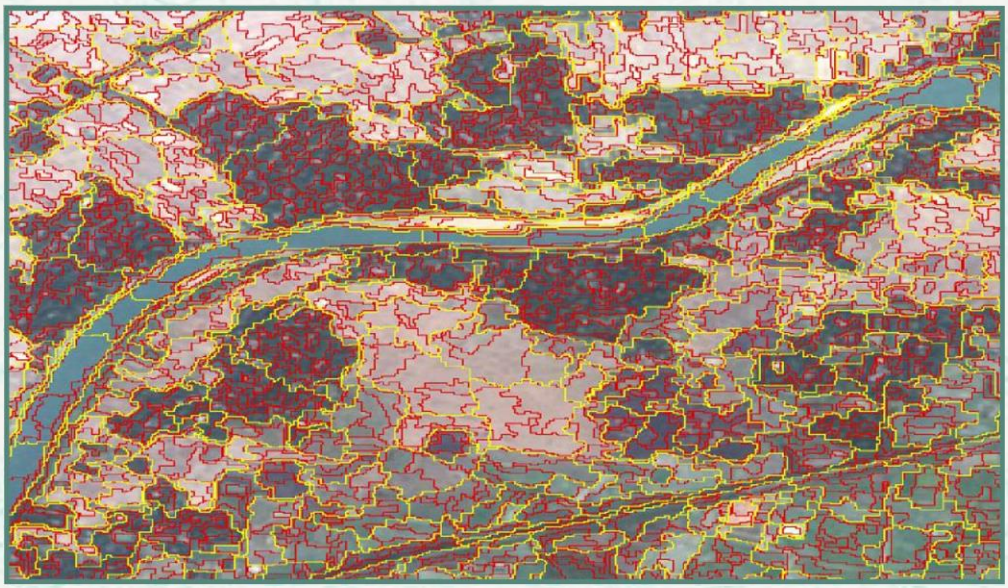
Production chain for Land Cover Mapping in Bangladesh



Bangladesh Forest Department
March 2016

USAID FROM THE AMERICAN PEOPLE

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 1.5 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), the Food and Agriculture Organization of the United Nations (FAO) and SilvaCarbon are supporting the development of technical and financial resources that will assist in institutionalising 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, climate change mitigation.

CONTACTS:

Zaheer Iqbal
Deputy Conservator of Forest
National Program Coordinator of NFI project
Bangladesh Forest Department (BFD)
Email: :z.iqbal60@gmail.com

Matieu Henry
Chief Technical Advisor
Food & Agriculture Organization of the United Nations
Email: matieu.henry@fao.org

Suggested Citation**: Franceschini, G., Jalal, R, Islam, M. S., Iqbal, Z., Aziz, T., Begum, A., Shewli, S. B., Shaunak, M. F., Jahan, M. N., Haque, S., Rahman, M. A., Hadi, A., Pramanik, T., Akhter, M., Costello, L., Udita, T. S., Henry, M.** 2016. Production chain for land cover mapping in Bangladesh. Dhaka. Bangladesh Forest Department, Food and Agricultural Organization of the United Nations.

Disclaimer

This report is designed to reflect the activities and progress related to the project GCP/GD/058/ USAID "Strengthening National Forest Inventory and Satellite Forest Monitoring System in support of REDD+ in Bangladesh". This report is not authoritative information sources – it does not reflect the official position of the supporting international agencies including USAID or FAO and should not be used for official purposes. Should readers find any errors in the document or would like to provide comments for improving its quality they are encouraged to contact one of above contacts.

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1 Introduction

The present document describes in details the activities, methodology, software, role and responsibilities that need to be defined to realize a land cover dataset for Bangladesh. Its intended use is to provide practical guidelines for map producers to support the final realization of a quality dataset and to monitor the activities to deliver the product within the defined timeframe. The document will not cover the aspects and methodology of accuracy assessment which represent the last mandatory step for the finalization and documentation of the land cover dataset.

This activity is conducted on the framework of an increased collaboration between the DECCMA project (GCP /GLO/546/USH) and the land cover and forestry monitoring (GCP/BGD/058/USAID) in Bangladesh. While the DECCMA project is interested on mapping the land cover of the 19 districts that constitute the coastal zone of Bangladesh, one of the main output of the forestry project is the land cover mapping of the whole country. The two projects have decided to build synergies sharing resources, methodologies and staff.

This document has been realized during a workshop in Bangladesh from 5 – 9 June 2016. The workshop alternated discussions, presentations and practical exercises with all the organizations involved in the two projects. It is part of a larger capacity development program on land cover mapping in Bangladesh, which follows three other workshops organized on this topic:

1. An initial workshop in Rome on the Land Cover Meta Language (LCML) and Land Cover Classification System (LCCS)
2. An additional LCML training in Bangladesh, involving a larger number of professionals from different organizations
3. A workshop finalized at the production of the National Reference System to characterize the overall reference land cover classes and attributes necessary to identify the land cover legend for Bangladesh.

