NASA LCLUC Program

An Integrated Forest Monitoring System for Central Africa

Progress Report - May 2000 - April 2001

Principal Investigator

- Dr : Nadine Laporte-Goetz
  Dept.of Geography,University of Maryland, College Park, 20742
  e-mail: nlaporte@geog.umd.edu, Tel : 301-405-74-75, Fax : 301-314-9299

Co- Investigators

- Dr. Jacqueline Le Moigne
  NASA-GSFC, Applied Information Sciences Branch, Greenbelt,MD 20771,USA
  e-mail: lemoigne@backserv.gsfc.nasa.gov

- Dr. Guoquing Sun
  NASA-GSFC, Biospheric Sciences Branch, Greenbelt,MD 20771,USA
  e-mail: guoqing@aspen.gsfc.nasa.gov

Collaborators

- Prof. Ralph Dubayah
  VCL Project Dir., Dept. of Geography, Uni. of Maryland, College Park, 20742
  e-mail: rdubayah@geog.umd.edu

- Dr. Mike Fay
  Wildlife Conservation Society, Bronx NY 10460-1099
  e-mail: mfay@ngs.org Tel: 202 288-9248

- Dr. Miro Honzack
  Inst. of Forest Ecos. Res., Areal 1 Jilovske a.s, 254 01 Jilove u Prahy, Czech Republic
  e-mail: mhonzak@yahoo.com

- Dr. Philippe Mayaux
  TREES/Global Vegetation Monitoring Unit, DG Joint Research Centre, Ispra, Italy
  e-mail : philippe.mayaux@jrc.it

- Dr. Lee White
  Wildlife Conservation Society, Lopé, Gabon - e-mail : wcsgabon@compuserve.com

Abstract

This project expands on previous work mapping forest types, extent, spatial distribution, and biomass of central Africa. It uses a network of contacts and collaborators in the region to develop a forest monitoring system. The work includes fusion of multiple image data sources and extensive field measurements to map land cover, land use practices, and biomass density at the local and regional scale. This work is based on participation in interdisciplinary programs focused on the region. It provides access to an unprecedented set of remote sensing and field measurements, which are just now available for monitoring regional forest resources and their associated dynamics. A range of land surface variable maps are planned for widespread distribution to an established user community. This will be done through the NASA/UMD Deforestation Mapping Group (this activity), contingents of the US AID-funded Central Africa Regional Program for the Environment (CARPE), the Africa program of the World Conservation Society.

Key words:
Research Fields: Habitat Conversion, Deforestation, Vegetation Mapping
Geographic Area/Biome: Central Africa, Tropical Forest
Remote Sensing: Radar, MODIS, IKONOS, LANDSAT
Methods/scales: Local to Regional Scale, Data Fusion, Change detection

Mapping and Monitoring Central African Rainforest

Remote sensing research and applications (75%), Social science (25%)
Carbon (25%), GOFC (50%), Biodiversity Monitoring(25%)

Central African forests are one of the largest carbon reservoirs on Earth but relatively little is known about the impact of agriculture and logging on carbon stocks in this region. Changes in forest biomass under different land use scenarios have been addressed in other tropical forest regions (e.g., the Amazon Basin), but the modes of forest harvest and use are very different in Africa. Levels of forest fragmentation and the intensity of forest biomass removal is still largely unknown or poorly documented. In the first year of our project we developed a strategy to address these needs, and made progress on implementing them, as summarized below.

Goals / Science implication

- Better characterisation of tropical forest land surfaces and processes.
- Multi-scale multi-sensor data integration methods and appropriate validation tools.
- Integration of central African research scentists in regional science activities.

Approach / Methods

Develop new forest monitoring approaches under the framework of Global Observations of Forest Cover (GOFC), including:

