement and Homestead Vegetation' between 1989 and 2009.

Table 4.10. Land use/cover statistics of Dudpukuria-Dhopachari Wildlife Sanctuary within the 5 km buffer of the PA boundary

Land Uses/Covers	Year					
	1989		2000		2009	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	6,526	18.5	6,037	17.1	6,465	18.3
Herb/Shrub/Bush	15,999	45.4	19,916	56.7	18,814	53.4
Fallow or Agricultural Land	10,920	31	7,407	21	7,788	22.2
Settlement and Homestead Vegetation	1,552	4.5	1,647	4.7	1,870	5.4
Water	199	0.6	189	0.5	259	0.7
Total area	**35,196**	**100**	**35,196**	**100**	**35,196**	**100**

Percentage of total PA area

4.7   Sitakunda RF

Table 4.11 shows the area coverage of the land use/cover in hectare for the Sitakunda RF. Within the PA boundary, the 'Forest' area is increasing gradually. In 1990, the 'Forest' area was 1,269 hectare (15.4%) and it was increased to 2,461 hectare (29.9%) in 2010. During this period the forest area was increased by 93.9% of the forest area. The 'Herb/Shrub/Bush' area was also increased gradually within the PA boundary – 3,882 hectare (47.2%) in 1990, 3,559 hectare (43.3%) in 2000 and 4776 hectare (58.1%) in 2010. The herb/shrub/bush area was increased by 23% of the 'Herb/Shrub/Bush' area during this period. The fallow or agricultural land was decreased by 69.6% of the 'Fallow or Agricultural Land' between 1990 and 2010. Within the PA boundary the settlement and homestead vegetation was increased by 38% of the "Settlement and Homestead Vegetation" during this period.

Table 4.11: Land use/cover statistics of Sitakunda RF within the PA boundary:

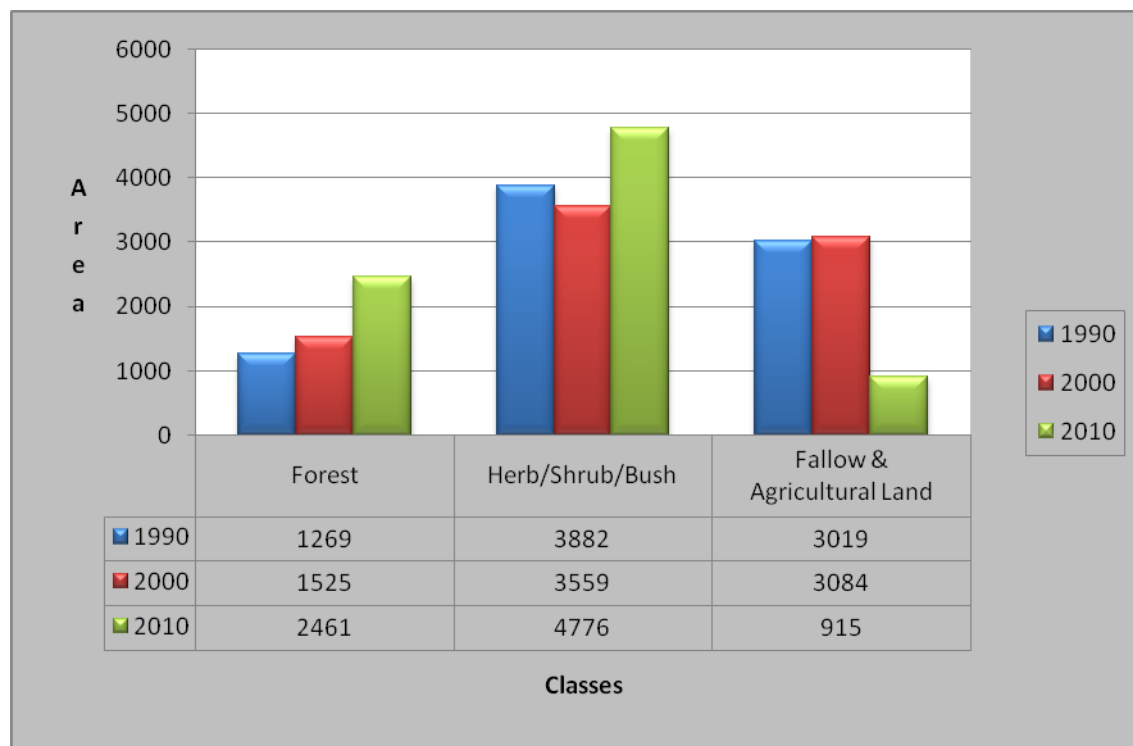| Land Uses/Covers	Year					
	1990		2000		2010	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	1269	15.4	1525	18.6	2461	29.9
Herb/Shrub/Bush	3882	47.2	3559	43.3	4776	58.1
Fallow or Agricultural Land	3019	36.7	3084	37.5	915	11.1
Settlement and Homestead Vegetation	50	0.6	52	0.6	68	0.8
Total area	**8,220**	**100**	**8,220**	**100**	**8,220**	**100**

