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Rwanda forest cover mapping.

Author Names:
Eduard Westinga, International Institute for Geo-information Science and Earth Observation (ITC), Enschede, The Netherlands
Florent Lasry, National University of Rwanda (CGIS-NUR), Butare, Rwanda

Introduction

Rwanda is a small mountainous, landlocked country covering 25,312 km2 with 8,16 million people and an average population density of about 317 people per km2; it is characterized by vast hills and mountains interspersed with valleys. In spite of its spatial exiguity, Rwanda is covered with diversified ecosystems: natural ecosystems constituted by ombrophiles forests of mountain like Nyungwe with 89,450 ha in 1999, Mukura with 1600 ha, Gishwati estimated between 20 and 700 ha remaining area, the Volcano National Park with 12,720 ha; forests galleries with 163 ha and wooded areas covered 256,300 ha.(*National strategy and action plan for the conservation of biodiversity in Rwanda, April 2003*).

Rapid changes in the state and extent of Rwanda's natural resources, including forests, give rise to a growing environmental concern. The need to manage these resources in a more sustainable way is widely acknowledged. There is a need for data on the actual forest extent, deforestation, forest structure and composition. The latest forest cover information is from 1988 based on the topographical maps of the 1970's. New information can be gathered through satellite data.

Therefore, from 2005 to 2006, a project of Forest Mapping was carried out by the Minister of Lands, Environment, Forests, Water and Mines (MINITERE). The project was realized by the Center of Geographic Information Systems and Remote Sensing of the National University of Rwanda (CGIS-NUR), in collaboration with the National Institute for Agronomy (ISAR).

The overall objective of this study is to undertake the mapping of forests resources in Rwanda at 1/25 000e to support the elaboration of the National Action Plan for Forest 2006-2008, focusing on research and operationalisation of the application of remote sensing in forested area.
More specifically, the aims were to:

- Inventory and estimate forest/woodlands location, area (at least 0.5 ha), floristic composition, age, type (natural or not, public, private), soil type, density and health status using existing maps, aerial photography, satellite imagery and field data collection
- Monitor changes of forest land occupation overtime
- Inventory, organize, standardize and centralize national geographic and other databases available on forest in Rwanda to allow interested institutions and decision-makers to access easily to update information critical in the decision-making processes
- Develop a National GIS&RS based Information System for Forest in Rwanda
- Develop capacity building in the application of RS and GIS tools and methods for Forest inventory and mapping.

The International Institute for Geo-Information Science and Earth Observation (ITC) was requested by CGIS-NUR to make a forest cover map on scale 1:25,000 for the whole of Rwanda. In this paper this activity is presented. The methodology is explained and an indication on the accuracy is given and some results are shown.

Methodology

Mapping was based on Aster, Spot and TM images. The most recent and cloud free images were selected. The images with the best spatial resolution were preferred. That is Aster with 15 m, then Spot4 with 20 m and finally TM with 30 m resolution. Not the entire country could be done with Aster images, as cloud free