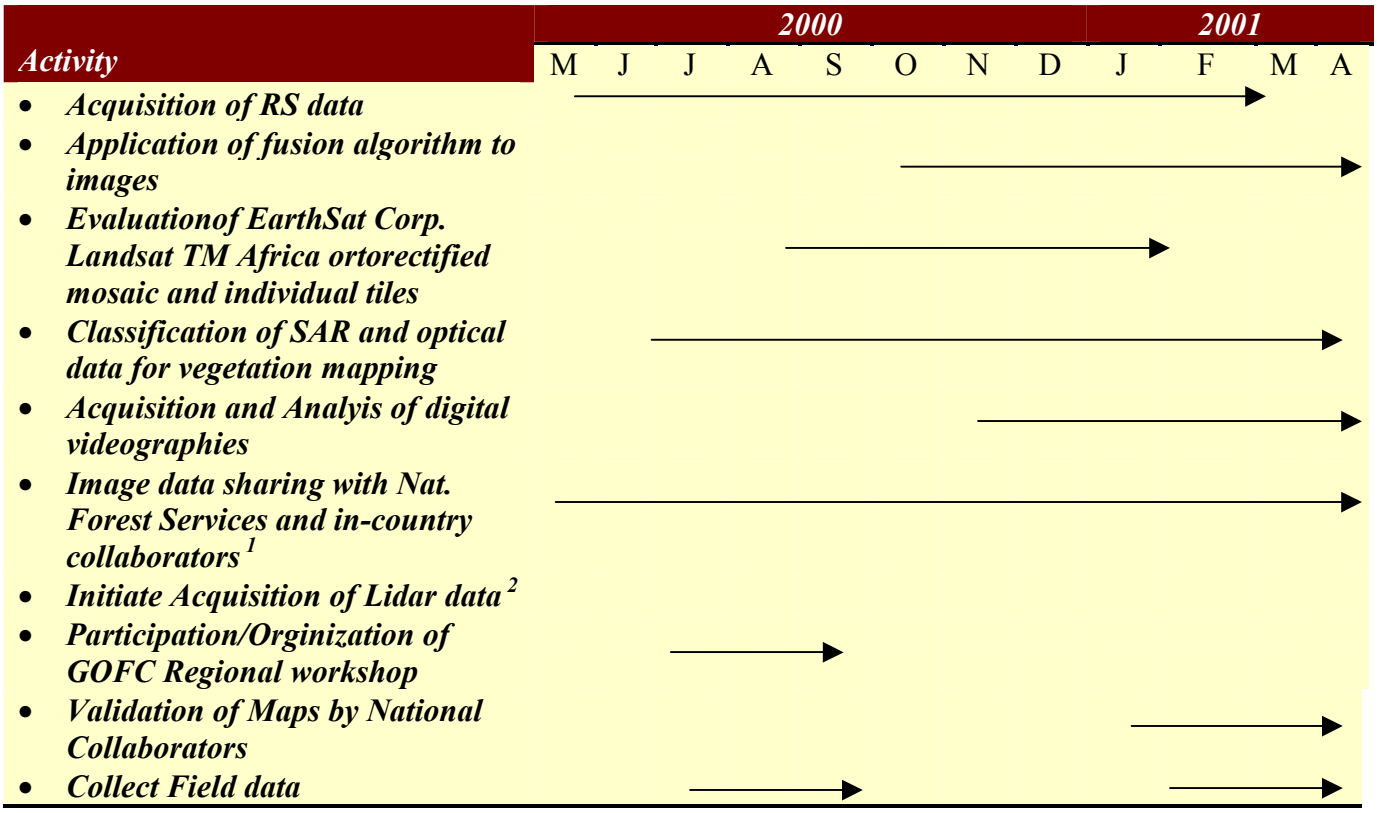
- Characterization and mapping of central Africa land cover and land use using multi-sensor, multi-scale satellite observations, providing improved vegetation maps for applications at the local and regional scale.

- Development of methodologies to assess and map central Africa biomass using RADAR imagery and new vegetation canopy LIDAR measurements to support regional carbon modeling.
- Development of forest monitoring techniques integrating new remote sensing information, biodiversity and forestry information in collaboration with international organizations and local stakeholders.

Phase 1 Achievements - Focus on Land Cover Mapping

Characterization and mapping of land cover/land use in Central African rainforest is complex. This complexity is exarcerbated by (1) the diversity of human land uses and (2) the lack of full and continuous cloud-free coverage by any single remote sensing instrument. In order to provide improved vegetation maps of Central Africa and to develop forest monitoring techniques for applications at the local and regional scales, we have focused Year 1 activities on: (1) Integrating multi-sensor remote sensing observations with in-situ data for land cover mapping, (2) Evaluating regional base maps (e.g. the Earthsat Mosaic) for monitoring applications, (3) Acquiring field information for mapping and validation, and (4) Distributing Landsat imagery, results and products to our GOFC/CARPE partners for forest monitoring applications (Table 1).