Percentage of total PA area

Figure 4.6 Bar diagram shows the area coverage of each class in Sitakunda RF

Table 4.12 shows the land use/cover statistics within the 5 km buffer area of the Sitakunda RF. Within the 5 km buffer area of the Sitakunda RF, the forest area was increased by 30.7% of the 'Forest' area from 1990 to 2010. During this period, the herb/shrub/bush area was increased by 26.4% of the 'Herb/Shrub/Bush' area. The 'Fallow or Agricultural Land' was decreased by 34.4% of the 'Fallow or Agricultural Land' since 1990 to 2010. During this period the settlement and homestead vegetation was increased by 2.3% of the 'Settlement and Homestead Vegetation'.

Table 4.12: Land use/cover statistics of Sitakunda RF within the 5 km buffer of the PA boundary

| Land Uses/Covers | Year | | | | | |
| | 1990 | | 2000 | | 2010 | |
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	9,707	18.1	8,260	15.4	12,696	23.6
Herb/Shrub/Bush	12,732	23.7	11,505	21.4	16,104	30.0
Fallow or Agricultural Land	19,223	35.8	22,028	41.0	12,608	23.4
Settlement and Homestead Vegetation	8,994	16.7	8,857	16.5	9,205	17.1
Water	3,114	5.8	3,120	5.8	3,157	5.9
Total area	**53,770**	**100**	**53,770**	**100**	**53,770**	**100**

Percentage of total PA area

4.8   Rema-Kalenga Wildlife Sactuary

Table 4.13 shows the area coverage of the land use/cover in hectare for the Rema-Kalenga Wildlife Sactuary. The forest coverage within the Rema-Kalenga boundary is decreasing gradually. The table shows that the 'Forest' area was 1,570 hectare (87.4%) in 1989. It reduced to 1,339 hectare (74.6%) in 1999 and 1,317 hectare (73.2%) in 2010. From 1989 to 2010 the forest area coverage within the PA boundary was reduced by 16.1% of the 'Forest' area. The 'Herb/Shrub/Bush' area coverage was 100 hectare in 1989 and it was increased to 415 hectare in 2010. The fallow or agricultural land was decreased by 58.8% of the 'Fallow or Agricultural Land' between 1989 and 2010.

Table 4.13: Land use/cover statistics of Rema-Kalenga Wildlife Sactuary within the PA boundary

| Land Uses/Covers | Year | | | | | |
| | 1989 | | 1999 | | 2010 | |
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	1570	87.4	1339	74.6	1317	73.2
Herb/Shrub/Bush	100	5.6	378	21	415	23.2
Fallow or Agricultural Land	126	7	70	3.9	52	2.9
Settlement and Homestead Vegetation	0	0	9	0.5	13	0.7
Total area	**1,796**	**100**	**1,796**	**100**	**1,796**	**100**

