Monitoring of Forest Cover Change in the Republic of Gabon between 1990, 2000 and 2010 Following IPCC Guidelines

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Abstract – The Gabonese Agency for Space Studies and Observations (AGEOS) was set up in 2010 with one of its aims to develop a national forest monitoring capability. In addition, the European Space Agency (ESA) has developed its activities in the Congo basin through the REDD extension of its GMES Service Element on Forest Monitoring program (GSE FM). The ESA GSE FM REDD extension project is seen by the Gabonese authorities as a precursor to the establishment of the newly created AGEOS for the monitoring of forest cover. During this first phase of the project the production of forest area maps and forest cover change maps for 1990, 2000 and 2010 was initiated with a wall to wall approach for about a third of the total area of Gabon. Initial results confirms the generally low level of deforestation expected in the Congo basin region and in Gabon in particular.

Keywords: Remote Sensing, Forest Cover change, Deforestation, MRV, REDD, Gabon.

1. INTRODUCTION

The Gabonese Agency for Space Studies and Observations (AGEOS) was set up in 2010 with the aim to establish a national infrastructure for environmental monitoring and preventing the impacts of climate change. One of the objectives of the AGEOS is to develop its capacity to monitor forest cover at national level. In addition, the European Space Agency (ESA) has developed activities in this area since 2003 through its GMES Service Element on Forest Monitoring program (GSE FM).

Recently, GSE FM further extended its activities in the Congo basin and more specifically in Gabon in support of the REDD process. The ESA GSE FM REDD extension project aims at developing a pre-operational system for monitoring forest cover within the REDD framework and is seen by the Gabonese authorities as a precursor to the establishment of the newly created AGEOS for the monitoring of forest cover.

During this first phase of the project the production of forest area maps and forest cover change maps for 1990 and 2000 was planned with a wall to wall approach for 37% (99,000km^2) of the total area of Gabon for 1990 and 2000. For 2010, the area for this first year was anticipated to cover about 13% of the country. The areas selected shown in Figure 1 below coincide with the Landsat TM scene area coverage and were chosen to provide a representative range of pressure on forest resources in Gabon.

Following discussions with AGEOS taking into account IPCC guidelines for forestry (IPCC, 2006), the following products and associated specifications were agreed as indicated in Table 1.

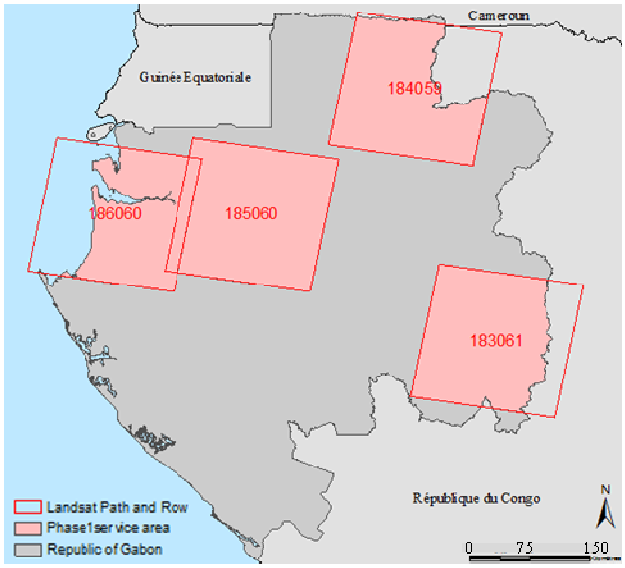


Figure 1. Area covered in the Republic of Gabon for the first phase of the project

Table 1. Forest Cover Maps 1990, 2000, 2010 and Forest Cover Change Maps 1990-2000 and 2000-2010 product specifications

Criteria	Specification	
Product	Forest Cover	Forest Changes
Map classes	Forest Non Forest	Cropland Grassland Wetland Settlement Other Land Use
Thematic accuracy	85% +/- 5%	
Geometric accuracy	Around 30 meters	
Reference system	WGS 1984 UTM GABON TM	
Image quality	30 metres	
Image acquisition	+/- 3 years	
Minimum mapping unit	1 ha	

The definition of forest follows the recommendations of the Marrakech Accord and an area greater than 1ha with trees greater than 5m and a percentage cover of at least 30% is considered as forest

2. DATA SOURCES

The production of the forest cover and forest cover change maps for 1990 and 2000 were exclusively based on Landsat imagery TM for 1990 and ETM+ for 2000. For 2010, a combination of Landsat ETM+ SLC off and Terra ASTER VNIR data were used.

