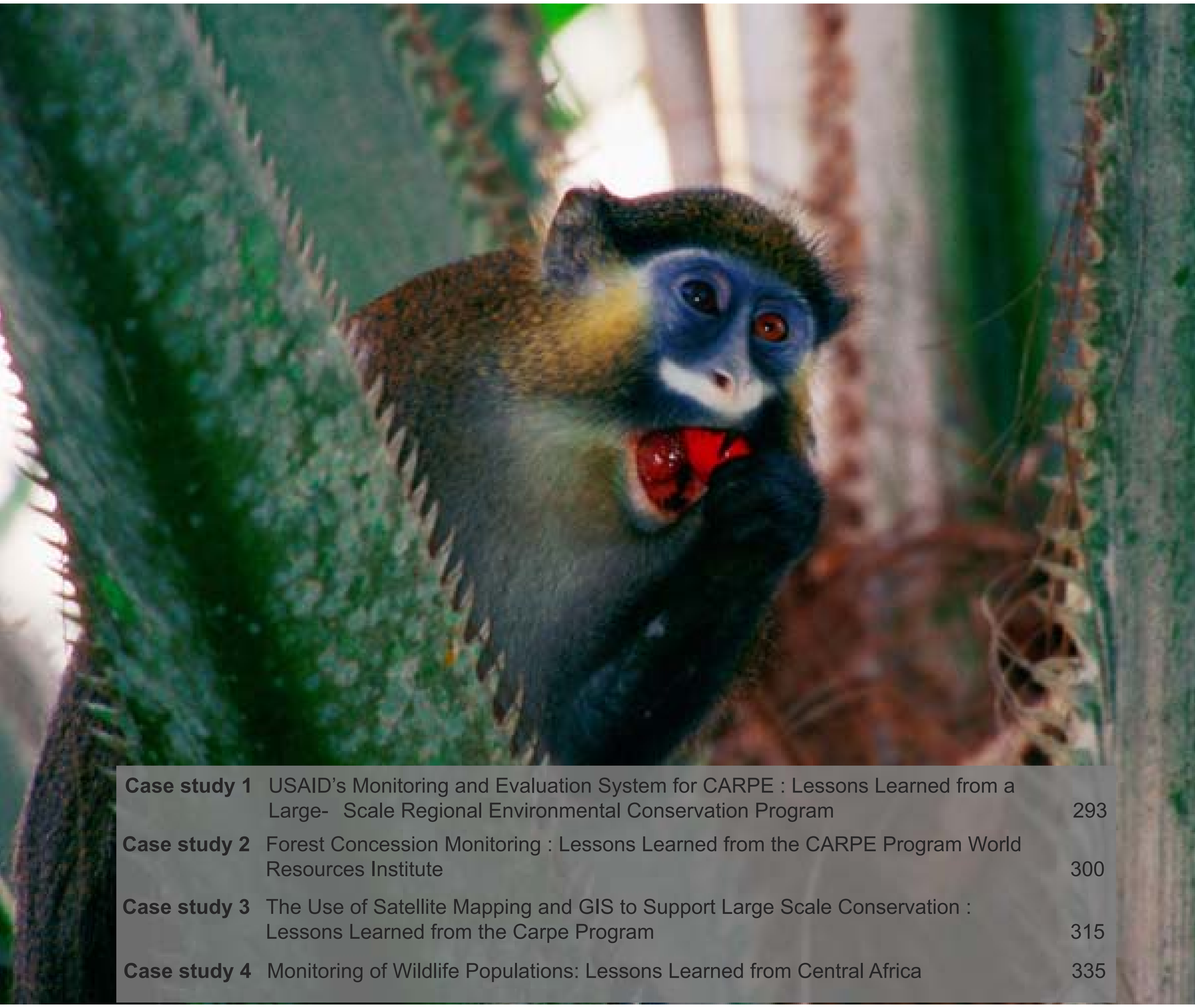
Chapter 8

THE MONITORING OF NATURAL RESOURCES TO SUPPORT CONSERVATION PROGRAMS



CARPE

Case study 1 - USAID's Monitoring and Evaluation System for CARPE : Lessons Learned from a Large-Scale Regional Environmental Conservation Program

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Introduction: The goals and challenges of monitoring and evaluating CARPE

Virtually all donors require some system for monitoring and evaluation (M&E) of their grants. The most fundamental goal of any donor M&E system is to create a conduit of communication between the donor and the programme implementers. These systems seek to increase the transparency of implementation while simultaneously gathering data to provide a basis for assessing the results of the project. The results assessment provides a feedback mechanism for adaptive management based on successes and failures, and thereby for restructuring the on-going project and/or future projects of a similar nature. In addition, a donor uses this information to inform decision making about continued funding by policy makers within the agency and, in the case of most government donors such as USAID, with the legislative branch of government and taxpayers.

CARPE presents some unique challenges for M&E given its large scale and complexity. The programme has been going for 20 years and has contributed over US$100 million in funding during its seven years of field implementation to date (2004–2010). The programme consists of three components: governance and policy; a landscape programme of field-based improved natural resource management; and monitoring. For simplicity this chapter focuses on the landscape and monitoring components.

The landscape programme is vast. It includes 12 different Landscapes in seven countries[1] and co-

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[1] Cameroon, Central African Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, Republic of Congo and Rwanda.

vers roughly 80 million hectares, approximately the size of the US state of Texas. These 12 Landscapes were prioritized for conservation in an international forum by a large number of national and international experts based on the level of intact forest, biodiversity richness and presence of endemic species.

The idea of the landscape approach is that ecosystems, and in particular wide-ranging animals such as elephants, need larger spatial areas than those covered by a typical protected area(PA)-focused strategy. A CARPE Landscape therefore includes not only PAs but also forest concessions (and other extractive resource zones or ERZs) and community-based natural resource management (CBNRM) zones, and explicitly considers the ecological interactions between these zones. The 12 Landscapes are made up of 37 PAs, 68 CBNRM zones and 43 ERZs, giving a total of 148 “macro-zones” as they are known in CARPE terminology.

Each of the 12 Landscapes is headed up by a institutional landscape leader from one of four international conservation NGOs that include the World Wildlife Fund (WWF), the Wildlife Conservation Society (WCS), Conservation International (CI) and the African Wildlife Foundation (AWF). Each landscape lead institution heads a consortium of institutional actors with competencies in diverse areas such are wildlife monitoring, botanical inventories, forestry, community development and institutional capacity building that are needed for an integrated conservation approach. In addition to the four lead institutions, there are currently 14 other consortium partners (many of whom work in multiple landscapes) and a significantly larger number of other institutional collaborators including notably national government institutions.

A further challenge has been that many of the conservation NGOs and the individuals working within them did not have a depth of experience of working on the large-scale field implementation of a conservation project such as CARPE. Much of the institutional culture and individual experiences related more to working on field research, often relatively narrow in scope.

Given the large number of institutional actors working across a large and widely dispersed geographical area, the USAID/CARPE team sought to use the M&E system as a means to provide coherence to the overall programme. The very word programme implies there is a desire to have a coordinated and consistent approach to attaining conservation objectives, and not simply a large number of disparate and isolated projects. Furthermore, disparate and isolated projects tend not to leave a lasting impact. An additional goal of CARPE and its M&E system is to leave structures in place that the national governments and NGOs as well as other donors can build upon in the future.

The funding given to each landscape is in the form of what USAID calls a “Cooperative Agreement”. USAID Cooperative Agreements specify that the USAID management team has a “substantial involvement” role which includes approval of annual budgets and work plans. The M&E system therefore needed to propose a standardized format for a technical work plan and technical budget in order to provide for consistent evaluations across partners and landscapes.

In sum, the challenge of developing the CARPE M&E system was to create a structure that harmonized the metrics for assessing the progress of numerous actors in a large number of remote sites with different ecological and socio-economic conditions. An additional objective of the system is to help the implementing partners coordinate their field-based conservation work over a broad range of sites and with multiple institutions within a landscape. All this has to be achieved while still leaving enough flexibility to meet a broad range of site-specific conservation challenges across the Congo Basin.

The USAID/CARPE approach to monitoring and evaluation

CARPE objectives

To introduce CARPE’s M&E system it is first necessary to discuss the specific objectives set by USAID for CARPE, in order to understand what exactly is being monitored and evaluated. There are in fact two levels of objectives: the ultimate objectives known as strategic objectives (SOs) and the shorter-term objectives know as intermediate results (IRs). The strategic objectives of the programme are to slow the rate of deforestation and to conserve biodiversity.

In order to measure the rate of deforestation over a large area such as the Congo Basin, CARPE has relied upon satellite data provided by the National Aeronautics and Space Administration of the United States, interpreted by researchers from the University of Maryland and South Dakota State University (SDSU). This specific indicator involves measuring forest-cover change over time. The initial baseline was set at 1990 with change measurements for 2000 and 2005 which have been updated annually up to 2009 using an automated system developed by SDSU. This analysis permits the generation of deforestation rates across the basin, within and outside landscapes, and helps to identify hotspots of environmental degradation in order to better plan conservation interventions.

For the biodiversity conservation objective, the chosen approach was to select a number of indicator species and track their population status over time in selected sites in each of the 12 Landscapes. The most common indicator species chosen include elephants and primates such as gorillas, chimpanzees and bonobos. A key challenge has been to standardize the methodologies used for measuring these indicator species so that spatial and longitudinal comparisons would be meaningful. A working group involving the lead international conservation NGOs was set up and has addressed this methodological issue.

The work on deforestation and wildlife indicator species, along with parallel work that monitors logging concessions, constitute the component of capacity strengthening for monitoring of natural resources in the programme (though obviously the M&E aspects of the programme go substantially beyond this particular component). An important initial observation is that results concerning both these strategic objectives (deforestation and wildlife populations) are long-term in nature and therefore do not permit a shorter-term feedback on progress from the CARPE M&E system. It was therefore necessary to define intermediate results (IRs) that contribute to reducing deforestation and biodiversity loss and track the shorter term progress of CARPE landscape partners' work. For the CARPE landscape management programme, these intermediate results revolve around land-use planning (LUP) processes for each of the 12 Landscapes and for all the macro-zones specified within each Landscape.

The CARPE/USAID management team has defined four stages in the LUP process. The first stage is the development of a "strategy document" and is known as "convening" the LUP process. A strategy document essentially describes how to develop a management plan and identifies the data needed, planning team members, an activity timetable, etc. The second stage, known as "design", involves the development of a management plan. The third stage is "adoption" and entails the recognition of the management plan by the competent national authority. The final stage is "implementation" and involves carrying out the needed management activities specified in the management plan. Each of these stages constitute benchmarks to assess progress in achieving the intermediate results.

The CARPE M&E system : into the heart of the matrix

The central operational tool of the CARPE M&E system is known as the CARPE monitoring and work planning matrix which can be found on the CARPE website[2]. Partners fill out and send to USAID annual matrices which are updated three times a year: prior to the beginning of the year with a proposed work plan and budget for USAID's review and approval; at a midpoint in the year with the semi-annual report; and after the end of the year as part of the annual report containing an assessment of the year's accomplishments. A review of the individual components of this matrix provides a detailed overview of the M&E system. The matrix is divided into

[2] http://carpe.umd.edu/Plone/resources/carpemgmttools.

three principal sections; a benchmark monitoring section, a work plan section and a budget section. The benchmark monitoring section defines and breaks down the yearly standardized LUP benchmarks from five-year established targets for each Landscape and every macro-zone. Each Landscape is a reporting unit and fills out an integrated matrix with all the consortium partners contributing.

The far left-hand side column of the monitoring and work plan section of the matrix lists all the intervention zones, starting with the Landscape itself followed by each individual macro-zone grouped in the three land-use categories starting with PAs, then CBNRM zones and finally ERZs. At the landscape level, there is a space to list the wildlife monitoring SO indicator of animal population densities. Moving to the right across the matrix, the next column lists the current year's LUP benchmarks for each of the zones. A benchmark is listed in percentage terms such as PA X is 100 percent convened, CBNRM zone Y is 50 percent designed, or ERZ Z is 25 percent implemented. The size of the zone in hectares is also listed in order to calculate the area of land that is engaged at any given stage of the LUP process.

The next column to the right lists the "means of verification" or MOVs that are needed to verify the progress of each zone in the LUP process. Partners propose these and the USAID management team's review of the initial work plan approves them or asks for revisions. The MOVs can roughly be divided into three categories following the LUP process. Planning MOVs during the convening process typically include reports on activities such as socio-economic surveys, ecological studies and stakeholder meetings that are conducted to inform the plans and contain informational inputs for the subsequent development of the management plan. LUP MOVs logically include strategy documents and management plans both in draft and final form. Finally there are implementation MOVs. These serve to document the application of the activities specified in the management plan and include reports on a broad range of activities such as ecoguard patrolling, environmental education, tourism, community livelihood activities and on-going site-specific monitoring.

It is worth underlining at this point, as just mentioned above, that all the individual zonal management plans have their own system of monitoring and evaluation. These M&E systems track results in each of the Landscapes and in each of the macro-zones as a function of the objectives set out in the management plans. These systems are a more site-specific layer of M&E and complement the standardized basin-wide CARPE M&E system.

Continuing to the right in the CARPE M&E matrix, the next section is the actual work plan itself. The work plan identifies six standardized work activity categories. These include: data collection and assessment; stakeholder meetings and workshops; training and capacity building; policy advocacy; media and outreach; and implementation. These activity categories are standardized and are included for each individual planning zone unit. The next level of disaggregation in the following column is for specific tasks associated with each activity category. Typically there are several tasks for each activity category. For example, in the training and capacity building category, there may be tasks related to community environmental education, GPS (Global Positioning System) training for ecoguards, and training in database management for national government collaborators. Finally, each task is assigned to one or multiple institutions in the consortium and a specific person or persons. The last column sets a target date for finishing the task.

The second main component of the M&E matrix is the budget section. As stated above, CARPE Cooperative Agreements require the USAID management team to approve annual budgets. A well designed budget matrix facilitates programme evaluation from a financial point of view. The budget section is disaggregated into six standard categories which match the work plan standardized activities. This alignment therefore provides consistent and useful insights into each Landscape's technical approach.

