Forest and Other Land Uses of Bangladesh

A Technical Report on the Remote Sensing Monitoring Component of the Project *Strengthening Capacity to Generate Quality Information on Forest Resources. FAO Project TCP/BGD/3001*

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Foreword

Forest is a valuable renewable natural resource. It provides significant support for sustaining life on the earth surface by maintaining ecological balance. It provides us with wood, food, fodder, medicines, recreational facilities and employment opportunity. The forests are under heavy pressure today for many reasons. Depletion of vegetation in a given geographical area below a minimum allowable value largely constraints the proper regulatory functioning of the forests. In consequence, frequency of cyclone, flood and land erosion hazards increases universally and more so in Bangladesh because of typically difficult geographical position. Therefore, more efforts should be provided on the better scientific management of the forest ecosystem on the sustaining yield basis. Bangladesh Space Research and Remote Sensing Organization (SPARRSO) feels proud for undertaking the project titled "Strengthening Capacity to Generate Quality Information on Forest Resources: TCP/BGD/3001" in collaboration with Bangladesh Forest Department (BFD). No doubt it is a timely venture.

In Bangladesh the demand of fuel and timber are increasing day by day to cater the need of increared population as well as enhanced development activities. We have very few reliable information on forests and its environment. Globally reliable information on forest and tree resources is in dearth. From the imperative felt need of data on forest and tree resources, FAO initiated this programme as a support to National Forest Assessment (NFA). I appreciate FAO for providing financial support to this important programme.

A huge and new data base has been created on the forest and other land uses of Bangladesh through this project. I hope the data set generated through this project will be of immense use in Bangladesh, and also in Global Forest Assessment programme.

I take the opportunity to convey my thanks to the Project Director Dr. Jinnahtul Islam and other Scientists, Engineers and Technologists and all colleagues in SPARRSO for their sincere efforts for completing successfully the project work.

Md. Nazmul Huda Khan, ndc
Chairman , SPARRSO

Acknowledgement

I am grateful to FAO for providing financial support for this study. I express my gratitude to Mr. Ad. Spijkers, the FAO Country Representative, Bangladesh, Dr. Mahmudul Islam, Programme Officer, Expatriates from FAO, Rome, Mr. Saket Mohamed and Mr. Dan O Altrell, FOMR, Mr. Leif Lyckeback, International consultant, Mr. Carlo P. Consolacion , TCDC Expert, and Mr. Ruhul Mohaiman Chowdhury, National Forestry Information System Consultant, for providing valuable guidelines in completing this arduous job.

I extend my sincere thanks to the former successive Chairmen of SPARRSO for their continued support to this project work. I record my thanks to the current Chairman Md. Nazmul Huda Khan, ndc for his keen interest in the completion of the project and preparation of the project report. I am grateful to Shamsuddin Ahmed, Member Application, Md. Abdus Samad, Member Research, Dr. Syed Umar Khyyam , Member Technology, Babul Chandra Roy, Secretary and Saraf Uddin, Financial Adviser and other colleagues of SPARRSO for their all out support in completing the project work.

Special thanks are due to my Team Leaders, Technical Supervisors and System Manager for their sincere efforts. I acknowledge with thanks the contribution of Noor Hossain Sharifee, MA Salam, Begum Nasrin Ahmed, Sukumar Dutta and BM Liaquat Hosain for their sincere efforts in correcting the inconsistencies referred by FAO. I also thank four Assistant Conservator of Forest of BFD for providing valuable input to this project.

I am grateful to the successive National Project Directors of BFD and Forest Officers in the field for their cooperation during the ground truth work. Last but not least I am grateful to my family members for their support and sacrifice during the execution of this project work.

Dr. Jinnahtul Islam
Project Director

List of Abbreviation and Acronyms

ACF	Assistant Conservator of Forest
ARC/Info	Name of a GIS Software
AVHRR	Advanced Very High Resolution Radiometer
BDT	Bangladesh Taka
BFD	Bangladesh Forest Department
BTM	Bangladesh Transverse Marcator projection system
CHT	Chittagong Hill Tracts
DBH	Diameter at Breast Height (1.3m)
ERDAS	Name of a Image Processing Software
LoA	Letter of Agreement
LUC	Land Use Class
FCC	Falls Colour Composite
FAO	Food and Agricultural Organization
GPS	Global Positioning System
GCP	Ground control point
GIS	Geographic Information System
NFA	National Forest Assessment
NOAA	National Oceanographic and Space Administration
PC	Personal Computers
SOB	Survey of Bangladesh
SPARRSO	Bangladesh Space Research and Remote Sensing Organization
TCP	Technical Cooperation Project
TM	Thematic Mapper
U N	United Nation

Remote Sensing Monitoring Component of the Project

Strengthening Capacity to Generate Quality Information on Forest Resources: FAO Project TCP/BGD/3001

Summary

In support of the objectives and activities of the project Strengthening Capacity to Generate Quality Information on Forest Resources: TCP/BGD/3001 of Bangladesh Forest Department (BFD), FAO signed a Remote Sensing Monitoring Component Project separately with Bangladesh Space Research and Remote Sensing Organization (SPARRSO) on 12 Feb, 2006. SPARRSO was responsible for the preparation of a national over view map at 1: 1000 000 scale and a set of detailed Land use/ land cover map at 100 000 scale and train four technicians of BFD for their capacity building of staff and institution.

In view of the above, SPARRSO collected Landsat TM Imagery (2004-06) of bands 3 4 5 from FAO, distributed man power and responsibility, managed computers and software. Scientists exported the imagery to ERDAS imagine compatible format and stacked as aggregated layer of 3 4 5, did geo-rectification by using the ERDAS Imagine software with reference of 1997 Landsat TM geo-referenced mosaic of Bangladesh, constructed mosaic of Bangladesh, carried out photo- interpretation and ground validation for producing final vector layers, prepared Map Composition and printed Land use/ Land cover maps at 1: 1000 000 and 1: 100 000 scale.

