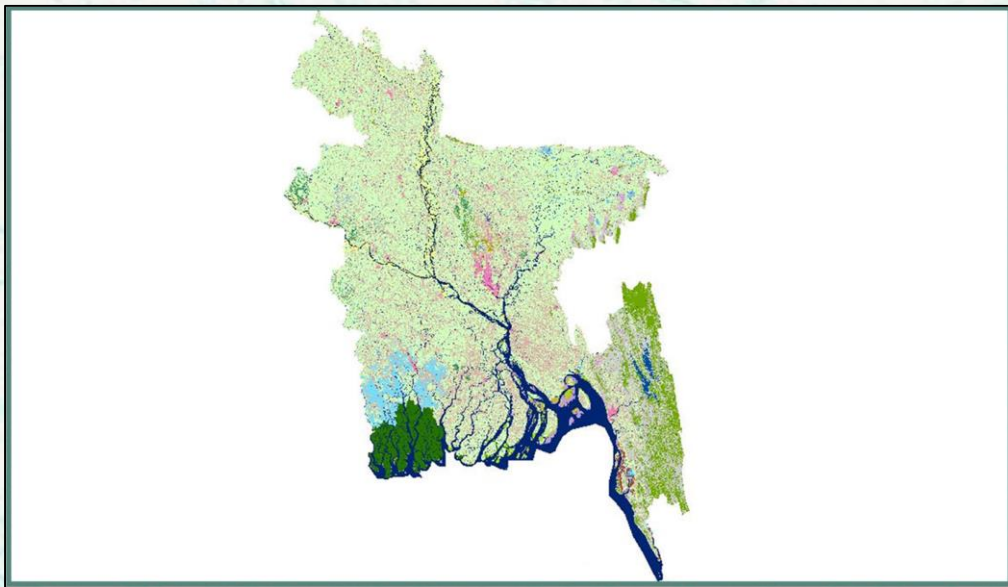




Historical land cover mapping of Bangladesh



Bangladesh Forest Department
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Historical Land Cover Mapping of Bangladesh

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EXECUTIVE SUMMARY

To contribute to forest and natural resources management programs, National Forest Monitoring Systems (NFMS) intend to monitor forest changes and services over time. In this context, under Letter of Agreements (LoA) between the Food and Agriculture Organization of the United Nations (FAO) and Center for Environmental and Geographic Information Services (CEGIS) land cover maps for the years of 2000, 2005 and 2010 were developed. The maps were prepared using a combination of remote sensing and available ground based reference information.

Visual interpretation and on screen digitization were used to develop the historical land cover maps of 2000, 2005 and 2010 using Landsat images for respective years. In order to ensure consistency with the previously prepared land cover map of 2015, legend classes were developed based on the National Land Representation System (NLRS) of Bangladesh. Land cover dataset of 2015 (from SPOT 6/7 data) were overlaid on the Landsat images of 2000. Boundaries of the land cover classes of 2015 were edited and updated based on the visual interpretation of the Landsat images of 2000. These procedures were followed to developed the land cover maps of 2005 and 2010.

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Chapter 1: Introduction

1.1 Background

Assessment and monitoring of land cover dynamics are essential for the sustainable management of natural resources, environmental protection, biodiversity conservation and developing sustainable livelihoods particularly for a populated country like Bangladesh where the land cover/uses are subjected to continuous changes. National forest monitoring systems, in this regard, is intended to contribute to forest and natural resource management programs through monitoring forest changes, and forest services, over time.

FD-RIMS and CEGIS are building on the comparative advantage and their respective technical expertise to develop the national land cover map for the year 2015. This process is supported mainly by three projects (NFI, DECCMA and UN-REDD). As part of this process, the national land representation system (NLRS) is developed in close collaboration with other national institutions such as BARI, BIP, BSGI, BUET, SoB, SPARRSO and SRDI. Using the FAO Land Cover Classification System (LCCS) and based on the NLRS, the legend for the national land cover map 2015 is developed, ensuring that the objectives and consideration of the different national institutions are reflected.

In the context of mitigation of climate change, monitoring forest cover by developing system with the potentials to produce data in line with international recommendations, particularly UNFCCC decisions and IPCC guidelines is very important. In this context, the NLRS will serve as the basis for the identification of broader land cover classes that will be used for land cover change analysis in general and for monitoring the forest resources in particular. Such a system is important for national, regional and local development especially for a country like Bangladesh.

Under this LoA, CEGIS is supposed to provide technical support for the development of land cover maps for the year 2000, 2005 and 2010 of Bangladesh by using a combination of remote sensing and available ground-based reference information. This includes technical support for the finalization of the document describing the methodology, the selection/development of national land cover classes for the change assessment, the preparation of a final report describing the results.

1.2 Objectives

The main objectives of this assignment are: i.) Prepare land cover map of 2000, 2005 and 2010 and ii.) Land cover change analysis.

1.3 Scope of Work

Develop land cover maps of Bangladesh for the year 2000, 2005 and 2010 using Landsat images

1.4 Deliverables

The deliverables of the assignment are as following:

- Digital geo-referenced Landsat Satellite Images of 2000, 2005, 2010
- Legend of land cover map prepared using LCCS
- Digital land cover datasets of 2000, 2005 and 2010
- A report on methodology of land cover mapping

Chapter 2: Methodology

2.1 Introduction

The Land cover map 2000, 2005 and 2010 of Bangladesh were prepared using visual interpretation of LANDSAT images. The legend of the land cover map of 2000 was prepared following the National Land Representation System developed in 2015 by FAO, Bangladesh. A total of twenty four different land cover classes were selected from the National Land Representation Systems and those classes were identified from 30m resolution LANDSAT images. The detail methodology of the study is shown in the **Figure-2.1**.