The first disaggregation is between USAID funding and match funding. The level of match funding a consortium raises is a performance criterion and also allows the US Government to show how much additional funding it has leveraged into the programme. Activities supported by match funding must be integrated into the CARPE work plan and must also correspond to the landscape programme description found in the Cooperative Agreement between USAID and the landscape consortium lead organization.

Another level of disaggregation is by consortium partner. Each consortium partner typically contributes a specific competency for the integrated conservation programme. The institutional distribution of funding therefore gives an insight into the weight given to different landscape programme components providing an input to USAID's evaluation. In addition, USAID put a special provision into the landscape cooperative agreements that states that any change in a consortium's teaming arrangement must be approved by USAID. This was included principally as a guarantee against landscape lead organizations taking unilateral action to redistribute budgets in a way that could undermine an integrated conservation approach. Budget disaggregation at the partner level allows for this type of monitoring oversight.

Finally, budgets are disaggregated by zonal categories (Landscapes, PAs, CBNRM zones and ERZs) and by the six standard work plan activity categories for each zonal category (but not for each individual zone). The landscape approach seeks to balance conservation interventions between protected areas, extractive resource zones and community zones. In fact, USAID/CARPE requires that a minimum of 50 percent of financial resources be spent outside protected areas. This level of disaggregation allows USAID to evaluate whether a landscape consortium is implementing a balanced landscape conservation approach.

The activity category budget disaggregation also gives useful insights into evaluating a Landscape's technical approach. For example, at earlier stages in the LUP process it is logical that an important percentage of funding should go towards planning activities related to data collection and stakeholder engagement. As the LUP process matures, this percentage should shrink as more funding goes towards implementation activities. In some cases, certain institutions and/or individuals were more comfortable with research-related activities and continued to emphasize data collection beyond the initial planning stages of the LUP process. As CARPE is an applied conservation programme, USAID used this budget information for evaluations and to provide constructive feedback as needed.

Lessons learned

CARPE is relatively unique in that it is a 20–year-old programme operating in nine different countries and with 18 direct institutional partners in the landscape component alone. It would be difficult to overstate the level of complexity of the programme. A number of experiences and innovations associated with the M&E system could prove useful particularly to other large-scale conservation initiatives.

The M&E system design primarily took place over a period of two years, from about 2004 to 2006. As this timeframe implies, the design was an iterative process based on trial and error, and incorporating feedback from the CARPE implementing partners. An M&E workshop was held in 2005 for all the landscape leaders. There was a dual purpose to this workshop. Firstly, to teach the landscape leaders how to use this M&E system and secondly, to provide a venue for eliciting feedback from the implementing partners on how to improve the system.

The workshop adopted a learning-by-doing approach and partners filled out sample M&E matrices for their landscapes and then shared their questions and concerns with the other landscape leaders and the USAID/CARPE management team. This greatly increased partners' comfort level with the CARPE M&E system and significantly improved the quality of reporting. To further reinforce the workshop training, USAID developed a CARPE reporting guidance manual (see CARPE website) that explains section by section how to fill out the M&E matrix. This manual has been updated as the M&E system has evolved over time. The lesson learned from this experience is that a complex M&E system needs to provide supplementary training and guidance to users in order to ensure quality implementa-

tion.
Secondly, given that the CARPE partners are the direct users of the M&E systems (i.e., they fill out the matrix) they have the best knowledge of the challenges to actually making it operational. By facilitating partner feedback and using their suggestions, the USAID/CARPE management team has been able to improve the effectiveness of the system as well as to reduce the time burden needed to fill it out. The lesson learned here is that a participatory approach to M&E development with end users is critical to improving the system's design and to achieving a greater buy-in from the partners and therefore increasing their willingness to provide the highest-quality information.

Another example of the critical importance of technical backstopping involves the development of LUP documents (management plans and strategy documents). As noted previously, LUP planning is at the heart of the programme and therefore its M&E system as well. Further, the LUP documents are arguably the most important category of MOV required to show accomplishment of established benchmarks. However, land-use planning can mean different things to different people, and certain partner institutions and individuals have had limited experience with this aspect of conservation.

The USAID/CARPE management team therefore decided to call upon the US Forest Service (USFS) to write a series of technical guides (see CARPE website) for each of the four CARPE zone categories. These guides focus on identifying the minimal common components that should be found in a management plan and strategy document while leaving ample flexibility for site-specific applications. USAID and the USFS organized two parallel workshops in Libreville and Kinshasa to train landscape partners in LUP. The minimal common components now serve as a standard by which USAID can evaluate the quality and completeness of the LUP documents. A lesson learned is that for particularly complex endeavours such as land-use planning, it may be necessary to provide outside technical backstopping that not only trains partners but also provides a clear standard by which their accomplishments will be evaluated.

The institutional cultures of many of the conservation NGOs and the individuals within them often were more oriented to narrow research and did not include experience in implementing complex large-scale conservation programmes. Many of the partners initially viewed the CARPE reporting system as an additional burden beyond their actual conservation work. And yet any applied conservation or development project needs to set objectives and establish a work planning framework. The CARPE M&E system, as designed, sets clear benchmarks and lays out a rigorous system for planning conservation work. With time and training, CARPE partners came to appreciate the M&E reporting system as a useful tool for structuring their own activities, in particular for coordinating and integrating the activities of diverse consortium partners within a Landscape. The lesson learned here is that an M&E reporting system should be designed to facilitate work-planning and objective-setting activities that an implementing organization needs to conduct regardless of donor requirements.

An enormous amount of data has been generated by the CARPE M&E system. There are a large number of variables, numerous sites, and many years of data. The USAID management team developed an MS Access database that facilitates the aggregation and analysis of the data received. This tool is critical for the evaluation of partners' performance and reporting to USAID headquarters, the US Congress, other donors and interested stakeholders in general. A typical data query, for example, could be how many hectares of each type of macro-zone are under an operational land-use management plan. This database can also be used to engage in more policy-oriented analysis, such as the average cost per hectare of the development of management plans for the different types of macro-zones. The lesson learned from this experience is that a complex M&E system needs to establish a database system that can easily upload data from standardized reporting matrices in order to facilitate the ability of the management team to evaluate and disseminate programme results in a timely fashion.

Adding together the Landscapes and macro-zones, there are 160 zones. For each one of these zones, a CARPE partner typically sends in several MOV documents per year. The CARPE management team thus receives well over 500 documents each year. There is a tremendous wealth of information contained within these reports. One of the key constraints the CARPE management team noted was that these reports were not easily accessible to national governments, other Landscapes in the programme or even within a given conservation NGO working in multiple sites.

In response to this situation, the USAID/CARPE management team in collaboration with the University of Maryland developed the web-based CARPE Information Management Tool[3] or IMT. The IMT organizes and makes publicly available on the web all the MOV reports generated by the programme. In order to facilitate locating the reports, the IMT presents a Congo Basin-wide map with the Landscapes outlined. By clicking on a given Landscape, the user is directed to all the information for that Landscape. The user can then click again to get a map of all the individual macro-zones within each Landscape. A final click brings the user to all the reports for a given macro-zone categorized under the following headings: land-use planning, ecological information, socio-economic information and stakeholder participation documents. The lesson learned from this experience is that information sharing can be a critical constraint in any large-scale conservation programme so a mechanism for sharing is of critical importance to facilitate collaboration and to disseminate programme results. Web-based geo-referenced information management tools can be particularly effective to this end.

This chapter has previously noted that CARPE M&E takes place both within different timeframes and at different geographical scales. The wildlife population and deforestation monitoring take place over the long term, whereas the LUP process, which contributes to reducing deforestation and biodiversity loss, is a short to medium-term result. The CARPE M&E matrix is a standardized system that covers all twelve Landscapes across the Congo Basin. The individual management plans developed by CARPE and national partners for each Landscape and macro-zone are site-specific and adapted to local conditions and objectives. The lesson learned from this experience is that, for a large-scale and long-term programme such as CARPE, it is useful to carefully consider multiple time and spatial scales and to design a multi-layered M&E system to capture the full range of spatial and temporal results generated.

A final lesson learned concerning M&E involves the generation of lessons learned. The CARPE M&E system generates a massive quantity of data and information that permits the monitoring and evaluation of results achieved by the programme. However, this information does not always permit a more analytical evaluation of the conservation practices and strategies employed by the different actors in the programme. The USAID/CARPE management team therefore decided to launch this CARPE Lessons Learned Initiative covering all the key thematic components of the programme and of which this article represents one of many chapters. These lessons learned are published both in book form and on the web. They permit a sharing of conservation experiences both between partners and geographical sites within the programme as well as with the broader conservation community. The documentation and dissemination of lessons learned add to the overall knowledge base and therefore contribute to improving the effectiveness of conservation programmes in the Congo Basin and around the world.

[3] http://carpe-infotool.umd.edu/IMT/.

Case study 2 - Forest Concession Monitoring : Lessons Learned from the CARPE Program *World Resources Institute*

Pierre Méthot, Matthew Steil

Introduction

The objective of this paper is to share the most relevant lessons that WRI has learned on forest concession monitoring in Central Africa (CA) through its USAID-CARPE funded activities with CARPE, its partners, and other stakeholders.

Forest monitoring and WRI objectives and goals

WRI's overall mission statement is "to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations". Its contribution to CARPE falls under WRI's People and Ecosystems Program's goal of reversing the rapid degradation of ecosystems and assuring their capacity to provide humans with needed goods and services. More specifically, through its Forest Information and Governance Initiative, WRI seeks to:

> *"…increase the capacity of governments, businesses, and civil society to act upon better and more widely-shared information to protect intact forests, manage working forests more effectively, and restore deforested lands".*

The main premise behind WRI's forest strategy is that the provision of accurate, user-friendly information will promote more sustainable forest management (SFM) practices when linked to relevant decision-making and capacity-building efforts coupled with making this information publicly available as a means to hold decision makers accountable for their actions.

WRI's niche is the provision of accurate, credible, accessible and timely forest landscape information and the promotion of its inclusion in decision making. This information is developed through strategic partnerships with national, regional and international actors (private sector, governments, multilateral and bilateral agencies, research institutes, and local and international NGOs). WRI's ability to work across multiple levels (local, national, regional and international) and sectors is crucial to its effectiveness in connecting forest information to the variety of decision-making processes focused on strengthening forest management in Central Africa. This includes its ability to draw on WRI's experience in other forest-rich regions, including Southeast Asia, Russia and South America. Other players in the region typically focus at the site scale (i.e., specific protected areas or landscapes).

In that respect, WRI's mission, goals, objectives and programmes respond directly to CARPE's strategic objective, which is to :

> *"reduce the rate of forest degradation and loss of biodiversity through increased local, national and regional natural resource management capacity in nine Central African countries: the Central African Republic, Equatorial Guinea, Gabon, Republic of Congo, Burundi, Cameroon, Rwanda, Sao Tome & Principe and the DRC".*

The above highlights the compatibility between WRI's involvement in forest concession monitoring in Central Africa and USAID-CARPE's goals.

The need for forest concession monitoring

Monitoring production forests

Forest concessions and other logging titles (e.g., council or communal forests, sales of standing volumes, etc. – "production forests" writ large) represent the vast majority of classified forest in the forested countries of Central Africa (Figure 1). Within these forests exist immense and valuable renewable resources: from the timber itself targeted by the extractive industries to the non-timber forest products (e.g., bushmeat, fruits, nuts, medicinal plants, etc.) on which local populations are largely dependent for subsistence, to ecosystem services provided (locally and globally) from an intact tropical forest ecosystem.

Additionally, logging titles form much of the connecting forested corridors between protected areas. Therefore, maintaining current production forests as integral habitats with viable floral and faunal populations is integral to conservation planning at both the landscape and regional scale. The monitoring of resource extraction activities occurring within production forests is critical in addressing issues of legality and SFM, as well as for providing information on how land use within these areas affects the overall landscape.

Status of commercial logging in the Congo Basin

While commercial logging does not officially constitute more than 15 percent of GDP in any of the countries of the region, it is the most important sector in terms of occupied forest surface area and formal employment for most of the region's countries. On a positive note, the last 10–15 years have seen improvements in the commercial forest sector in Central Africa, particularly in terms of generally adhering to SFM practices, establishing a clear definition of the legal boundaries of logging titles, building the capacity to actually monitor logging activities, contributing to the improvement of local livelihoods and, finally, pursuing certification or other legality standards.

On the other hand, however, industrial logging continues to extend into areas of the Congo Basin not previously exploited, thus opening up these new areas to pressures from hunting, forest degradation and/or conversion. Furthermore, while some companies have committed to best practices (environmental and social) in their activities, many continue to operate outside environmental and social dictates, and institutional capacity to enforce adherence to the law or management plan obligations remains weak.

Objectives of forest monitoring

Forest concession monitoring

The monitoring of activities in production forests and more generally in forested areas allows stakeholders to address several important issues.

