COMIFAC

International Conference

MONITORING FOREST CARBON STOCKS AND FLUXES IN THE CONGO BASIN

CONFERENCE REPORT

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Central Africa Forestry Commission

COMIFAC

Monitoring Forest Carbon Stocks and Fluxes in the Congo Basin

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Executive Summary

The Central African Forests Commission (COMIFAC) and its partners (OFAC, USAID, EC-JRC, OSFAC, WWF, WRI, WCS, GOFC-GOLD, START, UN-FAO) organized an international conference on "Monitoring of Carbon stocks and fluxes in the Congo Basin" in Brazzaville, Republic of Congo, 2-4 February 2010. The conference brought together leading international specialists to discuss approaches for quantifying stocks and flows of carbon in tropical forests of the Congo Basin. The conference provided a unique opportunity to assess the status and capacity to monitor forests in the Congo Basin and to identify key technical issues related to carbon monitoring in the region.

The specific objectives of the conference were to: (a) provide an overview of current land cover, land use and carbon monitoring activities in the Congo Basin, including both field based and remote sensing projects; (b) assess current capacities for land cover, land use and carbon monitoring at the regional and national levels; (c) establish scientific and technical guidelines for successful carbon monitoring in the Congo Basin; (d) identify current satellite data needs for Congo Basin land cover and carbon monitoring, including data acquisition, data access and data dissemination, and develop a strategy to meet these needs; and (e) identify a mechanism to inform COMIFAC and national governments on the technical issues associated with carbon monitoring, particularly in the context of Reducing Emissions from Deforestation and Forest Degradation (REDD).

The report summarizes key points from the plenary sessions and working groups, and presents recommendations for near and medium term actions. In addition to supporting the REDD process, the findings presented here apply as well for advancing regional capacity for land cover and land use monitoring in general (e.g., for land use planning, agricultural monitoring, conservation of biodiversity). Key findings of the conference include:

1. Estimating forest cover change using remote sensing has reached a good level of maturity in the Congo Basin. This work will contribute to MRV systems in the region. Two operational approaches, basin wide mapping (by SDSU-OSFAC) and thematic sampling of 400 km2 (by JRC-UCL- OFAC-FAO and national experts), used Landsat images to establish rates of deforestation in the Congo Basin. The rates (~ 0.2% / year) are low compared to other tropical continents. It is recommended that these results be consolidated and national authorities collaborate in producing this vital information.
2. Central Africa has suffered from poor spatial data acquisition policies. Only Landsat data are routinely available (through OSFAC), with limitations on quality in recent years. 2010 seems to mark a turning point in improved data acquisition: (i) DMCii coverage is being finalized (GMES), (ii) free SPOT data for REDD+ in the Congo Basin should soon be available (AFD), (iii) a satellite ground receiving station is to become operational in Libreville in 2011 (French-Brazilian-Gabon project), (iv) free CBERS data are available to African users, (v) recent ALOS-PALSAR radar data, with wall to wall coverage for the Congo Basin, is available (Japan), and (vi) the GEO Forest Carbon Tracking initiative in Central Africa will facilitate data access to designated national demonstrator countries. With these efforts Central Africa should catch up in the years to come. However, further efforts should be made in two areas relating to data access: fostering a policy of open data and making data readily available from receiving stations and data providers to domestic users by strengthening infrastructure for data dissemination (e.g., internet, GEONETcast).
3. Despite the progress in mapping biomass using satellite Earth observations (a combination of radar and optical images), a number of challenges need to be met to reliably estimate carbon stock, including: (i) collection of forest inventory data pertinent for biomass estimates for different forest types (including soil, litter, dead wood and

below-ground biomass), (ii) establishment of allometric equations to link forest inventory data and biomass (and hence carbon stocks) for different forest types, and (iii) the establishment of permanent plots to measure the increase in carbon stock in different ecological conditions.

4. For an MRV system to be effective, national training strategies need to be established and a critical mass of managers and technicians trained with expertise in remote sensing, field inventories and reporting techniques. It is suggested that RIFFEAC make a first inventory of projects and training institutions which can facilitate the development of REDD+.

5. Although MRV systems will be established nationally, it is recommended that these be strengthened by regional coordination which will: (i) continue the inventory of REDD+, (ii) build regional databases of forest inventories and allometric equations, (iii) establish rules for data sharing and use (e.g., through a Creative Commons license), (iv) establish and oversee the training strategy, (v) maintain coherence among the national MRV systems and facilitate dialogue with financial partners, and (vi) establish a scientific committee to advise the stakeholders in the region. Such regional coordination should be placed under the auspices of COMIFAC, with operational support of OFAC and OSFAC.

Résumé exécutif

Un peu plus d'un mois après le sommet de Copenhague qui a consacré le rôle fondamental des forêts tropicales dans l'atténuation du changement climatique, la COMIFAC et ses partenaires (OFAC, EC-JRC, OSFAC, WWF, WRI, WCS, GOFC-GOLD, START, UN-FAO) ont organisé une conférence scientifique sur le «Suivi des stocks et flux de carbone dans le Bassin du Congo» à Brazzaville du 02 au 04 février 2010. Cette conférence, destinée à tous les acteurs du processus REDD+ dans le Bassin du Congo, a mis l'accent sur les aspects de MRV (Monitoring, Reporting, Verification) du processus REDD+. Cette conférence fut une opportunité unique d'évaluer l'état et la capacité de suivi des forêts du Bassin du Congo et d'identifier les principaux verrous scientifiques du suivi opérationnel du carbone dans la sous-région. Les principaux enseignements de ces 3 jours de travaux intenses sont ci-dessous.

1. L'estimation des changements de couvert forestier par télédétection est arrivée à un bon niveau de maturité par application de techniques robustes et éprouvées et permettra de nourrir des systèmes MRV dans la région. Deux projets régionaux, basés sur l'analyse d'images Landsat, ont montré des applications opérationnelles complémentaires, en cartographie complète (SDSU-OSFAC), ou sur base d'analyses thématiques plus détaillées d'échantillons de 400 km2 (JRC-UCL-OFAC-FAO et experts nationaux). Les deux études montrent une déforestation faible dans le bassin du Congo (~0.2%/an) par rapport aux autres continents tropicaux. Il est recommandé de consolider ces résultats et d'impliquer davantage les administrations nationales dans la production conjointe de ces informations cruciales.

2. L'Afrique centrale a souffert d'une politique d'acquisition sporadique de données spatiales. Seules les données Landsat sont actuellement disponibles de manière routinière (OSFAC), avec des limitations de qualité sur les dernières années. L'année 2010 semble marquer un tournant en ce domaine : (i) couverture DMCii en voie de finalisation (GMES), (ii) ouverture gratuite des archives SPOT pour les activités REDD+ dans le bassin du Congo (AFD), (iii) station de réception de Libreville opérationnelle en 2011 (projet franco-brésilio-gabonais), (iv) données CBERS mises à disposition des utilisateurs africains, (v) couvertures radar ALOS-PALSAR (Japon), (vi) initiative GEO Forest Carbon Tracking. L'Afrique centrale devrait donc rattraper son retard dans les années à venir. Il faut toutefois poursuivre les efforts dans deux domaines : favoriser une

politique des données ouverte et permettre la dissémination physique des images depuis les stations de réception jusqu'aux utilisateurs nationaux, en renforçant les infrastructures de rediffusion (Internet, Geonetcast…).

3. Malgré certains progrès montrés dans la cartographie de biomasse à partir d'observation de la terre (combinaison d'images radar et optiques), il reste un grand nombre de défis à relever dans l'estimation du stock de carbone : (i) la récolte de variables d'inventaire forestier pertinentes pour les estimations de biomasse pour les différents types forestiers (incluant le sol, la litière, le bois mort et la biomasse souterraine), (ii) l'établissement d'équations allométriques qui permettront de relier ces données d'inventaires forestiers à une biomasse réelle (et donc à un stock de carbone) pour les différents types forestiers, (iii) la mise en place d'un réseau de placettes permanentes permettant de mesurer finement l'augmentation du stock de carbone dans différentes conditions écologiques.

4. Pour un système MRV efficace, il faut établir des stratégies nationales de formation et amener une masse critique de cadres et techniciens formés à un niveau adéquat dans les domaines de la télédétection, des inventaires de terrain et des techniques de reporting. Le RIFFEAC pourrait réaliser un premier inventaire des projets et institutions de formation susceptibles de servir la mise en place d'un système REDD+.

5. Bien que les systèmes MRV se mettront en place par pays, il est recommandé de renforcer ces composantes nationales par une coordination régionale qui devra : (i) continuer l'inventaire des projets REDD+, (ii) construire des bases de données régionales des inventaires forestiers et des équations allométriques, (iii) mettre en place des règles de partage et d'utilisation des données, notamment à travers des licences de type Creative Commons, (iv) établir et suivre la stratégie de formation, (v) maintenir le cohérence entre les systèmes MRV nationaux et le dialogue avec les partenaires financiers, (vi) établir un comité scientifique chargé de conseiller les acteurs de la région. Cette coordination régionale se placera sous les auspices de la COMIFAC, avec l'appui opérationnel de OFAC et OSFAC.

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1 INTRODUCTION

1.1 Background and Objectives

The Congo Basin forest is the world's second largest tropical forest; as such it has the ability to sequester large amounts of carbon and regulate global climate. Understanding stocks and flows of carbon in Central Africa is fundamental to improving our knowledge of climate change.

Technical Challenge

From a technical perspective there is still a lack of scientifically proven and internationally recognized methodologies for estimating and monitoring of stocks and flows of carbon. Specific to the Congo Basin, some information useful for this purpose is currently available from land cover and land use changes studies derived from remote sensing (wall-to-wall or sampling based), generic allometric equations for the estimation of aboveground tree biomass and inventory data from permanent sample plots and management inventories for several million hectares of forest concessions. However uncertainties remain and there is scope to improve estimates with better field data collected for carbon stocks assessment, allometric equations designed specifically for the region and improved access to satellite imagery.

There has been long standing interest in monitoring of Congo Basin Forests, largely driven by research on biodiversity, ecosystems, land use and earth system observations. The inclusion of Reducing Emissions from Deforestation and Forest Degradation (REDD) in the climate change treaty negotiations has generated intense interest in forest monitoring in the Congo Basin.

According to the "State of Forest 2008" report of the Central Africa Forest Commission (COMIFAC), " No matter which final REDD mechanism is chosen, we will need to know as accurately as possible how much carbon (C) is: stored in different standing vegetation types (especially forests) and soils; released through AFOLU (agriculture, forestry and other land use) activities." (State of the Forest 2008, p191)

Regional Coordination Challenge

In February 2000, the UN-sponsored Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) held a regional workshop at Libreville. The workshop initiated the establishment of the OSFAC (Observatoire Satellital des Forêts d'Afrique) regional network. With support from Central African Regional Program for the Environment (CARPE) and others, the OSFAC office was established at Kinshasa in 2004, with its point of contact based in Cameroon. The first joint initiative by all OSFAC members was preparing inputs to the State of the Forest reports for 2006 and 2008. With EU support and numerous partners in the, the OFAC (L'Observatoire des Forêts d'Afrique Centrale) was formed in 2007, acting as a reference center supporting COMIFAC. Since 2007, OSFAC and OFAC have partnered on forest mapping and assessment topics, as well as capacity strengthening activities. The partnership has been challenged with: strengthening links to national entities; effectively transferring data and information to members; involving academic institutions; and retaining a long-term and active cadre of members. The emergence of REDD and the national readiness activities initiated in the Congo Basin region necessitate that the networks now address:

- a stronger integration between OFAC, OSFAC and other regional partners;
- official link with COMIFAC;
- more joint activities directly involving all the countries;
- links with training institutions in order to create critic mass; and

- need for a scientific committee for guaranteeing the quality of the products delivered by the countries to the international conventions.

It is with this background that the Central Africa Forest Commission (COMIFAC) and its partners invited those with a technical interest in monitoring land use change, land cover and their relationship to carbon quantification to the international conference on “Monitoring Carbon Stocks and Fluxes in the Congo Basin”. The conference was held from 2-4 February 2010 at Brazzaville, Republic of Congo.

The conference brought together leading international specialists to discuss approaches for quantifying stocks and flows of carbon in tropical forests of the Congo Basin. The conference provided a unique opportunity to assess the status and capacity to monitor forests in the Congo Basin and to identify key technical issues related to carbon monitoring in the region. The specific objectives of the conference were to:

- provide an overview of current land cover, land use and carbon monitoring activities in the Congo Basin, including both field based and remote sensing projects,
- assess current capacities for land cover, land use and carbon monitoring at the regional and national levels,
- establish scientific and technical guidelines for successful carbon monitoring in the Congo Basin,
- identify current satellite data needs for Congo Basin land cover and carbon monitoring including data acquisition, data access and data dissemination, and develop a strategy to meet these needs, and
- identify a mechanism to inform COMIFAC and national governments on the technical issues associated with carbon monitoring, particularly in the context of REDD.

1.2 Conference Organization

Sponsoring Agencies

The following agencies are gratefully acknowledged for providing support to the conference:

- COMIFAC: Commission des Forêts d’Afrique Centrale
- UN FAO: United Nations Food and Agriculture Organization
- USAID Central African Regional Program for the Environment
- JRC: Joint Research Centre, European Commission
- OFAC: Observatoire des Forêts d’Afrique Centrale
- GOFC–GOLD: Global Observation of Forest and Land Cover Dynamics
- START: Global Change SysTem for Analysis, Research, and Training
- OSFAC: Observatoire Satellital des Forêts d’Afrique Centrale
- WCS: Wildlife Conservation Society
- WRI: World Resources Institute
- WWF: World Wildlife Fund for Nature

Organizing Committee

The following individuals organized the conference and are thanked for their contributions.

- COMIFAC – Raymond Mbitikon
- FAO – Erik Lindquist
- OFAC – Carlos de Wasseige, Robert Nasi
- GOFC-GOLD / OSFAC – Landing Mané , Chris Justice, Alice Altstatt, Michael Brady
- WRI – Lyna Bélanger, Matthew Steil
- WWF – Paya de Marcken, Ken Creighton
- JRC – Philippe Mayaux
- WCS – Paul Telfer

The committee gratefully acknowledges the conference hosts in the Republic of Congo, including the Ministry of Sustainable Development, Forest Economy and Environment, and the Ministry of Foreign Affairs.

Organization of the Conference and Report

The conference was attended by 136 participants from all countries in the Congo Basin and from 14 countries outside of the region (Appendix 1).

Opening remarks were provided by COMIFAC's Deputy Executive Secretary, Martin Tadoum, followed by a welcoming address from the Principal Private Secretary of the Sustainable Development Ministry, Republic of Congo. Opening remarks on Carbon budget challenges and opportunities were also provided by Emilie Wattelier of the European Union delegation and John Flynn of the USAID Central African Regional Program for the Environment (CARPE).

Following the opening session, the three-day conference included several plenary sessions and working group discussions (Appendix 2). Plenary sessions were as follows: Day 1 (i) Overview of carbon monitoring and REDD projects and (ii) land cover and land use monitoring activities at the national and regional levels. Day 2 (iii) technical approaches for carbon monitoring: methods and results from projects with emphasis on remote sensing and field measurements, (iv) projects relating to other environmental services provided by the forest and (v) access to satellite data; current and future regional acquisitions. The third day was devoted to working groups with the following themes: 1) monitoring, reporting and verification (MRV) systems in support of REDD, 2) capacity building, information dissemination and data sharing in the sub-region, 3) satellite data requirements and access, and 4) estimating forest biomass.

The conference report includes in section two an international overview of the forest carbon and REDD issue, with a focus on monitoring, reporting and verification (MRV) under the United Nations Convention on Climate Change (UNFCCC). Section three includes the short papers and abstracts prepared from plenary presentations (Appendix 3). Section four is a synthesis of the working group discussions, while section five provides conclusions and recommendations.

2 OVERVIEW OF CARBON AND REDD: THE NEEDS OF MRV SYSTEMS

'REDD-plus' requirements for the Congo Basin countries / Quelles sont les exigences techniques du REDD?

Philippe Mayaux and Frédéric Achard

Joint Research Centre -EC/Observatoire des Forets d'Afrique Centrale

Context

At the 15th Conference of Parties (COP-15) of the United Nations Framework Convention on Climate Change (UNFCCC) held in Copenhagen in December 2009, the need to provide incentives for the reduction of emission from deforestation and forest degradation was for the first time mentioned in the final declaration of the Heads of State and governments, referred as Decision 2 of the COP-15 (2/CP.15). This decision follows on Decision 2 of the COP-13 (2/CP.13) on "approaches to stimulate action" for "reducing emissions from deforestation in developing countries". The "Copenhagen Accord" recognizes "the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests" and encourages the "immediate establishment of a mechanism including REDD-plus (...) to enable the mobilization of financial resources from developed countries".

Decision 4 of the UNFCCC COP-15

Beyond the recognition of the crucial role of tropical forest and the agreement on the need to provide incentives to such actions of Decision 2/CP.15, Decision 4/CP.15 provides methodological guidance for activities related to Decision 2/CP.13 taken in Bali. In this short summary, we propose to underline the salient points of this most recent decision (2/CP.15).

Decision 2/CP.13 invited Parties "to further strengthen and support ongoing efforts to reduce emissions from deforestation and forest degradation on a voluntary basis" and has been completed in Decision 4/CP.15 by requesting "developing country Parties, ... (a) to identify drivers of deforestation and forest degradation resulting in emissions and also the means to address these; (b) to identify activities within the country that result in reduced emissions and increased removals, and stabilization of forest carbon stocks; ...".

In the case of the Congo Basin, humid forests are distributed in 3 main land-use categories of equivalent area: protected areas (450,000 km2), logging concessions (600,000 km2), slash-and-burn agriculture (440,000 km2), which means that in order to exploit the full benefit of a potential REDD+ mechanism, the full forest domain should be monitored by the national inventory (monitoring and reporting) systems.

Decision 4/CP.15 further recognizes that forest reference emission and forest reference levels should be established transparently taking into account historic data and national circumstances.

The core of Decision 4/CP.15 on methodological guidance deals with the establishment of **"robust and transparent national forest monitoring systems** and, if appropriate, sub-national systems" with the following characteristics:

- combination of remote sensing and ground-based forest carbon inventory approaches;

- transparent, consistent, as far as possible accurate estimates taking into account national capabilities and capacities; and
- results available and suitable for review as agreed by the Conference of the Parties.

Decision 4/CP.15 also invites "Parties in a position to do so and relevant international organisations" to enhance the capacities of developing countries to collect and access, analyse and interpret data, in order to develop estimates and to enhance coordination of the activities of the different stakeholders. Finally, it recommends the effective engagement of indigenous peoples and local communities in monitoring and reporting.

IPCC guidelines definitions

Parties are requested "to use the most recent Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines, as adopted or encouraged by the COPs, as appropriate, as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes". It that context, it is useful to remind a few basic definitions agreed by the international community and that will serve of reference for the future agreements and mechanisms.

For the Kyoto Protocol, **"forest"** have been defined in the "Marrakesh accords" as a minimum land area of 0.05 to 1 ha matching the two following criteria: (i) minimum height at maturity of 2 to 5 m, (ii) minimum tree crown cover (or equivalent stocking level) of 10 to 30%. Each individual country has now to define the thresholds corresponding to its definition of forests. In Central Africa, DRC has already defined its forest for the Kyoto Protocol, as minimum areas of 1 ha, with a minimum height at maturity of 5 m and tree cover of 30%. This definition can now be adapted to the REDD context.

Subsequently, **"deforestation"** is defined as "the direct human-induced conversion of forested land to non-forested land". There is no official definition of **forest degradation** but, in a REDD+ context, it corresponds to a loss of carbon stocks in forests remaining forests due to human activities.

Estimation of emissions

In order to produce the greenhouse gases inventories in the LULUCF sector (Land Use, Land Use Change and Forestry), the IPCC guidelines define the following equation with two major terms:

Emissions = Activities x Emission Factor

where ***Activity Data*** correspond to the (Land use) area changes and the **Emission Factor** to the emissions per hectare for the different processes of land use change. Usually emission factors are calculated as the change in carbon stock contents between two different land use categories (i.e. C stocks of forests minus C stocks of grasslands). Carbon stocks are calculated for all Carbon pools (Above Ground Biomass, Litter, Dead wood, Below Ground Biomass or Roots, Soil Carbon).

The IPCC guidelines foresee different options for measuring the terms of the equation, adapted to the national capacities and expertise. The following tables summarise the progressive levels of accuracy that can be achieved in the monitoring systems.

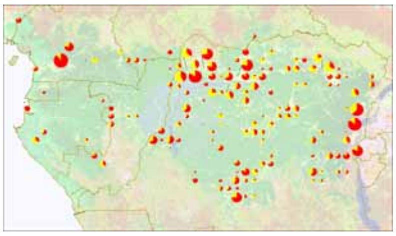
Approach	Area change estimate (activity data)
Approach 1 Not suitable for REDD because only net changes are provided	Total area for each land use category at two dates, but no information on conversion

	Forest	Degraded	Non forest	Total t0
Forest				191,171
Degraded				17,399
Non forest				316,961
Total t1	180,758	24,703	320,070	

Approach	Area change estimate (activity data)
Approach 2 Not applicable for REDD because land use changes are not identifiable and traceable	Tracking of conversion between land-use categories from different inventories

	Forest	Degraded	Non forest	Total t0
Forest	172,456	12,468	6,247	191,171
Degraded	6,157	9,986	1,256	17,399
Non forest	2,145	2,249	312,567	316,961
Total t1	180,758	24,703	320,070	

Approach	Area change estimate (activity data)
Approach 3 Applicable for REDD	Spatially explicit tracking of land use conversion



For the emission factors, the three 'Tiers' listed in the IPCC Guidance for the LULUCF sector are applicable for REDD.

Tier	Emission factor (Change in C stocks)
Tier1	IPCC default factors (Emission Factor Database) http://www.ipcc-nggip.iges.or.jp/index.html
Tier 2	Country specific data for key factors
Tier 3	Detailed national inventory of key C stocks, repeated measurements of key stocks through time and modelling

Situation in the Congo Basin

In the Congo Basin, accurate estimates of the extent of deforestation exist since a few years (e.g. Duveiller et al., 1998). A few other papers/chapters of this report describe the regional forest monitoring systems developed by two groups of institutions: JRC/UCL/FAO/OFAC and SDSU/OSFAC. It must be underlined that the regional deforestation rate of the Congo basin is much lower than the rates in the two other tropical continents for the period 1990-2000. Results of the next period (2000-2005-2010) will be available in a near future.

For the emission factors, the current measurements of carbon content of the different types of vegetation in Central Africa are extremely patchy and are not a representative dataset for the diversity of the Congo Basin forests, from swamp forests to mountain ecosystems. It illustrates the need for setting up regional field inventory databases by ecosystem type in order to minimise the cost of data collection and to reduce the variance of the estimates.

Conclusions

In order to establish operational national Monitoring (and Reporting) systems in the perspective of a potential REDD-plus mechanism a series of fundamental steps must be put in place in the Congo Basin:

- Ensuring the provision of satellite data for area change estimates.
- Setting up of REDD-plus national teams with the right equipment and well-trained human capacities.
- Building ground-based inventories of vegetation biomass for all the carbon pools.
- Making information available at regional level in order to reduce costs and increase accuracy of the estimates of carbon emissions.

The linkage between the political authorities in charge of the negotiation ('negotiators') and the technical bodies in charge of forest monitoring and inventories ('foresters') must be improved in order to guarantee to the COMIFAC countries the possibility to play a key role in the international negotiations on climate change. To fulfil this objective, it is recommended to reinforce the capacities of the national forestry inventory teams and OFAC at regional level (as centre mandated by COMIFAC, in full respect of the subsidiary principle).

Methodological Aspects for Forest Area Change Assessment through Remote Sensing, REDD / Livre de référence 'Source book' du REDD

Danilo Mollicone

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Background and rationale for the Sourcebook

The sourcebook provides a consensus perspective from the global community of earth observation and carbon experts on methodological issues relating to quantifying the greenhouse gas (GHG) impacts of implementing activities to reduce emissions from deforestation and degradation in developing countries (REDD). While international policies and mechanisms for implementing REDD are still under discussion within the UN Framework Convention on Climate Change (UNFCCC), it is emphasized that not only reduced emissions from deforestation and degradation, but also forest conservation, sustainable forest management and enhancement of forest carbon stocks are to be included in the agreement which will be discussed during the Conference of the Parties of the UNFCCC in Copenhagen in December 2009. The UNFCCC negotiations and related country submissions on REDD have advocated that methodologies and tools become available for estimating emissions and removals from deforestation and forest land with an acceptable level of certainty. Based on the current status of negotiations and UNFCCC approved methodologies, the Sourcebook aims to provide additional explanation, clarification, and methodologies to support REDD early actions and readiness mechanisms for building national REDD monitoring systems. It compliments the Intergovernmental Panel on Climate Change (IPCC) good practice guidelines for Land Use, Land-Use Change and Forestry (LULUCF). The book emphasizes the role of satellite remote sensing as an important tool for monitoring changes in forest cover, provides guidance on how to obtain credible estimates of forest carbon stocks, and provides clarification on the IPCC Guidelines for estimating and reporting emissions and removals of carbon from changes in forest carbon stocks at the national level.

The sourcebook is the outcome of an ad-hoc REDD working group of "Global Observation of Forest and Land Cover Dynamics" (GOFC-GOLD, www.fao.org/gtos/gofc-gold/), a technical panel of the Global Terrestrial Observing System (GTOS). The working group has been active since the initiation of the UNFCCC REDD process in 2005, has organized REDD expert workshops, and has contributed to related UNFCCC/SBSTA side events and GTOS submissions. GOFC-GOLD provides an independent expert platform for international cooperation and communication to formulate scientific consensus and provide technical input to the discussions and for implementation activities. A number of international experts in remote sensing, carbon measurement and reporting/accounting have contributed to the development of this sourcebook.

Scope of the Sourcebook

This sourcebook is designed to be a guide to develop reference levels and to design a system for measurement, monitoring and estimating carbon dioxide emissions and removals from deforestation, changes in carbon stocks in forest lands and forestation at the national scale, based on the general requirements set by the UNFCCC and the specific methodologies for the land use and forest sectors provided by the IPCC.

The sourcebook introduces users to: i) the key issues and challenges related to monitoring and estimating carbon emissions from deforestation and forest degradation; ii) the key methods provided in the 2003 IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (GPG-LULUCF) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for Agriculture, Forestry and Other Land Uses (GL-AFOLU); iii) how these IPCC methods provide the steps needed to estimate emissions from deforestation and forest degradation and iv) the key issues and challenges related to reporting the estimated emissions.

The sourcebook provides transparent methods and procedures that are designed to produce accurate estimates of changes in forest area and carbon stocks and resulting emissions of carbon dioxide from deforestation and degradation, in a format that is user-friendly. It is intended to complement the GPG-LULUCF and AFOLU by providing additional explanation, clarification and enhanced methodologies for obtaining and analyzing key data.

The sourcebook is not designed as a primer on how to analyze remote sensing data, nor how to collect field measurements of forest carbon stocks as it is expected that the users of the sourcebook would have some expertise in either of these areas.

The sourcebook was developed considering the following guiding principles:

- Relevance: Any monitoring system should provide an appropriate match between known REDD policy requirements and current technical capabilities. Further methods and technical details can be specified and added with evolving political negotiations and decisions.
- Comprehensiveness: The system should allow global applicability with implementation at the national level, and with approaches that have potential for sub-national activities.
- Consistency: Efforts have to consider previous related UNFCCC efforts and definitions.
- Efficiency: Proposed methods should allow cost-effective and timely implementation, and support early actions.
- Robustness: Monitoring should provide appropriate results based on sound scientific underpinnings and international technical consensus among expert groups.

- Transparency: The system must be open and readily available for third party reviewers and the methodology applied must be replicable.

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GOFC-GOLD, 2009, A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation. GOFC-GOLD Report version COP15-1, (GOFC-GOLD Project Office, Natural Resources Canada, Alberta, Canada) Available at: http://www.gofc-gold.uni-jena.de/redd/

3 REVIEW OF REDD-RELATED ACTIVITIES IN THE CONGO BASIN REGION

3.1 Overview

Carbon Stocks and Land Cover Change Estimates in Central Africa - Where Do We Stand? / Etat des connaissances sur les stocks de carbone et leurs variations dans les forêts d'Afrique centrale

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Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that 1.7 billion metric tons of CO_2 are released annually to the atmosphere because of land use change and largely from tropical deforestation, dwarfing the possible impact of possible forest CDM projects. The magnitude of the emissions from deforestation not included in the Kyoto Protocol triggered the Conference of Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) to initiate a two-year process to address issues relating to reducing emissions from deforestation in developing countries. This process peaked during the COP13 in Bali in December 2007 with the Decision 2/CP.13 "Reducing emissions from deforestation in developing countries: approaches to stimulate action". It is interesting to note that it took more than 10 years for the international community to accept that reducing emissions from deforestation or sequestering carbon from standing forests is more effective than through planting trees and reintroduce this topic to the international climate negotiations. Put simply, without entering into ongoing arguments about baselines or financial mechanisms, the idea behind REDD is to provide financial incentives to help developing countries voluntarily reduce national deforestation rates and associated carbon emissions below a baseline. Countries that demonstrate such reduced emissions would be able to sell carbon credits on the international carbon market or receive financial compensation in one way or another for their good behavior.

No matter which final REDD mechanism is chosen, we will need to know as accurately as possible how much carbon (C) is:

- stored in different vegetation types (above and below ground),
- stored in the other C pools (litter, dead wood matter and soil), and
- released through AFOLU (agriculture, forestry and other land use) activities.

What information is available and what is missing?

Available:

- Land cover and land use changes derived from remote sensing (wall-to-wall or sampling based)
- Generic allometric equation for the estimation of aboveground tree biomass

- Inventory data: Permanent Sample Plots, management inventories for several million hectares of forest concessions

Missing or largely inadequate:

- Agreed vegetation typology across the region
- Agreed methods for the measure of forest degradation
- Inventory data specifically collected for carbon stocks assessment: soil and belowground carbon, dead wood matter, litter
- Allometric equations specifically designed for the region by vegetation or land-cover types
- Adequate field data for vegetation outside of forest concessions or protected areas (peri-urban areas, wetlands, flooded forests, montane forests, etc.)

The available and ad-hoc estimates of the other information needed were used in the State of Forest 2008 and the reader can refer to those for more details.

About errors and uncertainties

Most of the estimates of C stocks in living vegetation are calculated on an unacceptably small area of permanent sample plots (probably less than 300 ha for the whole region) and/or calculated by allometric equations derived from an even smaller sample of destructive biomass studies and extrapolated to use extensive forest inventories, which were never designed to assess biomass but instead commercial volume. The uncertainties in building a biomass equation, in deriving biomass using plot or inventory data are numerous and significant. It is even more complicated to estimate the propagation of these errors from one stage of the biomass evaluation process to another and to the final result. The relation is not simple, errors being additive or multiplicative and though some errors might compensate, the confidence interval of any biomass estimation is likely to be disturbingly large.

The use of satellite data has undoubtedly increased the accuracy of forest maps and of forest-cover change estimates. However, uncertainties remain in the current datasets and affect the overall accuracy of estimations. New techniques and datasets that have been tested are still part of the research domain (like radar sensors). Forest cover changes occur at a very fine scale and require the use of time-series of fine spatial resolution images. The methods available (spectral differences wall to wall, image segmentation on a limited sample) can be affected by several sources of errors (underestimation of subtle changes, inadequate sampling).

The direct assessment of carbon stocks by remote sensing still suffers from errors due to the absence of clear and understandable relationships between parameters influencing the carbon amount and the spectral and backscattering properties in the optical and radar domains. Although these relationships have been demonstrated in the savanna domain with low to medium biomass, the radar signal saturates at high biomass levels and the other parameters influencing the spectral properties of the vegetation (moisture, slope, leave structure…) lead to significant instability in carbon estimates. New techniques such as LIDAR can improve the quantification of carbon stock changes during logging operations, but there is still a need for more investigation before that technology may provide reliable figures.

Where are we now in our estimates for the region?

Carbon stock estimates for the region

Based on the available information on C stocks in soil and vegetation and on land-cover classes, the estimated C stored for the region is 46 billion Mg. An estimate by country and a comparison with existing published literature is given in table 1.

Table 1. Estimates of carbon stocks for the region and countries by land cover types (millions of tons).

	Cameroon	Congo	Gabon	Eq. Guinea	CAR	DRC	Congo Basin
1. Closed evergreen lowland forests	3,162	2,762	4,029	379	886	16,082	27,299
2. Swamp forests	0	501	2	0	0	1,000	1,761
3. Sub-montane forests (900-1,500m)	39	0	2	4	0	857	770
4. Montane forests (>1,500m)	2	0	0	0	0	117	119
Total humid forests (1-4)	3,203	3,263	4,033	383	886	18,056	29,949
Mosaic forest / croplands	414	534	287	57	167	1,945	2,791
Mosaic forest / savanna	628	145	20	3	2,437	3,059	3,955
Closed deciduous forest	6	73	10	0	54	1,625	3,403
Deciduous woodland	684	6	2	1	1,658	1,812	4,149
Open deciduous shrubland, sparse trees	108	199	31	0	258	760	1,770
Total	5,043	4,219	4,383	445	5,460	27,258	46,016
Total (Gaston *et al.* 1998)	3,131	2,822	3,892	349	3,740	16,316	-
Total (Gibbs *et al.* 2007)	3,454 - 6,138	3,458 – 5,472	3,063 – 4,742	268 – 474	3,176 – 7,405	20,416 – 36,672	-

Emissions

Based on the estimation of deforestation between 1990 and 2005 (about 43,000 km2) and on the average C stock of dense humid forests (147 Mg/ha without considering the fate of the Soil Organic Carbon (SOC)), we can estimate that the region has released approximately 0.63 billion Mg of C in 15 years. This is still a crude estimate based on available information and not considering the wood C life cycle.

No matter which REDD mechanism is adopted we will need to be able to assess carbon changes linked to specific AFOLU classes. This is still largely impossible in the Congo Basin due to the lack of comprehensive studies on the effects of land use changes on carbon stock pools. Some preliminary and pioneer studies, however, do exist that provide us an idea of the relative magnitude of the primary potential cases. Using published and unpublished data we have been able to plot variations of C from aboveground living biomass pools for five land use systems:

1. High-grade selective logging (one species, *Entandrophragma cylindricum*, constituting 95% of the logged individuals) in a semi-deciduous rainforest managed with a 30-year rotation (LOG_EXT)
2. Intensive selective logging in a large-scale permanent sample plot, same forest type as above but with a higher logging intensity (LOG_INT)
3. Secondary succession in an area that was slashed and burned to plant dry rice, abandoned and reverted to 40 year old secondary forest (SECSUC)
4. Oil palm plantation (130 plants/ha), with re-planting every 20 years (OILPAL)
5. Complete 20-year shifting cultivation cycle in Southern Cameroon (SHICUL)

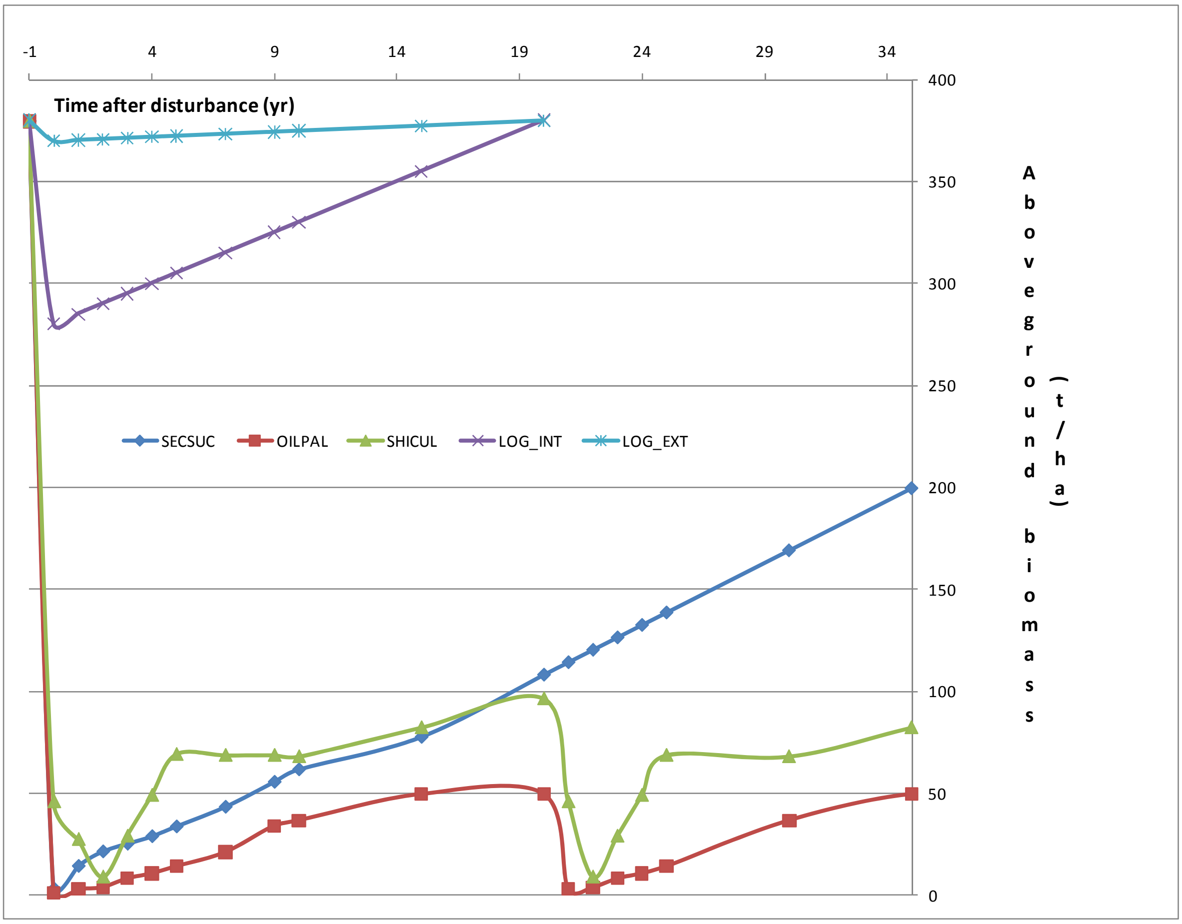

Figure 1. Temporal evolution in aboveground living biomass of different land use systems.

Figure 1 shows that except for selective logging and secondary succession after 20 years, the overall aboveground living biomass following disturbance remains below 100 Mg/ha. This does not take into account the dead wood and litter carbon pools but these are small (except for some shifting cultivation stages where many unburned logs remained on the forest floor) and come essentially from the aboveground tree C pools. Oil palm plantations and shifting cultivation, unless abandoned and left to revert to forest, represent a loss of about 70-90% of the original forest C stock. The two logging examples show a full biomass recovery in about 20 years. This does not mean however that the C stock will have reconstituted to the same level, as some of the growth could be composed of fast growing light-demanding trees with lower specific densities or of smaller-size shade-tolerant species. It also does not imply that forest quality will have fully recovered after 30 years, as forest composition, structure and functioning will still be recovering after such a time period.

These examples demonstrate the magnitude of C-pool variations to be expected for the most frequently encountered land use systems in the Congo Basin region. Agriculture, traditional or modern, seems to be the by far biggest potential emitter of C as opposed to selective logging as practiced in the region. It appears that in complement to protected areas, allocating a permanent forest estate under Sustainable Forest Management practices using controlled selective logging will contribute significantly to the reduction of emissions from deforestation as well as provide an economic value to the forest.

Overview of REDD projects/ carbon quantification in Central Africa - Survey Results / Aperçu des Projets REDD et/ou de Quantification du Carbone Forestier en Afrique Centrale

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Introduction

Les forêts du Bassin du Congo sont au cœur de nouveaux enjeux de services environnementaux. En particulier, les négociations autour du changement climatique et du rôle des forêts dans la régulation du climat sont de première importance pour les pays de la COMIFAC.

De nombreux projets de recherche et de développement ont récemment été initiés sur ces sujets, couvrant à la fois la sphère scientifique d'estimation des stocks et des flux de carbone et la sphère politique de rétribution de ces services. Devant cette abondance de projets non concertés, le risque existe qu'il y ait (i) redondance dans certains domaines, ce qui en soi permet de corroborer les résultats, mais aussi (ii) absence d'activités de recherche dans certains domaines cruciaux. Des résultats qui seraient trop différents entameraient considérablement la crédibilité de la région.

La COMIFAC a donc décidé de lancer un exercice systématique d'identification des projets existants ou planifiés, ayant pour sujet général le processus REDD en Afrique Centrale, que ce soit en amont pour l'estimation des surfaces affectées par les changements de couvert forestier et l'évaluation des stocks de carbone, ou plus en aval sur les mécanismes de rétribution de ces services environnementaux.

A cette fin, la COMIFAC a demandé à l'OFAC d'entreprendre la mise en œuvre et le suivi d'une enquête sur les projets REDD, les projets MDP liés à la forêt et les études sur la quantification du Carbone en Afrique centrale. L'objectif est d'identifier dans la mesure du possible toutes les initiatives dans l'espace COMIFAC dans ces domaines. Etant convaincue que l'échange d'informations scientifiques ne peut que bénéficier à tous les pays de la région et aux équipes scientifiques qui réalisent les différents projets, la COMIFAC souhaite la publication des projets sur le site de l'Observatoire (www.observatoire-comifac.net) qui doit en outre permettre la bonne visibilité des équipes de recherche et garantit la paternité des résultats scientifiques.

Méthode

L'inventaire des projets a débuté par le lancement d'un questionnaire destiné aux promoteurs de projets identifiés comme contributeur important dans ces domaines. Les questions posées portent sur les objectifs et les priorités, les régions d'étude, les partenaires techniques, institutionnels et financiers, le budget, les données spatiales et de terrain utilisées, les méthodes développées, les résultats attendus, etc. Le questionnaire a été envoyé sous forme de fichier texte à compléter, mais il convient à l'avenir de le rendre disponible directement à travers une interface internet. De cette manière, cela permettra de rendre les projets directement visibles à la communauté internationale à travers un site internet dynamique mis à jour au fil des questionnaires remplis en ligne ou retournés à l'OFAC.

Résultats

A ce jour, 14 questionnaires ont été remplis par 14 promoteurs de projets différents. Près de la moitié des promoteurs font partie d'ONG (6). Les autres promoteurs sont des centres de recherche (3), des bureaux d'études (2), une Université, une Administration nationale et un bailleur.

La première partie du questionnaire demande au promoteur d'identifier par ordre de priorité les domaines d'activité parmi un choix de 9 domaines dans lequel s'inscrit son projet. Le tableau 1 montre la synthèse des réponses à cette première partie du questionnaire.

Tableau 1. Synthèse des domaines d'activités prioritaires de 14 projets liés à la REDD et au carbone forestier en Afrique centrale. La deuxième colonne reprend le nombre de réponses obtenues par domaine d'activité, la troisième comptabilise le nombre de fois que le domaine d'activité a été identifié comme prioritaire.

Domaine d'activité - plusieurs réponses possibles, avec ordre de priorité (1 étant la plus haute)	Nbre Réponses	Priorité 1
Suivi du couvert forestier (déforestation et dégradation)	9	9
Mesures des stocks de carbone	9	6
Dynamique forestière	5	2
Modélisation des dynamiques forestières (dont scénario de référence)	7	3
Contexte Institutionnel et Politique	7	4
Renforcement des capacités nationales et transfert de technologie	10	5
Promotion de la participation des communautés locales	9	4
Projet de terrain ayant un potentiel REDD (projet permettant la réduction des GES liées à la déforestation et la dégradation sans composante MRV)	2	0
Projet Pilote REDD (projet visant la réduction mesurable et vérifiable des émissions de GES liés à la déforestation et à la dégradation forestière)	4	2

Les principaux enseignements que l'on peut retirer de l'analyse de ce tableau sont que:

- le domaine « Suivi du couvert forestier » est cité dans 9 cas sur 14 mais il est aussi à chaque fois reconnu comme prioritaire (100% des réponses) et arrive en tête des considérations prioritaires,

- la mesure des stocks de carbone est le deuxième élément qui ressort comme prioritaire et également cité dans 9 cas sur 14. Ce qui est une bonne chose vu l'état des faibles connaissances actuelles sur la quantification des stocks de carbone forestier et des flux associés,
- le renforcement des capacités et le transfert de technologie est un sujet traité dans 10 projets, mais pour la moitié de ces projets n'est pas considéré comme prioritaire.

Le formulaire contient également une zone de texte libre pour la description des objectifs des projets. Ceux-ci rejoignent les éléments repris dans le tableau 1, mais sont bien plus explicites quant aux buts poursuivis. Sans retranscrire les textes in extenso, la liste ci-dessous en reprend les grandes idées :

- Renforcement des capacités
- Garantir le droit des populations locales
- Aide à la négociation, aide à la compréhension du REDD
- Faire la démonstration d'un projet pilote REDD
- Remplacer des sources d'approvisionnement en bois de chauffe
- Modéliser les émissions de GES du fait de la déforestation
- Établir des scénarii de référence
- Elaborer une méthodologie de télédétection validée pour implémenter le REDD
- Améliorer la cartographie de l'occupation du sol

Comme déjà mentionné par l'analyse du tableau 1, la quantification des stocks et l'estimation des flux de carbone sont des préoccupations majeures de la part des promoteurs. Tous font état d'un manque important de connaissance à ce niveau. Ils déclarent utiliser la télédétection pour leurs études (7 d'entre eux) et/ou avoir des activités de terrain (6 d'entre aux), notamment pour l'établissement d'équations allométriques spécifiques pour la région, ce qui est reconnu unanimement comme étant un manque d'information important pour l'estimation des stocks de carbone. Cinq projets font état d'analyse combinant à la fois des données provenant d'inventaire de terrain et des images satellites. Il convient de noter que les promoteurs qui font usage d'images satellites font tous usage de données satellites à haute résolution spatiale, y compris les projets à portée régionale qui pour certains les utilisent en combinaison avec des images à base résolution spatiale, mais haute résolution temporelle.

Les promoteurs des projets ont pour la plupart établi des partenariats avec des acteurs locaux. Sont cités la COMIFAC (2 projets), les Ministères et administrations nationales (5 projets) et les universités (2 projets). Il est à noter, dans ce dernier cas que les promoteurs ont mentionné l'Université de Kisangani (RDC), qui pour le moment canalise beaucoup d'initiatives en termes de renforcement des capacités.

La localisation des projets

En termes de localisation des projets, il convient de distinguer trois niveaux d'intervention : (i) le niveau régional (exprimé par exemple par « l'ensemble des pays de la COMIFAC », ou « les pays forestiers du Bassin du Congo », notamment dans les résumés des présentations de la conférence), (ii) le niveau national, quand un projet concerne un ou deux pays entier et (iii) le niveau local, quand un projet porte son activité sur une zone limitée (une aires protégées, une concession forestière, une province, etc…). Le but de la représentation cartographique de la figure 1 est bien sûr d'une part de localiser les interventions en Afrique centrale, mais surtout de montrer pour les 10 pays de la COMIFAC les lieux de concentration des projets REDD. Les projets comptabilisés pour la figure 1 sont d'une part ceux pour lesquels des formulaires ont été remplis, mais aussi les projets dont un résumé avait été reçu lors de la préparation de la conférence de Brazzaville. De ce fait le nombre de projets cartographiés dépasse les 14 projets recensés lors de l'enquête.

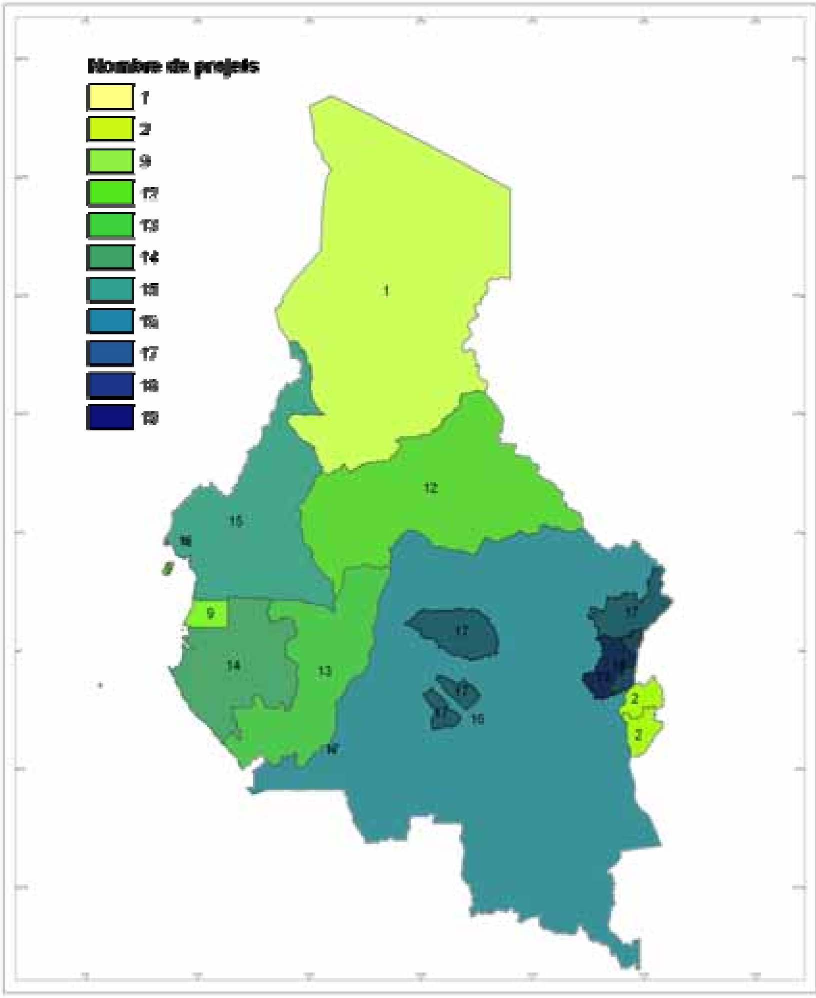

Figure 1. Localisation des projets recensés dans l'espace COMIFAC. Les chiffres correspondent aux nombre de projet recensés pour une même zone. Les couleurs foncées traduisent un nombre de projet plus élevé que les couleurs claires.

On remarque que la RDC est non seulement le pays qui reçoit le plus d'attention pour le REDD (suivi par le Cameroun, le Gabon puis le Congo), mais aussi celui où les projets à l'échelle locale sont les plus présents.

Les budgets

Les montants consacrés au REDD pour 12 des 14 projets, sont repris à la figure 2. Certains projets sont totalement orientés vers des perspectives générales de réduction d'émission de gaz à effet de serre, d'autres dépassent le cadre du REDD mais présentent des volets spécifiques y consacrés. Cela se traduit par une différence des montants alloués aux activités « REDD ». De manière générale, on retrouve des projets à petit budget (inférieur à 500.000 USD) et des projets à budget conséquent proche des 2. 000. 000 USD ou plus.

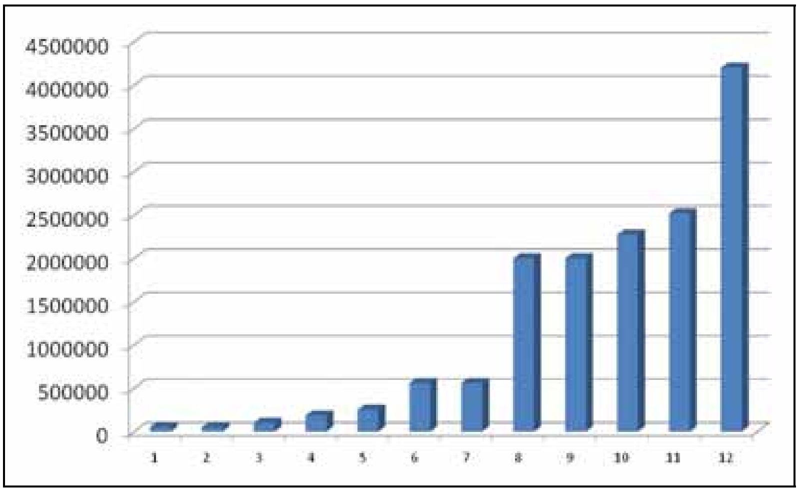

Figure 2. Budget consacré au volet « REDD / Carbone » pour 12 des 14 projets (en US Dollars).

La moitié des projets ont une source de financement unique, l'autre moitié fonctionne avec des systèmes de cofinancement. Les financements proviennent principalement et sans surprise des bailleurs de fonds internationaux (7 projets), mais aussi de Fondations (2), organismes privés (2) et des fonds propres (1).

Conclusions

Cette enquête basée sur l'analyse de 14 répondants apporte des enseignements intéressants. Notamment, l'analyse des objectifs mentionnés montrent que les aspects techniques et scientifiques liés au REDD sont de première importance pour le succès du système. Il se fait en effet que les pays d'Afrique centrale se sont lancés tôt dans un processus de négociation alors que les chiffres en circulation pour l'Afrique centrale (tant sur les stocks de carbone que sur les dynamiques et les changements d'occupation des sols) étaient d'une pertinence et d'une précision douteuse. Les scientifiques tentent à présent de pallier à cet état de fait, mais une concertation entre eux est plus que jamais nécessaire. L'objectif de cette enquête est bien de mettre en visibilité les multiples initiatives relatives au REDD et de favoriser les interactions entre les acteurs, qu'ils soient de la sphère des scientifiques ou celle des politiques.