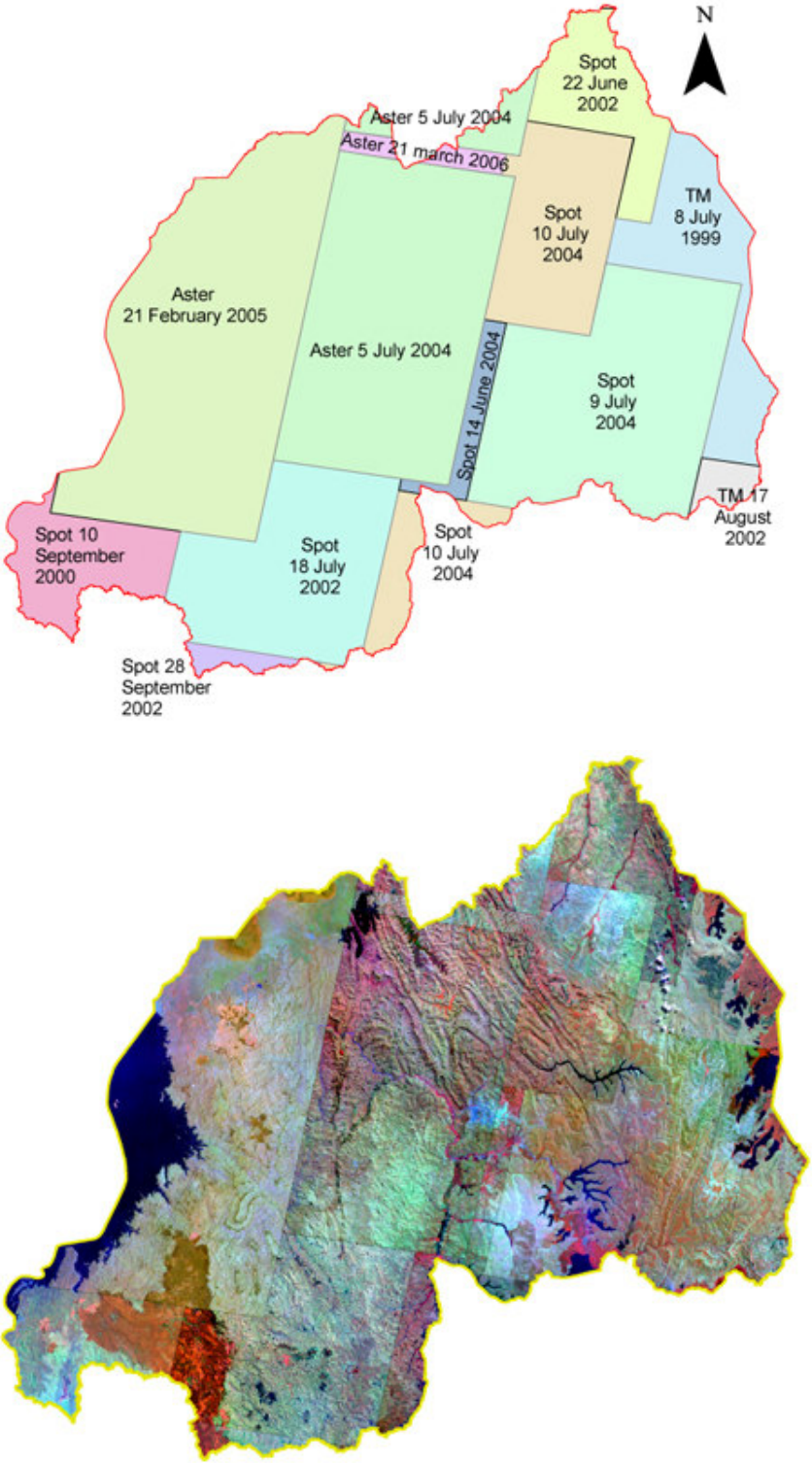

Figure 1. The coverage of the most recent images by 5 November 2005

Aster images did not exist for the entire country on November 2005. So for the remaining areas Spot images were ordered to fill the gaps. Not all gaps could be filled completely and for these last gaps TM images were used.

In Figure 1 the coverage of the most recent images by 5 November 2005 is given.

Because of the enormous terrain height differences the images needed to be corrected with a Digital Elevation Model. Geo-coding was to the Rwandan co-ordinate system from the topographical maps. The geo-coded images were overlaid with vector data of roads and rivers. A perfect match was observed. Some errors observed at limited places were maximum15 meters.

Because the images are from different dates they each had to be classified separately. After classifying the first image, the next one was classified (excluding the overlapping areas). From each next image the part, what was covered already by the previous images, was masked. So for each area the best available resolution and most recent was used. Before classification the images, which were covering beyond the Rwanda border, were first clipped according the boundary of the Rwanda border.

The images were each classified in Erdas Imagine separately in several classes and recoded in two classes; forest and non-forest. The large forest areas were selected from this classification and separately classified in different forest types.

The next forest types were distinguished:

1. Humid natural forest
2. Dry natural forest
3. Eucalyptus plantation forest
4. Pine plantation forest
5. Young forest plantation or coppices
6. Bush
7. Bamboo forest
8. Bush ridge forest

In the humid region forest are areas larger than 0.5 ha with tree cover more than 20 % and trees are > 7m. In the dry region (Akagera) this is > 5m. Young forest plantation and coppices are only found in the humid area.
Young forest plantation have trees less than 7 m and cover from 10- 40 % or trees more than 7 meter and cover from 10- 20 %. Bush is found in the larger humid natural forest. Tree cover is by definition less than 20 % and in practice mostly less than 10% and shrub cover more than 20 % and high forbs and grasses. Bamboo and bush ridge are only found in the Volcans area. The separation of these classes is based on other maps (*DFGFI, Rutgers University, GTRI and Informatics International Ink, under USAID funding)* and was verified by forest experts from this area.