Table 1- Project Timetable May 2000- April 2001



(1) It would be helpful if the entire data set of Landsat orthorectified images, as well as archived data from the NASA Landsat Pathfinder archive, were available through the UMD/GLCF website.
(2) VCL launch postponed to ca. 2005.

New Potential

- **Image Data Acquisition Preprocessing and distribution to GOFC collaborators in Central Africa**

A series of Landsat TM, ETM+ and IKONOS images have been acquired through the NASA data purchase program and have been distributed on CD to in-country CARPE and GOFC collaborators in order to implement local-scale land cover mapping activities.

- **Outreach: Organisation of CARPE-GOFC regional forest monitoring workshops with international NGOs and national forest services.**

We organized, in collaboration with WCS, a GOFC/CARPE workshop in Gabon (July 2000) to build national capacity for operational forest monitoring. More than 30 in-country researchers participated in the workshop (Figure1). We focused on practical applications of satellite data to forest monitoring and conservation. We have begun organizing a follow-on workshop in the region in collaboration with USFS and WCS. We are expecting CARPE/USAID funds will be available for funding African participation in the workshop.

- **Fusion of SAR and optical data for vegetation mapping in Lopé.**

Results on the fusion of SAR and Landsat image data of the Lopé Reserve in Gabon are shown in Figure 2. We developed a wavelet-based fusion method (Figure 3), integrating high-frequency components of the higher spatial resolution data (SAR data at 6m resolution) and low-frequency components of lower spatial resolution data (Landsat-TM at 30m resolution).

The fusion provides a new image data set at 6m spatial resolution, which contains more detailed texture features used to improve land cover classification. At the same time, the fusion preserves the large homogeneous regions that are observed by the Thematic Mapper sensor. We are using the same approach at the regional scale to fuse and classify MODIS data with radar imagery at 150 m resolution.

New Products

- **Land Cover Land use mapping for forest conservation**

Wildlife management requires knowledge of habitat distribution and potential threats. Landsat TM imagery allows us to monitor forest cover around parks. In collaboration with WCS researchers a vegetation map of the Okapi reserve was produced (Figure 4). Validation of the map is underway.

- **Mapping potential CO_2 sinks**

In order to identify potential carbon sinks in Central Africa it is critical to understand the history and projections of logging in the region. Millions of hectares of forested land in the region are under concession (i.e., allocated for logging). To assess the extent of this potential C sink, and its implications for carbon modeling in the region, we are analyzing land use changes associated with logging activities in several regions (Figure 5).

- **Assessing rates of deforestation in logging towns**

Northern Republic of Congo is an important area to develop an understanding of the impact of logging on central African forests. Logging is the dominant land use for most of this otherwise largely undisturbed natural region (and National Park). Current rates of deforestation associated with logging in the region are poorly documented. Our mapping of land use change associated with logging at the Pokola site is shown in Figure 6.

- **Assessment of the EarthSat orthorectified Landsat TM Africa image mosaic**

As part of a GOFC/NASA LCLUC collaboration, a series of EarthSat orthorestified TM images were evaluated for geolocation accuracy. Four orthorectified images provided by the GLCF were used to assess the accuracy of this image data set. We found that images accuracy was less than a pixel, for both the indiviual tiles and the mosaic. An example orthorectified Ndoki image with GPS locations is shown in Figure 7.