The document is organized in the following sections:

- Description of the team, roles and responsibilities
- Description of the land cover legend and the criteria to identify each class
- Image acquisition
- Image pre-processing
- Object-based segmentation
- Photo-interpretation
- Quality control
- Final GIS database structuring
- Monitoring the production chain
- File naming convention

2 DESCRIPTION OF THE TEAM

This section describes in details the different unit, roles and responsibilities.

GIS Unit

The GIS unit is responsible for all the GIS activities, for downloading, storing and selecting the satellite images to be mosaicked for each district. It provides support to the photo-interpreters for editing and other GIS-related tasks and for managing the ancillary information required for the analysis, including support on downloading additional free satellite imagery.

Components: Rashed Jalal (FAO); CEGIS

IT support unit

This unit is responsible for back-up of all the data created and for storing the final dataset. A dropbox folder will be created and shared with the interpreters. All the data will be stored in that folder. It is also responsible for the hardware and software required during the process. The following software will be needed:

- LCCS3 (description of the legend in LCML) – 1 license
- Erdas (mosaic and radar images pre-processing) – 1 license
- ArcGIS (for interpretation) –all the photo-interpreters have advanced skills on using ArcGIS. If licenses for all the interpreters will not be available, it is important to train interpreters on the main functionalities of QGIS, focusing on basic browsing functionalities, editing of geometries and selection of data. It is suggested to activate the OpenLayers plugin for displaying high resolution imagery as background.
- eCognition Developer (segmentation) – 1 license
- Google Earth (to support the interpretation)

Components: Nandini Sarker (FAO)

Technical supervisor

The technical supervisor is the key reference person for the production chain. It is responsible for the overall supervision of the activities, of informing the projects on foreseen delays and problems, on providing and testing additional methodologies to increase the productivity. It is also the leader of the photo-interpreters team. In particular:

- He supervises the overall quality on the photo-interpretation, particularly on the first stages where interpreters still need to reach full productivity. He informs the team if changes in the legend occur. He discuss with the interpreters problems and provide solutions.
- As leader of the interpreters unit, he is the main responsible for selection of personnel. He ensures that all the photo-interpreters are trained both on the understanding and criteria for interpretation of each land cover classes as well as on the use of GIS software. It is suggested that he organizes a small workshop with the all staff where the legend is discussed in the group. He also ensure that the monitoring table is update.
- He is responsible of the reference technical documents of the land cover mapping, in particular of a document for the land cover legend, a document explaining the methodology applied and the full metadata of the final products.

Technical supervisor: Mohammad Shahidul Islam (CEGIS), Md. Zaheer Iqbal (FD-RIMS)

Technical support

The technical support team is responsible of providing training and support to the technical supervisor and to the photo-interpreters. It suggests technical solutions to increase work productivity and assist the technical supervisor on technical problems found during the production chain.

Components: Antonio Di Gregorio (FAO), Gianluca Franceschini (FAO), DAnnunzio, Remi (FAO), Andreas Vollrath (FAO)

Quality control unit

The quality control team is responsible of provide a critical review of the interpretation of the land cover. It can comments or reject the interpretation (see details on the quality control section).

Components: Antonio Di Gregorio (FAO)

Photo-interpreters

The photo-interpreters have the heaviest workload of the project. Led by the technical supervisors, they are responsible of mosaicking the images of the scenes for each district and of applying the segmentation algorithm. To note that these activities can be conducted by a smaller group under the direct supervision of the technical supervisors. All the interpreters are responsible for the classification of the polygon codes by visual or semi-automatic classification. Because of few organizations involved, some interpreters may have particular field knowledge of determined classes. It is recommended that districts to classify are assigned taking into consideration these particular skills. It is foreseen that the following interpreters will be employed:

- 10 interpreters from CEGIS (4 for coastal districts and 6 for other districts)
- 2 interprets from BUET
- 3 interpreters from RIMS (Forest department)

It is highly recommended that the interpreters do not change during the interpretation process.

LEGEND DESCRIPTION

The final land cover classes that will be used to portioning the whole country have been selected on the basis of a number of criteria:

- The knowledge of the photo-interpreters to identify the individual classes
- Availability and quality of satellite imagery procured
- Availability of ancillary information (e.g. field surveys, datasets from other mapping projects)
- Representativeness of the classes in the country, also considering the minimum mappable unit
- Needs to detail specific classes for the overall objectives of the two projects involved

The identification of the land cover classes have been done from the analysis of the diagram of the National Reference System (NRS). For each ramification of the diagram, a group discussion with all

the organizations involved, allowed to understand to which level of the System the land cover classes can be detected within the considered criteria. This allows to consider the whole NRS without gaps on the features to be detected. For few cases, the group agreed on adding extendable attributes (e.g. species name) to the master reference classes for further differentiation of land cover features.