The current remote sensing study defined the **total forest cover of Bangladesh to 1.07601 million ha (7. 30%) of the total land** which includes only Broad leaved forest **and plantation. Other Wooded Land** (Wooded land with shifting cultivation (fallow), Shrubs and Swamp with shrub) covers 0.92 million ha (6.22%). The remaining land cover is the **Other land** (Urban settlements, Rural settlements with tree cover + Agriculture, Tea garden, Mango plantation, Highway and other artificial areas) that covers 11.03 million ha (74.73%) and **Inland Water** (Haor & Baor, Lakes, River and Ponds) covers 1.70 million ha (11.76%). The interpretation of land uses in the remote sensing study was limited to a fewer number of land use classes than field inventory and therefore the NFA final statistics on land use areas will employ statistics from both studies to express the most detailed and correct situation of the land uses of Bangladesh (Please refer to NFA report).

One hundred copies of National over View Maps and 5 national sets of Detailed Land Use Maps have been printed and supplied to BFD. The interim products like vector layers, digital copies of the both map composition, 17 Landsat scenes have also been handed over to BFD. Four Assistant Conservator of Forest (ACF) of BFD have been trained in remote sensing and GIS for six months for developing the capacity building of the staff and institution.

The Land Use/ Land Cover (LUC) statistics as shown above is obtained from the attribute tables and the maps produced will be used as the supplement of the TCP project of BFD. More over, by this project we have understood the new land use associations of Bangladesh including the actual forest cover for which there is controversies in the country. Department of Agriculture and Department of Fisheries can also use the data and maps for Fish resource and Water resource inventory of the country. SPARRSO can use this data set for precise rice crop inventory as NOAA satellite data has a number of limitations in many Land use/ Land cover monitoring.

Remote Sensing Monitoring Component of the Project

Strengthening Capacity to Generate Quality Information on Forest Resources: FAO Project TCP/BGD/3001

1. Introduction

A forest is an area with a high density of trees. The forest ecosystem is defined by the plants and animals that live there and how they interact with each other and their physical environment. Trees and other woody vegetation are the main types of plants found in forest ecosystems. Tree and animal species vary depending on the type. The definition of forest is somewhat different to that of the United Nations Food and Agriculture Organization (FAO), which is 'land with tree crown cover of more than 10% and area of more than 0.5 ha. Trees should be able to reach a minimum height of 5 meters at maturity'. Plant communities covering large areas of the globe provide carbon-sink, oxygen-release, habitat, and soil-retention functions. Therefore, Earth's forests constitute one of the most important aspects of our biosphere.

Forest is a very valuable renewable natural resource and very important for the humanity. It provides foundation for life on the earth surface through ecological balance. They provide us with wood, food, fodder, medicines, recreational facilities and employment opportunity. The forests are under much pressure today for many reasons. Increasing demands from the land based product and services often leads to the conversion of forests into unsustainable land use. When the forest vegetation is lost by deforestation, the forest can not work as a regulator of the environment and increases the frequency of cyclone, flood and land erosion hazards universally and specially in Bangladesh. Therefore, efforts should be undertaken to the scientific management of the forest ecosystem on the sustaining yield basis. Remote sensing application can play an important role in this regard.

In recent years, the demand of country and global level reliable information on the forest and tree resources are on increase. In response of these demand FAO initiated a programme to provide support to National Forest Assessment (NFA).The programme included developing a harmonized approach to NFA, information management and support to policy impact analysis for national level decision making. It will introduce countries to an alternative approach designed to generate cost effective information on forest and trees out side forests including all benefits, uses and users of the resources and their management. Special attention was paid to monitor the changes of the forest and the related environment. The programmne will also build national capacity and harmonize method and classification system among the countries of the world.

In view of the above, FAO initiated a project **Strengthening Capacity to Generate Quality Information on Forest Resources:TCP/BGD/3001** in Bangladesh with Bangladesh Forest Department (BFD) in 2005. With the financial support from the FAO, BFD started working on the various activities and objectives of the project. The main objectives of this project were: a. Estimation of areas by forest types and Land Use

Classes by Ecological zones, b. Estimation of Volume/ ha and total standing Volume, c. Estimation of Woody Biomass above Ground, d. Estimation of Carbon Stock, e. Dbh Distribution, f. Study of Biodiversity, g. Comparison with the past results, h.Uses of resources with highlight of productive, protective and social function of forest and trees, i. Forest fire and local population trend & activities, j. Capacity Building of staff and institution and k. Time and cost analysis.

For supporting the above objectives and activities FAO signed a **Remote Sensing Monitoring Component Project** with SPARRSO. SPARRSO who was responsible for the preparation of national over view map at 1: 1000 000 scale and 5 natonal set of Detailed map at 100 000 scale on 12 Feb, 2006. SPARRSO will also train four forest officers from BFD for capacity building of staff and institution. SPARRSO carried out the mapping work according to the following Letter of agreement (LoA).

2.0 About Letter of Agreement (LoA)

2.1 Responsibility

According to the LoA SPARRSO will (1) interpret the land use/ land cover on satellite imagery, carry out ground truthing to validate the interpretation work and produce land use/land cover maps, (2) finalise and reproduce an up to date national land use/ land cover map and, (3) provide support to the Forest Department in mapping component of the project by strengthening capacity of BFD in remote sensing and GIS. The duration of the work was 6 month starting from the date of receiving the Landsat imagery.

2.2 Final Report

SPARRSO shall submit to FAO Representative in Bangladesh a final report describing the methodology followed, the resource used, and the results achieved in terms of (1) capacity building and (2) new information sets of areas of different land uses in the country. The final report shall be completed within 3 months after the completion of the project.

2.3 Activity

(1) SPARRSO will, together with BFD and FAO create a legend for the land use map, (2). SPARRSO will, together with BFD and FAO select a suitable satellite imagery, (3) SPARRSO will, together with BFD and FAO acquire a selected set of high resolution satellite imagery covering the entire country, (4) SPARRSO will, georectify the Landsat imagery with reference to 1997 Landsat mosaic prepared by SPARRSO, (5) SPARRSO will, carry out digital interpretation (1: 50 000 scale) of the whole set of the satellite imagery to assess the coverage of the national land use and verify the land uses by ground truthing, (6) SPARRSO will prepare and deliver the printed copy of the National Over View Land Use Maps scale,1: 1000 000 (100 copies) and Detailed Land Use Maps, scale 1: 100 000, 5 national sets). This work should be included in the final report. If SPARRSO do not have the facilities for printing these maps internally, funding for this

budget will be used for financing external printing,(7) BFD shall supply one set of topographic map to SPARRSO, (8) During the project period 4 technicians from BFD will participate in the interpretation of satellite imagery and the preparation of final maps,(9) During the project SPARRSO will give adequate training and supervision to the technicians from BFD. This work should be included in the final report, (10) SPARRSO will provide its facilities equipments and supplies to the project and its staff, (11) SPARRSO will responsible to provide necessary technical expertise to the project. The SPARRSO team member should be fixed and their names should be communicated with BFD and (12) SPARRSO will deliver all products (final maps, processed and interpreted satellite imagery etc.) to BFD. All materials should be delivered digitally. SPARRSO will also get a set of all sorts of data and out puts in the archive.