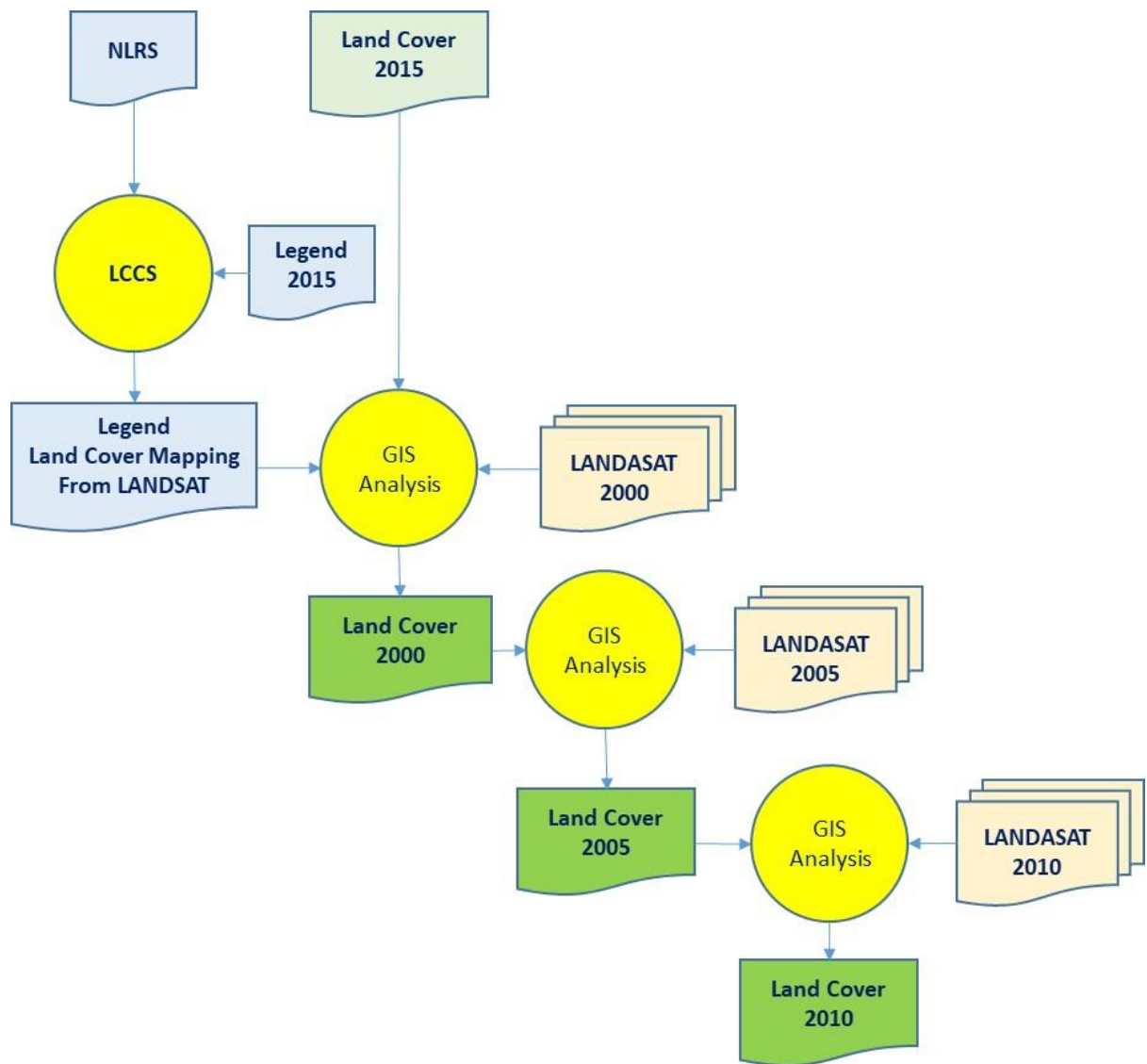


Figure-2.1: Methodology of Land Cover Mapping

2.2 Satellite Imagery

The cloud free multi-spectral LANDSAT 5TM images of 2000, 2005 and 2010 were used for land cover mapping of 2000, 2005 and 2010 respectively. Total Thirteen scenes (images) are required to cover the whole country. Landsat 7 ETM images were also used when LANDSAT 5 TM images are not available or not suitable for visual interpretation due to cloud coverage. In some cases, LANDSAT images of 2006 and 2011 were also used for land cover mapping of 2005 and 2010 respectively due to unavailability of required images in 2005 and 2010. The spatial resolution of the LANDSAT image is 30m. The radiometric resolution of both LANDSAT 5TM and 7ETM images is 8 bit.

2.3 Image Pre-processing

All selected LANDSAT images were downloaded from USGS Earth Explorer in Tiff format. The individual band layers of each image were stacked together and converted into ERDAS IMAGINE supported img format. Each of the images were projected into Transverse Mercator Projection system which is locally known as Bangladesh Universal Transverse Mercator (BUTM). The projection parameters of BUTM are given below:

Projection Type	: Transverse Mercator
Spheroid Name	: WGS 84
Datum Name	: WGS 84
Scale factor at Central Meridian	: 0.9996
Longitude of Central Meridian	: 90:00 E
Latitude of Origin of Projection	: 0.0 N
False Easting	: 500000.0 meters
False Northing	: 0.0 meters

2.4 Land Cover Legend Development

The legend for land cover mapping of 2000, 2005, and 2010 was developed following the National Land Representation System (NLRS) and the resolution of LANDSAT images. The legend which was developed for land cover mapping of 2015 using spot satellite image (6 m resolution) includes 33 (thirty three) classes. Not all of these classes were possible to identify from 30m LANDSAT images. Finally, 24 (twenty four) land cover classes out of 33 classes, which are possible to extract from LANDSAT images using visual interpretation were selected to finalize the legend of the historical land cover maps of 2000, 2005 and 2010. Table-1 shows the legends for land cover mapping from SPOT and LANDSAT images respectively.