La place d'un Observatoire pour centraliser les informations n'est plus à démontrer. Cela est d'ailleurs inscrit dans le plan de convergence de la COMIFAC. L'OFAC a donc ce double rôle qui est (i) de recueillir les informations relatives aux projets en cours et (ii) d'analyser et diffuser les résultats et enseignements à en tirer. Cette enquête se poursuit et a l'ambition de recenser tous les projets liés de près ou de loin au REDD en Afrique centrale.

The REDD + Readiness Process in the Democratic Republic of Congo / Le Processus de préparation à la REDD+ en République Démocratique du Congo

Bruno Guay

Coordination Nationale REDD de la RDC, Ministère de l'Environnement, Conservation de la Nature et Tourisme / National REDD Coordination of the DRC, Ministry of Environment, Conservation of Nature and Tourism

De faibles taux de déforestation (0,20%) et de dégradation (0,12%)1, mais une surface boisée de 145 millions d'ha (selon la définition nationale), placent la RDC dans les 10 premiers pays qui perdent les surfaces les plus importantes de couvert forestier au niveau mondial chaque année. Devant l'urgence du changement climatique, et l'enjeu important lié au maintien des forêts de RDC, le pays souhaite s'engager rapidement dans une démarche résolument tournée vers l'action. C'est pourquoi la RDC à préparer un plan de préparation (R-PP)[2] ciblant les activités clés à réaliser au cours des 3 prochaines années. Ce plan de préparation à la REDD comporte 6 composantes principales:

- Coordination et consultation
- Stratégie REDD
- Niveau de référence et niveau de référence d'émission
- Monitoring, reporting (notification) et vérification (MRV)
- Plan de travail et budget (22 millions de dollars sur 3 ans)
- Cadre de suivi et évaluation (non traité ici)

Coordination et consultation

La préparation au REDD sera conduite par les structures nationales établies par le décret du 26 novembre 2009, à savoir pour le niveau national, un comité national, un comité interministériel et une coordination nationale3. Ce décret prévoie également la création de trois structures équivalentes au niveau de chaque province. En 2010 et 2011, un coordinateur sera mis en place dans chaque province. La participation de la société civile est cruciale à tous les niveaux, que ce soit local, provincial ou national. Des partenariats sont déjà formalisés en ce sens avec le Groupe de Travail Climat REDD de la société civile. Les capacités de l'ensemble de ces structures seront renforcées durant les 2 années qui viennent, pour leur permettre de jouer le rôle clé qui leur a été confié pour la préparation du pays et le déploiement anticipé de la stratégie nationale REDD.

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1 États des Forêts 2009

2 République Démocratique du Congo / Ministère de l'Environnement, Conservation de la Nature et Tourisme / R-PP de la République Démocratique du Congo / soumis au Fond de Partenariat pour le Carbone Forestier le 11 janvier 2010. www.forestcarbonpartnership.org.

3 République Démocratique du Congo, Primature. Décret No 09/40 du 26/11/2009 portant création, composition et organisation de la structure de mise en œuvre du processus de réduction de émissions issues de la déforestation et de la dégradation des forêts, « REDD » en sigle

Depuis la mise en place de la coordination nationale. Des consultations ont été réalisées avec une grande diversité d'acteurs : autres ministères, parlementaires, universités, organisations de la société civile, ONG internationales, partenaires techniques et financiers, etc… Des ateliers de lancement provinciaux ont déjà été tenus dans 4 provinces de façon à aboutir fin février à un plan d'action détaillé et consensuel. En partenariat avec le Groupe de Travail Climat REDD et d'autres organisations de la société civile, un ambitieux plan IEC et de consultations provinciales a également été construit pour les trois années de préparation du pays à la REDD, entre 2010 et 2012.

Développement de la stratégie REDD+

L'analyse préliminaire des causes de déforestation aboutit au constat que certaines causes de déforestation sont aussi des facteurs ralentissant le développement du pays (causes politiques et institutionnelles par exemple), alors que d'autres sont collatérales d'un développement économique (construction d'infrastructures par exemple). La stratégie nationale cherchera à adresser directement les premières, et à accompagner les secondes de façon à réduire leurs impacts négatifs sur le couvert forestier et les services environnementaux associés. Le partage d'un consensus sur les facteurs de déforestation est primordial pour mettre en place une stratégie efficace, comme pour mobiliser les acteurs du REDD autour des mêmes objectifs. Des analyses complémentaires seront donc menées pour mieux cerner les causes de déforestation et de dégradation, à la fois au niveau provincial et au niveau national, et seront partagées pour aboutir à un consensus national.

Les travaux exploratoires sur le potentiel REDD + de la RDC, conduits en partenariat avec McKinsey1 ont permis d'identifier des programmes d'actions préliminaires. Cependant, le plan d'action REDD national est bien plus qu'une série de programmes, et les travaux des trois années à venir viendront le renforcer. Une stratégie nationale consensuelle, opérationnalisée en plans d'actions, sera disponible fin 2012, suite à plusieurs études, à un travail de veille et à une série d'actions pilotes. La construction de la stratégie nationale se veut résolument opérationnelle, et nous partons du constat qu'un plan d'action doit être testé avant d'être validé. Ainsi, dès 2010, des projets pilotes sectoriels et intégrés géographiquement seront respectivement orientés ou développés pour servir de champ d'expérimentation à la stratégie nationale (voir fig.1).

Puisque le mécanisme REDD+ sera basé sur la performance, l'établissement d'un niveau de référence servant de base à l'octroi de crédits et le développement d'un système MRV (mesure, reporting et vérification) permettant de suivre l'évolution des émissions liées à la REDD sont des éléments essentiels de la préparation de la RDC.

Niveau de référence d'émission et autres niveau de référence

Le pays sera appeler à développer un niveau de référence sur la base des (1) émissions historiques, (2) des circonstances nationales et de modèles prospectifs (scénario de référence) (voir fig.2). Pour analyser les circonstances nationales le pays devra d'une part faire une analyse du contexte socio-économique du pays (emploi, éducation, santé) et valoriser les données récoltées dans les projets de terrain existants où en cours. D'autre part le pays devra conduire une analyse des besoins de développement futur, au niveau national et provincial. Ces données doivent permettre de construire et de calibrer un scénario de référence national faisant des projections des émissions. Il est obtenu à partir de techniques de modélisation ayant une composante spatiale (modèle SIG) et une composante quantitative (impact des trajectoires de

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1 République Démocratique du Congo / Ministère de l'Environnement, Conservation de la Nature et Tourisme / Potentiel REDD+ de la RDC / décembre 2009.

développement sur la déforestation). A long terme, on vise le développement d'un outil d'aide à la décision permettant de guider le développement et l'affinement de la stratégie REDD+.

Monitoring, reporting (notification) et vérification (MRV)

Le pays est aussi engagé dans le développement d'un système MRV répondant aux lignes directrices du Groupe Intergouvernemental d'Expert sur le Climat (GIEC) (voir fig. 3). Ce système comporte trois composantes principales (1) un système de suivi des terres par satellite permettant de produire les données d'activités, (2) un inventaire forestier national couvrant l'ensemble du territoire à travers des milliers de parcelles temporaires et centaines de parcelles permanentes permettant d'évaluer les facteurs d'émission et finalement (3) un inventaire national des GES au travers duquel le reporting (notification) est fait à la CNUCC.

Le développement de ces deux dernières composantes techniques (MRV et niveau de référence), s'appuiera sur les travaux de nombreuses institutions œuvrant dans l'espace COMIFAC et bénéficieront d'une coopération accrue entre les acteurs pertinents.

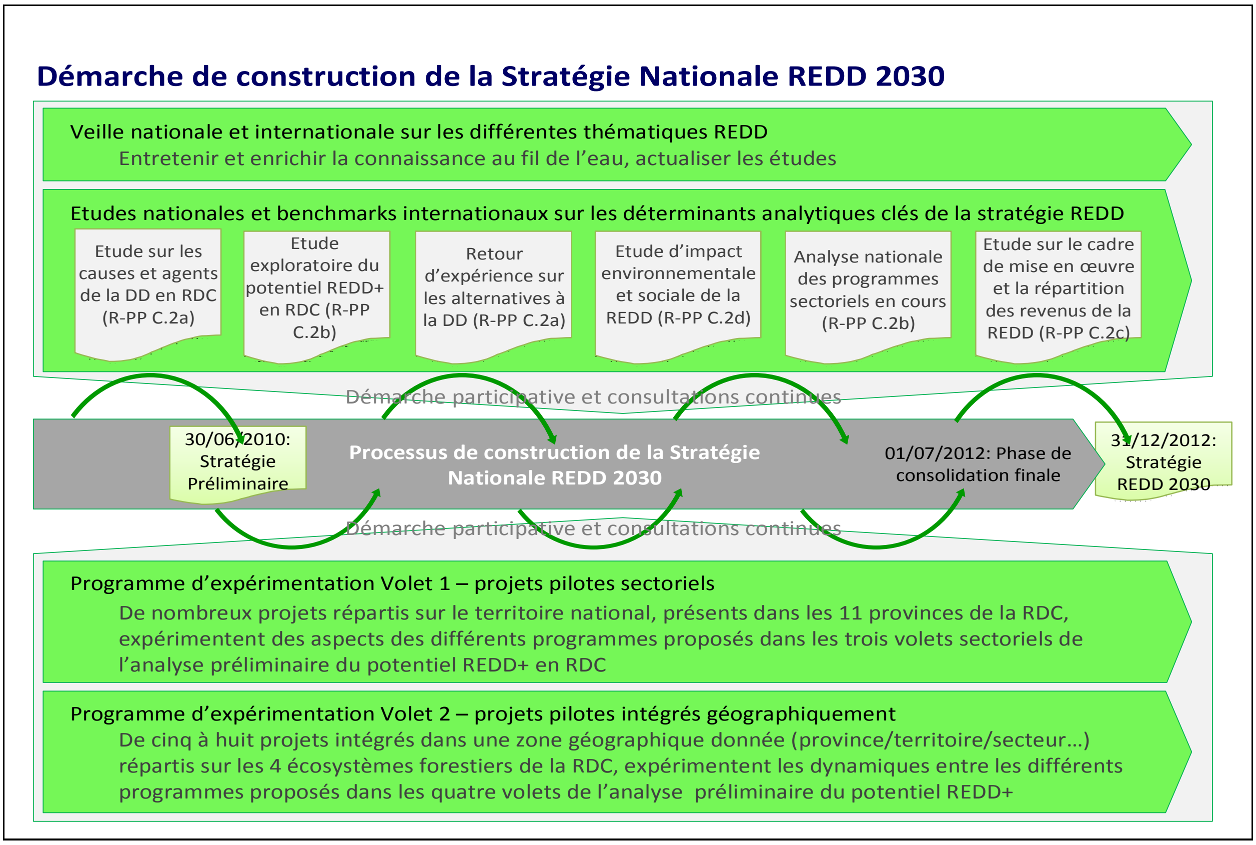

Figure 1. Le développement de la stratégie nationale.

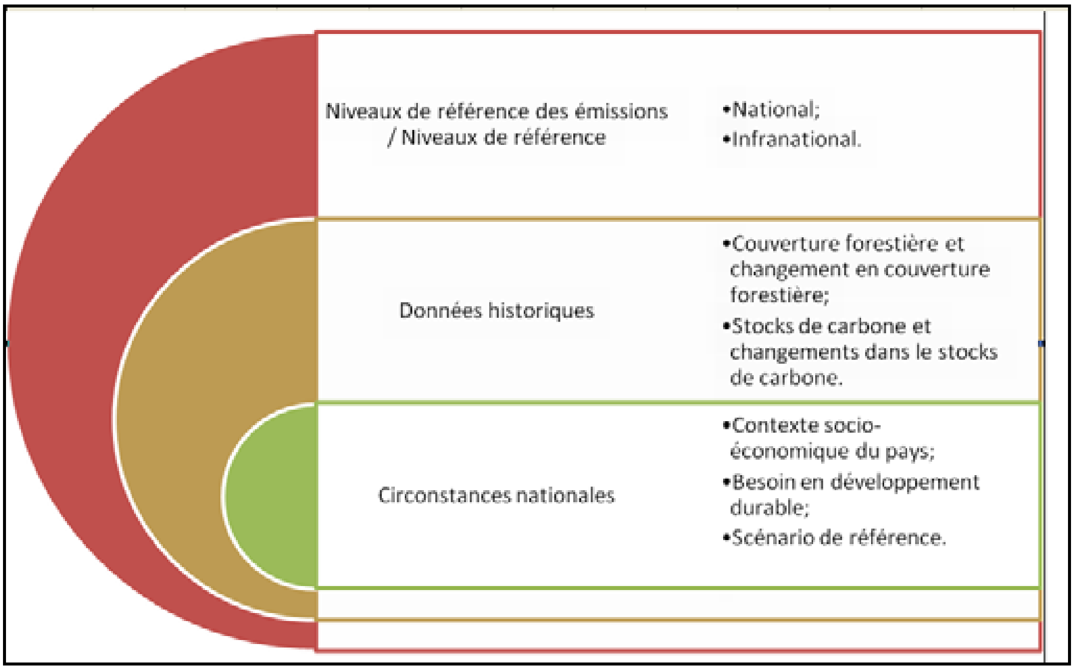

Figure 2. Le développement du Niveau de Référence.

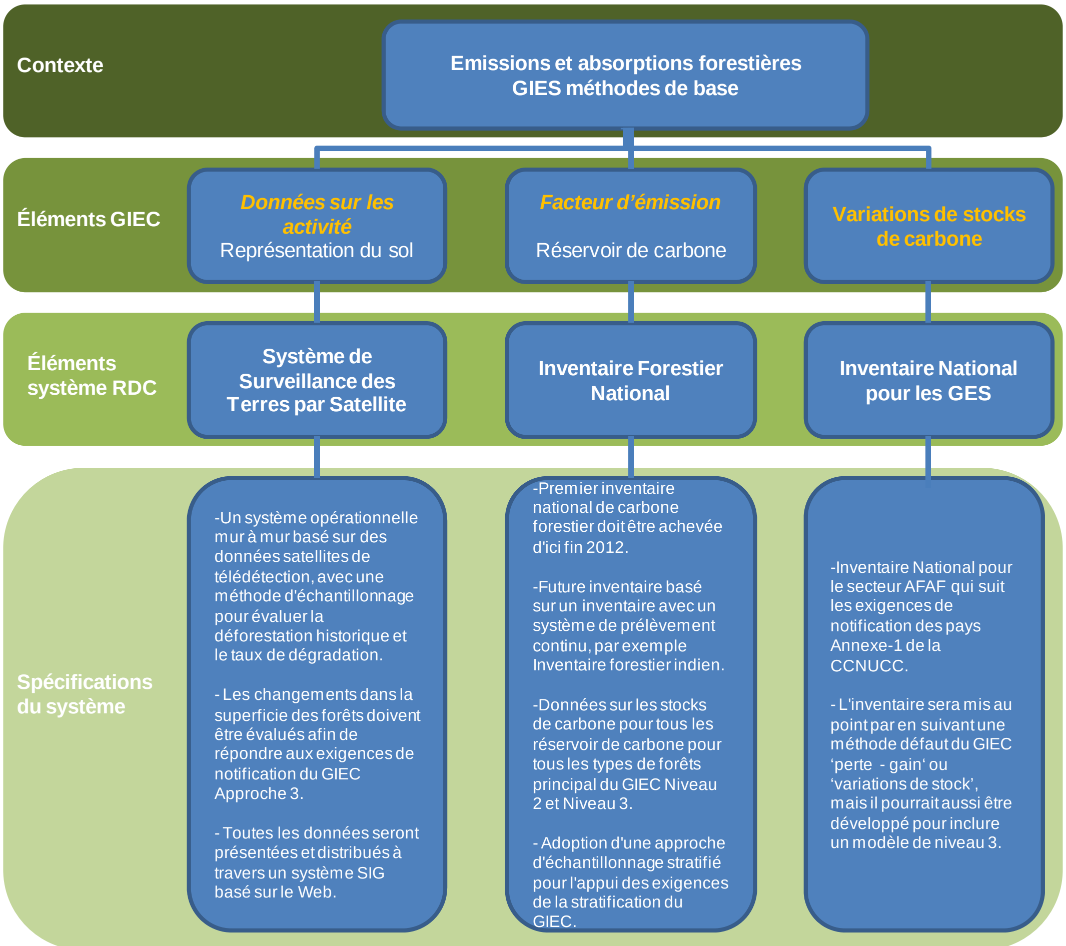

Figure 3. Le développement du système MRV de la RDC.

3.2 Estimation and Analysis of Forest Cover Change

The FAO Global Forest Resource Assessment 2010 Remote Sensing Survey: Monitoring Tree Cover and Forest Area Change Globally from 1990 to 2005 / Application dans le cadre du FRA

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Background and context

Change in the extent of tree cover and forest is a critical variable in quantifying carbon fluxes globally. To provide statistically valid, regional information on forest cover change, the Global Forest Resource Assessment 2010 (FRA2010) is implementing a comprehensive Remote Sensing Survey (RSS) in partnership with national experts, the European Commission's Joint Research Centre (JRC), the Université Catholique de Louvain (UCL) and the South Dakota State University (SDSU). As part of the RSS, a Central African regional remote sensing survey validation workshop was held as a side event to the main carbon monitoring meeting. Participants at the workshop validated the land use classification for selected sample sites within their country. The document below describes the remote sensing survey in general terms and global context.

Introduction

The Food and Agriculture Organization of the United Nations (FAO) has provided detailed information on the world's forests, their condition and their uses, at 5 to 10 year intervals since 1946, based on data that countries provide to FAO in response to a questionnaire. FAO compiles and analyses the information and presents the current status of the world's forest resources and their changes over time as part of the Global Forest Resources Assessment (FRA). Historically, FRA reporting has evolved to reflect the major issues of concern at the time. Early reports focused on timber stocks in response to post-war needs for building materials while more recent emphasis has shifted to deforestation and conservation issues.

Forest cover dynamics change on local to regional scales but contribute to local, regional, and global impacts on climate, biodiversity and ecosystem services. FRA reporting provides data on tree cover and forests to policy makers, scientists and civil society that document these dynamics on national scales. Historically, however, the quantity and quality of data available for reporting varies widely on a country-by-country basis. Forest definitions change from place to place based on national definitions, cultural values and the purpose of the assessment and the methodology used. Many countries also lack consistent, historical records and technical or financial capacity to adequately report on changes in forest area over time.

The Global Forest Resource Assessment 2010 (FRA2010) is implementing a comprehensive Remote Sensing Survey (RSS) in partnership with national experts, the European Commission's Joint Research Centre (JRC), the Université Catholique de Louvain (UCL) and the South Dakota State University (SDSU). Satellite remote sensing offers the advantage of broad area coverage, systematic observations, and the ability to use standardized, repeatable analyses to characterize the Earth's surface. It is one of the only comprehensive sources of information available for many of the large, forested areas on Earth. Though remote sensing does not replace the need for field-collected data, it offers distinct benefits when conducting large-area surveys for broad vegetation-type categories.

The RSS will examine both land cover and land use globally through a systematic sample of remotely sensed imagery. Land cover refers to the biophysical attributes of the Earth's surface and can be directly detected from a remote sensing instrument; e.g. tree cover – or land occupied by tree vegetation in quantities detectable by the instrument used. Land use involves a human dimension or purpose characterizing a location and is typically only verified with local, expert knowledge or data collected from field inspections, e.g. forest cover. Accurate information on land use is critical to understand the drivers of forest cover change and help develop effective policies and strategies to reverse forest loss. By incorporating both land cover and use, the remotely sensed imagery and classification process of the RSS will more adequately describe both physical tree cover and the variably defined 'forest area'.

Methods

Pre-processing, segmentation and classification

The RSS sampling grid consists of 13 689 systematically distributed sites at every intersection of land-based latitude and longitude between 75 degrees North and South in latitude (Figure 1). The JRC will process nearly 4 000 sample sites pan-tropically and the FAO will process the remaining sites globally. The United States Geological Survey's Landsat Global Land Survey dataset (GLS) provided the imagery data for interpretation and classification. The GLS is a spatially consistent dataset composed of the single best Landsat image acquisition covering most of the Earth's land surface and centered on the years 1975, 1990, 2000, and 2005[2]. Complementary satellite imagery (Landsat TM, ASTER, IRS) provided by space agencies (INPE-Brazil, GISTDA-Thailand, Geoscience-Australia and ISRO-India) or acquired through satellite image providers has been used to fill a number of gaps (clouds, missing data) existing in the initial Landsat GLS database. The initial focus of the RSS is the GLS1990, GLS2000 and GLS2005 datasets.

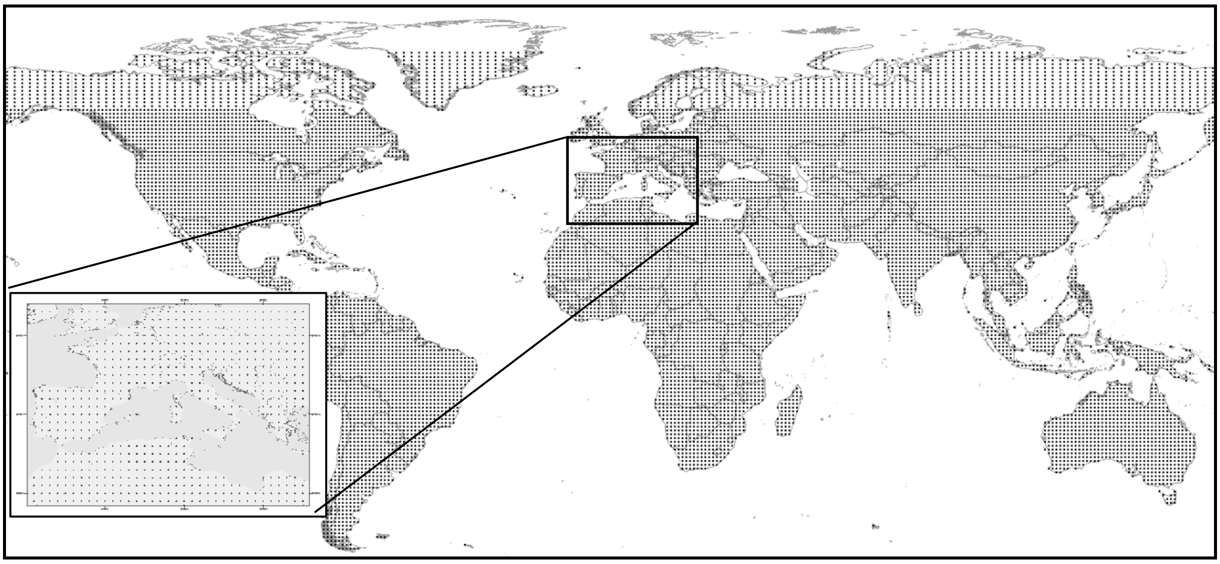

Figure 1. Distribution of the 13 689 FRA 2010 RSS global survey sites. FAO designated tiles are shown in blue and JRC designated tiles are in yellow. Inset shows detail of sample sites across Europe, N. Africa.

For each survey tile, Landsat optical bands 1-5 and 7 (also 8 in the case of ETM+) of the GLS acquisitions were compiled. These were clipped to a 20km by 20km box centered on each one-degree latitude and longitude intersection to create imagery 'chips'. This produced 56 219 individual imagery chips for the three time periods. The central 10km by 10km box of each sampling tile will be used for area calculations and statistical analysis. Additional imagery inputs for each chip include a cloud mask, water mask, and data/no data mask.

The RSS used a multi-date, multi-resolution image segmentation approach and a nominal minimum mapping unit of 5 hectares to classify each survey tile. Normalized Landsat bands 3, 4, and 5 from the GLS1990, 2000, and 2005 datasets are used for producing the image segments (or polygons). Image segmentation was performed using the commercially available software e-Cognition3. The result was a single polygon layer containing information from the different time periods of imagery. The polygon layer was classified separately for each time period using Landsat optical bands (1-5 and 7), resulting in three land cover maps representing 1990, 2000, and 2005. Changes in land cover over time are captured in the polygons and reflected in changes in land cover labels.

Following land cover classification, a land use label was automatically assigned to each polygon. The FAO-developed Land Cover Classification System (LCCS)4 has been adapted for labeling polygons by land cover and includes five land cover classes (plus no data). Nine land-use codes have been developed for use in the RSS based on FRA definitions. See table 1 for a list of land cover and land use categories used in the RSS. Where there is a change to/from forest, a more detailed land use and cover classification of the "other land" category is undertaken. The main purpose of labeling polygons by land use is to assess forest area change and the major drivers of these changes.

Table 1. Land cover (left column) and land-use (right column) classes to be used in the RSS. Grey-shaded classes represent a more detailed level of classification to be labelled where possible.

Land Cover Class	Land Use Class
Tree Cover	Forest
Shrub Cover	Other wooded land
Herbaceous / Other	Other land with tree cover
	Grass and herbaceous cover
	Agricultural crops
	Built up habitation
	Bare land
Wetlands	Wetlands
Water	Water
No data	No data

Validation

Polygons, pre-labeled with land cover and use attributes, and the remotely sensed imagery will be provided to countries and regional experts for validation. Polygon labels will be checked for accuracy by national experts against each time period of imagery. Ancillary, country-specific data sets (such as forest inventory and vegetation type maps where available) and qualitative information obtained from the Degree Confluence Project (www.confluence.org), Panoramio™ and Google Earth™ will also be used for validation.

Results and discussion

The expected results of the RSS include summary statistics of tree cover and forest area change at global and regional spatial scales. Forest area changes both positive (afforestation or natural expansion) and negative (deforestation) between time periods will be summarized by global ecological zones and at regional levels. Where forest areas have changed to other land uses or vice-versa, the land use change over time will be further analyzed to provide insight into the main mechanisms driving the changes. Pan-tropically, the FAO will rely on the results obtained by the concurrent TREES-3 research programme of the JRC.

The RSS is a globally comprehensive, systematic sampling approach covering one percent of the land surface of the Earth. Systematic sampling of medium spatial resolution imagery was chosen as a solution that achieves manageable data volumes, comprehensive coverage of sample plot locations, and returns statistically valid results at regional and global spatial scales. Landsat data was chosen as the preferred data source for the FRA RSS because it has a suitable pixel size (30m) to detect small patches of forest change and because it has the best historical archive of global data7. The commendable decision in 2008 by the USGS to open the entire Landsat archive for free use overcomes one of the major historical limitations to use of these data.

FAO and its partners is working closely with remote sensing and forest inventory specialists in national governments and with a wide range of non-governmental organizations to complete the RSS. The analysis and validation of land cover and use will benefit greatly from individual country contributions including national data and local knowledge to help ensure accurate results. FAO and JRC will provide computer software free of charge to all participating countries for viewing the imagery and labelling land cover and land use changes. The access to free remote sensing data and software will particularly benefit developing countries with limited forest monitoring data or capacity.

FAO has also built a web-based data portal to facilitate public access to the Landsat imagery used in the survey (http://geonetwork4.fao.org/geonetwork/srv/en/fra.home). Password protected download and upload capabilities are provided to all participating countries enabling them to access and store the results of validation work as it is completed. Upload of ancillary data such as photographs or other information is also facilitated. The RSS is scheduled for completion by the end of 2011, in the International year of Forests.

Conclusion

The FRA 2010 Remote Sensing survey is a systematic, comprehensive, global study of tree cover and forest land-use changes from 1990 to 2000 to 2005. It presents a consistent methodology for monitoring forest change at a global level that can be expanded for more detailed studies.

It is expected that the survey will improve understanding of total forest area changed and the processes driving forest cover change globally. This is information that governments, land managers, researchers and civil society groups can use to make better-informed decisions regarding the world's forest resources.

If countries choose and have the resources to do so, the methods have the potential to form a platform for developing more detailed reporting capabilities at a national level such as those required on land use and land use change for the UN Framework Convention on Climate Change and the Kyoto Protocol and the REDD mechanism currently being negotiated.

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Observatory of Central African Forests: National and Regional Estimate of Forest Cover and Forest Cover Change for 1990, 2000 and 2005 / La cartographie forestière et le changement d'occupation et utilisation du sol: Description de la méthodologie

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Introduction

Tropical forests, although covering less than 10% of the total land surface of the Earth, represent the largest terrestrial reservoir of biological diversity[1], changes in these biome have major impacts on climate change and biodiversity loss. The Congo Basin hosts the second-largest contiguous block of tropical forest after the Amazon[2]. To assess these impacts, dynamic forest cover change is more than ever a challenge. Today, optical earth observations methods are fully operational for forest type definitions, mapping and forest cover changes over local scale. National and international decision makers need reliable, objective, verifiable according to international standards and up-to-date information to define and monitor forest policies and to report to international conventions. Only satellite images can provide enough information on processes such as deforestation at the scale of Congo Basin. In this context the Observatory of Forests of Central Africa (OFAC) and the Forest Resources Assessment (FRA-2010) led by FAO, invited each country to work together to estimate forest cover changes for years 1990-2000-2005 (and later 2010).

1 Duveiller et al., 2008

2 FAO, 2009.

Methods

Pilot Study

Based on 390 sampling sites (10*10 km) systematically-distributed every 0.5° over the whole densely forested areas of Central Africa, a pilot study has been conducted by Duveiller et al.[1] to detect forest cover change for 1990-2000. The approach adopted to analyze these extracts was partly automated (multi-date segmentation and unsupervised classification) and partly manual (interactive labeling). The deforestation rate obtained by this study and combined with the one from Hansen et al.[1] has been published in State of the Forest 2008[2].

Operational results

Selection and pre-processing of imagery

The study consists of 1168 samples of Landsat/Aster extracts at 30 m spatial resolution of 20 x 20 km systematically distributed every 0.5°. Due to the lack of data on cloudy regions, Equatorial Guinea and Gabon was over-sampled every 0.25°. The satellite imagery for around years 1990, 2000 and 2005 have been selected and pre-processed by Joint Research Centre (JRC). Four important steps have been realized: imagery selection, radiometric calibration, correction for haze and a cloud and shadow mask if needed. An advanced automated data pre-interpretation have been designed and run by UCL-Geomatics. The methodology is based on precedent research of the laboratory related to change detection[3] and to Congo Basin deforestation estimates[4]. The automated pre-processing chain can be decomposed in three important steps. A multi-date image segmentation is applied on each satellite pairs or triplet; groups of adjacent pixels that show spectrally homogeneous and similar land cover change trajectories between two dates are delineated into objects with a minimum size corresponding to the minimum mapping unit (MMU)[5]. Two levels of segmentation have been implemented making sure that the smaller level is included in the largest one. The smaller level contains 95% of objects which have a MMU of 1 ha and will be used for the automated pre-labeling and the interactive interpretation by national experts. As for the largest level (95% of object which have a MMU of 5 ha), it will be used for change processes and statistics computation. The objects (1 ha MMU) delineated by the segmentation step are then classified in 20 land cover classes by an unsupervised classification. Six land cover classes are pre-labeled by the automatic chain based on old/coarse land cover maps. The resulting land cover legend is the following:

- Tree cover: the canopy density of the tree layer should be at least 10%, and tree height should be 5m or more
- Shrub cover: any woody vegetation layer of less than 5m height
- Other land cover: Contains land cover other than tree and shrub cover
- Water
- Cloud and shadow
- No data

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1 Hansen et al., 2008.

2 De Wasseige et al., 2009

3 Desclée et al., 2006.

4 Duveiller et al., 2008.

5 Achard et al., 2009

Objects considered as outliers are flagged by a statistical object-based method over two-time intervals: 1990-2000 and 2000-2005. Outputs of the automatic process are a pre-labeled land cover map for each date and a set of objects considered as changed between two dates.

A collaborative approach

Involvement of national experts is an essential part of the process. In order to enhanced capacity in the eight countries of the Congo Basin for monitoring, assessing and reporting on forests and land use changes and thanks to the positive feedback of the pilot UCL validation experience in February 2009, the OFAC team together with JRC-EU and FAO invited 15 national experts with profound knowledge on regional context and an international team (Figure 2) to validate the automatic pre-interpretation for land cover mapping and the change detection.

Figure 2. National experts and international team at the regional validation workshop in Kinshasa, 2009.

The regional validation workshop was held at the 'Ecole Régionale post-universitaire d'Aménagement et de gestion intégrées des Forêts et Territoires tropicaux' (ERAIFT) in Kinshasa (September 2009).

After few days of training, national experts started the interactive interpretation thanks to an object-based validation tool developed by JRC (Figure 3). They had the opportunity to check, adjust when needed the pre-interpretation of each sample and to verify the objects flagged as changed. 897 samples (two or three dates) were available and 443 (Figure 4) have been validated by experts thanks to an intensive and fruitful work. Because of bad georeferencing, compatibility problems with JRC-validation tool or to multi-date segmentation errors, some of the extracts points were marked as error. Few extracts have been validated in savannah areas (south of DRC, north-west of CAR) due to the priority given to forested landscape.

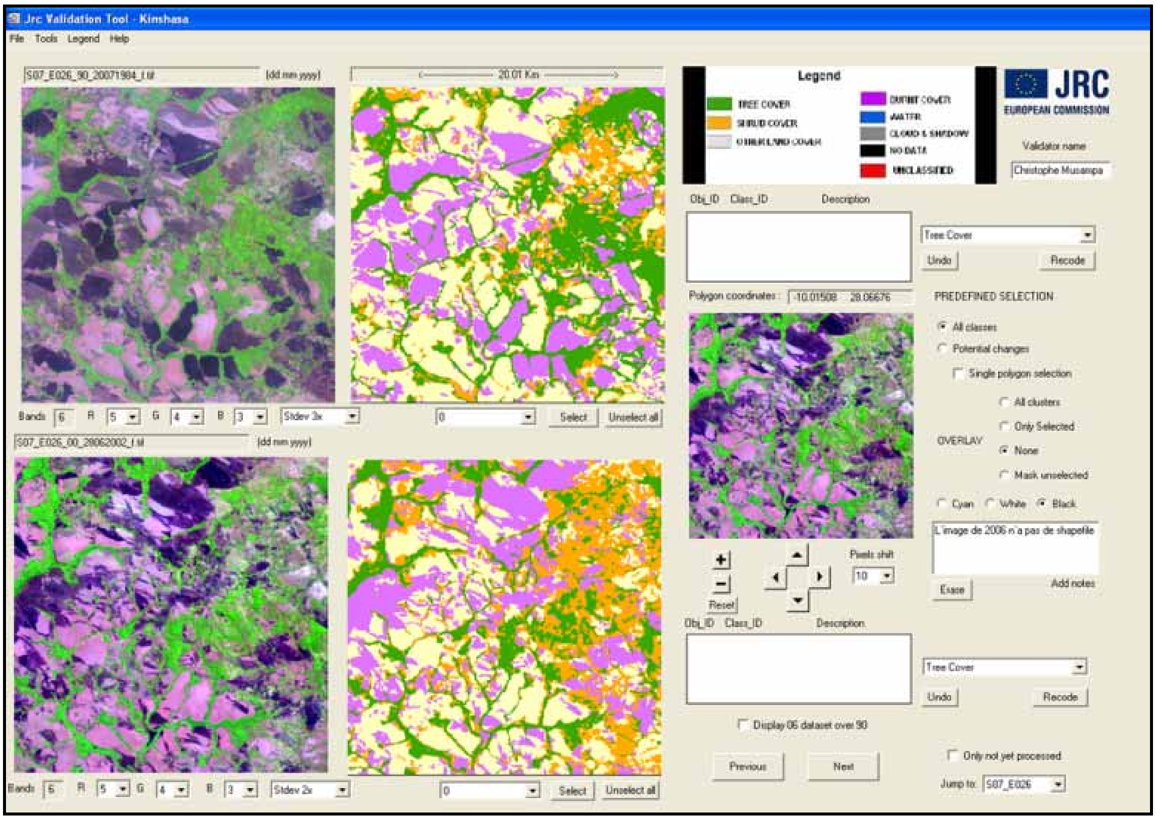

Figure 3. Object-based validation tool developed by JRC.

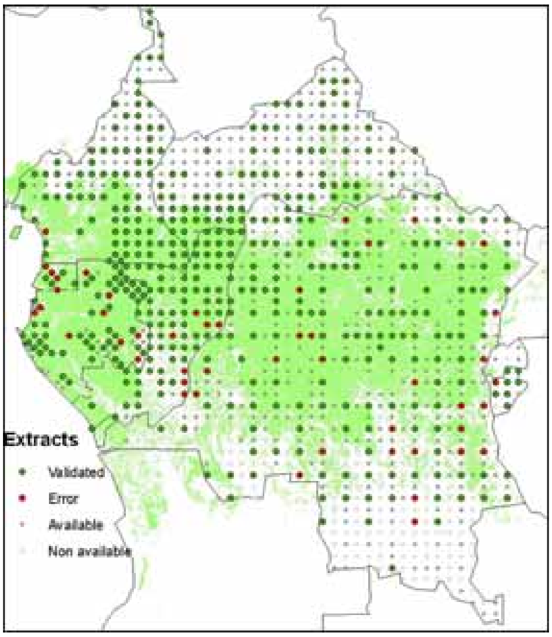

Figure 4. Data availability and validation process.

Statistics computation

This last steps leads to the final assignment of land cover labels. The land cover information of small objects (MMU of 1 ha) is aggregated into largest image-object with a MMU of 5 ha thanks to decision rules taking into account the proportion of the different land cover classes. This step allows for two additional vegetation classes:

- Tree cover Mosaic High: the ratio of tree cover area within the object (MMU of 5 ha) is between 40 and 70%;
- Tree cover Mosaic Low: the ratio of tree cover area within the object (MMU of 5 ha) is between 10 and 40%.

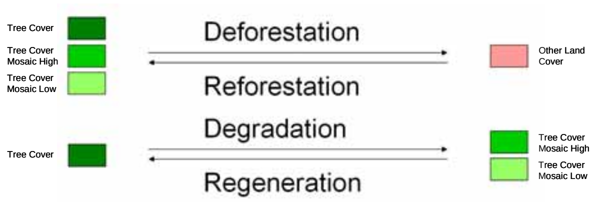

Figure 5. Forest cover change processes.

Thanks to these additional classes, complex land cover processes can be extracted. This unique exercise will estimate not only deforestation and reforestation but also degradation and regeneration (Figure 5) which are particularly important in Central Africa. Very preliminary results have been presented for forest cover change estimate using the currently available data set (Figure 6).

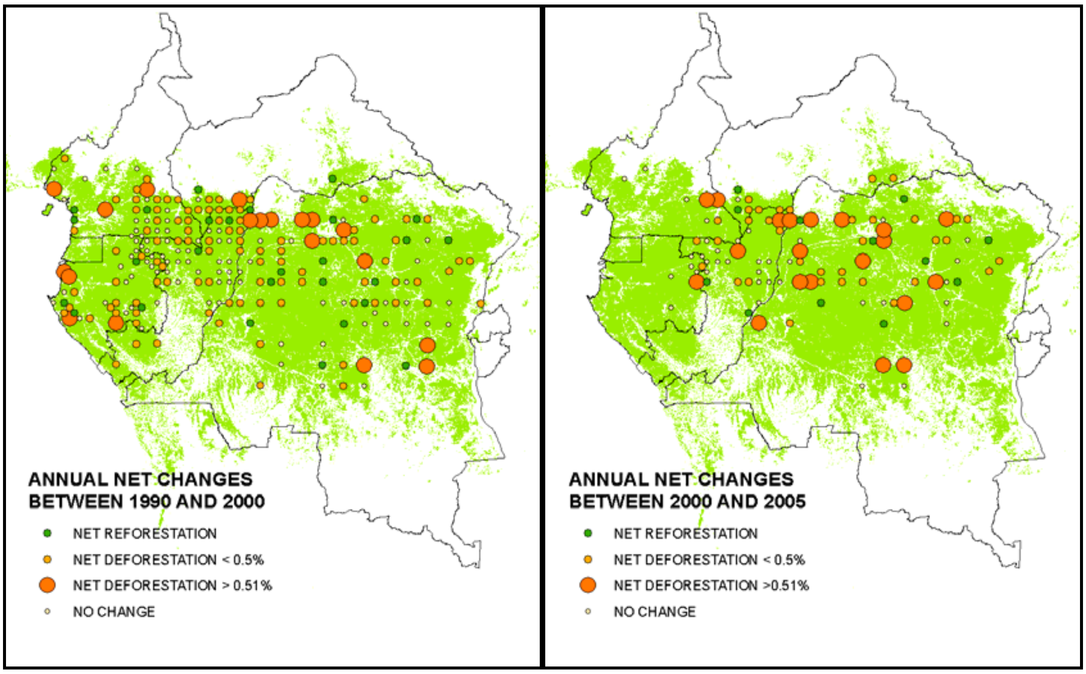

Figure 6. Preliminary forest cover change estimate.

For every sample site, the transition matrix is calculated for the two time intervals (if available), i.e. 1990-2000 and 2000-2005. Since each satellite image is not acquired at the same date but around the first of June 1990, 2000 and 2005, land cover area and change matrix are linearly extrapolated to these pivot dates.

From these very preliminary results (Table 2) only net changes (gross reforestation minus gross deforestation) have been extracted from the matrix. These results must be considered as illustrative and should not be used as they are still too many missing samples and further validation still has to be completed for the errors samples.

Table 2. Annual net deforestation rates between 1990 and 2000 and between 2000 and 2005.

	n (90-00)	Net deforestation (1990 – 2000)	n (00-05)	Net deforestation (2000 – 2005)
Central Africa	246	0.12% ± 0.03%	115	0.35% ± 0.16%

Conclusion and perspectives

A the time of this writing, only preliminary results are available but consolidated estimate for the forest biome and at national level will be available soon. This unique exercise is a combination of advanced earth observation methods and of significant contribution of national experts. . Once available, these statistics compiled by all are expected to serve as basis for discussion on the reduction of CO_2 emissions from deforestation and forest degradation (UN-REDD). This experience also demonstrates the importance of capacity building and technology transfer to countries in the Congo Basin as a necessary and feasible step for national and regional ownership.

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Results and validation tools for FRA / Résultat et outil de validation par les experts nationaux des classes d'occupation du sol et changement

Bruno Nkoumakali[1], Christophe Musampa[2]

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Introduction

Les experts nationaux en télédétection et forêts des pays du Bassin du Congo ont été conviés à un atelier de validation de l'interprétation des données de télédétection pour l'estimation et le suivi du couvert forestier à ERAIFT sur le campus de l'Université de Kinshasa en République démocratique du Congo du 28 septembre au 9 octobre 2009. Cette invitation a été faite par l'Observatoire des Forêts d'Afrique Centrale, l'équipe FORAF conjointement avec le Centre Commun de Recherche (CCR) de l'Union Européenne et la FAO FRA-2010. Ladite rencontre rentre dans le cadre de l'Observatoire des Forêts d'Afrique Centrale mis en place pour la COMIFAC. A l'initiative de Forest Resources Assessment (FRA) 2010 conduit par la FAO, chaque pays du Bassin du Congo est invité à fournir des données d'estimation du changement du couvert forestier pour les années 1990-2000-2005 obtenues à partir de la télédétection spatiale.

Le présent travail de validation constitue une approche essentielle de la nouvelle méthode opérationnelle orientée-objet pour la cartographie des surfaces forestières et la détection de leur changement à partir des données de télédétection à haute résolution (Landsat et Aster) développée par l'Université catholique de Louvain (UCL-Géomatique). Nous allons voir tout d'abord la démarche intégrée de ce processus de validation et de l'interprétation des données. Ensuite nous présenterons le travail effectué, l'outil de validation et nous énoncerons enfin les perspectives de cette collaboration.

Une démarche intégrée au processus de validation et de l'interprétation des données

Pour la première fois, la FAO à travers sont initiative FRA 2010, avec le concours du projet FORAF et le CCR ont convié les experts nationaux en télédétection et forêts des pays du Bassin du Congo pour un atelier de validation de l'interprétation des données de télédétection pour l'estimation et le suivi du couvert forestier (cf. Tableau 1).

L'équipe des formateurs de l'UCL et du CCR a été complétée par des membres de l'OSFAC. L'Angola assistait en tant que pays observateur car ne faisant pas partie des pays du Bassin Congo.

Tableau 1. Les noms des experts nationaux en télédétection et forêts des pays du Bassin du Congo.

N°	Noms et prénoms	Pays
1	IBARA Marcel	République du Congo
2	OUISSIKA Chérubins Brice	République du Congo
3	BEGOTO Grégoire	RCA
4	NKOUMAKALI Bruno	Gabon
5	MAKAK Jean Sylvestre	Cameroun
6	NEBA SHU Gideon	Cameroun
7	MENDOMO BIANG Jean Daniel	Cameroun
8	MUSAMPA Christophe	RDC
9	KONDJO SHOKO André	RDC
10	KOY KONDJO Héritier	RDC
11	NCOGO MOTOGO Roberto	Guinée Equatoriale
12	ESONO MBA Fidel	Guinée Equatoriale
13	BARARWANDIKA Astère	Burundi
14	MATEUS Andre	Angola
15	MANDE Francisca	Angola

Prise en compte et niveau d'implication de l'expertise nationale

L'implication de l'expertise nationale pour la validation et l'interprétation des données de télédétection pour l'estimation et le suivi du couvert forestier s'est faite à plusieurs niveaux. L'expérience et la connaissance des experts locaux du terrain de leur pays a été longuement sollicitée. En effet, pour évaluer le changement du couvert forestier entre 1990-2000-2005 sur base d'extraits de 20 x 20 km d'images Landsat (fig 1), l'approche retenue par l'UCL est de travailler sur une segmentation multi-temporelle de ces images (trois par trois ou deux par deux selon la disponibilité des scènes). Le produit de cette segmentation est un ensemble d'objets cohérents, spectralement et spatialement identiques pour les trois (ou deux) images (FAO FRA-2010). Il arrivait que certaines images apparaissent non géoréferencées ou présentaient des défauts techniques leur rendant parfois illisible et difficile à traiter.

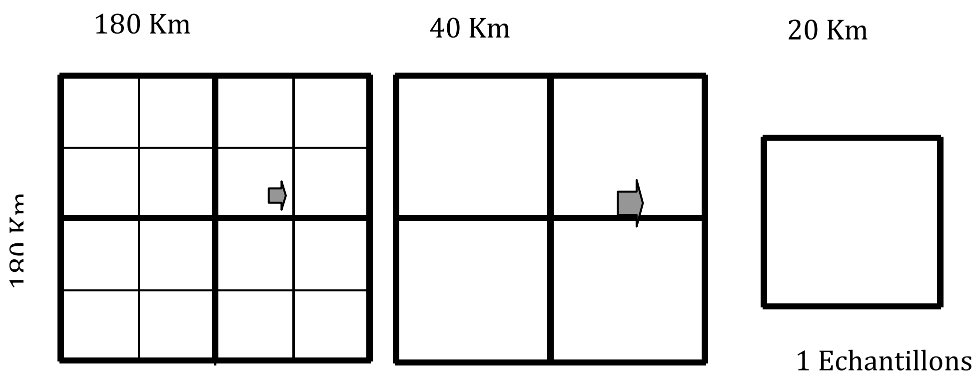


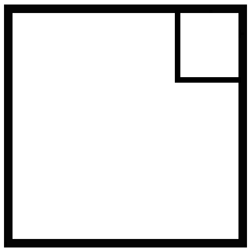
Figure 1. Processus d'extraits de 20 x 20 km d'images Landsat.

Le processus d'extraits de 20 x 20 km d'images Landsat pour aboutir à la segmentation échantillon s'est déroulé de la manière suivante:

Un échantillon tous les 100 km (à chaque 1 degré) sur une carte 1/200 000. C'est une image de Landsat (180 x 180 km) qui est prise pour référence et subdivisée en 4 imagettes de 20x20 km. La segmentation aboutit au regroupement des pixels quasi identiques : c'est la classification non supervisé en 20 classes (cluster). (G. Duveiller, P. Defourny B. Desclée, P. Mayaux 2008).

De la segmentation on obtient les clusters qui sont composés des pixels un cluster est une unité de paysage agrégée qui représente un hectare sur l'image. Il s'agit pour les experts nationaux de vérifier si les unités de paysage sont homogènes et correspondent à une occupation du sol comme le propose la légende de la FAO FRA-2010.

Un hectare est composé de 3x3 pixels (30x30 m = 90 m2), une image de Landsat (180 x 180 km) et subdivise en 4 imagettes de 20x20 km. Une imagette de 20x20 km est composée de plusieurs pixels



A chaque objet (cluster) on attribue une légende de huit (8) strates, regroupée en 20 classes. Ces objets (cluster) sont les unités du travail pour les processus de cartographie et la détection de changement que les experts nationaux doivent valider et interpréter.

Présentation du travail effectué et outil de validation

Chaque Expert dispose d'un jeu de données de son pays déjà pré-traité et segmenté par l'Université catholique de Louvain (UCL-Géomatique). Ces données sont les objets regroupés en vingt classes pour les trois dates d'observation (1990-2000-2005). Un label est donné à chacune de ces classes à l'aide de cartes d'occupation du sol préexistantes. La prise en compte de l'expertise nationale intervient dans l'identification de ce label qui doit correspondre exactement à la classe d'occupation du sol selon la légende produite par le Centre Commun de Recherche (CCR) sur la base de leur connaissance et expérience du terrain (fig. 2).

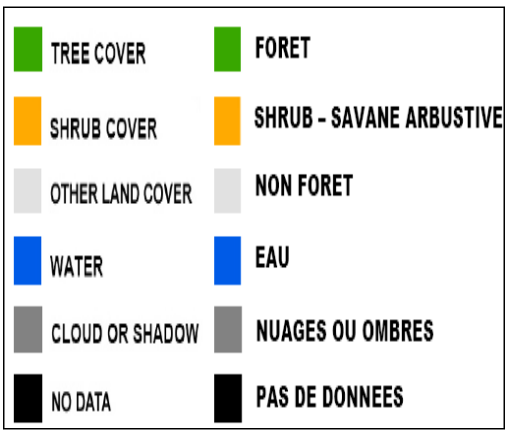


Figure 2. Légende proposée par CCR.

Les experts nationaux sont chargés de vérifier ou de modifier la pré-interprétation de chaque échantillon de leurs pays au niveau des micros objets (taille minimale de 1ha) à l'aided'un outil de validation spécialement développé par le JRC.

Chaque expert national a été d'abord formé pendant deux jours à la manipulation de l'outil de validation et interprétation précise de l'occupation du sol et du changement en forêt à partir des images (fig. 3). S'en suit une période de travail intense pour valider et interpréter les 897 échantillons.

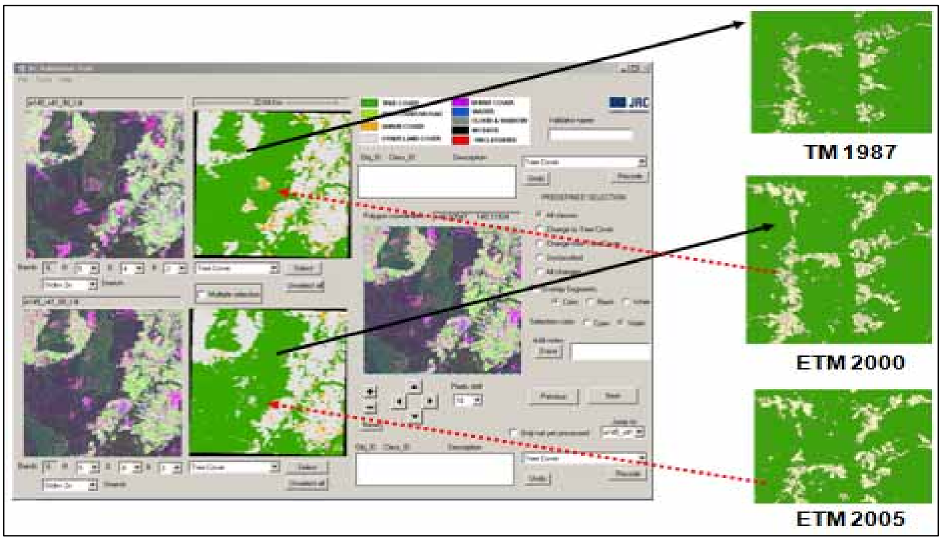


Figure 3. L'interface de l'outil de validation du JRC.

La responsabilité des experts nationaux dans la validation de 20 clusters pour les 897 échantillons est primordiale, car il suffit d'une erreur d'appréciation d'un objet (cluster) et toute la cartographie d'occupation se trouve erronée. Dans ce sens, les experts nationaux sont au cœur de la dynamique de changement (déforestation, reforestation, régénération, dégradation) qui sera attribuée au niveau de chaque macro-objet qui contient des micro-objets changés. Les produits finaux de cette chaîne de traitement sont ainsi : -une carte d'occupation du sol pour chaque date, -une cartographie des zones changées entre deux dates ainsi que quatre taux associés à ces changements pour chaque dynamique décrite ci-dessus portent une partie des empruntes des experts nationaux.