Due to the heavy cloud cover conditions generally experienced over Gabon, several images were required to cover the selected Landsat scene areas entirely. As illustrated in Figure 2 below, up to 10 images were required to cover the entire area. It was almost always possible to acquire the required imagery with the period specified (i.e. +/- 3years from the reference year) except for less than 1% of the total area for 1990.

In total, 68 Landsat and 7 ASTER image scenes were acquired and processed representing an average of 7.5 scenes per site and reference year.

In addition to that, data from the interactive forest atlas of Gabon (Mertens and Maka, 2009) was used as ancillary data together with the SRTM DTM, Google Earth and Bing Maps. Reference for the geometry of the imagery was provided by the GLS2000/2005 data set (Gutman *et al.* 2008) some of which was also used as input to the production process.

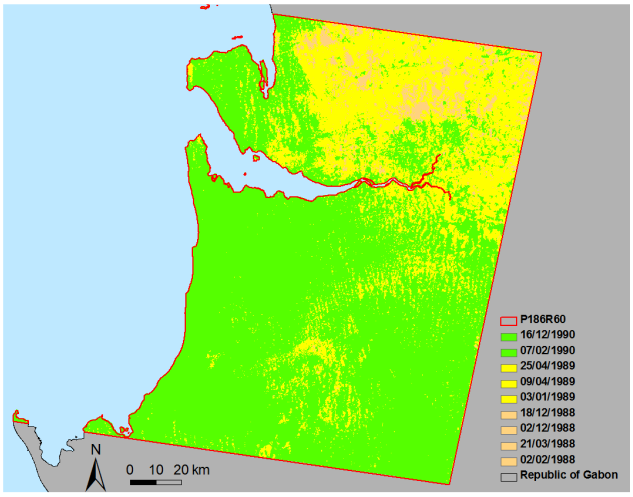


Figure 2. Landsat TM image data acquisition for Path/Row 186/60 to provide full coverage for 1990

3. METHODOLOGY

3.1 Pre-Processing

All the satellite imagery acquired for phase 1 was already geo-referenced, some of which was even terrain corrected. Each image was initially checked visually and a minimum set of 10 evenly distributed check points were selected to assess the quality of the registration by comparing against the GLS2000 ortho-rectified data. In cases when the computed RMS exceeded 30m, the image was rectified using a first order polynomial model. A final visual check was performed using the "Swipe" tool in ERDAS Imagine ®.

A cloud detection algorithm was developed based on the combination of an unsupervised classification approach combined with a visual comparison of the results with the input image to determine the threshold between cloudy and non cloudy pixels. A cloud mask was produced for each input image to derive cloud cover statistics and to determine the effective coverage of each image as illustrated in Figure 2.

3.2 Thematic Processing

In a first step, the segmentation and classification of the historical dataset from 2000 was carried out, followed by manual/visual enhancements of the classified Forest Cover Map. 2000 was selected as it provided the most complete and homogeneous image coverage. The derived classified map product from 2000 and the Landsat data from 1990 are used to derive the Forest Cover Map for 1990 and the Forest Cover Change Map 1990/2000 (classified into IPCC compliant Land Use classes). The 2000 Forest Cover Map and the current EO data set from 2010 (here Landsat 7 ETM+ and ASTER) are then the basis to derive the Forest Cover Map from 2010 and the respective mapped Forest Cover Changes. A more detailed description of the single processing step is outlined in the following paragraphs.