Table-2.1: Legends for Land Cover Mapping from SPOT and LANDSAT

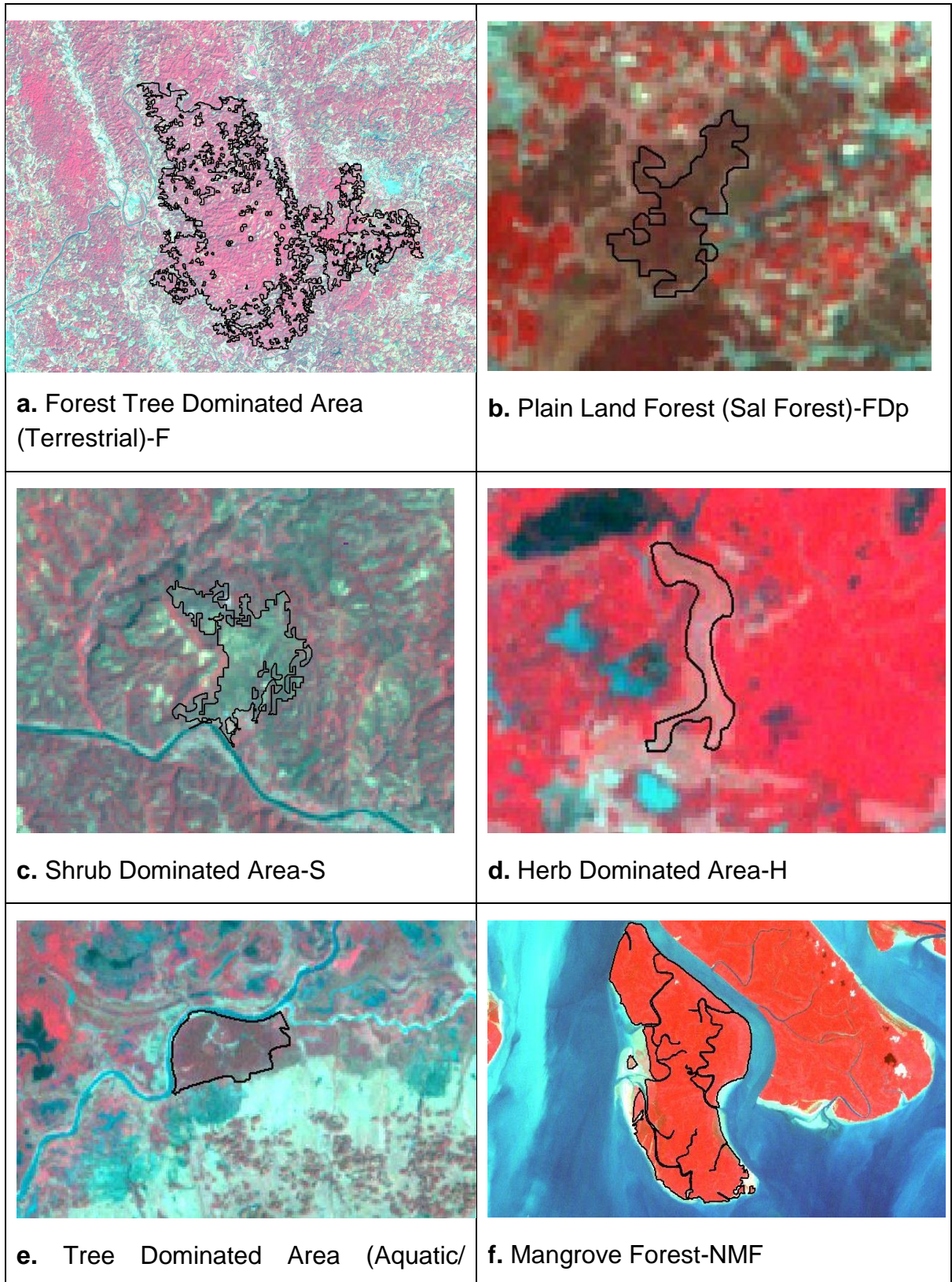
SI No	Legend	
	Land Cover Mapping from SPOT, 2015	Land Cover Mapping from LANDSAT 2000,2005,2010
<i>Natural Vegetation (Terrestrial) -NV</i>		
1	Hilly Forest- FEh	Forest Tree Dominated Area (Terrestrial)- F
2	Mixed Hill Forest- FMh	
3	Bamboo Forest- BF	
4	Plain Land Forest (Sal Forest)- FDP	Plain Land Forest (Sal Forest)- FDp
5	Shrub Dominated Area- S	Shrub Dominated Area- S
6	Herb Dominated Area- H	Herb Dominated Area- H
<i>Natural Vegetation (Aquatic / Regularly Flooded Vegetation) - NVF</i>		
7	Swamp Forest- SF	Tree Dominated Area (Aquatic/ Regularly Flooded)- NFT
8	Mangrove Forest- NMF	Mangrove Forest- NMF
<i>Cultivated Vegetation (Terrestrial) - CV</i>		
9	Forest Plantation- FP	Forest Tree Dominated Area (Terrestrial)- F
10	Rubber Plantation- FPr	Rubber Plantation- FPr
11	Orchards and Other Plantations	Cultivated Trees- CT
12	Orchards and Other Plantations	Shrub Dominated Area- S
13	Single Crop- PCs	Herbaceous Crops- CH
14	Multiple Crop- PCm	
15	Shifting Cultivation- SC	Shrub Dominated Area- S
<i>Cultivated Vegetation (Aquatic / Regularly Flooded Vegetation) - CVF</i>		
16	Mangrove Plantation- FMp	Mangrove Plantation- FMp
17	Swamp Plantation- FSp	Tree Dominated Area (Aquatic/ Regularly Flooded)- NFT
18	Swamp Reed Land- RP	Shrub Crop (Regularly Flooded)- Fc
<i>Natural Surface - NS</i>		
19	Mud Flats or Intertidal Area- MF	Mud Flats or Intertidal Area- MF
20	Sand- BS	Sand- BS
21	River Banks- RB	Sand- BS

SI No	Legend	
	Land Cover Mapping from SPOT, 2015	Land Cover Mapping from LANDSAT 2000,2005,2010
Artificial Surface -AS		
22	Built-Up Non-Linear- BNI	Built-Up Non-Linear- BNI
23	Dump Sites/ Extraction Sites- DS	Artificial Surface - AS
24	Salt Pans- SP	Salt Pans- SP
25	Brickfields- Br	Brickfield- Br
26	Air Port- AP	Built-Up Non-Linear- BNI
Natural Water Bodies - WN		
27	Rivers and Khals- R	Rivers and Khals- R
28	Baor- Ba	Baor- Ba
29	Perennial Beels/Haors- BH	Perennial Beels/Haors- BH
Artificial Water Bodies - WA		
30	Lake- L	Lake- L
31	Ponds- Po	Ponds- Po
32	Brackish Water Aquaculture- BWa	Aquaculture- Aq
33	Fresh Water Aquaculture- FWa	
Rural Settlement		
34	Rural Settlements- RS	Rural Settlements- RS

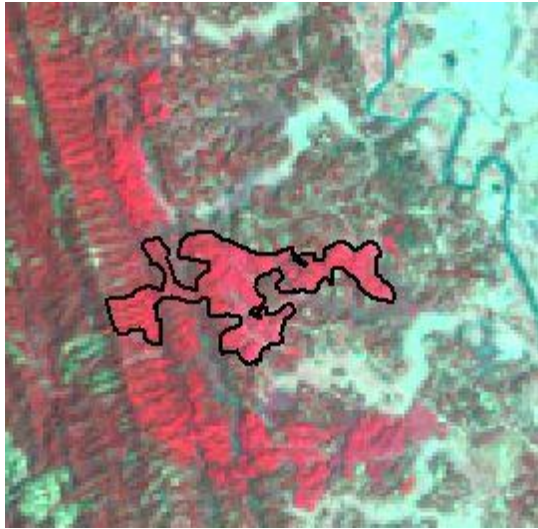
2.5 Visual Interpretation and Thematic Layer Preparation