Résultats et perspectives

Résultats

Les premiers résultats attendus incluent les données statistiques synthétiques sur le travail effectué par les experts nationaux. Il s'agit bien entendu du nombre d'échantillons de départ qui était de 1168 échantillons des images de Landsat (30 m, 20*20km) et représentant les classes d'occupation du sol. Après un lourd et labeur travail sur le campus de l'Université de Kinshasa en République démocratique du Congo, 443 échantillons ont été interprétés sur 897 disponibles. Les résultats détaillés par pays sont présentés dans le tableau ci-dessus (Tableau 2). (Defourny P. 2010)

Tableau 2. Résultat préliminaire du nombre d'échantillons interprétés par pays.

Noms des Pays	Extraits Disponibles	Extraits Validés	Extraits Erreurs	Extraits Validés 90-00-05	Extraits Validés 90-00	Extraits Validés Degrés FRA 90-00-05	Extraits Validés Degrés FRA 90-00
RDC	411	151	27	102	49	78	38
Congo	86	75	8	36	39	10	12
RCA	199	76	1	63	13	30	5
Gabon	60	50	10	10	40	1	9
Guinée Equatoriale	8	4	4	0	4	0	0
Cameroun	119	80	2	45	35	23	7
Burundi	9	7	1	6	1	1	1
Rwanda	5	0	0	0	0	0	0
Total	897	443	53	262	181	143	72

Source : Defourny, P. et Ernst, C. 2010. Résultats de l'Atelier de validation de Kinshasa. UCL-Géomatique.

Les perspectives

Les initiatives impliquant l'expertise nationale dans la validation des projets communs à la sous région du Bassin du Congo sont rares et celle que nous avions vécue sur le campus de l'Université de Kinshasa en République démocratique du Congo est à féliciter et encourager. C'est dans ce sens que nous formulons ces recommandations à savoir :

- renforcer le réseau des experts nationaux en télédétection et le suivi du couvert forestier;
- adapter l'outil de validation développé par le JRC à d'autres sources de données;
- former et renforcer les capacités en amont (segmentation - Légende) et aval (validation finale) de la méthode des experts nationaux dans ce domaine; et
- appuyer et développer cette initiative dans les écoles de la foresterie de la sous région du Bassin du Congo.

Conclusion

Le travail effectué lors de l'atelier de validation de l'interprétation des données de télédétection pour l'estimation et le suivi du couvert forestier est une expérience louable, c'est une étude systématique et exhaustive de la couverture forestière et des changements d'utilisation des terres forestières de 1990 à 2000 et 2005. Elle s'appuie sur une méthodologie adaptée à la surveillance des forêts à l'échelle sous régionale du Bassin du Congo, mais aussi mondiale, qui peut être étendue à des études plus approfondies. Ce travail devrait apporter une meilleure connaissance des changements de surface forestière. Ces informations pourront être utilisées par les gouvernements, les gestionnaires, les chercheurs ou la société civile pour la prise de décision concernant la gestion des ressources forestières de la sous région. Les activités de formation et les échanges de connaissance mises en œuvre par la FAO, le JRC et les partenaires apporteront des compétences techniques pour la surveillance des ressources forestières dans les pays du Bassin du Congo.

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FAO FRA-2010 2009. L'enquête par télédétection Evaluation des ressources forestières mondiales 2010.Objectif, Données, méthode et approche. Rome, Document de travail n° 155 16 pages

G. Duveiller, P. Defourny, B. Desclée, P. Mayaux 2008. Deforestation in Central Africa: Estimates at regional, national and landscape levels by advanced processing of systematically-distributed Landsat extracts. In *SienceDirect*, Remote Sensing of Environment n° 112 pp: 1969–1981

Quantitative Analysis of Deforestation Drivers in DR Congo: Preliminary Results / Analyse des causes de déforestation

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Introduction

In the framework of the UN-REDD Program (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries), a quantitative analysis of deforestation and forest degradation drivers in DRCongo is currently carried out for the period 1990-2005. The aim of the overall study is to identify and quantify the influence of different variables explaining changes in forest cover, i.e. deforestation and degradation, for the period 1990-2000-2005 across the territory of the DRC.

The institutional context in which the study is taking place includes the REDD National Coordination (UN-REDD program - *FAO, PNUD and UNEP partnership* and CBFP program -*World Bank*) and the REDD Working group of administration and numerous NGO stakeholders (AWF, CI, Rainforest Foundation, WCS and WWF).

The objectives of this on-going study are twofold. The first one is the identification and quantification of the various drivers of deforestation and degradation for 1990-2000-2005 periods at national level for DRC. This should build a national consensus based on scientific and quantitative results. The second objective is to provide a field survey protocol for validation of the major drivers and processes identified by the quantitative study. These tasks are currently achieved in close collaboration with *Observatoire des Forêts d'Afrique centrale* and the EU-FORAF consortium.

Available data and statistical methods

The best available results about deforestation and degradation estimate in Congo Basin for 1990-2000 (Duveiller et al., RSE 2008)[1] are provided by the UCL-JRC pilot study which has served as basis for the FAO-FRA 2010 approach (FAO et al., 2009)[2]. As shown in the figure 1, this study delivered deforestation, degradation, reforestation and regeneration rates based on 267 Landsat samples of 10 x 10 km in DRC. These results have been published in the Observatoire des Forêts d'Afrique centrale. A GIS data base for DRC combining the data from the Observatoire des Forêts d'Afrique, from the Référentiel Géographique du Congo, from the 1: 2 000 000 national map (UCL 2007)[3] and from the DRC land cover map (Vancutsem et al., 2009)[4] was compiled to document the road and river networks, the topography, the protected areas, the land cover, the forest and mining concessions, the urban areas. In addition, a recent population distribution map (Kibambe et al., 2010)[5] was also included as key variable.

The current approach for the drivers' analysis proceeds in two main steps. First an expert knowledge based analysis was performed to highlight the main causes of deforestation and forest degradation.

Once the possible causes of deforestation and forest degradation were identified, they were respectively modelled thanks to GIS analysis from the compiled data base described here above. Such a spatial analysis allowed deriving 25 potential explanatory variables such as population density, distance to village, land cover type, elevation, agriculture, road density… All these variables were grouped into five types of drivers: agriculture, demography, economy, transportation and land cover.

The relationships between the remotely-sensed forest cover change and the potential explanatory variables have been systematically investigated. A systematic exploratory analysis has been first completed for each variable separately. Based on these results, the second statistical approach relies on a multivariate analysis.

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1 Ref: Duveiller Grégory, Defourny Pierre, Desclée Baudouin, Mayaux Philippe, Deforestation in Central Africa: Estimates at regional, national and landscape levels by advanced processing of systematically-distributed Landsat extracts, Remote Sensing of Environment, 112, 2008, p. 1969-1981.

2 Ref: FAO, JRC, SDSU, UCL, 2009. *The 2010 Global Forest Resources Assessment Remote Sensing Survey: an outline of the objectives, data, methods and approach.* Forest Resources Assessment Working Paper 155. Published by FAO with FRA RSS partners, Rome, 2009.

3 Ref: UCL, 2007. Carte générale de la République Démocratique du Congo 1: 2 000 000, Presses Universitaires de Louvain, ISBN 2-87463-019-5, 2ème édition.

4 Ref: Vancutsem C., Pekel JF., Evrard C., Malaisse F., Defourny P., 2009. *Mapping and characterizing the vegetation types of the Democratic Republic of Congo using SPOT VEGETATION time series.* International Journal of Applied Earth Observation and Geoinformation, 11, (1), 62-76.

5 Ref: see the paper included in this volume.

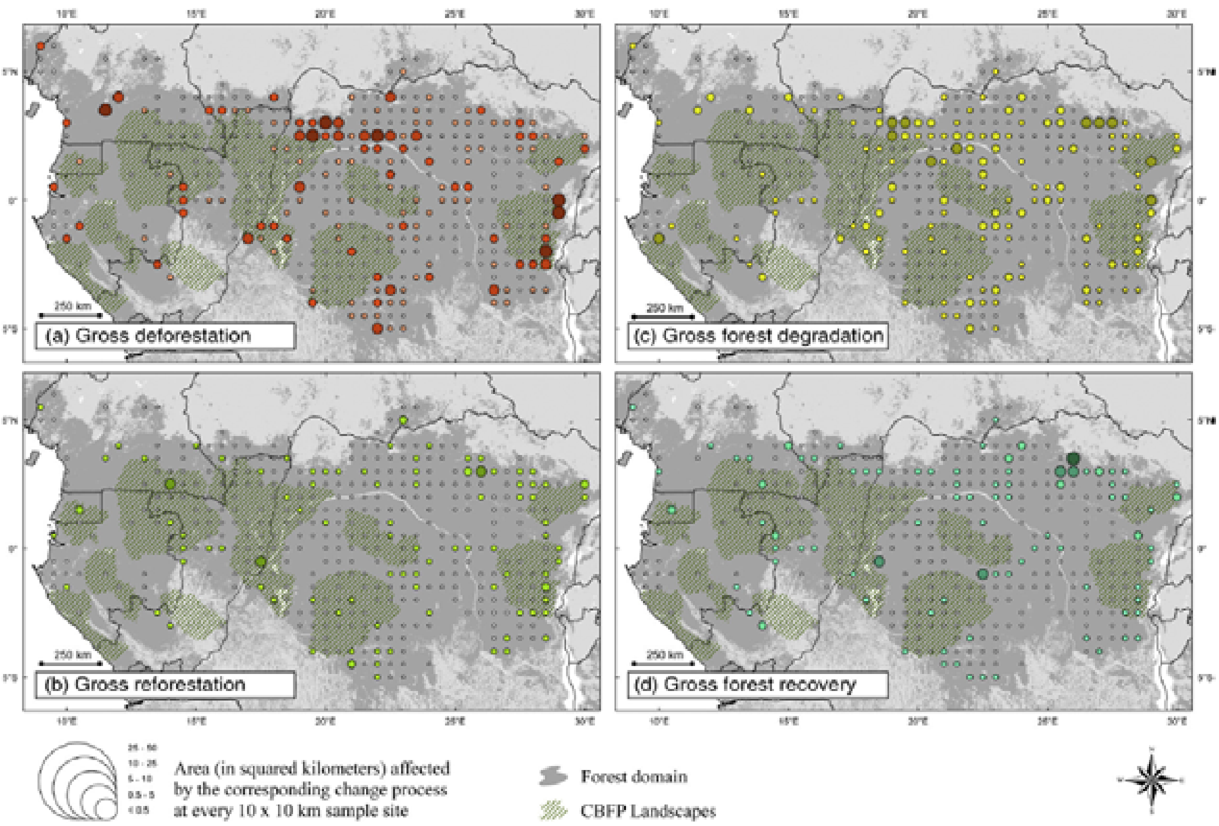

Figure 1. Spatial distribution of forest cover change processes that occurred between 1990 and 2000 over the Central African forest (Duveiller et al., 2008).

Preliminary results

Based on a collaborative effort involving various stakeholders, a conceptual framework describing the main forest cover change processes observed in DRC (figure 2) has been established according to the already proposed template (Geist and Lambin, 2002)[1].

The first exploratory analysis studying successively each explanatory variable consisted of a statistical test on mean difference. These results shows at this stage that large deforestation corresponds to a high density of population, proximity to roads and villages, proximity to large surface occupied by agricultural zones and more fragmented and degraded forests. Deforested areas are closer to cities, to roads and to national borders.

The averages of deforested samples and no change samples are not significantly different with regards to the distance to rivers, the elevation and the presence of mining and forest concessions. It was then considered at this stage of the study that these variables do not play a significant role in the explanation of the deforestation.

1 Ref: Geist HJ., Lambin EF., 2002. Proximate causes and underlying driving forces of tropical deforestation. BioScience. 52:143–150.

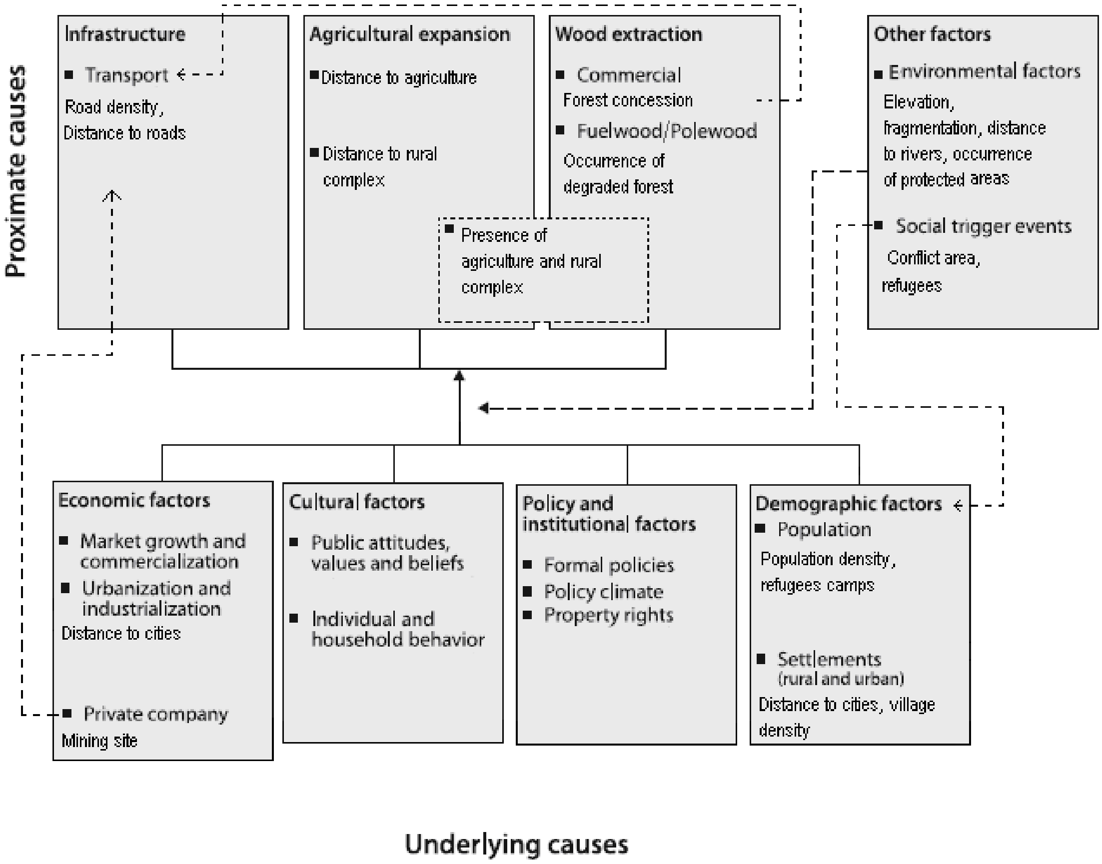

Figure 2. Drivers of deforestation as identified for DRCongo (organized according the overall framework proposed by Geist and Lambin, 2002).

A second exploratory analysis computed univariate regression models relating each of the 25 variables with the deforestation process. These models show that variables representing the agriculture driver, the population driver, the land cover driver, the economical driver and the transportation driver are the most correlated with the change due to deforestation and forest degradation (table 1).

Based on these exploratory results, the variables explaining most of the forest cover change were selected to perform the multivariate analysis. The first multivariate analysis was a stepwise regression model using all the 267 samples. As we can see in the fig. 3a more than 50% of the samples have zero deforestation and degradation. Thus we tested a stepwise regression model using only the changed samples. This leads to a coefficient of determination R^2 of 0.45 (fig.3b). This is because the "zero samples" contain information that we can't just simply ignore.

Table 1. Coefficient of determination for different univariate regression computed between the potential driver and the 1990 - 2000 forest cover change in DRCongo.

Explanatory variable		r	r^2
Driver	Variable		
Agricultural	Rural complex area in sample [%]	0,65	0,42
Land Cover	Fragmentation [-]	0,58	0,34
Demographic	Population density [hab/km^2]	0,56	0,31
Agricultural	Distance to rural complex [km]	-0,51	0,26
Demographic	Village density [vill./km^2]	0,44	0,19
Land Cover	Degraded forest [%]	0,43	0,18
Agricultural	Distance to agriculture [km]	-0,42	0,18
Transportation	Road density [-]	0,35	0,12
Transportation	Distance to roads [km]	-0,35	0,12
Economical	Distance to cities [km]	-0,33	0,11
Transportation	Road of type 2 in sample [%]	0,32	0,10

The Tobit regression model was then selected to take into account the information in the "zero samples" (fig. 3c). This Tobit model highlights ten variables that play an important role in the deforestation and degradation explanation. These drivers are as follows: presence and distance to rural complex (agricultural driver), forest fragmentation (land cover driver), distance to national borders (economical driver), occurrence of degraded forest (land cover driver), distance to roads (transportation driver), occurrence of frequently used roads (transportation driver), village density (demographic driver), distance to urban areas (economical driver), and distance of less used roads (transportation driver).

The figure 3 showed promising results which confirmed that the GIS computed variables seems relevant to explain the observed forest cover change processes and a multivariate model should allow explaining a significant part of the deforestation and degradation.

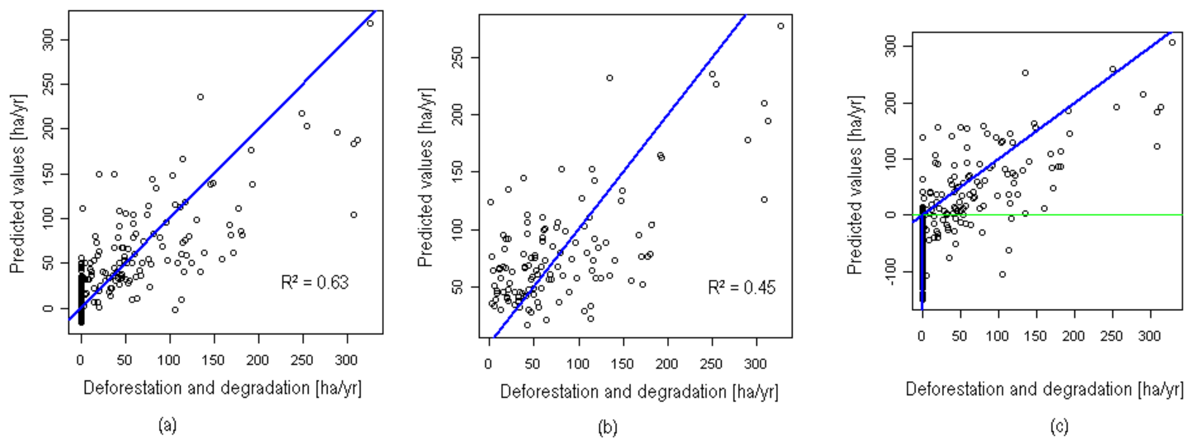

Figure 3. Scatter plots of the multivariate regression model for (a) Change and unchanged samples; (b) Change samples only; (c) Tobit regression model.

Further investigation already demonstrated that sub-national models could be more efficient to identify the key drivers. Preliminary results seem to show that all the drivers don't have the same importance in the different groups of Provinces (Figure 4). For instance, the presence of rural complex plays a more important role in the Province of Mongala, Nord Ubangi and Sud Ubangi whereas forest fragmentation is an important variable for the Province of Sankuru, Kasai and Lulua. The spatial diversity of the key drivers could appear of great interest to document the different situations and subsequently to define a more targeted strategy for the national REDD program.

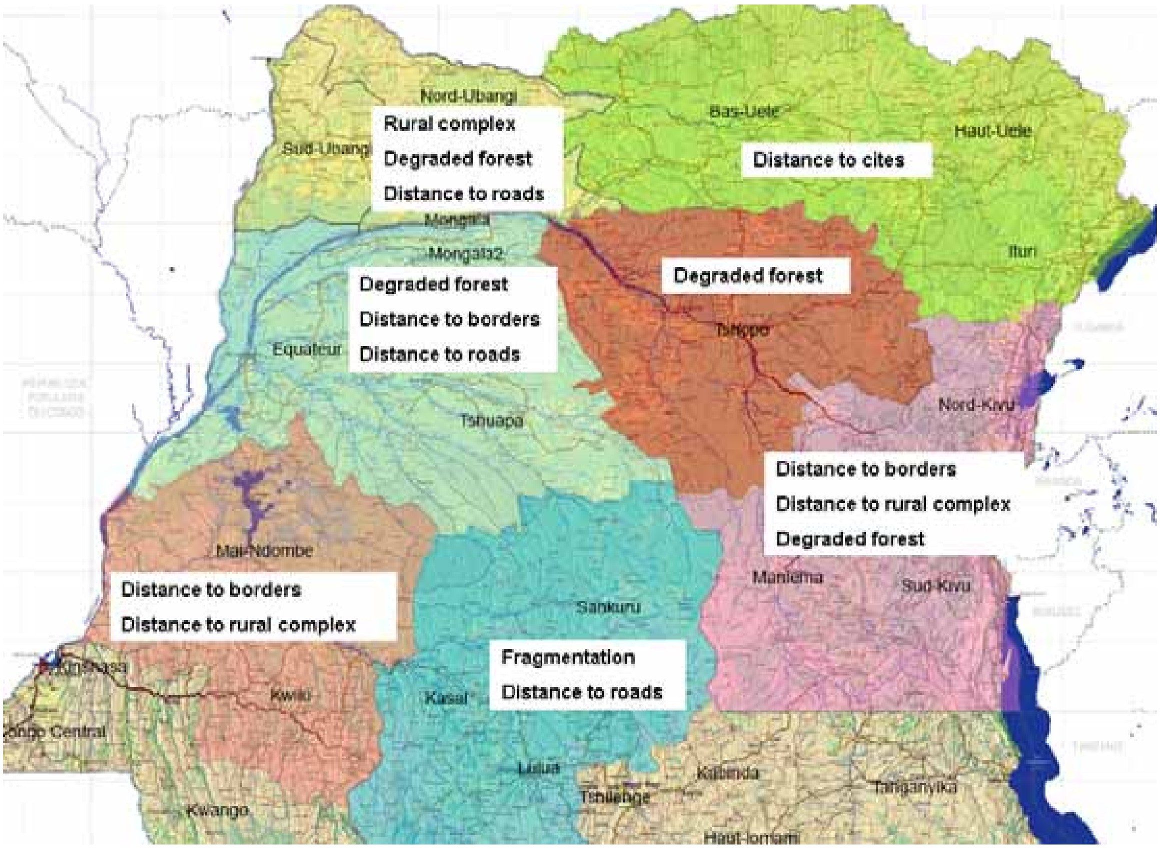

Figure 4. Spatial variation of the explanatory variables of the deforestation and degradation processes.

Perspectives

The preliminary results of this deforestation drivers' analysis clearly illustrate the great potential of such a study based on a large number of samples well distributed across the country. These results still have to be confirmed and complemented by in-depth analysis and should not be used as final output of the study. Further validation work is also expected in the context the REDD national coordination.

More results are expected to be delivered soon and additional features tested. For instance, an accessibility model will be integrated as an input variable to explain the link between the deforestation/degradation and the accessibility to market. The model will also be applied for the new 1990 – 2000 – 2005 samples. From these findings predictive model will be derived in order to simulate the expected deforestation and forest degradation across the DRC according to different scenarios.

Central African Deforestation 2001-2004-2007 Mapped Wall-to-Wall with Landsat 7 Data: New Methods Exploring the Recently Opened Landsat Archive / La cartographie du couvert forestier et de la déforestation en Afrique centrale

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Introduction

Detailed contemporary maps of forest cover and deforestation are critical for policy that aims to regulate and reduce deforestation. Mapping forest cover and deforestation with optical remote sensing data over Central Africa is challenging because of persistent cloud cover. Previously, moderate spatial resolution wall-to-wall maps were generated by compositing few selected Landsat images with limited cloud cover for the 1990 and 2000 epochs[1]. The recent opening of the EROS Landsat archive, the largest and longest record of remote sensing data at moderate spatial resolution, provided an unprecedented opportunity to create deforestation maps at 60-m x 60-m pixel size and a high temporal resolution.

Methods

We generated image composites centered on 2001, 04, 07 and deforestation maps for 2001-04 and 2004-07 using approximately 60 ETM+ images per path/row over Central Africa. Persistent cloud cover and scan gaps due to the SLC-off state made it necessary to compile imagery over three years (e.g. the composite centered on 2001 used data from 1999-2002) to produce gap-free composites[2]. The number of images used for each composite is shown in Table 1. We considered every cloud-free and cloud shadow-free observation of every pixel across 73 path/rows from 2000 to 2008. The data were passed through an automatic processing chain consisting of dark object subtraction normalization, across track normalization, cloud and cloud shadow masking, forest classification, median compositing, and deforestation classification using a decision tree algorithm.

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1 Hansen, M. C., Roy, D., Lindquist, E., Justice, C. O., & Altstaat, A. (2008). A method for integrating MODIS and Landsat data for systematic monitoring of forest cover and change in the Congo Basin. Remote Sensing of Environment, 112, 2 495–2513.

2 Lindquist, E., Hansen, M., Roy, D. P., & Justice, C. O. (2008). The suitability of decadal image data sets for mapping tropical forest cover change in the Democratic Republic of Congo: Implications for the mid-decadal global land survey. International Journal of Remote Sensing, 29, 7269–7275.

Table 1. Number of Landsat images used to create three-year composites.

Composite centered on	Number of Images used	Data volume
2001	1,272	~1.5 TB
2004	1,258	
2007	1,200	
All	3,730	

Results

We produced image composites and deforestation maps for the entire study area. The composites are generally gap-free and only areas along the coast show data gaps due to clouds and scan gaps. An example of a study area-wide composite is shown in Figure 1. The composites are spatially consistent and their spatial resolution of 60-m x 60-m allows the provision of locally and regionally relevant deforestation information (Figure 2). Deforestation in the study area is dominated by small subsistence agricultural clearings that cause a slow encroachment of the 'rural complex' into areas with primary forest cover.

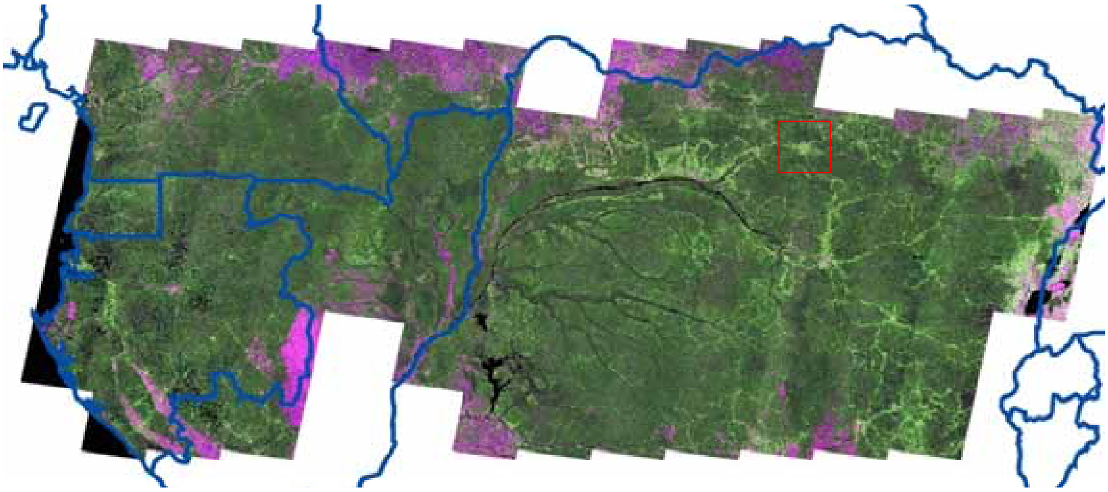

Figure 1. Landsat image composite (5/4/7 RGB) centered on 2001. This cloud-free composite provides a spatially consistent dataset between the Central African coast in the west and the Ugandan boarder in the east. The pixel size of 60-m x 60-m allows the provision of locally and regionally relevant deforestation information. The area outlined in red is shown in Figure 2.

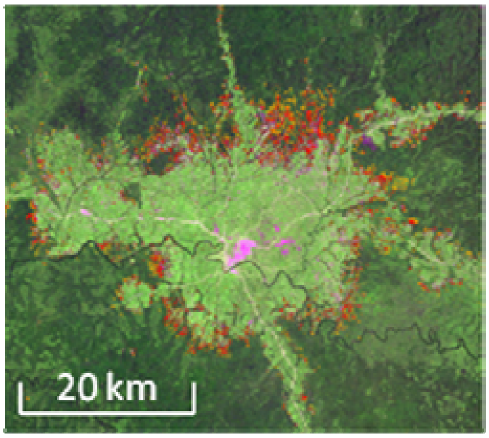

Figure 2. Landsat image composite (5/4/7 RGB) of the area around Buta, Democratic Republic of the Congo. Deforestation 2001-04 and 04-07 is shown in red and yellow, respectively.

For selected Central African Regional Program for the Environment (CARPE[1]) landscapes we calculated annual deforestation rates for the 2001-2007 interval. We compared deforestation rates inside these landscapes with rates calculated within a 100-km buffer zone around each landscape (Figure 3). All annual rates (percent deforestation within the study area) were < 0.25% and rates inside the CARPE landscapes were <= 0.16%. The deforestation rates inside Sangha Tri-National and within the 100-km buffer around this landscape were similar, yet the buffers around Maringa-Lopori-Wamba and Ituri-Epulu-Aru showed higher rates than the landscapes themselves (Table 2). We did not yet provide rates for the western part of the study area where a lower signal to noise ratio due to fewer cloud-free observations require refinement of the processing algorithm.

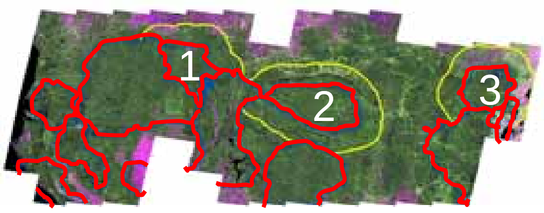

Figure 3. Annual deforestation rates were calculated for selected CARPE[2] landscapes (red) and a 100-km buffer around these landscapes (yellow). The landscapes investigated are1) Sangha Tri-National, 2) Maringa-Lopori-Wamba, and 3) Ituri-Epulu-Aru.

1 http://carpe.umd.edu/

2 http://carpe.umd.edu/

Table 2. Annual deforestation rates 2001-2007 within three CARPE Landscapes[1] and within a 100-km buffer about these landscapes. Refer to Figure 3 for location of the landscapes.

Land scape name	% annual deforestation	
	inside landscape	inside buffer
Sangha Tri-National	0.12	0.11
Maringa-Lopori-Wamba	0.13	0.23
Ituri-Epulu-Aru	0.16	0.25

Conclusion

The image composites and deforestation maps presented here are valuable for policy support as they provide full cover information for Central Africa generated through a consistent, automated, and reproducible method at an unprecedented temporal resolution of three years. This temporal resolution and spatial consistency of our product is possible thanks to the now freely accessible Landsat archive, the richest global archive of systematically acquired moderate spatial resolution remote sensing imagery[2].

[1] 1USGS/EROS. (2008). Free Landsat Scenes Go Public by the Million

http://landsat.usgs.gov/products_data_at_no_charge.php

Transition to a regional mapping initiative : OSFAC / OSFAC vers un monitoring régulier des forêts du bassin du Congo : Transition vers une exploitation Régionale

Landing Mane, Patrick Lola Amani, Guguy Mangono, Marcelline Ngomba, Eddy Bongwele, Huguette Ngilambi

Observatoire Satellital des Forêts d'Afrique Centrale (OSFAC)

Introduction

L'Observatoire Satellital des Forêts d'Afrique Centrale (OSFAC) a été crée à Libreville (Gabon) en 2000. L'OSFAC devint alors le Représentant pour l'Afrique Centrale du réseau « Global Observation of Forest and Land Cover Dynamics » (GOFC GOLD).

En 2005, l'OSFAC prend le statut d'Organisation Non Gouvernemental (ONG) à vocation régionale basée à Kinshasa en République Démocratique du Congo et dispose des Points Focaux dans tous les pays du Bassin du Congo (Cameroun, Centrafrique, République du Congo, Congo RD, Gabon et Guinée Equatoriale).

Dans le cadre de ses activités, l'OSFAC bénéficie du soutien technique et financier de l'Université du Maryland (UMD), de la South Dakota State University (SDSU), de la NASA et de Central African Regional Program for Environment (CARPE) (Figure 1).

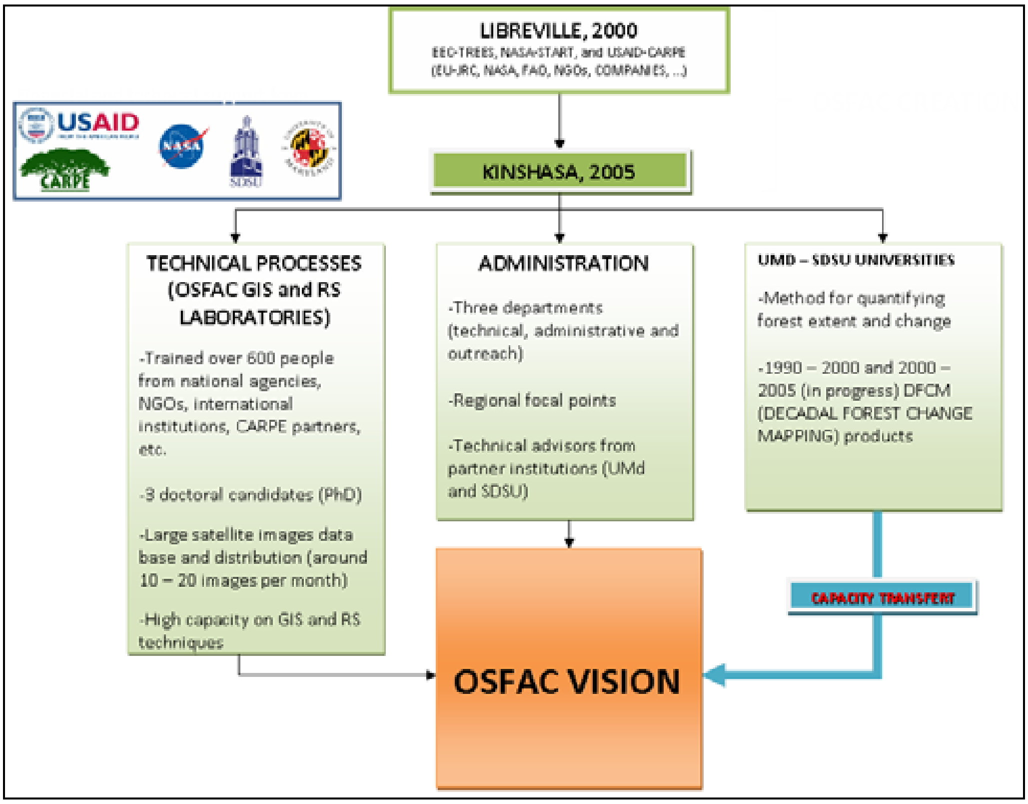

Figure 1. OSFAC overview.

OSFAC aujourd'hui

Actuellement, les activités de l'OSFAC concernent essentiellement trois domaines :

1. le monitoring du couvert forestier et des changements par télédétection;
2. la dissémination des données satellites et produits dérivés à travers l'Afrique Centrale; et
3. le renforcement de capacités des Institutions nationales et des Organisations internationales dans les domaines de la télédétection, l'utilisation du SIG et du GPS.

En tant que représentant de GOFC GOLD, l'OSFAC joue un grand rôle dans l'amélioration de la qualité et de la disponibilité des données spatiales en Afrique Centrale.

A travers une convention avec l'Université du Maryland et la NASA, l'OSFAC a pu disposer d'une banque de données très fournie d'images satellites (Landsat, ASTER et SRTM) couvrant tout le Bassin du Congo et des produits dérivés dont il assure la dissémination gratuitement dans la sous-région.

Dans le domaine du renforcement des capacités, l'OSFAC assure des formations ciblées de différents niveaux en SIG, télédétection et GPS aux structures nationales et internationales. A ce jour, OSFAC dispose de deux laboratoires (SIG et télédétection) et compte à son actif plus de 600 personnes formées (professionnelles et étudiants) d'au moins 50 institutions (Photo 1). A travers une convention avec l'UMD, l'OSFAC participe au monitoring de la déforestation et des changements du couvert forestier dans le Bassin du Congo en utilisant l'imagerie satellitaires (Planche 1).

Planche 1. Formation au sein du Laboratoire OSFAC/Université de Kinshasa.

C'est dans ce domaine du monitoring que les activités de l'OSFAC vont se développer davantage dans un futur proche.

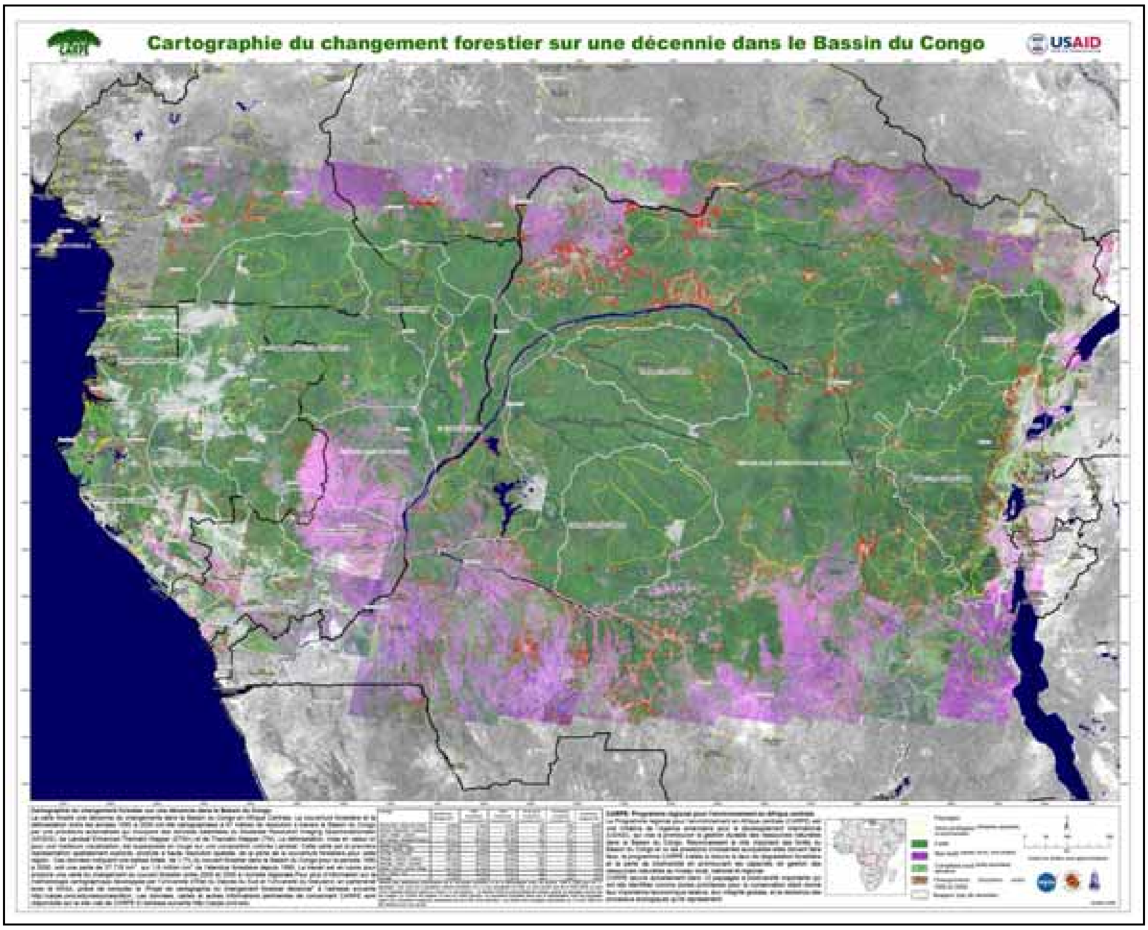

Planche 2. Cartes des changements 1990-2000.

OSFAC demain

Si dans les domaines de la dissémination des données et du renforcement des capacités l'OSFAC a engrangé une grande et riche expérience ; dans le monitoring des forêts, il doit effectuer des avancées significatives eu égard aux nouvelles problématiques en relation avec les changements climatiques, les activités humaines de plus en plus importantes et les questions relatives à la Réduction des Emissions liées à la Déforestation et à la Dégradation (REDD).

Par conséquent, les activités de l'OSFAC vont de plus en plus s'orienter vers une exploitation régionale des données satellitaires, à savoir, le monitoring régulier des forêts du Bassin du Congo.

Dans l'optique d'une réalisation de ses ambitions à devenir un Centre d'Excellence pour le monitoring des forêts par télédétection, l'OSFAC i) modernise ses équipements de travail, ii) identifie le type de produits à mettre à la disposition des utilisateurs et décideurs, iii) s'implique dans plusieurs projets et programmes régionaux et internationaux.

Acquisition d'équipements pour le laboratoire de télédétection

Depuis octobre 2009, l'OSFAC a acquis de nouveaux équipements dédiés essentiellement au monitoring des forêts du Bassin du Congo. Il s'agit de:

- Serveurs (avec LINUX OS) pour l'archivage et le traitement de masse de données satellitaires
- Workstations (avec windows OS) pour l'analyse des données en utilisant le SIG
- UPS pour la protection du matériel informatique

- Logiciels de télédétection (PCI Geomatica) et Scripts pour le traitement numérique et l'analyse des images, etc.

Du point de vue ressources humaines, deux Ingénieurs assistés par des stagiaires professionnelles s'investissent totalement dans cette activité de monitoring des forêts par télédétection.

Monitoring régulier des Forêts et production d'informations

Le produit issu des activités de monitoring effectuées par l'OSFAC portera désormais le nom de FACET (Forêt d'Afrique Centrale Evaluée par Télédétection). Cet acronyme proposé par Matthew Hansen de la SDSU comprend les informations sur la superficie des forêts, leur structure, l'occupation et l'utilisation du sol, les changements dans le temps et l'espace, etc.

L'accent sera particulièrement mis à l'analyse de l'étendue du couvert forestier et des changements (déforestation, reforestation et dégradation) en utilisant la méthodologie Wall-to-Wall développée par les Universités américaines de SDSU et UMD (Hansen et al. 2008). Cette méthodologie a été entièrement transférée au laboratoire de télédétection de l'OSFAC et un personnel formé à son utilisation.

Certaines thématiques de recherche viendront s'ajouter à celles déjà en étude, il s'agit entres autres, de l'analyse des séries temporelles (annuelles, pluriannuelles, etc.), des indicateurs du changement et la modélisation de la dynamique des forêts d'Afrique Centrale.

L'OSFAC s'oriente de plus en plus vers un monitoring régulier des forêts du Bassin du Congo et vers un partenariat diversifié.

OSFAC vers un partenariat multiple

En sus de ses partenaires traditionnels, en l'occurrence les Ministères en charge des forêts dans les pays du Bassin du Congo, USAID/CARPE, UMD, SDSU, NASA, FORAF (OFAC), la sphère du partenariat de l'OSFAC s'élargit de plus en plus. Une collaboration étroite se met en place avec plusieurs institutions nationales et internationales :

- Forest Monitor : Cartographie participative des espaces et des ressources forestières des Communautés locales en République Démocratique du Congo (RDC).
- Congo Basin Forest Fund (CBFF) et WRI : Quantification des stocks de carbone et des émissions dans les forêts du Bassin du Congo.
- START : Dissémination des données dans le cadre du Projet Data Initiative for Africa.
- Group on Earth Observation (GEO) : Forest carbon tracking (National demonstrators).
- Northern Research Institute Tromso (NORUT) : Combinaison des données optiques et Radar (SAR) pour le suivi des forêts humides du Congo.
- EUROSENSE : Monitoring des forêts et estimation du stock de carbone dans les forêts d'Afrique Centrale pour le REDD.

Conclusion

Dans le court et moyen terme, la vision de l'OSFAC peut se décliner comme suit :

- Fournir des informations et produits fiables pour l'aide à la prise de décision dans le cadre de la gestion durable des forêts du Bassin du Congo.
- Poursuivre le renforcement de capacités des partenaires dans les domaines du SIG, télédétection et GPS.
- Devenir un Centre d'Excellence dans la production de données sur le couvert forestier et la dynamique des paysages en Afrique Centrale.

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3.3 Estimation of Forest Carbon

Mapping and Monitoring Forest Carbon in Central Africa: Fusion of Ground and Space Measurements / Le suivi du carbone dans les forêts du Gabon: Fusion des données de terrain et spatiales

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[f] Environmental Change Institute, University of Oxford, UK

Abstract

Recent advances in the use of space technology to measure and monitor forest structure, biomass, and the degree of degradation have created a suite of applications in mapping and monitoring forest carbon for both scientific analysis and carbon offset and trading markets. These applications have also created new demands and challenges to develop statistically systematic and spatially distributed field inventory data to both develop and verify remote sensing algorithms and products. In this presentation, we will cover, the recent available technology, provide a synopsis of various approaches to combine field inventory and remote sensing data, and demonstrate the applications for mapping and monitoring forest carbon in Central Africa.

Canopy Textural Properties from Metric Resolution Imagery : Validation, Sensitivity and Perspectives within REDD / Suivi de la structure forestière

Nicolas Barbier[1], Pierre Couteron[2], Jean-Philippe Gastellu-Etchegorry[3], Christophe Proisy[4]

[1]AMAP, ULB-FNRS
[2]IRD-AMAP
[3]CNRS-CESBIO
[4]IRD-AMAP

Introduction

Lors d'un récent atelier à Yaoundé, l'IRD a invité ses unités et partenaires en Afrique Centrale à une réflexion sur les recherches prioritaires qui pourraient être menées en commun autour des forêts denses humides. Au cours des échanges, il est clairement ressorti que les enjeux assortis à ces forêts appelaient un accroissement des recherches à l'interface entre un grand nombre de disciplines scientifiques intéressées par le climat (et son changement), les problèmes de santé, l'érosion des sols, les cycles hydrologiques et géochimiques, la biodiversité, la gestion forestière, l'archéologie et les sciences humaines. Plus particulièrement, l'enjeu que représentent les forêts tropicales par rapport au climat se traduit par l'engagement de certains pays occidentaux à Copenhague de mettre à disposition plusieurs milliards de dollars dans un fond destiné à ralentir la dégradation des forêts et la déforestation dans les pays du Sud (REDD). Ceci confirme l'ampleur des enjeux sociétaux et économiques désormais en balance (UNFCCC[1], draft decision COP15, 2009) qui au demeurant ne se limitent pas qu'au stockage du carbone (habitats, biodiversité, populations locales, etc.). En Afrique Centrale, de nombreux acteurs institutionnels s'impliquent activement sur le terrain dans la mise en application du REDD (cf. atelier conjoint de Brazzaville, 2-4 février 2010). Au niveau national, le Gabon semble montrer la voie, et c'est activement engagé dans un processus d'évaluation de ses ressources en Carbone.

On l'aura donc compris, la capacité à caractériser l'état des forêts denses de manière répétée et fiable à l'échelle du territoire d'un pays ou d'un sous-continent devient un enjeu important. La structure forestière et l'état de dégradation des forêts (qu'elle peut permettre de caractériser) acquièrent le statut d'information de base, tant pour les autres disciplines scientifiques que pour les décideurs politiques et institutionnels. Pourtant, on en est pour le moment réduit à extrapoler les données issues d'inventaires forestiers, nécessairement localisés dans l'espace et le temps et qui ne décrivent la structure qu'au travers de variables très simples (liées au diamètre des arbres, dbh). Malgré les perspectives de mise à disposition des données SPOT5 et d'installation d'une antenne de réception en Afrique Centrale (à Libreville), les limites des données satellitaires proposées (résolution spatiale, saturation du signal optique dans les gammes de forte biomasse), ou le coût des méthodes aéroportées (e.g. LiDAR), cf. ci-après) et l'état des techniques de traitement ne permettent pas de fournir une information fiable et répétée sur les biomasses aériennes et l'état de dégradation, du moins à large échelle et dans les limites d'une opérationnalité raisonnable dans le contexte des pays du Sud[2].

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1 UNFCCC: United Nations Framework Convention on Climate Change.

2 R. DeFries, F. Achard, S. Brown et al., *Environmental Science & Policy* **10** (4), 385 (2007).

Au sein de l'UMR-AMAP[1], une quinzaine de chercheurs s'intéressent au développement d'approches nouvelles pour caractériser, comprendre et modéliser la structure 3D des forêts denses, et intégrer ces modélisations avec l'information de télédétection.

Etat de l'art

Deux approches dominent à l'heure actuelle pour tenter d'explorer la structure et la biomasse des forêts denses à large échelle. La première se base sur des inventaires forestiers, coûteux et peu reproductibles dans le temps, car les surfaces traitées par échantillonnage peuvent être étendues. Ils sont en général restreints à la mesure des diamètres à hauteur de poitrine (DBH) pour les individus de plus de 10 cm de DBH[2]. Les interpolations dans l'espace à partir de telles données, en dépit de leurs limites, font foi aux yeux d'une partie de la communauté scientifique[3]. L'autre approche se base sur des données optiques multi-spectrales (MODIS, Landsat, etc.) ou radar (bande Uk, X ou L), de résolution spatiale moyenne (décamétrique – hectomérique)[4]. Cependant, ces signaux ont clairement montré leur limites pour détecter des différences au sein de forêts à forte biomasse (>250 t/ha, voire moins)[5].

Une alternative encore peu exploitée passe par l'utilisation de l'information texturale disponible dans des images optiques de résolution métrique (pixels proche ou inférieurs à 1 m ; Quickbird, Ikonos, GeoEye, Formosat, etc.). Correctement exploitée, la texture permet de quantifier l'organisation de la canopée (rarement accessible du sol) quant au nombre, à la taille et à la distribution spatiale des couronnes des arbres dominants et des trouées. En raison des relations allométriques relativement générales, quoique encore à explorer, qui régissent l'organisation des forêts denses[6], de tels indices texturaux, comme ceux issus de la méthode FOTO (Fourier transform Textural Ordination, voir Figure 1) mise au point à l'AMAP, permettent d'obtenir de bonnes corrélations, non seulement avec la distribution de taille des couronnes[7], mais aussi avec le DBH moyen, la densité, la hauteur[8], ou même la biomasse épigée (Figure 2)[9], (sans saturation apparente jusqu'à 500 t/ha). Pour une application à large échelle, il faut cependant (i) vérifier la robustesse de ces corrélations, établies aux travers d'études de cas limitées, sur de grandes surfaces; (ii) être à même d'employer des images acquises dans des conditions différentes. Il est particulièrement important de pouvoir mitiger les effets des angles de prise de vue et de soleil, qui modifient la taille des ombres perçues et donc la texture. Ces effets ont cependant pu être caractérisés, et réduits, au cours de nos recherches antérieures 8, permettant la publication de la première carte de structure de canopée pour le bassin Amazonien.Une autre approche en cours d'étude, est basée sur des données LiDAR (Light Detection and Ranging), et présente également des aspects prometteurs. Les capteurs à petite empreinte (résolution

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1 Botanique et Bioinformatique de l'Architecture des Plantes (http:/amap.cirad.fr)

2 Y. Malhi, D. Wood, T. R. Baker et al., *Global Change Biol* **12** (7), 1107 (2006).

3 J Penman, M Gytarsky, T Hiraishi et al. eds., Definitions and methodological options to inventory emissions from dirext human-induced degradataion of forest and devegetation of other vegetation types. (IPCC National GHG Inventories Programme - IGES, 2003).

4 S. S. Saatchi, R. A. Houghton, R. C. D. S. Alvala et al., *Global Change Biol* **13** (4), 816 (2007). A. Baccini, N. Laporte, S. J. Goetz et al., *Environmental Research Letters* **3** (4) (2008).

5 G. M. Foody, *Int J Remote Sens* **24** (20), 4035 (2003); G. P. Asner, *Environmental Research Letters* **4** (3) (2009).

6 B. West, B. J. Enquist, and J. H. Brown, *P Natl Acad Sci USA* **106** (17), 7040 (2009).

7 N. Barbier, P Couteron, C Proisy et al., *Global Ecol Biogeogr* **19** (1), 72 (2010).

8 P. Couteron, R. Pelissier, E. A. Nicolini et al., *J Appl Ecol* **42** (6), 1121 (2005).

9 C. Proisy, P. Couteron, and F. Fromard, *Remote Sens Environ* **109** (3), 379 (2007).

métrique) sont pour l'instant uniquement aéroportés. Si les informations sur la structure de canopée qu'ils procurent sont extrêmement riches et ont démontré leur pertinence face aux forêts tempérées, la répétition dans le temps et l'espace est obligatoirement très limitée dans le contexte des pays du Sud, compte tenu du coût de survol. De telles données peuvent cependant servir de base à la calibration d'autres méthodes sur des sites de référence.