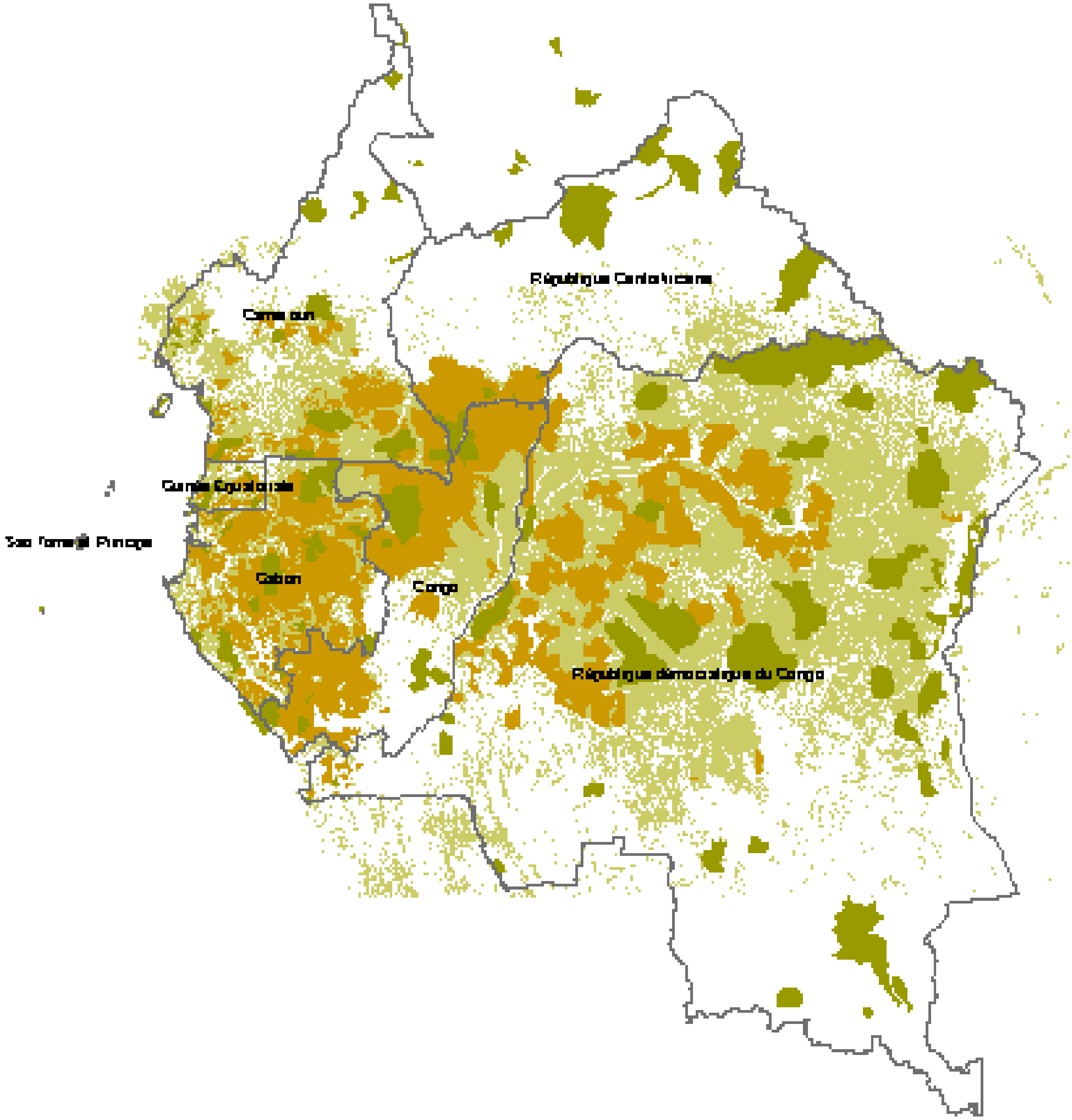


Figure 1. Distribution of forest concessions, protected areas and dense tropical forest cover in Central Africa
Key : Brown – forest concessions; dark green – protected areas; light green – dense tropical forest cover.

Some general environmental and social applications for example include :

- Monitoring and measuring forest cover change over time;
- Determining drivers of deforestation or forest degradation, notably through slash-and-burn agriculture;
- Monitoring and mapping the extension of road infrastructure;
- Monitoring environmental compliance;
- Combating illegal trade of bushmeat;
- Monitoring populations of key indicator species to measure impacts and guide mitiga-

tion;
- Informing landscape management of plants and animals;
- Addressing issues of resource-use overlap with local populations.

When done well, commercial logging can be a sustainable contributor to local employment and the national economy; when executed poorly it can be a purveyor of forest degradation, local impoverishment, corruption and tax evasion. Monitoring commercial logging activities can provide necessary information to support the enforcement of national laws and development goals as well as help ensure that these activities are carried out within the realm of SFM and that they contribute to local wellbeing. With regard to logging activities, the main applications of forest monitoring include :

- Combating illegal logging outside legally allocated logging titles (forest concessions and annual logging coupes) or inside protected areas;
- Combating illegal activities related to logging such as non- or under-reporting of logs felled, harvesting forbidden species, felling below authorized minimum diameters, deliberately reporting wrong species, etc.;
- Enhancing the ability of the ministries in charge of forests to carry out more targeted enforcement of logging infractions, thus reducing the overall costs of field controls;
- Monitoring implementation of sustainable forest management plans;
- Monitoring adherence to allotted annual volume or surface area restrictions;
- Informing stakeholders of the requirements and effectiveness of certification programmes with the aim of moving towards more socially responsible and environmentally sustainable logging;
- Verifying compliance of logging companies to the social contracts (cahier des charges);
- Verifying compliance with forest certification and legality processes;
- Monitoring contribution of industrial logging to local livelihoods, notably through the payment and redistribution of area and volume-based forest taxes.

Complementary initiatives

In addition to addressing the immediate needs listed above, monitoring production forests and forested areas contributes valuable information that informs ongoing and proposed bilateral, multilateral and international initiatives. Amongst actual and potential beneficiaries are :

- Carbon sequestration initiatives related to climate change;
- The World Bank programme to reduce emissions from deforestation and degradation (REDD);
- Timber trade agreements such as the European Union's Forest Law Enforcement, Governance and Trade (FLEGT) process;
- Convention on Biological Diversity and other global biodiversity conservation initiatives (e.g., IUCN's Red List).

Methodology of forest concession monitoring

Integrated approach to forest concession monitoring

Forest concession monitoring, especially if it aims to combat illegal logging, requires an integrated approach that encompasses three un-dissociable components :

1. Ways or tools to identify ongoing activities: Remote sensing (RS) and field controls;
2. Indicators to measure or assess those activities: Criteria and indicators, notably of legality and of sustainable forest management;
3. Ways to collect, process, verify and communicate the information collected on the activities : *Geographical Information Systems* (GIS), *Interactive Forest Atlases*, *Forest Information Management Systems* (FIMS).

WRI activity in Central Africa over the last several years covers all three of these components, to varying degrees. WRI has also provided input and support to the FLEGT and other forest certification processes, thus further contributing to forest concession monitoring and the fight against illegal logging.

Remote sensing and field controls

The forest concession monitoring work performed by WRI under CARPE in Central Africa has not been limited to forest concessions, but extended to include all types of logging titles, such as communal and community forests and annual logging coupe sales as well as protected areas (national parks, game ranches, reserves, etc.). Consequently it is best to discuss forest monitoring at large, rather than simply forest concession monitoring.

There are basically two major methods by which to identify ongoing activities in the forests: remote sensing and field controls. Each of these two methods has their advantages and limitations, as can be seen in Table 1 below :

It is important to note that neither of these methods is a practical or complete forest monitoring method in isolation – rather that they are best used complementarily to achieve some effective results. WRI has limited its efforts to remote sensing and has not been involved in actual field controls of logging or other forest-related activities other than validating limits of forest titles and forest roads identified through RS, notably through the use of GPS. The information generated by WRI with remote sensing has, however, been widely used by other forest actors to actually conduct field controls, notably the ministries

Table 1. Description, advantages and limitations of the two main forest monitoring methods

Methods	Remote sensing	Field control
Description	Interpretation of satellite images or aerial photography to monitor canopy loss, forest degradation, logging activity and road building.	Physical inspection of logging activities by technical staff – generally involves the use of maps, GPS and other hand-held tools.
Advantages	- Covers large tracts of forest with limited costs; - Access to remote regions; - Limited staff requirements; - Provides global picture; - Limited field work needed; - Discreet.	- Enables one to control a very large number of elements that can not be seen from satellite images or aerial photography (e.g., logs, stumps, bushmeat hunting, working conditions, etc.); - Information collected stands up legally; - Can be carried out with limited technical training.
Limitations	- Only able to detect activities visible within resolution ability of images; - Regular cloud-free satellite images difficult to get for many areas of Congo Basin; - Resolution of available images often not high enough to detect certain activities; - Technology-dependent – requires certain amount of training, software, hardware and ability to acquire necessary images; - Requires some field verification.	- Requires large workforce and supporting infrastructure; - Expensive and time-consuming; - Difficult to construct global picture – site-specific; - Not capable of measuring land-use change effectively; - Leaves more room for corruption between operator and enforcement agents; - Extremely difficult to access remote areas.

in charge of forests as well as international NGOs involved in combating illegal logging and poor forest governance, such as Resource Extraction Monitoring (REM), Global Witness and Greenpeace.

Criteria and indicators

From 2003–2006, WRI was active in developing and promoting the implementation of a step-wise approach to forest certification in Central Africa, in partnership with IUCN and the InterAfrican Forest Industries Association (IFIA). This Forest Concession Monitoring System (FORCOMS) was conceptualized as a voluntary and independent monitoring system that would provide information on the status of the legality of the logging and wood-processing operations and on the actual commitment to SFM of the participating forest concessionaires. Legality and the meeting of certain environmental and social criteria were to be third-party verified through a specific set of targeted indicators (see Figure 2 for outline of structure). This was not meant to be another certification or legality verification system, however; rather, it was intended to support ongoing initiatives in filling the large gap between the certified and non-certified actors in the region. FORCOMS was developed to be the first step towards meeting baseline legality standards and towards the eventual achievement of certification (Figure 3).

GIS, Interactive Forest Atlases, FIMS

GIS and Interactive Forest Atlases

Most WRI activities within CARPE over the last seven years have focused around the development and implementation of remote sensing, GIS and mapping tools to monitor activities within or surrounding logging titles and protected areas. The culmination of these activities is the deve-