Percentage of total PA area

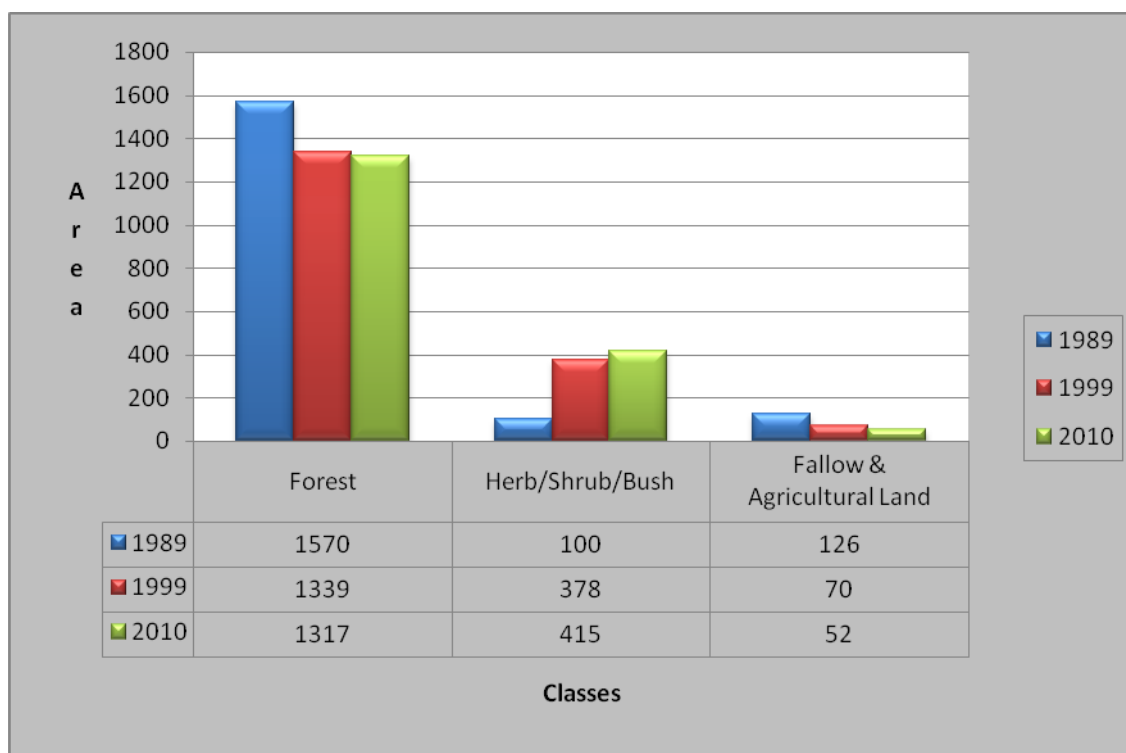|	Forest	Herb/Shrub/Bush	Fallow & Agricultural Land
1989	1570	100	126
1999	1339	378	70
2010	1317	415	52

Figure 4.7 Bar diagram shows the area coverage of each class in Rema-Kalenga Wildlife Sactuary

Within the 5km buffer zone of Rema Kalenga WS, forest coverage area was decreased from 3,729 hectare to 2,291 hectare between 1989 and 1999. During this period the forest area was decreased by 39% of the forest area. After 1999, the forest area coverage started to increase and was 2,975 hectare in 2010. By this time, it was increased by 30% of the forest area. Table 4.14 shows that the 'Herb/Shrub/Bush' area increased from 1989 to 1999 but decreased between 1999 and 2010.

Table 4.14: Land use/cover statistics of Rema Kalenga WS within the 5 km buffer of the PA boundary

Land Uses/Covers	Year					
	1989		1999		2010	
	Area (Hectare)	%*	Area (Hectare)	%*	Area (Hectare)	%*
Forest	3,729	26.5	2,291	16.4	2,975	21.2
Herb/Shrub/Bush	1915	13.7	4,082	29	3,573	25.5
Fallow & Agricultural Land	5,422	38.6	4,485	31.9	3,363	23.9
Settlement and Homestead Vegetation	1,360	11	1,571	11.3	2,201	15.7
Tea garden	1,548	9.8	1,527	10.9	1,878	13.4
Water	65	0.4	83	0.5	49	0.3
Total area	**14,039**	**100**	**14,039**	**100**	**14,039**	**100**

Percentage of total PA area

Chapter 5

Conclusions

5.1   Conclusions

The main objective of this study was to identify changes in the landuse/land cover of the seven Protected Areas using satellite imageries (Landsat TM). Three time series for each PA were used in this study (1989, 2000, and 2009/2010). Ground truth data collected within the PA boundary and buffer areas were also used for analysis of the images.