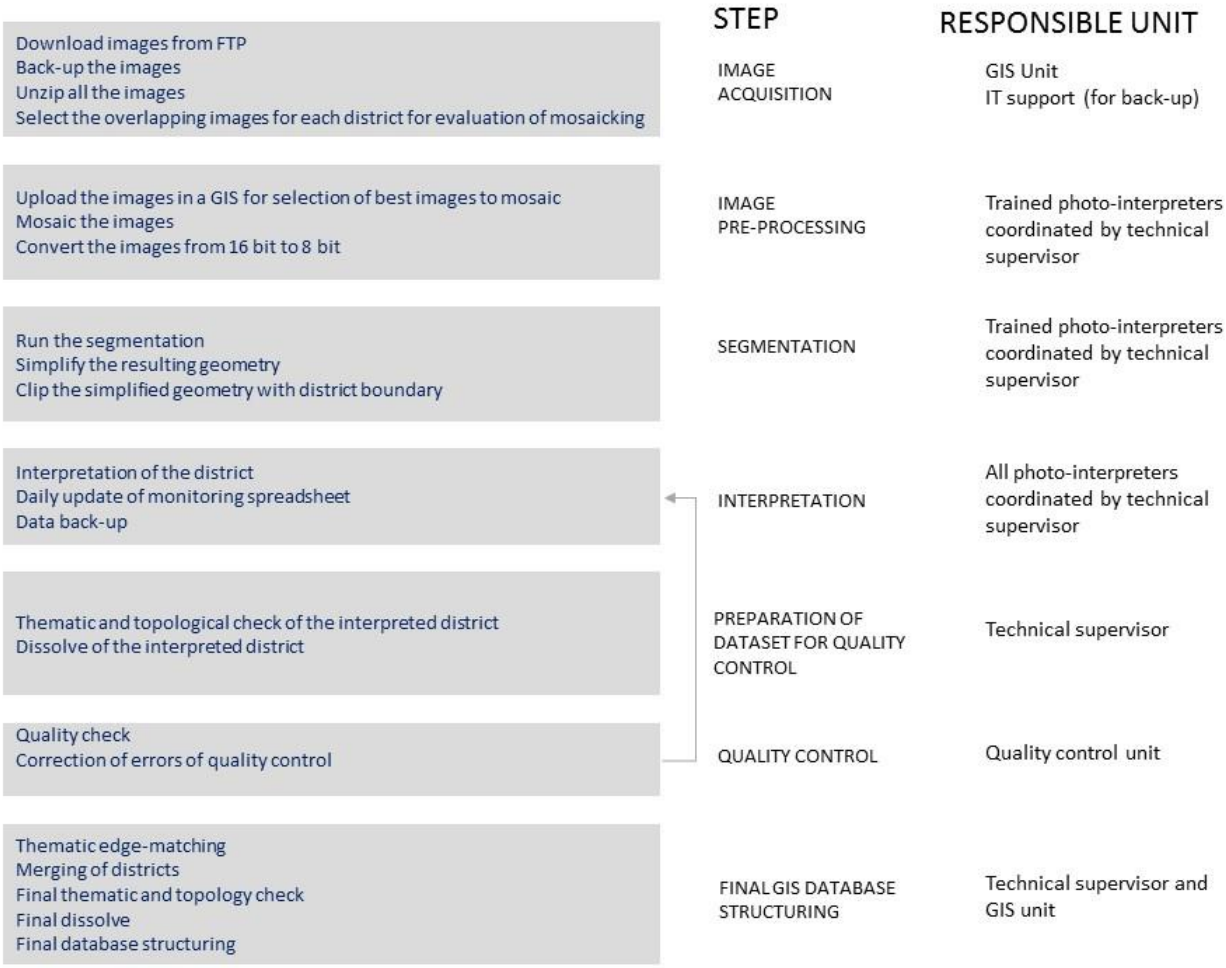
Then, the group was split in two teams and they were asked to identify samples of each class both on the Spot images and in Google Earth and to create a shapefile or kml for reference. This exercise allowed to verify that the photo-interpreters have sufficient ability to locate the classes and also allowed to refine the choice of land cover classes excluding those that were judged impossible to be differentiated with the current imagery. For each sample, two photo-keys were created and criteria to identify the classes were discussed. Following, a description of the land cover classes selected for the legend of the land cover dataset:

ID	Description	LC Code	Criteria for identification
1	Hill forest	FH (Proposed)	Hilly region, DEM, local knowledge
2	Bamboo	FB	Visual interpretation, NFA 2005, FIGNSP 2013
3	Plain land forest (Sal forest)	FDp	Digital map of occurrence of Sal forest from RIMS
4	Forest plantation	FP	Visual interpretation, local knowledge, NFA 2005, FIGNSP 2013
5	Rubber plantation	FPr (Proposed)	Visual interpretation
6	Forest Plantation Deciduous	FPd	TO BE TESTED
7	Natural shrub dominated area	S	Visual interpretation, in specific areas
8	Tree orchards and other plantation	OT	Visual interpretation (Ex: Mango, Lichi etc.)
9	Shrub orchards and other plantation	OS	Visual interpretation (Ex: Tea Garden)
10	Cultivated herbaceous single crop	PCs	Boro and Amman crops will be interpreted separately. If the object shows some growth during the period April/March is a Boro crop. If it shows growth during September / November is Amon crop. Landsat or Sentinel-2 will be used for Boro and Spot, Landsat and SPOT for Ammon. Then, overlapping the two will produce the single and multiple crop
11	Cultivated herbaceous multiple crop	PCm	