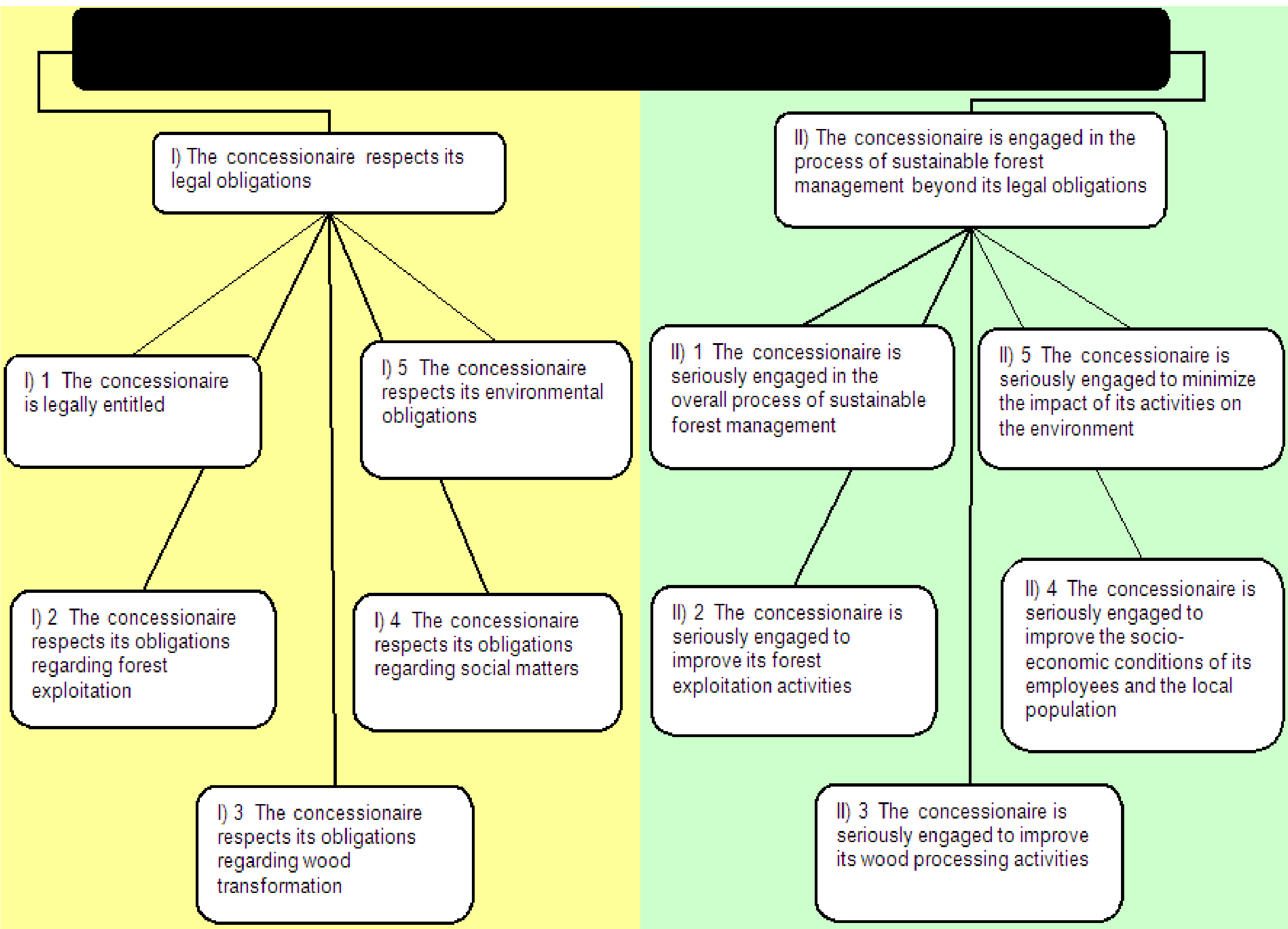


Figure 2. FORCOMS means of sssessment architecture

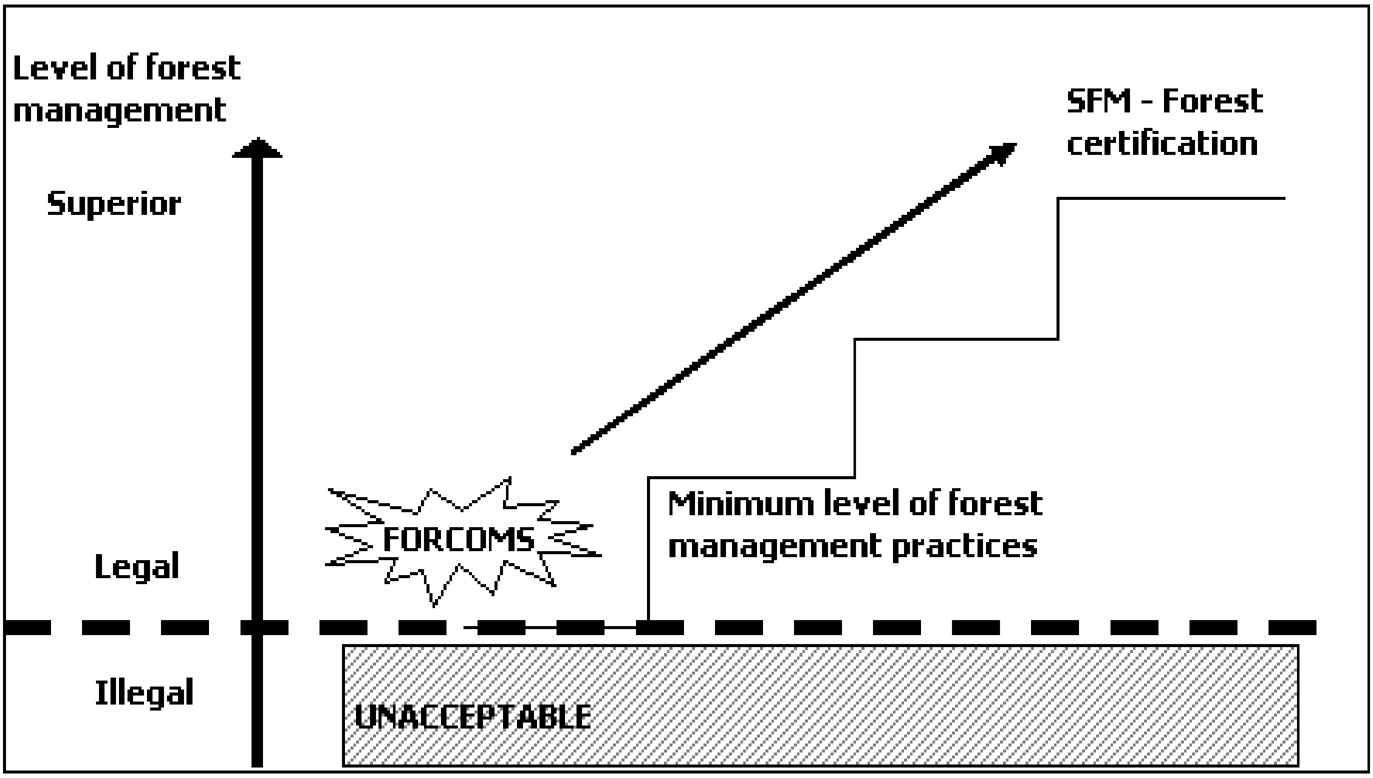


Figure 3. Presentation of FORCOMS and step-wise certification scheme

lopment and dissemination of the interactive forest atlases and related products (see Figure 4).

The aim of developing these tools and associated activities is to :

- Provide and map verified geo-referenced boundaries of all logging titles and protected areas;
- Locate, qualify, date and map the forest roads and trails within and outside forest titles and protected areas;
- Partner with host country forest ministries to collect, process and disseminate this information;
- Build local capacity in remote sensing, GIS and mapping to carry out the monitoring of logging titles.

The GIS and Interactive Forest Atlases databases, and the Forest Information Management Systems, are cross-feeding each other with useful forest monitoring information.

Forest Information Management Systems (FIMS)

Since 2006, WRI has been working with the Ministry of Forests in both the Republic of Congo (RoC) and the Democratic Republic of Congo (DRC) to design and implement an integrated computer-based Forest Information Management System (FIMS, or SIGEF – Système d'Information de Gestion Forestière – in French).
The FIMS is a an important decision-support tool that allows for the collection, processing, control and publication of data pertaining to commercial logging, log and wood products declaration, wood processing, and forest taxes (see Figure 5).

The FIMS is comprised of two integrated subsystems: a computerized forest accounting system and a physical log tracking system. The forest accounting system allows for the collection, processing and logical (e.g., paper trace) validation of data. The forest accounting system can, for instance, trace the various operational steps through the value-chain of a log ready to be exported, from the actual allocation of a valid logging title, to pre-harvesting forest inventory, felling, skidding, transport, storage and finally loading onto a sea-going vessel or entering into wood-processing plants. Finished product (sawn wood, plywood, etc.) value-chains can also be

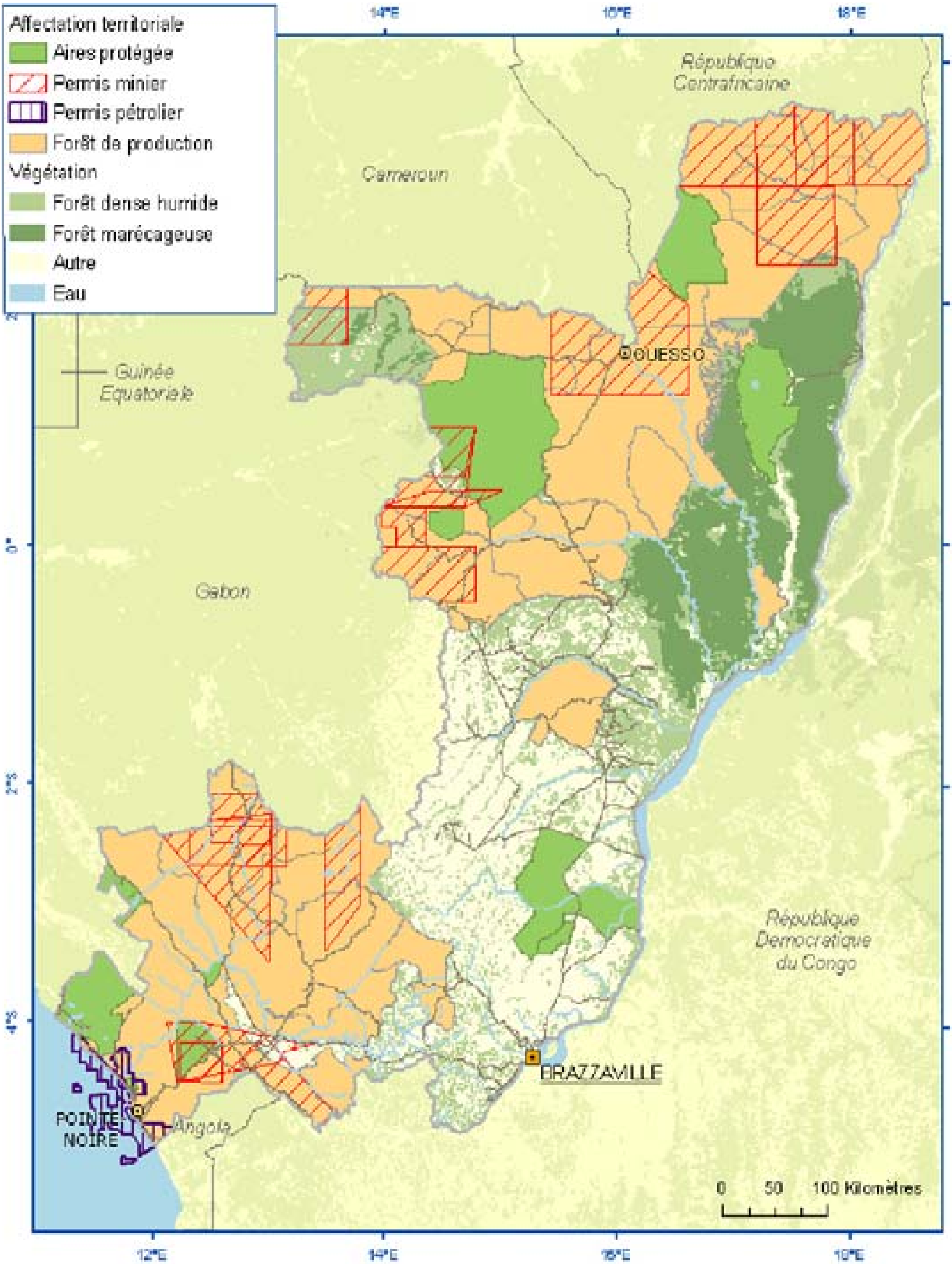


Figure 4: Distribution of production forests, protected areas, mining and oil permits in the Republic of Congo
Source : Spatial data and map developed through the Interactive Forest Atlas 1.0 for Congo.

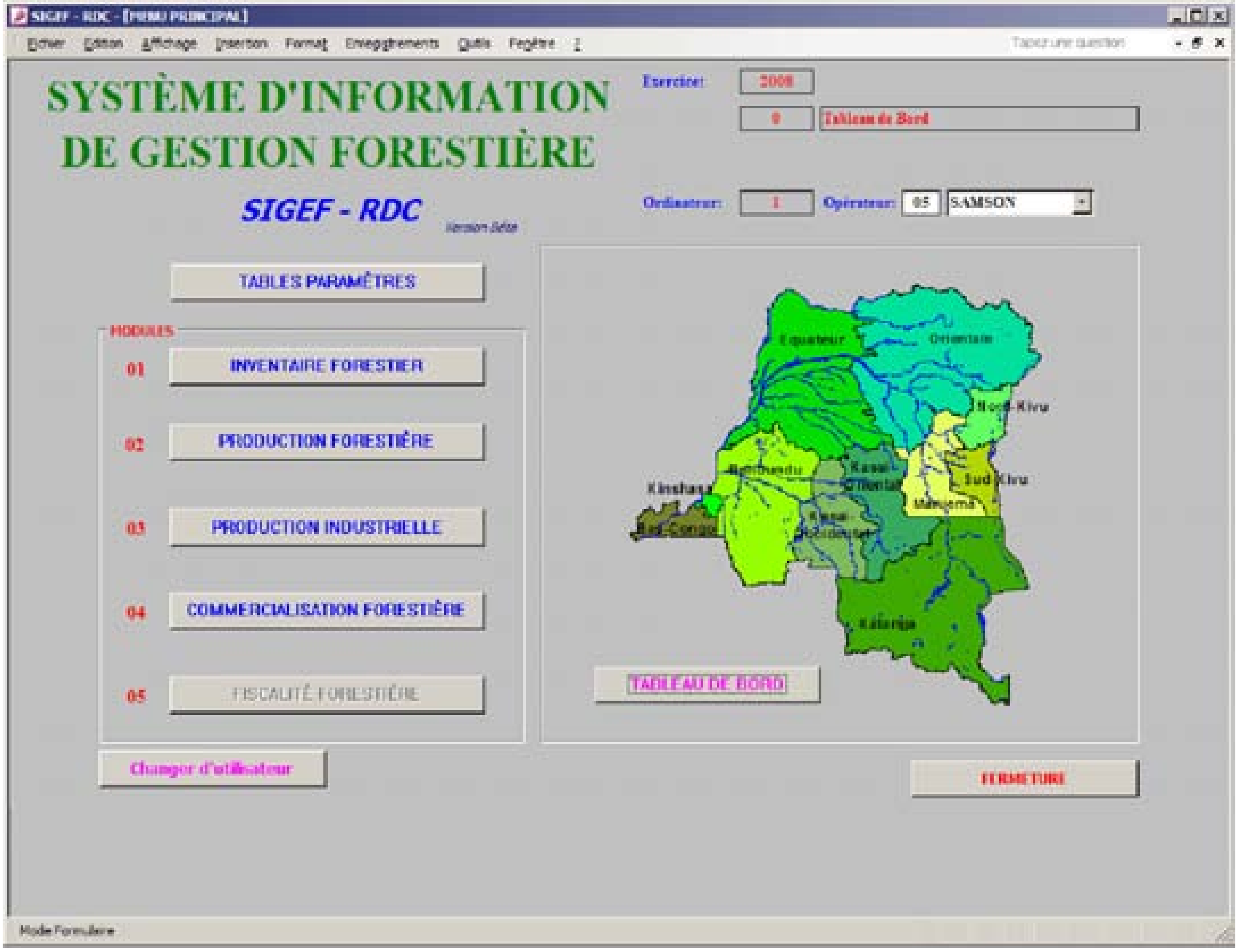


Figure 5. Presentation of FIMS database interface

tracked with the FIMS. The log tracking system allows for the actual physical field control of the validity of the data fed into the forest accounting system. Log tracking is thus one of the numerous required field verifications for a complete forest concession monitoring system. The log tracking system now in use in Central Africa is based on paint numbering on logs and a set of paper supports for every step of the value-chain, such as the DF10 in Cameroon to report volumes logged. More modern log tracking systems use bar-coding with hand-held computers to scan, verify and communicate the data directly to the forest accounting system.

Through deployment in all Ministry of Forestry departments and active logging companies, FIMS allows for the government to monitor logging activities much more effectively throughout the country as well as over time. Anticipated results include increased capture of forest tax revenue, improved monitoring of management plan implementation, and an overall reduction in illegal logging and corruption in the sector. When fully operational, the FIMS will enable countries like RoC and DRC more easily to meet the Voluntary Partnership Agreement (VPA)'s legality requirements being negotiated under FLEGT.

Support to FLEGT and forest certification processes

WRI has been providing direct and indirect support to FLEGT and forest certification initiatives in Central Africa notably through: a) the provision of spatial information on forest concessions (Interactive Forestry Atlases); b) FORCOMS legality and sustainable management indicators; c) development and deployment of FIMS; and d) participation in sub-regional meetings.

Results achieved

Interactive Forest Atlases – remote sensing, GIS and mapping

The use of the Interactive Forest Atlases as a tool, the dissemination of verified spatial and non-spatial data on logging titles to involved stake-holders and all levels of the forest administration, together with capacity building in remote sensing and GIS, has enabled the participating governments and collaborating partners to better monitor logging titles by :

- Assessing where illegal logging might have taken place in recent years;
- Improving administration capacities and knowledge for monitoring and control activities; and
- Enabling the administration to avoid future conflicts in forest production areas.