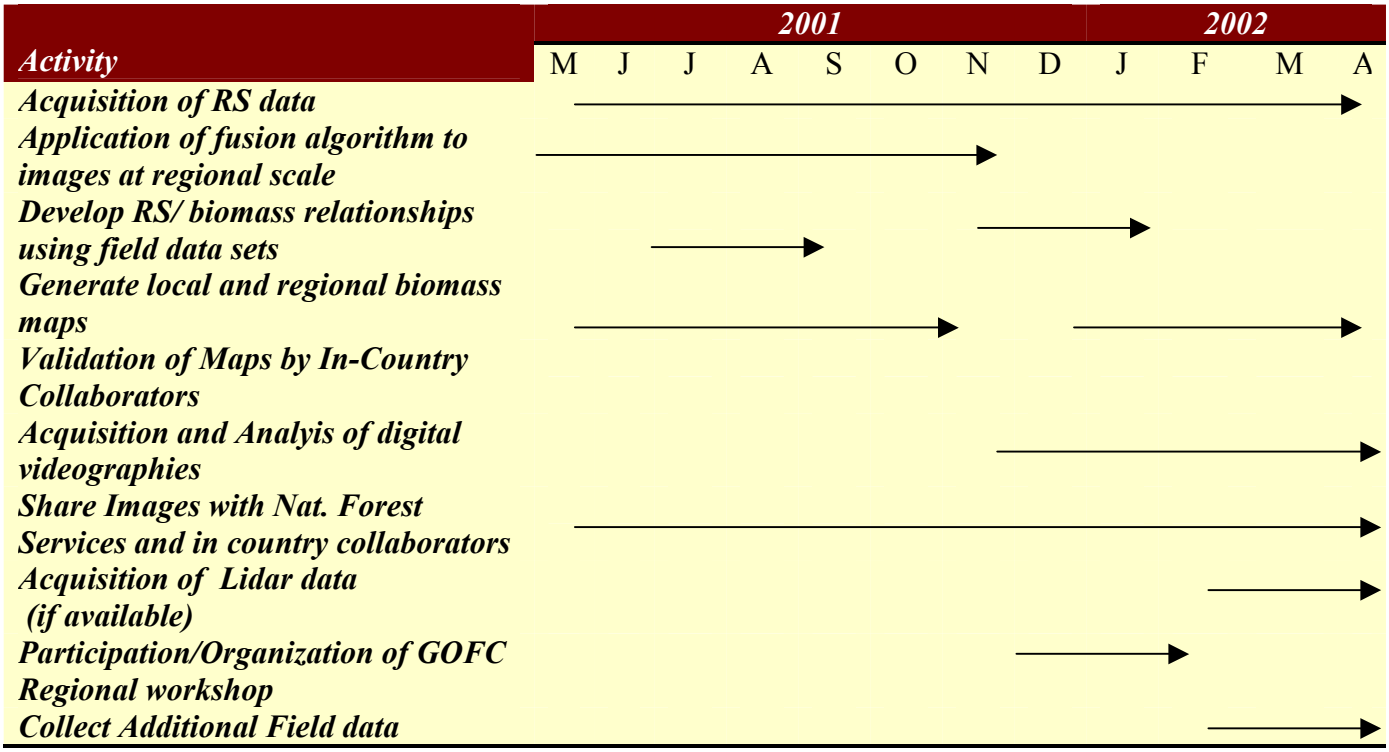
- **Digital videographies for vegetation classification and validation at Ndoki**

An archive of over 200 low-altitude digital videographies, collected by WCS since 1995 over Gabon and Republic of Congo, were acquired by our project in VHS format (Figure 8). New digital video transects were acquired in March 2001 in collaboration with WCS (Figure 9). These data sets are invaluable for validating land cover/use classifications, and for evaluating the spatial variability of vegetation at the local scale. The new transects allow us to improve our vegetation classification and validation activities. We are now preparing to survey our Cameroon and Central African Republic sites. Flights are also planned for the Salonga region in the Democratic Republic of Congo, if security issues can be resolved.

Next steps (Phase 2) - Focus on Biomass assessment

For the next phase of the project we are planning to develop biomass estimation algorithms at field sites and assess the accuracy of land cover maps using our various collected and contributed field data sets. Table 2 summarizes the timelines for these activities.

Table 2: Project Timetable, May 2001-April 2002



Conclusions & Issues

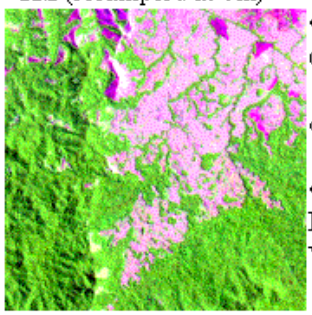
Good progress has been made on satellite land cover / use mapping activities in several study areas (Lopé, Okapi, Ndoki) within the greater Central Africa region. Valuable field data sets and digital videographies have been acquired for improving our land cover classifications, and for validating areas of identified change. Using some of these data sets we organized and ran a GOFC Remote Sensing workshop in the region, in collaboration with the WCS and CARPE (a simliar workshop is being planned for the coming year pending availability of CARPE funds). The fruits of this effort are already being realized - we received an evaluation from workshop participants at the University of Kinshasa (DRC) on one of the first land cover mapping studies under the GOFC umbrella in the DRC. In order to continue this success it is important that all the Central African orthorectified TM imagery and archived Landsat image data be made available to the project and collaborators. Data access has historically been a limitation for remote sensing science applications in Africa. We request these be made available at the cost reproduction through the UMD/GLCF www image data server.