12	Shifting Cultivation	SC	Visual interpretation
13	Swamp forest	SF	Visual interpretation, NFA 2005, FIGNS 2013
14	Mangrove forest	NMF (Proposed)	TO BE TESTED WHETHER IS POSSIBLE TO MAP INDIVIDUAL SPECIES like: Sundari, Goran, Gewa, Kewra, Gewa+Sundari, Gewa+Goran
15	Rural settlements	RS	Digital map of rural settlements, visual interpretation, available ancillary data
16	Mangrove plantations	FMp	Visual interpretation, FIGNSP 2013, CRPARP plantation monitoring
17	Regularly flooded herbaceous single crop	PRs	Similarly to herbaceous crop, Amon and Boro cultivation will be mapped independently. Radar images may be used for the period July / September to detect cultivated area. A land type digital map with 0 cm, 1-30 cm, 30-90 cm shows the elevation and can be used to detect flat plains that are inundated.
18	Regularly flooded herbaceous multiple crop	PRm	
19	Mud flats	MC	Visual interpretation
20	Beaches	B	Visual interpretation
21	River banks	RB	Visual interpretation
22	Built-up non-linear	BNI	Visual interpretation
23	Built-up linear	BL	Visual interpretation
24	Extraction/ Mining sites	DS	Visual interpretation
25	Salt pan	SP	Visual interpretation
26	River	R	Digital map of water distribution + NDVI
27	Baor	Ba	Digital map of water distribution + NDVI
28	Beels/ Haors	BH	Digital map of water distribution + NDVI
29	Standing artificial Water body	L	Digital map of water distribution + NDVI
30	Ponds	Po	Digital map of water distribution + NDVI

It is very important that during their work of interpretation, the photo-interpreters have an understanding of each single class from the analysis of the LCML diagram, complemented by a narrative description and photo-keys from the field, the SPOT images and from higher resolution data. They should also discuss the criteria to identify each class and way of disambiguation with similar classes.

The following diagram shows the steps necessary to apply a production chain and will detailed in the following sections.



3 IMAGE ACQUISITION

In this activity the criteria for choosing the images to be used in the land cover mapping are set and images are procured. Minimum acceptable quality of images for cloud coverage is considered 10%. 6m multi-spectral ortho (level 3) SPOT 6/7 images with bit depth of 12 bits are acquired for the land cover mapping of 2015. Bands are delivered in this order:

- Band 1 = red
- Band 2 = green
- Band 3 = blue
- Band 4 = NIR

4 IMAGE PRE-PROCESSING

The whole land cover mapping will be done by portions of the whole country that will be mosaicked, segmented and interpreted individually. The final step will verify that all the individual elements are merged together and are topologically and thematically consistent. The 64 districts will be used as individual elements. This choice has been motivated for the need to select a scale sufficient to avoid the generation of unmanageable files size but also to accommodate the specific needs of the two projects involved in the realization of the land cover dataset, which consider different districts as end-target. Moreover, to accommodate future changes in international boundary, for the districts confining with neighboring countries, a 1 km buffer (on the side of the boarder) will be considered.

The fact that Airbus delivered three different datasets and the large number of small segments around the international boundary has generated a high number of scenes or sub-scenes that can be potentially used. All the images sent by vendor are in UTM projection system. Bangladesh partially falls in UTM zone 45 and partially in 46. The provided projected images are combination of both zones. The first step is to convert the all images (*.JP2) into ERDAS IMAGINE supported *.img file with 16-bit.

In order to generate a small manageable file the next step is to convert the images from 16 bit to 8 bit. This process has an impact on the spectral ranges of the bands of the images and consequently affects the result of the segmentation. A test has been conducted to assess this effect. The same sub-scenes was segmented both at 16 bit and 8 bit with the scale parameters. The scene segmented at 16bit had 160 076 polygons while the scene at 8 bit resulted with 33 172 polygons. It has been proved that the scene at 8 bit generate homogeneous polygons without overestimate the number of objects. To compensate for the loss of spectral information it will be lowered the scale parameter used in the segmentation.

The next step requires the identification of the scenes that encompass a particular district. Then all the SPOT scenes (8-bit *img fiels) that fall in a specific district will be copied in a separate folder and sent for evaluation of potential mosaicking.

All the images are uploaded in a GIS desktop and the best images (in terms of cloud coverage and contrast) that allow a full coverage of the district are selected for mosaicking. Also the order of the images is determined to allow to minimize cloud coverage in the overlapping areas.