Over the course of working with the ministries in charge of forests in five countries of the sub-region over the past seven years, WRI has achieved some significant results towards improved definition of legality in the forest sector and the monitoring of logging titles. Some of the major achievements generated through these activities include :

- Versions 1.0 and 2.0 of the Interactive Forest Atlas in Cameroon and version 1.0 in RoC have helped these respective governments to resolve commercial disputes over boundaries between logging titles as well as between logging titles and protected areas.
- The Congolese Ministry of the Forest Economy has been able to make more efficient use of limited enforcement personnel and resources by using information contained within the Interactive Forest Atlas to identify suspected cases of logging encroachment and thus more effectively target field control missions by the Ministry's agents.
- In Cameroon, the Atlas data and derived products (i.e., maps, GPS points, satellite images, road datasets, etc.) are extensively used by CETELCAF (the Ministry of Forest technical unit in charge of producing forest title maps and definitions) and the Control Brigades in order to access information with improved accuracy, and plan and support field missions. One of the more notable examples was the identification of logging in the Mengamé Gorilla Sanctuary by the neighbouring concessionaire (see Figure 6).
- GIS mapping tools enabled the Congolese government to verify and revise the taxable area of each forest concession using standardized and objective GIS-based surface area calculations. This exercise led to an overall increase in forest tax revenues for Congo.
- As a result of extensive training in GIS and remote sensing, the Congolese Ministry of Forest Economics is now requiring all logging companies in the country to submit their annual logging coupe requests on a GIS platform (as opposed to paper-based).
- An analysis of the current status of forest title information conducted in Gabon provided the impetus for the Gabonese government to dedicate resources and personnel to collaborate with WRI in the verification and reconciliation of forest title spatial and non-spatial data.

Additionally, indirect but very important achievements through this work included the generation of political support vis-à-vis this decision-support tool and a change in mindset regarding its utilization in lieu of the existing antiquated and inefficient systems in place, as well as the willingness of the Forest Administrations to provide the information and allow for it to be made widely public. Those are very significant steps towards transparency and improved governance in the forest sector.

Finally, through a series of capacity-building and training activities related to remote sensing, GIS, mapping and GPS, the forest administrations have been reinforced.

Criteria and indicators (FORCOMS)

For numerous reasons, FORCOMS as a system remains non-operational. However, work under FORCOMS has provided impetus and support to the concept of regional frameworks and a step-wise process to forest certification schemes. Fur-

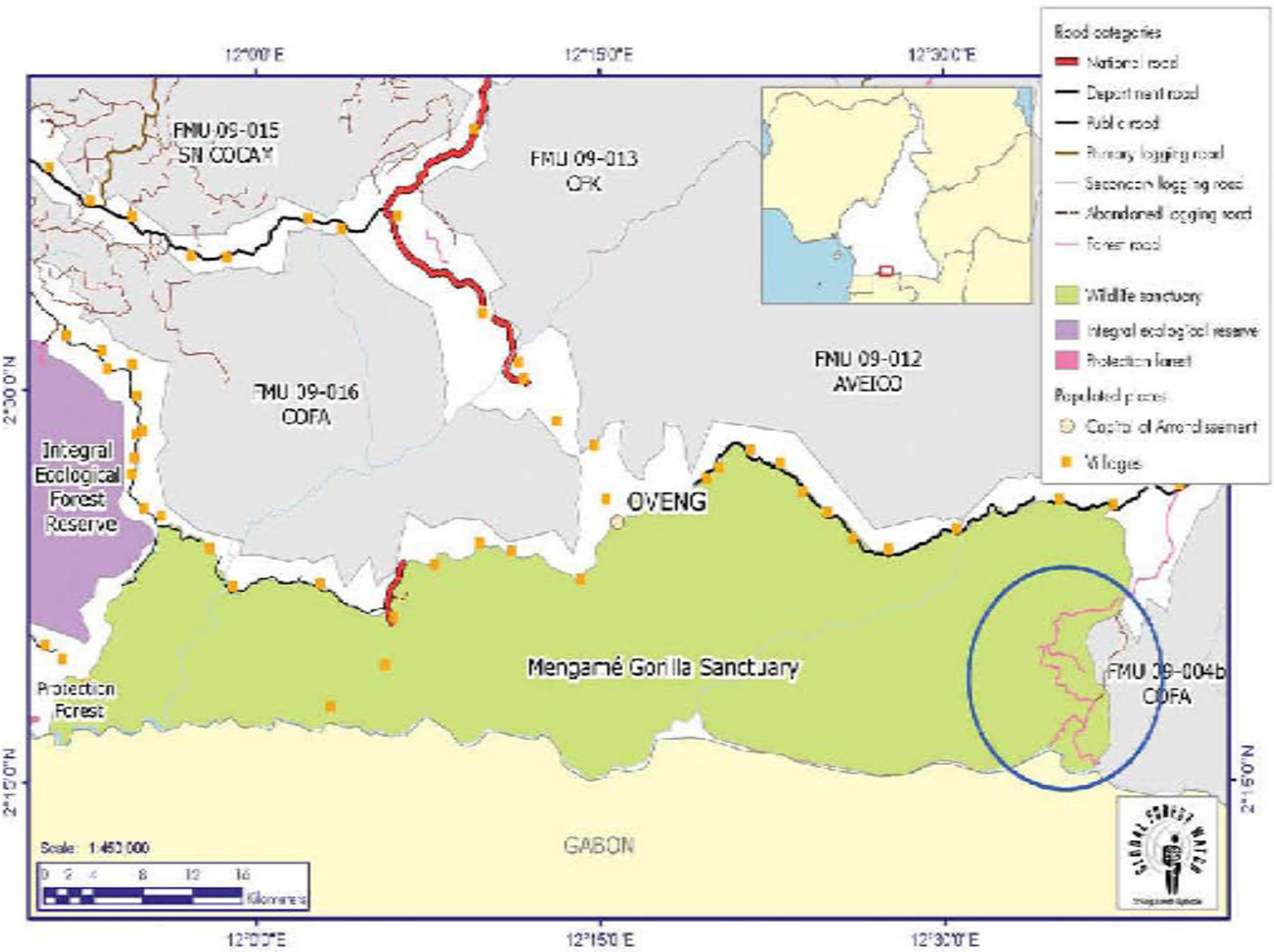


Figure 6. Presentation of logging road encroachment in a protected area in Cameroon
Source : Information and map from the Interactive Forest Atlas 1.0 for Cameroon.

thermore, it produced a complete set of indicators on legality and SFM that are being largely used by countries in the sub-region to develop their own national legality standards, notably in view of their upcoming FLEGT VPA negotiations with the EU.

Forest Information Management Systems (FIMS)

Much work has been invested up-front in the participative development of FIMS in both RoC and DRC with the host-country forest ministries, but only a test field deployment has been carried out so far. However, WRI work has thus far been limited to the forest accounting sub-system of the FIMS, with no action taken on field log tracking.

A pilot deployment of the forest accounting sub-system of the FIMS took place in the RoC during the first half of 2008, with full national implementation to begin following successful execution of the pilot. Implementation in DRC will follow that in RoC.

As with WRI's GIS and Interactive Forest Atlas work, the FIMS work has generated some initial indirect but very important achievements by generating political support for this decision-support tool as well as a change in mindset regarding its utilization in place of the existing antiquated and inefficient systems currently in operation on the one hand, and the willingness of the forest administrations to provide the information and allow for it to be made widely public on the other hand. Those are very significant steps towards transparency and improved governance in the forest sector.

Finally, through a series of capacity-building and training activities related to database management and forest statistics, the forest administrations have been reinforced.

Lessons learned – analysis and recommendations

The most important lessons that can be drawn from WRI's work over the past seven years in its forest monitoring activities are presented below.

Analysis

Limitations of monitoring tools

WRI's work in forest monitoring at large and with concession monitoring in particular has provided numerous practical and significant results. However, much more still needs to be done to ensure compliance with legality and SFM requirements by logging operators, as well as to better understand how current industrial logging practices are impacting the forest ecosystem in order to inform landscape and national resource management agendas. The bulk of WRI's activities revolve around the use of remote sensing, GIS and forest accounting system (databases) with only limited field control activities in support of data verification and ground control points.

While the Interactive Forest Atlases and FIMS are highly practical and effective tools, they are limited in the information they are able to provide with regards to forest concession monitoring on the ground as well as the real-time tracking of logging activities. For example, these methods are useful in determining where new roads are being built, ensuring there is no overlap between forest titles, keeping tabs on the status of forest concessions and titles, planning effective field missions, and tracking harvested logs. However, they are not directly capable of monitoring activities which are not detectable by satellite images (e.g., bushmeat hunting, overharvesting trees, creation of skidder trails, and other social and environmental obligations) or measuring change on a regular (weekly, monthly or semi-annual) basis. They are also of limited use for detecting illegal felling of individual trees by chainsaw operators. These other activities can only be detected through on-site field verification, and thus the Atlas and FIMS tools are most effectively used in conjunction with targeted field verification – each one complementing the other. Similarly, the FIMS has to include both the forest accounting and log tracking sub-systems in order to be fully efficient.

As shown in Table 1 above, by relying on satellite imagery and GIS-based monitoring tools, the process is inherently limited by the technological constraints. In our experience, depending on Landsat images for road detection has severely limited our ability to monitor forest concessions remotely, due primarily to the malfunction and subsequent discontinuation of Landsat 7 in 2003 and lack of an affordable and comparable substitute. Furthermore, even when the images are available, large swathes of the Congo Basin are rarely cloud-free enough to be effectively observable with visible band imagery. Another type of obstacle faced is the barrier that this technology may impose to certain users who are not computer-literate.

Limitations of the approach

Besides the technical questions identified above, there are constraints accompanying our chosen approach that limit our ability to tackle forest concession monitoring, especially for combating illegal logging. Indeed, this approach :

- Puts the emphasis on law enforcement while other tools, such as putting pressure on importers of CA timber products only to buy timber from legal and sustainable operations, for instance, could have a stronger impact;
- Does not tackle the issue of the legal and regulatory environment which may not allow proper determination of legality;
- Does not take into consideration illegal activities related to wood processing, timber trade, and financial management and flows;
- Does not properly define illegal logging;
- Is not able to deal with the legal and regulatory environment varying from one country to another, thus making it difficult to have a standardized approach to illegal logging in

CA (some activities that are illegal in one country could be legal in another);
- May be seen as taking over governments' responsibilities (e.g., law enforcement) and therefore as interference;
- Is hampered by widespread corruption in the sector;
- May not get cooperation from governments or logging companies ;
- Doesn't tackle the problem of political will i.e., if there is a lack of political will to enforce laws, no amount of tools or methods are going to be effective;
- May generate animosity and conflicts with logging companies as well as local populations with whom they have to work if we are perceived to be engaged in law enforcement activities aimed against them;
- Is in real danger of not being able to properly and completely identify the various illegal activities and thus being seen as incompetent or inefficient; and
- May be unwillingly perceived as green-washing certain logging companies since the monitoring is not capable of capturing all illegal activities and, as such, it may harm the international credibility of the programme.

In conclusion, a wide array of tools and actions are needed to be comprehensive and efficient in combating illegal logging. Table 2 provides a general schematic view of various factors allowing illegal activities to occur and identifies the different sets of actions and tools required to combat illegal activities.

Need for partnerships

The data required to perform forest concession monitoring has to come from various stakeholders including: the ministries in charge of the forest and their specialized services (such as the Service Permanent d'Inventaire et d'Aménagement Forestier in DRC or the Centre National des Inventaires et Aménagements Forestiers et Fauniques in Congo), the private sector (logging companies, the Société Générale de Surveillance), international NGOs (CI, WWF, AWF, IUCN, etc.), local NGOs and, finally, parliamentarians.

Solid and well-working partnerships between WRI and those main actors have to be established to ensure not only the collection of data but also the validation of the end-products, as well as the integration of the data and the tools developed by WRI into the decision-making process.

Recommendations

Taking into account the achievements to date, as well as the identified constraints and limitations, WRI proposes the following recommendations for future forest concession monitoring conducted under CARPE :

- Pursue the remote sensing, GIS and mapping activities and expand their scope both thematically and geographically;
- Pursue and intensify the FIMS work in both Congos, notably by also getting involved in the development and implementation of the log tracking sub-system and eventually by expanding to the sub-region. This will however require substantial new funding;
- Continue working on finding solutions to the lack of affordable cloud-free satellite images;
- Work to promote the involvement of new partners within the programme to assist the governments of the sub-region in conducting field verifications, in collaboration with other donors involved in that issue (such as the World Bank);
- Expand forest concession monitoring collaborations with complementary initiatives (e.g., REM, Global Witness), where feasible; and
- Work on ensuring continued strong political will so that the tools are fully incorporated in the decision-making processes.