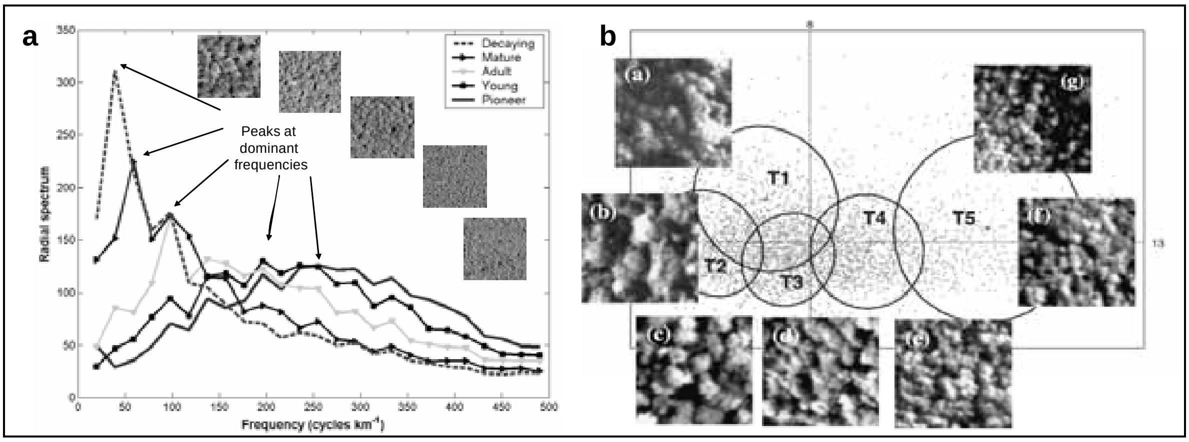

Figure 1. Illustration du fonctionnement de la méthode FOTO : A partir de données optiques métriques, la texture (structure spatiale) de la canopée est quantifiée dans des fenêtres d'1ha environ. Cette quantification se fait sur base du périodogramme 2D de Fourier, qui quantifie la proportion de variance expliquée par des fonctions périodiques de fréquences variables dans toutes les directions[11]. (a) Spectres radiaux (moyenne du périodogramme 2D dans toutes les directions) pour des canopées à grains contrastés. On voit que les spectres présentent un pic pour des fréquences croissantes en fonction de la finesse du grain de canopée. (b) Ordination multivariée (ACP) d'un grand jeu d'images de canopée sur base de leur spectres radiaux[10]. L'axe dominant (abscisse) représente clairement un gradient de finesse de texture.

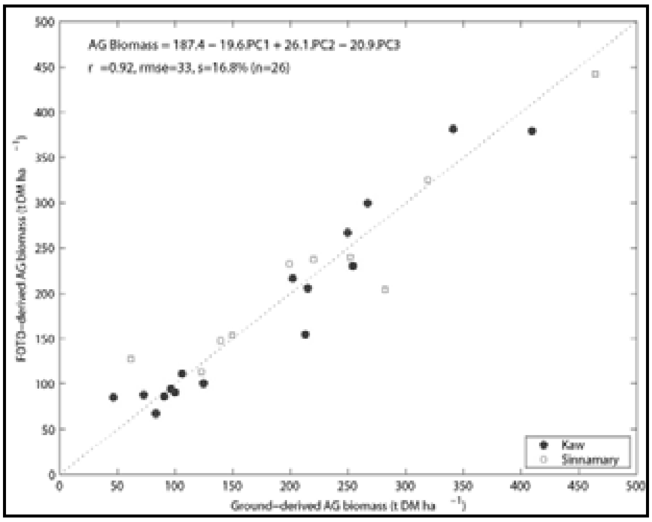

Figure 2. Corrélation entre la biomasse épigée inversée sur base de la texture de canopée et la biomasse mesurée sur le terrain dans des peuplements de mangroves (Guyane).[11]

Projet

Le présent projet de recherche part du constat qu'une quantification à large échelle de la structure et de la dégradation des forêts est indispensable pour étudier : (i) leur fonctionnement, ce qui comprend les déterminismes environnementaux et les lois d'organisation qui les régissent ; (ii) leur interaction avec le climat (e.g. cycles du carbone et de l'eau); (iii) leur interaction avec les sociétés humaines (exploitation/dégradation, santé) ; (iv) leur composition (biodiversité végétale). L'objectif du projet comprend le développement et la validation de méthodologies opérationnelles pour la mesure de la structure et de la dynamique des forêts denses par télédétection et nécessite de comprendre le lien entre la structure forestière et l'information (signaux physiques de différents types) obtenue par télédétection. Les progrès les plus probables à court terme reposent sur l'utilisation de données optiques de résolution métrique, via des approches spatialement explicites (texture) comme la méthode FOTO, qui quantifient l'organisation de la canopée. Les approches employées dans les recherches en cours consistent (i) à mettre en relation les données de télédétection avec des paramètres forestiers acquis au sol sur des superficies importantes, et (ii) à modéliser le transfert du signal dans des peuplements de différentes structures modélisés en 3D. Ce projet nécessitera l'appui de physiciens du signal (C. Proisy, IRD-AMAP ; J.-P. Gastellu-Etchegorry et T. Le Toan, UMR CESBIO) et la collaboration de bureaux d'études (FRM), d'institutions (UN-REDD, ministères, CIRAD, etc.) et d'entreprises (forestières), impliqués dans la mise en œuvre d'aménagements forestiers en Afrique Centrale, et détenant des données d'inventaire forestier.

WP 1 - Texture – validation

L'objectif d'ensemble de ce WP est de faire le lien entre la texture, telle que quantifiée par la méthode FOTO, et le structure forestière mesurée sur le terrain dans des types forestiers diversifiés. Un important chantier de validation de la méthode FOTO, a ainsi été entamé par l'AMAP en Afrique Centrale (Cameroun, Gabon, RCA, Congo, RDC). Une trentaine d'images optiques de résolution métrique ont déjà été acquises ; d'autres acquisitions sont en cours. Sur le terrain, une collaboration avec le bureau d'étude FRM (Montpellier) nous permet d'accéder à une large base de données d'inventaires forestiers (14 106 ha échantillonnés à 1%) couvrant une gamme de couverts forestiers intacts et dégradés. Pour la conversion de ces données d'inventaires en biomasse/carbone, des protocoles de mesures destructives sont prévus lors de prochaines phases d'exploitation forestière. Des travaux similaires sont d'ailleurs prévus par différentes institutions de la sous-région, notamment au Gabon.

WP 2 – Quantification de la texture – modélisation

La modélisation reste un intermédiaire indispensable pour valider l'approche et comprendre ses limites, face au coût d'acquisition de données structurales précises (et les limites intrinsèques à l'observation de terrain), sur des superficies importantes et à intervalle de temps régulier, et sur une période compatible avec les dynamiques lentes des forêts denses. Au cours des trois dernières années, nous avons pu simuler des peuplements tridimensionnels simples (« maquettes »), pour ensuite obtenir des images 2D de la canopée, grâce à un modèle réaliste de transfert du signal électromagnétique, DART[1]. En termes de texture d'images, les répliques ainsi produites se sont avérées suffisamment réalistes pour s'insérer de façon cohérente dans des classifications texturales avec de vraies images de canopée, bien que seules les textures les plus simples (peuplements à structures homogènes) aient été reproduites. Une approche complémentaire a été de se baser sur une description précise de la surface de canopée fournie par des données LiDAR aéroportées et de recréer l'équivalent de données métriques optiques en simulant le transfert du signal lumineux. ceci afin d'étudier de manière systématique la distribution des effets instrumentaux sur la texture (notamment via les effets d'ombrage) en

1 Gastellu-Etchegorry, J. P. (2008) Meteorol Atmos Phys 102, 187-207.

fonction des angles soleil et capteur (en introduisant la notion de Bidirectional Texture Distribution Function).

Pan Tropical Biomass Mapping in Support of Forest Monitoring / Une premiere estimation de la biomasse ligneuse aérienne d'Afrique sur la base d'images satellites et d'inventaires forestiers

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[a]Woods Hole Research Institute (WHRC)

[b]Ministère des Eaux et Forêts, de l'Environnement et du Développement Durable (Gabon)

Résumé

L'Afrique a l'un des plus grands blocs de forêt humide tropicale au monde et possède un potentiel d'émissions de dioxyde de carbone (CO_2) élevé connaître avec une plus grande précision la quantité et la distribution du carbone dans ces forêts aidera à évaluer plus exactement les émissions de CO_2 associées à la déforestation et la dégradation.

En 2008, Le Woods Hole Research Center (WHRC) a produit une première carte de la distribution de biomasse ligneuse aérienne couvrant la région tropicale de l'Afrique en utilisant des images satellites du capteur MODIS à la résolution de (1 km) avec des données d'inventaires forestiers récents, couvrant la période 2000 - 2003. Nous avons développé un modèle statistique qui explique 82% de a variance de la biomasse ligneuse aérienne avec une erreur quadratique moyenne de 50.5 Mg/ha. La carte présente un gradient de biomasse allant de 0 a 354 Mg/ha. Nous avons trouvé une corrélation élevée (r^2 : 0.90) entre notre carte de la biomasse et la hauteur de la canopée qui ont été dérivées de données lidar du Système Laser Altimétrique Géoscience (GLAS). Les données GLAS sont maintenant calibrées avec des inventaires forestiers récents afin de développer une nouvelle carte de la biomasse ligneuse aérienne à 500m de résolution pour 2006-2007. Cette carte a été présentée à la COP15 de Copenhague et elle sera distribuée à Cancun lors de la Conférence des parties (COP16). La carte de 2000-2003 est accessible ce site internet http://www.whrc.org/africa/carbonmap2000.htm

Introduction

Les forêts contiennent environ 80% des stocks globaux de carbone ligneux aérien et 40% du carbone total (sol, feuille, racines) et elles jouent un rôle important dans le cycle du carbone global[1] . Les forêts tropicales sont aussi un puit de carbone important[2]. En Afrique, on estime que les forêts denses humides fixent environ 0.63 MgC/ha/an[3] mais la déforestation tropicale mondiale contribue environ à un cinquième du total des émissions annuelles des gaz a effet de serre d'origine anthropique dans l'atmosphère.[4]

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1 Houghton R A 2005 *Glob. Change Biol.* **11** 945–58

2 Stephens B B *et al* 2007 *Science* **316** 1732–5

3 Lewis, Simon L. et al, 2009 *Nature* 457 1003-1006.

4 Houghton R 2007 *Annu. Rev. Earth Planet. Sci.* **35** 313–47

L'Afrique a le deuxième plus grand bloc de forêt tropicale dans le monde, après celui du bassin de l'Amazone, mais c'est un des moins connu en termes de stocks de carbone et des taux de conversion des forêts[1]. C'est en Afrique centrale, que les blocs de forêts humides les plus importants s'étendent, ils sont menacés par la dégradation associée à l'exploitation forestière industrielle[2] et la déforestation pour l'agriculture[3].

La télédétection a été utilisée depuis longtemps pour étudier la structure forestière et la biomasse ligneuse aérienne.[4,5] Bien que les observations obtenues par télédétection ne mesurent pas directement la biomasse, la radiométrie est sensible à la structure de la végétation (taille de la couronne et la densité des arbres etc.), la texture est très sensible à l'ombre portée des grands arbres, donnant une rugosité du couvert plus importante, et la radiométrie est corrélées à la biomasse, en particulier dans les bandes infrarouges courtes. Par conséquent, les mesures obtenues par télédétection, réflectance spectrale, peuvent être des prédicteurs utiles de la biomasse[6]. Plus récemment, le lidar (Light Detection And Ranging) a été utilisé pour caractériser avec succès la structure verticale de la vegetation, la hauteur, et d'en déduire une estimation de biomasse.[7], [8]

Données et méthodes

Zone d'étude

La zone d'étude couvre environ 20 millions de km^2 d'Afrique tropicale. La région se caractérise par un gradient de formations végétales important allant des forêts tropicales humides aux savanes sèches. [9,10]

Données MODIS

Nous avons selectioné les données MODIS (NBAR) – produit gratuit "MOD43B4.V4" pour cette étude. Le produit NBAR a été corrigé des problèmes de réflectance bidirectionnelle, et des effets atmosphériques[11]. Ce produit a une résolution temporelle de 16 jours et une résolution spatiale de 1km. Les sept bandes spectrales de MODIS de la longueur d'onde 459 nm à 2155 nm sont utilisées. Pour chaque bande spectrale la meilleure mosaïque temporelle a été construite pour l'ensemble de l'Afrique en combinant [4] années consécutives de données entre 2000 et 2003, ceci a permis de produire une mosaique qui n'est pas affectée par les nuages.

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1 Laporte N., S. Lin, J. LeMoigne, D. Devers, and M. Honzak (2004), Toward an Integrated Forest Monitoring System for Central Africa. In: *Land Change Science: Observation, Monitoring, and Understanding Trajectories of Change on the Earth Surface*, Remote Sensing and Digital Image Processing, Vol (6), Ed. G. Gutman. ISBN: 1-4020-2562-9, p 97-110.

2 Laporte, N.T., J. A. Stabach, R. Grosch, T.S. Lin, and S.J. Goetz. 2007. Expansion of Industrial Logging in Central Africa. Science316:1451.

3 Hansen M. C. *et al* 2008. *Proc. Natl Acad. Sci. USA* **105** 9439–44

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8 Drake B J, Dubayah R O, Knox R G, Clark D B and Blair J B 2002 *Remote Sens. Environ.* **81** 378–392

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10 White F. 1983. *The Vegetation of Africa*(LaChaux-de-fonds,Switzerland: UNESCO)

11 Schaaf C B *et al.* 2002. *Remote Sens. Environ.* **83** 135–48

Pour la mosaïque MODIS de 2006-2007, nous avons utilisé la même technique, mais les données sont à la résolution spatiale de 500m au lieu de 1km, cette mosaïque sera à l'origine de la prochaine carte de la biomasse ligneuse aerienne pour l'Afrique développée par le WHRC.

GLAS mesures lidar

L'instrument GLAS à bord du satellite (ICESat) est un capteur lidar. Initialement conçu pour l'observation des glaciers[1], il échantillonne la surface de la planète avec une empreinte de 65 m au sol. Les mesures lidar ont été utilisées depuis longtemps pour caractériser la structure de la végétation[10] et la biodiversité[2]. Drake et al (2003) ont constaté une corrélation forte entre la biomasse ligneuse aerienne et la hauteur de la canopée ainsi que l'énergie médiane (home) dérivée des mesures de lidar en forêt tropicale[3].

Les données d'inventaires forestiers

Pour la carte de 2000-2003, les biomasses ont été calculées à partir d'inventaires forestiers existants en République du Congo (ROC), au Cameroun et en Ouganda. Nous avons utilisés le produit Landsat GeoCover pour déterminer visuellement s'il y avait eu de la dégradation ou des changements de l'occupation des terres entre la période de mesure des images MODIS et les mesures de terrain.

Pour la carte de 2006-2007, les biomasses sont tirées de nos propres inventaires. Dans ce cas, la méthode d'échantillonage a été conçue dans l'optique de calibrer les données GLAS dont l'empreinte au sol est de 64m. Il faut donc absolument que les parcelles soit de taille inferieure à celle de l'empreinte de mesure lidar pour la calibrer le plus précisément possible. Plusieurs centaines de points de mesures nous permettent alors de développer un modèle statistique qui lie directement les biomasses estimées à partir des inventaires forestiers avec les données GLAS. Dans ce cas, la parcelle échantillonnée est d'une surface de 40m par 40 m, et tous les arbres vivants de DBH > 5cm sont mesurés. De plus, les hauteurs des 3 arbres les plus grands à partir du centre de la parcelle sont mesurées. Le protocole est disponible en envoyant un courrier électronique à cette adresse : biomass@whrc.org

République du Congo

Nous avons utilisé des mesures d'inventaire recueillies par la Congolaise Industrielle des Bois (CIB) sur la période 2001-2003, portant sur quatre unités d'aménagement forestier dans le nord de la République du Congo. L'intensité d'échantillonnage était de 1% pour les grands arbres (diamètre du tronc de 40 cm et plus), 0,5% pour arbres de petite taille (dans la gamme 20-40 cm) et 0,2% pour «les arbres en régénération (5 - 20 cm de large)[4]. Pour les grands et les petits arbres, tous les individus ont été dénombrés; pour les arbres en régénération seulement les espèces commerciales. Nous avons utilisé l'équation allométrique de Brown[5] pour dériver la biomasse des données d'inventaire. Au total, 942 points d'échantillonnage ont été retenus.

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1 Zwally H J *et al* 2002 *J. Geodyn.* **34** 405–45.

2 Goetz S, Steinberg D, Dubayah R and Blair B 2007 *Remote Sens. Environ.* **108** 254–63

3 Drake B J, Knox R G, Dubayah R O, Clark D B, Condit R, Blair J B and Hofton M. 2003.

Glob. Ecol. Biogeogr. **12** 147–59.

4 Wilks C 2003 An outside look at the CIB management inventory in northern Congo *Technical Report* Congolaise Industrielle des Bois

5 Brown S, Pearson T, Moore N, Parveen A, Ambagis S and Shoch D 2005. Impact of selective logging on the carbon stock of tropical forests: Republic of Congo as a case study *Technical Report 6 Winrock International*

Inventaires du Cameroun

Ils s'étendent sur environ 200 km par 700 km de forêts dense humide. Comme dans le cas de la République du Congo, les images Landsat GeoCover ont été utilisées pour exclure les échantillons où des changements du couvert forestier avaient pris place entre le moment des inventaires (1994) et les acquisitions MODIS (2000-2003). Dans ce cas, les mesures d'inventaires avaient été déjà converties en biomasse en utilisant les équations allométriques de Brown[1]. Au total, 61 points d'échantillonnage ont été retenus.

Ouganda

Les données de biomasse ont été tirées de la carte de l'inventaire national de la biomasse[2]. Les mesures sur le terrain ont été recueillies entre 1995 et 1999. Après un contrôle des points avec Landsat GeoCover, nous avons retenu 442 points d'échantillonnage pour notre analyse.

Méthodes

Un modèle statistique de type "Regression Tree" a été utilisé dans de nombreuses études de télédétection.[3,4] Ici le "Random Forest", est utilisé pour prédire la biomasse en intégrant les échantillons de biomasse de l'Ouganda, de la République du Congo et du Cameroun avec les mesures de réflectance des 7 bandes de MODIS sur la période 2000-2003. Pour évaluer la précision de ce modèle, un sous-échantillon de données de biomasse a été réservé afin de faire une validation croisée. Nous avons ainsi gardé 10% (154 échantillons) des données, qui ont été extraites de façon aléatoire

Pour la carte de 2006-2007, nous sommes encore dans une phase de collection des données d'inventaires pour un échantillon de points de mesure lidar (GLAS). Des données ont déjà été collectées en Tanzanie, en Uganda, au Gabon et en République Démocratique du Congo pour l'Afrique, ainsi que dans plusieurs pays de l'Amazonie et de l'Asie du sud-est. La carte de la biomasse finale sera distribuée pour l'ensemble des tropiques en décembre 2010 à la COP16.

Résultats pour la carte de 2000-2003

La carte de la biomasse ligneuse aérienne (Figure 1) présente un gradient de biomasse allant de 0 a 354 Mg/ha. Les valeurs les plus élevées sont concentrées en Afrique centrale, dans les forêts denses humides. Il faut cependant noter des biomasses importantes pour les forêts sèches au sud de la République Démocratique du Congo, en Zambie, et en Tanzanie. Les biomasses les plus faibles s'observent dans les régions saheliennes au Mali, Burkina Faso et au Soudan. Dans cette région, la végétation se caractérise par un couvert d'arbres clairsemés de taille plus réduite que ceux des forêts denses humides. Ce paysage est dominé par la réflectance du sol nu.

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1 Brown Estimating biomass and biomass change of tropical forests. A primer *Technical Report 134* Food and Agriculture

Organization of United Nations (FAO), Rome Brown S, Pearson T, Moore N, Parveen A, Ambagis

2 Drichi P. 2003. National biomass study *2003 Technical Report* Forest Department, PO Box 1613, Kampala, Uganda.

3 Hansen M, Dubayah R and DeFries R 1996. *Int. J. Remote Sens.* **17** 1075–81.

4 Saatchi S S, Houghton R A, Alvala D S, Soares J V and Yu Y 2007 *Glob. Change Biol.* **13** 816–37.

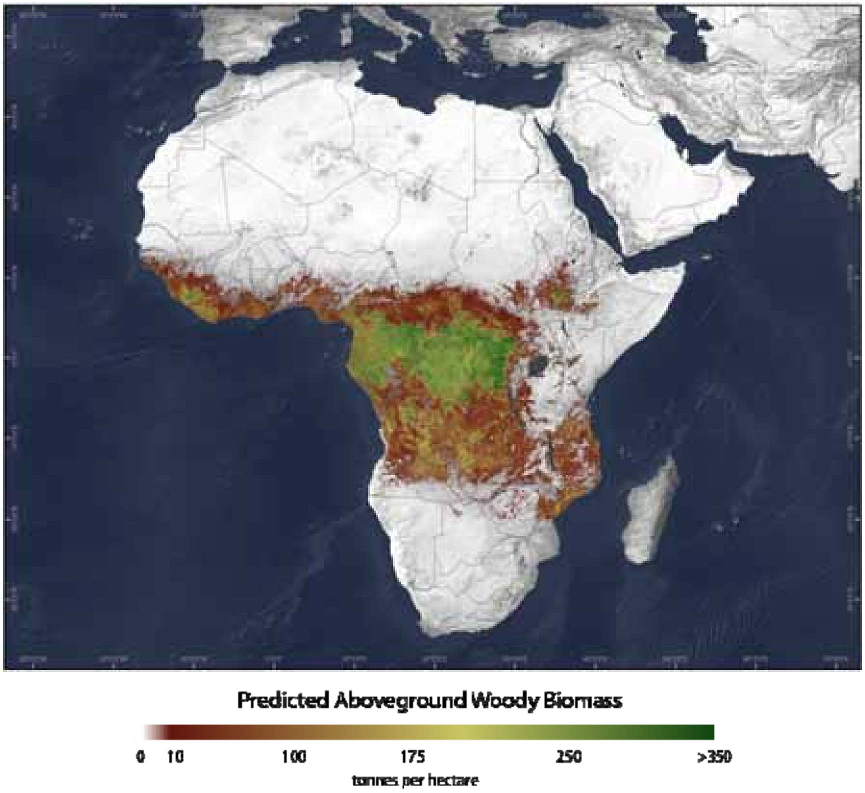

Figure 1. Carte de la distribution de la biomasse 2000-2003.

Le modèle statistique développé pour cette carte explique 82% de variance de la biomasse ligneuse aérienne avec une erreur quadratique moyenne de 50.5 Mg/ha. Nous avons trouvé une corrélation élevée (r^2 : 0.90) entre notre carte de la biomasse et la hauteur de la canopée qui a été dérivée des données lidar du Système Laser Altimétrique Géoscience (GLAS) ; avec les plus grands arbres associés aux biomasses les plus élevées et les arbres les plus petits aux biomasses les plus faibles. Parce que la biomasse forestière est liée à de la taille des arbres (DHP et la hauteur) et le nombre d'arbres par unité de surface, les mesures lidar sont donc très utiles pour estimer la biomasse. Nos résultats sont cohérents avec ceux des autres études lidar de la biomasse des forêts tropicales.[1]

Cette carte nous permet de faire des estimations de stocks de carbone par type de végétation, par pays ou pour l'ensemble de l'Afrique centrale, dans le tableau ci-dessous nous avons reproduit la table 12.7a. du chapitre 12 du rapport sur l'Etat des forêts d'Afrique Centrale de 2008. Les estimations combinent notre carte de la biomasse ligneuse aérienne avec une carte des types de végétation de Mayaux et al (2004).[2]

Le stock de carbone total estimé dans le basin du Congo à partir de la carte MODIS (tableau 1) est de 48 gigatonnes; il est de 46 gigatonnes pour le rapport de l'état des forêts[3]. Avec l'essentiel du carbone contenu dans les Forêt dense humide de basse altitude fermée (54%) et la classe de mosaïque Forêt /savane (10%).

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1 Lefsky M A,et al. 2005. *Geophys. Res. Lett.* **32** L22S02.

2 Mayaux P, Bartholome E, Fritz S and Belward A 2004 *J. Biogeogr.* **31** 1–17.

3 Nasi R.et al, 2008. State of the Forest 2008: The forests of the Congo basin.

Tableau 1. Estimation du stock de carbone total dans le basin du Congo.

Type de vegetation (1)	Surface Km2 (2)	Carbone aerien (0.47C/AGB) (3)	R/S (4)	Carbone dans racines (5)	Carbone organique sol (6)	Total C (millions de tonnes)
Forêt dense humide de basse altitude fermée	155458587	16331007160	0.235	3837786683	5907426304	26076.22
Forêt dense d'altitude moyenne	11202854	1370017427	0.235	321954095.4	425708455.2	2117.68
Forêt de montagne	2226266	202060411.9	0.235	47484196.8	84598107.08	334.14
Forêt marécageuse	13309942	1568144699	0.235	368514004.3	505777783.6	2442.44
Mosaïque de forêt/terre cultivée	22609376	1838379240	0.275	505554291.1	859156292.9	3203.09
Mosaïque de forêt/savane	54457481	2003950227	0.42	841659095.2	2069384289	4914.99
Forêt dense décidue	28916729	1145526991	0.275	315019922.5	1098835703	2559.38
Savanes boisées décidues	62970922	1362919545	0.322	438860093.4	2392895046	4194.67
Savanes arbustives décidues, arbres épars	9990291	122301097.9	0.42	51366461.14	379631069	553.30
Savane arbustive décidue ouverte	20032272	285322241.4	0.42	119835341.4	761226348.9	1166.38
Savanes herbeuses fermées	9070093	87775261.15	0.42	36865609.68	344663546.9	469.30
Savane herbeuse ouverte avec arbustes épars	314603	926326.90	0.42	389057.29	11954931.52	13.27
Savanes herbeuses ouvertes	1975	0	0.42	0	0	0
Savane herbeuse éparse	12364	23729.20578	0.42	9966.27	469844.4701	0.50
Marais, broussailles et prairies	1340156	32456025.71	0.42	13631530.8	50925920.06	97.01
Basin du Congo						48142.37

Nous avons utilisé les mêmes coefficients de conversion que Nasi et al, 2008.

(1)Type de végétations (Global Land cove 2000)- (2) Surfaces de pays (FAO, 2005) (3) AGC carbone aérien (facteur de conversion pour passer de la biomasse au carbone est de (0.47) (4) RS ratio racine/tige il varie en fonction du type de végétation (5) R Carbone dans racines (6) COS carbone organique dans sol.

Le tableau 2 présente les résultats des estimations de stock de carbone (en millions de tonnes) pour six (6) pays du basin du Congo et les compare aux études de Nasi et al. (2008) et de Gibbs et al. (2007). De façon générale, notre méthodologie a produit des estimations qui paraissent supérieures à celles de Gibbs et al. (2007) et inférieures à celles de Nasi et al. (2008). Ces résultats obtenus à partir de la carte MODIS pourraient être considérés comme des valeurs moyennes des estimations de stock de carbone pour ces pays du basin du Congo. Néanmoins, nous constatons de façon exceptionnelle qu'il y a deux (2) pays où nous avons obtenu des valeurs plus élevées par rapport aux études sus-mentionées, à savoir la république du Congo (4455 contre 4219 et 3455) et de la République Démocratique du Congo (29507 contre 27258 et 20418) – (unites : millions de tonnes).

Tableau 2. Biomasse et stock de carbone estimés à partir de MODIS GLC2000 par pays (millions de tonnes).

Name	Cameroun	ROC	Gabon	Guinee Eq.	R. CAF	RDC
Forêt dense humide de basse altitude fermée	2892.9	2974.6	3523.7	311.2	1317.3	15056.5
Forêt marécageuse	1.2	887.4	14.3	0	0	1539.6
Forêt dense d'altitude moyenne	137.3	0.01	13.9	3.8	4.44	1958.1
Forêt de montagne	23.5	0	0	0	0	310.6
Total Forêt dense humide (1-4)	3054.9	3862	3551.9	315	1321.7	18864.7
Mosaïque forêt/terres cultivées	286.9	257.2	190.8	53.5	31.63	2382.9
Mosaïque forêt/savane	617	0.45	0.36	0.032	1692.9	2604.1
Forêt dense décidue	0	100.3	20.3	0	0	2438.7
Savanes boisées décidues	608	5.99	4.63	2.89	1455.5	2117.6
Savanes arbustives décidues, arbres épars	110	239	39.2	0.03	231.48	1099.5
Total par pays WHRC	4677	4465	3807	371	4733	29507
Nasi et al, 2008 [27]	5043	4219	4383	445	5460	27258
Gibbs et al, 2007**1**	3454	3458	3063	268	3176	20418

Limitation du modèle utilisé

Ce modèle tend à sous-évaluer les valeurs de biomasse élevées et à l'inverse à surestimer les biomasses les plus faibles. Cette tendance est intrinsèque aux modeles statsitique de type "arbre de regression". Cette limitation en soit n'est pas un problème pour la REDD puisqu'il est recommandé d'avoir des estimations conservatives du carbone.

Le modèle est aussi fortement influencé par le nombre d'échantillons utilisés pour l'apprentissage et leur représentativité de l'ensemble des biomasses existantes, et donc de la variabilité de la biomasse en Afrique. Bien que notre échantillon soit représentatif du gradient de biomasse en Afrique centrale, il serait souhaitable de rajouter des parcelles pour les zones de faible biomasse en zone sahélienne.

Conclusions

Malgré les efforts pour étendre des mesures d'inventaires, notamment par le biais de la FAO, il existe actuellement peu d'inventaires pour l'ensemble des pays de la COMIFAC. Les inventaires sont limités et coûteux. En attendant le déploiement d'inventaire à l'échelle nationale pour l'ensemble des pays de la COMIFAC, la combinaison d'inventaires forestiers plus reduit, mais representatif de l'ensemble des biomasses avec des images semble un bon compromis.

La disponibilite d'une carte de la distribution de la biomasse et du carbone pour les pays de la COMIFAC est une étape importante pour le développement de leurs activités dans le cadre de la gestion des resources naturelles et aussi de la REDD. Cette information est fondamentale pour évaluer avec précision le flux de carbone provenant des activités de déforestation et de dégradation.

De plus le nouveau rôle de l'Afrique dans l'économie mondiale, en particulier en relation avec la demande en nouvelles terres arables pour l'agro-industrie, peut accroître considérablement la pression sur les ressources naturelles existantes. Il est donc essentiel de disposer d'informations

1 Gibbs H K, Brown S, Niles J O and Foley J A 2007 *Environ. Res.Lett.* **2** 045023

fiables et actuelles sur la distribution spatiale du carbone afin de pouvoir prédire avec plus de précision l'impact des choix de development économiques sur les flux de carbone.

Une nouvelle carte à une resolution de 500m pour les années 2006-2007 est en cours de développement à l'aide de nombreux partenaires dans la region. Les données d'inventaires récents pour l'ensemble des types de végétation d'Afrique centrale, permetront de mieux calibrer les données GLAS et d'améliorer la carte de la biomasse résultante.

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Canopy (Aerial) Carbon Stocks Measurement in Congo Basin Forest / Estimation des stocks de carbone aérien dans les forêts du Bassin du Congo : Cas des parcelles permanentes de l'Ituri et de la Salonga en RDC

Jean-Remy Makana

Wildlife Conservation Society

Introduction

La destruction et la dégradation des forêts contribuent pour près de 20% des émissions des gaz à effet de serre (GES) responsables du réchauffement climatique global ([1]GIEC 2007). Pour atténuer l'ampleur des changements climatiques associés au changement de l'utilisation des terres, la conférence des parties de la CCNUCC de 2007 à Bali a adopté un plan d'action incluant la mise en place des 'approches politiques doublées d'incitations positives dans le traitement de questions touchant à la réduction des émissions liées à la déforestation et à la dégradation de la forêt (REDD) dans les pays en voie de développement.' Toutefois, toute incitation positive visant à réduire les émissions des gaz à effet de serre, en particulier le dioxyde de carbone (CO_2), liées au changement de l'utilisation des terres doit reposer sur la capacité à mesurer avec précision les stocks de carbone forestier et de suivre le changement de stock ou flux de carbone dans le temps. L'estimation des émissions de CO_2 demande une connaissance des stocks (densité) de carbone, tonnes de carbone par unité de surface, et de l'étendue de chaque catégorie d'utilisation des terres dans une zone donnée. Ainsi, les directives de la CNUCC stipulent que chaque pays qui veut participer au mécanisme REDD doit développer un système robuste et transparent de mesure (suivi), reportage et de vérification (MRV) des émissions des GES sur tout son territoire national. Ce système MRV comprend deux composantes principales dont le suivi du couvert

1 GIEC, 2007. Bilan 2007 des changements climatiques. Contribution des Groupes I, II et III au quatrième Rapport d'évaluation du Groupe d'experts intergouvernemental sur l'évolution du climat. GIEC, Génève, Suisse, 103 pages.

forestier, qui se fait par l'analyse d'images satellitaires (télédétection), et la mesure des stocks et variation des stocks de carbone sur le terrain.

Importance des inventaires forestiers

Certaines techniques permettent aujourd'hui d'estimer la biomasse aérienne des forêts, et donc les stocks de carbone forestier, sur base d'images satellitaires de haute résolution. Cependant, les estimations les plus précises des stocks de carbone forestier sont obtenues par les inventaires forestiers, tandis que le monitoring des changements des stocks de carbone passe par l'établissement des parcelles permanentes dans lesquelles les arbres sont mesurés à intervalle régulier. Les mesures de terrain présentent donc des avantages que les techniques de télédétection ne peuvent encore offrir à ce jour. Premièrement, les mesures de terrain donnent des estimations plus précises qui permettent de détecter les variations spatio-temporelles à une échelle plus fine capable de fournir les informations requises sur l'impact des activités humaines sur les changements des stocks de carbone. De ce fait, elles servent aussi à tester et à calibrer les techniques de mesure basées sur l'analyse d'images satellitaires pour la cartographie des stocks de carbone à grande échelle. Dans le contexte du processus REDD, les inventaires forestiers détaillés sont requis pour qu'un pays puisse utiliser le niveau 3 du GIEC pour l'inventaire des émissions de gaz à effets de serre et aspirer ainsi au niveau de compensation le plus élevé.

Deuxièmement, les forêts tropicales jouent un rôle écologique beaucoup plus important que le simple fait de stocker le carbone. Il a déjà été démontré que les changements climatiques peuvent modifier de façon significative les processus écologiques naturels. Des études récentes indiquent une augmentation des taux de croissance et de mortalité des arbres et des lianes dans les forêts tropicales. Ce phénomène, ainsi que les changements dans la structure forestière et la composition floristique y associés sont supposés être la conséquence des changements climatiques ([1]Lewis et al. 2004; [2]Chave et al. 2008). Seules les mesures répétitives sur le terrain peuvent permettre une telle évaluation des impacts du changement climatique sur la structure et la composition des forêts.

Enfin, la réussite du processus REDD implique entre autre l'implication des acteurs responsables des changements de l'utilisation des terres, en particulier les communautés locales qui dépendent des ressources forestières. Les mesures de terrain à travers les inventaires forestiers permettent l'implication des acteurs locaux à travers l'évaluation participative des ressources naturelles, ce qui conduit au renforcement des capacités des communautés et facilite ainsi l'appropriation du processus REDD au niveau local.

Bien que présentant des avantages indéniables dans l'estimation des stocks et les flux de carbone forestier, les inventaires forestiers présentent aussi quelques désavantages dont les plus importants sont les difficultés liées à la stratification et l'échantillonnage, l'ampleur du travail de terrain et les couts élevés y associés, ainsi que le contrôle de la qualité des données.

Suivi des stocks de carbone forestier en Afrique Centrale

Une évaluation de l'état des lieux des parcelles permanentes en Afrique Centrale a révélé une grande disparité de couverture nationale et éco-climatique ([3]Picard, 2007). Si certains pays

1 Lewis, SL, OL Phillips, TR Baker, J Lloyd, Y Malhi et al. 2004. Concerted changes in tropical forest structure and dynamics: evidence from 50 South American long-term plots. Phil. Trans. R. Soc. Lond. B 359: 421-436

2 Chave, J, R. Condit, HC Muller-Landau, SC Thomas & CTFS Group. 2008. Assessing evidence for a pervasive alteration in tropical tree communities. PloS biology 6(3): e45. doi: 10.1371/journal.pbio.006 0045.

3 Picard, N. 2007. Dispositifs permanents pour le suivi des forêts en Afrique Centrale: un état des lieux. CIRAD.

comme le Gabon et le Cameroun possèdent des réseaux importants de parcelles permanentes, la République Démocratique du Congo, la République Congo et la République Centrafricaine ont très peu de parcelles permanentes. Par ailleurs, la quasi-totalité des parcelles permanentes de la région sont situées en forêts denses humides de basse altitude de terre ferme. Des écosystèmes forestiers importants comme les forêts sèches, les forêts marécageuses, les galeries forestières et les forêts de montagne ont fait l'objet de très peu d'études. Dans l'optique du processus REDD il serait aussi important d'évaluer les stocks de carbone dans les complexes agricoles constitués des matrices des champs actifs, des jachères ou forêts secondaires d'âges variables ainsi que des lambeaux de forêts primaires.

Parcelles permanentes de l'Ituri et de la Salonga

Les parcelles de l'Ituri, situées au nord-est de la RDC, ont été établies en 1994-1996 par la Wildlife Conservation Society (WCS) et le Center for Tropical Forest Science (CTFS) pour un suivi des changements de la structure et de la composition forestière en forêt primaire non perturbées et pour comparer ces paramètres entre les forêts monodominantes et les forêts mixtes de la région. Tous les arbres ≥ 1 cm dhp (diamètre à hauteur de poitrine) et les lianes ≥ 2 cm dhp ont été mesurés, cartographiés, étiquetés et identifiés dans quatre parcelles de 10 hectares chacune dont deux sont situées en forêts monodominantes et les deux autres en forêts mixtes ([1]Makana et al. 2004). Des inventaires et mensurations subséquents ont eu lieu en 2001 et 2007 pour le suivi des taux de croissance, de mortalité et de recrutement. Le premier tour de mensurations a duré deux ans et a connu la participation de plus de 30 personnes pour un cout total d'environ $100,000. Les mensurations suivantes ont chaque fois été accomplies pendant une période de douze mois avec une équipe d'environ 25 personnes et un cout total avoisinant $130,000 par cycle.

Les parcelles de la Salonga sont situées dans le plus grand parc forestier d'Afrique Centrale et elles ont été établies en 2007 sous l'initiative conjointe de WCS, de WWF et de CTFS en collaboration avec le Ministère de l'Environnement, Conservation de la Nature et Tourisme de la RDC (MECNT). Tous les arbres ≥ 10 cm dhp et les lianes ≥ 5 cm dhp ont été mesurés, étiquetés et identifiés dans 17 parcelles d'un hectare chacune réparties en forêts primaires (9 parcelles), forêts secondaires vieilles (4 parcelles) et jeunes (4 parcelles). Pour raffiner l'estimation de la biomasse, la hauteur de tous les arbres a été aussi mesurée.

L'estimation de la biomasse a été faite pour chaque arbre individuellement en utilisant des équations allométriques basées sur le diamètre et la hauteur de l'arbre, et la densité de bois de l'espèce. Deux modèles allométriques ont été utilisés. Le modèle qui a servi pour l'Ituri n'a fait appel qu'à deux variables, le diamètre et la densité du bois, tandis que celui utilisé pour la Salonga était basé sur tous les trois variables ([2]Chave et al. 2005). Les deux modèles se présentent comme suit:

$$BA_1 = \rho \times \exp(-1.562 + 2.148\ln D + 0.207\ln D^2 + 0.0281\ln D^3)$$

$$BA_2 = \exp(-2.977 + \ln(\rho D^2 H)),$$

où BA est la biomasse aérienne d'un arbre, ρ est la densité de bois de l'espèce à zéro pourcent d'humidité, D le diamètre à hauteur de poitrine (1.30 m du sol) et H la hauteur de l'arbre. Pour

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1 Makana, J-R, T.B. Hart. C. Ewango, I. Liengola, J.A. Hart &R. Condit. 2004. Ituri Forest Dynamics plots, DRC. In: E. Losos & E. Leigh (eds.) Tropical |Forest Diversity and Dynamism: Findings from a Large-Scale Network. University of Chicago Press, Chicago, pp. 492-505.

2 Chave, J, C Andalo, S Brown, MA Cairns, JQ Chambers, D Eamus et al. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99.

les individus ayant plus d'une tige, la biomasse a été calculée pour chaque tige séparément et les biomasses des différentes tiges ont été ensuite additionnées pour trouver la biomasse de l'individu. Etant donné que le carbone représente plus ou moins 50% de la biomasse sèche, celle-ci a été par deux pour obtenir le stock de carbone.

Table 1. Stocks et changement de stocks de carbone* dans quelques forêts tropicales humides.

Site (pays)	Type de forêt	Carbone (t/ha)	Changement de C (tC/ha/an)
Ituri, RD Congo	Forêt primaire monodominante	270.8	2.89
Ituri, RD Congo	Forêt primaire mixte	198.9	3.32
Salonga, RD Congo	Forêt primaire mixte	151.1	-
Salonga, RD Congo	Forêt secondaire veille (~40 ans)	114.6	-
Salonga, RD Congo	Forêt secondaire jeune (~10 ans)	79.0	-
Lambir, Malaisie	Forêt primaire	248.6	3.56
Yasuni, Equateur	Forêt primaire	141.2	3.38
Palanan, Philippines	Forêt primaire	145.0	2.40
Pasoh, Malaisie	Forêt primaire	169.9	3.48

*Les données de l'Ituri, Lambir, Yasuni, Palanan et Pasoh sont tirées de Chave et al. 2008

Il ressort du tableau ci-haut que les forêts primaires du bassin du Congo contiennent des stocks de carbone assez considérable. Les forêts monodominantes de l'Ituri, dominées par *Gilbertiodendron dewevrei*, sont particulièrement riches en carbone. Les données de suivi de changement des stocks de carbone en Ituri indiquent une accumulation de ~ 3 tC/ha/an, ce qui suggère que ces forêts sont potentiellement un important puits de carbone.

Conclusions et recommandations

Les mesures de terrain sont importantes car elles permettent de détecter des variations spatiales et temporelles de stocks de carbone que les autres techniques ne pourraient pas révéler. On note une grande variation des stocks de carbone dans les différentes forêts congolaises étudiées, et ces forêts contiennent des stocks de carbone élevés comparées à d'autres forêts tropicales. Comme celles de l'Amérique Latine, les forêts du bassin du Congo montrent aussi une accumulation significative de carbone et constituent ainsi un puits potentiel de carbone ([1]Lewis et al. 2009). La grande variation des stocks de carbone dans les forêts du bassin du Congo rend manifeste le besoin de multiplier les sites d'observation pour obtenir des estimations plus fiables de la densité de carbone forestier à travers l'ensemble des forêts du bassin. Pour y arriver, les actions suivantes sont recommandées:

– La création d'une structure sous-régionale pour coordonner la mesure de carbone forestier dans le bassin du Congo.

– Le renforcement des capacités des institutions gouvernementales chargées des forêts.

– La standardisation des méthodes pour la mesure du carbone forestier.

1 Lewis, SL, G Lopez-Gonzalez, B Sonké, K Affum-Baffoe, TR Baker, LO Ojo, OL Phillips, JM Reistma, L White et al. 2009. Increasing carbon storage of intact African tropical forests. Nature 457. doi: 10.1038/nature07771

L'extension du réseau des parcelles permanentes à tous les types forestiers majeurs du bassin du Congo, dont les forêts marécageuses, les forêts sèches, les forêts de montagne, les galeries forestières, les forêts secondaires et les complexes agricoles.

Développer des équations allométriques propres aux forêts du bassin congolais pour améliorer l'estimation des stocks et changement des stocks du carbone forestier de la région.

Ces actions sont d'une importance cruciale pour les pays de l'Afrique Centrale car elles permettent d'affiner les informations sur l'inventaire des émissions de dioxyde de carbone liées aux changements d'utilisation des terres afin de renforcer les positions de négociations des pays de la COMIFAC.

Carbon Stock Estimation in Forest Concessions / La gestion et le suivi des stocks de carbone et des émissions associées dans les concessions forestières en Afrique Centrale

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Introduction

En 2010, la forêt est au centre des débats sur la lutte contre le réchauffement climatique. Cette place est justifiée, car la forêt dégage plus de gaz à effet de serre que le secteur des transports. La déforestation, la dégradation, et plus généralement les activités de l'homme en forêt représente 15 à 20% des émissions de gaz à effet de serre. Aujourd'hui l'opportunité est donnée aux pays qui possèdent des surfaces forestières d'être « récompensés » pour la protection de ce patrimoine à travers les mécanismes de Réduction des Emissions liées à le Déforestation et à la Dégradation des forêts (REDD).

Dans ce contexte, les acteurs du secteur forestier, et notamment les sociétés forestières qui jouent un rôle prépondérant dans le cadre du REDD+, ont besoin d'outils pour le suivi et la gestion des stocks de carbone adaptés aux dimensions de leur entreprise. Les concessions forestières, qui couvrent approximativement 25% de la superficie forestière du Bassin du Congo, jouissent de données dendrométriques de terrain précises et exhaustives, acquises lors de la préparation des Plans d'Aménagement. Environ 18 millions d'ha de forêt sont déjà couverts par des inventaires d'aménagement forestier.

Cet article présente les outils de mesure du stock de carbone et de son évolution dans le temps développé s par FRM à travers les exemples des UFA Bétou et Missa au Nord Congo (595 948ha).

Evaluation des stocks de carbone forestier et étude des caractéristiques des forêts tropicales à l'échelle des concessions forestières

En se basant sur ces données d'inventaire d'aménagement (toutes les tiges DHP > 20cm ou 10 cm selon les cas, toutes essences confondues), FRM a développé un outil d'aide à la gestion du carbone forestier, FOREST CARBON PRINT module Stock (FCP-Stock) qui permet d'obtenir une carte des stocks de carbone sur la concession, avec une résolution fine, permettant de mettre en avant l'hétérogénéité spatiale du carbone contenu dans la biomasse aérienne ligneuse (cf. Figure 1). La connaissance des opérations forestières sur ces espaces permet de mesurer leur impact sur les stocks et par conséquent d'orienter les mesures de gestion de manière à diminuer l'impact de l'activité sur les stocks de carbone.

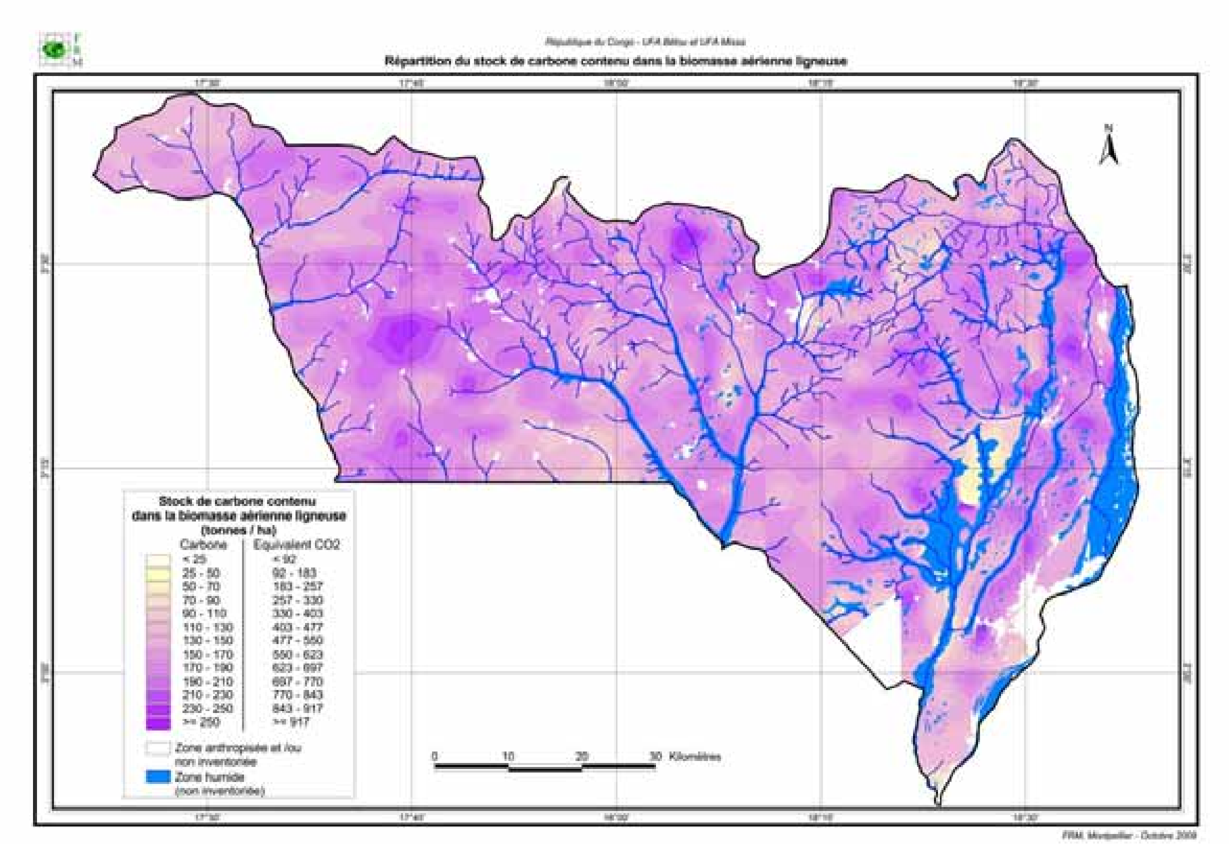

Figure 1. Cartographie des stocks de carbone de la biomasse aérienne de deux concessions forestière totalisant 594 948 ha (Nord Congo) -Avec la collaboration de Likouala Timber S.A.

FCP-Stock V.1 permet de calculer les stocks de carbone de la biomasse ligneuse à partir de données d'inventaires d'arbres > 10cm de DHP avec :

- Une estimation des stocks de la classe de diamètre [10;20cm[si le diamètre de précomptage commence à 20cm de DHP;
- Les calculs s'appuient sur un base de donnée de densité des bois de près de 1800 espèces tropicales du monde entier. La prise en compte de la diversité floristique locale, notamment pour les paramètres de densité des bois, permet d'accroitre considérablement la précision des résultats. Si la densité de bois d'une essence est inconnue alors une valeur de densité moyenne de la famille ou du genre est appliquée.

Les résultats sont exprimés par :

- placette échantillon afin de réaliser une cartographie de la répartition des stocks de carbone forestier de la zone d'étude ;
- strate forestière ou type de forêt si elles ont été délimitées au cours du plan d'aménagement.

L'outil permet de produire toute une série de résultats (cartographie des densités des bois, histogramme de répartition des stocks de carbone…) qui permettent d'améliorer la connaissance des forêts et les stocks de carbone qu'elles contiennent. Ces résultats présentent aussi bien un intérêt à l'échelle de concession forestières et de projets REDD qu'à des échelles plus globales pour une meilleure connaissance des bassins forestiers dans le monde.

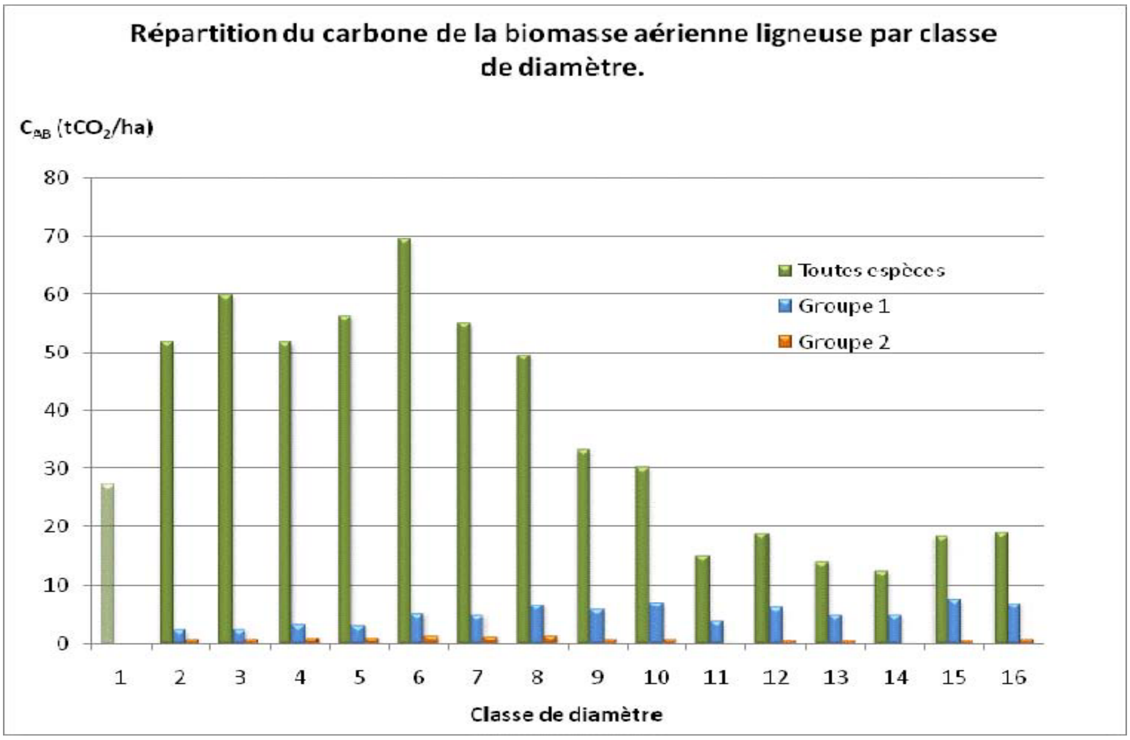

Figure 2. concessions forestières de Bétou et Missa (Nord Congo) -Avec la collaboration de Likouala Timber S.A..

