Proceedings of the workshop on the accuracy assessment and quality checking of land cover map of Bangladesh 2015

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Food and Agriculture Organization of the United Nations

The Forest Department of Bangladesh leads actions to improve forest management and conservation, adopting forward thinking, innovative approaches in its management of approximately 1.55 million hectares of land across the country.

In 2015, the Forest Department began a process to establish a National Forest Inventory and Satellite Land Monitoring System for improved forest and natural resource management. The process supports national objectives related to climate change mitigation and provides information in support of the UN-REDD programme aimed at Reducing Emissions from Deforestation and Forest Degradation (REDD+). The process also addresses domestic information needs and supports national policy processes related to forests and the multitude of interconnected human and environmental systems that forests support.

The activities implemented under the Bangladesh Forest Inventory process are collaboration between several national and international institutions and stakeholders. National partners from multiple government departments and agencies assist in providing a nationally coordinated approach to land management. International partners, including the United Stated Agency for International Development (USAID) and the Food and Agriculture Organization of the United Nations (FAO) are supporting the development of technical and financial resources that will assist in institutionalizing the process.

The results will allow the Forest Department to provide regular, updated information about the status of trees and forests for a multitude of purposes including for assessment of role of trees for firewood, medicines, timber, and climate change mitigation.

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Executive Summary

The workshop on 'Accuracy Assessment and Quality Checking of Land Cover Map of Bangladesh 2015' was held from 4 to 9 February, 2017 at BRAC Centre for Development, Savar, Dhaka.

The workshop involved a total of 21 participants (17 male and 07 female) from different organizations including Bangladesh Forest Department (BFD), Centre for Environment and Geographic Information System (CEGIS), Soil Recourse and Development Institute (SRDI), Bangladesh Society of Geoinformatics (BSGI), Bangladesh Agricultural Research Institute (BARI), Bangladesh Bureau of Statistics (BBS), Bangladesh Institute of Planners (BIP), Survey of Bangladesh (SoB) and Land Zoning project of the Ministry of Land. The workshop was conducted in order to support the quality control and accuracy assessment of the national land cover map of Bangladesh, developed in partnership between the National Forestry Inventory project and the DECCMA project.

After the consistency and attribute check of individual district by group, pseudo-ground truth validation in Google Earth with a stratified random sampling by district and by land cover class was implemented. All 64 districts were checked and assessed by the participants. Participants were divided into small teams where they discussed about the possible land cover classes from image interpretation (both SPOT and Google earth) before reassigning the class. The preliminary overall accuracy of the national land cover is approximately 90%, which is very high and consistent with the effort and the production chain developed. Limitations on the interpretation of few classes were discussed.

Along with the assessed land cover map, the workshop also included methodological analysis of mapping Sundarbans zone and initiated the process of preparing contents in order to publish the results on scientific journals and as an FAO Atlas.

Introduction

Land cover and forest monitoring activities are part of Bangladesh Forest Inventory (BFI) – a national process under the leadership of the Forest Department to assess and monitor national forest at regular time intervals. The NFI project is a collaboration of several Government, NGO, private and civil society partners. The project is supporting several activities related to BFI including the development of national land cover map (Akhter, Aziz et al. 2016).

The development of a national land cover dataset for Bangladesh in compliance with the highest standards in terms of data quality, production chain and classification systems represent an important achievement that has been successfully delivered in strict collaboration by two distinct projects:

i) "Strengthening National Forest Inventory and Satellite Land Monitoring System in support of REDD+ in Bangladesh (GCP /BGD/058/USA)" project that aim at the assessment of the state and trends of the forestry resources and

ii) the "Deltaic Environments, vulnerability and Climate Change: The role of Migration as an Adaptation and its policy implications (DECCMA) (GCP /GLO/546/USH)" project that analyze the impacts of climate change on three contrasting deltaic environment, including the coastal districts of Bangladesh.

The national land cover map has been prepared using SPOT images with 6m resolution where the whole country was mosaicked, segmented and interpreted individually. The final step was to verify that all the individual elements are merged together and are topologically and thematically consistent. The 64 districts will be used as individual elements (Franceschini, Iqbal et al. 2016). In order to finalize the national land cover map, the workshop was organized for quality checking and accuracy assessment.

Objective

The workshop was organized to support the quality control and accuracy assessment of the national land cover map of Bangladesh. It took place at the BRAC-CDM, Savar from the 4t^{h} to 9th February 2017 and gather 21 technical experts from different national institutions: BARI, BBS, BFD, BIP, BSGI, CEGIS, SoB, SPARRSO and SRDI.