Table 2. Main tools and actions to combat illegal logging

	Factors allowing illegal activities to occur	Typical example of illegal activities or problems generated in producing countries	Tools of actions to combat illegal logging					
			Remote Sensing, GIS and PIMS	Field Monitoring (including log tracking)	Capacity Building	Advocacy and public information	Policy, law and regulation changes	Stakeholders convening and dialogue
Within producing countries								
a)	Lack of legislation	Inappropriate and unfair allocation of forest concessions			X	X	X	
		Inappropriate and unfair allocation of other logging rights			X	X	X	
		Unsustainable extraction (no forest management plan)			X	X	X	
		Unfair benefit sharing of the use of the forests			X	X	X	X
		Socially or environmentally damaging operations			X	X	X	
		Difficulties in defining what is legal or illegal			X	X	X	
		Unenforceable regulations			X	X	X	
b)	Lack of law enforcement	Company is not legally authorized to do logging	x (PIMS)	X				
		Logging outside authorized areas (concession or annual coupes)	X	X	X (GIS)			
		Logging above allocated or authorized volumes	x (PIMS)	X				
		Logging forbidden or unauthorized species	x (PIMS)	X				
		Tallying wrong species to pay less taxes		X				
		Underscaling of volumes logged to pay less taxes		X				
		Not reporting all volumes logged		X				
		Not respecting all clauses of concession contract		X				
		Not paying taxes due (area taxes, felling, export taxes, corporate, etc.)		X				
		Transporting timber products without proper authorization		X				
c)	Lack of governance	All illegal activities listed in a) and b) above			X	X		X
d)	Lack of knowledge and information sharing	Inappropriate and unfair use of natural resources			X	X		X
		Inequity in benefit sharing			X	X		X
		All illegal activities listed in b) as logging unchecked			X	X		X
		Conflicts over use of forest resources			X	X		X
Within consuming countries								
e)	Lack of legislation	All illegal activities and problems in a), b) and c) above				X	X	X
f)	Lack of corporate accountability	All illegal activities and problems in a), b) and c) above				X		X
g)	Lack of legal verification and monitoring systems	All illegal activities and problems in a), b) and c) above	X	X	X	X	X	X
Within both producing and consuming countries								
h)	Lack of dialogue and engagement	All illegal activities and problems in a), b) and c) above				X		X
i)	Lack of appropriate technology	All illegal activities and problems in a), b) and c) above	X	X	X			

Annex

Acronyms and abbreviations

AFLEG African Forest Law Enforcement and Governance

AWF African Wildlife Foundation

CARPE USAID's Central Africa Regional Program for the Environment

CETELCAF Centre de Télédétection et de Cartographie Forestière

CI Conservation International

COMIFAC Commission des Forêts d'Afrique Centrale

FIMS/SIGEF Forest Information Management System

FLEGT Forest Law Enforcement, Governance and Trade

FORAF Forêts d'Afrique (EU-funded project)

FORCOMS Forest Concession Monitoring System

IUCN International Union for Conservation of Nature

GIS Geographical Information System

GPS Global Positioning System

NGO Non-governmental Organization

REDD World Bank programme: Reduce Emissions from Deforestation and Degradation

REM Resource Extraction Monitoring

SFM Sustainable Forest Management

USAID United States Agency for International Development

VPA Voluntary Partnership Agreement (component of FLEGT)

WRI World Resources Institute

WWF World Wildlife Fund

Case study 3 - The Use of Satellite Mapping and GIS to Support Large Scale Conservation : Lessons Learned from the Carpe Program

Alice Altstatt, Diane Davies, Paya deMarcken, Chris Justice, Erik Lindquist, Minnie Wong

Introduction

Establishing a reliable baseline of forest extent and monitoring forest cover change across the Congo Basin is critical to evaluating the progress of CARPE towards meeting its strategic objective of reducing the rate of forest degradation and loss of biodiversity. Satellite-derived maps and geographical information systems (GIS) provide spatial information and analytical tools essential for large-scale conservation planning and effective monitoring of Congo Basin forests. Analytical tools, such as GIS, help conservation planners integrate geospatial data on land cover, population centres and ecology to inform planning and policy decisions. Remote sensing (RS) provides the capacity to monitor the impacts of conservation initiatives on land cover and land use, which in turn relate directly to forest resources and biodiversity.

The Food and Agriculture Organization of The United Nations (FAO) compiled the Africover geospatial database in response to the lack of information on land cover for Africa and in recognition that this deficit limits planning, development and sustainable management of renewable natural resources. Africover includes feature datasets and land cover classifications that are derived from the visual interpretation of high resolution satellite imagery acquired between 1994 and 2001. These data are a significant mapping contribution, but they are not available for all CARPE countries, nor can they at present provide rates of forest cover change. The FAO Forest Resource Assessments (FRAs) provide statistics on forest cover, derived primarily from "best estimate" information provided by national forest ministries, although those published for 1990, 2000 and 2005 are supplemented by analysis of samples of multi-temporal satellite data to estimate deforestation rates. Variability in forest categories and methodologies between assessments makes it difficult to make statistical comparisons. The FRA data are not spatially explicit, making them less useful for baseline assessments, monitoring rates of deforestation on subregional scales or evaluating the effect of specific programmes in reducing the rate of deforestation within the Congo Basin Forest Partnership (CBFP) landscapes.

In order to address these shortfalls and produce the detailed and spatially explicit information necessary to support CARPE's conservation initiatives in the CBFP landscapes, CARPE has supported satellite mapping of forest cover in the Congo Basin and worked with CARPE partners to use geospatial data. The geospatial datasets produced under CARPE have broader applications beyond the programme's objectives.

The following sections summarize land cover mapping using remote sensing in the Congo Basin and describe recent developments in forest monitoring at the Basin level, including a discussion on the availability of remote sensing data. There is an overview of GIS applications within CARPE and the development of GIS/RS capacity in the region. Finally, lessons learned regarding the importance of GIS/RS for CARPE as a basin-wide regional conservation initiative are summarized.

Satellite mapping for Central Africa

Since the 1970s, earth observing satellites have provided data suitable for mapping land cover. These remotely sensed data have become the predominant means of mapping humid tropical forest on global and regional scales. Remote sensing data offer numerous advantages over ground-based data: large area coverage; collection over remote, inaccessible areas; internally consistent and repeatable measurements; systematic and continuous data acquisition; and, compared to labour-intensive field data collection, low cost. When coupled with corroborative ground-based data and improved geolocation methods, remote sensing data provide the means to produce vegetation maps of unprecedented precision and accuracy. Because remote sensing data capture biophysical and structural vegetation traits, the derived thematic classes are more general relative to the floristic detail that can be collected in ground-based surveys.

There are two classes of satellite[1] optical data used for global, continental and regional land cover monitoring: moderate (200–300 m) to coarse (1 km) spatial resolution data with daily/frequent global coverage, e.g., AVHRR, MODIS, SPOT VEGETATION; and high (15–30 m) spatial resolution data, e.g., Landsat and SPOT HRVIR, with repeat cycles of 2–3 weeks. The frequent acquisitions of the low resolution data increase the likelihood of collecting cloud-free data, which is particularly important for monitoring Central Africa due to persistent cloud cover in the western Congo Basin. Frequent data acquisitions enable depiction of vegetation phenology (seasonal effects) which can be very useful in discriminating vegetation types. However, moderate and coarse spatial resolution data with daily coverage cannot capture the fine scale changes in the forest domain resulting from shifting agriculture, a predominant driver of deforestation in the Congo Basin. Likewise, logging roads are often only detected in high spatial resolution imagery and may be the only indication of selective commercial logging activity. Thus, both low and high spatial resolution data have information of value in monitoring forest cover within an environment such as the Congo Basin.

A number of land cover characterizations of Central Africa have been derived primarily from satellite optical data, either specifically for the Congo Basin, or as part of larger mapping projects. A global tropical forest inventory, the Tropical REsources and Environment monitoring by Satellite (TREES), was undertaken by the European Commission Joint Research Centre (JRC) and the European Space Agency (ESA) in support of the International Geosphere-Biosphere Programme (IGBP). That project produced a 1:5,000,000 vegetation map of Central Africa from 1 km (Local Area Coverage) and 5 km (Global Area Coverage) AVHRR data acquired in

[1] A list of acronyms and a table of earth observing satellites that provide data for vegetation mapping is provided in Appendix 1.

A. SPOT VEGETATION (1 km) **B.** MODIS (250 m) **C.** Landsat (30 m)

Figure 1. Examples of satellite data used for vegetation mapping at different spatial resolutions

1992 and 1993 (Mayaux et al., 1999). In support of CARPE, a similar land cover map was also prepared from multi-temporal, multi-resolution AVHRR data acquired during the 1980s and early 1990s (LaPorte et al., 1998). The Global Land Cover (GLC) 2000 project of the JRC produced a 1 km land cover map of the entire African continent from SPOT VEGETATION year 2000 data, supplemented by radar data to map flooded forests and a Digital Elevation Model to identify montane forests (Mayaux et al., 2004). The Université Catholique de Louvain (UCL) produced a more detailed land cover classification for the Democratic Republic of Congo (DRC) also based on SPOT VEGETATION data from the year 2000 (Vancutsem et al., 2004). A 300 m resolution global land cover map, (GlobCover 2005) derived from Envisat MERIS data, is being produced by ESA in partnership with UNEP, FAO, JRC, the European Environment Agency (EEA) and GOFC-GOLD (Global Observation of Forest and Land Cover Dynamics).

Satellite radar data are also useful for mapping humid tropical forests because of the ability of the radar signal to penetrate cloud cover, to discriminate inundated forest from terra firma forest and to estimate forest biomass from radar interferometry. Processing and analysis of radar data are considerably more complex than for optical data. There have been two efforts to collect, process and derive forest maps from satellite synthetic aperture radar (SAR) data across the Congo Basin. The ESA/European Commission Central Africa Mosaic Project (CAMP) used C-band (3 cm wavelength) data from the European Remote Sensing (ERS) satellites, and the National Space Development Agency of Japan Global Rain Forest Mapping (GRFM) project relied on L-band (23 cm) data from the Japanese Earth Resources Satellite (JERS-1). Both of these mosaic datasets were used to produce vegetation maps for Central Africa that distinguished periodically and permanently flooded forest from lowland forest (Mayaux et al., 2002).

In recognition that discrete categorical depictions of forest cover in the maps described above can vary depending on forest definition, a global map of proportional tree cover at 1 km was produced from AVHRR data (DeFries et al., 2000). A similar approach was subsequently applied to MODIS data to produce a 500 meter resolution global percent tree cover map (Hansen et al., 2003). This Vegetation Continuous Fields (VCF) method was modified to create a 250 m resolution percent tree cover map specifically for the Congo Basin (Hansen et al., 2008). This map was consolidated with the GLC 2000 map to provide an initial survey of the Central African forest for State of the Forest 2006 (CBFP 2007).

Detection and mapping of the fine-scale forest cover changes that are characteristic of the Congo Basin require imagery with a spatial resolution of less than 100 m. The NASA Landsat Pathfinder Humid Tropical Deforestation Project was a collaborative effort by the University of Maryland (UMD), the University of New Hampshire, and the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center to map deforestation using Landsat data (30 m resolution) for three epochs (1970s, 1980s and 1990s) in Southeast Asia, the Amazon Basin and Central Africa. Production of forest cover maps from these data was time-consuming and labour-intensive, but the primary limitation for mapping deforestation was a lack of sufficient cloud-free data for each time period. Nonetheless, the data archive compiled by the Pathfinder Humid Tropical Deforestation Project has been essential for subsequent high resolution mapping efforts.

An alternative approach to exhaustive, i.e., "wall to wall", forest cover change mapping is to employ a sample-based method such as the systematic sampling scheme developed by JRC/UCL for estimating forest cover change. This approach used 10 km x 10 km subsets of Landsat data from 1990 and 2000 distributed every ½ degree across the Central African forest domain to derive rates of deforestation, reforestation, forest degradation and forest recovery (Duveiller et al., 2008). The FAO has proposed using this sampling strategy for future global FRAs. For this method to be effective in a region like the Congo Basin where forest cover change is relatively rare, a large number of samples must be obtained in order to produce estimates with reasonable levels of uncertainty. For the purposes of CARPE, where the areas of interest, the landscapes or macrozones, can be relatively small, estimates of change derived by this method would not be sufficient.

Recent Congo Basin forest cover and change mapping under CARPE: methods and results

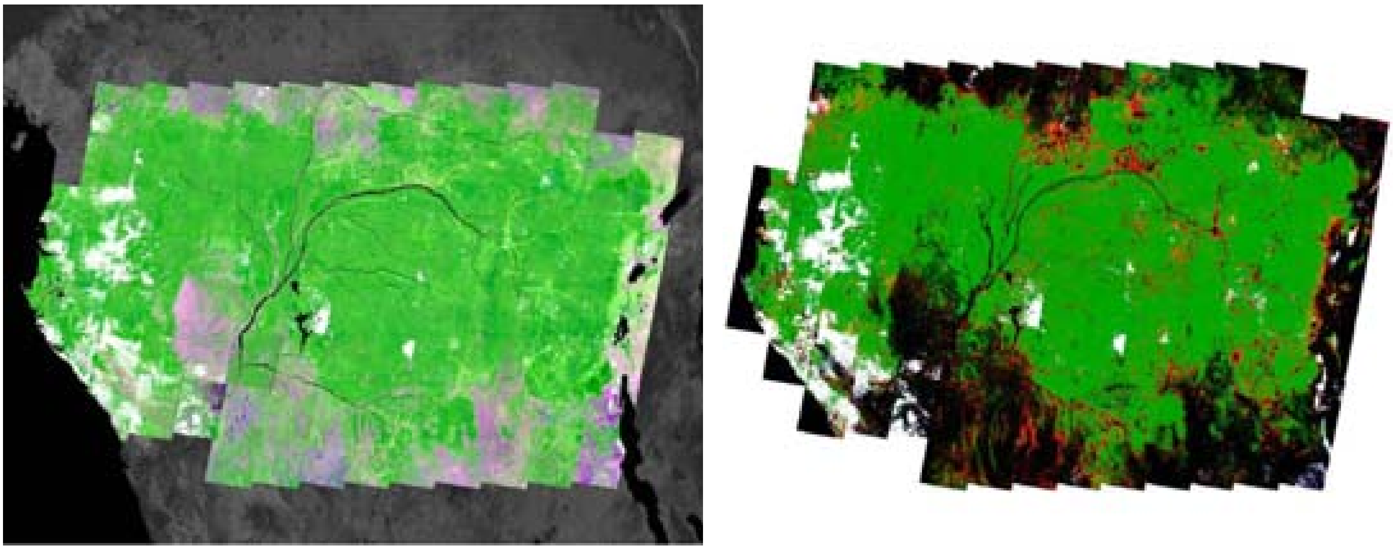
CARPE has supported the development of a sophisticated, innovative method to map forest cover and forest cover change exhaustively across the Basin which combines a consistent regional characterization of forest derived from MODIS data with spatially detailed forest cover and cover change derived from Landsat data (Hansen et al., 2008). The Decadal Forest Change Mapping (DFCM) project automatically maps a forest likelihood variable and forest cover change across the Congo Basin at 57 m, a resolution that is adequate to capture the small-scale changes in forest cover that are characteristic of this biome.

A 250 m resolution land cover map was produced from multi-temporal (2000–2004) MODIS data for the Congo Basin. The MODIS land cover map provides reference data to automatically derive land cover characterizations from Landsat imagery. Multiple Landsat acquisitions are included for each image tile to compensate for cloud cover. Two epochs of Landsat data, circa 1990 and circa 2000, are used to produce a forest likelihood map and map of forest cover change between the two time periods. The result is a consistent high resolution depiction of forest cover and forest cover change for the entire Congo Basin. It is the first spatially explicit high resolution representation of forest cover change ever produced for this region.
kelihood value of greater than or equal to 50 percent. Forest cover change is determined by a specific DFCM algorithm. Where persistent cloud cover obscured the Landsat mosaic, MODIS forest cover data were used to augment the calculation of forest cover area and loss. The landscape boundaries available as of 5 September, 2008 were used for these calculations.