The small plantation forest are mostly eucalyptus and some pine forest. After the conversion from raster to vector the polygons smaller than 5000 m2 (0.5 ha) were selected and eliminated in ArcGIS.

Field work

Fieldwork was carried out with handheld GIS and GPS. So in the field the location could be seen in relation to the polygons with the satellite image in the background. The samples were taken well inside the polygon. The sample should be at least 50 meters within the forest boundary from all sides, and preferably 100 meters. The cover of different vegetation layers was assessed, by estimating the crown cover in the field.

Forest are defined as areas larger than 0.5 ha with a tree coverage higher than 20 %. Trees are woody plants higher than 7 meters. In Akageera the definition for trees is > 5m.

The cover of trees higher than 15 m (emerging trees) was assessed, as well as the cover of trees from 7-15 m. For theses layers also the dominant species is recorded, in order to distinguish between the different types. In addition the cover of the layer from 2 till 7 meter and the layer from 0 to 2 meter were assessed.

The collected field data (Fig2), during the 4 missions, were classified forest cover classes: forest, bush and young plantation and non forest. Types were distinguished based on dominant species**.**

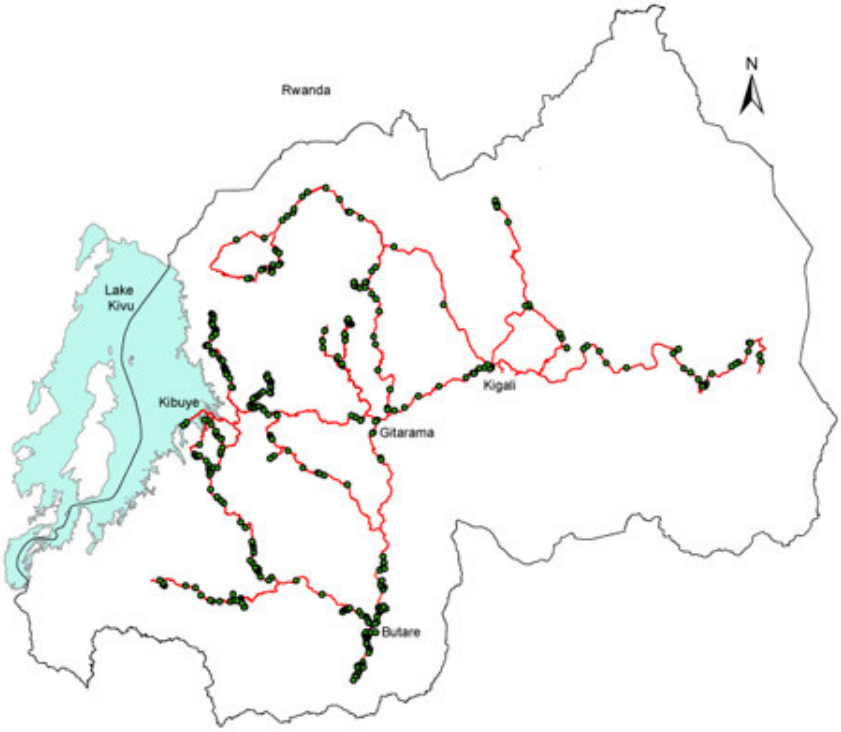

Fig.2. Travelled route and field observation points.

Final classification and interpretation.

Based on field data collected the forest map was improved. First the large forest area of Nyungwe was improved, based on polygons drawn in the field. This drawing indicates the boundary with forest and non_forest. In Fig 2.

In figure 3 the final result is shown with the field observed boundary of forest and the satellite in the background.

Four different satellite images were needed to make a complete cover of the Nyungwe area. The Aster image of 21 February 2005 is covering the northern part of the Nyungwe forest. The Spot image of 18 July 2002 is covering the eastern part, the Spot of 28 September 2002 the southern part and the Spot of 10 September 2000 the western part.

First the Spot of 10 September 2000 was improved, since the field polygon was on this image. A complete new classification for the forest area was made. New signatures were selected and several classifications made until the forest was correctly classified. In comparison to this classification the three other images were adjusted.