L'histogramme de la classe de diamètre [10;20cm[apparaît en transparence car les valeurs affichées sont issues d'une estimation, l'inventaire d'aménagement commençant au seuil de DHP 20cm sur ces concessions.

Groupe 1 = essences objectifs, groupe 2 = essences de promotion.

Même si à ce jour il n'existe pas d'équation carbone validée pour son application en Afrique Centrale, l'outil a été conçu de manière à s'adapter facilement à toutes nouvelles avancées scientifiques, et être utilisable sur tous les bassins forestiers du monde. Les résultats présentés ont été obtenus par application de l'équation allométrique développée par CHAVE et al. (2005)[1], calibrée à partir d'un échantillonnage remarquable de 2410 arbres.

Modélisation de la dynamique forestière en fonction des modes de gestion pratiqués sur les concessions forestières

Un travail de modélisation, prenant en compte la diversité floristique à l'échelle locale, est entrepris pour prédire l'évolution de ce stock de carbone selon les différentes options de gestion, permettant aux forestiers de choisir, en fonction du prix de vente de la tonne de carbone, les solutions les plus rationnelles en comparant les résultats économiques attendus de différents scénarios REDD+.

L'outil est en cours de paramétrage et sera présenté au début du deuxième trimestre 2010. Dans le contexte du REDD, il est évident que les lacunes actuelles concernant la connaissance de la

1 CHAVE, J., ANDALO, C., BROWN, S., CAIRNS, M.A., CHAMBERS, J.Q., EAMUS, D., FÖLSTER, H., FROMARD, F., HIGUCHI, N., KIRA, T., LESCURE, J.-P., NELSON, B.W., OGAWA, H., PUIG, H., RIERA, B. et YAMAKURA, T., 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 13p.

dynamique des forêts denses humides africaines doivent être comblées. Les résultats qui seront présentés s'appuient sur approche conversationniste d'une synthèse des connaissances actuelles des données de mortalité, d'accroissement et de recrutement des espèces des forêts denses africaines.

FCP-Dynamic ne constitue pas un outil de modélisation absolu, mais un outil d'aide à la décision qui peut être facilement amélioré en fonction des avancées concernant la connaissance de la dynamique des forêts naturelles dans le monde.

Grâce à ces outils de mesure des stocks de carbone souples et adaptables, un nouveau mode de gestion des forêts denses humides peut se mettre en place, intégrant leur multifonctionnalité, tant au regard des ressources en bois qu'elles constituent que des stocks de carbone qu'elles contiennent.

Résumé de l'intervention FRM au cours de l'atelier "Monitoring des stocks et flux de carbone dans le Bassin du Congo", 2 au 4 février 2010, Brazzaville, Congo

Carbon and Agroforestry in Cameroon / Stockage de carbone dans les agroforêts cacao au Cameroun et perspectives pour l'Afrique Centrale

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Introduction : Pourquoi s'intéresser aux agroforest?

La foresterie paysanne joue un rôle important dans la gestion des terres en Afrique Centrale. Le récent rapport sur l'état des forêts du Bassin du Congo fait ressortir que les six pays du bassin comptent 86, 11 millions d'habitants en 2005. Une bonne partie de ces populations vit en zone rurale sur les marges forestières ou elle pratique l'agriculture et des activités de foresterie paysanne dans les jachères et les plantations de cultures pérennes comme les cacaoyères. Des études dans le cadre du programme ASB ont permis d'avoir une idée sur les principaux types d'occupation de sol (ASB, 2002) que l'on retrouve dans le Basin du Congo. Dans la zone de référence définie pour comprendre les dynamiques liées aux occupations de sol, les agroforêts cacao occupaient environ la moitié des différents types d'utilisation des terres utilisées à des fins de production agricole. Les systèmes agroforestiers à base de cacao, sont crées par modification du couvert forestier (donc ainsi de la biomasse) pour planter les cacaoyers introduire/maintenir les plantes campagnes au cacaoyer (FAO, 2002). Cette transformation s'accompagne d'une modification/dégradation de la biomasse forestière pour introduire d'autres biomasses. Dans un contexte ou l'on veut comprendre les flux de Carbone liée aux différents types d'utilisation des sols, il est donc important de s'intéresse au mode d'exploitation qui concerne la moitié des terres productives agricoles sur les marges forestières. Cette review présente donc les stocks de carbone dans les agroforêts cacao du Cameroun, pourquoi il est nécessaire de s'y intéresser et les perspectives pour l'Afrique Centrale.

Stock et flux de Carbone liées aux activités des petits paysans

Les activités agricoles sont connues comme jouant un rôle dans la déforestation sur les marges forestières de l'Afrique Centrale (Nasi et al. 2009). Les paysans aménagent/transforment la biomasse forestière pour gérer sur la parcelle une biomasse nouvelle (cultures vivrières, arbres, arbustes, etc.…) dans la perspective de satisfaire les besoins du ménage et commercialiser le surplus. Les études dans le cadre du programme ASB sont celles qui se sont de plus prêt intéressées aux petits paysans et ses activités sur les marges forestières du Bassin du Congo. Le rapport de la phase 2 de cette étude globale qui avait une composante Basin du Congo était réalisé dans le sud Cameroun (Partie Nord du Bassin du Congo). Pendant cette phase des chercheurs du système CGIAR appartenant au centre de recherche comme l'IITA et le CIFOR ont travaillé avec des collègues des institutions nationales (comme l'IRAD et l'Université de Yaounde 1 au Cameroun) pour mieux comprendre les modes de gestion de terres et le lien avec les forêts. Les informations produites pendant cette phase sont aujourd'hui celle qui permettent le mieux d'avoir une idée précise sur les stocks de Carbone sur les marges forestières du bassin du Congo.

Les différents types d'utilisation de sols identifiés dans le cadre de ce programme sont : les forêts matures, les forêts secondaires jeunes, les vieilles jachères, les cacaoyères en forêt secondaire, les jeunes jachères, les champs de culture vivrières, les marécages forestiers et les autres types d'utilisation de sol. Le Document de Nolte et al. 2001, donne les informations suivante : 275, 208, 151, 179, 108 et 65 tonnes de carbone par Ha respectivement dans les forêts matures, les forêts secondaires, les vieilles jachères, les cacaoyères, les jachères jeunes et les champs des villages de la zone d'Ambam (localité la plus incluse dans le Bassin du Congo parmi les 4 retenus dans son étude). Dans les périphéries urbaines comme autour de Yaoundé (Cameroun), les travaux de ce consortium signalent l'ampleur et l'expansion de l'Agriculture urbaine qui se caractérisent par une forte pression sur non seulement les forêts, mais aussi sur les systèmes agroforestiers (Gockowski et Ndoumbe 2004 ; Sonwa et al. 2009). Marien (2009) souligne que la collecte des bois d'énergie joue aussi un rôle important dans la transformation du couvert végétal. Une pression forte se fait sentir autour des villes comme Kinshasa (RDC), Kisangani (RDC), Brazzaville (Congo), etc.… La consommation annuelle de bois de chauffe est de 0.99 m3 d'équivalent bois (bois de feu et charbon de bois) en Afrique Centrale (Statistique FAO citées par Marien 2009).

Ces exemples démontrent à suffisance qu'il serait difficile de parler des aspects de flux de carbone sans évoquer la place du paysan. La manière avec laquelle ces différents mode d'utilisation de sol sont gérées et l'implication que cela a sur les stocks de Carbone mérite d'être connu pour mieux planifier les activités d'atténuation sur les marges forestières. Dans le contexte du Sud Cameroun par exemple, il est nécessaire de connaitre avec plus de détails les différents pools forestiers dans les cacaoyères qui ont déjà été reconnu comme étant pourvoyeuses de revenus aux ménages.

Stock de carbone des agroforêts cacao au Cameroun

Quelques études existent sur les stocks de carbone dans les systèmes agroforestiers cacao au Cameroun au delà de ceux mentionnés plus haut. Sonwa (2004) trouve des stocks de carbone de 243 t/ha dans les cacaoyères. Dans cette étude, les plantes associées aux cacaoyers, les cacaoyers, la litière et les racines stockent respectivement 70, 13, 4 et 18 tonne par ha (t/ha). 37 t/ha de carbone sont stockés dans le sol sous cacaoyères. Les bois d'œuvre de haute valeur (Constituées des espèces généralement exportées du Cameroun), les plantes consommées et les plantes médicinales contribuent respectivement pour 30, 15 et 7% des stocks de carbone des plantes associées aux cacaoyers. Dans la zone de Kumba, des études plus récentes par Eyoho (à paraître; et Eyoho et al. 2009) permettent d'avoir des informations sur d'autres parties du Cameroun. Cette étude réalisée dans le Sud-ouest du Cameroun montre que les agroforêts dans la périphérie urbaine de Kumba stockent moins de carbone que celle du Centre et du Sud

Cameroun. Ceci semble se justifier par la structure des plantations du Sud-ouest, différente de celles des autres parties du pays (comme le Centre et le Sud et même l'Est). Les plantations de cette zone sont connues comme ayant généralement moins de couvert forestier que celles des autres parties du pays. Dans la périphérie de Kumba, les cacaoyères de plus de 40 ans stockent 86.5 tonnes de carbone par ha au dessus du sol, dans les cacaoyers et les plantes associées aux cacaoyers, contre 68.2 pour les plantations de moins de 25 ans. La contribution du bois d'œuvre au stockage de carbone passe de 13 t/ha dans les plantations de moins de 25 ans à 19.3 t/ha dans ceux de plus de 40 ans dans les cacaoyères périurbaines de Kumba.

Ces différentes informations montrent que les plantes associées aux cacaoyers parmi lesquelles les arbres forestiers jouent un rôle non négligeable dans le stockage de carbone. Les stocks varient suivant les zones écologiques. Les facteurs qui influencent la nature et le nombre des arbres impacte indirectement sur les stocks de carbone. Avec l'Age et la stabilité du système (équivalent de l'agroclimax selon la terminologie de Janssens et al….) les cacaoyers tendent à stocker un maximum de carbone.

Pourquoi prendre en considération des systèmes comme les agroforêts cacao dans les activités d'atténuation?

Les systèmes comme les agroforêts cacao surtout quand ils atteignent certains âges ont une structure similaire à celle des forêts. Elles remplissent donc les fonctions écologiques de la forêt avec une magnitude cependant faible. Elles ne stockent par exemple que 60% du carbone que l'on a dans les forêts matures. Les plantes associées aux cacaoyers procurent des produits consommés par les populations, les plantes médicinales, les revenus, etc.… (Sonwa et al. 2001). Les systèmes agroforestiers procurent de l'emploie et des revenus qui permettent de satisfaire les besoins de santé, d'éducation des enfants, etc.… Ces formations agroforestières sont nécessaire au bien être des populations en zone rurale. Certaines des plantes associées aux cacaoyers sont souvent exploitées par extraction des PFNL sans qu'il n'y ait perturbation de manière consistante des stocks de carbone. Les systèmes comme les cacaoyères sont généralement gérées pour une longue période, ce qui garantie aussi une longue période de stockage de carbone. En définitive, les systèmes multi strates comme les cacaoyères sont utiles aux petits paysans (Sonwa et al. 2001), à ceux qui s'intéressent à la conservation de la biodiversité (Sonwa et al. 2007 & 2009a) et au stockage de carbone (Sonwa et al. 2009b ; Eyoho et al. 2009).

Au niveau du Cameroun les systèmes agroforestiers à base de cacao ont été identifiés comme devant faire partir des projets MDP dans la zone de transition forêts - savane. Dans ces zones là l'établissement des agroforêts cacao permettrait de transformer des espaces dégradées en agroforêts qui auraient alors un rôle de stockage de carbone, mais aussi de satisfaction des besoins de populations (production de cacao, des PFNL et des Bois d'œuvre). L'établissement des systèmes multistrates dans le cadre des projets MDP constituent donc une piste à explorer. Dans les zones périurbaines comme autour de Yaoundé, il est bien établi que si des efforts ne sont pas faits l'Agriculture itinérante sur brûlis et l'urbanisation rampante menace des zones de biodiversité, et les systèmes agroforestiers (Voir Sonwa et al. 2009). Dans un contexte comme celui là les agroforêts peuvent donc très bien faire partir des activités REDD++. De même dans des contextes ou le REDD++ est appliquée les agroforêts sont de nature à jouer des rôles importants pour maintenir ou augmenter les stocks de carbone dans les paysages forestiers dégradées ou potentiellement dégradables. Ce qui est applicable au Cameroun peut aussi l'être dans d'autre partie de l'Afrique Centrale avec des systèmes multistrates appropriés à chacune des zones écologiques.

Comment avancer?

Autant que possible, il est nécessaire de continuer à mener des études sur les agroforêts cacao et/ou sur des systèmes qui leurs sont similaires (ex : système caféiers) dans les marges forestières. Mais il faut autant que possible augmenter la productivité de ces systèmes multistrates et encourager en leur sein la domestication des plantes forestières locales. Il est nécessaire de clarifier les aspects de tenure foncière et même d'accès à l'arbre. Les contraintes liées à "qui est propriétaire de l'arbre?" Entravent encore la plantation et la gestion des arbres dans le Bassin du Congo. Il est aussi utile de penser au PES (Payement pour Service Environnementaux) autre que le carbone. Dans cette perspective autant que possible il faut valoriser le fait que ces systèmes sont utiles pour la biodiversité. Pour faciliter la gestion durable de ces espaces, il est nécessaire d'améliorer les outils de gestion de ces formations. Avec l'appuie de l'USAID et des compagnies de chocolat, le STCP (Sustainable Tree Crops Program www.treecrops.org) travaille dans cette perspective sur l'Afrique Centrale et de l'Ouest. Quelques outils fiables de formation (Ex manuel de formation sur les « Farmers Field School ») existent grâce au STCP et méritent d'être vulgarisées dans la sous-région. Les activités du domaine 3 du CIFOR (i.e. "Improving livelihoods through smallholder and community forestry") visent à l'amélioration du bien être des paysans dans les zones forestières. Cette activité concerne aussi bien les activités forestières paysannes liées aux efforts d'atténuation des changements climatiques. Avancer avec les aspects d'atténuation et de considération des petits paysans doit pouvoir se faire avec une perspective large de planification intégrée du terroir. Ceci devrait l'être pour satisfaire pas seulement les aspects de réduction des émissions de carbone, mais aussi la promotion du bien être des populations riveraines des marges forestières.

Conclusion

Les paysans de par leurs activités quotidiennes jouent un rôle important dans les flux de carbone sur les marges forestières. Dans les systèmes agroforestiers, les composantes ligneuses forestières jouent un rôle important dans le stockage de carbone. Les systèmes agroforestiers offrent l'avantage d'être établie pour une longue durée, ce qui implique un stockage du carbone à long terme. Il serait donc difficile d'envisager des aspects du flux et stockage de carbone dans la sous région sans évoquer les activités de foresterie paysanne à l'exemple de l'établissement et la gestion des cacaoyères. Les programmes d'atténuation ont donc intérêt à placer les paysans des zones forestières au centre de leurs actions.

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3.4 REDD Projects

The GEO Initiative on Forest Carbon Tracking: Towards the Implementation of a Global Forest Carbon Tracking System

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Abstract

National bodies, space agencies and research institutions are working together within the intergovernmental Group for Earth Observations (GEO), to facilitate access to satellite, airborne and in situ data, to establish technical standards and to create the appropriate framework for the implementation a global forest carbon tracking system, based on a network of national system. Institutions from more than 20 Countries are currently involved.

The presentation provides a general introduction to the objectives, plans and activities of the Group on Earth Observations, and then an overview of the GEO FCT task, by describing the objectives, activities and progress of the GEO's effort to demonstrate the feasibility of this System, to develop its building blocks and to realize its vision for implementation.

Also reviewed is the GEO FCT approach for acquisition and processing of, user access to Satellite data for forest carbon tracking and their related information products. The presentation

explains what approach has been retained, the mechanisms put in place and the preliminary and available results to ensure: coordination of satellite data acquisition, data processing to users and associated capacity building, and access to data and products.

The Role of National Demonstrators in the GEO Forest Carbon Tracking Task

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Introduction

The Group on Earth Observations (GEO) established the forest carbon tracking (FCT) Task in 2008 to provide operational support to countries wishing to establish a national system for forest monitoring and carbon reporting. The main goal of the GEO FCT Task is to support countries on the path towards the establishment of sovereign national Monitoring, Reporting and Verification (MRV) systems, and the formation of a global network of MRV systems that comply with international agreements and guidelines (e.g. UNFCCC, IPCC). Such a global network of national MRV systems would operate under internationally agreed standards and transparency, to assist in verification and national-level reporting, and to address the needs of policymakers. The FCT Task is organized under the Group on Earth Observations (GEO) 2009-2011 Work Plan, Task CL-09-03b.

The FCT Task has identified the following key elements as essential: easy access to a continuous supply of mid-resolution Earth observation satellite data; sufficient in situ forest measurements for emission verification; appropriate methods to estimate and predict future national or sub-national carbon stocks; and spatial-data infrastructure, Graphical Information Systems (GIS) and web-delivery systems to produce reports according to prescribed accounting and reporting rules. A detailed description of the FCT Task can be found at www.geo-fct.org.

This paper explains the FCT Task, with emphasis on national demonstrator activities, including those in the Congo Basin. Activities discussed below include: collaboration with satellite data providers for input to thematic processing; analyzing satellite and in situ data and developing optimal multi-sensor procedures for thematic product generation; generating prototype products over selected verification sites; and validating thematic products.

2009-2010 National demonstrator countries

The Task has established seven reference demonstration areas – "National Demonstrators (ND)" for developing and testing approaches and methods in three major tropical forest regions: Southeast Asia, Africa and South America (Figure 1). Countries including Australia, Brazil, Cameroon, Guyana, Indonesia, Mexico and Tanzania are already taking part in the Task as NDs.

Figure 1. Network of seven National Demonstrator countries in three major tropical forest regions of Southeast Asia, Africa and South America. In 2010 the network of NDs will expand to include several other countries.

The NDs are areas large enough to demonstrate the wall-to-wall capability and they each contain several verification sites, where the in situ/aerial measurement are available and higher resolution/higher temporal frequency satellite data will be acquired. Several other countries have expressed interest in playing this role from 2010 onwards. About 3.8 Million km2 of forested territory and more than 50 Verification Sites in the seven countries are involved in the 2009-2010 demonstration.

Establishment of the national demonstrators

The GEO FCT Task team, together with the GEO, recognize that to ensure rapid progress by the Task in the lead-up to post-Kyoto negotiations, the selection of priorities for large-scale NDs and for validation/measurement reference sites therein, would primarily be based on the following general criteria (Held 2009):

The choice of NDs will be based on entire countries (or large regions within), where their central governments have formally stated an interest or intent to implement national forest carbon monitoring verification and reporting systems.

If needed, external donor countries and/or donor organizations would have been already identified for long-term involvement and support of capacity building, field measurement and satellite data acquisition and analysis, and monitoring system implementation.

National government institutions (e.g. environment/forest ministries or forest management authorities) would have committed local expert capability and access to field data, in support of the specific FCT in-situ measurement and validation activities.

ND Countries would preferably already have ongoing nested forest inventory, science validation test-sites, and committed to make this data available to the Task team.

Priority would be given initially to cloud-affected areas (e.g. Borneo, Congo Basin, Amazon Basin), with active forest management, including deforestation – aforestation activities and forest degradation, so that repetitive, wall-to-wall, accurate wide-area forest mapping capabilities can be demonstrated

In the Congo Basin, Cameroon was selected as a ND. Through its application to the Forest Carbon Partnership of the World Bank, its government has formally stated the intent to implement national forest carbon monitoring verification and reporting systems. Through its role as an ND, Cameroon intends to address the following critical gaps in infrastructure for forest monitoring:

– Ecological monitoring system is still embryonic

- The National institute of cartography not equipped with satellite data
- Few specialists in satellite data analyses and in situ measurements
- REDD pilot projects have just started

By engaging with the Task the ND governments and agencies also have several responsibilities. These include assisting and providing support in-kind and with appropriate local personnel in the field validation of the FCT satellite data products. If available, NDs are to provide access to forest inventory data of multiple sites for the purpose of ecosystem carbon model parameterization and subsequent validation/verification. The ND is also to provide support for local personnel to take part in capacity-building activities. The final and most important responsibility is for NDs to implement forest monitoring and carbon accounting systems (if appropriate) as part of government emissions reporting programs.

Coordinated ND activities

Each ND performs similar activities as part of the GEO FCT Task. These are described briefly below.

Data inventory

Common descriptions have been compiled for each ND, which include two general areas:

1. Readiness for National Carbon Accounting and REDD.

An example of this type of information is that found in Cameroon's REDD readiness process on-going with the World Bank Carbon Partnership Facility.

2. Extensive data available, including:

- Land Use/ Land Cover maps, Change detection
- Satellite imagery (by sensor type, and spatial and temporal extent)
- National Forest Inventory
- Delineation of forest area

Each ND identifies the forested areas within the national boundary, which will be addressed under REDD. The forest boundary information provided to the Task is used to delineate the acquisition of Earth observation data (both current and archived).

Acquisition of current Earth observation data

A key component in the establishment of long-term national monitoring systems for Forest Carbon Tracking is the development of an operational satellite data acquisition strategy and plan that provides coordinated and consistent multi-sensor acquisitions, by both optical and SAR sensors, over the global forest cover on a repetitive basis, for linkage to integrated forest inventory and emissions modeling frameworks. The first Task phase (June 2009–May 2010) is intended to demonstrate coordinated acquisitions over the seven NDs and associated verification sites. The CEOS agencies have been requested to:

- Acquire Optical and SAR data during Summer 09 over all 7 NDs
- Provide archived data / products for past years
- Acquisitions with both Radar and Optical instruments are on-going

The FCT NDs Browser summarizes of the 2009 data acquisitions for each of the demonstrators (http://www.geo-fct.org/national-demonstrators).

Identification of verification sites

Each ND has identified a number of verification sites within the forest boundary, which serve the following purposes:

- Demonstrate verification information needs and activities for RS forest products.
- Demonstrate CalVal information needs and parameterization for carbon modelling (stocks and fluxes).

Remote sensing data is being acquired over the verification site locations provided by the NDs (Table 1) on a monthly/bi-monthly basis in 2009 and early 2010.

ND	VS	Name	lat	long
Brazil	BRA-1	INPE_IFT	S3.74	W48.34
	BRA-2	INPE_Tapajos	S3.20	W55.50
	BRA-3	INPE_Marcelandia	S11.30	W54.75
	BRA-4	INPE_Braganca	S0.85	W46.65
	BRA-5	WHRC_Xingu-1	S11.91	W52.58
	BRA-6	WHRC_Xingu-2	S13.06	W52.38
Guyana	GUY-1	WUR_FRASAR-1	N5.00	W59.00
	GUY-2	WUR_FRASAR-2	N3.00	W59.00
Mexico	MEX-1	Chiapas-1	N17.00	W93.55
	MEX-2	Chiapas-2	N16.33	W90.65
	MEX-3	Campeche	N18.52	W92.25
	MEX-4	Oaxaca	N17.58	W96.46
	MEX-5	Hidalgo	N20.62	W98.62
	MEX-6	Nuevo León	N25.43	W98.52
	MEX-7	Michoacán	N19.57	W101.18
Cameroon	CAM-1	ESA-1	N4.03	E10.23
	CAM-2	ESA-2	N3.22	E13.68
	CAM-3	ESA-3	N3.87	E14.78
	CAM-4	ESA-4	N5.00	E13.51
Tanzania	TNZ-1	FAO_FRA-1	S4.00	E32.00
	TNZ-2	FAO_FRA-2	S10.00	E36.00
	TNZ-3	FAO_FRA-3	S10.00	E38.00
	TNZ-4	Nilo Forest Reserve	S4.92	E38.66
Borneo	BOR-1	WUR_E-Kalim/Sbh	N4.33	E117.01
	BOR-2	WUR_SW-Kalimantan	S1.82	E111.61
	BOR-3	WUR_SE-Kalimantan	S2.24	E114.41
	BOR-4	WUR_C-Kalim/Srwk	N2.55	E115.08
Tasmania	AU-1	Mathinna	S41.37	E147.76
	AU-2	Takone	S41.19	E145.60
	AU-3	Warra	S43.11	E146.90

Table 1. List of 2009-10 verification sites for the seven NDs in the FCT Task.

Site description and data collection

The verification sites are intended to reflect the range of forest types and land uses to be included in national carbon emissions modeling and accounting. Standard descriptions for each verification site include:

- Study area and land use activities
- Partners working in the area (local, national and international)
- Field work (by agency)
- Available GIS and RS information
- References

The verification sites are intended to provide detailed in situ site measurement data, which is to be used for calibration and validation of the remotely sensed Earth observation data over the ND countries. As well, the verification site data is to include the detailed carbon pool measurement data that will be required for Carbon budget modeling and associated Carbon emissions estimates (Table 2).

Pilot projects	Study site	N.San Juan, Michoacán	Selva El Ocote, Chiapas	Zacualtipán, Hidalgo	State of Chiapas
	Lead Institutes	SFU; NRCan; ECOSUR	ECOSUR, COLPOS	COLPOS	COLPOS, ECOSUR
	Pilot projects				
Input files	Forest inventory	x	x	x	x
	Forest classifiers	x	x	x	x
	Growth curves	x	x	x	??
	Age classes structure	x	x	x	x
	Disturbances types and events	x	?	?	?
	Transition rules	x	?	?	?
Climatic variables	Mean annual temperature	x	x	x	x
	Precipitation	x	x	x	x
Biomass variables	Volume to biomass conversior	x	x	x	x
	Biomass turnover parameters	x	x	?	?
Soil variables	DOM parameters	x	x	x	x
	DOM turnover parameters	x	no	?	no

Table 2. Example of in situ measurements from the ND verification sites in Mexico.

Processing and support

There are two main functional elements for processing support and FCT product development, including: (i) a network of processing support agencies and (ii) the FCT demonstration phase portal (www.geo-fct.org)

Support includes:

- Interfacing with satellite data providers and processing to Level 1
- Scientific analysis of satellite and in situ data
- Development of optimal multi-sensor procedures
- Collaboration with other ND product development teams
- Generation of prototype products over verification sites
- Thematic product validation

Capacity building

The development of human and technical capacity in the countries involved is a critical component of the FCT Task, as an increasing number of tropical forest countries are expected to become part of the GEO network and to eventually contribute to a Global Forest and Carbon Monitoring System.

With the assistance of donor countries, UN-bodies and NGO's, it is broadly envisioned that the Task will quickly move from a 2009-2010 "technical capability demonstration" onto more direct and active support for the establishment of multiple operational national forest MRV systems in subsequent years.

With Mexico, Guyana, Brazil, Cameroon, Tanzania, Indonesia and Australia already taking part in the Task as 'NDs", and additional countries likely to join the Task in the following years starting from 2010, the building of human and technical capacity in the countries involved is a critical component of the Task, as the capabilities and capacity of the GEO Task progresses, and an increasing number of tropical forest countries are encouraged and welcomed to become part the GEO network that is the Global Forest and Carbon Monitoring System. Coordination activities are already in place with UN-REDD and with the Forest Carbon Partnership of the World Bank.

Data acquisition and product development

Satellite data acquisition started in June 2009. Progress to date is impressive and it will result in the availability of an unprecedented set of time-consistent observations from different sensors (optical and radar-SAR) over the same areas.

To reach demonstration goals for 2009-2010 and beyond, the Task has established a Network of Processing Facilities, made up of agencies in GEO member countries and international participating organizations, which will ensure provision of consistent annual, mid-resolution 'forest change' time-series products for each of the NDs. The ND countries are an integral part of the relevant regional facility: they bring to the partnership their in situ data and their practices for forest monitoring, and they receive knowledge and training on technical and operational issues.

The 2009-2010 demonstration is expected to be completed in late spring 2010, when a coordinated review of products derived from different sensors/processing tools will be performed, together with an assessment of their accuracy and "comparability". The review will also provide recommendations on the overall approach, standard and guidelines, as well as for the planning of the 2010-2011 demonstration.

Summary of the benefits for national demonstrators

- Inclusion of the nominated ND into new satellite data acquisition plans by major international space agencies.
- Collection of border-to-border (or large region) full coverage data acquisition with both optical and synthetic aperture radar data at multiple times throughout the life of the Task.
- Satellite data freely available to in-country institutions, wishing to use it for multiple purposes.
- Satellite data processed from selected satellite data sets into agreed forest-change products (as per FCT guidelines).
- Provided the national governments and their relevant institutions provide approval, and the necessary funding is available from supporting NGO's or donor governments.
- Collaborations with local experts and international teams on ground-truthing and validation of satellite data products.
- In country capacity-building activities to transfer data, methods and analysis tools to national institutions.
- Assistance, if requested, in establishment of national forest carbon accounting methods and systems.

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Acknowledgements

The development of the GEO FCT Task is being led by governments with a strong interest in forest carbon monitoring: Australia, Canada, Japan and Norway. The Committee on Earth Observation Satellites (CEOS) and the UN Food and Agriculture Organization (FAO) are two other lead partners, while institutions in GEO member countries, Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) and the EC Joint Research Centre play important roles.

Development and Implementation of GSE FM REDD Pilot Projects in the Congo Region / Projet REDD au Cameroun

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Introduction

The Global Monitoring for Environmental and Security (GMES) initiative is a joint venture of the European Space Agency (ESA) and European Union (EU) which began in 2003; the initiative aims at providing a response to dynamic and growing global information needs. The GMES Service Element on Forest Monitoring (GSE FM), specifically supported by ESA which is led by GAF-AG, Germany provides operational forest services to support environmental policies and international Conventions such as the United Nations Framework Convention on Climate Change (UNFCCC). Since 2005, there has been an evolving policy process within the UNFCCC, targeted at supporting developing countries to reduce emissions from deforestation and degradation (REDD), such that they can also be financially compensated for these reductions. Parties agreed to a two year process of evaluation of REDD within the Subsidiary Body for Scientific and Technological Advice (SBSTA) activities. Many countries have therefore taken initiatives to develop REDD demonstration activities (pilot projects) and to work on methodological issues, technology transfer and capacity building which are all required for successful REDD implementation.

The GSE FM expanded the service provision for the development of REDD Pilot Project in Cameroon in 2007. The REDD Pilot Project in Cameroon has the overall aim at integrating the application of Earth Observation (EO) technologies with the policy formulation. The project intends to establish baseline projections of emissions caused by deforestation in a wall-to-wall approach. Key methodological issues that are being addressed in the pilots include estimation and monitoring of forest areas (using remote sensing methods), establishing reference emission levels, and assessing both national and sub/national approaches. Innovative institutional arrangements/mechanisms such as technology transfer with south-south co-operation between Bolivia and Cameroon have provided valuable contributions to facilitate the process. This paper will present a summary of key achievements in the Cameroon project as well as new GSE FM REDD initiatives in the Republic of Congo and Gabon.

Cameroon GSE FM REDD pilot project

Cameroon has been actively involved in the REDD process since its inception in the UNFCCC climate debate: participations in COP meetings, submissions to SBSTA via COMIFAC, elaboration and approval of the World Bank R-PIN and currently elaborating the R-PP. Therefore the implementation of the GSE FM REDD Pilot Project was strongly supported by the Ministry of Environment and Nature Protection (MINEP), who are responsible nationally for the UNFCCC reporting. A key aspect of the pilot project is the user-driven approach and stakeholder involvement in both the framework structures for project implementation as well as the technical issues that need to be resolved. This is reflected in the following main tasks that are being undertaken in a step wise manner in the Cameroon case:

Stakeholder Analysis: A country specific User Requirement /Analysis to identify the needs of stakeholders in terms of specific policy drivers; working practices and decision making cycles; status of geospatial infrastructure as well as the technical specifications for reporting.

Implementation framework for REDD: Legal and institutional framework for REDD at a national level

Reference scenarios/Estimating deforestation: How much has a country emitted in the past? How much is it likely to emit in the future? To address this issue a two-tier remote sensing analysis will provide forest area maps and forest cover change maps (1990-2000-2005) for the whole country.

Emission Accounting: This is based on a comprehensive biomass inventory, the use of the Intergovernmental Panel on Climate Change (IPCC) default methodologies and values, land use change policy scenarios agreed amongst stakeholders, and spatially explicit projections of future deforestation and degradation.

Capacity Building for REDD: Specific capacity building programmes will be conducted to ensure that project results, methodologies and lessons learned are provided in a manner to best support the work of national and regional co-operations and to inform the multilateral negotiations under the UNFCCC.

As common in most countries there is a division of national responsibilities related to the REDD process in Cameroon; the Le Ministre de l'Environnement et de la Protection de la Nature - Ministry of Environment and Nature Protection (MINEP) is responsible for the reporting requirements of the UNFCCC whilst the Ministère des Forêts et de la Faune - Ministry of Forestry and Wildlife (MINFOF) is responsible for the management and monitoring of the forest resources. Thus it was important to develop the relevant institutional arrangements with clear roles and responsibilities between these Ministries as well as other public sectors for the implementation of the REDD[1]. A national REDD Steering Committee was proposed by the stakeholders as a viable mechanism for the needed organisational framework, and this structure is now operational. The first steering committee meeting was held in Mbalmayo – November 2009 and it was agreed that a pre-requisite for a successful implementation of REDD nationally will require the consolidation and an active involvement of all stakeholders: related ministries; civil society; indigenous community etc. The need to sensitize these stakeholders on the REDD mechanism was strongly emphasized[2].

EO data (national coverage) for Cameroon was acquired for the periods 1990, 2000 and 2005/2006: full country coverage with Landsat for 1990 and 2000, and DMC data for 2005/06. Progress towards producing the forest mask (forest/no-forest maps) for these epochs and mapping the related land use change between these time periods have been made, as well as setting up an emission accounting to be based on a comprehensive biomass inventory has been developed. Forest/non-forest maps were produced for the years 1990; 2000; and 2005. The areas where land use change has occurred were further classified into the five IPCC compliant land cover classes: cropland, grassland, wetland, settlement and others.

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1 Haeusler, T., S. Gomez, J. Seifert-Granzin and J. Amougou,, 2009, REDD Pilot Projects in Cameroon and Bolivia: Contribution to the UNFCCC Post-Kyoto Protocol Process , ISRSE 33 Symposium Proceedings, 2009, Stress, Italy

2 Compte rendu de la Réunion du Comité de Pilotage du Projet Pilote REDD, 17. et 18. Novembre 2009 à Mbalmayo, Cameroun

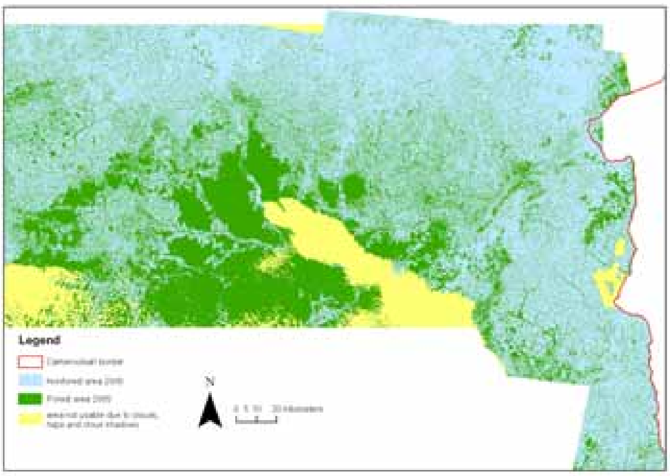

Figure 1. Example of forest area map produced for Eastern Province of Cameroon based on DMC 2005 satellite data.

One of the key activities of the REDD Pilot in Cameroon is a south-south co-operation between Bolivia and Cameroon in terms of technology transfer. In this context the Fundación Amigios de la Naturaleza (FAN) in Bolivia who have established experience in biomass accounting from Noel Kempff Climate Action Project, the world's first certified REDD activity, as well as Amazonia, Bolivia´s first sub-national indigenous REDD program are supporting the REDD Pilot in Cameroon. The REDD technical developments in Bolivia are being tested and adapted to the Cameroonian conditions and the technology transfer is done via training of local Cameroon counterparts in MINEP/MINFOF. A first co-operation was initiated in March 2009 with a stakeholder workshop conducted in Yaoundé, Cameroon where FAN presented the methods and protocols for the biomass accounting. In collaboration with MINFOF/MINEP counterparts, the protocol was adapted for the Cameroonian case. A national stratification of forest integrating the different forest management systems was also discussed. Stratification maps with varying levels of complexities were established based on the three IPCC tier levels respectively. The workshop was followed by field work and training of the local counterparts in setting up the field plots as well as field measurements (see Figure 2). Results of the fieldwork were used to develop a national biomass map which will further be an input for the GEOMOD modelling. The main objective of the field survey was to assess biomass and carbon impacts due to selective logging in a certified forest concession (PALLISCO forest concession) within the largest forest stratum (closed evergreen lowland forest). For this 67 carbon impact zones (CIZ) plots were installed and measured in the logging gaps of the annual harvestable area AAC 4-3 of PALLISCO forest concession in the south-eastern Cameroon. To estimate carbon stocks in mature forest 67 paired (or witness) plots were installed and measured at 50 m from the CIZ plots. To measure the impact of logging roads, skid trails and log landings on carbon stocks, the respective areas were measured.

Figure 2. Biomass measurements in South-East Cameroon, with south-south co-operation.

Carbon impacts by logging were estimated as a damage factor of 1.34 t C and the extracted wood was (67%) higher than the residual damaged biomass. Mean biomass stock in closed evergreen lowland forest stratum was 326.12 (tC/ha), which is higher than biomass stock estimations in the Democratic Republic of Congo and Bolivia, due to the higher number of trees per plot and trees diameter in Cameroon. The mean width of logging roads in the study area was higher than Bolivia logging roads in La Chonta forest concession, causing more impacts on biomass.

The technology transfer and capacity building exercises have been performed in EO applications for deforestation mapping; and carbon stock estimation from field inventories. Initially, in-country human and infrastructural capacity to monitor and assess forest area and carbon stock changes was evaluated, and the training modules tailored to match in-country needs. The capacity building has benefitted vastly from the south-south co-operation

New GSE FM REDD pilots: Republic of Congo and Gabon

The successful implementation of the GSE FM REDD Pilot Projects in Cameroon and Bolivia provided a substantial basis in terms of understanding the policy processes and the technical requirements for countries involved in the REDD process. This has led to ESA further supporting from December 2009, the GSE FM REDD expansion to additional countries in the Congo region- Gabon and the Republic of Congo. The GSE FM REDD services will focus on specific aspects of the REDD process related to forest monitoring and cannot fulfil the requirements for an entire REDD programme which includes the Carbon accounting, the issue of Carbon trading (market and fund-based approaches for financing REDD) and its impact on the management of forest resources as well as the livelihoods of local stakeholders and indigenous communities as these are all beyond the scope of the ESA

The main products of the services will be the deforestation and degradation products/maps based on high resolution satellite data. Production of the Forest/Non-Forest Maps will be conducted for 3 points in time - the years 2008, 2000 and 1990. Additionally the following products will be based / derived on these Forest Maps:

- Deforestation Maps (Classes: Deforested Areas, No Data) for the time periods between 1990-2000, 2000 – 2008.
- The new land use in the change polygons of both periods according to IPCC 2006: 5 classes: cropland, grassland, settlements, wetlands, other land use.

In addition to these products and services the GSE FM will provide basic conceptual training to the counterparts on the methods used, as this again has been deemed an important user requirement by the counterparts.

Throughout the implementation of the programme the main guidelines for provision of these services will be based on the Intergovernmental Panel on Climate Change (IPCC), Good Practice Guidance (GPG) of 2006. The user is thus guaranteed that there is a standardised service/product being produced and delivered as a unified approach to service quality control will be applied. Service quality control in the GSE FM follows defined technical specifications of products, as well as the production, quality control and verification processes including relevant standards.

Acknowledgements

We would like to acknowledge the work of the Institute for Digital Image Processing of Joanneum Research, Graz – Austria for all technical contributions related to satellite data processing and forest and landuse classifications on the Cameroon Pilot Project. Additionally we would like to thank ESA, the GTZ-COMIFAC and KfW for financial support for the projects.

We also appreciate the support of the National REDD Coordinator and the UNFCCC Focal Points of Cameroon, the Republic of Congo and Gabon for facilitating the REDD activities in their respective countries.

REDD+ in the Democratic Republic of Congo and the Congo Basin: A Measurement, Reporting and Verification System to Support REDD+ Implementation Under the UNFCCC / Le REDD et le développement d'un système MRV en RDC

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Abstract

REDD+ countries will have to establish a Measurement, Reporting and Verification (MRV) system in order to assess anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks. A national forest inventory (NFI) is one component of such and MRV system. Following the UNFCCC's Subsidiary Body on Scientific and Technological Advice, the most recent Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines have to be used as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes.

The presentation has three objectives: (i) to clarify the UNFCCC MRV framework in which a NFI has to be developed; (ii) to present a preliminary methodological approach for an MRV system for DRC to assess and to report carbon stock changes on forest land at least at a Tier 2 level; and (iii) based on (ii), to present the basic elements for a harmonised regional MRV approach in the Congo Basin where each country would have a sovereign national system but with a regional approach – such an approach would be developed in consultation with regional stakeholders such as the COMIFAC, the Congo Basin Forest Fund and so forth.

Keywords: carbon stock change, carbon pools, emission estimate, activity data, emission factor, accuracy

The REDD Project in Republic of Congo / Le projet REDD carbone en République du Congo

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[b] WRI (World Resources Institute)

Introduction

At he COMIFAC meeting WRI and the MDDEFE together presented the CBFF funded REDD project Quantifying carbon stocks and emissions in the forests of the Congo Basin – . Efforts to provide payments for ecosystem services (e.g., UNFCCC REDD or other mechanisms) or utilize other economic instruments may create incentives for curbing deforestation and, if designed appropriately, help address the needs of forest-dependent communities. However, countries in the Congo Basin region are not well poised to employ these mechanisms for several reasons, including: (1) Countrywide data on forest cover change is not gathered in a systematic fashion, (2) methods and systems for detecting forest degradation (the dominant form of land use change in the region) are absent, (3) information on forest carbon stocks and flows is absent, and (4) there is a lack of technical capacity to gather this information.

The World Resources Institute (in collaboration with a number of partners) proposes to address these technical and capacity challenges. The proposed project will improve detection and quantification of deforestation and forest degradation and the associated carbon stocks and emissions in the Congo Basin forests with a pilot in the Republic of Congo. We will also build the capacity for the entire region by building capacity as OSFAC in DRC and government agencies to conduct measurement and monitoring on an ongoing, consistent basis.

Objective

This project will assist the Republic of Congo in improving its readiness to join potential payment schemes by providing data, methods and assistance in developing national forest carbon accounting strategies and developing reference forest carbon emission levels. The methodologies, capacity, and results will be replicable in other Congo Basin countries.

Activities

To achieve these outcomes and results, the project will:

- Apply and institutionalize modern methods for detecting, measuring, and monitoring forest degradation in the Republic of Congo. WRI and partners will train OSFAC, government agencies, and other stakeholders on how to apply these methods and utilize the information for their forest management, climate change, and other strategies.

- Quantify the forest carbon emissions from land use change (forest loss and degradation) in the Republic of Congo, using the most up-to-date methodologies and following IPCC Good Practice Guidance. This analysis will include Congo Basin-wide update of forest cover change from 2005-2010 and fill in additional time-steps going back to the 1990s. WRI and partners will conduct training sessions on the carbon accounting methodologies and conduct outreach to stakeholders (OSFAC).
- Outline policy options and incentives for curbing forest degradation and associated emissions.

Project partners

SDSU: Will update regional tree cover change estimates to provide a history of forest change in the Congo Basin region from 1990s to 2010. For a select sub-national study area, SDSU will use a combination of Landsat and high resolution imagery (e.g., SPOT) to produce area estimates for forest degradation with reduced uncertainty.

Imazon: Will apply its Normalized Difference Fraction Index method (a low-cost, semi-automated method to evaluate the degree of forest canopy disturbance) and share Amazon experience.

Winrock International: Will apply leading methods of aerial videography for detailed and highly accurate estimates of forest biomass. Will collaborate with WRI to produce detailed carbon accounting of forest carbon stocks & changes for the Republic of Congo.

OSFAC: Will be trained to become a regional center of excellence on detecting forest degradation and forest carbon accounting that will serve the Congo Basin region

3.5 Field Projects and other Environmental Services

Forest Carbon Sinks in Ibi Bateke / Le puits de carbone forestier Ibi Bateke : état d'avancement et perspectives d'avenir

Olivier Mushiete, Ruphin Ngabulongo, Dany Mulabu

Novacel

Introduction

La Commission pour les Forêts d'Afrique Centrale (COMIFAC) a organisé un Atelier régional sur le «Monitoring des stocks et flux de carbone dans le Bassin du Congo» qui a eu lieu à Brazzaville, République du Congo, du 2 au 4 février 2010. L'atelier est destiné à tous ceux qui s'intéressent au suivi du changement de l'utilisation du sol, de l'occupation du sol et à leur relation avec la quantification de carbone dans le Bassin du Congo, comme Novacel. Celle-ci a participé à l'atelier pour présenter son projet puits de carbone agroforestier Ibi Bateke : système de monitoring, conception et mise en œuvre.

Le but de l'atelier

Les perspectives post-Copenhague pour les pays d'Afrique centrale furent entre autre, l'inscription de la problématique des forêts tropicales au cœur des préoccupations de la convention sur le climat, notamment à travers le mécanisme REDD.

Cet atelier a réuni les pays du bassin du Congo afin de présenter l'état des connaissances sur les stocks de carbone et leurs variations dans les forêts de la région.

Novacel

Depuis sa fondation, Novacel s'attache à assurer dans la région du plateau des Bateke en RDC un développement rural intégré dans le domaine de l'agriculture, de la sylviculture et de l'élevage au bénéfice des populations locales.

Le but est la préservation des ressources naturelles tout en leur ajoutant de la valeur sans les mettre en danger. Ainsi, par une succession continue et bien agencée d'efforts progressifs, le bien-être des habitants en sera amélioré.

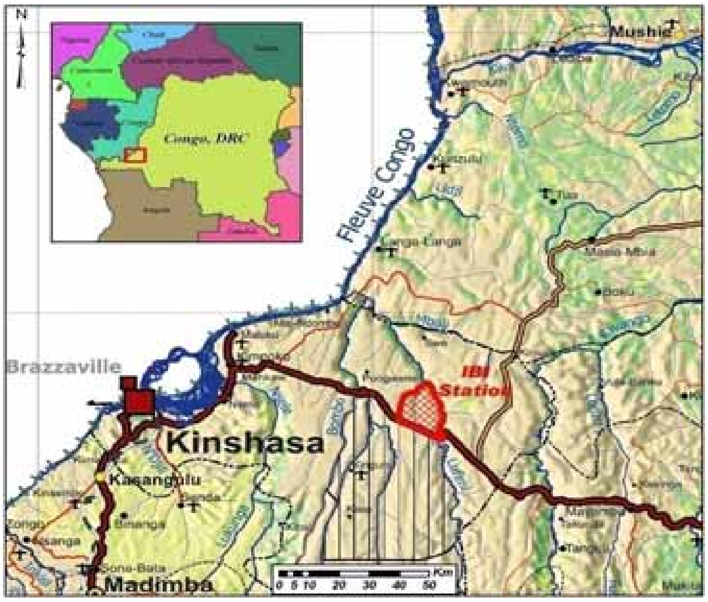

Figure 1. Plateau de Bateke

Avec son Puits de Carbone Agroforestier Ibi Bateke, Novacel convertit la savane peu productive en une source de biomasse renouvelable. Cette façon de faire est aujourd'hui un savoir-faire unique de Novacel.

Figure 2. Savane à l'état naturel

Figure 3. Savane transformée en forêt. puits de carbone.

La production des activités de Novacel est soumise au rythme des plantations et des récoltes. Les plantations font l'objet d'un engagement global consigné dans le PDD. Cet engagement se traduit par des objectifs annuels définis sur une saison (de septembre à mai de l'année suivante).

Résultats de l'atelier

Afin de participer à la REDD, les pays forestiers doivent être en mesure d'estimer les émissions de gaz à effet de serre liées à la déforestation et à la dégradation forestière.

Les exigences techniques du REDD sont telles qu'il faut faire:

- Le Suivi du couvert forestier via télédétection
- La Mesure du carbone sur le terrain dans les divers écosystèmes forestiers de la RDC
- Le développement d'une méthodologie pour mesurer la dégradation et recueillir des données sur l'extraction du bois-énergie
- La création d'un système gestion de l'information intégrant toute l'information
- La Production d'un inventaire des GES
- Le renforcement de capacité

La majorité d'intervenants lors de l'Atelier ont donné un message selon lequel le système REDD en RD Congo est plus avancé que dans d'autres pays de la région d'Afrique Centrale.

Suivi du puits de carbone Ibi

Le suivi du Puits de Carbone Agroforestier Ibi Bateke est couvert par le Protocole [CQSS-05 : Suivi du Puits de Carbone]

Au plus tard trois mois avant le début de la campagne de mesures de suivi (c'est-à-dire début mai), on procède à une stratification du domaine planté depuis un an (c'est-à-dire avant le début de la grande saison sèche de l'année précédente). On entend par « Domaine » l'ensemble des sous-blocs complètements plantés. Un sous-bloc partiellement planté est laissé pour l'année suivante. On vérifie que les rapports de plantation (fiches hebdomadaires d'évaluation) correspondent bien à la réalité. On portera une attention particulière aux endroits où les arbres ont été abattus (de façon programmée ou non) et aux endroits où les plantations ont échoué.

Une fois les strates déterminées, on procède au contrôle sur le terrain des parcelles nouvellement plantées et à leur relevé GPS. Les coordonnées du polygone et les surfaces réelles des sous-blocs du domaine. On en déduit la surface de chaque strate. On établit une carte des strates qui montre clairement l'appartenance des sous-blocs à leur strate respective.

Une fois les coordonnées réelles des sous-blocs et la surface des strates déterminées, on procède à la détermination du nombre des placettes en fonction de la surface des strates selon l'algorithme Winrock. Les valeurs de moyenne et d'écart-type sont celles reprises de la campagne de suivi de l'année précédente.

Une fois le nombre de placettes déterminé, on compare ce nombre avec les placettes existantes des années précédentes dans chaque strate. Si le nombre de placettes existantes est supérieur ou égal au nombre qui résulte de l'algorithme Winrock, on garde toutes les placettes existantes. Si le nombre de placettes à utiliser est supérieur au nombre de placettes existantes, on crée de nouvelles placettes pour combler la différence.

On localise les nouvelles placettes dans les strates de façon aléatoire. Le système retenu est celui des localisations aléatoires de placettes (plutôt qu'une grille régulière à partir d'un point aléatoire de référence). Un point de référence aléatoire est fixé pour chaque placette. Ce point est écarté si

– La placette établie à partir de ce point sort de la surface de la strate

– La placette établie à partir de ce point recouvre partiellement une placette existante

On répète l'opération de détermination aléatoire dans chaque strate jusqu'à obtenir le nombre de placettes demandées. Donc, au domaine d'Ibi, le système de suivi du puits de carbone agroforestier Ibi Bateke est conçu et mis en place de manière à mesurer le carbone sur le terrain.

La placette mesure 10 x 25m, comme indiqué au PDD. Les transects sont tirés à partir du point de référence comme indiqué sur le schéma ci-dessous.

Un mois avant le début de la campagne de suivi proprement dite, on procède au placement des nouveaux points de référence sur le terrain à l'aide des coordonnées GPS. L'emplacement est marqué dans le sol de manière non voyante à l'aide d'un tube semi enterré qui ne dépasse pas de plus de quelques centimètres de la surface du sol (en fonction de la végétation de l'endroit.

Juste avant la campagne de suivi, on procède sur un espace plat et dégagé au montage de la placette à l'aide des cordeaux étalonnés et on vérifie les dimensions obtenues. En cas de dérive, on procède aux ajustements nécessaires.

Une formation est donnée à l'équipe de mesures pour rafraîchir ses connaissances depuis la campagne précédente.

Figure 4. Atelier du Fonds Biocarbone sur les outils SMART à Ibi village.

Le cas échéant, des mesures sont prises à titre d'exercice pour s'assurer du bon fonctionnement de l'équipe et de la fiabilité des résultats.