2.4 Outputs

A final report describing the methodology followed, the resource used, and the results achieved in terms of capacity building and new information sets on the area of different land uses in the country. The major outputs of the project are (1) Adequately and sufficiently trained technicians of the BFD in the field of remote sensing and mapping, and (2) Printed copies of National Over View Land Use Maps scale, 1: 1000 000 (100 copies) and Detailed Land Use Maps, scale 1: 100 000 (5 national sets) and also digital maps.

The land use map shall have well defined vector delineation of land use polygons with corresponding land use codes. The processed satellite imagery should be used as background image.

2.5 Budget

SL NO	tems	Unit	Quantity	Unit cost US$	Total Cos US$
1.	Acquisition of imagery	Unit	13	700	9 100
2.	Interpretation of Sat. Imagery RS and Mapping Expert	M/M	4	1000	4 000
4.	Technicians specialized in interpretation of Satellite imagery	M/M	11	400	4 400
5.	Support to interpretation checking in the field	M/M	2	2000	4 000
6.	Use of facilities and supplies for map production	LS			2 000
6.	Over head cost/Misc.	LS			1 500
7	Total				25 000
8	Total			BDT	16 37 500

Table 1. Table showing the budget of the project

If FAO provides the satellite imagery, mentioned in the budget, to the project amount of Taka 16 37 500 should be reduced accordingly to FAO's actual cost for this procurement.

3.0 Objectives of the study

SPARRSO will (1) interpret the land use/ land cover on satellite imagery, carry out ground truthing to validate the interpretation work and produce land use/land cover map, (2) finalise and reproduce an up to date national land use/ land cover map, and (3) provide support to the Forest Department in mapping component of the project by strengthening the capacity of the BFD in remote sensing. However, the specific objectives of the Remote Sensing Monitoring Component of the Project are:

- Preparation of a National Over View Map of Bangladesh at 1: 1000 000 scale showing the Forest and other land uses/ Land cover using Landsat imagery (band 3 4 5): 100 copies,

- Preparation of detail land use map of Bangladesh at 1: 100 000 scale showing the Forest and other land uses/ land cover using Landsat imagery (band 3 4 5): 5 national set,

- Training of 4 ACF of BFD on Photogrammetry, Remote Sensing, Photo-interpretation and GIS, and

- Presentation of a new national Land use/ Land cover statistics for planning and development of the country.

4.0 Preparation of Legend

A number of meetings were held among SPARRSO, FAO representatives and BFD for the preparation of legend of the proposed land use map of Bangladesh before and after the initiation of the project. At last considering the land use/cover types of Bangladesh the following legend were selected for the preparation of National Over View Map at 1: 1000 000 scale and Detailed Land Use Map at 1: 100 000 scale.

Legend

Land Cover Classes	Code
Forest	
Broad-leaved forest	
Hill forest	FH
Sal forest	FSa
Mangrove forest (saltwater)	FM
Bamboo or mixed Bamboo/broad-leaved forest	FB
Forest plantation	
Mangrove plantation	PM
Rubber plantation	PR
Other Wooded Land	
Wooded land with shifting cultivation (fallow)	Fa
Shrubs (or shrubs/trees)	Sh
Swamp with shrub	Sw
Other Land	
Urban settlements	SU
Rural settlements with tree cover + Agriculture (annual and perennial crops)	SRT/CAP
Tea garden	CPT
Mango plantation	CPM
Highway and other artificial areas	HA
Inland Water	
Haor & baor	WHB
Lakes	WL
River	WR
Ponds (large)	WP

Table 2. Tabular statement of legend of the land use map

5. Instrument Used in the Study

1. Large Screen PC
2. Arc/Info and Microsoft Office software
3. GPS receiver
4. Camera (in the beginning of the project)
5. Transport
6. Laboratory facilities

6.0 Purchase of Landsat TM Imagery

In the beginning of the project, SPARRSO scientists, FAO and BFD sat together once for selecting the satellite imagery and the bands to be used for the Land use/ Land cover study of Bangladesh in keeping harmony with the terms and condition of this FAO TCP project. In the meeting it was decided to purchase the Landsat TM imagery (30 m) with bands 3, 4 and 5 keeping an eye with the budget and it was US. $ 9100. With this budget high resolution imagery was not possible to be purchased. Fifteen Landsat scenes cover the country. We wanted to buy most recent picture of 2006. Unfortunately, even after repeated searching we could not do it because they were not available in the Bangkok Ground Station at that time. At last Fifteen scenes were collected which were of different period extending from December, 2004 to March 2006. List and Specification of Satellite data are given in table No. 3. FAO purchased these imagery in favour of SPARRSO for many obvious reasons and the cost was deducted from the total budget. Landsat TM imagery of 137/ 043_ 15 12 2004 has been shown in page 15.

Satellite	Row	Path	Date of acquisition	Bands
Landsat 5 TM	135	045	03-02-2005	3 4 5
,,	,,	046	18-01-2005	,,
,,	136	043	13-02-2006	,,
,,	,,	044	28-01-2006	,,
,,	,,	045	13-02-2006	,,
,,	137	042	31-12-2004	,,
,,	,,	043	15-12-2004	,,
,,	,,	044	31-12-2004	,,
,,	,,	045	05-03-2005	,,
,,	138	042	24-02-2005	,,
,,	,,	043	07-01-2005	,,
,,	,,	044	07-01-2005	,,
,,	,,	045	07-01-2005	,,
,,	139	042	15-02-2005	,,
,,	,,	043	15-02-2005	,,
Total			**15 imagery**	