(a) Semi-Automatic Classification of Forest Cover and Segmentation Process

The classification of the area of interest into Forest & Non-Forest was performed for each cloud and cloud shadow masked image, by using the ERDAS Imagine software. The Landsat 2000 images and SRTM (DEM) data were used as input. An unsupervised classification of the area of interest was conducted with a large number of spectral classes to ensure a good representation of the thematic classes variability. An interactive comparison of the classified image was performed to label each spectral class according to the Forest/ Non Forest thematic classes. A post-processing classification routine was applied to vectorise the results and eliminate polygons smaller than 1 ha.

(b) Manual Post-Processing:

Subsequent to the automated classification, an intensive interactive post-processing was applied. Areas incorrectly classified were relabelled. The manual post-processing was performed using in house developed tools built on the ESRI software suite, especially designed for this type of activity. Additional information sources (e.g. topographic maps) can be used to support this interpretation. In case of discrepancies between the ancillary data sources and the satellite images, the most up-to-date information from the satellite imagery was used.

(c) Detection of Forest Cover Changes

The 2000 Forest Cover Map was used with the 1990 imagery to identify areas of change. The geometry of the 2000 map was

kept when no change was detected to avoid the creation of artefacts. This process was repeated for 2010.

The detected change areas identified as part of the 1990 and 2010 Forest Cover Map production process were classified into cropland, grassland, wetland, settlement or other land use.

3.3 Accuracy Assessment of Classification Results

Accuracy assessment of the Forest Cover is based on an area frame sampling approach illustrated in Figure 4 resulting in 267 2 by 2 km segments. Each segment was photo-interpreted by a qualified photo-interpreter independent from the production team using all available imagery and ancillary data. A set of 50 points were extracted from each interpreted segment and compared against the Map results.

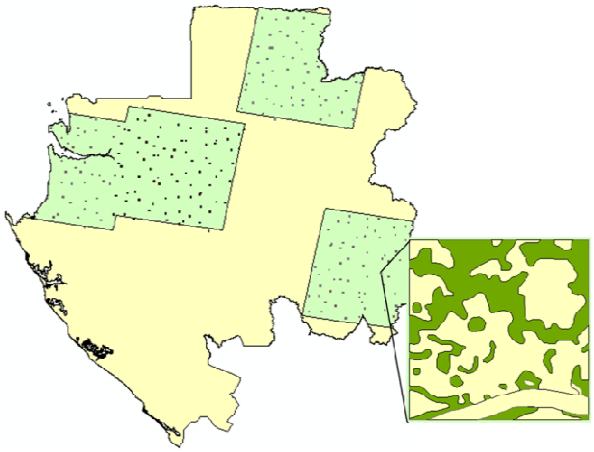


Figure 4. Area Frane Sampling Approach for the validation of the Forest Cover Map Products

4. RESULTS

4.1 Forest Cover Maps 1990, 2000 and 2010

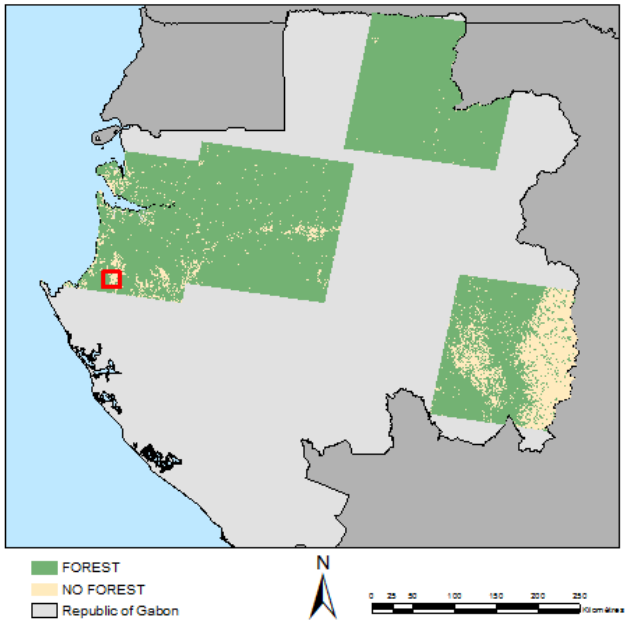
Initial results show that despite the heavy cloud cover present over Gabon, it was possible to cover the area planned. However, the large amount of cloud cover means that on average 7.5 Landsat images are required to cover the area of one scene.