Figure 1: GOFC/CARPE Remote sensing GIS Training Course (Lope, Gabon / 4 - 20 July 2000)

Central Africa GOFC Initiative

Figure 2: Fusion of SAR and TM data for Land Cover Mapping- Lope Test Site - Gabon

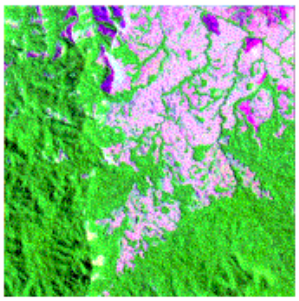
TM (resampled at 6m)

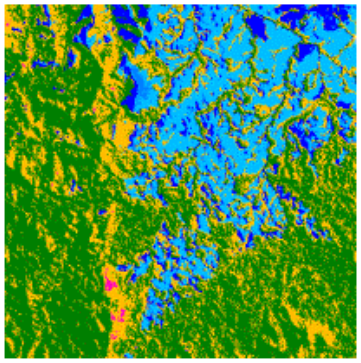


•Central Africa is characterized by a lack of full and continuous cloud –free coverage by any single remote sensing instrument. It is important to develop methods integrating multi-sensor data sets

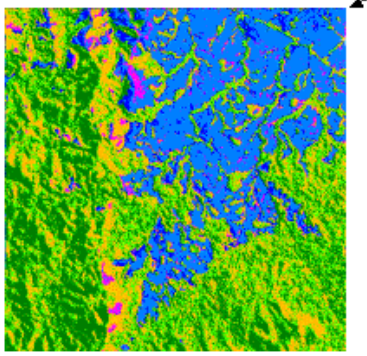
•Our fusion method is based on a wavelet approach . First tested with TM and SAR data at 6 m resolution We are now applying the same method at regional scale using a combination of MODIS and SAR data at 150 m resolution

TM +SAR fusion





TM landcover map



TM+SAR landcover map

Figure 3: Wavelet-Based Image Fusion Approach

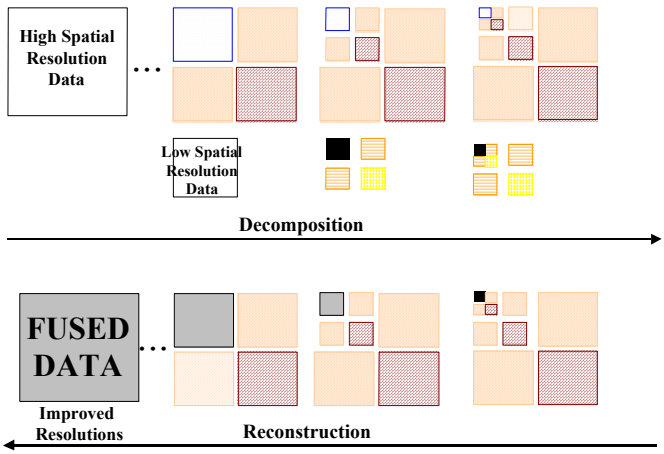


Figure 4: The vegetation of the Okapi Reserve- derived from classified Landsat TM imagery 1994

▪The Okapi Reserve is a World Heritage site located in the "Ituri Forest," a dense tropical rain forest in the northern part of the Congo River Basin in the Democratic Republic of Congo (formerly Zaire). It covers an area of over 62,900 sq km. The altitude of the forest varies from 700 m in the south to 1,000 m in the north. The name Ituri derives from the Ituri River, which runs from east to west across the forest, flowing into the Aruwimi before emptying into the Congo River. The Okapi are the only known living relative of the giraffe.

▪This first vegetation map of the Okapi Reserve, derived from Landsat imagery (1994), is being used to define new reserve boundaries and to monitor changes through time. This work and validation of the map (yellow dots) is part of a collaboration with the Wildlife Conservation Society.