The consistent basin-wide characterization of forest cover and forest cover change permits the derivation of comparable statistics at regional,

[2] Forest likelihood is a measure of the probability, from 0–100%, that a given mapping unit, in this case a 57 m square pixel, meets the definition of closed canopy forest. A continuous variable, rather than a categorical depiction, allows the data user to delineate subsets of forest based on user-defined thresholds. Forest cover change, on the other hand, is defined by a DFCM algorithm and is assigned a unique value. The forest cover data presented here are based on a forest likelihood value of greater than or equal to 50 percent.

[3] Landsat data is acquired in a fixed pattern of tiles across the earth's land surface. Each tile is referenced by path (the orbital ground track) and row (image segment).



A. DFCM multi-spectral 1990s to 2000s Landsat composite image for the Congo Basin superimposed on a grey-scale MODIS image

B. Forested area of the Congo Basin derived from Landsat imagery using the DFCM process (green is forest, black is non-forest). Areas of forest cover change detected between the 1990s and 2000s epochs are shown in red, enhanced for easier viewing. White areas within each mosaic were obscured by cloud cover in either or both of the time periods.

Figure 2. Forest cover and forest cover change in the Congo Basin (1990s–2000)

national and local levels. The spatially explicit data enable analysis of forest cover change processes at different scales, including investigations of local drivers of deforestation which are important for land-use management decisions. For example, in the DRC between 1990 and 2000, nearly 98 percent of all forest change took place within 2 km of a pre-existing forest clearing and approximately 50 percent of all forest clearing occurred within 6 km of a major road. These preliminary results reflect what is visually apparent in the data: most of the deforestation is the result of expansion of the rural complex (the mosaic of settlements, fields and degraded forest which exists along the road networks) into the forest.

A. Agricultural expansion into upland forest areas – flooded forest is avoided

B. Expansion of the rural complex and logging roads north of Bumba

C. Forest loss near Virunga National Park – as forest is lost outside the park, pressure on forest resources within the park increases

Figure 3. Examples of forest cover loss from circa 1990 to circa 2000, shown in red, overlaid on a multi-spectral Landsat composite from the same time period

CBFP Landscape	Landscape area (km²)	1990 Forest cover (km²)	2000 Forest cover (km²)	1990–2000 Forest cover loss (%)	2005 Forest cover (km²)	2000–2005 Forest cover coss (%)
Monte Alén-Monts de Cristal	26,725	26,229	26,101	0.49	NA	NA
Gamba-Mayumba-Conkouati	46,549	29,153	28,709	1.52	NA	NA
Lopé-Chaillu-Louesse	34,925	33,845	33,647	0.59	NA	NA
Dja-Odzala-Minkébé Tri-National (TRIDOM)	192,403	186,065	185,729	0.18	NA	NA
Sangha Tri-National (TNS)	44,134	42,820	42,743	0.18	42,607	0.32
Léconi-Batéké-Léfini	36,077	7,073	6,968	1.48	NA	NA
Lac Télé-Lac Tumba	131,292	100,285	99,366	0.92	99,177	0.19
Salonga-Lukenie-Sankuru	104,670	101,570	101,198	0.37	100,034	0.26
Maringa–Lopori-Wamba (MLW)	72,693	68,756	68,162	0.86	67,938	0.33
Maiko-Tayna-Kahuzi-Biega	106,210	92,376	91,404	1.05	90,600	0.88
Ituri-Epulu-Aru	41,045	39,663	39,449	0.54	39,310	0.35
Virunga	17,465	3,480	3,279	5.79	3,143	4.14

Regional analysis of the DFCM data shows a 1.4 percent overall decrease in forest cover in the Congo Basin from the 1990s to the 2000s. This corresponds to a loss of 25,720 km2 of an original forested extent of 1.8 million km2 at a rate of 0.14 percent per year (Lindquist et al., in preparation). This estimate is smaller than but close to the sample-based change estimate of Duveiller (2008) of 0.22 percent per year from 1990 to 2000. Given the very different methodological approaches, and the heterogeneous, fine scale nature of change within the Congo Basin, the relative agreement of the two estimates is an encouraging sign for monitoring within this environment. In the DRC, 19,575 km² of forest was converted from an original extent of 1.1 million km². This represents a 1.83 percent decrease in forest cover from the 1990s to the 2000s.

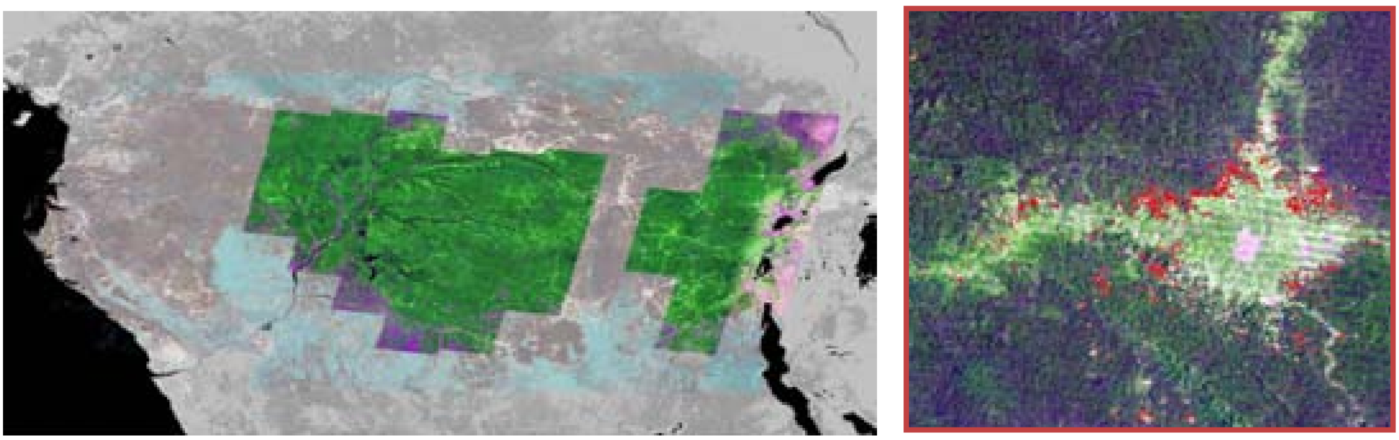
Table 2. Forest cover and forest loss between circa 1990 and circa 2000 inside and outside protected areas in the Democratic Republic of Congo

Forested region	1990 forest cover (km2)	2000 forest cover (km2)	Forest cover loss (km2)	Forest cover loss (%)
DRC	1,110,092	1,090,517	19,575	1.83
Inside protected areas	147,004	146,006	998	0.68
Outside protected areas	941,088	920,418	20,670	2.20

Mid-decadal Landsat composites and change detection

Because the DFCM method is an automated procedure, the maps can be updated as additional data become available. Work is currently underway to produce forest cover change maps for 2000–2005 from recent Landsat imagery, despite the Scan Line Corrector (SLC) failure of the ETM+ sensor which causes significant gaps in the data rendering about 22 percent of each image unuseable. While many researchers have purposely avoided using the Landsat SLC-off data, the DFCM approach generically handles the data gaps to create products for the 2000–2005 epoch.

Mid-decadal Landsat mosaics have been completed for over 60 percent of the Basin and seven of the 12 CBFP Landscapes. Landsat image tiles for which multiple acquisitions are available produce more consistent results (e.g., free of scan gaps and scan line artifacts) than tiles without such data richness. Figure 4 shows the current extent of the mid-decadal forest cover map for the Congo Basin with an example of forest cover change as detected using the automated DFCM algorithm. Quantitative estimates of basin-wide mid-decadal forest change are currently being developed.



A. DFCM multi-spectral 2005 Landsat composite for image tiles processed to date using the DFCM algorithm. The 2000 Landsat DFCM mosaic is in the background to show the total extent of the study area. A MODIS map of Central Africa provides the backdrop

B. Example of forest cover loss (in red) detected between 2000 and 2005 for a site in eastern DRC (red box on larger map).

Figure 4. Mid-decadal forest cover map for the Congo Basin with an example of forest cover change

Additional forest characterizations – degraded and flooded forest

Distinguishing degraded (secondary) forest from mature (primary) forest is important for habitat conservation, biodiversity, and estimation of carbon stocks. Since the DFCM forest cover is represented as a continuous variable, it is theoretically possible to initiate characterization of a degraded forest class based on thresholds of forest likelihood values. Forest likelihood values were compared for field plots classified as forest, non-forest or degraded forest as from an FAO National Forest Inventory of Cameroon. There was a clear separation of forest likelihood values for forest and non-forest plots, but degraded forest plots comprised a wide range of values which overlap the forest plot values. Work is continuing on the characterization of a degraded forest class.

Flooded forest is a crucial cover theme for modelling regional hydrology, assessing habitats and biodiversity and understanding human impacts on the forest environment. Most deforestation occurs within *terra firma* forests, due to greater agricultural suitability and easier access. Flooded forests can be difficult to discriminate from terra firma forests on the basis of optical (reflected) data alone. A method currently being implemented, with support from CARPE, employs Landsat image mosaics, elevation data and derived hydrographical parameters from Shuttle Radar Topography Mission (SRTM) data, and radar data to map wetlands, including forested wetlands, across the Basin at 57 m.

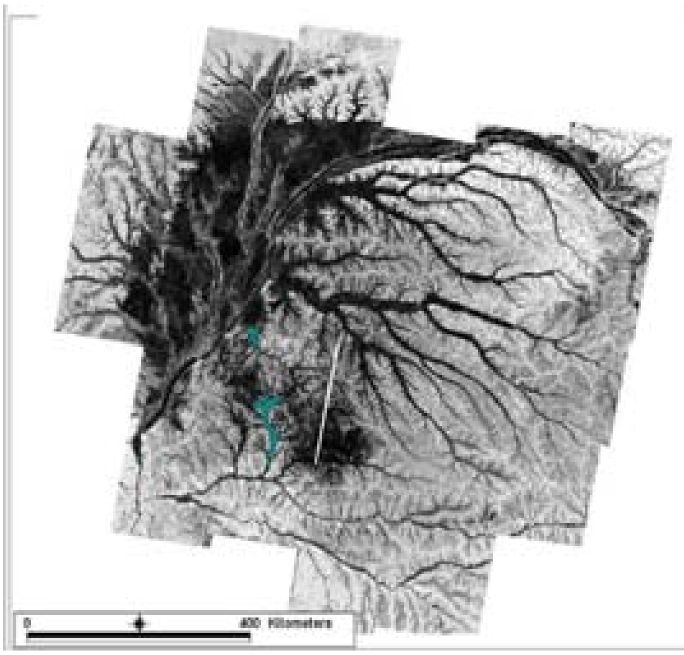


Figure 5. Preliminary wetland mask for the central Congo Basin

Key : Dark values indicate high likelihood of wetland occurrence, bright values are low likelihood. Lakes Tumba and Mai Ndombe are overlain.

As a suite of products, the forest cover, forest cover change, degraded forest and flooded forest maps will be valuable inputs for land-use planning, regional policy decisions, carbon accounting initiatives and climate modelling. They will also help to meet the goals of international monitoring programmes, such as the United Nations Framework Convention on Climate Change (UNFCCC) Reducing Emissions from Deforestation and Degradation (REDD) initiative.

Remote sensing data access

The success of RS-based forest mapping efforts has demonstrated the utility of satellite data for land cover mapping in Central Africa. Recent technological advances have made it easier to process large amounts of data, and methodologies for deriving vegetation characterizations continue to improve. Limitations to the derivation of more timely and accurate forest cover characterizations are primarily related to data access. Researchers typically use the data they can afford, not the data they truly need for implementing rigorous monitoring schemes. Therefore, it is paramount that future data policies ensure the regular delivery of the data required to meet policy goals. While some recent developments suggest a more liberal era of data access, the major hurdle to producing new satellite-based maps to date has been the cost of acquiring remotely sensed data.

NASA provides MODIS datasets for free through the United States Geological Survey (USGS) Land Processes Distributed Active Archive Center, and the National Oceanic and Atmospheric Administration (NOAA) AVHRR-derived Normalized Difference Vegetation Index (NDVI) is freely available via the Global Land Cover Facility. SPOT VEGETATION data that have been archived for three months or longer are also available free of charge. However, as mentioned previously, higher spatial resolution data are required to map the forest cover changes that occur in the Congo Basin.

The NASA/USGS Landsat series of satellites have been the workhorses for high resolution forest cover mapping since 1972. Landsat 5, launched in 1984, is still operational, but data must be directly downlinked to ground stations in view of the satellite, i.e., there is no on-board storage of data. Currently, due to the absence of a ground station in the region, there has been no collection of Landsat 5 data over most of the Congo Basin since 1999. The NASA/USGS Mid-Decadal Global Land Survey (MDGLS) initiated two limited Landsat 5 data acquisition campaigns which included part of the Congo Basin in 2008, downlinking to an ESA ground station in Malindi. However, this ground station will most likely not operate continuously due to technical challenges and the fact that the Landsat 5 sensor is likely to fail due to its advanced age. Landsat 7 was launched in 1999 and produced well calibrated, high quality images until May 2003 when the sensor SLC failed. As a result, there are linear gaps in the images which cause a 22 percent loss of data in any given image. Aside from the data gaps, the image quality remains unaffected, but additional images are required to compensate for the gaps. Meanwhile, the NASA/USGS Landsat Data Continuity Mission is striving to have a new Landsat satellite launched in 2011.