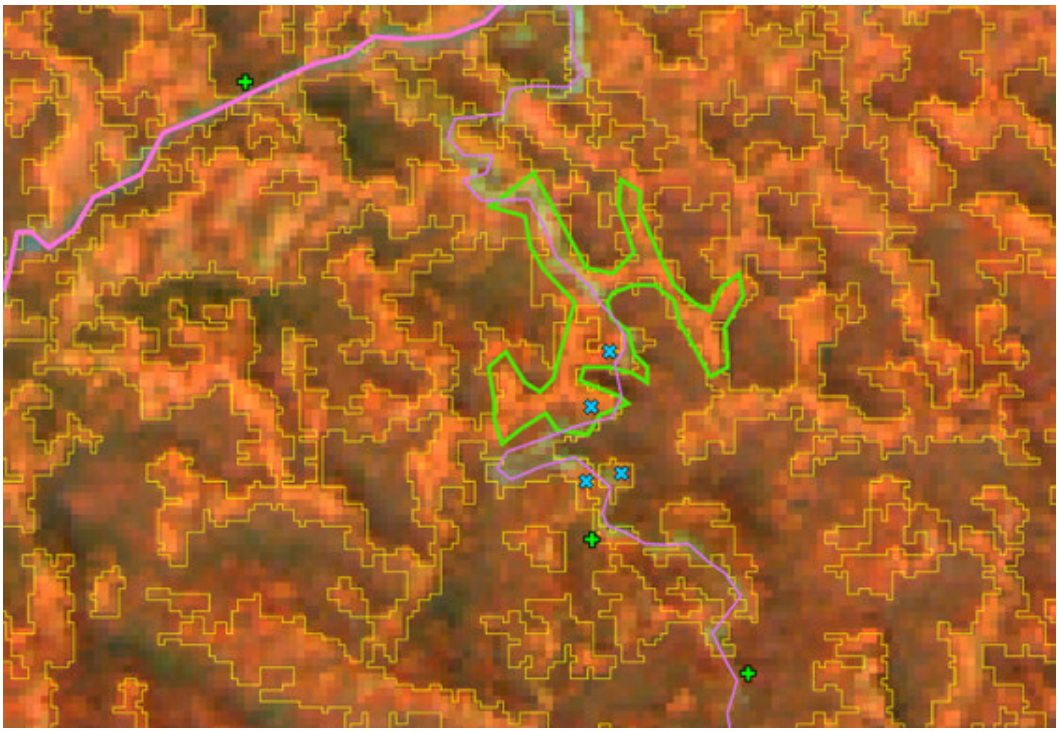

Fig. 3. SPOT satellite image of 10 September 2000 with the final classification in yellow and observed forest boundary in the field in green. Roads are in magenta The cyan crosses are bush and green plusses forest.

Manual improvement

This field data is used to update the forest polygons layer by manual editing. Polygons which were no forest in the field were deleted. In the few occasions where forest was in the field and no polygons were present, polygons were added based on visual interpretation.

The classification of the area covered by the aster of 21 February 2005 proved to be good during field inspection. This image was inspected and the forest polygons improved manually editing. In addition the first classification was screened and adjacent small areas (< 5000 ha) which could be connected with a visual interpretation, were combined by digitizing.

A distinction in forest type between the polygons was made based on field observation and visual interpretation. All single polygons are considered Eucalyptus, except if they were pine.

The next logical step would be to improve the area covered by the aster image of 5 July 2004. The classification of this satellite data gave quite some over classification of forest in some areas and under classifying in others. After detailed inspection of this data it became apparent that this problem was mainly caused by striping. Therefore the images would be newly imported with the de-striping option. Then also the geo-coding process had to be carried out again.

During searching for the original 1A level data, it was found that 2 more images of the same date were available, covering the area from Nyungwe and Butare. So these data were added as well.

At the same time a search for new data was carried out and additional aster image were found. One image of 14 September 2004, covering the south west area around Cyangugu
And one image of 21 march 2006 in the mid north between Byumba and Ruhengeri.

The cover of most recent images used for the final classification is presented in Figure 4.

From the new imported 5 images of aster of 5 July 2004 with de-striping option a mosaic was made and clipped with the Rwanda boundary. This image was newly classified. In ArcGIS this image was converted to polygon (without the simplify option). Polygons with areas smaller than 0.5 ha were selected and eliminated.