The forest area coverage within the Teknaf WS is decreasing gradually. From 1989 to 2009 the forest area coverage was reduced by 46% of the forest area within the PA boundary. On the other hand, the Herb/Shrub/Bush area within the PA boundary was increased by 25% of the Herb/Shrub/Bush area. Within the 5 km buffer area of the Teknaf WS the total forest area also decreased by 39% of the forest area and the total Herb\Shrub\Bush area increased by 13% of the Herb\Shrub\Bush area between 1989 and 2009.

In the Inani-Bangabondhu NP (Proposed), the forest is also decreasing, but the rate is more alarming than that of the Teknaf Forest area. From 1989 to 2009 the forest area coverage reduced by 46% of the forest area while from 1989 to 2009 the Herb/Shrub/Bush coverage area increased by 95% of the Herb/Shrub/Bush area. Within the 5 km buffer area of Inani-Bangabondhu NP (Proposed), the total forest area also decreased by 64% of the forest area and the Herb/Shrub/Bush area increased by 52% of the 'Herb/Shrub/Bush' area from 1989 to 2009. The major deforestation zone is in the eastern and southern parts of the study area.

From 1989 to 2009 the total forest area coverage reduced by 20% of the forest area in Medhakachapia NP. From 1989 to 2009 the Herb/Shrub/Bush area was increased by 4% of the Herb/Shrub/Bush area. Within the 5 km buffer of the Medhakachapia NP the forest area increased by 55% of the forest area from 1989 to 2009.

The total forest area coverage within Fasiakhali WS increased by 0.3% of the forest area between 1989 and 2009 and during this period the Herb/Shrub/Bush coverage increased by 11% of the Herb/Shrub/Bush area. Within the 5 km buffer area of the Fasiakhali WS, the forest area decreased by 52% of the forest cover and the Herb/Shrub/Bush area increased by 19% of the 'Herb/Shrub/Bush' area from 1989 to 2009.

The landuse change trend within the PA of Dudpukuria-Dhopachari WS is different from that of the other PAs. The forest increased gradually within this PA from 1989 to 2009. The forest area was increased by 11% of the forest area between 1989 and 2009. During this period the Herb/Shrub/Bush coverage was reduced by 10% of the 'Herb/Shrub/Bush' area. Within the buffer area of the Dudpukuria-Dhopachari WS, the forest area decreased by 1% of the forest area and the Herb/Shrub/Bush area was increased by 18% of the 'Herb/Shrub/Bush' area between 1989 and 2009.

Within the Sitakunda RF, the forest area is increasing gradually in the PA like that of the Dudpukuria-Dhopachari PA. During 1990 to 2010 the forest area increased by by 94% of the forest area. From 1990 to 2010, the Herb/Shrub/Bush area was increased by 23% of the 'Herb/Shrub/Bush' area. Within the 5 km buffer area of the Sitakunda RF, the forest area decreased by 31% of the forest area from 1990 to 2010. The Herb/Shrub/Bush increased by 26% of the 'Herb/Shrub/Bush' area within the 5 km buffer of Sitakunda RF.

The trend analysis of land use/cover within Rema-Kalenga WS shows that the forest cover declined from 1989 to 2010. During this period the forest area coverage within the PA boundary was reduced by 16% of the foreat area. Within the 5km buffer zone of Rema Kalenga WS, the forest area was decreased by 39% of the forest area between 1989 and 2010. After 1999, the forest was increased by 30% of the forest area.