Les mesures de terrain se déroulent par l'équipe formée à cet effet selon le prescrit de la Procédure [CQSS-05 : Suivi du Puits de Carbone]

Figure 5. Mesure de la biomasse existante.

Par ailleurs, la majorité des projets présents à l'atelier suivent le couvert forestier via la télédétection.

La majeure difficulté à laquelle est butée cette région quant à l'évaluation de stocks de carbone est le manque d'équations allométriques pour les espèces de la région tropicales, alors que la dite région est très riche en espèces végétales.

Aujourd'hui, un des soucis majeurs dans le suivi de carbone est l'établissement des équations allométriques pour les espèces de la région tropicales. Un facteur limitant de la mise place correcte du système REDD.

Explaining and Predicting the Impact of Global Change on Forest Biodiversity in the Congo Basin: The CoForChange Project / Impact du changement global sur la biodiversité forestière du bassin du Congo

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CIRAD

Abstract

The Congo Basin's tropical moist forests are critically affected by current climate and anthropogenic changes. How, why and where will tree species survive increasing pressure in this region is a challenging issue, which requires an urgent clarification and integration of tree ecological strategies to produce decision-making tools essential for sound management and conservation policies.

The CoForChange project, funded by three european agencies in the context of the Era-Net Biodiversa, gathers an interdisciplinary consortium linking 14 institutes from four European and four African countries, and an international organization. The project started in January 2009 and is involving: (i) cross-analysing satellite imagery, extensive forest inventories, maps of the main environmental factors to produce a comprehensive vegetation map; (ii) assessing critical tree species functional traits through field experiments; (iii) linking the status of the current structure/composition/diversity of forests with past climatic and anthropogenic disturbances; (iv) integrating knowledge in a vegetation model to predict the impact of various policy and climate change scenarios. Besides strengthening a wide pool of knowledge on the ecology of the Congo Basin's forests, and providing scientific advances in this field, the project will produce thematic maps and databases helping the prioritization of environmental activities and regulation in the region.

Congo River Watershed Hydrology in Interaction with Carbon Stocks and Fluxes / Interaction entre l'hydrologie et les stocks et flux de carbone dans le bassin du fleuve Congo

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The Congo River Watershed Hydrology interacts strongly with Carbon Fluxes in the Basin and beyond. Recent studies have demonstrated that the amount of runoff volume produced on the surface considerably depends on carbon flux to the atmosphere[1]. Other studies suggest that freshwater inputs from large rivers [similar to the Congo] into the Ocean, impact significantly the oceanic carbon cycle in the tropical Atlantic[2]. However, the impact of the river on the CO_2 budget is still poorly documented. On the other hand, it has been reported that reliance on traditional biomass as the main source of energy in the form of wood for woodfuel (fuelwood and charcoal), is particularly high in sub-Saharan Africa, where biomass accounts in some countries for 70-90% of primary energy supply[3]. The wood energy-based system that is favored in heavily forested countries results in losses of terrestrial carbon through forest removal.

The Congo River Watershed Hydrology is worth investigating within the context of Carbon stock and flux monitoring in the Congo Basin. Indeed, in view of the aforementioned, parameters such as runoff volume can serve as a proxy variable for straightforward carbon quantification in the Congo Basin, recognizing the significant correlation between runoff volume and carbon flux to

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Ternon, J.F., *et al*, 2000, A seasonal tropical sink for atmospheric CO_2 in the Atlantic ocean: the role of the Amazon River discharge, *Marine Chemistry* , *68* (3), 183-201

Takahashi, T., et al, 2002, Global sea-air CO_2 flux based on climatological surface ocean pCO_2 , and seasonal biological and temperature effects, *Deep Sea Research* , 49 (9-10), 1601-1622

3 Karekezi, S., 2002, Poverty and energy in Africa—A brief review, *Energy Policy,* 30, 915–919

the atmosphere. All things being equal, consistent runoff analyses could be particularly useful in situations in which other evidence of CO_2 is limited.

Concerns about forest and consequently carbon depletion due to energy production with biomass can also be addressed by Congo water resources exploitation. Indeed, thanks to the stability of their regime, the Congo River and its tributaries can solve energy problems, being a potential asset to supply hydropower. In this century, as the world seeks to mitigate carbon emissions, non-carbon producing electricity generation is defined as 'green' and 'renewable'. This makes Congo hydro-electricity an attractive notion. Yet, due to the adverse effects of large scale hydropower, small scale hydropower (SHP) is considered "greener". Preliminary estimates of the clean development mechanism (CDM) potential of SHP projects indicate that there is a vast theoretical potential of CO_2 mitigation by their use. Moreover, the (CDM) under the Kyoto Protocol allows developing countries to generate emission credits for industrialized countries by greenhouse gas emission reduction projects such as SHP. It should be noted that, hydroelectricity has been one of the most successful project types in the carbon market to date.

Under the current NASA funded project entitled "Hydrological Response to Land Cover and Land Use Change in the Congo Basin", an attempt is made to quantify Congo watershed flows and to assess the hydropower potential of the river network using remote sensing in shortage of ground-based hydrological data. Temporal and terrestrial satellite-based data are ingested into the USGS Geospatial Streamflow Model (GeoSFM) for daily flow generation. The model is parameterized with global terrain, soil and land cover data and run operationally with precipitation and evapotranspiration datasets[1]. Initial research on the Congo Basin compared streamflow estimated with GeoSFM against available historical mean streamflow data. While initial results were promising, some discrepancies were revealed, attributed to the accuracy of the input data and the non-calibration of the model[2]. Another key finding was that the existing parameterization of land cover using coarse resolution data (1 kilometer) was inadequate to accurately characterize rainfall-runoff processes in the Congo.

In attempt to improve the agreement between modeled flows from satellite-derived data and observed flow data from hydrometric field stations, higher resolution Land Cover and Elevation data have been used for the central part of the Congo River watershed. The Land Cover dataset incorporates wetland data delineated for the core area of the Congo Basin. The wetlands characterization was made with Landsat (TM) and ETM+, JERS-1 radar and SRTM data, all resampled to a common 57 m resolution grid[3]. The new Land Cover dataset includes also three savannah classes (woodland, parkland and grassland) extracted from a MODerate Resolution Imaging Spectroradiometer (MODIS) 250 m derived land cover product[4] and three other classes (intact forest, degraded forest/rural complex and water) extracted from a Landsat-derived forest probability and forest cover change product from circa 1990 to 2005. It should be noted

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2 Munzimi, Y., 2008, Satellite-derived Rainfall Estimates (TRMM products) used for Hydrological Predictions of the Congo River Flow, *START/US NSF/USCCSP Report*

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4 Hansen, M., *et al*, 2008, A method for integrating MODIS and Landsat data for systematic monitoring of forest cover and change in the Congo Basin, *Remote Sens. Enviro*., 112, 2495-513

5 Lindquist, E., *et al*, 2008, The suitability of decadal image data sets for mapping tropical forest cover change in the Democratic Republic of Congo: implications for the global land survey, *Intern. Journal of Remote Sensing,* 29 (24): 7269-7275

that since the accurate representation of wetland distribution is restricted in the core area of the watershed, the wetland map acts as a limiting factor for setting the window extend of the new LCLU used for the present hydrological analysis (that is approximately an area of 1,176,000 km^2).

As finer resolution elevation data allow for improved GeoSFM stream and sub-basin delineation, Shuttle Radar Topography Mission (NASA SRTM) 90 meters elevation data were used as the primary input for terrain analysis and surface topography basin characterization in place of GTOPO30 elevation data (30" by 30" resolution, approximately 1km2 at the equator). Standard ArcView® GIS functions are used to delineate hydrologic modeling units for GeoSFM. A minimum drainage area threshold of 324 km^2 is used for stream initiation resulting in 1760 river reaches each about 26 km in length.

Satellite-derived precipitation from the Tropical Rainfall Measuring Mission (NASA TRMM) is the primary input for the GeoSFM water balance module. The 0.25^o TRMM 3B42 product has complete spatial coverage for Africa. TRMM records are available for a relatively long time period (1998 -2008) and are extensively used. Past studies that have explored the adequacy of satellite-derived Rainfall Estimates through intercomparison and validation processes have demonstrated enhanced performance over other estimates in Africa when employing TRMM data (Dinku et al 2008). The archive of daily grids used in this study covers 2001 to 2007.

Soil data from the Digital Soil Map of the World (Food and Agriculture Organization 1998) and the World Soil File (Zobler, 1986) are used to determine predominant soil parameters in each catchment.

NOAA GDAS Global Daily Reference Evapotranspiration (GDET) dataset produced by USGS EROS are used in conjunction with TRMM precipitation data to generate water balance. 1^o GDET has full spatial coverage of Africa. The archive of daily grids used in this study covers from 2001 to 2007.

Results

Streamflow hydrograph: Previous implementation of GeoSFM for the Congo Basin demonstrated some inconsistencies in the monthly hydrographs. When compared to hydrometric stations data, the seasonality of the flow was generally captured. But, for most of the stations, there was a substantial underestimation of flow discharge. The water balance generated from TRMM precipitation and GDAS evapotranspiration data is assumed to be consistent due to the acceptable level of accuracy of TRMM1. No validation of USGS GDAS-based daily reference ET has been performed specifically in Africa due to the unavailability of field data sets. But conclusive validation performed in the US shows very high correlations between station-based ET and GDAS-ET (~ 0.99)[2], suggesting the reliability of using GDAS reference ET for regional water balance studies in many parts of the world and their potential for large-scale hydrological applications. This conclusion led us to deduce that the major source of inconsistency in the hydrograph was not due to the water balance but other parameters of the model. That explains our focus on improving Land Cover characterization of the Congo Basin as a major model input. We assume that at equal water balance, finer resolution LCLU data will provide improved hydrological characterization (Figures 3, 4). Indeed, finer resolution LCLU data contribute to a

1 Dinku, T., *et al*, 2008, Comparison of global gridded precipitation products over a mountainous region of Africa, *International Journal of Climatology,* vol 28, 12, 1627-1638

2 Senay, G., *et al*, 2008, Global Daily Reference Evapotranspiration Modeling and Evaluation, *JAWRA 44*, vol4, 969-979

better spatial distribution of Land Cover classes leading to a better spatial distribution of hydrological parameters (Table 2).

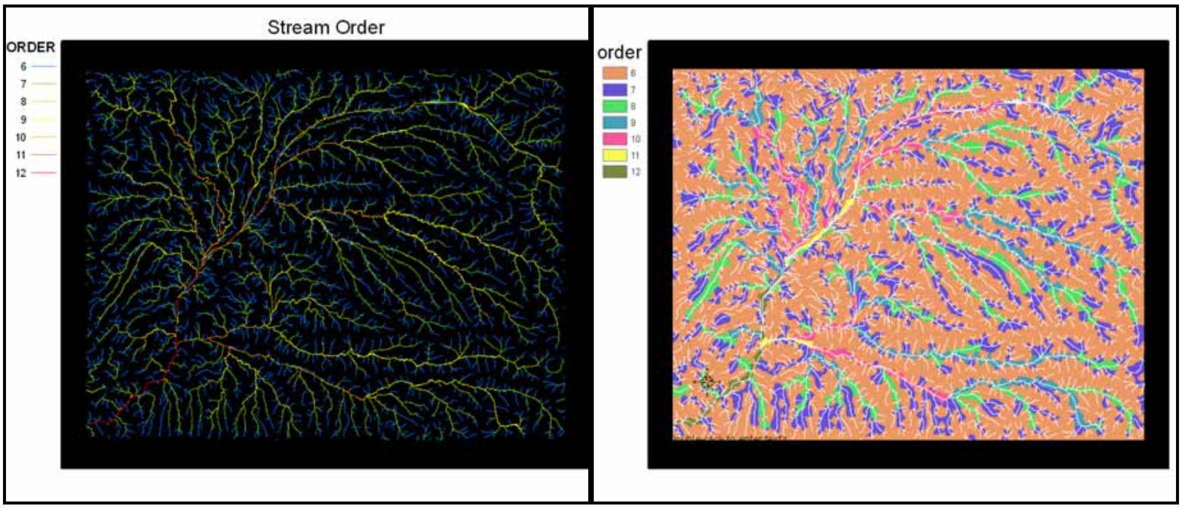

Figure 1. SRTM derived stream order in 6 classes (from 6 to 12) and their corresponding cover areas that directly impact runoff generation. Table 1 describes the dominant cover type found around each order class.

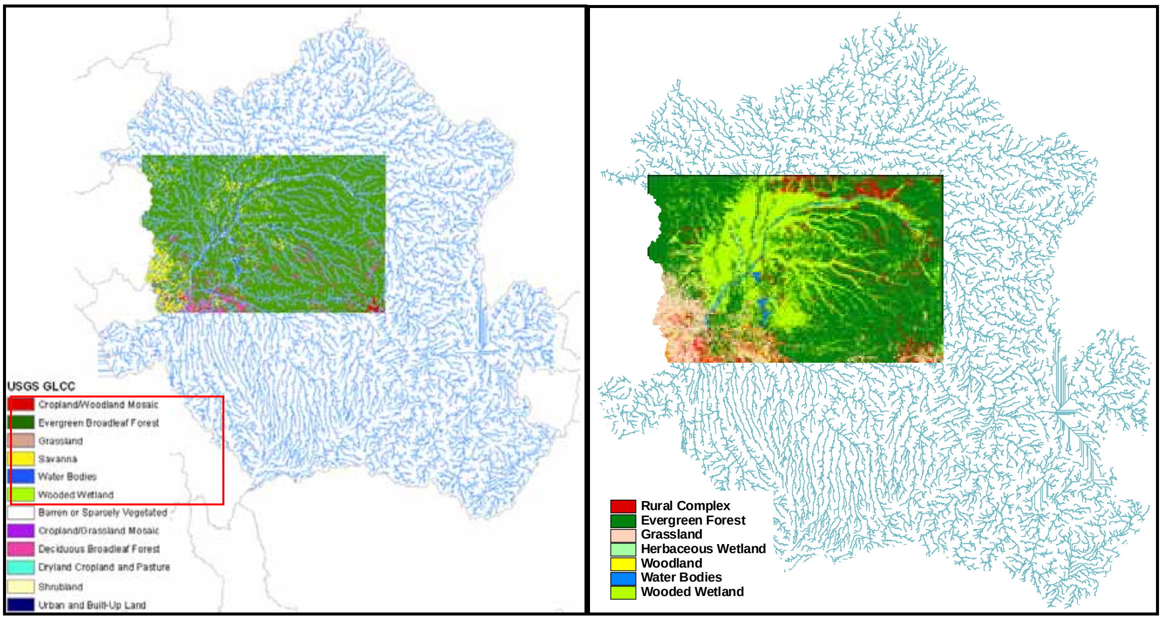

Figure 2. Coarse and fine resolution Land Cover data in the core area – on the left the CLCC coarse resolution product, on the right the multisource enhanced fine resolution data. According to expert knowledge, the 6 classes of interest, particularly the wetland and the rural complex classes, are more accurately represented in the fine resolution data map.

Table 1. Stream order characteristics – Slope and its standard deviation (Std).

Order	Mean Slope	Std	Dominant Cover
6	1.00875	1.52	Dense Forest
7	0.77203	1.25	Dense Forest
8	0.87809	1.40	Dense Forest
9	1.10107	1.46	Dense Forest
10	0.92230	1.49	Wooded Wetland
11	0.45311	1.03	Water bodies

Table 2. Hydrological Parameters (velocity and Manning coefficient) for the 6 Land Cover classes (adapted from the USGS GeoSFM technical document).

Land Cover class	Velocity	Manning
Rural Complex	0.33790	0.040
Grassland	0.67578	0.050
Dense Forest	0.23652	0.120
Water Bodies	0.59130	0.035
Herbaceous Wetland	0.47300	0.050
Wooded Wetland	0.23652	0.050

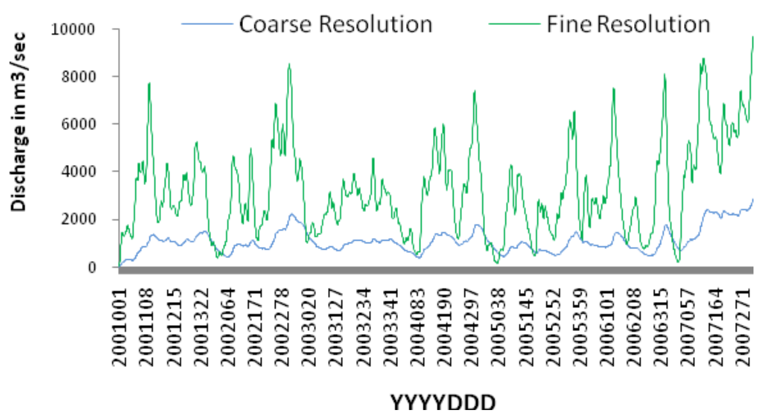

Figure 3. Hydrographs at Lulonga - At equal water balance, two different GeoSFM simulated hydrographs are generated with coarse (blue) and with fine (green) land cover and elevation data. A significant increase of flow discharge can be observed on the green hydrograph. However, increase occurs only for peak flow and not for lower flow corresponding to dry season. Unfortunately, without any gauge data in this area, it is impossible to evaluate the simulated flow.

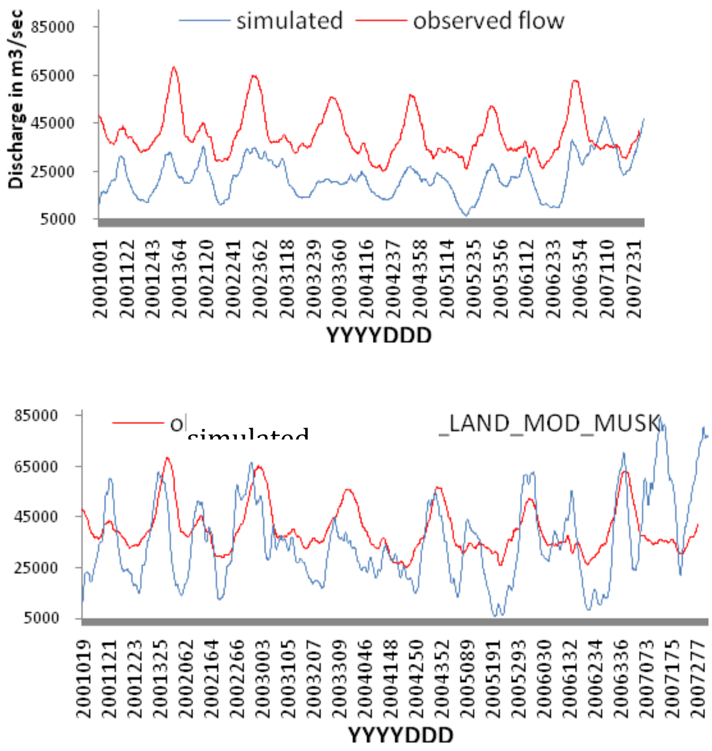

Figure 4. Hydrographs at Kinshasa Station - At equal water balance, two different GeoSFM simulated hydrographs are generated with coarse land cover and elevation data (left) and with fine land cover and elevation data (right) .

A significant increase of flow discharge can be observed on the right hydrograph in figure 4. However, since the flow accumulation grid was run only in the core area of the Basin, it does not include all upstream sub-basins. Thus, the flow simulated at Kinshasa is likely underestimated. Implications are, with a basin-wide fine resolution land cover data, the simulated flow might overestimate the flow as observed in this station. That would necessitate a calibration process to adjust the simulated flow to the observed one. Another observation is related to the increase occurring only for the peak flow. For the lower flow corresponding to the dry season at Kinshasa, the flow magnitude is still the same with either coarse or fine resolution data. That might suggest the necessity to improve the GeoSFM algorithm that transforms water balance into runoff during the dry season.

Hydropower Assessment: In the absence of calibrated simulated flow, gross hydropower potential has not been estimated for the Basin. However, a test has been performed to estimate hydropower potential for the month of October in the area of study. We use the simulated peak flow aggregated for the month of October and a head grid generated with SRTM 90 meters. The Hydropower potential is calculated by applying the power equation below to the flow discharge and to the head available along 100 meters on the reach

Power $[L^2MT^{-3}] = Head\ [L]*\ Q[L^3T^{-1}]*\ p[ML^{-3}]*\ g[LT^{-2}]*0.001$, (P: hydropower potential (KW); H: head (m); Q: flow (m^3/s); p:water density (1000 kg/m^3);g:gravitational acceleration (9.81 m/s^2)

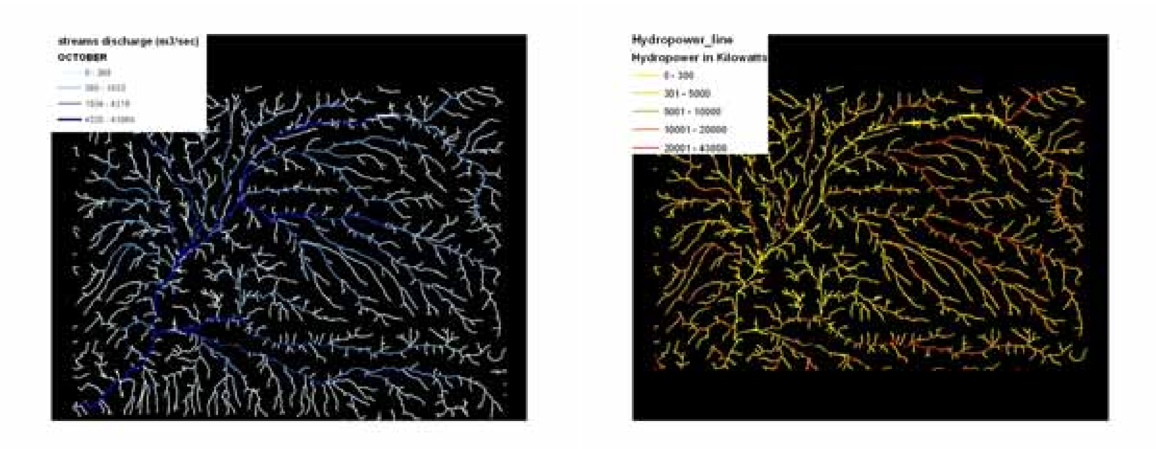

Figure 5. October Stream discharge and gross hydropower potential.

Discussion

The use of high resolution LCLU and DEM data (for the central part of the Basin) improves the flow magnitude but only during the rainy season. This suggests the necessity to calibrate the model to better fit low period flow conditions. There are flow losses, particularly during the dry season, caused by evaporation from the ground, transpiration by vegetation and seepage of surface water to groundwater. Groundwater can take weeks or months to appear as streamflow, and is a major component of the streamflow during dry periods. Next efforts will focus on incorporating this component in the GeoSFM algorithm to improve the calibration of the hydrological model. The next efforts will also consist in the completion of Basin-wide multisource high resolution Land Cover data set that will serve for Basin-wide Hydrological model implementation.

Conservation Prioritization, Livelihood Improvement and Potential for Carbon Credits in the Maringa-Lopori-Wamba Landscape, Democratic Republic of Congo / Développement territorial et utilisation du sol dans le paysage Maringa-Lopori-Wamba

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[1]African Wildlife Foundation;
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[3] ONF-International

The 74,000 km2 Maringa-Lopori-Wamba (MLW) landscape is located in Equateur and Orientale provinces in northern Democratic Republic of Congo (DRC) (Figure 1). It was identified in 2002 by the Congo Basin Forest Partnership as a priority area for conserving biological diversity, improving people's livelihoods, and developing sustainable forestry practices within. To assist with these tasks, a consortium of partners from several local and international institutions led by the African Wildlife Foundation (AWF), have been working together to build the foundation for sustainable land use planning. The MLW Consortium, which was established with support from the United States Agency for International Development's (USAID) Central African Regional Program for the Environment (CARPE), includes such partners as the World Agroforestry Centre (ICRAF), the Tropical Soil Biology and Fertility Institute of the International Centre for Tropical

Agriculture (TSBF-CIAT), the University of Maryland (UMD), and the Université Catholique de Louvain (UCL). Other project partners include the U.S. Forest Service (USFS), the DRC government, and a selection of local community-based organizations.

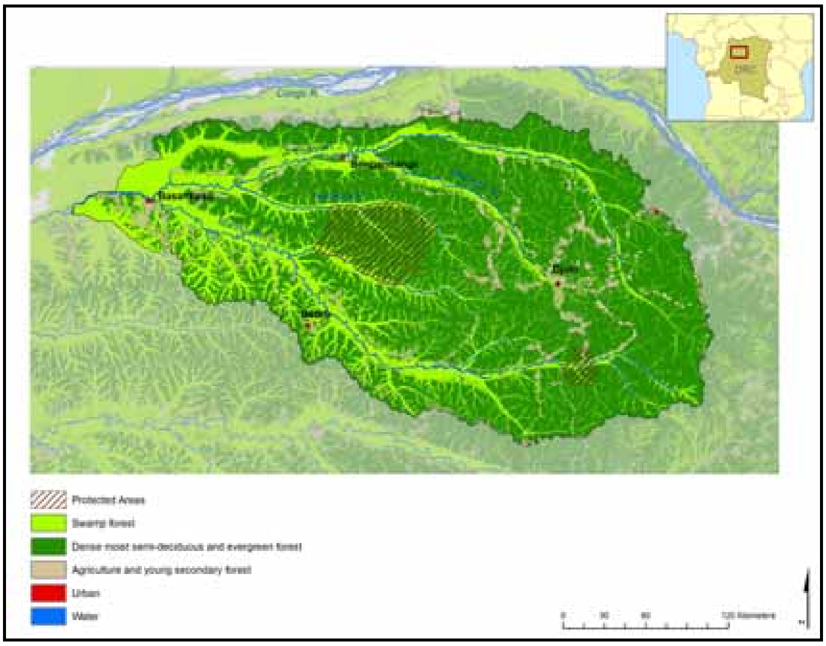

Figure 1. Maringa-Lopori-Wamba (MLW) landscape.

The project responds to a crucial need to better understand major drivers of deforestation and subsequent reduction of biodiversity in the Landscape while ensuring the well-being of local communities. The project is currently beginning work exploring potential for future REDD+ efforts. MLW is one of the poorest and remote areas of DRC where human populations depend directly on the benefits of their surrounding ecosystems. Our project aims to improve human well-being in the MLW landscape by providing economically and environmentally sustainable alternative livelihood strategies which minimize forest degradation and fragmentation. The primary mechanisms for achieving this objective are participatory land use planning, coupled with increasing economic returns from agriculture. Since 2006, the Consortium has been working with local community, state, and national government institutions on strategies for reductions in forest conversion and avoided deforestation. Central to these strategies is building knowledge assets for livelihoods, providing incentives for enhanced agroforestry and agricultural productivity on converted lands, and developing a sustainable land-use plan for the landscape. The consortium has engaged in participatory land use planning in MLW which has been based upon consultation with local and state institutions. Activities have included the development of spatially-explicit models for conservation land-use planning, consultation with local stakeholders, and assistance with on-the-ground intensification of tree and crop systems in already farmed areas.

Deforestation monitoring and conservation prioritization

Our project has employed the use of spatial data and models to monitor patterns of deforestation in the MLW Landscape and to identify the areas of highest conservation priority. The landscape harbors an array of terrestrial mammals, including the bonobo ape (Pan paniscus), the Congolese peacock (Afropavo congensis), and the forest elephant (Loxodonta cyclotis), among others. The landscape already has two recognized protected areas: the Lomako Faunal Reserve and the Luo Scientific Reserve. Biological surveys conducted in both reserves indicate presence of the bonobo ape (listed as Endangered as of 1996 on the IUCN Red List of Endangered Species). One goal of the project is to harness remote sensing tools to monitor slash-and-burn activity from human settlement and agriculture in the protected areas as well as in remote forested areas. Locations of active fire points detected by satellite imagery are mapped using data from the Fire Information for Resources Management System (FIRMS, managed by the University of Maryland) and assist in understanding and quantifying the extent of human encroachment across the MLW landscape. We also employ analysis of satellite imagery to monitor past and current patterns of deforestation in the landscape.

Another goal of the project is to understand the spatial distribution of human activity in the landscape to help pinpoint the areas of highest conservation potential as well as locations of wildlife corridors connecting the protected areas as well as an array of larger, less-disturbed forest blocks. A multi-criteria model was developed using GIS tools to identify the spatial extent of human threats to biodiversity. The inverse of the result was then used to identify the least-disturbed forest habitats and to model the locations of the wildlife corridors connecting them (Figure 2). We will use these modelled outputs to inform management and future land-use planning in the MLW Landscape and monitor the impacts of human activity in these areas over time.

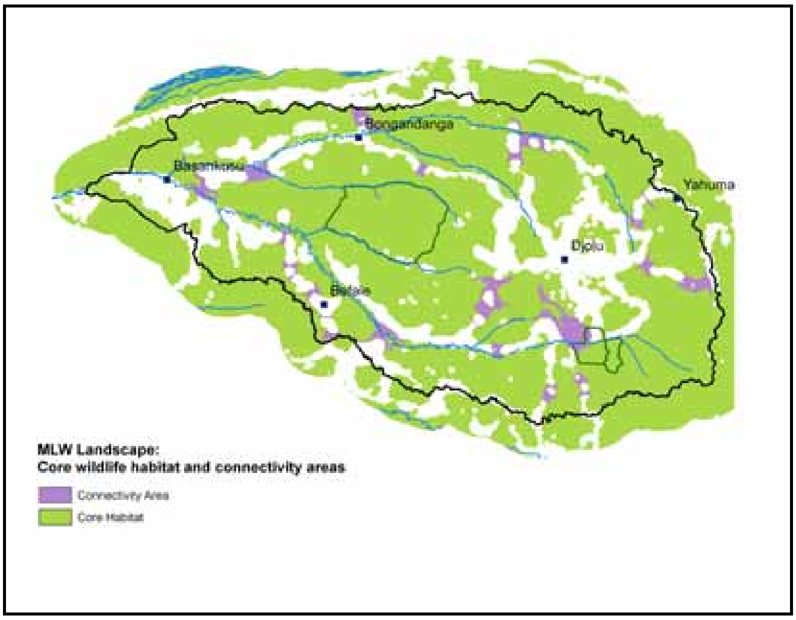

Figure 2. Least-disturbed forest habitats and locations of wildlife corridors.

Participative land-use planning and zoning

Participative land-use planning is being employed in the MLW Landscape to meet the goals of reducing deforestation from slash-and-burn agriculture, improving management of natural resources, and reducing poverty. At the macro-, or landscape-level, participatory approaches have been used to propose land areas for various uses including protected areas, production forest, community-based natural resource management (CBNRM), and expansion of agricultural activities. These proposals are subject to actual ratification by appropriate authorities and stakeholders, but they do provide a vision for the future of the larger landscape. In September 2009, an agreement was signed between the DRC Ministry of Environment, Nature Conservation and Tourism (MECNT) and AWF designating the MLW landscape as a pilot site for land-use planning and zoning. MLW is the first region in the DRC that has been formally recognized as a pilot site for zoning.

Using a combination of spatially-explicit modelling and participatory approaches, the project team has begun to identify the spatial extent of areas best suited for inclusion in a proposed

Rural Development Zone (RDZ). The RDZ is primarily intended to constrain the spatial extent of future agricultural activity while taking areas of conservation priority into account. Land that is not part of the rural complexes should then become permanent forest, devoid of slash and burn agriculture but made available for collection of non-timber forest products for human livelihoods. This planning model, created using a spatial conservation planning tool called Marxan, considers a host of factors influencing future agricultural suitability including assumptions about future population growth and agricultural activity, the influence of existing agricultural areas, human accessibility, and the locations of areas important for conservation prioritization. Figure 3 shows in red the existing rural complexes, and in orange the proposed areas most suitable for future agricultural expansion to 2015, with conservation needs in mind.

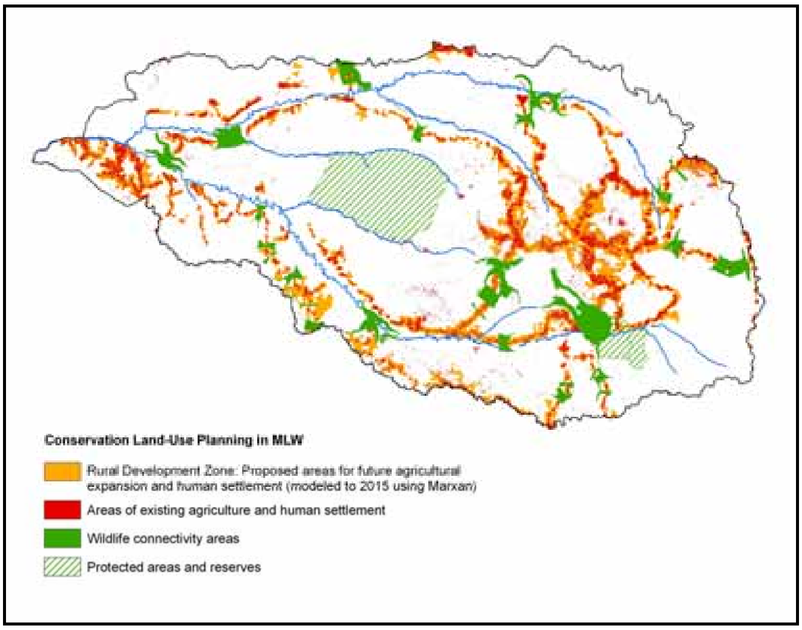

Figure 3. Existing rural complexes and proposed areas most suitable for agricultural expansion.

SOIL: Micro-zoning for livelihood improvement and poverty reduction

Through the Sustainable Opportunities for Improved Livelihoods (SOIL) project, the MLW program is engaging with local communities in 17 villages situated within a 2,000 km2 study site in eastern MLW (Figure 4) for micro-zoning and livelihood improvement at both the village and household level. The study site was chosen for this particular focus because it contains a large center of slowly expanding agricultural production in addition to a large wildlife corridor important for connectivity between MLW's two protected areas. The main objective of the SOIL program is to increase household well-being for 4,200 households in the study area by providing economically sustainable alternative livelihoods that mitigate negative environmental impacts of existing livelihoods strategies, notably forest conversion and degradation.

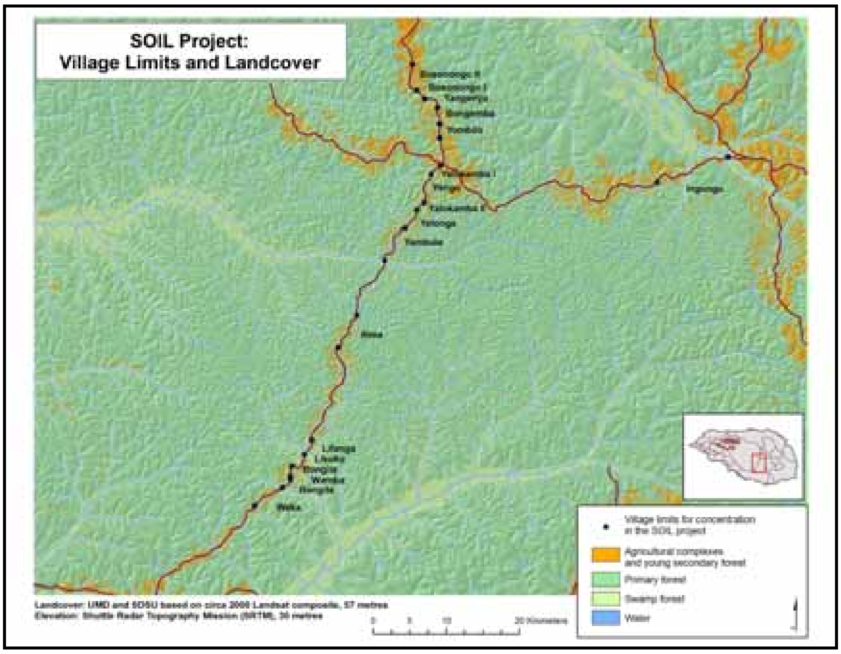

Figure 4. MLW program is engaging with local communities.

The project team is using participatory mapping strategies coupled with GPS data collection to delineate active agricultural boundaries on satellite images for the villages in the study area. This work will help inform our understanding of current land management practices in order to develop appropriate and complimentary participatory land use planning strategies, including defining the boundaries of the RDZ. The work will also inform our understanding of land use both inside and outside the village agricultural center.

The project will then work with each of the villages under a quid-pro-quo agreement, providing support for agricultural intensification and increased access to markets within the agreed limits of each village's identified RDZ. This support includes, but is not limited to, support for agro-forestry, distribution of germplasm, seeds and natural fertilizers to each village, providing direct agricultural training for application, providing product storage and enhanced market access, and providing training in product transformation and quality to increase market competitiveness and enterprise. The SOIL project has also deployed household surveys for 200 households within the 17 villages. The surveys include qualitative and quantitative information about household characteristics and well-being, food production and farming techniques, markets and market access. The surveys will serve as a baseline for future project planning, monitoring and evaluation.

Modeling future impacts of deforestation and examining potential for carbon credits

An emerging objective of the SOIL program is to provide a cost-effective foundation for designing systems for monitoring, reporting and verifying greenhouse gas (GHG) emissions reductions and carbon stock enhancements attributable to the SOIL program. Two major activities undertaken in the SOIL project are relevant to this aim: reduction of GHG emissions from deforestation through constraining the extent of forest conversion to the dedicated RDZ; and carbon sequestration through the establishment of agro-forestry systems. Opportunities for undertaking REDD+ initiatives will also be investigated.

To accomplish this objective, baseline data will be collected and satellite imagery will be analyzed to assess carbon sequestration and GHG emissions linked to the different land uses in the SOIL study site. Data used will include biomass estimates from intact, managed and secondary forests, agricultural areas and agro-forestry systems, time series remote sensing data on historical agricultural rotation and forest conversion, and a review of the relevant literature.

The potential impact of the SOIL program on GHG emissions reduction and carbon sequestration can be estimated by comparing a modelled business-as-usual scenario of land use change with a project scenario defined by the SOIL micro-zoning plan. A business-as-usual scenario for forest change in MLW has already been developed using Idrisi's Land Change Modeler extension for ArcGIS. The model shows projected landcover changes in MLW for each 10-year interval from 2000-2050. It illustrates the spatial extent of forest loss as local communities open up formerly primary forest, away from roads and centres of habitation to pursue expanding agricultural livelihoods. The MLW and SOIL team hope to reverse this trend through the defined project activities, monitored by satellite image analysis over time.

Towards Land Use Dynamics Modeling: A Case Study of the Democratic Republic of the Congo / Dynamique d'utilisation du sol et distribution de la population humaine en RDC

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Keywords: Population distribution; Accessibility; Land use; spatial modeling; DRC

Introduction

Human population distribution and accessibility to main markets appear among high ranked drivers of land use dynamics including forest cover change. Unfortunately, central African countries as the DRC often lack reliable and detailed data related to above mentioned drivers. The current research illustrates how the population distribution and accessibility measures can be derived using spatial modeling techniques.

Estimating human population distribution presents many challenges. Typically, population modelers are faced with limited data availability, both in quantity and quality. As population data mostly rely on large-scale census campaigns, they tend to be inconsistent across temporal and geographic scales. For developing countries which often lack proper resources to support national censuses, this is a major problem[1]. In addition, country-level population information is often aggregated to areas sometimes covering thousands of square kilometers. One major challenge in population distribution modeling consists in the appropriate assignment of population counts from source zones (i.e., the aggregated data) to another superimposed set of (target) zones or to a regular grid of cells. This assignment has been generally addressed by areal interpolation, defined as a series of techniques to transform data from one set of zones to another[2].

Accessibility models have been widely implemented using GIS software, mostly in a data rich context about travel time by road types, timetable information for public transportation, precise location of railway stations, exhaustive road and railway databases covering all the study area,

1 Mennis, 2009

2 Goodchild and Lam, 1980

etc. However, in many developing countries, such information is really scarce (and most of the time unavailable) which prevents the implementation of a reliable accessibility model[1]. Meanwhile, there is an urgent need in those countries for operational accessibility models as many projects conducted in these regions rely on the evaluation of the accessibility to health care centers for a better public health management[2], to main cities or markets for land use dynamics assessment or infrastructures development[3] or to primary and secondary schools for improving the educational system[4].

To overcome these limitations originating from the lack of detailed population and transport system data in developing countries, the present research proposes a set of spatial modeling techniques for estimating the human population distribution and the accessibility to main cities at the DRC national scale. Both population distribution and accessibility can afterwards be combined with other important land information (e.g., protected areas and forest concessions) to support an overall modeling scheme (see Fig.1) suitable to investigate land use dynamics.

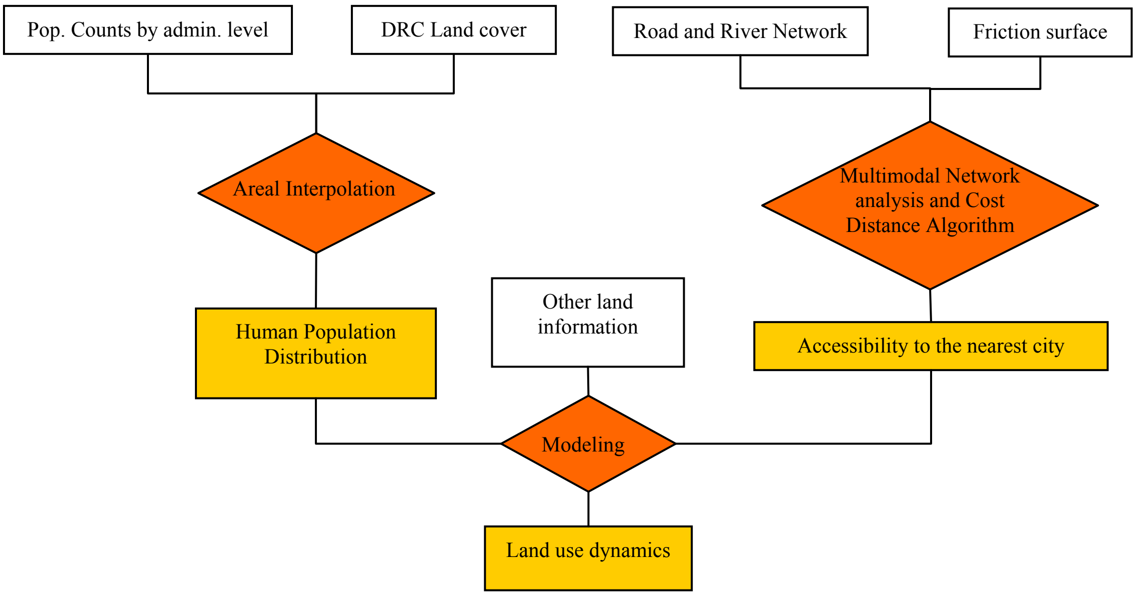

Figure 1. Overall modeling framework.

Mapping human population distribution

Assuming that the observed human population over a source zone is strongly related to the land cover patterns, population densities per unit of each land cover class can be computed by regressing source zone counts on land cover areas. These density estimates can subsequently be used to estimate populations over any other areas and at any other spatial scale, providing that the corresponding land cover composition is known.

Let us denote y_i as the observed population over the *ith* administrative unit among n units. Let us consider a set $\{l_1,\ldots,l_k\}$ of land cover classes, and let us denote $x_{i1},\ldots,x_{ik}$ the corresponding areas (in

1 Tanser et al., 2006

2 Murawski and Church, 2009

3 Castella et al., 2005

4 Vasconcellos, 1997

km[2]) covered by each land cover class in this unit. Assuming that densities are spatially invariant, a simple linear regression model can thus be written as:

$$y_i = \beta_1 x_{i1} + \ldots + \beta_k x_{ik} + \varepsilon_i \qquad \forall = 1,\ldots,n \qquad (1)$$

Where β_i is the population density (inhabitants/km^2) and where ε_i refers to the corresponding error in terms of population. It is worth noting that this regression corresponds to a no-intercept model in the sense that a null area necessarily yields a zero population. The estimation of β_i is straightforward in a classical ordinary least square framework.

As linear regression only aims at minimizing the sum of the squared ε_i, there is no control over the total estimated population as resulting from the model. The current research circumvents this limitation by introducing linear constraints using the Lagrangian formalism. These constraints include the total population and the percentage of the total population in specific land cover classes when the information is available. For DRC, it is generally agreed that the urban population represents about 30% of the population total[1]. The remaining 70% were considered in the present study as spreading over the other land cover classes. By taking into account these two specific constraints, the solution of the resulting system is given by the Equation 2 below:

$$\begin{pmatrix} X'X & sa & sb \\ s'_a & 0 & 0 \\ s'_b & 0 & 0 \end{pmatrix} \begin{pmatrix} \beta \\ \lambda_a \\ \lambda_b \end{pmatrix} = \begin{pmatrix} X'y \\ (0.3)y_T \\ (0.7)y_T \end{pmatrix} \qquad (2)$$

with y_T = the total population, $s'_a = (s_1, 0, \ldots, 0)$ and $s'_b = (0, s_2, \ldots, s_k)$, where s_1 denotes the total urban area, respectively, whereas $s_2, \ldots, s_k$ refer to total areas for various other classes. λ_a and λ_b being Lagrangian multipliers. The resulting human population distribution for DRC is then compared to existing data sets and discrepancies between observed and predicted populations at the DRC Territory administrative level are explored using simulations.

Estimating accessibility to nearest markets or cities

The use of isochrones in accessibility models appears to be one of the most appropriate approaches for creating an accessibility surface[2]. An isochrone in GIS can be seen from two perspectives: as a line of constant time or as a surface composed of areas lying within a set of range time values. Both isochrone types can be computed using network analysis tools, given that the network dataset (and related travel times by segments) and origin (and destination) points are provided. The value of an isochrone line is directly related to the input travel time of the corresponding network segment and its distance from the destination point. However, the value of an isochrone surface is somehow mitigated when moving away from network axes, or in areas of sparse input data (i.e., a coarser street grid)[3]. Clearly, the underlying land cover (or other land characteristics as the topography) should play a role in the calibration of isochrone surface values between network segments.

The current research developed a methodology which takes a full advantage of network analysis tools (e.g., the ESRI™ Network Analyst extension for ArcGIS) and uses an updated DRC multimodal transport system (roads and rivers) for deriving isochrone lines. Those isochrone

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1 BAfd/OCDE, 2008

2 Brainard et al., 1997

3 Brainard et al., 1997

lines are afterwards integrated into a model which involves friction surfaces for computing the accessibility to main cities. The resulting accessibility surface presented here below (see Fig. 2(b)) only illustrates the multimodal simulation for pedestrians and non-motorized boats.

Results and discussion

The DRC population densities at 1 square kilometer are estimated by land cover classes using a constrained linear regression model. Figure 2(a) shows the resulting human population distribution for DRC at national scale. Estimated densities are in good agreement with general considerations about DRC human population distribution. For example, the model depicted a density of about 90 inhabitants/km^2 for mountain forests in the quite populated regions of North and South Kivu. This is a DRC specific case while mountainous ecosystems are elsewhere associated to very low human population densities. It is worth noting that Kinshasa being a particular case of urban area was discarded during the constrained regression process.

From Figure 3(b), it can be seen that spatially varying densities (simulated based on a multivariate Gaussian hypothesis) have indeed an impact on the results, but this variability is far from explaining what is really observed. Also based on simulations, the present research shows how a confusion matrix originating from the land cover classification can serve for evaluating the impact of classification errors on the population density estimates. While the corresponding errors were quite limited and were not expected to notably change the estimations for the specific DRC case study (see Fig. 3(c)), it might prove to be useful to account for them in other circumstances.

Though one may of course imagine a wide array of potential sources of other errors, it is unlikely that they can account for the observed discrepancies (see Fig. 3(a)), so the problem should probably be found on the so-called census counts side[1], which are merely projections from the 1984 DRC census data.

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1 De Saint Moulin, 2006

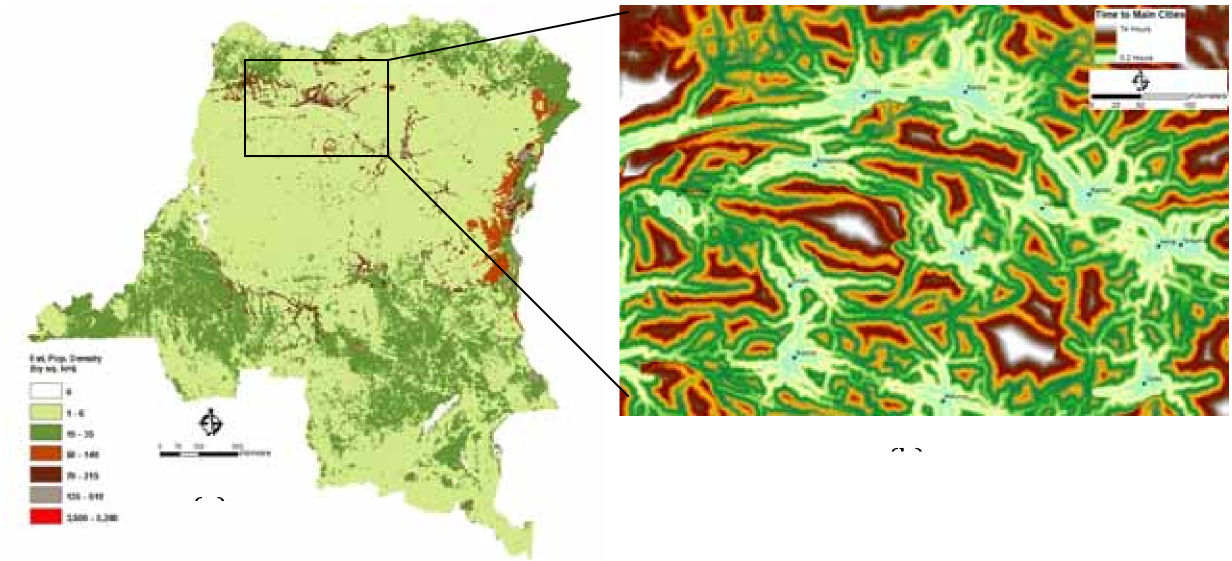

Figure 2. (a) Estimated spatial distribution of human population and (b) Accessibility to main cities as simulated from a multimodal network.

Preliminary results of the accessibility modeling showed that combining a network-based analysis with friction surfaces can overcome limitations coming from the single use of a coarse transportation network as input data when estimating the accessibility of given destinations. However, there are still some issues on calibrating how (and how much) these complementary land information (e.g., the topography) acting as friction surfaces, impact the accessibility to targeted locations.

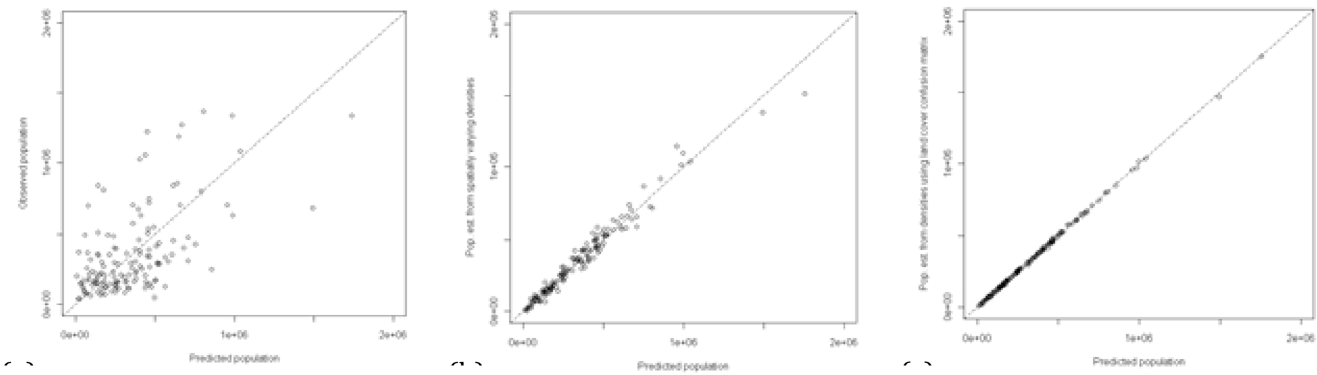

Figure 3. DRC population estimates from constrained model vs. (a) observed population per administrative units, (b) population estimates from simulated spatially varying densities, and (c) population estimates using land cover confusion matrix.

Perspectives

The results obtained from the constrained regression weighted areal interpolation provide probably one of the best approximations of the population distribution at a 1-km spatial resolution for DRC. The current results also demonstrate the effectiveness of combining a network-based accessibility analysis with friction surfaces to provide realistic estimations of the accessibility to DRC's main cities. Further integration of these results in an overall spatially distributed model designed for land use dynamics simulation should support the discussion of land and infrastructure development at national level.

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3.6 Regional Acquisition of Satellite Data

Satellite Data Accessibility for Forest Monitoring in Central Africa / Accès aux données satellitaires

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[b]Natural Resources Canada/Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD)
[c]University of Maryland

Introduction

Earth observation satellite data are a necessity for the successful monitoring of forest cover and execution of programs relating to the Reduction of Emissions due to Deforestation and Forest Degradation (REDD). The satellite data used for forest cover monitoring vary in spatial resolution (1 Km to sub-meter), image acquisition frequency (daily to monthly), spectral characteristics (including optical and radar) and data access costs (Table 1). A general observation is that access to satellite data, although improved in the last few years, remains limited in many regions of the world. The main constraints include:

– high cost of purchasing images,

– absence of receiving stations for systematic data acquisition,

– persistent cloud cover in tropical zones, and

– poor access to Internet and low bandwidth, which restrict data dissemination.