The selected scenes are added to Erdas and MosaicPro is launched. It is important in this stage that the order of the scenes is maintained. It is very important that the photo-interpreter have an understanding of which scene is used for mosaicking in order to understand the date of capture. This should be done by providing to the interpreters the bounding boxes of the scenes with the corresponding date and order of mosaicking. No color correction or stretch must be applied to the image during the mosaicking process. The image will be saved according to the identified naming convention in a *.img format at 8bit.

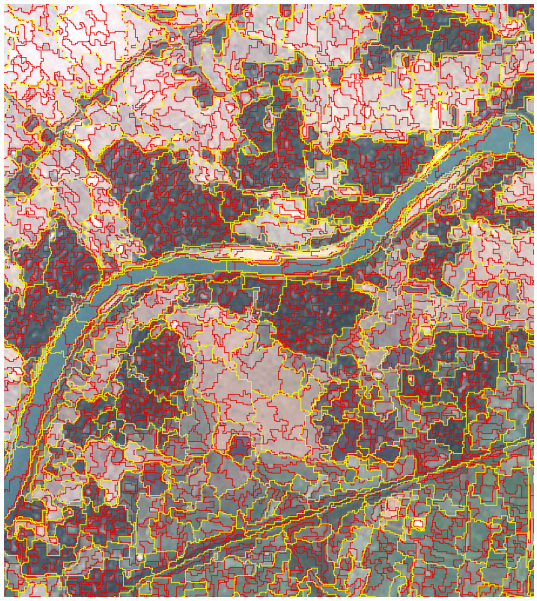
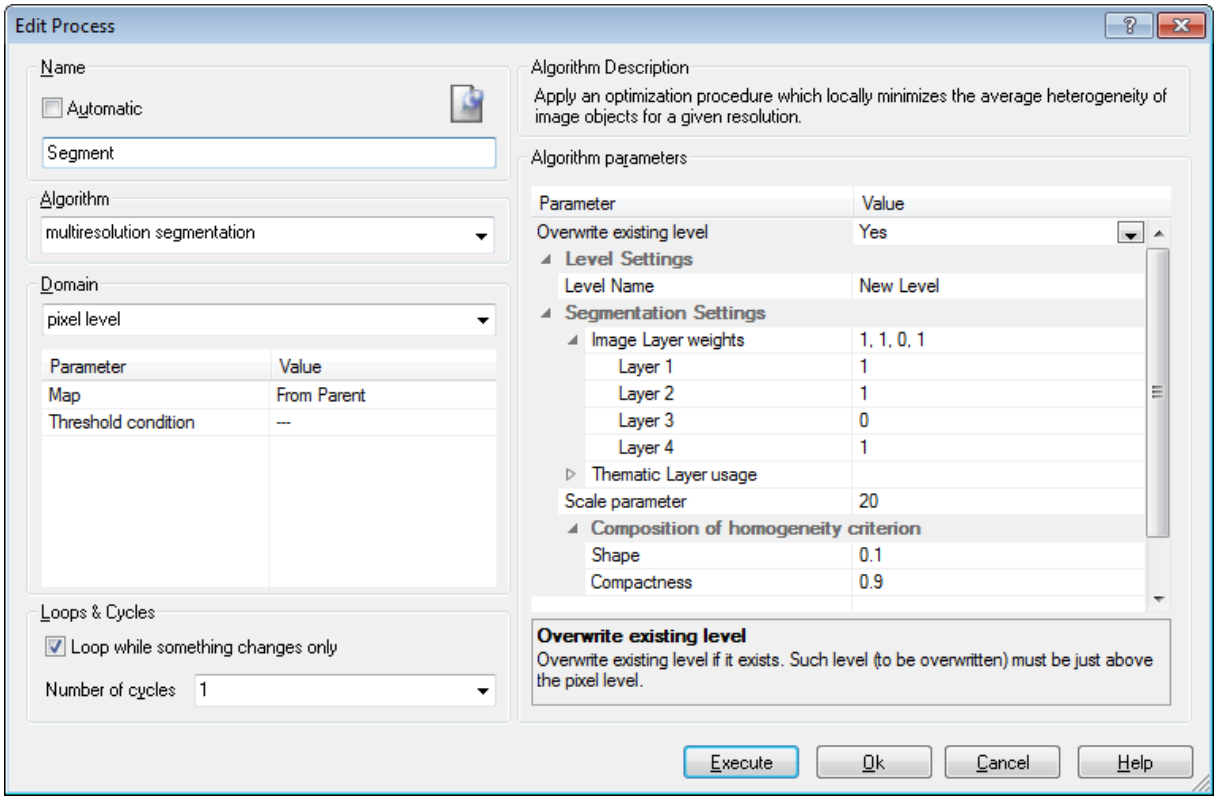


Figure 1: In red objects generated at 16bit, in yellow objects at 8bit.