The thirty three land cover classes of the land cover data of 2015 were aggregated into twenty four classes according to the legend developed for land cover mapping of 2000, 2005 and 2010. The aggregated land cover data of 2015 were overlaid on the LANDSAT images of 2000. When required, the class name and boundaries of each polygon, representing a land cover class, were edited and updated according to the spectral characteristics of the LANDSAT images of 2000. Figure 2.2 (a-x) shows the spectral pattern of 24 land cover classes. All land cover classes, except Forest Tree Dominated Area (Terrestrial), Tree Dominated Area (Aquatic/ Regularly Flooded) and Shrub Dominated Area, were updated based on LANDSAT images of 2000. The ArcGIS software was used for editing and updating activities. Forest Tree Dominated Area (Terrestrial)-F, Tree Dominated Area (Aquatic/ Regularly Flooded)-NFT, Shrub Dominated Area-S classes were delineated by using unsupervised classification method. The unsupervised classification was performed in ERDAS imagine software. After this digital

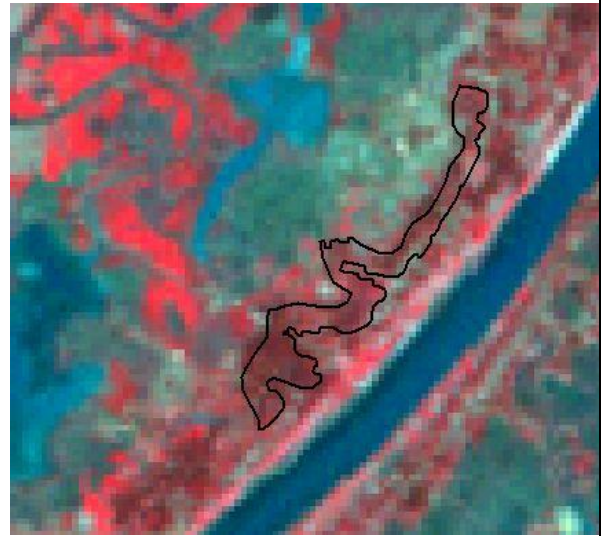
classification, the final thematic layer of Forest Tree Dominated Area (Terrestrial)-F, Tree Dominated Area (Aquatic/ Regularly Flooded)-NFT, Shrub Dominated Area-S classes were converted into an individual shape file and the shape file was simplified using Bend Simplify algorithm and Resolve Errors check with a reference baseline around 60 meters.