Satellite data play a key role for monitoring land cover and forest dynamics, including the evaluation of biomass and estimation of carbon stocks, etc. Compared to the collection of data on the ground, the use of satellite data has additional benefits such as simultaneous coverage of large areas, the possibility of regular updating of changes in land cover, wide area accessibility, and relatively low costs.

Since January 2008, the US Department of Interior/US Geological Survey has been providing terrain-corrected Landsat data over the Internet for free. Roy et al (2010) report on the size and proportion of the US Landsat archive that is over Africa by each Landsat sensor and discuss the current bandwidth constraints on users accessing free Landsat data over the Internet from Africa. In spite of the quantity of data collected since the launching of the first earth observation satellites, the share of data for Africa remains modest (Table 2).

Table 1. Characteristics of earth observation satellites data available for forest cover analysis in Africa.

Satellite	Sensor(s)	Spatial Resolution	Revisit Frequency	Application Scale[1]
	Optical			
NOAA[2]	AVHRR[3]	1 km	daily	Global NDVI[4]
SPOT[5]	VEGETATION	1 km	daily	Global
Terra / Aqua	MODIS[6]	250 m – 1 km	daily	Global, Regional
Envisat	MERIS[7]	300 m – 1 km	3 days	Global, Regional
CBERS-2[8]	CCD, IRMSS, WFI[9]	20 – 260 m	5 / 26 days	Regional, Local
IRS-P6[10]	LISS, AWiFS[11]	5.8 – 56 m	5 / 24 days	Regional, Local
Landsat 5 / 7	TM / ETM+[12]	15 - 60 m	16 days	Regional, Local
SPOT- 4 / 5	HRVIR / HRG[13]	10 – 20 m	26 days	Regional, Local
Terra	ASTER[14]	15 – 90 m	On demand	Local
EO-1	ALI[15]	10 – 30 m	16 days	Local
	Radar		Orbit overpass[16]	
ERS-2[17]	SAR (C-band)[18]	30 m	35 days	Regional
Envisat	ASAR (C-band)[19]	30 m	35 days	Regional
ALOS[20]	PALSAR[21] (P-band)	7 – 88 m	46 days	Regional
RADARSAT	SAR (C-band)	25 m	24 days	Regional

[1]Regional corresponds to the entire Congo Basin and local corresponds to the CBFP landscape level; [2]National Oceanic and Atmospheric Administration satellite series; [3]Advanced Very High Resolution Radiometer; [4]Normalized Difference Vegetation Index; [5] Satellites Pour l'Observation de la Terre satellite series ; [6]Moderate Resolution Imaging Spectrometer; [7] Medium Resolution Imaging Spectrometer; [8]China Brazil Earth Resources satellite; [9]CCD High Resolution, Infrared Multi-Spectral Scanner, Wide Field Imager; [10]Indian Remote Sensing Resource-1 satellite; [11]Linear Imaging Self Scanner, Advanced Wide Field Sensor; [12] Thematic Mapper / Enhanced Thematic Mapper; [13]High Resolution Visible and Infrared, High Resolution Geometric; [14]Advanced Spaceborne Thermal Emission and Reflection Radiometer; [15]Advanced Land Imager; [16]Revisit frequency depends on mode and incidence angle.; [17]European Remote Sensing satellite; [18]Synthetic Aperture Radar; [19]Advanced Synthetic Aperture Radar; [20]Advanced Land Observing Satellite; [21]Phased Array type L-band Synthetic Aperture Radar.

Table 2. Availability of global Landsat scenes in the US Landsat archives and percentage that are over the Africa continent (as of September 2009) (Roy et al 2010).

Sensor	Archive Total	Images over Africa	Percent
MSS 1-3	288,874	10,580	3.66
MSS 4-5	225,432	18,099	8.03
TM 4-5	795,711	47,519	5.97
ETM	930,271	117,247	12.60
Total	2,240,288	193,445	8.63

Due to the current significance of global issues such as climate change and the associated environmental and social impacts, regional and international initiatives are being established to improve the availability and accessibility of satellite data. Some of these initiatives are described below.

DMC international imaging

DMC International Imaging Ltd (DMC) promotes and sells imagery from a suite of small earth observation satellites. The Disaster Monitoring Constellation was designed as a proof of concept, capable of multispectral imaging of any part of the world every day. Although its objective is to support the logistics of disaster relief, DMC's main function is to provide independent daily imaging capability to the partner nations: Algeria; Nigeria; Turkey; UK; and China.

DMC has started the acquisition and the provision of satellite data covering the Congo Basin for EU FP7 projects. A testing and validation stage of these data for forest monitoring is ongoing.

SPOT image initiative

In support to international programs on climate change and particularly to REDD, the French government plans to open the archives of SPOT imagery. Archived imagery of different spatial and radiometric resolution will be made available to users, free of charge. The access to these images will be allowed to all, nevertheless, with preference for initiatives connected with the objectives of REDD.

Libreville satellite data receiving station

The governments of Gabon, France and Brazil plan to install, before the end of 2012, a satellite data receiving station at Libreville, Gabon. The station will allow the systematic reception of data from several satellites such as SPOT, CBERS, etc. In principle, this type of acquisition could help to partly resolve the current problem of cloud contamination in optic satellite data over tropical zones. In fact, with the systematic acquisition of satellite data, the probability of obtaining cloud-free images is maximized.

Initiative GeoNetCast

The primary objective of the GEONETCast system set up by Group on Earth Observation (GEO) is the dissemination of environmental data and derived products. GEONETCast is a near real time, global network of satellite-based data dissemination systems designed to distribute space-based, air-borne and in situ data, metadata and products to diverse communities (www.earthobservations.org/geonetcast.shtml). The initiative involves the EUMETSAT, the United States, China, and the World Meteorological Organization. The GEONETCast system will hold a central place in the cost-effective data distribution system via a satellite network.

In Central Africa, several national meteorological services are already equipped with PUMA receiving stations which could be used as part of the GEONETCast program. Currently, EUMETSAT provides transmission coverage across Africa.

GOFC- GOLD regional network data initiative

Regional Network Initiative of the Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) is currently one of the most active programs working for the improvement of quality and availability of land observation data (http://www.fao.org/gtos/gofc-gold/networks.html). In order to carry out this program, eight regional networks located in South America, in Asia and in Africa have been established.

For Africa, four regional networks are involved in the Regional Data Initiative: (1) Miombo (Angola, DR Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe); (2) OSFAC (DR Congo, Congo Brazzaville, Cameroon, Gabon, Central African Republic and Equatorial Guinea); (3) SAFNET (Botswana, Namibia, Swaziland, Lesotho, South Africa, Zambia, Zimbabwe, Mozambique, Tanzania, Uganda, Malawi, Angola, Sudan, RD Congo and Madagascar); and (4) WARN (Benin, Burkina Faso, Gambia, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal, Togo, Sierra Leone, Liberia, Ivory Coast and Cape Vert).

Krankina (2009) and Roy et al (2010) describe the Africa Data Initiative, which took place in April and May 2009. Specialists from the four networks, visited several agencies and institutions in the United States with earth observation programs. At the EROS Data Centre (EDC) in South Dakota, the specialists received training and subsequently obtained on hard media extensive Landsat and MODIS data for their network region of interest. The data were brought back to the respective network centres and then made available to network members throughout the region for scientific studies or to validate the results of thematic analyses.

In addition to data access, the Regional Data Initiative supports capacity building in the processing of satellite data for network members. Technical support is provided by START, NASA and GOFC GOLD, in partnership with USGS, UNEP and SDSU. It is also supported by several other national and international institutions such as: Canadian Forest Service, Canadian Space Agency, European Union, European Space Agency and the Global Terrestrial Observing System-GTOS (sponsored by FAO, WMO, UNEP, UNESCO, ICSU).

Satellite observatory of Central African forests network

In the sphere of the Regional Data Initiative, the Satellite Observatory of the Forests of Central Africa (OSFAC), which represents GOFC-GOLD in Central Africa, provides satellite data and available by-products for free. Three types of data are currently being distributed: Landsat (TM, ETM +), ASTER and SRTM (Figure 1), as well as derived forest and land cover products for the region.

The OSFAC has national Focal Points or Points of Contact, in charge of the distribution of satellite data, and which represent nearly all member countries of the Commission of the Forests of Central Africa (COMIFAC): Gabon, Democratic Republic of Congo, Congo Brazzaville, Cameroon, Central African Republic and Equatorial Guinea. In addition to providing a mechanism for the distribution of data and data products, OSFAC provides training in remote sensing and GIS. OSFAC maintains a close working relationship with DIAF, within the DRC Ministry of Environment, and is poised to enhance its relationships with other COMIFAC country ministries through the OSFAC Focal Points. OSFAC also works closely with the Observatoire des Forêts d'Afrique Centrale (OFAC), contributing to the State of the Forest Report, and works with other NGOS on regional forest monitoring activities. These working relationships contribute to the use and dissemination of satellite data and products in the region.

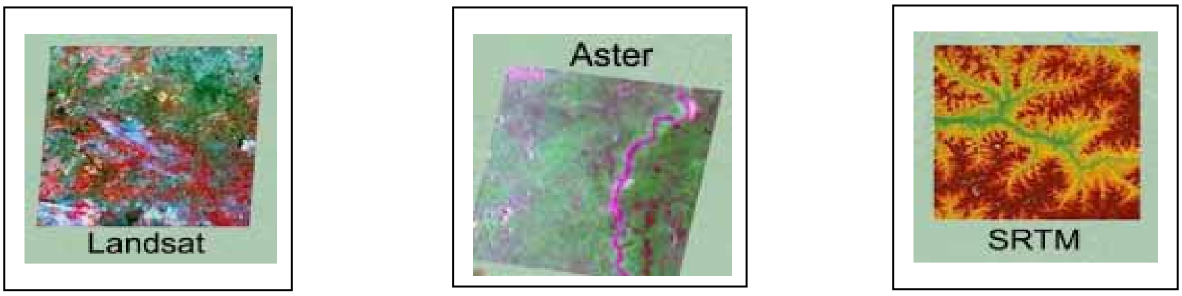

Figure 1. The three types of satellite data distributed by OSFAC.

Conclusions and recommendations

The accessibility of the earth observation data can be improved in Africa provided that:

- data producers continue to make the access to satellite data easier and in favorable conditions (e.g., preprocessed) for users, particularly in developing countries;
- an effective data distribution system is created within regional centers, such as the GOFC-GOLD OSFAC Regional Network, which will facilitate effective collaboration with other existing networks such as GEONETCAST, OFAC-FORAF, GLCN, etc.;
- radar data and associated training in its use, is made available, especially in zones with persistent cloud cover, as a supplement to optical data;
- satellite data receiving stations are established in the Congo Basin region where there is active demand for earth observation data;
- agencies are encouraged to consider free and open distribution of data and overcome the current obstacles to data access, with special consideration of the limitations of Internet network access and low bandwidth in Africa;
- installation of new fibre-optic cables continues, which will open up access to broadband connectivity and Internet use;
- donors and international projects are encouraged to coordinate their various satellite and in situ forest mapping and measurement activities to minimize duplication and maximize sharing of information in the Congo Basin.

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Pan-Tropical ALOS/PALSAR Mapping in Support of Forest Carbon Tracking / Le suivi des forêts tropicales avec PALSAR

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Robust forest monitoring tools, based on the broad range of available data sources, are needed if Central African nations are to develop effective monitoring, reporting and verification (MRV) systems to support the tracking of forest carbon under mechanisms now being negotiated to reduce emissions from deforestation and forest degradation (REDD). In 2006, the Japan Aerospace Exploration Agency (JAXA) launched the Advanced Land Observing Satellite (ALOS) featuring the Phased Array L-Band Synthetic Aperture Radar (PALSAR). The ALOS/PALSAR sensor has emerged as an invaluable data source for ingestion into MRV data streams for a number of reasons including: (1) the ability of radar to operate day or night while penetrating clouds and other atmospheric particulates including haze and smoke, (2) the long operating wavelength (23.6 cm), which is sensitive to forest structure and moisture characteristics, (3) a dedicated global observation strategy providing wall-to-wall, i.e., spatiallyexhaustive, imaging of all forested ecosystems at least twice annually during narrow, three- to fourmonth observation timeframes, (4) and an operating lifetime expected to exceed 10 years (i.e., beyond 2016). While these characteristics complement very well the features of existing Earth observation platforms, the space agencies of Japan, Argentina, Brazil, China, Germany, and the United States are actively involved in mission planning that would extend operational monitoring by L-Band radar well into the future, thereby ensuring long-term data continuity. In addition to supporting fine-resolution (15 m) mapping of forest and land cover, PALSAR data also has the potential to feed into biomass estimations derived from the fusion of field and multi-sensor remotely sensed data as well as emissions estimates when coupled with carbon stock maps or emissions models.

Pan-tropical mapping of forest cover

A mapping effort to generate consistent pantropical maps of forest cover and aboveground carbon stocks is currently underway at the Woods Hole Research Center (http://whrc.org/pantropical). This effort includes the compilation of an ALOS/PALSAR database that now includes 16,000+ fine-beam dual-polarimetric (FBD) PALSAR scenes (Figure 1). The objective is to construct a consistent ca. 2007 pan-tropical database, including wall-to-wall coverage of all COMIFAC countries (Figure 2), using the first full year (2007) of PALSAR dual-polarimetric data to produce a baseline forest-cover map product against which subsequent observations can be compared and changes in forest and lan cover can be assessed (Figure 3). A wall-to-wall PALSAR-based map of forest cover spanning the entire pan-tropical belt will be made publicly available in late 2010.

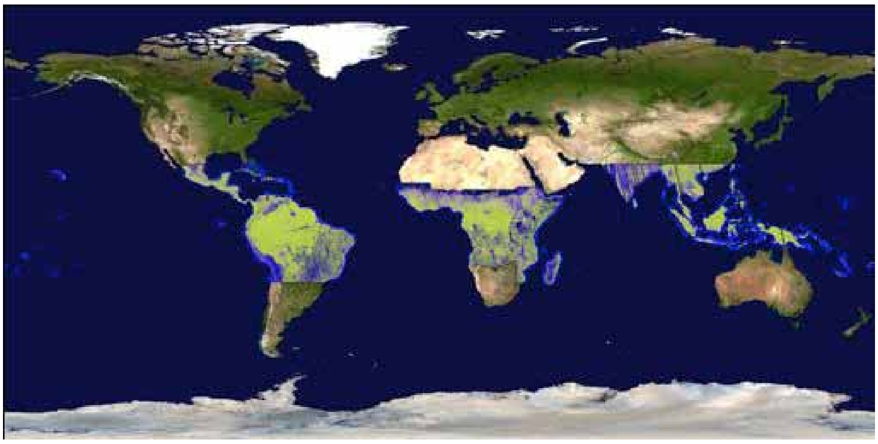

Figure 1. Dual-polarimetric (HH/HV) L-band ALOS/PALSAR mosaic of the pan-tropical belt superimposed on a 2002 global MODIS composite. The PALSAR mosaic consists of 16,189 individual 70 x 70 Km^2 scenes.

Pilot study: Xingu River headwaters, Mato Grosso, Brazil

In this pilot study, we evaluated the suitability of modern spaceborne radar data for the production of wall-to-wall maps of tropical land cover with special emphasis placed on applications of forest-cover mapping across large geographic extents.[1] The Xingu headwaters region, representative of many areas along the Amazon's agricultural frontier has more area in dense humid forest (~221,000 km2) than 90% of the world's tropical nations.[2] The region is currently being considered for a REDD pilot project, which would be integrated into the state's plan for meeting its obligations under the Brazilian National Climate Policy. Additionally, the Xingu headwaters has been selected by the Group on Earth Observations' (GEO) Forest Carbon Tracking (FCT) task as one of several key sites across the tropics where advanced methods for combining high-resolution imagery and in-situ forest data are being demonstrated in order to advance the development of national MRV systems (www.geo-fct.org).

1 Walker, W.S., C.M.. Stickler, J.M. Kellndorfer, K.M. Kirsch, and D.C. Nepstad. In Review. Large-area classification and mapping of forest an land cover in the Brazilian Amazon: a comparative analysis of ALOS/PALSAR and Landsat TM data sources. Submitted to: Journal of Selected Topics in Applied Earth Observations and Remote Sensing.

2 Stickler, C.M., D.C. Nepstad, M.T. Coe, H.O. Rodriguez, D.G. McGrath, W.S. Walker, B.S. Soares-Filho and E.A. Davidson, 2009. The potential ecological costs and cobenefits of REDD: a critical review and case study from the Amazon region. *Global Change Biology* 15:2803-2824

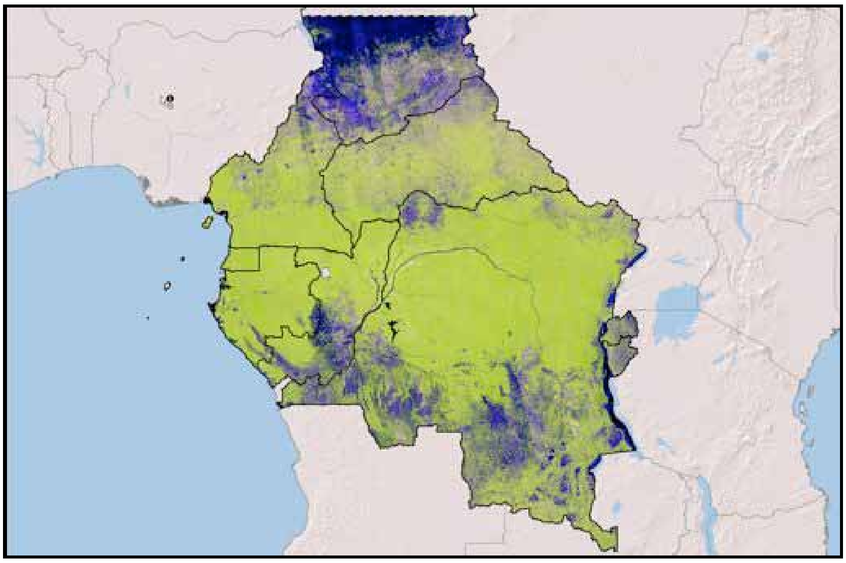

Figure 2. ALOS/PALSAR mosaic of Central Africa including all COMIFAC contries. The mosaic consists of approximately 1,600 PALSAR scenes with approximately 75% coverage from the period June-August, 2007, and nearly 95% coverage from June-October, 2007.

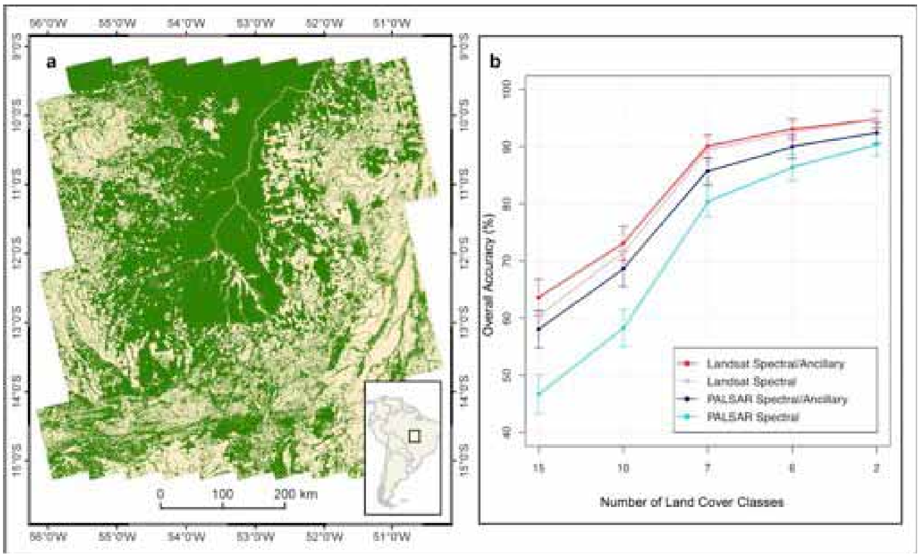

Figure 3. Land-cover classification results. (a) Two-class PALSAR-based categorical map of the Xingu River headwaters region distinguishing forest (green) from nonforest (beige); overall classification accuracy = 92.4 ± 1.8%. (b) Overall accuracies associated with 20 separate PALSAR- and Landsat-derived land cover classifications.

For the purposes of our analysis, two spatially and temporally consistent image mosaics derived from ALOS/PALSAR and Landsat TM data were generated for a 387,000-km2 region in the southeastern Brazilian Amazon encompassing the headwaters of the Xingu River (Figure 3a). Each mosaic was subjected to an empirical decision-tree algorithm with the primary objective of classifying land cover (a) at five different levels of class aggregation (15, 10, 7, 6, and 2 classes) and (b) using two different predictor-variable subsets (spectral and spectral/ancillary variables). Through a comprehensive comparative analysis involving twenty separate PALSAR- and Landsat-based classifications, we confirm the potential of PALSAR as an accurate (> 90%) source for map-based estimates of forest cover based on data and analyses from a large and diverse region encompassing the Xingu River headwaters in southeastern Amazonia (Figure 3b). Pair-wise spatial comparisons among maps derived from PALSAR, Landsat, and PRODES, the Brazilian Amazon deforestation monitoring program, revealed a high degree of spatial similarity.

Conclusions and future work

Given that a long-term data record consisting of current and future spaceborne radar sensors is now expected, our pilot study results point to the important role that spaceborne imaging radar can play in complementing optical remote sensing to enable the design of robust tropical forest monitoring systems. Our results confirm that modern spaceborne radar can contribute significantly to the generation of accurate, map-based estimates of forest cover across expansive and diverse regions like the Xingu headwaters, with accuracies nearly equaling those produced by Landsat, the most widely used sensor, and PRODES, the most highly regarded system, for monitoring tropical deforestation.

Further research is needed in other parts of the humid tropics to determine if comparable results can be achieved. Regions such as Central Africa, where fine-scale (! 1 hectare) anthropogenic forest disturbance results in a more heterogeneous mosaic of land cover classes than those typical of Amazonia, are key areas where new research should focus. Additionally, as state-of-the-art radar data become increasingly available to the forest monitoring community (several sensors are now in operation or are planned), further research on the topic of multi-sensor active (radar/lidar) and passive (optical) data fusion is needed.

DMCii Global Forest Services / Les données de DMCii

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Introduction

REDD+ funding requires countries to have an operational system for monitoring of national forests to provide actionable information on which to base forest management. Satellite mapping is an essential tool to provide timely reliable management and monitoring data.

In the Congo Basin the work of The Central African Regional Program for the Environment (CARPE) has provided valuable decadal maps of the Congo Basin Forests based upon satellite data. However the persistent cloud cover and the use of single satellites prevented mapping at more frequent time intervals than 5-10 years.

The advent of REDD+ now requires annual or 6-monthly wall-to-wall monitoring of these resources so that Forest Departments can have timely information on which to take action for forest management, and international funding agencies have objective information on which to base decisions. The most efficient and comprehensive way to provide this information is through the acquisition of satellite imagery.

New technologies such as Synthetic Aperture Radar are still at the research and development stage, so optical imagery provides a tried-and-tested way to monitor forests. Monitoring tropical forests at this frequency requires multiple satellites to avoid cloud, and this is made possible using the international Disaster Monitoring Constellation (DMC). The five optical imaging satellites built by Surrey Satellite Technology Ltd. (SSTL) work together to provide rapid repeat imaging capability. They are individually owned and operated by the DMC Consortium member nations; Algeria, Nigeria, China, Spain and UK.

Since the first DMC satellite was launched in 2002, the constellation has provided a commercial imaging service coordinated by DMC international Imaging Ltd (DMCii). The company, established at the request of the consortium, coordinates the key functions of:

- Calibration & validation of data – to match Landsat radiometry
- Disaster response - part of the International Charter; Space & Major Disasters
- Commercial imaging campaigns – to finance the system

Data continuity has been ensured with the launch of both new (Spain) and replacement (UK) satellites into the constellation. The multispectral sensors have been upgraded from 32metres gsd to 22metres, doubling the number of pixels per hectare. Two additional satellites are scheduled for launch in Quarter 4 2010 for Nigeria, including an additional 22m satellite, and a very high resolution satellite with 2.5 metre panchromatic, 5m multispectral and 32m multispectral imagers. The diagram below shows the data continuity timeline.

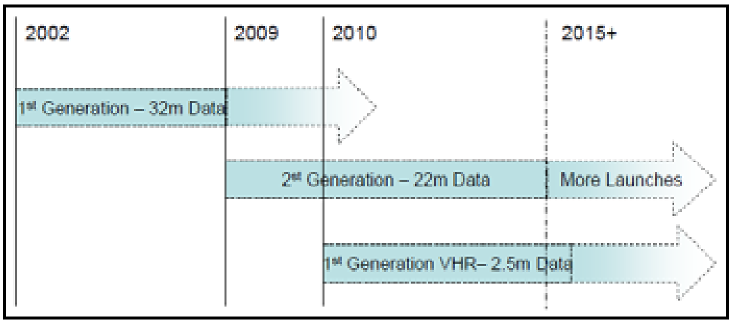

Figure 1. Data continuity timeline of the DMCii constellation.

The success of SSTL small satellites has been in building on the rapid improvements in terrestrial computing power to continuously improve price-performance ratios. The following diagram shows how the addition of the latest generation of DMC satellites increased dramatically the overall capacity of the constellation.

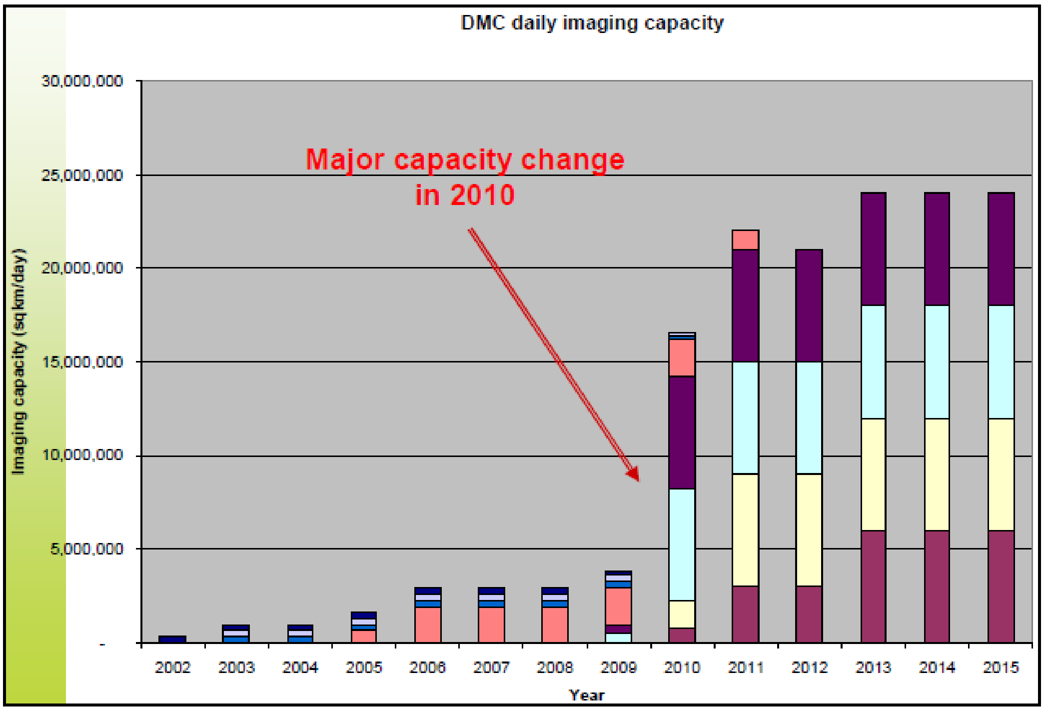

Figure 2. Capacity improvements in the DMCii constellation since 2002, and projected to 2015.

Since 2005 DMCii has successfully delivered monitoring in annual and monthly timescales of the world's largest tropical forest in the Amazon Basin, as part of the Brazilian Space Agency's exemplary PRODES programme for monitoring deforestation.

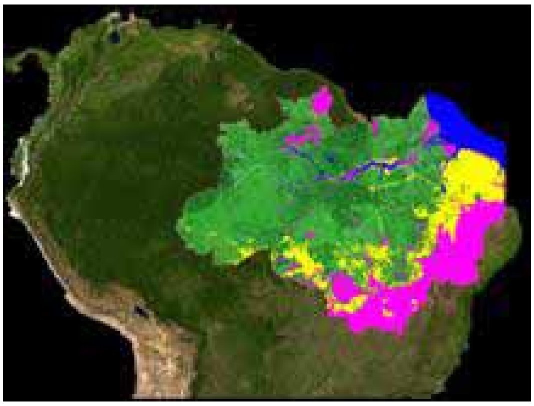

Figure 3. Amazon Basin deforestation map (INPE).

The constellation has also delivered timely coverage of 38 countries in Europe within tightly specified dates, and within 6 months has almost completed the first annual coverage of sub-Saharan Africa as a core data set for Europe's GMES programme (Figure 4). DMCii data is also used in Europe, North and South America for precision agriculture and land cover mapping.

The latest increase in DMCii capacity provides the ability to deliver global monitoring of forests on a regular annual basis. The second largest tropical forest in the world covers the Congo Basin, and DMCii will cover the region under the GMES programme in 2010 as shown in Figure 4. DMCii is also mapping forests in Indonesia.

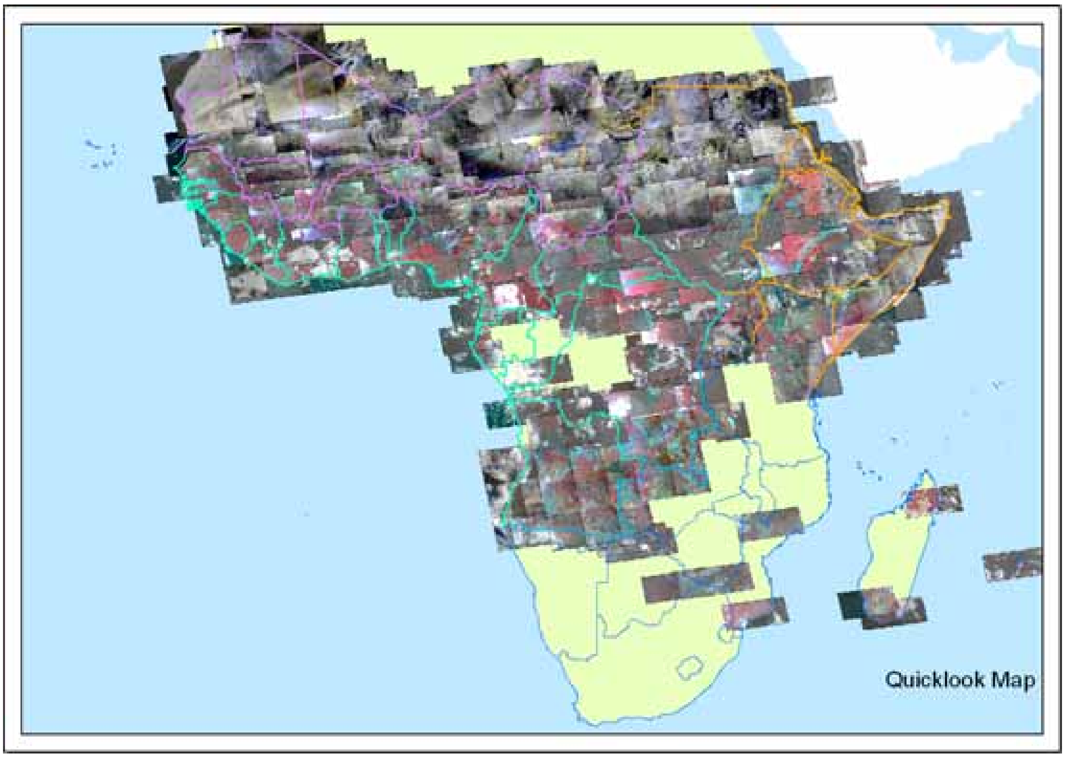

Figure 4. DMCii Africa coverage Oct '09 – Jan '10 commissioned by the European GMES programme.

The satellite data can be used to derive clear cut maps or to analyse degradation using multi-temporal datasets.

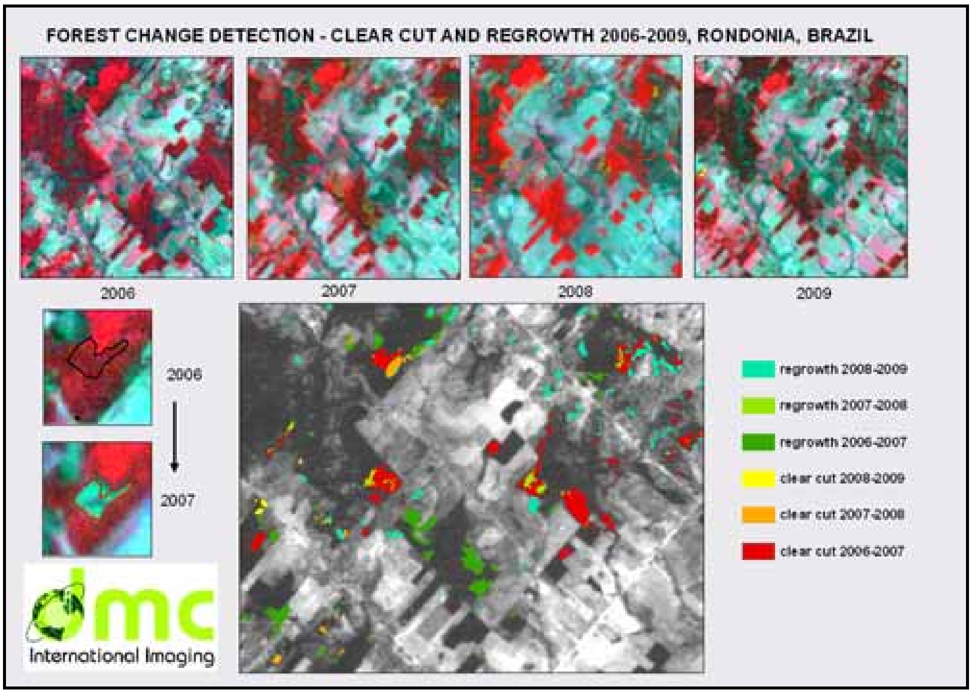

Figure 5. Multi temporal forest change analysis.

The data enables analysis of clear cuts, logging trails, and with multi-temporal data can derive other changes such as degradation, re-growth, burnt areas, and flooding.

With a resolution of 22metres – 32 metres the data provides excellent level of detail and benefits from the very wide area coverage achieved by the 650km-wide image swath.

DMCii now proposes, through the Congo Basin Forest Fund, a long term service plan to sustainably provide COMIFAC with:

- A comprehensive training and awareness building package for stakeholders in the Congo Basin with focus on capacity building with the Observatoire Satellital des Forets d'Afrique Central (OSFAC). Training events will include satellite data processing and map production and field training for map interpretation.
- A project to develop government involvement in sustainable provision of forest information.
- Fostering of South-South cooperation between COMIFAC and their Brazilian counterparts, INPE, IMAZON and IBAMA.
- Annual and better than annual basin wide imagery of the Congo Basin forests.
- More regular survey of Priority Landscapes and other key areas.
- Printed and digital forest maps, specified to meet REDD+ requirements.
- Harmonisation with existing projects to meet their data needs, including CARPE and Observatoire des Forets D'Afrique Central (OFAC).
- Licensing of al DMC data for any user globally, to stimulate uptake and remove barriers to exploitation.
- Focus on collaboration with existing actors in the region.

Partners, co-funding bodies and stakeholders include;

- UN-FAO, European Space Agency, CIFOR, World Resources Institute, EC-FORAF (OFAC), OSFAC, CARPE, IUCN, Jane Goodall Institute, GMES-REDD

- DG of Environment (RC)
- Association Congolese pour la Preservation des Forets
- Institution Congolese pour la Conservations de la Nature
- Ministry of Fauna and Forest (Cameroun)
- Geographical Institute of Burundi
- Further stakeholders in Gabon, Guinea Equatoriale
- Other forest responsible organisations

Summary

During the period 2010 onwards there is a REDD+ requirement for regular better than annual optical mapping of the Congo Basin and other tropical forests, in order to monitor and manage degradation and deforestation.

A review of available satellite systems showed that the Disaster Monitoring Constellation (DMC), established in 2002, is the only suitable operational system which provides the capacity, image resolution and quality of calibration to provide consistent and timely information for COMIFAC in the period from 2010 to 2014. The launch of additional DMC satellites for Nigeria in 2010 ensures data continuity.

Integrating this data with capacity building in the region through local organisations will deliver regular maps of the entire basin's forests and the training to produce and interpret these to effectively participate in the REDD+ process. DMCii is working with OSFAC and international organisations such as World Resources Institute and CARPE to integrate sustainable annual satellite imaging into the mapping and management of Congo Basin Forests.

An Earth Observation Ground Station and Research Laboratory for Long Term Monitoring in Central Africa / Le spatial au service de la surveillance de l'environnement et de la gestion durable des forêts en Afrique centrale

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Introduction

Les forêts du bassin du Congo et d'Afrique centrale représentent le second massif forestier mondial après l'Amazonie. Avec les forêts d'Asie du Sud-Est, les trois massifs concentrent la quasi-totalité des forêts tropicales de la planète. Aujourd'hui la contribution de ces forêts au suivi des stocks et flux de carbone est au cœur des débats scientifiques sur les changements climatiques. La mise en évidence des relations directes ou indirectes entre l'évolution des forêts, leur contribution aux variations des teneurs en gaz à effet de serre (GES) de l'atmosphère et les modifications du climat passent par une bonne connaissance des mécanismes en jeu sur ces forêts et leur évolution sous l'action de multiples facteurs au premier rang desquels les facteurs anthropiques. Cette connaissance nécessite de disposer d'informations fiables et continues sur ces espaces.

De nombreuses études ont montré que le recours aux images issues des technologies spatiales d'observation de la Terre est indispensable pour l'amélioration des connaissances sur les mécanismes de suivi des forêts. Mais le constat général actuel est que l'accès aux données spatiales est encore très difficile dans beaucoup de régions tropicales, et plus particulièrement en Afrique centrale. Pourtant des initiatives existent comme celles du réseau Global Observation of Forest and Lands Cover Dynamics (GOFC GOLD) qui, au travers des activités de l'Observatoire Satélitalle des Forêts d'Afrique Centrale (OSFAC) tente de remédier à cette situation. Cependant, les conditions climatiques liées à la permanence et la forte nébulosité, « la fracture spatiale » du fait de l'absence de station de réception directe des images et « la fracture numérique » imputable au faible accès à Internet, limitent considérablement les possibilités d'accès aux données satellites de qualité exploitable. C'est dans ce contexte que s'inscrit le projet de Surveillance Environnementale Assistée par Satellite dénommé « SEAS Gabon ». Ce projet qui ambitionne de mettre le spatial au service de l'environnement et de la gestion durable des forêts d'Afrique centrale vise à installer à Libreville une antenne de réception multi-satellites associée à un centre de compétence régionale et internationale en télédétection.

Les lignes qui suivent présentent de façon synthétique : i) le contexte et l'historique du projet, ii) les objectifs et résultats attendus, iii) le dispositif fonctionnel et les activités.

Contexte et historique du projet

Dans le cadre de la Commission des Forêts d'Afrique Centrale (COMIFAC), les pays du bassin du Congo se sont engagés depuis plusieurs années dans la mise en œuvre d'une politique concrète et concertée d'aménagement durable des forêts publiques, politique d'importance capitale au regard du rôle de la réduction des émissions de GES isues de la déforestation et de la dégradation des forêts (REDD) pour la limitation des risques du changement climatique. La possibilité de participer activement à la définition de l'inclusion des forêts dans les futurs mécanismes de négociations sur le climat, discutés notamment à Copenhague en décembre 2009, va dépendre principalement de la capacité des pays d'Afrique centrale à produire, à partir de méthodes et techniques de mesures fiables, les informations nécessaires à la définition des politiques, mesures et actions nationales visant à réduire les émissions de GES issues de la déforestation et de la dégradation des forêts. Faute de compétences suffisantes, ces pays risquent d'être absents ou réduits à de simples spectateurs des débats sur le choix des références méthodologiques et technologiques des mécanismes de limitation du risque climatique, au moment où ces discussions peuvent avoir des implications importantes sur la manière de traiter le thème des forêts dans le cadre de la Convention et du Protocole de Kyoto.

Ainsi, l'acquisition de compétences scientifiques et techniques suffisantes en matière de suivi des forêts représente un enjeu déterminant pour ces pays. Il a été démontré que l'essentiel de ces compétences, particulièrement celles ayant trait au suivi du couvert forestier, porte sur l'utilisation des technologies spatiales d'observation de la Terre. Cependant, l'accès aux données exploitables dans ces pays est confronté à une forte complexité résultant de la combinaison de plusieurs facteurs d'ordre historique, structurel, technologique et naturel.

L'installation d'une station de réception de données issues de différents satellites d'observation de la Terre, dans des zones africaines stratégiques, permettra l'acquisition systématique d'informations temporelles et spatiales distinctes, facilitant ainsi le suivi du couvert forestier et de ses dynamiques. La garantie d'une réception multi-satellitaire, l'accès libre et continu aux données comme la capacitation technique et scientifique, exigent un engagement international tant en termes d'investissements technologique et financier qu'en terme d'installation d'infrastructures adéquates.

Suite aux expériences réussies de la France et du Brésil, tant dans le développement de technologies spatiales pour l'observation de la Terre que dans l'utilisation effective des données obtenues, pour l'évaluation et le suivi des ressources naturelles, il existe une volonté forte de développer ces technologies dans des pays où elles sont encore insuffisantes ou inexistantes.

Le Gabon offre des atouts indiscutables tel que son positionnement géographique qui permet de couvrir l'ensemble des forêts du bassin du Congo et qui est en parfaite complémentarité avec le réseau d'antennes de réception CBERS prévu en Afrique tout en étant une composante essentielle du réseau des plates-formes SEAS animé par l'Unité ESPACE de l'IRD, et surtout une stabilité politique indispensable tant en terme d'investissement que de sécurité des équipements. De plus l'engagement historique du Gabon dans une politique forte et cohérente en faveur d'un développement économique compatible avec la préservation des écosystèmes forestiers et ses bonnes relations politiques avec les pays voisins en font une proposition cohérente à un projet à caractère régional sur la gestion durable des forêts.

L'année 2009 a été marquée par de nombreuses rencontres entre les partenaires du projet et par des prises de décisions officielles marquantes:

En mars, en liaison avec son engagement dans la gestion durable des forêts et dans le processus REDD (notamment avec sa participation au Forest Carbon Partnership Facility - FCPF), le gouvernement du Gabon a décidé la réalisation d'une étude de faisabilité d'un projet d'implantation de station de réception d'images satellites qui pourrait être financé sur l'accord de conversion de dette avec la France et un financement de l'Agence Française de Développement (AFD).

En avril, la Direction générale de l'environnement du Gabon (Ministère des Eaux et Forêt, de l'Environnement et du Développement Durable - MEFEDD) participe au symposium de télédétection organisé à Natal (XIV SBSR) par l'Institut brésilien de recherches spatiales (INPE), avec l'appui de l'AFD, de l'IRD, du Centre National d'Etudes Spatiales (CNES), du représentant français de GMES et du GEO (Group on Earth Observations) et de l'Ambassade de France au Brésil.

En juin, le Ministère de l'Environnement du gouvernement du Gabon oranise à Libreville, avec l'appui et la participation de l'AFD, de l'IRD, du CNES et de l'INPE, un atelier pour le lancement officiel du projet d'implantation de station de réception satellitaire, projet dorénavant dénommé SEAS Gabon. Des ministres gabonais participent à ce séminaire, ainsi que les Ambassadeurs de France et du Brésil au Gabon. Le partenariat entre le Brésil et la France apparaît ainsi prometteur pour la coopération avec les pays d'Afrique centrale.

En décembre, le projet SEAS Gabon qui concrétise ce partenariat est officiellement annoncé lors de la conférence des Parties à Copenhague (CPO-15) et approuvé par le Comité d'Orientation Stratégique du mécanisme de conversion de la dette Gabon-France. La volonté du Gabon à investir dans ce type d'infrastructure démontre l'intérêt de cette coopération tripartite et l'engagement des institutions des trois pays sur une nouvelle forme de coopération Sud-Sud.

Objectifs du projet et finalités

Le projet de Surveillance Environnementale Assistée par Satellite (SEAS-Gabon) a pour objectif de développer un pôle de compétence en télédétection pour la gestion durable des territoires au Gabon et en Afrique centrale. Ce pôle est constitué d'une plate-forme technologique comprenant une antenne de réception directe d'images satellitaires optique et radar à haute résolution associée à un centre compétence en traitement d'images et géomatique dédié aux applications de l'observation de la Terre et en particulier à la gestion durable des ressources forestières du Gabon et en Afrique centrale.

Les objectifs spécifiques du projet sont:

- implanter une plate-forme technologique : station de réception en bande X permettant la programmation et l'acquisition des données optiques et radars de haute résolution en temps quasi-réel ;
- installer une chaîne de réception, de traitement et de stockage des données multi-satellites permettant d'assurer le suivi du couvert forestier en adéquation avec les exigences de la législation nationale et des conventions internationales ;
- mettre en place une infrastructure permettant la diffusion dans la sous-région des données spatiales en temps quasi-réel ;
- développer des programmes de recherche pluridisciplinaires et des projets pilotes d'application impliquant des partenaires nationaux et internationaux ;
- accompagner les institutions de formation existantes par la mise en place d'actions de formation spécifiques pour accroître les capacités nationales et régionales et créer une expertise en Afrique centrale ;
- assurer l'innovation et les transferts en Afrique de méthodes et savoir-faire développés par les partenaires en Amazonie.

Ce projet se traduira par la création d'un centre de compétence en télédétection pour la recherche, la formation et le développement de services opérationnels pour le suivi des forêts et de l'environnement en Afrique centrale.

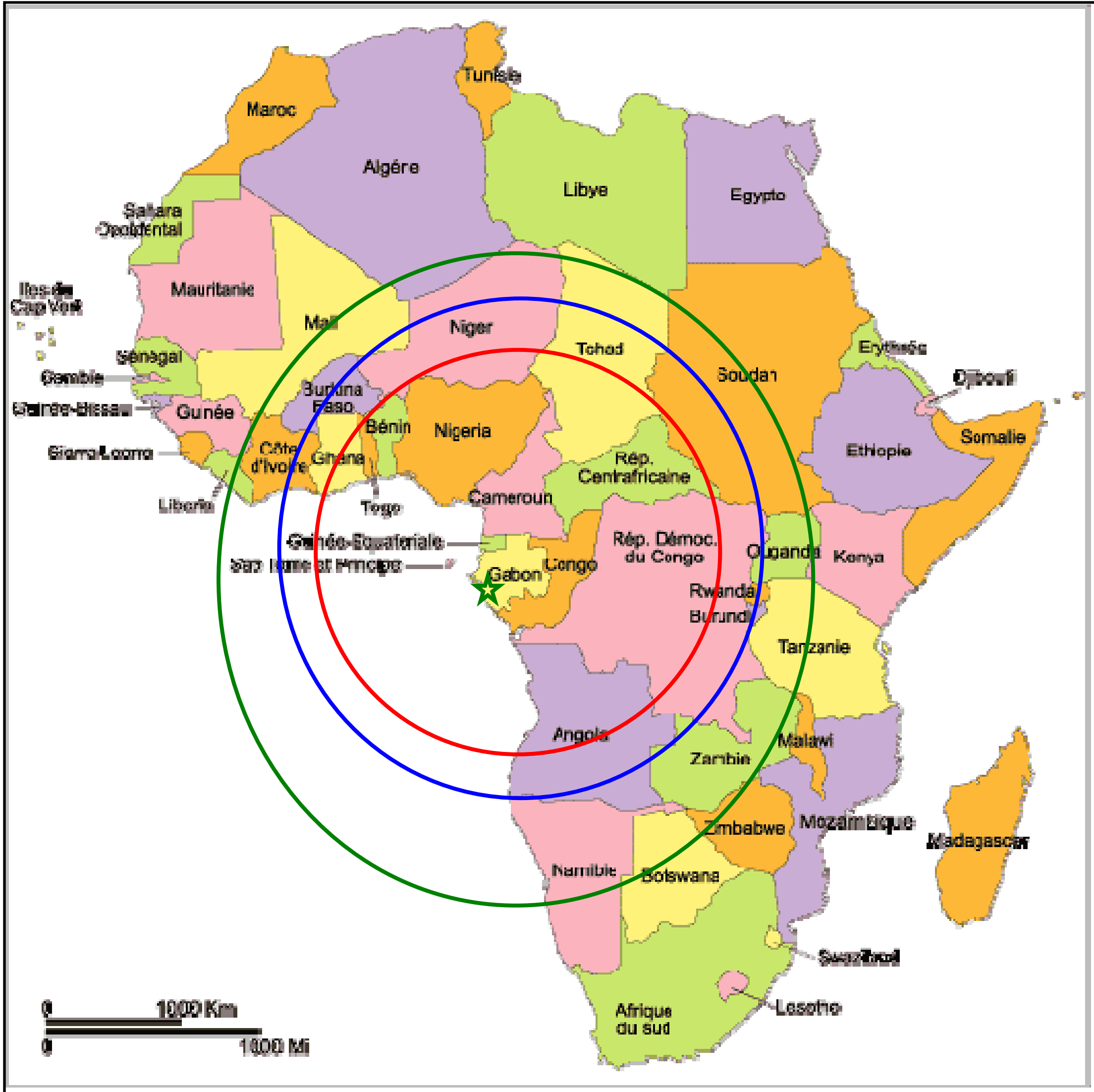
Ce centre aura vocation à:

- Regrouper des équipes de recherche nationale et internationale, des capacités de formation dans le cadre de partenariats public/privé dans le domaine de la forêt notamment.
- Construire des modules de formation qualifiants (à la carte) et intégrés dans les formations diplômantes pour créer un Master international en « Télédétection, Environnement et Forêts Tropicales ».
- Développer et faire vivre des « observatoires de l'environnement par le spatial » au service du développement durable dans le cadre d'une coopération régionale avec les institutions des pays de la zone Afrique centrale.

Dispositif fonctionnel et activités

Implantée à Libreville au Gabon, l'antenne de réception directe fera l'acquisition des images prises par certains satellites lors de leur passage dans sa zone de couverture, soit un cercle d'environ 2 800 km de rayon. Cette zone comprend, outre les états forestiers d'Afrique centrale de la COMIFAC, une partie des pays d'Afrique de l'Ouest et d'Afrique de l'Est (Figure 1).

Cette plate-forme technologique (PFT) de réception multi-satellites permettra d'accéder à une constellation de satellites d'observation de la Terre et d'acquérir des images optiques et radars de la filière CBERS, SPOT, Pléiades, ENVISAT, LANDSAT, Radarsat, ALOS. La PFT et le centre de compétence (CC) régional seront en liaison directe avec les centres de ressources nationaux (CR) installés dans les pays partenaires via le réseau Internet à très haut débit ou un réseau d'antennes secondaires spécifiques.



☆ Plate forme de réception directe des satellites à Libreville

Limite du cercle de réception d'une antenne à 15°

Limite du cercle de réception d'une antenne à 10°

Limite du cercle de réception d'une antenne à 5° (cas nominal)

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La politique d'accès aux données sera basée sur le principe de la « gratuité » conformément aux engagements pris par les Gouvernements Gabonais, Français et Brésilien et dans le but de conforter le pôle d'excellence Gabonais, le rendre attractif tout en favorisant les dynamiques régionales et le renforcement des capacités des pays Africains à disposer de la maîtrise de leurs territoires.

La réception de satellites CBERS s'inscrit dans le cadre d'une politique régionale, menée par le Brésil et la Chine, de distribution gratuite des données à l'ensemble des pays de la zone de réception de l'antenne (programme CBERS4Africa). La France, au travers de l'accord AFD-EADS/Astrium, souhaite que la station SEAS-Gabon puisse intégrer des capacités de réception de la filière SPOT pour assurer la continuité des acquisitions engagées en 2010 pour disposer de données SPOT gratuites dans le cadre de REDD et REDD+ pour l'ensemble des régions forestières couvertes par le cercle de réception de l'antenne du Gabon. Des négociations seront engagées avec d'autres agences spatiales pour définir d'autres modes d'accès aux données d'autres satellites dans le contexte particulier du développement durable des pays du Sud et dans le cadre d'installations à caractère scientifique et technologique (CNES-ESA-GISTDA-JAXA-NASA…) et en fonction des réponses au cahier des charges (Landsat, IRS, ALOS, etc.).