5 SEGMENTATION

The mosaicked image is then uploaded in eCognition Developer and the multi-resolution segmentation algorithm is applied. The scale parameter is the most important parameter to set. It represents an abstract term which determines the maximum allowed heterogeneity for the resulting image objects. It is suggested to keep it small, but it is not possible to give a unique number since depends on the homogeneity and quality of the image to segment. The suggested range is between 20 and 50, and the technical supervisor must judge the quality of the segmentation and eventually alter the final scale parameter used.



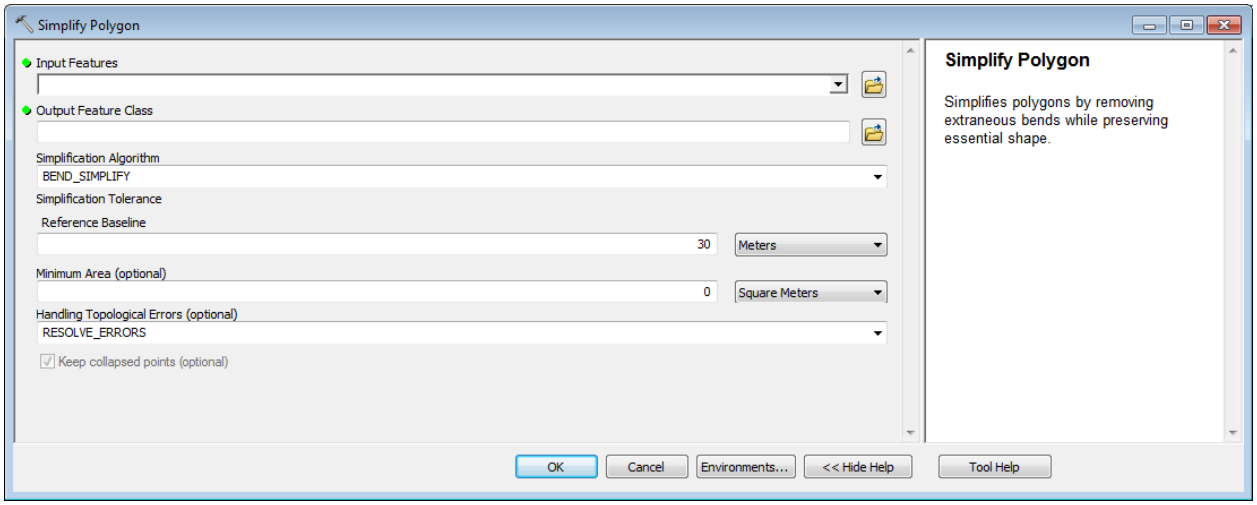
The band combination of the SPOT images is 1) Red 2) Green 3) Blue 4) NIR. Typically, only the green, red and NIR bands are used with same weight while the blue band (the third in the order) has a weight of 0.

For reference, it is recommended to save in an excel file the parameters used for the segmentation. Once the segmentation has been done, the result needs to be exported in a shapefile format. During the export a number of attributes can be automatically attached to the shapefile.

It is recommended to add the following attributes during the export:

- Mean value of each band
- Brightness
- NDVI
- Length/Width ratio

The result shape file is saved and then uploaded in ArcGIS. A procedure to smooth the line boundaries is applied to reduce the vertex density and the consequent file size. In ArcGIS the Simplify Polygon tool is applied with the **Bend Simplify** algorithm and with **Resolve Errors** checked with a reference baseline around 30 meters.



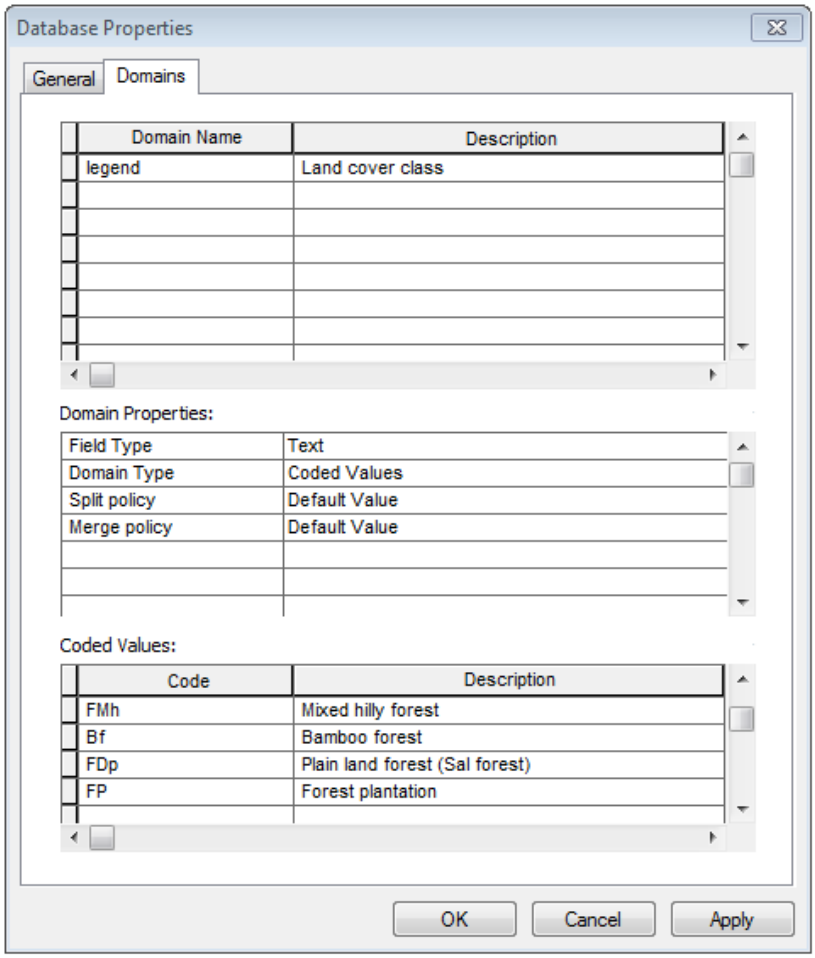
It is important to check that the number of record between the original and the simplified layer correspond. It is sufficient to open the two table of attributes and check that the number of records correspond.