Table 2. Error matrix of correct and incorrect classified pixels of the Forest Cover Map from 2000 over the phase 1

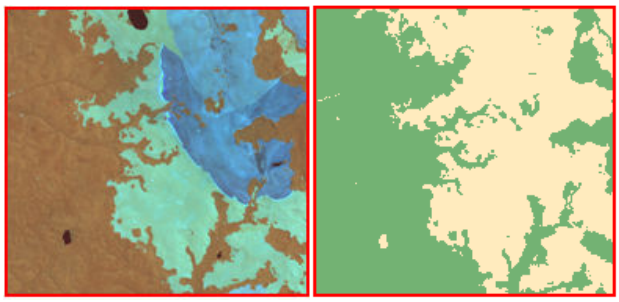
		Map			
		Non-Forest	**Forest**	**Sum Row**	**Producer Accuracy**
Reference	**Non-Forest**	1506	198	1704	88,38%
	Forest	206	10720	10926	98,11%
	Sum Column	1712	10918	12630	
	User Accuracy	87,97	98,19	**Overall Accuracy:**	96,8%

The Forest cover map for 2000 is shown in Figure 5. The accuracy assessment of the Forest Cover Map for 2000 is summarised in Table 2. It should be highlighted that as the selection of the reference data was unbiased, the proportion of forest and non forest sample points corresponds to the actual proportion of forest in the study area.

Results for 1990 and 2010 are very similar and it should be noted that omission and commission are almost identical meaning that surface areas as extracted from the maps produced are representative of the actual area of forest cover on the ground.



(*a*)



(*b*) (*c*)

Figure 5. Forest Cover Map 2000 (*a*) with an a detailed example for a selected location showing (*b*) the Landsat image band 4, 5 and 7 and (*c*) the corresponding map product.

4.2 Forest Cover Change 1990-2000 and 2000-2010

Change statistics indicate a deforestation rate of 0.02% per annum between 1990 and 2000. Forest represented 86.8% of the study area in 1990 and 86.6% in 2000 as detailed in Table 3.

The area covered in 2010 is smaller (about 13% of the country), but similar results are found with even a slower rate of deforestation.

Table 3. Forest cover in 1990 and 2000 for phase 1 of the project

	1990		2000	
	ha	%	ha	%
Forest	8 624 815	86,82%	8 605 950	86,63%
Non Forest	1 308 963	13,18%	1 327 828	13,37%
Total	9 933 778	100%	9 933 778	100%

The main causes of deforestation are primarily forest logging with the creation of logging tracks as illustrated in Table 4. There is a significant amount of reforestation with savanna converted into forest.

Table 4. Forest cover change statistics between 1990 and 2000

	Reforestation		Deforestation	
	ha	%	ha	%
Cropland	545	4,81%	2 038	6,75%
Wetland	438	3,87%	1 591	5,27%
Grassland	6 107	53,94%	5 964	19,76%
Settlement	129	1,14%	3 117	10,33%
Other (inc. logging roads)	4 102	36,23%	17 475	57,89%
TOTAL	11 321	100%	30 185	100%
Changes 1990/2000	11 321	0,13%	30 186	0,35%

5. CONCLUSIONS

It was shown that despite one of the heaviest cloud cover in the world, it is possible to use optical satellite data to produce wall to wall forest cover maps at 3 time periods. The maps produced are fully compliant with the product specifications agreed at the beginning of the project with AGEOS

Initial results confirm the generally low level of deforestation expected in the Congo basin region and in Gabon in particular. The results need to be confirmed for the whole country, but they would appear lower than previously published figures for Gabon (de Wasseige *et al.* 2009).

Further work will involve the completion of the mapping of forest cover for the whole country and the development of robust validation methodology based on *in situ* observations and very high resolution imagery.

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