Table 3. List and Specification of Satellite data

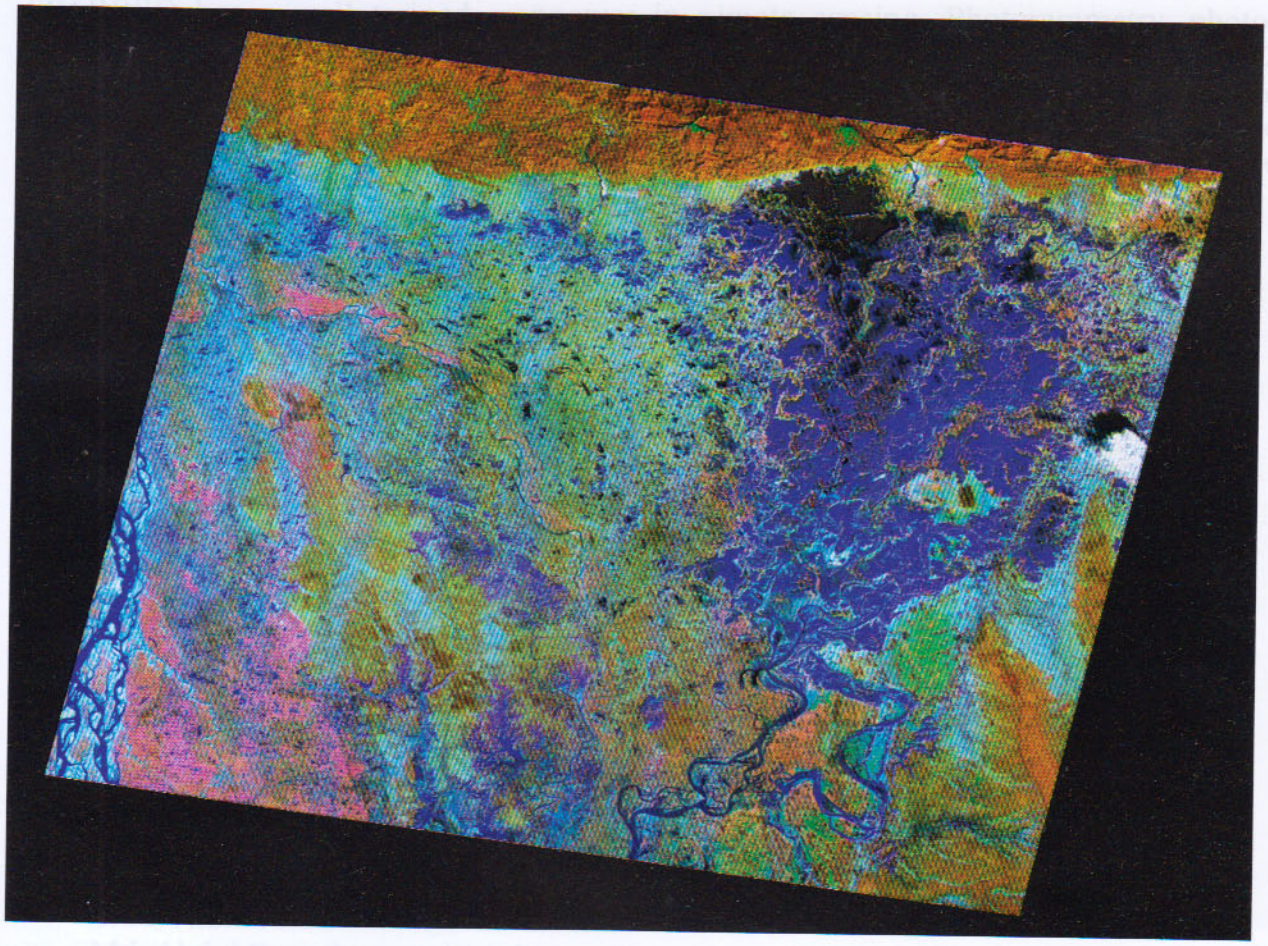

Fig. 1. Landsat TM image 137/043_15 12 2004

7.0 Collection of topographic- maps

Topographic maps are very important in survey and mapping the natural resources and Land use/ Land cover using remote sensing and GIS. They are extremely used in ground validation of the remote sensing imagery. BFD wanted to supply one national set of topographic map prepared by Survey of Bangladesh (SOB). Unfortunately they could not supply them and we used them from the SPARRSO archive. We collected plantation maps and journals from the Range Offices and used them in the field.

8.0 Distribution of man power and responsibility

SPARRSO has a well trained manpower in remote sensing, Photgrammetry, photo-interpretation and GIS. In a meeting Chairman SPARRSO selected all together 32 scientists, engineers and technicians and were engaged in this arduous job. They were divided in to four groups. Moreover personnel engaged in administration and finance were also associated with the project and performed their respective duties. List of the manpower follows:

Dr. Jinnatul Islam, PSO. Project Director

1. Md. Raquib Azam, PSO. System Manager
2. Ahmed Sayeed, PSO. ,,

Team 1
Meherun Nessa, PSO: Technical Supervisor
Dr. Mahamudur Rahman, SO: Team leader
Mizanur Rahman, S E: Member
Hashem Uddin SO: Member
Fazlul Hoque, JE: Member
Zebunnessa, Draftsman: Member
Md. Jaheer Iqbal, ACF, BFD

Team 2
Dr. Hafizur Rahman, SSO: Technical Supervisor
A. Salam, SO: Team leader
Suraiya Begum SSO: Member
Afroza Nasrin, SSO: Member
S. M. Akhteruzzaman, AE: Member
Md. Abdul Bari, Tech-1: Member
Md. Liaquat Hoassain, SSA: Member
Md. Ali Haider Khan, ACF, BFD

Team 3
M. H. Sarker, SE: Technical Supervisor
Nur Hossain Sarifee SO: Team leader
Md. Abu Taleb, SO: Member
Md. Ziaul Islam, Field Assistant: Member
Sumangal Chakma, AE: Member
Akhteruzzaman JE: Member

Sultana Razia, Draftsman: Member
Bilkis Rukhsana, ACF, BFD

Team 4

Dr. M. A. Shahid, PSO: Technical Supervisor
Sukumar Dutta AE: Team leader
SM Humayun Kabir, SO: Member
Safiqul Islam, JE: Member
Md. Shaheb Ali, AE: Member
Abdullah Zahir, SSA: Member
Shamima Begum Shewli, Research Officer, BFD

9.0 Management of computers and software

The system manager was asked to arrange the 12 Large Screen PC equipped with ERDAS Imagine and ARC/ Info soft wares. Each Team leaders were advised to use 3 pc for his men associated with the project. They did accordingly. When any trouble was noticed the system manager used to mange it immediately. During the photo-interpretation and vector data management no problem was faced by the working groups.