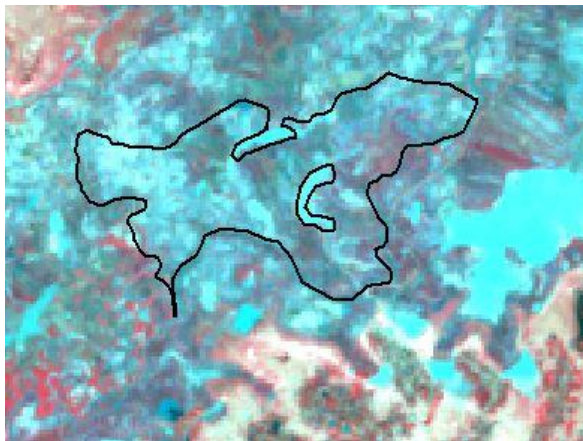
Regularly Flooded)-NFT



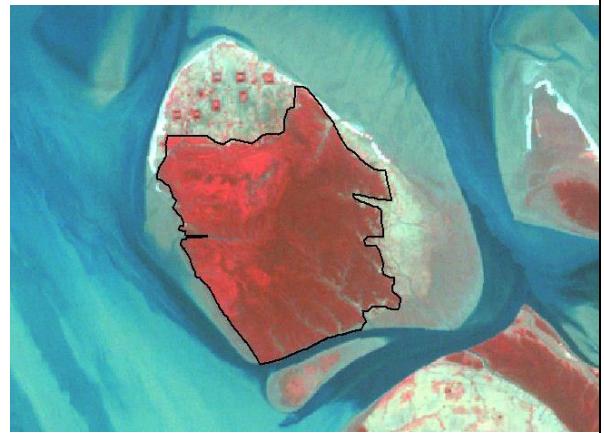
g. Rubber Plantation-FPr



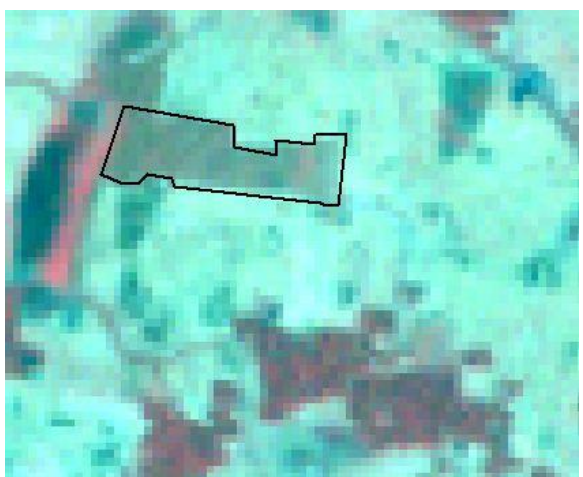
h. Cultivated Trees-CT



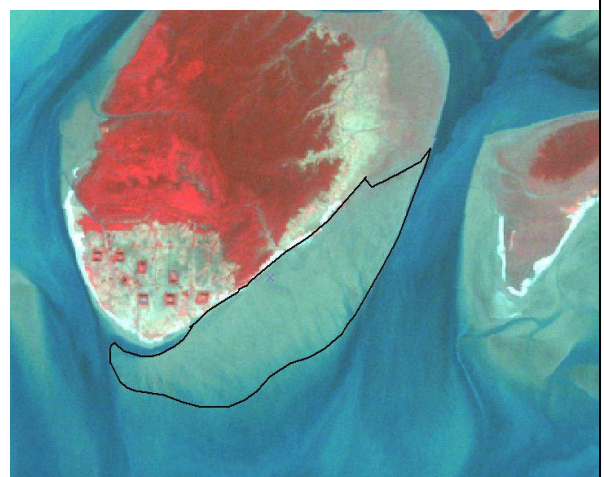
i. Herbaceous Crops-CH



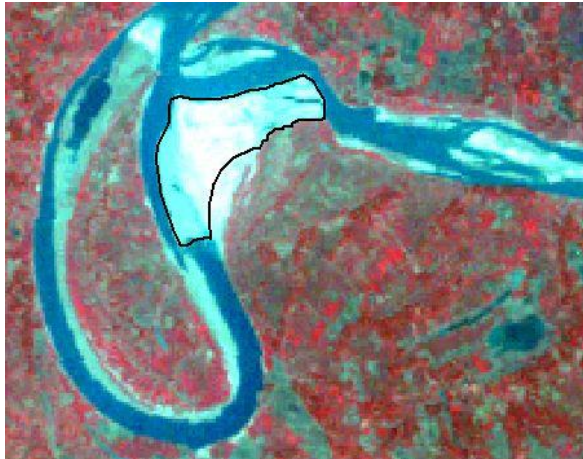
j. Mangrove Plantation-FMp



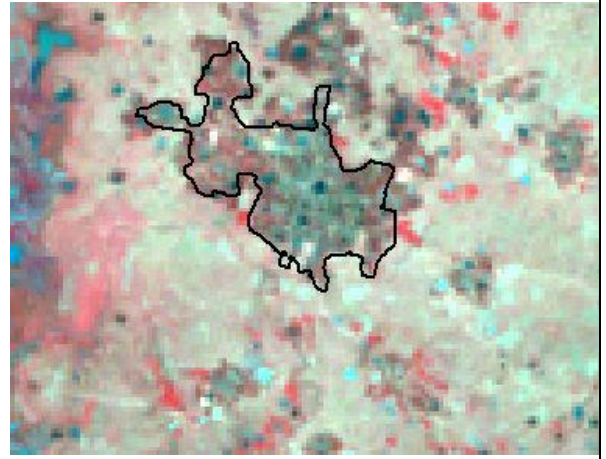
k. Shrub Crop (Regularly Flooded)-Fc



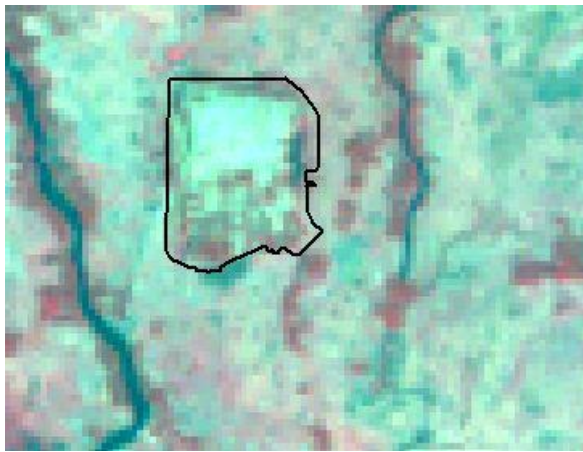
l. Mud Flats or Intertidal Area-MF



m. Sand-BS



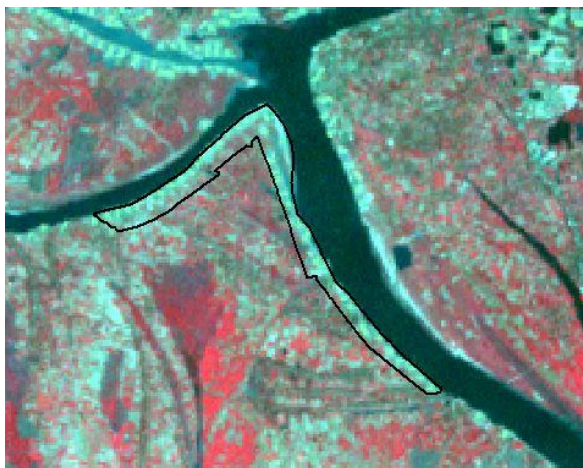
n. Built-Up Non-Linear-BNI



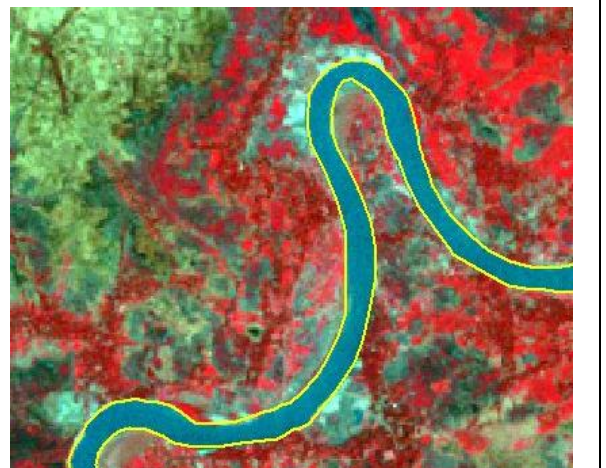
o. Artificial Surface -AS



p. Salt Pans-SP



q. Brickfield-Br



r. Rivers and Khals-R

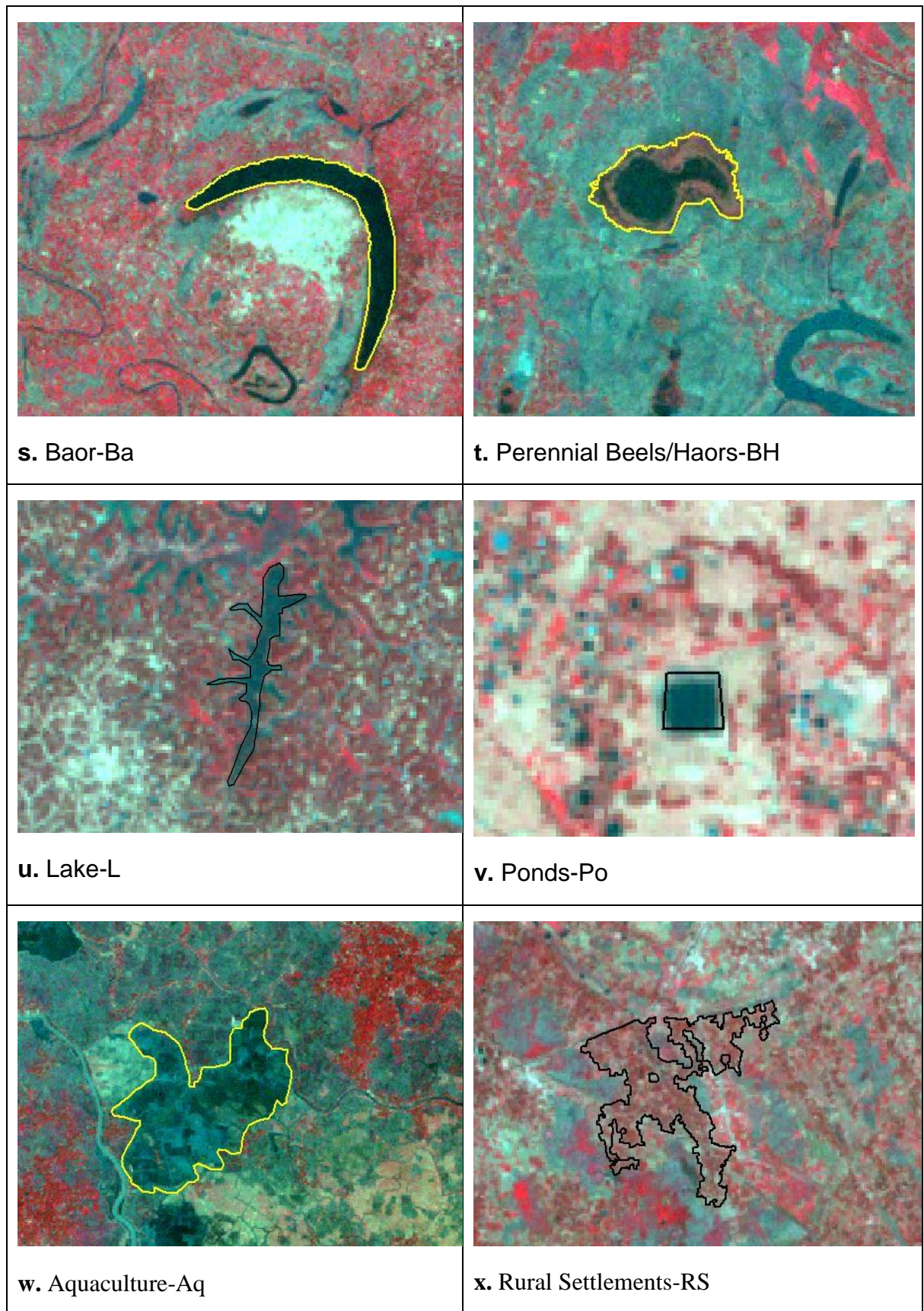


Figure-2.2: Visual Interpretation key for LANDSAT image

The methodology described above was also applied for land cover mapping of 2005 and 2010.

2.6 Land Cover Map

When thematic layers or shape files of 24-land cover classes were completed, GIS analysis was performed to compile all shape files into a single shape file. In a sequential manner based on priority each thematic layers were updated using update analysis tools of ArcGIS software. Minimum mapping unit 3600 sqrmeter for all land cover features and 5000 sqrmeter for Tree Dominated Area (Terrestrial)-F, Tree Dominated Area (Aquatic/ Regularly Flooded)-NFT, Cultivated Trees-CT were selected to prepare the land cover maps. The area of classes which area below the selected minimum mapping unit were eliminated using eliminate analysis tool. The topological error was done and rules like Must Not Overlap (polygon), Must Not Have Gaps (polygon) were set for error checking. After topological error checking a geodatabase of land cover data 2000 was prepared (Figure 2.3). In this way, land cover Map of 2005 (Figure 2.4) and 2010 (Figure 2.5) were prepared.