▪Two main natural vegetation types dominate the area : Monodominant *Gilbertiodendron dewevrei* forest (light green), and the mixed semi-deciduous forest (dark green). Agriculture is mainly located along roads (orange) and outside the northeast corner of the Park. Villages are depicted by red dots. Protection will require adequate habitat for wildlife and collaboration with local population. The reserve is listed on the list of the endangered World Heritage sites because of its unique biodiversity and threats from mining activities (col-tan, gold)

Central Africa

Okapi Johnstoni

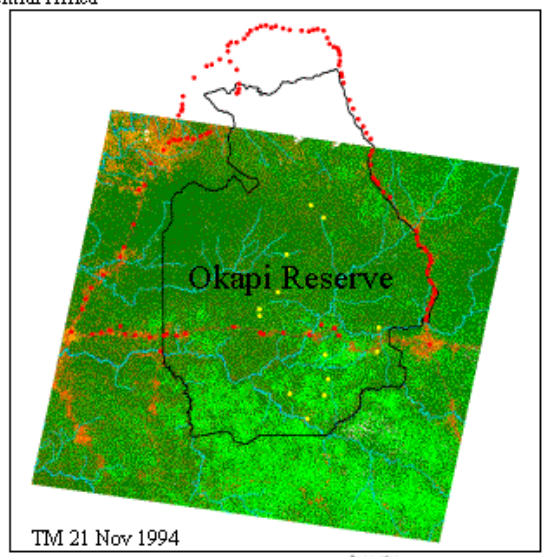


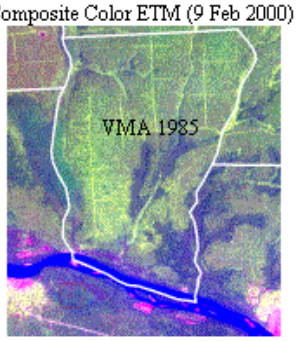
Figure5: Mapping potential CO_2 sinks: Northern Congo Site

1year old *Mussanga* regrowth

- Landsat ETM allows us to estimate the extent of forest impacted by logging, as well as logging intensity.

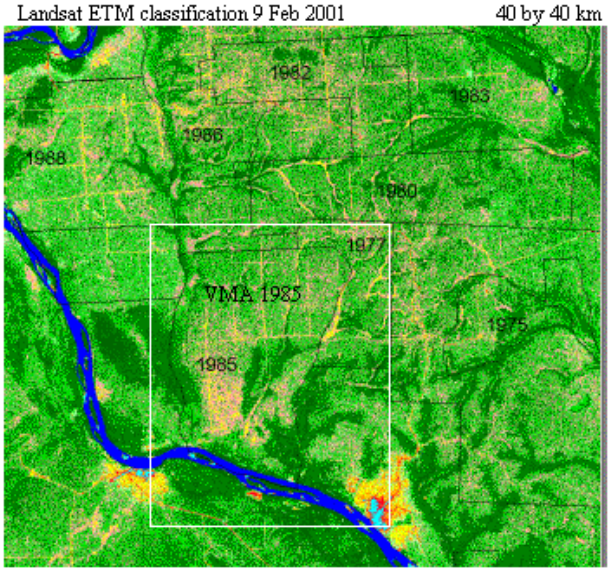
- We estimate that more than 1,000 km² of forest (pink class) is dominated by regrowth in the CIB company concessions . Early stages of regeneration (0-12 year) are dominated by pionner species like *Musanga cecropioides*.

Composite Color ETM (9 Feb 2000)



Red= Band5, Green=Band4, Blue=Band3

Landsat ETM classification 9 Feb 2001 40 by 40 km



Dark green=*Gilbertiodendron* forest. Light green= Mixed forest. Pink=Logged forest
Cyan= Bare soils. Red and Yellow = Agriculture. Dark blue= rivers.
Black lines= CIB company forest exploitation units (VMA) and dates of exploitation.