10.0 Methodology

To achieve the result of the above objectives and for the preparation of maps at different scales SPARRSO collected Landsat TM Imagery of bands 3 4 5 from FAO, distributed man power and responsibility, managed the computers and software, did geo-rectification by using the ERDAS Imagine software with reference of 1997 Landsat TM geo-referenced mosaic of Bangladesh, constructed the mosaic of Bangladesh, carried out photo- interpretation and ground verification for producing vector layers. They prepared Map Composition and printed Land use/ Land cover maps at 1: 1000 000 and 1: 100 000 scale. The detailed methodology as follows:

10.1 Export of Landsat Imagery

We needed 17 Landsat scenes to cover Bangladesh. The Landsat Imagery bought from Bangkok were exported to ERDAS Imagine compatible format and stacked as aggregated layer of bands 3 4 5 by using ERDAS Imagine software . This is the first step of processing of remote sensing data for image interpretation.

10.2 Geo-rectification of Landsat Imagery

Geo- rectification is a process by which each and every point of the earth surface on the imagery could be linked with a real world coordinate system. Without geo- rectification mosaic could not be made and also vector layers could not be created. After completion of this process we can understand the geographic location of each point on the imagery in degree, minute and second (Lat/ Long). SPARRSO's Georectified Landsat mosaic (1997) has been used as the reference image for geo rectification of new Landsat Imagery. Geo rectification of the Landsat Imagery was carried out by using the ERDAS Imagine software. Ground Control Points (GCP) of easily identifiable points from this mosaic were transferred digitally to the Landsat new frames independently and geo- rectification of each Landsat frame were performed with the help of specific command of the software. No new GCP collected from the ground were incorporated into the rectification process. After geo-rectification the 15 Landsat scenes were ready for producing a single Landsat mosaic of Bangladesh.

10.3 Construction of Mosaic

A mosaic is an assembly of aerial photographs or satellite imagery for achieving a composite view of the terrain. It is prepared for bringing the whole area into a common national scale for the preparation of map. In case of aerial photographs there are three types of mosaics namely, uncontrolled, semi-control and controlled mosaic. As the question of tilt and relief displacement generally does not arise in case of satellite imagery the mosaic we prepare from satellite imagery is the controlled mosaic and is prepared after the radiometric and geometric correction.

Fifteen Landsat imagery covered the whole area of Bangladesh. The geo-rectified Landsat imagery were laid down side by side. They were stitched together digitally with the help of the ERDAS Imagine software for creating a composite view of Bangladesh with a common national scale. Much tonal variation was noticed between the adjacent image of the mosaic because of the multi-date Landsat imagery of the mosaic. The tonal mismatch were prominent in the districts of Bogra, Chittagong and Chittagong Hill Tract (CHT). Subsequently efforts were made to correct the tonal variation a number of time and fourth generation mosaic was finalized with still some negligible variation and error. The colour Mosaic of Bangladesh Prepared from Landsat TM imagery 2006 is shown in the next page.