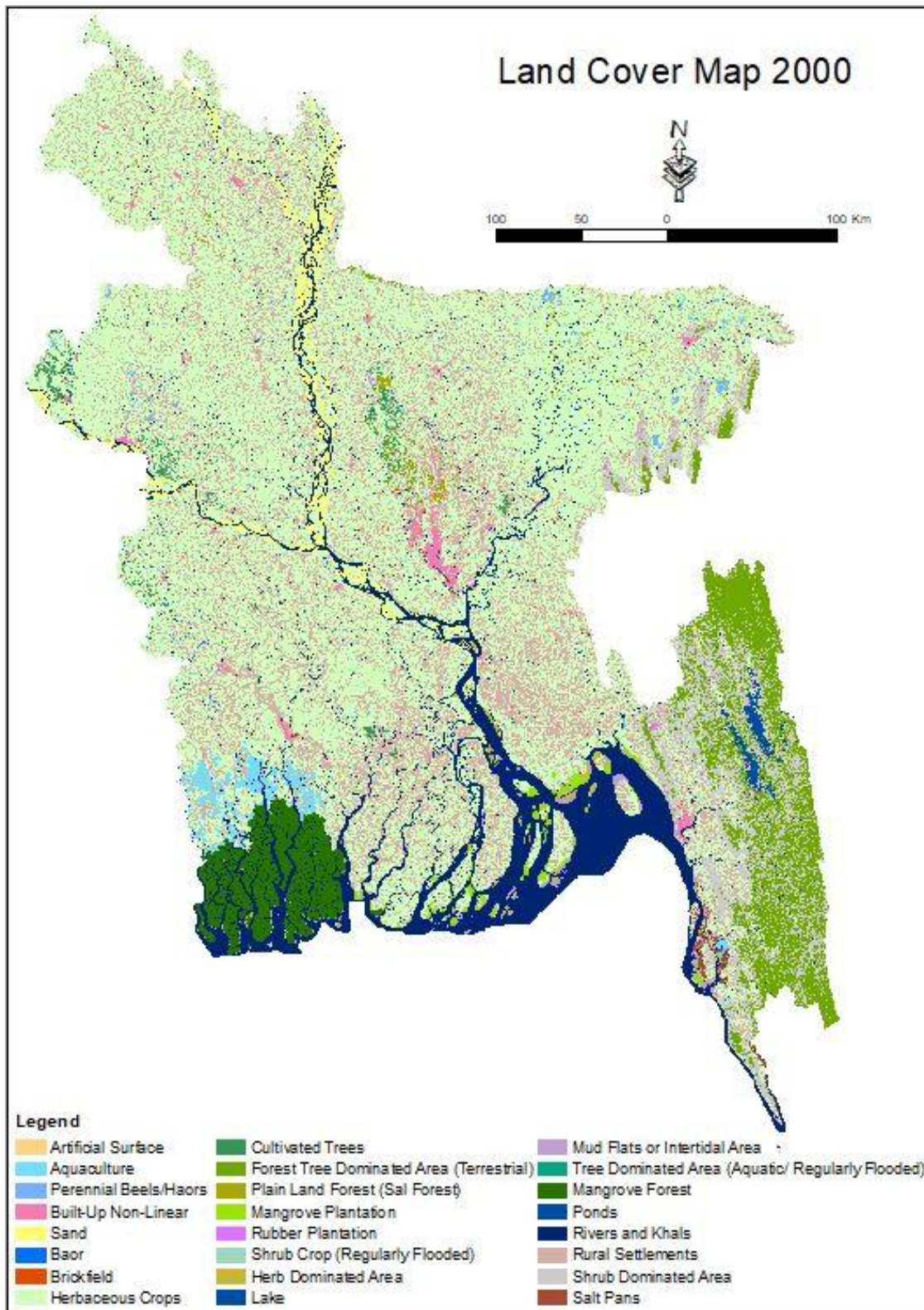


Figure 2.3: Land Cover Map, 2000 of Bangladesh

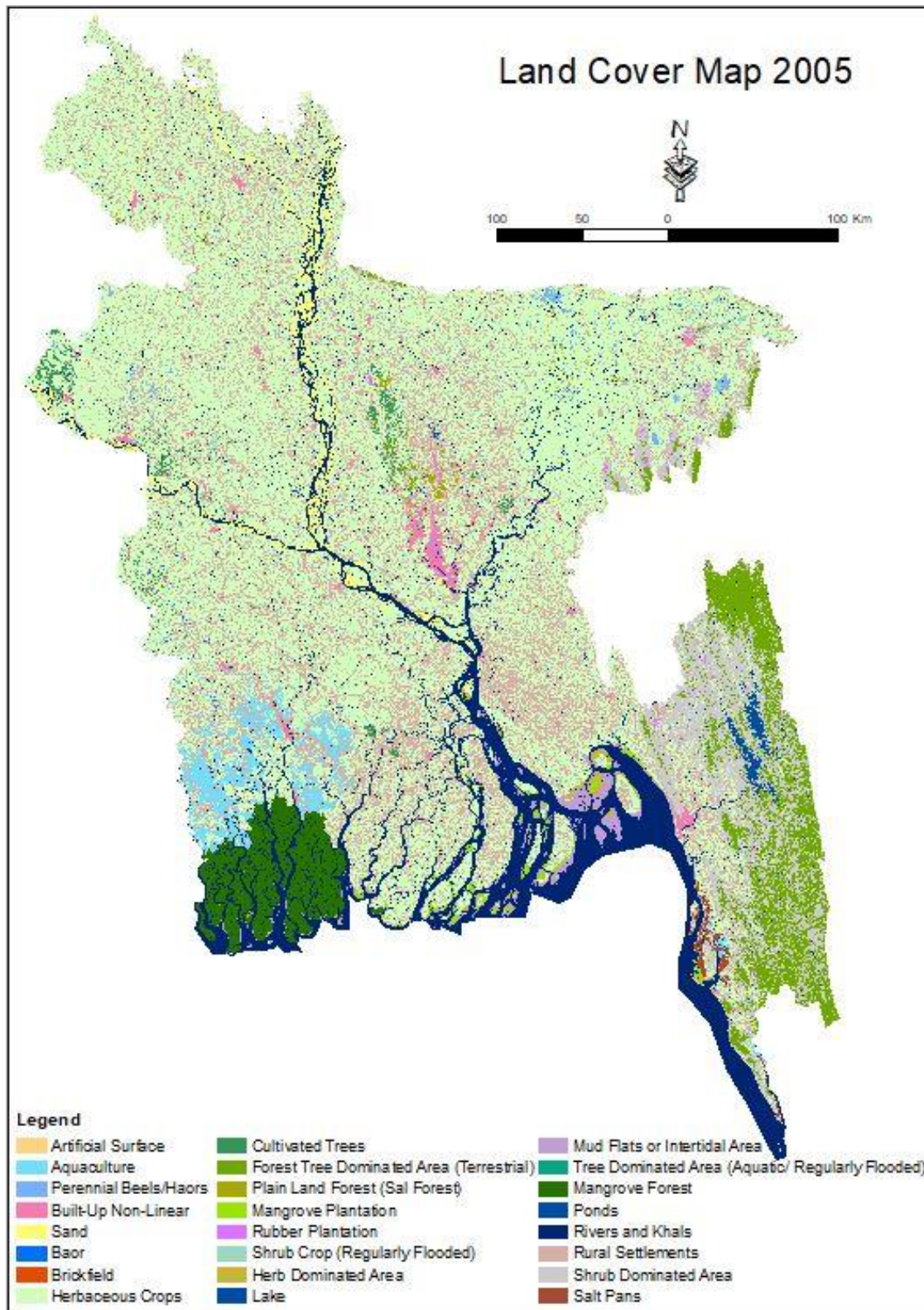


Figure 2.4: Land Cover Map, 2005 of Bangladesh

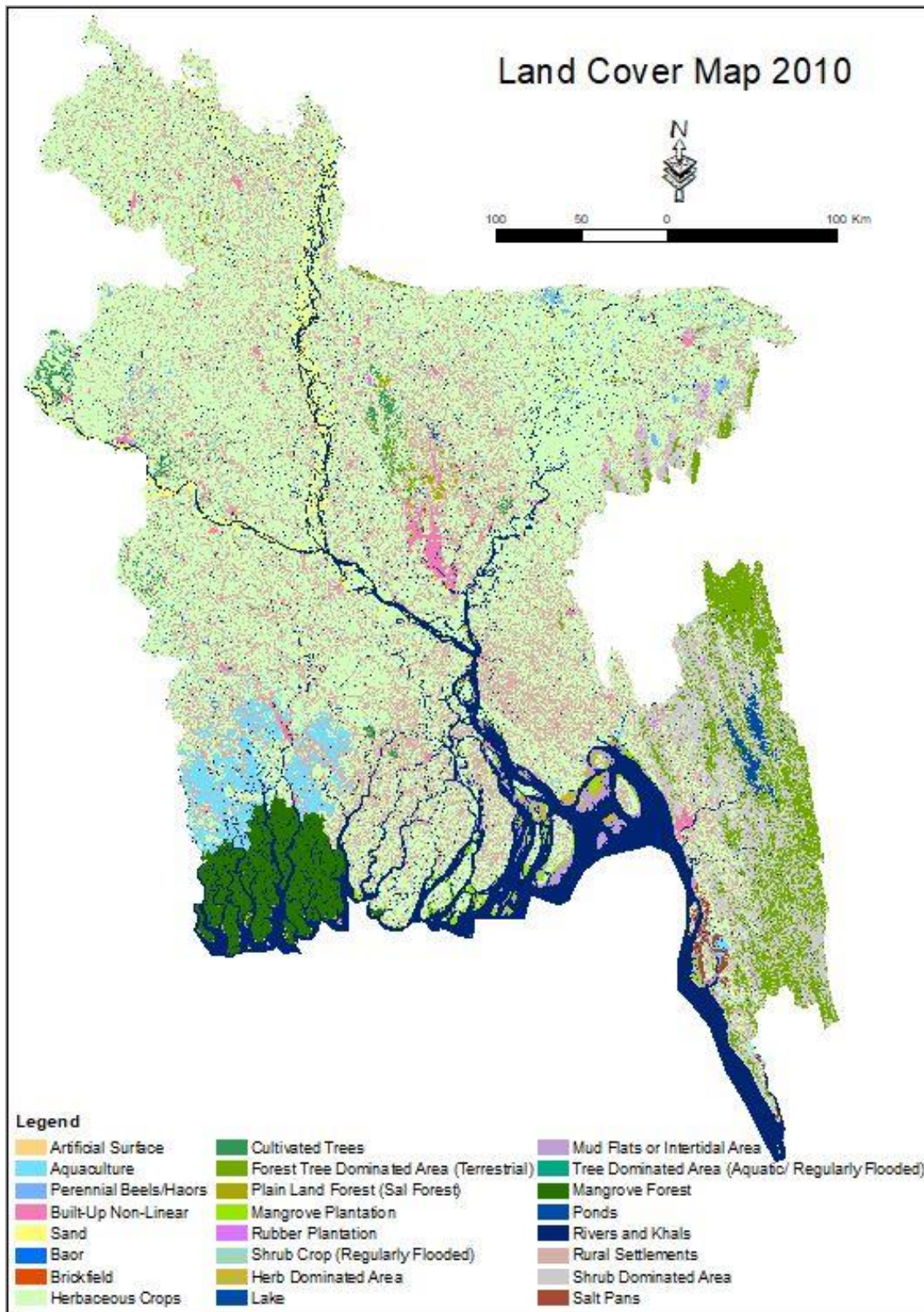


Figure 2.5: Land Cover Map, 2010 of Bangladesh

Chapter 3 Results and Conclusion

The land cover map 2000, 2005 and 2010 of Bangladesh that prepared from legend for Land cover mapping from SPOT and LANDSAT represent the 24 land cover classes. The area statistics of this 24 land cover classes of 2000, 2005 and 2010 are given in Table 3.1-3.3.

Table 3.1: Area Statistics of land cover classes of Land Cover Map, 2000 of Bangladesh.

Code	Class Name	Area (sqkm)	Area (hectare)	Percentages (%)
Aq	Aquaculture	1239.77	123976.81	0.82
AS	Artificial Surfaces	18.73	1872.79	0.01
Ba	Baor	241.41	24141.29	0.16
Br	Brickfield	121.51	12150.69	0.08
BNl	Built-Up Non-Linear	1052.88	105288.35	0.70
CT	Cultivated Trees	933.50	93349.71	0.62
F	Forest Tree Dominated Area (Terrestrial)	8311.50	831150.30	5.52
H	Herb Dominated Area	591.20	59120.04	0.39
CH	Herbaceous Crops	75811.00	7581100.02	50.31
L	Lake	561.66	56165.96	0.37
NMF	Mangrove Forest	4030.39	403039.13	2.69
FMp	Mangrove Plantation	630.17	63017.37	0.42
MF	Mud Flats or Intertidal Area	641.28	64128.37	0.43
BH	Perennial Beels/Haors	665.53	66552.97	0.44
FDp	Plain Land Forest (Sal Forest)	228.81	22880.74	0.15
Po	Ponds	50.59	5058.99	0.03
R	Rivers and Khals	14493.49	1449348.83	9.04
FPr	Rubber Plantation	123.76	12375.93	0.08
RS	Rural Settlement	30918.99	3091899.28	20.65
SP	Salt Pans	276.76	27676.03	0.18
BS	Sand	2705.28	270527.95	1.81
Fc	Shrub Crop (Regularly Flooded)	143.22	14321.77	0.10
S	Shrub Dominated Area	6889.02	688902.24	4.60
NFT	Tree Dominated Area (Aquatic/ Regularly Flooded)	7.98	798.27	0.01
Total		150688.44	15068843.81	100.00

Table 3.2: Area Statistics of land cover classes of Land Cover Map, 2005 of Bangladesh.

Code	Class Name	Area (sqkm)	Area (hectare)	Percentages (%)
Aq	Aquaculture	2608.39	260838.68	1.73
AS	Artificial Surface	0.91	90.66	0.00
Ba	Baor	206.37	20637.11	0.14
Br	Brickfield	149.87	14986.97	0.10
BNl	Built-Up Non-Linear	1283.27	128327.06	0.85