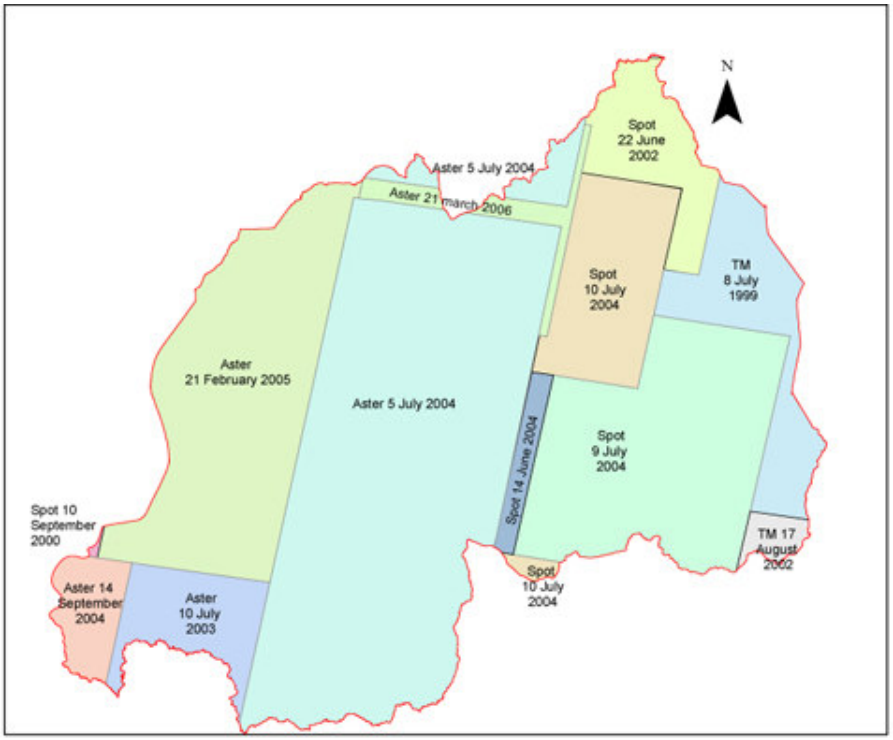

Figure 4. The cover of most recent images used for the final classification.

The classification was screened and adjacent small areas (< 5000 ha) which could be connected with a visual interpretation, were combined by digitizing. Subsequently different forest types were assigned to the polygons, based on visual inspection.

The area covered by the aster images of 26 April 2005 was visual inspected for the area which was classified with Spot images. This Aster image was partly covered with clouds and therefore not used for classification. But in the not cloudy areas a visual interpretation was made and forest were digitized and added in the file.

The south west part (Cyangugu) was visual inspected and adjusted with digitizing, based on the Aster images of 14 September 2004 and 10 July 2003.
Whenever possible, other images of different dates, were inspected to verify for the presence of forest.

The polygon map and images were visual inspected and improvements were made by digitizing on the screen.

In figure 5. a generalised map of the final result is presented. Only areas larger than 10 ha are shown.