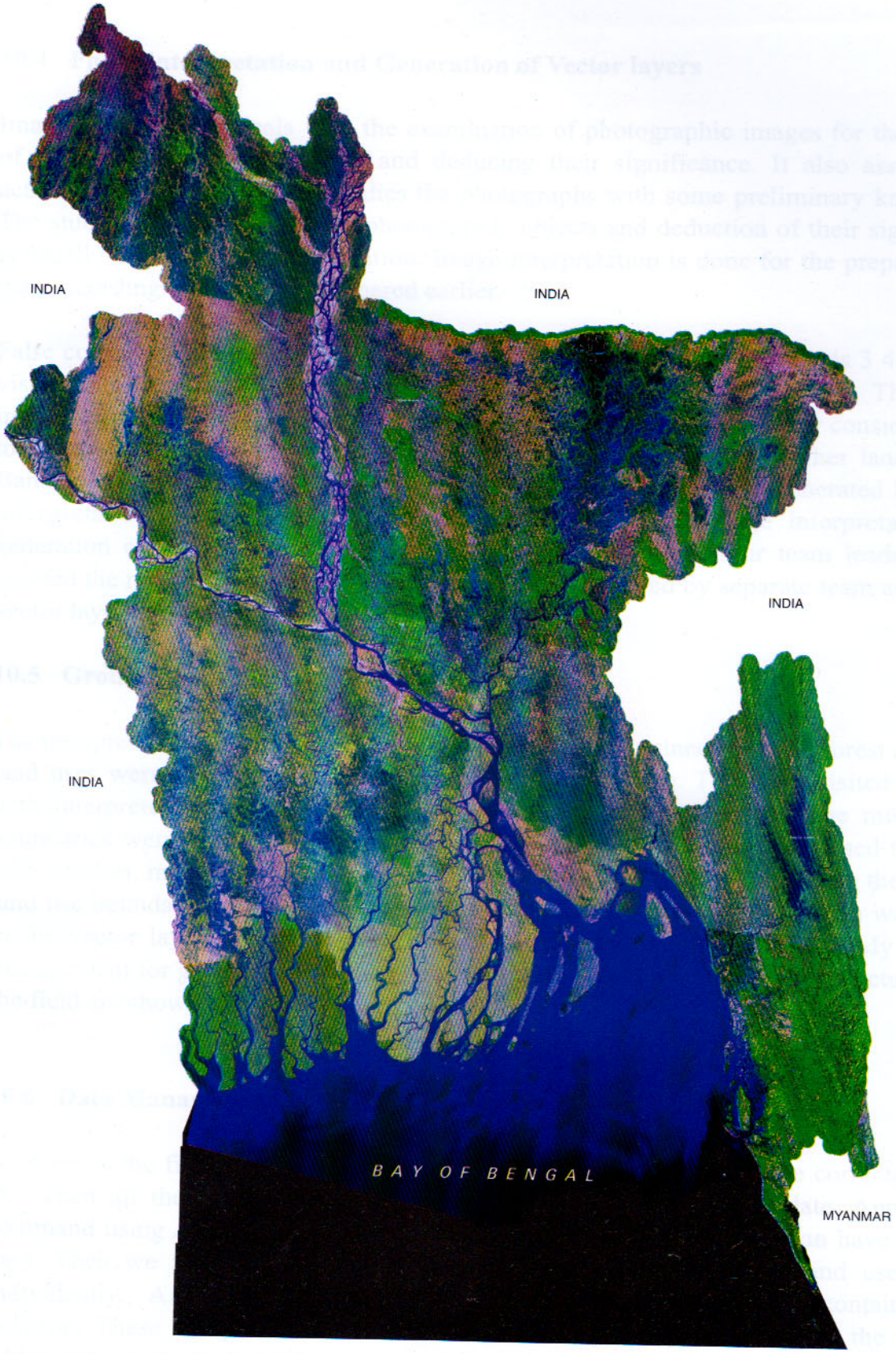

Fig. 2. The Colour Mosaic of Bangladesh Prepared from Landsat TM imagery, 2006

10.4 Photo-interpretation and Generation of Vector layers

Image interpretation deals with the examination of photographic images for the purpose of identification of the objects and deducing their significance. It also assumes the activity of the observer who studies the photographs with some preliminary knowledge. The study of image of different photographic objects and deduction of their significance is usually called image interpretation. Image interpretation is done for the preparation of map according to the legend prepared earlier.

False colour composites (FCC) were prepared using the Landsat TM bands 3 4 5 for the visual interpretation in the PC using the ERDAS Imagine software. The visual interpretation of different land uses was carried out on the screen digitally considering the tone, texure, pattern, size, shape, shadow and colour of forests and other land uses of Bangladesh. According to the legend 14 digital vector layers were generated by image interpretation. First generation mosaic was used for the image interpretation and generation of vector layers. The mosaic was supplied to the four team leaders. They divided the mosaic into four parts. Each part was interpreted by separate team and the 14 vector layers were generated.

10.5 Ground Verification

The interpretation results and the primary vector layers obtained from the forest and other land uses were verified in the field throughout Bangladesh. The crew visited the field with interpreted imagery on which the vector layers were marked. The mismatched boundaries were corrected by walking along the field boundaries. They used transport, GPS handset, measuring scale, measuring tapes etc. in the field for correcting the primary land use boundary layers. After returning from the field necessary correction were made in the vector layers and they were finalized in the PC. Now these are ready for data management for generating individual vector layers for each land uses. Two pictures from the field are shown in page number 21 and 22.

10.6 Data Management for Generating Vector Layers

As soon as the field verification was completed, the vector layers were corrected in the PC. Then all the layers were processed by using Build, Clean, Update, Append etc. command using ARC/Info software. In the processed vector layer we can have attribute data. Then we add code in the attribute data files for identifying land use classes individually. After that we created a composite polygon layer which contain all the polygon. These composite layers were used for map composition. From the attribute tables areas and number of polygons were derived and subsequently the total areas of various land uses have been found out.

Fig. 3. A panoramic view of Kat tuli Mangrove Plantation (1990) with Keora (Soneratia appetala). Av. St ht is 35 ft : Not/ ha is 15000 : Av dbh is 6 inch

Fig. 4. Natural Views of Teak Forest at Dulhazra, Cox's Bazar Forest Division

10.7 Preparation of Map Composition

Two types of map composition were prepared. One for National over View Map at 1: 1000 000 scale and the second one is the detailed land use map at 1: 100 000 scale. The Map Composition menu of the ERDAS Imagine software was displayed in the PC. The mosaic of Bangladesh was displayed on the Map Frame as background layers. Then all the combined polygon for forest, water body, river, road, plantation etc. were displayed one by one on the mosaic. Then the individual land use was assigned for different colour. The legend prepared early was put on the right side of the map frame. A bar scale has also shown on the map. The map title was placed at the top of the map. The Geographic Lat/long coordinate system was chosen for placing the latitude and longitude in degree, minute and second out side map boundary. Necessary footnotes were given in a suitable place. Finally the Map Composition was run by giving specific command for it. Now the map is ready for printing. Bangladesh Transverse Marcator (BTM) projection system has been used in the Map Composition. The specification is as follows:

Projection: Bangladesh Transverse Marcator (BTM)
Unit: Meter
Spheroid: Everest
Datum: India (Bangladesh)
Latitude of Original Projection: 0 00 00 N (equator)
Longitude Central Meridian: 90 00 00E
Scale Factor of Central Meridian: 0.9996
False Easting: 500 000 meter
False Northing: -2 000 000 meter.

11.0 Printing of Maps

Test prints of both types of map were made from out side SPARRSO. SPPARRSO scientists sat together for necessary correction on the map print and they suggested some correction. Accordingly the corrections were installed on the map. Then SPARRSO sat with the BFD and the local consultant of FAO to elucidate suggestion if there were any. BFD and FAO proposed some ornamental renovation and we did them accordingly. Finally Dan O. Altrell , Carlo P. Consolacion. and Ruhul Mohaiman Chowdhury called us in a meeting at BFD over the map finalization. We responded and it was decided that the FAO team will visit SPARRSO to see the map composition on the screen. The next working day the FAO team visited SPARRSO and sat before the PC screen and made some alteration and advised to go on with printing if BFD agrees. BFD accepted the proposal

In the first phase two hundred copies of National over View map at 1:1000 000 scale were printed on 100 gsm glossy paper from out side SPARRSO as the SPARRSO's printer had some problem. We printed 5 national set (295 copies) Detailed Land Use Map from out side SPARRSO. These will be handed over to BFD. Two pictures of National overview map and detailed map are shown in the next pages.