CT	Cultivated Trees	960.03	96002.87	0.64
F	Forest Tree Dominated Area (Terrestrial)	6836.08	683607.95	4.54
H	Herb Dominated Area	638.60	63860.50	0.42
CH	Herbaceous Crops	73966.03	7396603.32	49.09
L	Lake	527.51	52750.72	0.35
NMF	Mangrove forest	4038.65	403864.74	2.68
FMp	Mangrove Plantation	509.85	50985.36	0.34
MF	Mud Flats or Intertidal Area	1196.79	119679.34	0.79
BH	Perennial Beels/Haors	619.52	61951.69	0.41
FDp	Plain Land Forest (Sal Forest)	221.60	22160.39	0.15
Po	Ponds	48.43	4843.29	0.03
R	Rivers and Khals	14668.11	1466810.80	9.73
FPr	Rubber Plantation	169.88	16988.23	0.11
RS	Rural Settlement	31106.55	3110654.55	20.64
SP	Salt Pans	293.31	29330.73	0.19
BS	Sand	2143.20	214320.40	1.42
Fc	Shrub Crop (Regularly Flooded)	168.53	16852.77	0.11
S	Shrub Dominated Area	8319.35	831935.38	5.52
NFT	Tree Dominated Area (Aquatic/Regularly Flooded)	7.60	760.32	0.01
Total		150688.44	15068843.81	100.00

Table 3.3: Area Statistics of land cover classes of Land Cover Map, 2010 of Bangladesh.

Code	Class Name	Area (sqkm)	Area (hectare)	Percentages (%)
Aq	Aquaculture	2929.95	292994.59	1.94
AS	Artificial Surface	19.29	1929.49	0.01
Ba	Baor	201.91	20190.69	0.13
Br	Brickfield	169.84	16984.19	0.11
BNl	Built-Up Non-Linear	1300.83	130082.61	0.86

CT	Cultivated Trees	964.05	96405.09	0.64
F	Forest Tree Dominated Area (Terrestrial)	6738.93	673892.60	4.47
H	Herb Dominated Area	696.32	69632.23	0.46
CH	Herbaceous Crops	74147.05	7414704.57	49.18
L	Lake	526.52	52652.18	0.35
NMF	Mangrove forest	4019.89	401988.82	2.67
FMp	Mangrove Plantation	545.05	54505.41	0.36
MF	Mud Flats or Intertidal Area	1133.83	113382.85	0.75
BH	Perennial Beels/Haors	583.61	58360.65	0.39
FDp	Plain Land Forest (Sal Forest)	220.90	22089.78	0.15
Po	Ponds	48.82	4881.79	0.03
R	Rivers and Khals	14648.35	1464834.91	9.72
FPr	Rubber Plantation	175.42	17542.31	0.12
RS	Rural Settlement	31051.05	3105105.12	20.60
SP	Salt Pans	296.12	29611.85	0.20
BS	Sand	1748.77	174877.39	1.16
Fc	Shrub Crop (Regularly Flooded)	169.18	16918.07	0.11
S	Shrub Dominated Area	8414.16	841415.73	5.58
NFT	Tree Dominated Area (Aquatic/Regularly Flooded)	7.56	755.77	0.01
Total		150757.39	15075738.70	100.00