Summary of the Sessions

The first day a plenary discussions allowed to identify those districts with a thematic inconsistencies between the mapped land cover classes and the expected classes according to expert knowledge. For those districts where a discrepancy was observed, the team discussed possible reasons and approaches to fix the problem. Ancillary data from Forestry department are considered necessary to solve these cases. **Table *1*** shows the results of consistency check of one district.

Table 1: Consistency check results for Panchagarh district

Class (Code)	Expert judgment	Presence in LC map	Problem	How to fix (if problem)
Air Port (AP)	No	No	FALSE	
Baor (Ba)	No	Yes	TRUE	Check LC map
Bamboo Forest (BF)	No	No	FALSE	
Perennial Beels/Haors (BH)	No	Yes	TRUE	Check LC map
Built-up Non-Linear (BNl)	Yes	Yes	FALSE	
Brickfield (Br)	Yes	Yes	FALSE	
Beaches or Sand Bar (BS)	Yes	Yes	FALSE	
Brackish Water Aquaculture (Bwa)	No	No	FALSE	
Dump Sites/Extraction Sites (DS)	Yes	Yes	FALSE	
Plain Land Forest (Sal Forest) (FDp)	Yes	No	TRUE	Check with Data from RIMS/ACCF MP
Hilly Forest (FEh)	No	No	FALSE	
Mixed Hill Forest (FMh)	No	No	FALSE	
Mangrove Plantation (FMp)	No	No	FALSE	
Forest Plantation (FP)	Yes	No	TRUE	Check with Data from RIMS/ACCF MP
Rubber Plantation (FPr)	No	No	FALSE	
Swamp Plantation (FSp)	No	No	FALSE	
Fresh Water Aquaculture (FWa)	Yes	Yes	FALSE	
Herb Dominated Area (Terrestrial) (H)	Yes	Yes	FALSE	
Lake (L)	No	No	FALSE	
Mud Flats or Intertidal Area (MF)	No	No	FALSE	
Mangrove Forest (NMF)	No	No	FALSE	
Orchards & Other Plantations (Shrub) (OS)	Yes	Yes	FALSE	
Orchards & Other Plantations (Trees) (OT)	Yes	Yes	FALSE	
Multiple Crop (PCm)	Yes	Yes	FALSE	
Single Crop (PCs)	Yes	Yes	FALSE	
Ponds (Po)	Yes	Yes	FALSE	
Rivers and Khals (R)	Yes	Yes	FALSE	
River Banks (RB)	Yes	No	TRUE	Check definition
Rural Settlement (RS)	Yes	Yes	FALSE	
Shrub Dominated Area (Terrestrial) (S)	No	No	FALSE	
Shifting Cultivation (SC)	No	No	FALSE	
Swamp Forest (SF)	No	No	FALSE	
Salt Pans (SP)	No	No	FALSE	
Swamp Reedland (SWr)	No	No	FALSE	

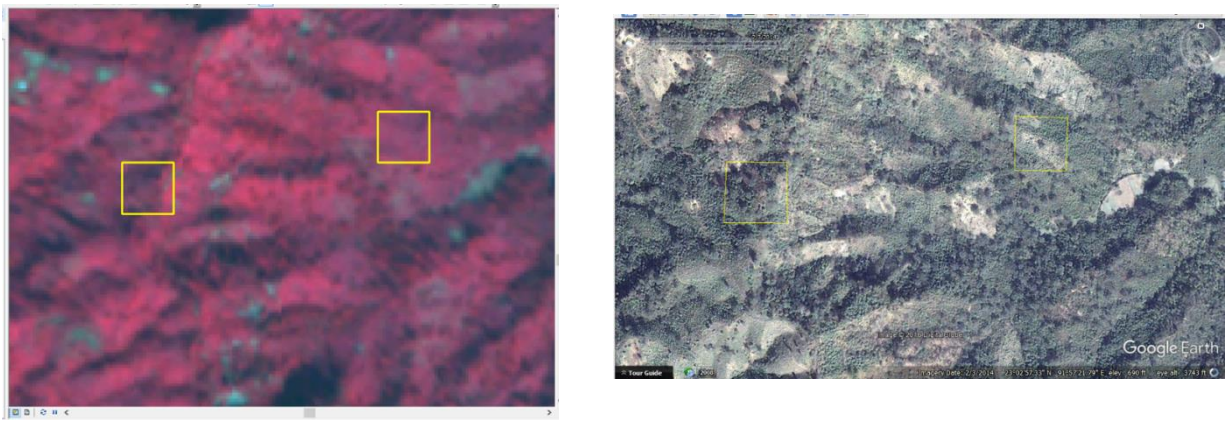
In the next days an accuracy assessment analysis was designed using a pseudo-ground truth validation technique, with a stratified random sampling by district and by land cover class. The following steps were applied for each district:

- Create a regular fishnet grid of 100x100 meters around the district.
- Intersect the fishnet grid with the land cover dataset to validate.
- Select the gridded sampling units with an area of 10000 square meter (this exclude those sample unit grids where multiple land cover classes are present) and export it in a new shapefile.
- Create an ID field and assign a unique ID to the new shapefile.
- Classify the districts in three groups (small, medium, large) based on their size. Districts were sorted by total area and three equal groups defined.
- Assign the number of sample units to be generated based on the district size as follows:
    - 150 sample units for smaller districts
    - 200 sample units for medium size districts
    - 250 sample units for largest districts

The sample units were stratified to be randomly selected by the relative percentage of land cover class distribution. For those classes where the relative occurrence was less than 1%, one sample unit was assigned.

- Randomly select the sample units with a routine in R
- Export the selected sample units to shapefile and kml.

Sample units were uploaded in Google Earth and in ArcGIS (**Error! Reference source not found.**). In ArcGIS also the original SPOT mosaic used for the segmentation was uploaded for reference. Then, sample units were visually classified according to the images available in Google Earth. The first two districts (one in the coastal area and one on the hilly area) were classified jointly by all participants to have a general understanding on the process, about the legend and on basic browse and data entry on Google Earth. Then, participants were split in group of 2/3 people and continue with the validation on the remaining districts.



(a) (b)

Figure 1: Samples in yellow boxes (a) overlaid on SPOT images and (b) exported in google earth

Aggregation of land cover classes for validation

For some classes, a visual discrimination from Google Earth imagery is not possible, since the correct attribution has been done with the support of ancillary data or expert knowledge. In these cases, the classes have been grouped to a higher level of the National Reference System.

Single crop (PCs) – Multiple crop (PCm)

Natural mangrove forest (NMF) and Mangrove plantation (FMp)

Hill forest (FEh) and Mixed hill forest (FMh)

Brackish aquaculture (BWa) and Freshwater aquaculture (FWa)

Finally for each district and for the overall land cover a matrix of error was generated.

Table *2* below shows the preliminary results of the sampling units of approximately 30 districts. The overall accuracy is 89.8 percent and user accuracy and producer accuracy for each class has been generated

Table 2: Preliminary results of the sampling units

Land cover classes	AP	Ba	BH	BNl	Br	BS	Bwa	DS	F	FDp	FP	FPr	FWa	H	L	MF	NMF	OS	OT	PC	Po	R	RS	S	SC	SP	TOT	**USER ACCURACY**
Ap - Airport	1			1										2													4	**25**
Ba - Baor		1	3										2							1		4					11	**9**
BH - Beels		1	12																	28							41	**29**
BNL - Built-up non linear				69									1							1	1		35				107	**64**
Br - Brickfields					32															1							33	**97**
BS - Beaches			2	1		12										4				5		2					26	**46**
Bwa - Brackish aquaculture													2														2	**0**
DS - Dump sites						1		1												1			1				4	**25**
F - Hilly Forest									594					1										67	1		663	**90**
FDp - Sal forest										2	1																3	**67**
FP - Forest plantation									4		10								2				1				17	**59**
FPr - Rubber plantation									1		3	11		1									1				17	**65**
Fwa - Fresh aquaculture				1									32							61	2		1				97	**33**
H - Nerbaceous			1											18		16				6		2					43	**42**
L - Lakes													1		2					1	1						5	**40**
MF - Mudflat						2										49				8		8					67	**73**
NMF/FMp Mangroves																	86							4			90	**96**
OS - Shrub orchard									1									3						1			5	**60**
OT - Tree orchard				1					1		1							2	30	13			1				49	**61**
PC - Permanent cropland		3	11	2	2				1				29	8	3	8			18	3680	5	5	20				3795	**97**
Po - Ponds													3							2	4					1	10	**40**
R - River						3										24				1		1378	1				1407	**98**
RS - Rural settlements				59					1		1		11						33	57	2	2	1382	1			1549	**89**
S - Shrubland				1					159		3	3		4				1	10	6			9	82	11		289	**28**
SC - Herbaceous crop shifting														1									2	1			4	**0**
SP - Salt pan																										3	3	**100**
TOT	1	5	29	135	34	18	0	1	762	2	19	14	81	35	5	101	86	6	93	3872	15	1401	1454	156	12	4	8341	
PRODUCER ACCURACY	**100**	**20**	**41**	**51**	**94**	**67**	**NA**	**100**	**78**	**100**	**53**	**79**	**40**	**51**	**40**	**49**	**100**	**50**	**32**	**95**	**27**	**98**	**95**	**53**	**0**	**75**		

Although the table is preliminary, some general conclusions can be drafted. The analysis shows a very good overall accuracy which is consistent with the effort and the quality of the land cover production chain. This is also consistent with the very high accuracy of the most represented classes: rural settlements and cropland.