Ces partenariats, qui feront l'objet d'études et négociations spécifiques, permettront de garantir l'accès à d'importantes séries d'images à diverses résolutions pour couvrir les besoins en données, à long terme, pour contribuer durablement à la mise en place d'observatoires de l'environnement pour le développement durable. D'où la nécessité de développer une infrastructure d'accès aux données spatiales au travers d'un portail d'accès via catalogue, sur projets pour optimiser la programmation éventuelle des satellites ou au travers de centres de ressources nationaux (sous réserve de leur mise en place). Ainsi, le projet cherche à développer la coopération régionale dans les domaines prioritaires des pays d'Afrique centrale et à favoriser l'innovation et le transfert de savoir faire et de technologies pour la mise en place de services de suivi et de surveillance du territoire.

Sur le plan scientifique et technique, ce projet s'accompagnera tout d'abord d'un renforcement des équipes locales et proposera rapidement des programmes de formation spécifiques tant nationaux que régionaux. Des programmes régionaux de recherche et d'applications pilotes pourront alors être mis en place ainsi qu'un observatoire de l'environnement et des forêts. Ces programmes couvriront des thématiques telles que la gestion forestière, l'aménagement des territoires, l'agriculture, le suivi du milieu marin et côtier, la surveillance épidémiologique et la gestion des risques. Enfin, cette dynamique de recherche et de formation et l'accès aux données permettront d'actualiser la couverture cartographique multi-thématique nationale et régionale.

Le développement économique en aval de la station sera favorisé par une politique d'innovation (projets de R&D), d'incubation d'entreprises et d'installation d'entreprises privées dans le centre de compétence pour mettre en œuvre des services (observation de la Terre, cartographie, environnement) en appui à la gestion des ressources naturelles et de surveillances environnementales.

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Conclusion

Au travers du projet SEAS Gabon, la coopération tripartite Brésil-France-Gabon offre aux professionnels gabonais l'accès aux technologies et services les plus avancées en termes de suivi forestier, favorisant le développement durable au Gabon dont l'exploration des forêts constitue un point important de sa politique économique. Au Brésil, les images CBERS sont actuellement utilisées par l'INPE dans le cadre de leur programme de suivi du taux annuel de déforestation brut de l'Amazonie Légale (PRODES). De plus, l'INPE s'est engagé à faciliter l'échange d'experts et de scientifiques afin de promouvoir le transfert du savoir-faire technique et scientifique du Brésil. En définitive, l'installation d'une antenne de réception directe des images à Libreville assurera aux pays d'Afrique centrale un accès continu aux données satellitaires de qualité et contribuerait ainsi à une meilleure quantification des stocks et flux de carbone dans les forêts de la sous région. La mise en place de la station SEAS Guyane, en contexte similaire, a permis de réaliser la première mosaïque ortho-rectifiée de la Guyane et de quantifier la contribution de la forêt tropicale française à l'émission des gaz à effet de serre dans le cadre des engagements du protocole de Kyoto.

L'état d'avancement et le calendrier du projet prévoient les échéances suivantes : i) mars 2010 : dépôt du document projet pour le Comité technique du mécanisme de conversion de dette, ii) mai 2010 : finalisation de l'étude de faisabilité et du cahier des charges, iii) mars 2010 à août 2011 : a) mise en place de la plate-forme technologique (antenne et équipements), b) formation des opérateurs et des formateurs et c) construction et équipement du centre de compétence, iv) décembre 2011 : réception directe des images et inauguration du centre de compétence.

The National Institute for Space Research of Brazil (INPE) and Advances in Space to Monitor Tropical Forest / Les données CBERS pour l'Afrique

Claudio Aparecido de Almeida and Alessandra Rodrigues Gomes

INPE (Brazil National Institute for Space Research)

The National Institute for Space Research (INPE) is regarded as a global benchmark in space research and development for the tropical forest regions. Over 21 years, develops monitoring related-project for the Brazilian Amazon, especially the Project for Mapping the Amazon Deforestation (PRODES), Near Real Time Deforestation Detection Project of the Brazilian Amazon (DETER) and Design Detection Wood Extraction and Selective Thinning (DETEX/DEGRAD).

Whereas PRODES (Figure 1) produces on a yearly basis rates of Amazon deforestation based on Landsat and CBERS sensors, DETER (Figure 2) produces deforestation alerts every 15 days CBERS and MODIS data with low resolution also used by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) for monitoring these areas and DETEX/DEGRAD (Figure 3) maps the selective logging and forest degradation after a sequence of digital processing.

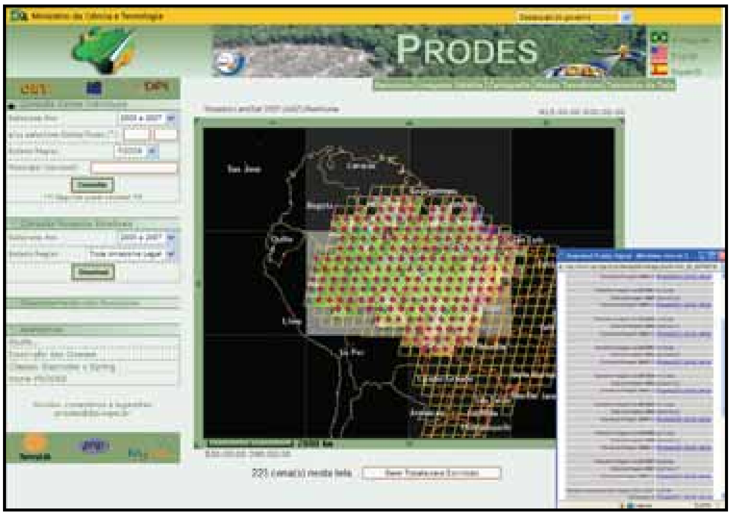

Figure 1. PRODES Project.

Figure 2. DETER Project.

Figure 3. DETEX/ DEGRAD Project.

Furthermore, INPE has missions in the field of earth observation, which include control and reception of signals from different satellites, data distribution, which means knowledge and new possibilities in the space. In the satellite field, we took part in the CEOS virtual constellation with

CBERS, Amazon, Sabia-Mar and GPM-BR. In soil has been developed to control units and systems, reception and distribution of satellite data (Figure 4).

Figure 4.

The free data distribution policy is adopted by INPE since 2004 and by 2008 representing a total of 1 million images produced for different purposes. The areas of space weather, numerical weather prediction, astrophysics, global change, satellite technologies, space technology, geographic information systems and remote sensing also aim to provide access to knowledge through innovative products and services to society.

The Regional Center of the Amazon - INPE

The Brazilian Amazon has more than 5 million square kilometers and by 2008, approximately 700,000 km^2 have already been deforested and were observed by monitoring projects (Figura 5). Currently this monitoring is carried out in São José dos Campos, southeastern Brazil, where the headquarter of INPE is based.

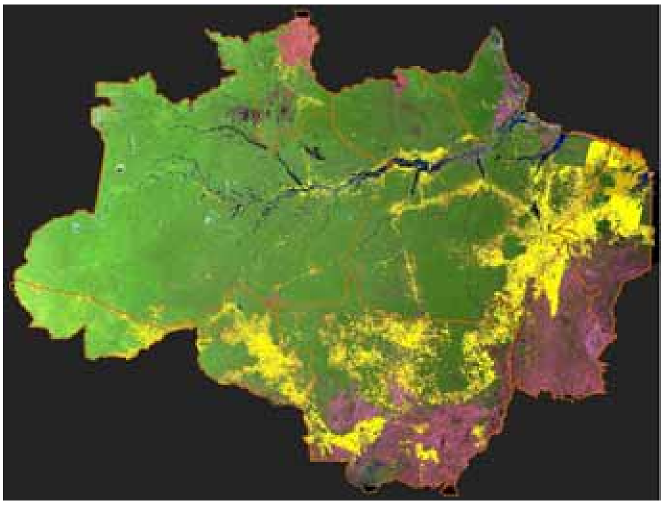

Figure 5. Deforestation in the Brazilian Amazon.

To sort out some logistics related issues such as difficulty in carrying out field work, dissemination of science and technology, and participate more actively in political actions in the region, the Regional Centre was established in the Amazon in Belem, Pará, and North Brazil in a strategic area of the Brazilian Amazon forest.

It is expected to transfer to this center the monitoring projects (PRODES, DETER, DETEX/ DEGRAD) and actively participate in the training of Brazilian technicians who work in state and municipal agencies, and also from other countries to work in tropical forest in their country.

The new facility of INPE will be inaugurated in the second term of 2010 and will have a capable structure of housing more than 40 researchers, 20 fellows and will be equipped with training-room, video conferencing, library and auditorium. This structure will incorporate Guamá Science and Technology Park. Belém being inserted in the local community, as well as taking part in the local people training of the region (Figure 6).

Figure 6. INPE office complex.

CBERS program

Due to the importance of Earth Observation, INPE develops the CBERS program in partnership with the Chinese Academy of Space Technology (CAST), a model of cooperation between nations in the southern hemisphere (South-South Cooperation) for the development and transfer of high technology. The program started off in 1988 and has already launched 3 satellites into orbit and plans a few more satellites and operating for at least another 12 years. The data are freely available via the web to all registered users in Brazil and neighboring countries (Figure 7).

Figure 7. CBERS Satellite.

In 2009 a protocol was signed between Brazilian and Chinese for the free distribution of CBERS images also the entire African continent, a program known as "CBERS for Africa." Due to it, 5 antennas will be installed for receiving data (plus Palomas, Egypt, Malindi, Gabon and South

Africa) that will cover the continent and allow free distribution of images (Figure 8). The African continent has reserves of tropical forests that should be monitored as to their exploitation and CBERS data will assist in this task.

Figure 8. CBERS role in the world.

In addition, training courses are planned in the system developed by Brazil and African countries with technical training required minimum area of computer science and forestry. Thus, each country may conduct its own monitoring and assisting in monitoring and improvements in conditions of occupation of land in their areas.

In fact, INPE uses space technology and enables data acquisition at no charge to them becoming a useful back to society. Thus, each country should be able to monitor their tropical forests, calculate deforestation rates and also enable more advanced studies in the environmental area.

4 SYNTHESIS

Building on the scientific and technical presentations during the conference plenary sessions, four working groups addressed the following themes: 1) monitoring, reporting and verification (MRV) systems in support of REDD, 2) capacity building, information dissemination and data sharing in the sub-region, 3) satellite data requirements and access and 4) estimating forest biomass. The key points and recommendations of each theme are presented below.

4.1 Systems for REDD Monitoring, Reporting and Verification

The break-out group on monitoring, reporting and verification (MRV) in support of REDD discussed a number of issues and assembled a list of recommendations for implementing MRV. The following overview topics were discussed: technical; communication and coordination; and regional capacity continuity, and synergy. The following describes the consensus viewpoint of the break-out group.

Technical issues

A first point concerned the maturity level of various proposed MRV methods. It is important that implementing agencies, as well as funding groups, understand which methods are in the research domain compared to those that are mature enough for operational implementation. At present, all researchers present their methods without regard to operational considerations. This issue also concerns data sources – which data sources, such as imagery, are operationally acquired, processed and made available? A recommendation would be to review the general methods to create an assessment of methodological maturity for the various MRV approaches currently being advocated.

With regards to land use, and land-use change and forestry (LULUCF), five forest-related activities have been identified in the REDD+ context (FCCC/AWGLCA/2009/L.7/Add.6): (i) deforestation, (ii) forest degradation, (iii) conservation, (iv) sustainable management of forests and (v) enhancement of forest carbon stocks. Technical methods for incorporating all 5 activities under REDD+ have not been substantively addressed. This is understandable as REDD+ is a new construct. However, formal assessments of how MRV's will materially address these issues are needed.

The group stressed the need to be able to provide data for REDD+ with known accuracy and uncertainty (a technical ability that currently exists) as required in the IPCC Guidance and Guidelines. Although the IPCC Guidance and Guidelines have not been specifically developed for REDD+, they provide the necessary information on the accuracy and uncertainty information required with certain types of data. Again, this topic needs to be better understood and addressed.

Communication and coordination

The group stressed the need for consiliance across all scales of institutional responsiblity at regional and national scales. For example, the political will at the highest levels must be reflected in the capacity and understanding at the scale of MRV implementation. In other words, national willingness to engage and advance MRV activities must be reflected through clear communication and concrete support at the level of MRV implementation. Political will alone will not lead to action on the ground. Disconnects in this regard will critically limit any proposed MRV.

Mechanisms and forums for transparent communication between and among COMIFAC, national governments, donors, and NGO's are required. For example, the responsible agency for producing activity data for MRV monitoring from each country should be formally identified, with focal points named and involved in periodic reporting duties. Tranparency in the institutional arrangements will facilitate sharing of data and methods, targeting of support activities, and overall improved efficiency of MRV-related activities. Improved regional communication will also benefit REDD+ programs, data sharing programs, accords, etc.

Regional capacity, continuity and synergy

The group believes that central Africa should have an MRV equal to or superior than that of other tropical regions. This will require considerable effort in building capacity and require long term commitments and vision. Given the limited capacity at present, methods that are well-supported and efficient in implementation will be needed. Of particular concern is the continuity and depth of institutional expertise. For example, MRV implementation will require a range of skill sets, from advance degree expertise in MRV methods and adapation, down to technical degree practical experience in forestry mensuration. The depth of skill at all levels is shallow in Central Africa. With a plethora of activities anticipated for the region related to MRV, it is important that institutional capacity be retained and not repeatedly lost due to new sponsored activities by third-parties. Expert continuity will ensure capacity is retained over the long-term as depth in expertise is developed.

Capacity should not improve in a piecemeal fashion at the regional scale. Annual workshops within the region should be held to inform and share MRV implementation expertise. As it is known that regional integration will afford methodological efficiencies, it is important that all responsible institutions grow in capability together. MRV implementation plans that emphasize regional synergies are advocated.

Translating technical methods for in-region implementation will be a challenge. Whether national agencies or NGO's, advanced computing hardware and software requirements will need to be installed and maintained, as will any proposed in situ measurement infrastructure. Additionally, costs for various methods are highly variable, and the long-term costs of any recommended MRV must be considered.

In summary, the MRV breakout group recognized the need for operational methods that are efficient and able to be implemented over the long-term. To achieve this, improved regional and national communication, coordination and synergy must be promoted. By doing so, an improved use of resources for building capacity and ensuring long-term continuity may be achieved.

4.2 Regional Networks for Data Dissemination and Capacity Building

The working group assessed the main challenges and obstacles to data sharing, information dissemination and capacity building in the central Africa sub-region. Salient points were summarized into short term actions and medium term recommendations to be implemented under the leadership of COMIFAC.

A generalized synthesis of the discussions on capacity-building, networking and data management is provided below.

Capacity building

The need was identified for capacity building in national structures/institutions based on clearly defined themes and as a part of a monitoring and evaluation system of forest information use. Initiatives will require the identification of relevant beneficiary ministries and individuals within those ministries such as Forest and Environment Ministries as recipients of capacity-building inputs. There is also a need to facilitate capacity building; information, exchange, training, etc, of community levels stakeholders regarding Carbon concepts. As well, university curriculums should be strengthened in relation to current knowledge contexts of forest carbon in relation to climate change.

COMIFAC should sponsor the forest networks to carry-out a competence, dynamic needs assessment (current situations at each point in time), against a check-list of requirements, then develop a strategy for filling the gaps, relevant to the identified needs and capacities. From this, an overview inventory could be prepared of service providers/trainers to meet the identified needs for capacity building in the different areas of assessing forest carbon. The information on training opportunities should then be made available to potential users, such as students and the general public requiring training and other forms of support (e.g. scholarships..). Once training activities are underway, the following should be considered:

- Ensure that means are put at the disposal of institutions receiving training to enable them use skills acquired through training (e.g., making available freeware to potential users as a starting point.
- Ensure formalization of skills development (e.g. certificate training) and seek ways which encourage human resources to stay-on. Develop strategies to sustain capacity within institutions once developed, in other to address leakages once these occur within institutions.
- Encourage skills development to reflect other dimensions of forest measurements beyond carbon.

Human resources and network strengthening

There is an opportunity for linking and learning lessons from existing networks. Actions could include identifying existing networks, analyzing their functioning and evaluating the need for strengthening. For instance, if there are projects that can be linked to the network in order to better evaluate strengths, weaknesses and opportunities.

A related topic discussed was how do regional efforts at networking between projects, benefit, link to and relate to higher level networks (e.g. global networks) or other networks? How do regional networks communicate (e.g. by publishing their metadata on websites) learning from existing networks (e.g. www.afritron.org, biodiversity network of Madagascar). It was recognized that there is need to consider a data sharing (policy), guidelines and codes of conduct, within and between networks

Data type, quality, availability and harmonization

There is a need for a common understanding of carbon quantification methods in the region. Issues include: harmonization of datasets across countries; format, completeness standards, collection methods, gap analyses, structuring, uniformization, etc (refer to MRV Working group). Common definitions would also be helpful for data needs and types across countries, availability and needs for quality control.

An agreed suggestion is to establish a credible system of data validation and standardization (e.g., 'creative commons' license-OFAC; refer also to OFAC user-friendly procedures for validation), to include meta data standards; rights, methods used, limits to accuracy, error margin, protection, etc. Incorporation of questions of property rights in data collection protocols, dissemination strategies was also discussed.

Depending on data type (e.g. satellite, allometric data, inventory, socio-economic data, infrastructure, forest cover change), there is a need to determine what type of organizations can manage and have responsibility for dissemination.

The following are the key actions, to be carried out under the leadership of COMIFAC, needed to overcome the challenges and obstacles to data sharing, information dissemination and capacity building:

Short-term (12-18 months) action points under the leadership of COMIFAC:

- Facilitate quantitative/qualitative needs assessment (based on current situation of regional capacity), per country/geographic site, against a check-list of pre-established requirements.
- Ensure synthesis of regional capacity needs assessment and develop roadmap for meeting them.
- Prepare an overview and inventory of service providers in the domain of carbon quantification.
- Evaluate role that existing networks (such as RIFFEAC) can play in carrying out some of these tasks.
- Ensure the sharing of information presented and generated by regional workshops (such as the proceedings of current conference, State of Forest report, etc..) in the most effective and efficient way possible, at national levels, through both electronic media and appropriate public forums.
- Help re-enforce mechanisms for uptake of recommendations of conference by relevant State structures, via the COMIFAC country focal points while ensuring that all other mechanisms and entry-points into government are fully served.
- Analyze the organizational structure of relevant national ministries and departments, including COMIFAC focal points and network members, to ensure better alignment of capacity-building support initiatives with national priorities.

Recommended medium-term actions (2-3 years) under the leadership of COMIFAC:

- COMIFAC should ensure centralization of regional data and later-on assume responsibility for its dissemination, working as a Clearing House Mechanism.
- OFAC should be officially integrated into the functional structure of COMIFAC as a technical direction and operational department.
- GOFC-GOLD should strengthen and extend its support to COMIFAC countries by providing regular and updated satellite datasets through focal persons of the OSFAC network.
- Mechanism and support should be sought to improve internet connectivity within/between the COMIFAC countries for information sharing and dissemination.
- The capacity of existing national and regional networks needs to be evaluated to help them maintain a comprehensive meta data system.
- OFAC and OSFAC should seek ways through which to strengthen the capacity of national institutions in information and data dissemination.

4.3 Satellite Data Requirements and Access

Problem identification

There are a number of constraints to satellite monitoring of the forests of Central Africa:

- There has been very poor data acquisition for the Congo Basin. This is primarily due to: (1) a lack of ground receiving station in Central Africa; (2) lack of full acquisition over

Central Africa by currently operating satellites; and (3) low demand (due to prohibitive costs) for commercial satellite images for Central Africa which has led to low levels of acquisition by these satellites over the region.

- Access to or diffusion of the available imagery and derived products remains a major challenge. Major obstacles affecting access to imagery/derived products include: (1) low internet bandwidth; (2) lack of an effective distribution network; (3) high cost of commercial data 3) data policies which prohibit data sharing, 4) lack of awareness and information as to what is available and how to access the data.
- Application of available imagery to the subject of forest monitoring is rendered difficult by: (1) insufficient coverage from optical systems that suffer from consistent and significant cloud cover in many areas of the Congo Basin; (2) lack of availability of current software to analyze the data and data formats which vary considerably and can be incompatible with available software, (3) the learning curve for routine use of microwave data is steep – few products – little use to-date; (4) very few trained remote sensing professionals in the region; (5) very few applicable derived products and/or "ready to use" satellite imagery (i.e. processed to a level of usability without advanced training in RS).

Current activities / Short term solutions (<3 years)

The current and near-term availability of imagery for Congo Basin is summarized by satellite sensor in Table 1 (derived from conference presentations 37-42, Appendix 3). There are some activities which are either underway or planned for the near term to partially address the image availability issues listed above, notably:

1. Current Data Initiative. NASA/USGS have provided the Landsat GLS (orthorectified) data sets for the Congo Basin, using the best available date for 2000, 2005 and is in the process of developing 2010. This included a special arrangement with the University of Rome and ESA to activate the Malindi Ground Station for periodic campaigns to increase the acquisitions for the eastern part of the Basin. These data are freely available to all.
2. Current Data Initiative. Through the USAID-CARPE program, the acquisition of high resolution data from Landsat 7 and ASTER have been increased. The Landsat data have been made broadly available through OSFAC (http://osfac.net/). The ASTER data are available to CARPE and its Partner Programs.
3. Current Data Initiative. ESA is currently sponsoring full Basin coverage of data from the DMCii satellite. Currently data use is restricted to EU FP 7 projects. DMC are Seeking more funding to make this dataset freely available.
4. Recent and Current Data Initiatives. Recent forest cover and change maps for the Cong Basin derived from satellite data have been developed by UCL http://ionia1.esrin.esa.int/index.asp http://www.observatoire-comifac.net/docs/confCOMIFACcarbon/Jour1/Defourny_OFAC_Forest cover change_v2.pdf; and SDSU (http://www.observatoire-comifac.net/docs/confCOMIFACcarbon/Jour1/Hansen_deforestation.pdf) which is available at http://carpe.umd.edu/resources/map-library/. Tabulated estimates of Forest Cover and Change are being made available routinely through the Congo Forest Partners, State of the Forest report (http://carpe.umd.edu/resources/sof/)
5. Data acquisition for Central Africa. If realized, the Libreville ground receiving station (under an agreement between the governments of France, Gabon and Brazil) has the potential to substantially increase the capture of imagery for Central Africa from multiple moderate resolution satellites. As it stands, the Libreville ground receiving

station is primarily for Gabon, but discussions are underway to make data acquired through this downlink available for the Congo Basin region. CBERS data is set to increase for the region in the near future with launch of CBERS 3 and downlink to ground receiving station (planned).

6. Access to data or derived products. Both WRI and OSFAC have carried out coordinated, efforts to distribute available satellite imagery (Landsat, ASTER and ALOS) and some derived products to collaborators across the region. To date, this has mostly been done via CDs and hard drive transfers – thus labor intensive. OSFAC has plans to strengthen its regional capacity and increase imagery and derived products dissemination. Landsat archive is now open, greatly increasing access to this dataset, however, low internet bandwidth restricts direct image downloads from Central Africa. GEO has plans to support image and derived product dissemination for areas within in its National Demonstrator countries in the near future (GEOnetcast). The Libreville ground receiving station plans to put in place a more systematic means by which collaborators will be able to access multi-source images coming through their network – though the exact means by which this will occur remain to be defined.

7. Application of available imagery to the subject of forest monitoring. Limited training events have occurred in the region – notably by OSFAC, SDSU, ERAIFT and FAO FRA. Several nationals from Central Africa region have recently or are currently pursuing advanced RS degrees in Europe and USA. Overall though, regional RS capacity remains low. A number of derived products have been developed by SDSU, JRC, UMD and efforts are underway by these institutions and others (e.g. OSFAC, ALOS-PALSAR regional mosaic) to increase the amount and availability of these products. Radar has been applied to forest monitoring in Central Africa on several occasions (e.g. Saatchi/Lewis, WHRC), but remains mostly at an academic research level with little to no broad application within the region. Access to Erdas Imagine software has been facilitated by WRI to technical departments of Ministries of Forestry across the region, but the number of posts with these licenses remains far from adequate at present.

However, these efforts remain largely inadequate to meet demand for satellite based monitoring. Compared to other tropical regions, Central Africa is severely underserved with data and capacity to use RS data is lagging behind.

Table 1. Comments on current and near-term availability of imagery for Congo Basin.

General category	Sensor(s)	Notes/Comments from Group
Optical – High resolution (≤ 5m)	Geoeye; Quickbird; Ikonos; Digital Globe; DMC (2.5m), others	Generally, need to push harder as a community to have images purchased and made available to others. GEO will be coordinating acquisition of some of these images over their National Demonstrator sites. Could push for this under a REDD funding mechanism for key sites.
Optical – Moderate resolution (10-50m)	Landsat	• Landsat 5: direct acquisition only, people are still using it. Only station in this region is Malindi. Lifespan is extremely limited and radiometric issues exist. Lack of receiving station limits data acquisition. • Landsat 7: SLC off issue remains and hampers its application. Currently, not getting complete Landsat acquisition which is problematic. • Archive currently open and free. Data access is unrestricted and use has greatly increased. • LDCM OLI will have thermal sensor on same platform, online expected in 2012
	ALOS AVNIR	• More publications coming out of AVNIR (10m) /Prism (2.5) data • Data policy is restrictive but Congo Basin forest monitoring institutions could potentially access this archive for free through collaborating research institutes in Europe/USA (e.g. via PIs)
	DMCii	• 2 more satellites launch this year (22m) ; adds to 32m already available • Similar filters to Landsat (2, 3, 4) but no SWIR. • Large swath acquisition (650km) • Store and forward data collection methods. Could participate in direct downlink (e.g. Libreville receiving station) to consistently cover the region. • Hoping to get a more or less cloud free mosaic over sub-Saharan Africa with EC/ESA in near term. Would like to have enough funding to make this dataset freely available. ESA expected to extend their funding and thus this data would become freely available
	CBERS	• Currently with CBERS 2B, 2.5m. • CBERS 3 will be launched in 2011, will have one 5m sensor, one 20m sensor, one 60m sensor (wide scan) • Open access to CBERS for Africa but needs ground station downlink. Congo Basin cannot have access

General category	Sensor(s)	Notes/Comments from Group
		without receiving station. • In Brazil, using CBERS for forest monitoring, works fine. Current use of CBERS in Africa To be determined • Onboard energy supply issue with CBERS 2
	SPOT	• Spot 4 no longer commercial, data archive will be made available soon through ESA. GEO will take action to get this data. Data distribution modalities to be determined. • Spot 5 remains commercial. Lifespan is through 2015. • Spot 6 will have same characteristics of Spot 5 and set to launch in 2013 • Spot announcement to provide complete Congo Basin Coverage for REDD studies – details on data availability and sharing remain TBD.
	ASTER-SWIR	• Global coverage over 2-3 year period • NASA PIs and their partner projects/programs can get free access to limited amount of data through request • 1.6 channel no longer working • No replacement foreseen (thermal capability on NASA HySpIri) • For data capture need to formally request turning on over region of interest (being done by UMd/CARPE) • DEM freely available through GEO, USGS, etc. Could high grade this and make available through OSFAC or other network.
Radar/Microwave	Radarsat	• Disseminated by commercial entity, broader access to archive needs to be negotiated with Canadian Government • Restrictions on its use
	ASAR (Envisat)	Access is through demand (proposal) only, if accepted, this data can be shared within project partners/collaborators
	ALOS PALSAR	• Japanese have released recently for Central Africa Wall to Wall Palsar coverage (50m) for 2007-09 – this data is freely available to the public through their website. • Dedicated data continuity with ALOS 2
	TerraX	• German, high res (1m; X band) • Commercial, negotiate with DLR (?)

General category	Sensor(s)	Notes/Comments from Group
	CosmosSkymed	• Constellation of 3 satellites • Commercial, negotiate through Italian Space Agency • Trying to get it available through GEO for National Demonstrators
	General situation	• Microwave Data continuity looks good overall • Need to focus better on access and dissemination of higher order products of known accuracy • A regional development and training unit is needed for generating microwave derived products for Central Africa • Long Term we would Advocate open access to the higher resolution data
Derived products	Current	• Land Cover / vegetation type • Forest cover change • % tree cover • Coarse biophysical variables LAI, fire, burned area • Biomass
	Future	• Land use (1m) • Vegetation structure and height

Recommendations

Near Term (executing agency in parentheses)

- Open up SPOT (ESA, CNES) and ASTER (Miti, USGS) archives for the Congo Basin for free and open access.
- Landsat 7 – request full (every scene) acquisition over the Congo Basin (USGS).
- Continue producing ALOS-PALSAR mosaic through 2010-11 (JAXA).
- DMC to acquire and make freely available to Congo Basin partners an annual wall to wall compilation (including 2010, 2011) (ESA, CBFF).
- SPOT Congo Basin Coverage Announcement – welcomed but should minimize obstacles to access (licensing) giving free and open access for forest monitoring (CNES).
- GEONETCAST to be tested for moderate resolution data dissemination capability (GEO Sec, NOAA, Eumetsat, OSFAC).
- Support a center of excellence and training for remote sensing capacity in general and microwave applications in particular (REDD readiness – UN REDD/GEO).
- Test use of high resolution data for REDD applications in Central Africa (commercial vendors/GEO ND and FCT task).
- An ad-hoc technical working group is needed on Central Africa satellite data acquisition and availability for the next 3-5 years - i.e. this study expanded in the context of forest and carbon monitoring (COMIFAC/CBFP/OSFAC technical sub group).

Mid Term (3 – 5 years)

- Standardized products (pre-processing) and derived products (validated products) e.g. LDCM, Sentinel 2 - CEOS / GEO.
- Gabon (Libreville) Ground Station – multisource satellite acquisition for the Basin. Free and open access to the data. Data distribution approaches to overcome limited internet bandwidth. Put in place a mechanism (e.g. an advisory board) for ensuring regional objectives of the ground station meet the regional user needs (DFID, France, Gabon, Brazil).
- Increase level of coordination for data continuity and moderate and high data acquisition (GEO, CEOS).
- An Open Data Policy needs to be elaborated and put in place for the GEOSS (GEO).
- There is need for a coordinated international moderate resolution acquisition strategy – to bring the Congo Basin under continuous observation.

4.4 Advances in Estimating Forest Biomass

Problem identification

The absence of known allometric relations for timber from Central Africa (including large diameter trees and root fraction) is a major difficulty for estimating forest biomass stocks. These gaps are partly due to the fact that the acquisition of data is traditionally difficult to finance and a lack of interest by donors for this type of study with low immediate return. What little data are available are often not shared due to problems associated with ownership and lack of protocol for data sharing.

This situation may be improved through REDD as there is increased awareness of the need for field data to better determine carbon stocks. Rules for data sharing are being developed including implementation of a creative commons licensing.

The working group noted that efforts to centralize data on allometric relations for Central African timber are underway. Initiatives by AfriTRON (http://www.geog.leeds.ac.uk/projects/afritron/) and OFAC (http://www.observatoire-comifac.net/?l=en) are making metadata for forest inventory data available centrally. Work carried out by Forêt Ressources Management (FRM) and COFORCHANGE (http://www.coforchange.eu/) have used existing forestry inventory data to make preliminary estimates of forest carbon stocks.

The group also noted efforts underway to: calibrate remote sensing and biomass data (see studies conducted by Sassan Saatchi, Simon Lewis et al., presentation no. 22), combine optical and radar data (Laporte et al. presentation no. 25), and use LiDAR (ICESat / GLASS) data to determine the textural properties of optical data metric resolution (Barbier et al., presentation no. 24).

5 CONCLUSIONS AND RECOMMENDATIONS

Building on the scientific and technical presentations and synthesis discussions during the conference, four thematic areas of importance emerged: 1) monitoring, reporting and verification (MRV) systems in support of REDD, 2) capacity building, information dissemination and data sharing in the sub-region, 3) satellite data requirements and access and 4) estimating forest biomass. The key points and recommendations of each theme are presented below.

5.1 Development of MRV Systems in Support of REDD

National GHG emissions directly related to land use and land cover change can be estimated using satellite-derived land cover and land use change maps, in combination with in-situ measurements derived from activities such as national forest inventories. To be useful, such field measurements should include the five carbon pools of above and below ground biomass, dead wood, and organic matter in litter and soil.

The conference highlighted the need for a harmonized approach to regional REDD+ activities. To be successful it was agreed that: REDD+ activities should comply with UNFCCC guidelines; MRV systems should be integrated into national policies and legislation; countries should be able to carry out MRV independently; and countries should integrate the "safeguards" embedded in the text of the UNFCCC agreement on long-term cooperative action.

There is need to establish a roadmap for MRV projects across the sub-region under COMIFAC. The roadmap should be undertaken in partnership with national institutions in charge of MRV, with the support of the UN-REDD-DRC pilot.

Conference recommendations derived from the synthesis discussions in section 4.1 on MRV include:

- A formal assessment should be conducted on how MRVs will address the five forest–related activities (deforestation, forest degradation, conservation, sustainable management and enhancement of carbon stocks) identified in REDD+.
- There needs to be a clear distinction between the MRV methods, and data sources that are, or can be, operational and those that require further research.
- Data provided for REDD+ activities should be presented with known accuracy and uncertainty.
- Political commitment to engage and advance MRV activities must be reconciled at all levels through clear communication and concrete support at the implementation level. Mechanisms and forums for transparent communication between and among COMIFAC, national governments, donors, and NGO's are required.
- Central Africa should have an MRV system equal to or superior to those of other tropical regions. This will require considerable effort in building capacity and require long term commitments and vision.
- MRV related activities should foster and not erode the depth and continuity of institutional expertise.

5.2 Building Capacity, Sharing Data and Disseminating Information

The conference identified the need to compile a regional inventory of training courses and service providers in the areas of remote sensing, land cover, forest biomass assessment and carbon quantification. Such courses could well serve the REDD process. The OFAC and OSFAC are well suited to compile such an inventory on behalf of COMIFAC and RIFFEAC.

The conference identified a detailed list of both short term and medium term recommendations in Section 4.2. Key recommendations include:

- Facilitate quantitative/qualitative needs assessment (based on current situation of regional capacity), per country/geographic site, against a check-list of pre-established requirements.
- Prepare an overview and inventory of service providers in the domain of carbon quantification.
- Ensure the sharing of information presented and generated by regional workshops (such as the proceedings of current conference, State of Forest report, etc..) in the most effective and efficient way possible, at national levels, through both electronic media and appropriate public forums. COMIFAC should ensure centralization of regional data and later-on assume responsibility for its dissemination, working as a Clearing House Mechanism.
- OFAC and OSFAC should seek ways to strengthen the capacity of national institutions in information and data dissemination.

5.3 Improving Access to Satellite Data

Satellite data access for the Congo Basin is limited by data acquisition strategies, distribution policies and cost structures, and inadequate infrastructure for data dissemination. Efforts to improve the situation were noted: a satellite receiving station is scheduled to become operational Libreville in the next 2 years. The team responsible for establishing the receiving station is well aware of the technical requirements to transfer data from Gabon to other countries. Proper mechanisms for data transfer and sharing will be critical for successful functioning of the regional receiving station. This is an important issue to be addressed. In addition (i) DMCii coverage for Central Africa is being finalized for 2010, (ii) France announced the availability of free SPOT satellite images for REDD+ activities in the Congo Basin, (iii) CBERS data will be made freely available to users in Central Africa and (iv) two blanket coverages of ALOS PALSAR data have been made available to the scientific community and this coverage may be extended with data from AVNIR2 and PRISM.

Most radar images and very high resolution optical images are expensive and need to be available at lower cost to be widely used. GEO intends to negotiate with data providers to lower the cost of images with very high spatial resolution.

Accessibility (both physical and in terms of distribution policy) and the local capacity to process the images are considered the main impediments to optimal use of remote sensing technology. Despite recent efforts in training and improving the dissemination of data undertaken by different entities (e.g., OSFAC, OFAC, WRI, WWF, WCS), demand for geographic information from satellite imagery is widely unsatisfied. Currently, partnerships with international teams for the processing of satellite imagery is the best option to guarantee sufficient information quality for REDD monitoring activities which incorporate remote sensing.

Networks for sharing satellite data should be strengthened. The roles of OSFAC, OFAC, GOFC-GOLD and GEO should be clarified; national centers, network nodes should be strengthened as well as the link to COMIFAC. Data and information should be shared through the OSFAC and FAO FRA (Forest Resources Assessment) focal points. An updated list of focal points will be established by OSFAC.

Strategies and means of disseminating information to end users must be reconsidered. The network should include a data committee comprised of national focal points whose purpose, among other things, is to facilitate the smooth flow of data and images to end users.

The conference identified a detailed list of both short term and medium term recommendations in Section 4.3. Key recommendations include:

- An ad-hoc technical working group on Central Africa satellite data acquisition and availability in the context of forest and carbon monitoring, is needed for the next 3-5 years.
- There is need for a coordinated international moderate resolution acquisition strategy to bring the Congo Basin under continuous observation. For example, Landsat 7 acquisitions should be increased. High resolution data should be tested for REDD applications in Central Africa.
- Open data policies need to be encouraged and put in place, e.g., for SPOT, ASTER and DMCii data. An open data policy should be established for the proposed satellite data ground receiving station in Gabon.
- The dissemination of standardized (pre-processed) and derived products would facilitate the use of the data. Mechanisms for data dissemination to and within the region must be established, e.g., GEONETcast should be tested for this purpose.
- A center of excellence and training for remote sensing capacity in general and microwave applications in particular should be supported.

5.4 Challenges of Estimating Forest Biomass

The absence of known allometric relations for timber from Central Africa (including large diameter trees and root fraction) presents a major difficulty for estimating forest biomass stocks. These gaps are partly due to the fact that the acquisition of data is traditionally difficult to finance and not usually acquired even where national forest inventories are in place. What little data are available are often not shared and difficult to compare due to differing collection protocols.

This situation may be improved through a REDD mechanism as there is as explicit requirement for field data to determine carbon stocks. The conference also noted efforts underway to calibrate remote sensing and biomass data, and to combine optical, radar and Lidar data.

Recommendations derived from the working group on biomass estimation (section 4.4) include:

- Efforts be made to harmonize protocols for estimating the carbon content in different compartments (aboveground biomass, belowground biomass, litter, dead wood, soil organic carbon).
- Conduct a census of relevant data and a review of existing work, to develop an overview of existing allometric relations, a spatial metadata assessment of studies on carbon stocks and permanent stands and inventories.
- Legal mechanisms be explored for the sharing of data.
- Further research be undertaken on calibrating biomass estimates from remote sensing and field data. A preliminary synthesis of the existing methods and comparison of existing maps should be produced.
- A network of permanent plots be established in the region for REDD.

5.5 Other Key Points

REDD project inventory

OFAC has initiated an ongoing inventory of REDD projects and projects related to the quantification of stocks and flows of carbon (presentation 7). The inventory aims to enable users to share experiences and information on methods used and data collected. Results are available on the OFAC website. This initiative will compliment the work of national REDD coordinators.

The majority of initiatives and projects focussing on REDD and the quantification of forest carbon have specific websites. It was recommended that OFAC establish a web portal with links to these initiatives.

Ministries and administrations in charge of forests have been requested to produce a chart of contact persons for REDD.

Scientific committee

The conference recommended that a scientific committee be established as part of COMIFAC, to oversee the various components of REDD. The committee should be composed of international and regional experts who will monitor studies and REDD projects taking place in Central Africa. The committee would also act as an advisory body to the country focal points and an important interlocutor through COMIFAC to the international community.

Organizational matters

Clarification is needed regarding roles of OSFAC (Observatoire Satellital des Forêts d'Afrique Centrale) and OFAC (Observatoire des Forêts d'Afrique Centrale). This is partly due to the similarity of acronyms. For clarification, the roles are restated here as follows:

- OSFAC is mandated to (i) make available (free or under certain conditions) satellite images to any user who so requests, (ii) provide training in remote sensing and geographic information science, and iii) provide satellite derived forest cover and forest cover change products.
- OFAC is mandated to establish a database in order to provide information on forest cover change, monitoring the recovery of biodiversity and monitoring the economic value of forests. It also coordinates the publication of the State of the Forests reports.

6 APPENDICES

Appendix 1. Conference Participants

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Appendix 2. Conference Agenda

2 February 2010

Opening: Monitoring Carbon Stocks and Fluxes in the Congo Basin		
9:15 – 9:22	Welcome and introduction	Martin Tadoum COMIFAC Secretary
9:23 – 9:28	Opening Speech	Principal Private Secretary of the Sustainable Development Ministry, Republic of Congo
BREAK		
9 :34 – 9 :39	Carbon budget challenges and opportunities for EU	Emilie Wattelier (EU)
9 :40 – 9 :55	Carbon budget challenges and opportunities for CARPE	John Flynn (USAID)
9 :56 – 10 :11	Common ground for research and conference objectives	Philippe Mayaux (JRC), Chris Justice (UMD)
10 :12 – 10 :30	REDD Post-Copenhagen perspectives for Central Africa countries	Raymond Lumbuenamo (WWF)
BREAK		
11:09 – 11:20	REDD technical requirements	Phillipe Mayaux
Carbon and REDD		
11:21 – 11:39	Carbon and Land Cover Change in Central Africa	Robert Nasi (CIFOR)
11:40 – 11:59	Methodological aspects for forest area change assessment through remote sensing, REDD	Danielo Mollicone, FAO GOFC-GOLD
11:59 – 12:12	Overview of REDD projects/ carbon quantification in Central Africa - Survey Results	Carlos DeWasseige, FORAF
12:12 – 12:25	UN – REDD in Democratic Republic of the Congo	Bruno Guay (ONFi)
12:26 – 12:48	Q/A session	
BREAK		
Forest and Land Cover Monitoring		
2 :08 – 2 :22	The FRA Remote Sensing Survey: Global context	Erik Linquist (FAO)
2 :23 – 2 :47	Observatory of Central African Forests: National and Regional Estimate of Forest Cover and Change	Pierre Defourny and C. Ernst (UCL)
2 :48 – 3 :06	Results and validation tools for FRA	Bruno Nkoumakalo, Christophe Musampa
3 :07 – 3 :24	Quantitative analysis of deforestation and degradation drivers in D.R. Congo	Pierre Defourny and Céline Delhage (UCL)

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BREAK		
4:34 – 5:41	Land cover and deforestation mapping in Central Africa	Matt Hansen (SDSU)
	Description of methods and results	Erik Lindquist (SDSU)
	Next Steps: Advanced methods	Mark Broich (SDSU)
	Mapping Wetland Extent Conservation land Use Planning Interactions Between Hydrology and Carbon Stocks and Fluxes	Jean-Robert Bwangoy (SDSU) Janet Nackoney (UMD) Yolande Munzimi (SDSU)
	Transition to a regional mapping initiative: OSFAC	Landing Mane (OSFAC)
	Q/A session	

3 February 2010

Methods and Projects		
8 :40 – 9 :05	The GEO Forest Carbon Tracking (FCT) Task	Giovanni Rum (GEO Secretary)
9 :05 – 9 :25	National Demonstration in the GEO FCT Task	Michael Brady (Natural Resources Canada and GOFC-GOLD)
9 :25 – 9 :45	Mapping and Monitoring Carbon in Gabon Forests	Simon Lewis (University of Leeds) & Sassan Saatchi (NASA)
9 :45 – 10 :00	Canopy Textural Properties from Metric Resolution Imagery	Barbier Nicolas (IRD-ULB/FNRS)
10 :00 – 10 :20	Biomass and Carbon Mapping in Central Africa using Remote Sensing and Forest Inventories	Nadine Laporte & Andréana Mekui Biyogo (WHRC)
BREAK		
11 :05 – 11 :25	REDD Project in Cameroon	Thomas Haeusler (GAF)
11 :25 – 11 :45	REDD MRV System Development in D.R. Congo	Danae Maniatis (FAO)
11 :45 – 11 :55	Canopy (Aerial) Carbon Stocks Measurement in Congo Basin Forest	Jean Remy Makana (WCS)
11 :55 – 12 :05	Evaluating the Effects of Reduced Impact Logging on Forest Carbon	Vincent Medjibe (WCS)
12 :05 – 12 :25	Carbon Stock Estimation in Forest Concessions	Nicolas Bayol (FRM)
12 :25 – 13 :00	Q/A sessions	
Projects and Other Environmental Services		
2 :10 – 2 :20	The Congo Basin Forest Fund (CBFF)	Pierre Nguinda (BAD)
2 :20 – 2 :30	Carbon and Agroforestry in Cameroon	Denis Sonwa (CIFOR)
2 :30 – 2 :37	Forest Carbon Sinks in Ibi Bateke	Olivier Mushiete (NOVACEL)
2:37 – 2:53	REDD Carbon Project in Rep. of Congo	Georges Boudzanga (MDDEFE) & Fred Stolle (WRI)

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2 :54 – 3 :08	Impact of Global Change on the Forest Biodiversity of the Congo Basin	Sylvie Gourlet-Fleury (CIRAD)
3 :08 – 3 :19	Land Use Planning in the MLW-Landscape and its Potential for Carbon Credits	Jeff Dupain (AWF)
3:19 – 3:29	Land Use Dynamics and Population Distribution: Case Study of the Democratic Republic of the Congo	Jean-Paul Kibambe & Pierre Defourny (UCL)
3 :30 – 3 :55	Q/A sessions	
BREAK		
Satellite Data and Regional Acquisition		
4 :25 – 4 :40	Satellite Data Access	Landing Mane (OSFAC), Michael Brady (NRCan)
4 :40 – 4 :53	Pan Tropical Biomass Mapping in Support of Forest Monitoring	Nadine Laporte (WHRC)
4 :54 – 5 :10	DMCii Global Forest Services	Paul Stephens (DMCii)
5 :10 – 5 :15	Provision of SPOT Data for Forest Cover Analysis in the Congo Basin	Corentin Mercier (AFD)
5 :15 – 5 :31	An Earth Observation Ground Station and Research Laboratory for Long Term Monitoring, Libreville, Gabon	Jean Marie Fotsing (IRD)
BREAK		
5:31 – 5:40	CBERS Data for Earth Observation in Africa	Claudia Almeida (INPE)
5 :40 – 6 :00	Q/A session	
6 :00 – 6 :10	Working groups Introduction	Chris Justice (UMD)

4 February 2010

Working Group Parallel Sessions		
8 :30 – 11:00	Working group sessions: 1) Coordination and information dissemination of REDD activities in the region 2) Regional networks and capacity building 3) Satellite data and receiving stations in the region 4) Biomass and Carbon stock estimation	
11 :30 – 12 :30	Continued work in four working groups	
BREAK		
1 :30 – 2 :30	Plenary: working group summary presentations	
Synthesis, Perspectives and Conclusions		
2 :30 – 3 :15	Panel session: perspectives, priorities, strategies and future steps	John Flynn (USAID), Raymond Lumbuenamo (WWF), Danillo Molicone (FAO), Guillaume Ernst
3 :30 – 4 :00	Synthesis and summary of actions	Philippe Mayaux (JRC)
4 :00 – 4 :53	Concluding statement from COMIFAC and close	Martin Tadoum (COMIFAC)

Appendix 3. List of Presentations

The presentations listed below are available at: http://www.observatoire-comifac.net/carbonCconfBrazza.php and http://osfac.net/workshop/presentations.html

No.	Title	Author
1	Carbon budget challenges and opportunities for EU	Emilie Wattelier
2	Conference objectives	Chris Justice/Phillipe Mayaux
3	REDD Post-Copenhagen perspectives for Central Africa countries	Raymond Lumbuenamo
4	REDD technical requirements	Phillipe Mayaux
5	Carbon and Land Cover Change in Central Africa	Robert Nasi
6	Methodological aspects for forest area change assessment through remote sensing, REDD	Danielo Mollicone
7	Overview of REDD projects/ carbon quantification in Central Africa - Survey Results	Carlos de Wasseige
8	UN – REDD in Dem. Republic of the Congo	Bruno Guay
9	The FRA Remote Sensing Survey: Global context	Erik Linquist
10	Segmentation methods in FRA	Pierre Defourny
11	Results and validation tools for FRA	Bruno Nkoumakalo and Christophe Musampa
12	Quantitative analysis of deforestation and degradation drivers in D.R. Congo	Pierre Defourny
13	Land cover & deforestation mapping in central Africa	Matt Hansen
14	Description of methods and results	Erik Lindquist
15	Next Steps: Advanced methods	Mark Broich
16	Mapping Wetland Extent	Jean-Robert Bwangoy
17	Conservation land Use Planning	Janet Nackoney
18	Interactions Between Hydrology and Carbon Stocks and Fluxes	Yolande Munzimi
19	Transition to a regional mapping initiative: OSFAC	Landing Mane
20	The GEO Forest Carbon Tracking (FCT) Task	Giovanni Rum
21	National Demonstration in the GEO FCT Task	Michael Brady
22	Mapping and Monitoring Carbon in Gabon Forests	Simon Lewis and Sassan Saatchi
23	REDD Carbon Project in Rep. of Congo	Georges Boudzanga and Fred Stolle
24	Canopy textural monitoring	Barbier Nicolas

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No.	Title	Author
25	Biomass and Carbon Mapping in Central Africa using Remote Sensing and Forest Inventories	Nadine Laporte and Andréana Mekui Biyogo
26	REDD Project in Cameroon	Thomas Haeusler
27	REDD MRV System Development in D.R. Congo	Danae Maniatis
28	Canopy (Aerial) Carbon Stocks Measurement in Congo Basin Forest	Jean Remy Makana
29	Evaluating the Effects of Reduced Impact Logging on Forest Carbon	Vincent Medjibe
30	Carbon Stock Estimation in Forest Concessions	Nicolas Bayol
31	The Congo Basin Forest Fund (CBFF)	Pierre Nguinda
32	Carbon and Agroforestry in Cameroon	Denis Sonwa
33	Forest Carbon Sinks in Ibi Bateke	Olivier Mushiete
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35	Land Use Planning in the MLW-Landscape and its Potential for Carbon Credits	Jeff Dupain
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38	Pan Tropical PALSAR Mapping in Support of Forest Monitoring	Nadine Laporte
39	DMCii Global Forest Services	Paul Stephens
40	Provision of SPOT Data for Forest Cover Analysis in the Congo Basin	Corentin Mercier
41	An Earth Observation Ground Station and Research Laboratory for Long Term Monitoring, Libreville, Gabon	Jean Marie Fotsing
42	CBERS Data for Earth Observation in Africa	Claudia Almeida
43	Coordination and information dissemination of REDD activities in the region	Working Group 1
44	Regional networks and capacity building	Working Group 2
45	Satellite data and receiving stations in the region	Working Group 3
46	Biomass and Carbon stock estimation	Working Group 4
47	Synthesis and summary of actions	Philippe Mayaux

Appendix 4. List of Acronyms

AFOLU	Agriculture, forestry and other land uses
ALOS	Advanced Land Observing Satellite (owned by JAXA)
AR4	Assessment Report 4 - IPCC 4th assessment report, published Nov 2007
ARR	Agriculture, Reforestation and Revegetation
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer (NASA)
BAD	Banque Africaine de Developpement
CB	Capacity building
CBD	Convention on Biological Diversity
CBERS	China-Brazil Earth Resources Satellite Program
CC	Carbon Credits
CDM	Clean Development Mechanism
CEOS	Committee on Earth Observation Satellites
CER	Certified Emission Reduction (units)
COMIFAC	The Central African Forest Commission
COP	Conference of the Parties
DMC	Disaster Monitoring Constellation (survey satellites)
EC	European Commission
EF	Emission Factor
ESA	European Space Agency
FAO	United Nations Food and Agriculture Organization
FCPF	Forest Carbon Partnership Facility of the World Bank
FRA	Forest Resource Assessment
GEO	Group of Earth Observation
GHG	Greenhouse Gas
GLCN	Global Land Cover Network (FAO)
GOFC-GOLD	Global Observations of Forest and Land Cover Dynamics
GPG	Good Practice Guidance
GW	Global Warming
INPE	National Institute for Space Research (Brazil)
IPCC	Intergovernmental Panel on Climate Change
IRS	Indian Remote Sensing Satellite
JAXA	Japan Aerospace Exploration Agency
LC	Land Cover
LULUCF	Land Use, Land Use Change and Forestry

MERIS	Medium Resolution Imaging Spectrometer (ESA)
MODIS	Moderate-resolution Imaging Spectroradiometer (NASA)
MRV	Monitoring, reporting and verification
NASA	National Aeronautics and Space Administration
NETS	National Emissions Trading Scheme
NFMA	National Forest Monitoring Assessment Report of FAO
NGO	Non-Governmental Organisation
NIR	National Inventory Report
PRP	The Prince's Rainforests Project
REDD	Reducing emissions from deforestation and forest degradation
REDD+	Reducing emissions from deforestation and degradation, conservation of existing carbon stocks and enhancement of carbon stocks
RIFFEAC	Forestry Schools In Central Africa Network
R-PIN	Readiness Project Idea Note (submitted by countries to FCPF)
RS	Remote Sensing
SPOT	Satellite Pour l'Observation de la Terre (France)
SRTM	Shuttle Radar Topography Mission
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
VCF	Vegetation Continuous Fields
VCM	Voluntary Carbon Market
VCS	Voluntary Carbon Standard
WSSD	World Summit on Sustainable Development