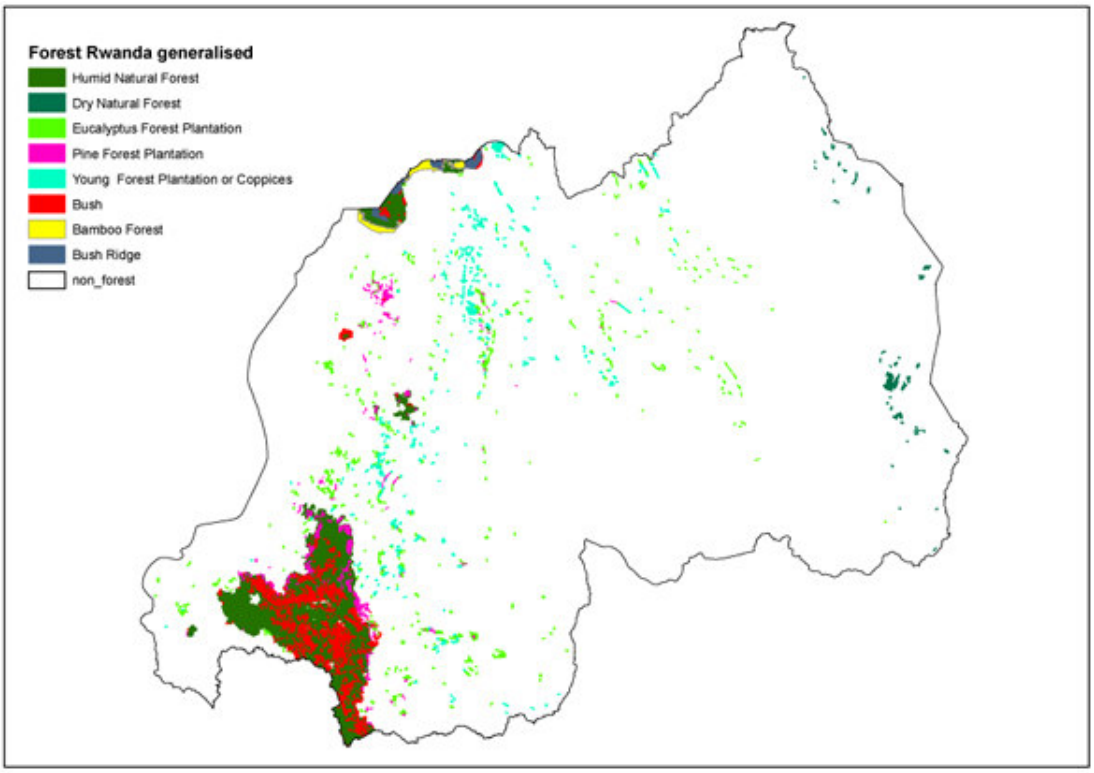

Figure 5. Generalised forest cover map. Area larger than 10 ha are shown.

The amount of forest types in km² of the final result is as follows:

Forest type	no of polygons	km²	%
non forest	699	23252	91.9
Bush	5584	343	1.4
Bamboo Forest	8	44	0.2
Bush Ridge	5	30	0.1
Dry Natural Forest	664	37	0.1
Humid Natural Forest	1430	798	3.2
Eucalyptus Forest Plantation	11645	306	1.2
Pine Forest Plantation	663	110	0.4
Young Forest Plantation or Coppices	22728	392	1.5
Total	43426	25312	100.0
All forest	37143	1717	6.8

The natural forest, bamboo forest, bush ridge and forest plantations are summarised as forest. Bush can not be considered as forest. The total amount of forest in % of the area is 6.8 %.

Map accuracy.

The accuracy of a map can be assessed by comparing what is on the ground and what is on the map at several places. For a proper accuracy assessment the selection of these places should be unbiased. This can

be done by random sampling or systematic sampling. Either way fieldwork to do this is much more time consuming than field data collection as was carried out during the 4 missions.

During the missions observations were made close to the road, because of time constraints. And observations were mostly done at places were polygons indicted the presence of forest, based on the first classification. So in theory these points can not be used for accuracy assessment.

However since no other data is available, the information of these points can given a rough indication about the accuracy of the map. The field data were sorted and later classified on cover and dominant species. This was matched with the classification.

Below is the result of crossing the points with the result of classification, before this was corrected with the field observations.

Since in the mapping not all species were classified we can generalise the 2 sample points of Callitris, the 1 Macaranga and the 3 Grevillea under Eucalyptus. And Cupressus together with pine and Acacia mea as natural. The two mixed forest points are half pine and half eucalyptus. Both are classified as eucalyptus, which can be considered as correct. With yellow the correct classified boxes are indicted. This is summarised in the table below.

	non forest	shrub	dry natural	humid natural	eucalyptus	pine	young plantation	Total
non_forest	126	1			4		27	158
Bush	1	9						10
Dry Natural Forest			3					3
Humid Natural Forest				9	4			13
Eucalyptus Forest Plantation					135	24	1	160
Pine Forest Plantation					6	26		32
Young o Forest Plantation	2				7	2	14	25
Total	129	10	3	9	156	52	42	401

The amount of correctly classified points is 322 and overall accuracy performance is 80%.

When we only consider the forest structure and do not separate on dominant species we get the table below.

Map unit	non_forest	shrub	forest	young plantati	Total
non_forest	126	1	4	27	158
Bush	1	9			10
Forest			207	1	208
Young Forest Plantation	2		9	14	25
total	129	10	220	42	401

The number of correctly classified points is now 356 and overall performance is 89%.

Below is a table after generalising in forest and non forest.

Map unit	non	forest	total
non-forest	137	31	168
forest	2	231	233
total	139	262	401

Now 368 points are correctly classified and overall accuracy is 92%.

Map production

From the final result prints on 1:50,000 scale were prepared. The tiling system is based on a quarter degrees lat/lon. In total 43 maps were prepared.

An example of a forest cover map is shown in annex 1.

Annex 1. Example of a forest cover map.