Fig. 5. A Picture of National Over View Map

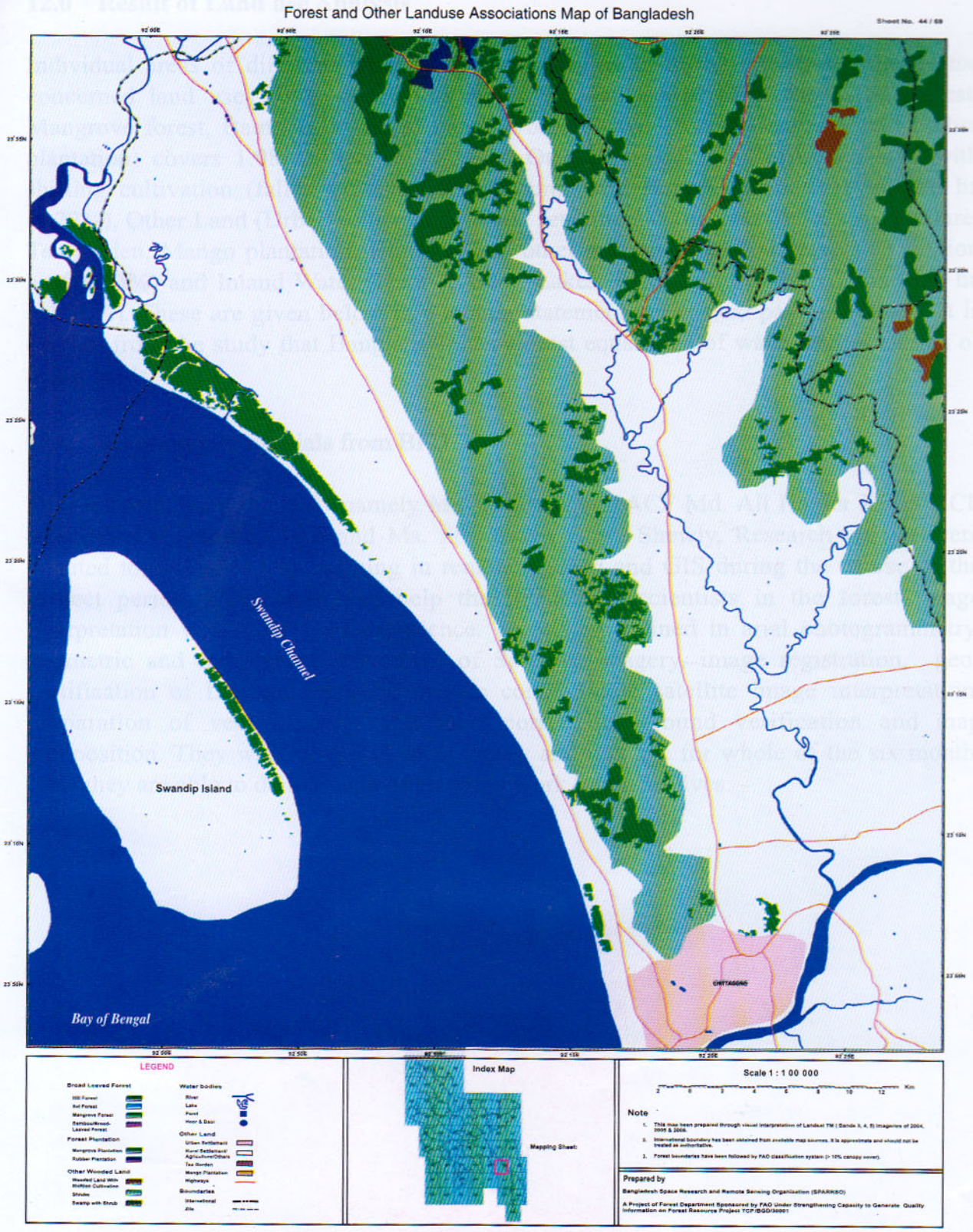

Fig. 6. A Picture of one sheet of Detail Land Use Map

12.0 Result of Land use Analysis

Individual areas of different land uses were collected from the attribute tables of the concerned land uses. It is found that Broad Leaved Forest (Hill forest, Sal forest, Mangrove forest, Bamboo or mixed bamboo/broad-leaved forest mangrove and rubber plantation) covers 1.08 million ha (7.29%), Other Wooded Land (Wooded land with shifting cultivation (fallow), Shrubs and Swamp with shrub) covers 0.92 million ha (6.22%), Other Land (Urban settlements, Rural settlements with tree cover + Agriculture, Tea garden, Mango plantation, Highway and other artificial areas) covers 11.03 million ha (74.73%) and Inland Water (Haor & Baor, Lakes, River and Ponds) 1.70 million ha (11.76%). These are given below in a tabular statement in the next page (Table. 2). It is evident from the study that Bangladesh has almost equal area of water bodies as that of forest lands.

13.0 Training of 4 officials from BFD

Four officials from the BFD namely Md. Jaheer Iqbal, ACF Md. Ali Haider Khan, ACF Ms. Bilkis Rukhsana, ACF and Ms. Shamima Begum Shewly, Research Officer were deputed to SPARRSO for training in remote sensing and GIS during the course of the project period. They will also help the SPARRSO scientists in the forest image interpretation with their field experience. They were trained in arial photogrammetry, geometric and radiometric correction of Satellite imagery, image registration, geo-rectification of Landsat imagery, mosaic construction, satellite image interpretation, preparation of vector layers and their correction, ground verification and map composition. They were also trained in theory and practice for whole of the six month. Now they are able to do this type of mapping work by themselves.

Statistics on Forest & Other Land Cover of Bangladesh derived through a remote sensing survey (2005-06)

Land Cover Classes	Code	Area (million ha)	%
Forest		**1.07601**	**7.29**
Broad-leaved forest			
Hill forest	FH	0.559280	3.79
Sal forest	FSa	0.033197	0.22
Mangrove forest (saltwater)	FM	0.417367	2.83
Bamboo or mixed Bamboo/broad-leaved forest	FB	0.009326	0.06
Forest plantation			
Mangrove plantation	PM	0.047585	0.32
Rubber plantation	PR	0.009255	0.06
Other Wooded Land		**0.917449**	**6.22**
Wooded land with shifting cultivation (fallow)	Fa	0.098813	5.39
Shrubs (or shrubs/trees)	Sh	0.795208	0.67
Swamp with shrub	Sw	0.023428	0.16
Other Land		**11.027990**	**74.73**
Urban settlements	SU	0.085651	0.60
Rural settlements with tree cover + Agriculture (annual and perennial crops)	SRT/CAP	10.864240	73.62
Tea garden	CPT	0.059672	0.40
Mango plantation	CPM	0.018433	0.12
Highway and other artificial areas	HA	-	-
Inland Water		**1.735548**	**11.76**
Haor & baor	WHB	0.600817	4.07
Lakes	WL	0.041107	0.28
River	WR	1.032381	7.00
Ponds (large)	WP	0.061243	0.45
Total		**14.757**	