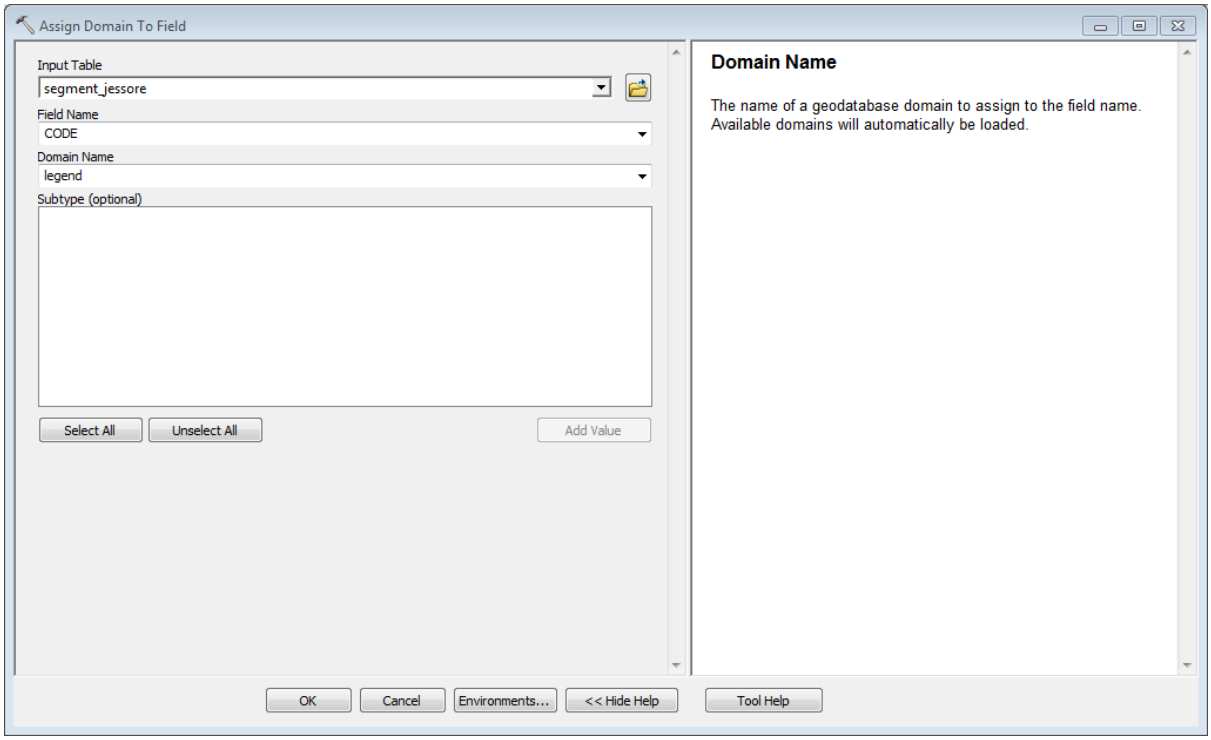
After the generalization tool is applied, a clip with the original district boundary is performed to ensure topological consistency between districts.

6 INTERPRETATION

The interpretation is the phase where the photo-interpreters assign the land cover codes to the polygons. This is normally the most consuming task of the whole production chain and require the largest number of staff. This stage needs to be carefully planned and monitored to avoid long delays of the final realization. All the photo-interpreters need to have a clear understanding of the land cover legend that they apply and of all the conditions and criteria to detect each class. It may be useful to indicate the land cover classes that may generally occur in each district (e.g. bamboo and

hilly forest only occur on the hilly districts, while mangrove only occur in the coastal area) and to assign the districts to interpret based on the individual knowledge of the photo-interpreters (e.g. forestry officer may have more experience to detect tree-dominant classes). Interpretation will be done in a geo-database with domain assigned to attribute field to avoid typing mistake.