Figure 6: Land Use Land Cover Change around logging towns- Pokola (1990-2001)

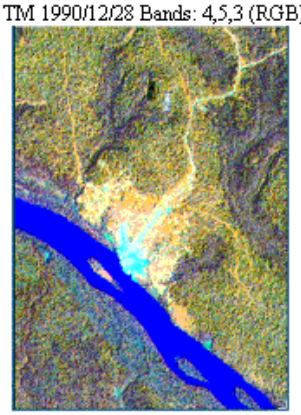
Pokola is a logging town located in the North of Republic of Congo. Logging is the main land use of this region and the CIB logging company is managing 1.5 million hectares of forest. The main towns are Ouesso, Pokola, and Kabo.

Only a few hundred people were living in Pokola in the 1970's. It was a small fishing town on the Sangha River. The population of Pokola has increased rapidly with the arrival of the logging company and the population is now estimated to 9,000 inhabitants.

Pokola is an important town to understand the impact of logging in the central African forest. Rates of deforestation across the region are very variable and little is known on the impact of logging on forest cover and wildlife.

Between 1990-and 2001, the "urban" area of Pokola increased by 38% while agricultural land increased only by 5%. The total forest area decreased by 12%. The annual rate of deforestation is 1.1%.

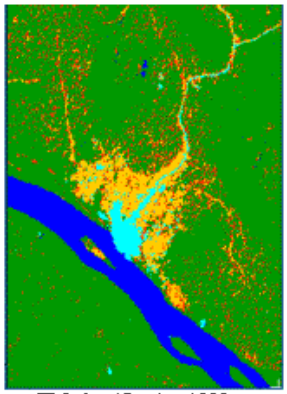
TM 1990/12/28 Bands: 4,5,3 (RGB)



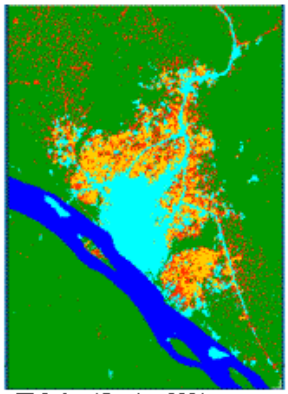
7 km by 10 km

TM 2001/02/09 Bands: 4,5,3 (RGB)

7 km by 10 km



TM classification 1990



TM classification 2001

Green = Forest

Red = Degraded Forest

Orange = Agriculture

Cyan = Bare Soil

Blue = Water

Figure 7: Assessment of the orthorectified Earthsat

Geocover product

Landsat TM orthorectified 28 Dec 1990

Composite color image (B5=R, B4=G,B3=B)

To assess the accuracy of the Landsat orthorectified images GPS points were acquired at road intersections and bridges by WCS and CIB collaborators. The same approach was used for Okapi and Lope.

Figure 8: An archive for Land cover validation:

Historical digital video flights for Central Africa (WCS)