Table 4. Tabular statement of area of forest and other land uses of Bangladesh

14. Activity - wise Progress of Work

SL. No	Activity/Items	Status
1.	Legend Preparation	Legend /Landuse classification has been selected and procured accordingly
2.	Selection of Landsat TM imagery confirmed by FAO	
3.	Acquiring High Resolution Sat. magery	Done
4.	Geo - Rectification of Landsat imagery	Done
5.	(a).Interpretation of imagery for land use classification and (b).Ground verification	(a). Completed and reported to FD & FAO (b)100% completed and reported
6.	Preparation and delivery of printed map	Printed and delivered
7.	BFD will supply one set Topographic map to SPARRSO	SPARRSO maps has been used
8.	Participation of 4 FD Officers in the interpretation work	4 BFD Officers participated the work
9.	On Site Training and Supervision of 4 FD officers	Done
10.	SPARRSO will provide its Facilities	SPARRSO provided its facilities
11.	Provide of Tech, Expertise to project	Provided
12.	Delivery of interim and final products	Delivered all the maps and interim products

Table. 5. Activity-wise progress report of the project

15.0 Works Completed

- Collection of Landsat Imagery for whole of the country from Bangkok in collaboration with FAO,
- Geo- Rectification and Geo- reference of the imagery with Reference to Landsat imagery. 1997,
- Construction of Mosaic and correction of tonal variation,
- Preparation of Legend according to various Land use,
- Image interpretation,
- Field Verification,
- Preparation of Vector Layers,
- Map Composition for National Over View and Detailed land use Map, and
- Printing of maps.

16.0 Limitation of the Study

- Delay of six month in procuring remote sensing imagery
- Forest types, village/homestead, ponds and Rice crop field could not be discriminated precisely,
- Mosaic has been prepared by using a mixture of 2004, 2005 and 2006 imagery. Much time has been spent in matching inter-frame imagery, however Temporal variation could not be minimized much,
- Cover types could not be discriminated for stratification of the forest,
- About 10% error has been incorporated in area estimation of forests which cannot be corrected by merely Field survey without very high resolution remote sensing imagery.

17.0 Delivery of interim and final products

SPARRSO has delivered 100 copies of National Over View Map, 5 national sets of Detailed land use map, 15 frame of Landsat imagery, and all interim product to BFD and FAO immediately after completion of the work.

18. Conclusion

SPARRSO has prepared a national over view map at 1: 1000 000 scale and a detailed Land use/ land cover map at 100 000 scale and trained four officials of BFD in remote sensing and GIS for six months for their capacity building according to LoA with FAO.

For the accomplishment of the above work SPARRSO collected Landsat TM Imagery of bands 3 4 5 from FAO and related maps and literatures, distributed man power and responsibility, managed computers and software. Scientists exported imagery to ERDAS imagine compatible format and stacked as aggregated layer of 3 4 5, did geo- rectification by using the ERDAS Imagine software, constructed mosaic of Bangladesh, carried out photo- interpretation and ground verification for producing vector layers, and Map Composition. The remote sensing study found that **Broad leaved forest and Plantation** cover 1.08 million ha (7.29%), **Other Wooded Land** covers 0.92 million ha (6.22%), **Other land** covers 11.03 million ha (74.73%) and **Inland Water** cover 1.70 million ha (11.76%). The present study also reveals Bangladesh has almost equal areas of water bodies (~12%) as that of forest land. Statistics on other land uses have also been given. One hundred copies of National Overview Maps and 5 national sets of Detailed Land Use Maps have been printed and supplied to BFD with the interim products and 15 Landsat scenes.

The Land Use/ Land Cover statistics will be used as the supplement of the TCP project of BFD. Department of Agriculture and Department of Fisheries can also use the data and maps for Fish resource and Water resource inventory of the country. SPARRSO can use this data set for precise rice crop inventory as NOAA satellite data has a number of limitations in other major Land use/ Land cover monitoring. We have deduced the new areas of land use associations of Bangladesh with special emphasis to actual forest cover for which there are controversies in the country. Despite limitation in the study this document will provide country level reliable information on the forest and other land uses of Bangladesh.

However, this study paves the way for further research to find out more accurate data. If this study comes of use in generating further interests in research that will be considered as a success.

19. Recommendation

After the study the following recommendations appeared to be pertinent:

- Interpretation and digitization should not be started before completion of mosaic preparation,
- Care should be taken in digitization so that duplicate polygons are not created. All land use classes should be brought in a single layer so that there would not have any missing or overlapping LUC,
- Adjacent land uses should share a common boundary without any gap in between. These boundary lines of LUCS either create overlaps or gaps; consequently creates sliver polygons,
- This kind of national inventory should be carried out using high resolution picture. No Development Project works or National Resource inventory could be done precisely without high resolution picture,
- Measurement of area is an important determining factor in resource inventory specially forest and rice crop inventory. In this type of resource inventory high resolution picture should be used and follow the proper sampling design and analysis for precision,
- The area of forest and other land uses of Bangladesh as found from this study will not be the same as those obtained by field sampling method used by FAO.
- SPARRSO should use this land use/ Land cover data for improvement of precision in rice crop inventory twice a year.
- This study will pave the way of further study on natural resources inventory using remote sensing and GIS.

Dr. Jinnahtul Islam

Profile of the Author

Dr. Jinnahtul Islam is the Principal Scientific Officer and Head of the Forestry and Environment Division of Bangladesh Space Research and Remote Sensing Organization (SPARRSO). Dr. Jinnah had his Ph.D degree in the field of Forest Inventory using Remote Sensing from Jahangirnagar University, Bangladesh. He had his Postgraduate Diploma in Forest Survey using Aerospace Remote Sensing from the International Institute for Aerospace Remote Sensing and Earth Science, ITC, The Netherlands. He obtained his certificates on GIS from the Environmental System Research Institute (ESRI), Maryland and California, USA. He studied on Tropical Deforestation and Global Warming in the International Institute for Geospatial Research and Remote Sensing (IGRS), Eastern Michigan University, USA under Fulbright Scholarship Programme of US State Department.

Dr. Jinnahtul Islam was born in the village of Pirpara, Kagail under the district of Bogra, Bangladesh on 11th January, 1952. He started his career as an Investigator in the Forest Research Institute (FRI) Chittagong in (1977) immediate after having his M.Sc degree in Physics (1977) with Hons. Then he joined SPARRSO in 1980 and started working on Forest resource inventory, Land Use land Cover Changes, Environmental study, Global Warming, Climate change: Mitigation and Adaptation, and Natural resource survey using Aerospace Remote Sensing and GIS. He is a leading scientist of Bangladesh and is now working on Tropical Deforestation and Global Warming. Dr. Jinnah has a number of national and international publications in his credit and traveled worldwide for attending a number of seminar, workshop and symposium related to forest and environment.