Apart from the understanding of the legend and the local knowledge of the conditions occurring in the field, the photo-interpreters need to have skills on GIS, particularly on the following topics:

- Editing of geometries (setting snap environment, most common editing tools, topology)
- Selection of polygons (by attributes, by spatial join)

The district should be interpreted by assigning the code in a specific order of major land cover classes rather than assigning the code by sequential polygons. In principle, the most represented classes and the most difficult should be interpreted later. It is suggested to interpret the classes in this order:

1) Water classes
2) Rural settlements
3) Bareland and other artificial classes
4) Forest classes
5) Cropland classes

Earth Engine provides a multi-temporal and multi-scale environment for analyzing massive archive of free satellite data in a cloud system, through a Javascript code editor. In this project, it will be investigated the possibility to upload the whole segmentation for a district and calculate average NDVI curves (quarterly aggregated for the last few years) for each polygon, in order to identify major temporal vegetation patterns.

After the interpretation is completed the technical supervisor apply some routine control to check thematic and topological consistency of the interpreted district. He verifies that all the geometries have been interpreted and that the codes used corresponds to the codes of the legend. It is recommended to check this with the **Frequency** tool, that generates a summary table of the codes in use in the layer.

He also apply a topological check to verify that no overlaps or gaps exists in the geometry.

7 QUALITY CONTROL

Quality control is an essential step for the realization of a qualitative land cover product. Once a district has been fully interpreted and checked, it is dissolved on the land cover legend field and sent for quality control. Two possible cases may result from the quality control:

1) The number of wrong codes is geographically documented (i.e. wrong polygons are less than 10% of the total polygons or the area affected is less than 20% of the total area of the district). In this case, the person responsible for the quality control, add a field at the interpreted shapefile, where he describes how to fix the error.
2) The number of wrong codes is so high that is not worth to indicate them and the interpreted scene is sent back to the photo-interpretation with a clear indication of the errors to consider but without a geographic identification. In this case, the supervisor must be carefully check the new interpretation to prevent further delays.

Two possible sources of errors may occur:

- Wrong assignation of the polygon code.
- Polygons include other classes, larger than the defined minimum mappable unit. These polygons need to be split and the new segments properly classified.

8 FINAL GIS DATABASE STRUCTURING

Once all the districts have reached the final stage of the production chain, the final structuring of the database is applied. Neighboring districts may present inconsistency on contiguous land features that cross two or more districts because of different choice of photo-interpreters.

A critical review of bordering edges of districts must be performed and some changes in codes or in geometries can be needed to re-establish contiguity of land features.

After this step, the single districts are merged together. A final thematic and topology check is applied to verify that the final dataset is free from error. Then, a dissolve is applied to remove boundaries between districts.

The final dataset is prepared in the final format, a color scheme is decided, statistics on the extent of each class are calculated and metadata are prepared.

9 MONITORING

An essential step to determine the current status of the implementation of the production chain is the monitoring of the whole process. This is fundamental to understand and foreseen potential delays and to take in advance countermeasures (e.g. extended deadline, increasing the number of photo-interpreters). In order to have a constant understanding of the status of work, the following methodology is suggested:

A shared document will be created (e.g. Google drive or similar) with a tabular file with the following information for each district:

- ID of the district
- District name
- DECCMA districts (whether the district is in the DECCMA area of interest for dual monitoring)
- Mosaic (yes/no to indicate if the district has completed the mosaicking)
- Number of polygons after segmentation
- Number of interpreted polygons (this field needs to be updated by the photo-interpreter each day at the end of the work)
- Start date interpretation
- End date interpretation
- Comments / Problems found
- External Quality check (if the district has been sent for quality control check)
- Final (if the district has passed the quality control and can be considered completed)
- Photo-interpreter code

Based on tests executed on two districts with similar parameters for segmentation it has been estimated the following number of polygons that will be produced from the segmentation:

- Number of polygons in the segmented districts (Jessore and Pirojpur) = 138 000
- Surface of the two districts = 4006 km2
- Surface of Bangladesh = 147 570 km2
- Estimated number of polygons = 5 000 000
- According to past experience and assuming to use 15 full-time skilled photo-interpreters two scenarios of length of photo-interpretation (CEGIS and FAO) are proposed:
- CEGIS: 6 000 - 7000 polygons per day per person
- FAO: 3 000 polygons per day per person
- CEGIS estimated number of days: 42 days
- FAO estimated number of days: 113 days

To note that the FAO estimation is still optimistic since imply skilled photo-interpreters that reached their most efficient rate of interpretation with no technical delay.

9.1 FILE NAMING CONVENTION

The following naming convention is suggested for save files:

- 3 characters for the main tool applied
  - Msc (mosaicked)
  - Seg (Segmented)
  - Dis (Dissolved)
  - Int (Interpreted)
- Underscore
- Four digit district code
- Underscore (Optional)
- Few digits to specific additional information (Optional)

Examples:

Msc_1100_8bit.img (Mosaicked image of district 1100 at 8 bit)

Seg_2001.shp (Segmented shapefile for district 2001)