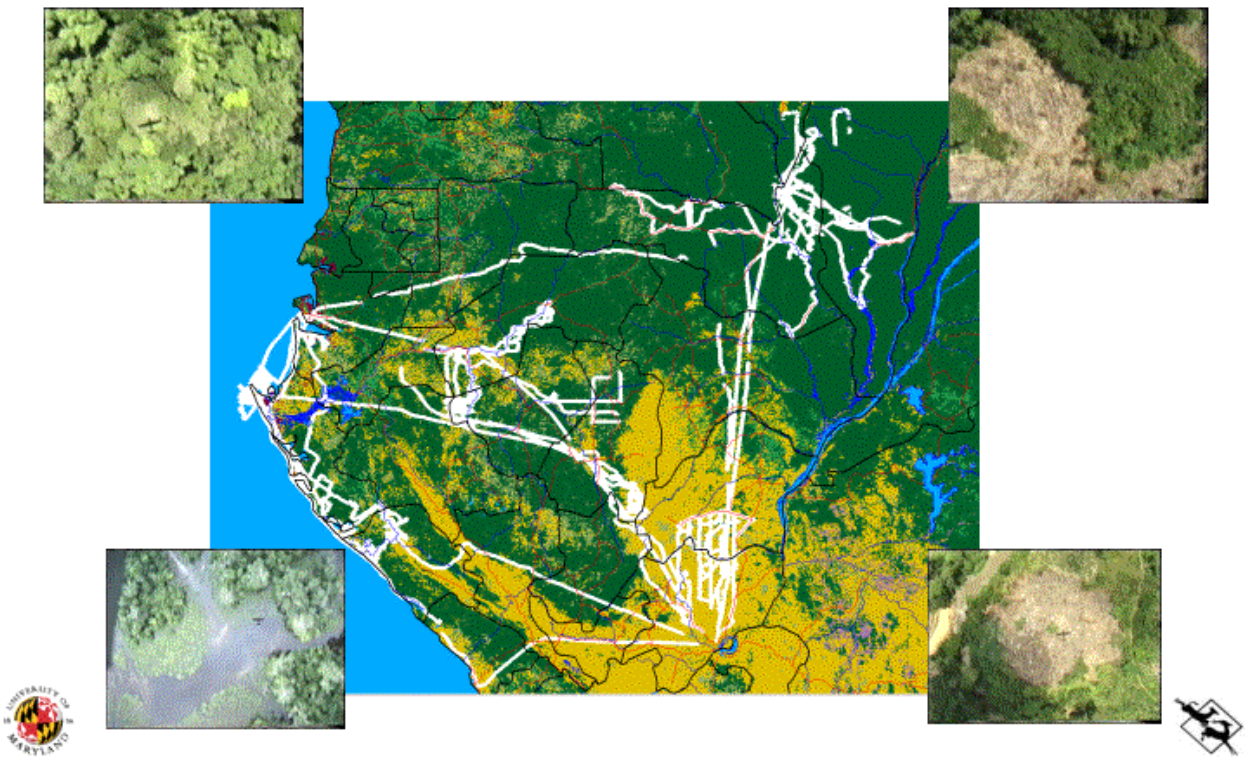
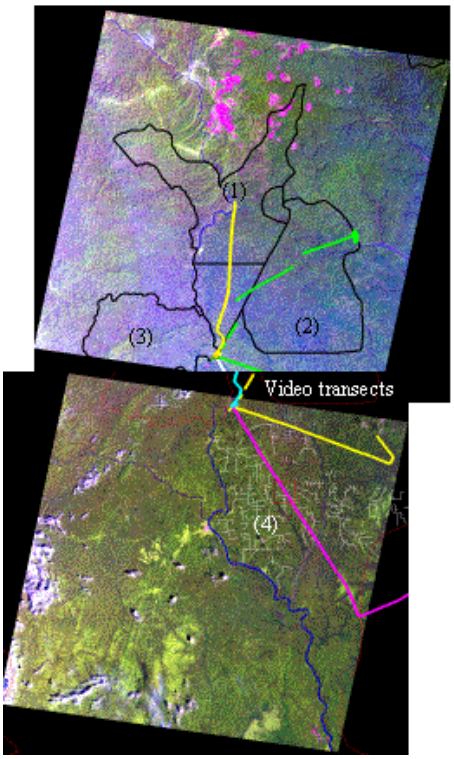
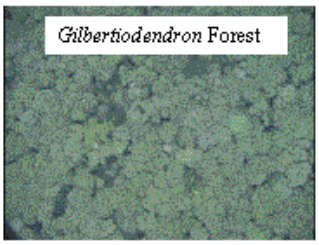
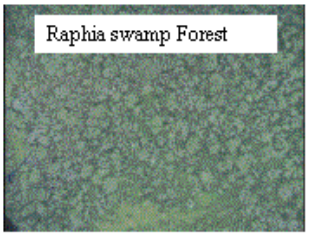


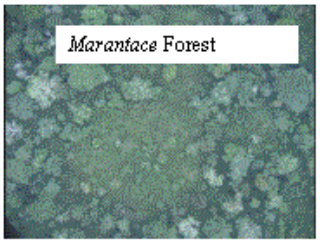
Figure 9: Ndoki airborne digital video data March 2001

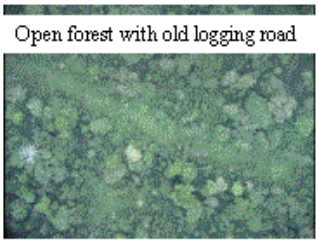
Trinational Park Area:
(Nouabale-Ndoki (1), Dzanga Sangha (2), Lac Lobeke (3) and CIB logging area (4)

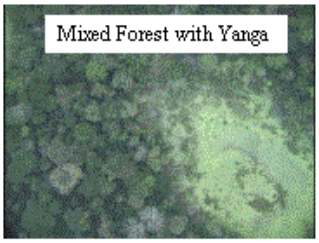












To document and validate vegetation types, frames were extracted from recent digital videos