Two major source of errors are found:

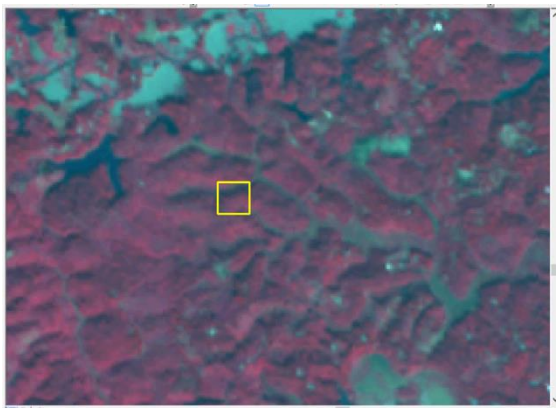


Figure 3: Sample area (Yellow box) on SPOT image

Figure 2: Land cover in sample area is difficult to identify (whether shrub or forest)

It is very difficult to distinguish between shrub dominated area and forest. This is reflected in a small accuracy for shrub dominated area, particularly from the user perspective. The validation from Google Earth is problematic since dense shrub dominated area are difficult to distinguish from tree cover.

Due to seasonality and persistence of water in some particular classes, a single date interpretation can reduce the accuracy in some classes. This is particularly true for fresh aquaculture sites, where the land is cultivated in the dry season. Similarly, in beels, when the water is absent, the land is occupied by cropland. To better distinguish these classes, is recommended to display historical dates in Google Earth in order to verify if in some season water is persistent.

Recommendations and follow-ups

Due to the sources of mistakes considered it is recommended a second validation with multiple historical images for particular combination of classes:

- Ba – BH
- Ba – Fwa
- Ba – R
- BH – PC
- BS - MF
- H – MF
- OT – PC
- S – F

It is important to highlight that this second validation (which involve only a very small number of samples) does not have the aim to increase the single class or overall accuracy of the map, but it is intended to provide more realistic figures of accuracy. In other words, the overall objective of the accuracy assessment is to provide final users with a sufficient quality of the map, and this is fully achieved, but also to inform on limitations and possible sources of errors for each land cover class.

The outline of a peer-reviewed publications were discussed. The publication will be defined in two parts: part 1 will deal with the definition of the National Reference System and the legend, part 2 will focus on the land cover production chain.

It has been also recommended to publish tabular results and layout maps as an atlas.

It is recommended to calculate error matrix and accuracy statistics both for all the districts and for the coastal districts only to serve the purpose of the two projects involved.

It is suggested to complete the final land cover dataset following these steps:

- Merge the districts
- Visually inspect edge-matching between boundaries
- Validate land cover codes with actual codes in the legend
- Final topology check on the complete dataset

References:

Akhter, M., et al. (2016). National Land Representation System of Bangladesh. Bangladesh Forest Department, Food & Agriculture Organization of the United Nations.

Franceschini, G., et al. (2016). Production chain for land cover mapping in Bangladesh. Dhaka, Bangladesh, Food and Agriculture Organization of the United Nations: 21.

Appendix-i

Date	Programme	Facilitator
	Day 1	
09:00	Registration of the participants	All participants
09:15	Opening of the workshop (Welcome Address)	BFD
09:30	Introduction of participants	All participants
09:45	Presentation of the content and objectives of workshop	FAO
10:00	Presentation of the work plan of workshop	FAO
10:15	Presentation of the processing chain and the land cover legend	CEGIS/BFD
11:00	Tea break	
11:30	Presentation on topology check	BFD/CEGIS
12:00	Presentation on attribute and consistency check	BFD
12:15	Presentation on outliers identification	BFD/CEGIS
12:30	Presentation on identification of wrong codes	BFD/CEGIS
13:00	Lunch break	
Remaining day	Group formation and preparation of tables for each district with the possible land cover classes	All participants
	Day 2 to 6	
Whole day	Quality check of land cover map 2015	All participants

Appendix-ii

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