Until very recently, Landsat data have not been generically free, and pricing and distribution policies have varied over the duration of the programme. CARPE and its partners have benefited from NASA-funded acquisitions of Landsat data, under the Pathfinder project and the Science Data Purchase for the production of the GeoCover datasets. The GeoCover data consist of select, orthorectified Landsat scenes for the 1970s, circa 1990 and circa 2000, with near global coverage for each epoch, that are made freely available. These data sets are being reprocessed, with improved geometric and topographic inputs, under the USGS GLS project. In addition, the MDGLS is producing another global orthorectified Landsat dataset, the Global Land Survey 2005 (GLS 2005), from Landsat 7 and Landsat 5 data. Both the GLS 2000 and the GLS 2005 datasets for Africa are freely available for download from the USGS Glovis website (http://glovis.usgs.gov) as of March 2008. As of December 2008, the USGS is providing Landsat 7 archival data (both SLC-off and SLC-on) and Landsat 4 and 5 archival data at no charge through the Glovis website. New Landsat 7 and Landsat 5 images are also made available shortly after they are acquired This is a significant positive development for forest cover monitoring under the CARPE programme.

Cloud cover will always be an issue for the Congo Basin, and full access to the entire Landsat archive will greatly facilitate the production of a mid-decadal forest change map for Central Africa. Other optical data can supplement the Landsat data. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data has been acquired over the Congo Basin by UMD through the NASA Science Data Purchase, and will be used for filling data gaps for the DFCM method. ASTER scene footprints are approximately 1/9 the size of a Landsat scene and data acquisition is not systematic. Although thousands of scenes have been acquired over the Congo Basin since the sensor was activated in 2000, large areas remain for which there is no useable ASTER data. The Indian Remote Sensing Resource-1 Satellite (IRS) and SPOT HRVIR provide data that are suitable for forest mapping but the data are currently prohibitively expensive. IRS data at 50 m also offers the added advantage of obtaining several acquisitions per month. China and Brazil announced in November 2007 that they would make China Brazil Earth Resources Satellite (CBERS) data available to African countries, but the mechanism for data acquisition and transfer for Central Africa has not been established.

To meet the needs of CARPE, radar data may provide the best opportunity for monitoring CBFP landscapes in persistently cloudy regions. SAR C-band instruments are on two ESA satellites: Envisat and ERS-2. A radar instrument with multiple polarization capability (Phased Array type L-band Synthetic Aperture Radar or PALSAR) is on board the Japanese Advanced Land Observing Satellite (ALOS), launched in January 2006. A systematic observation strategy is planned for PALSAR in order to produce a consistent, global time-series data set. The ESA and Japanese data can be made available to researchers on a limited basis. A commercial SAR satellite, RADARSAT-2, was launched in December 2007.

GIS and CARPE

The integration of remote sensing products with other geospatial data using GIS can provide useful information for conservation and natural resource management. Within CARPE, GIS has been used to compile, model, analyze and disseminate geospatial data. Outputs in the form of digital and hard copy maps are used for orientation, education, community discussion and mapping, visualizing land cover and land use, highlighting areas of forest change, and land-use planning.

When CARPE was first authorized in 1995, there was a dearth of geo-referenced data for the Congo Basin. Initial data collection efforts focused on collating and digitizing the locations of towns and settlements, as well as road features from paper maps or Landsat images. Currently, there are many more sources of geospatial data for Central Africa (Box 1), but these datasets are not always compatible, and depending on the scale of the application, datasets may be too coarse or imprecise. To help users determine what data are available, and whether they are suitable for a specific application, CARPE II placed more emphasis on the collection and sharing of geospatial data from and between CARPE partners. UMD established CARPE Data Explorer to facilitate this process (see Box 2).

BOX 1. GEOSPATIAL DATASETS CURRENTLY AVAILABLE FOR CENTRAL AFRICA

- ESRI (Environmental Systems Research Institute) global datasets
- UNEP-WCMC (World Conservation Monitoring Centre) and IUCN (International Union for Conservation of Nature) World Database on Protected Areas
- UN FAO Africover
- UCL maps of the Democratic Republic of Congo
- World Resources Institute (WRI) Forestry Atlases for Cameroon, the Republic of Congo and Democratic Republic of Congo (coming soon)
- Data at the landscape level from NGOs and in-situ projects, including ECOFAC (Ecosystèmes Forestiers d'Afrique Centrale)

An on-line central data repository allows users to easily determine if geospatial data is available and suitable for their needs, and provides data access. For geospatial data to be of real value, ancillary information, or metadata, must accompany the geospatial data. Metadata, at a minimum, should include: spatial extent, projection, datum, information on when and how the data was created, and an explanation of attribute fields. Metadata is often compiled as an afterthought when data collection is completed and unfortunately, when resources are limited, the creation of adequate metadata is not a priority. Partners may be reluctant to contribute geospatial data through the CARPE Data Explorer due to a lack of adequate metadata, or the datasets are

Key datasets are those that relate directly to CARPE activities; they include priority landscape boundaries, population centers, hunting camps, roads, rivers, protected areas, logging and oil concessions, flora and fauna inventories, habitat assessments, and more recently delineations of the land use management zones.

incomplete or partners are waiting to publish results. Datasets are sometimes revised by partners but not re-submitted in a timely fashion. The end result is that many GIS datasets held at CARPE are out-of-date or do not reflect new information. USAID has encouraged more sharing of GIS data within CARPE, requiring that geospatial data (e.g., shape files) be submitted as part of the MOV (means of verification) documents.

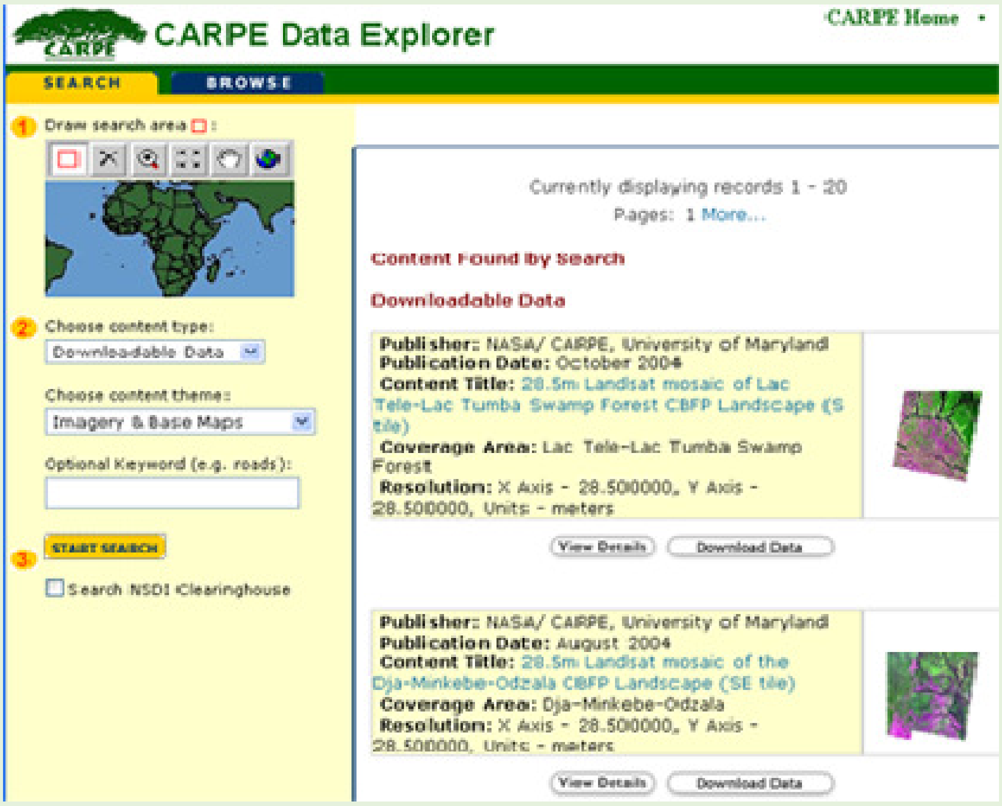
GIS integrates RS data and results with other geospatial datasets, which is critical for CARPE monitoring and reporting. Using GIS it is possible to analyze changes in forest cover by, for example, landscape, protected area, administrative area, watershed or distance from roads. An examination of the spatial variability of forest cover change helps to understand drivers of land cover change such as human population distribution, land-use practices, resource management policies, and socio-economic factors.

One of the most useful outputs from GIS are maps that integrate satellite imagery, forest change and local feature data to provide users with a bird's-eye view of the landscape. These maps have proved to be a powerful tool for interpreting land cover and land-use dynamics, as images reveal detail that cannot possibly be represented by strictly cartographic elements. The maps have been used for field work, engaging local communities and have provided focal points for discussion. An example of such a map produced for CARPE is shown in Figure 6.

Spatial modelling with GIS is also making significant contributions to CARPE. Simulating how natural resources (such as wildlife population distributions or socio-economic impacts on forest resources) would be affected under different land-use scenarios is useful for guiding land-use planning. An example of spatial modelling used in land-use planning for a CBFP landscape is

BOX 2. CARPE DATA EXPLORER

CARPE Data Explorer is a customized version of ESRI's ArcIMS (Arc Internet Map Server) Metadata Explorer. Geospatial data and mapping services are organized to enable map-based or keyword searches for geospatial data. These data can be viewed and downloaded over the Internet. In our experience, users unfamiliar with geo-portals have found that the search function is not very comprehensive. Alternative solutions for accessing data are currently being assessed for improved functionality.



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presented in Box 4.

Regional activities : establishing the capacity and infrastructure to use geospatial data in forest management and monitoring in the Congo Basin

Prior to the implementation of CARPE Phase II, it was widely acknowledged that there was a paucity of reliable and updated information on forest cover and forest cover change. National institutions recognized that accurate mapping and remotely sensed data, in conjunction with in-situ data, were essential to producing this information efficiently and on a regular basis, but no critical mass of experts in this field existed in the Congo Basin. Capacity was limited to several individuals

Figure 6. A poster for the Maringa-Lopori-Wamba Landscape which incorporates a Landsat composite and forest cover change map from the DFCM along with information provided by the landscape partner

BOX 4. LAND-USE PLANNING IN THE MARINGA-LOPORI-WAMBA (MLW) LANDSCAPE

As a pilot project for the CARPE Landscapes, UMD, in partnership with the African Wildlife Foundation (AWF), UCL, the US Forest Service (USFS) and others, are using GIS and products derived from remote sensing to build a suite of spatially-explicit land-use models for the MLW landscape, located in northern Democratic Republic of Congo. Modelled outputs include human population distribution and human accessibility in the landscape, as well as identification of biodiversity hotspots and important wildlife corridors connecting existing protected areas. The DFCM satellite-derived forest change products have been used to predict land cover change in the landscape over the course of the next 50 years. To contribute directly to land-use zoning initiatives, the team will use a spatially-explicit site selection modelling tool to identify areas most suitable for future human expansion, taking into account conservation and human needs.

and site-specific projects scattered across the region and no appropriate infrastructure existed to support a regional initiative on forest mapping.
In 2000, stakeholders concerned with using spatial data in forest management met in Libreville, Gabon for a GOFC-GOLD Central Africa regional workshop, co-sponsored by TREES, NASA (through the Global Change SysTem for Analysis, Research and Training initiative, START), and USAID-CARPE. A panel of the Global Terrestrial Observing System, GOFC-GOLD works at the global and regional scale to improve the quality and availability of forest observations and produce functional products for users of this data. The main agenda of the 2000 GOFC-GOLD workshop was to create a Central African GOFC-GOLD chapter that would link national agencies and the user community with producers of this information.

Participants of the workshop agreed that the network would be coordinated from Kinshasa, and that it would operate under the French acronym OSFAC (Observatoire Satellital des Forêts d'Afrique Centrale). As a regional GOFC-GOLD network, OSFAC's unique long-term objective is to build regional capacity to use remotely sensed data and mapping techniques to produce reliable information on forest cover and forest cover change across Central Africa. Simultaneously, OSFAC works to tackle some of the obstacles to establishing and maintaining operational forest mapping in the region. These primary constraints have been identified by national agencies as: a lack of human and financial resources, poor access to data (imagery) and information, poor internet access, and a lack of local expertise.

In order to operate efficiently within the DRC and across Central Africa, OSFAC sought recognition as a Congolese NGO concerned with facilitating access to satellite data, building capacity and forest cover monitoring. On 17 September 2005, OSFAC was granted authorization to function in the DRC by the Ministry of Justice and on 6 February 2006, OSFAC established a technical agreement with the Ministry of the Environment. Currently, OSFAC operates as a legally recognized NGO under the direction of a seven-member Board of Advisors. It supports six full-time professionals, including three high-level GIS program officers and trainers. Day-to-day management is overseen by a small group of advisors. In addition to its technical and administrative departments in Kinshasa, OSFAC also works to reinforce their regional network through voluntary points of contact in countries across the Congo Basin.

When OSFAC began, the capacity to develop and implement a methodology for monitoring forest cover using remotely sensed data did not exist in Central Africa; however, the need to establish baseline information was critical. The decision was made to develop a methodology for monitoring forest cover within a scientific institution outside of the region while simultaneously building capacity within Central Africa to analyze and use the information generated. This approach made it possible for OSFAC to receive continued technical and financial support from UMD under the "resource monitoring institutionalized" objective of CARPE. Within CARPE, OSFAC provides technical support to implementing partners and is seen as the primary channel through which capacity to monitor forests using remotely sensed data can be transferred to the region.

As part of CARPE, OSFAC receives technical support from both South Dakota State University (SDSU) and UMD. UMD has maintained a full-time technical consultant for OSFAC in the DRC since 2005. OSFAC has also established a close relationship with the national university system in the DRC and since 2005, OSFAC has maintained and managed a GIS/RS lab within the School of Agronomy at the University of Kinshasa (UNIKIN).

Building capacity

To build capacity for GIS and RS in Central Africa, the OSFAC network predicted the need for two levels of training: (1) periodic basic training courses across the region and (2) more specialized and higher-level training courses and exchange programmes to develop scientific expertise and introduce new satellite and information technology to OSFAC staff.

In 2005, OSFAC began offering basic and more advanced training courses to outside agencies (see Box 5). Over 400 individuals (see Table 3) have participated in technical courses in GIS and RS at the OSFAC lab and ex-situ sites in the DRC, Gabon and the Republic of Congo. Courses typically last 1–4 weeks and are designed to increase capacity in GIS software such as ArcView, ArcGIS and/or the RS image-processing software, ENVI. Each course is adapted to its participants in order to prepare trainees to use spatial data in their area of implementation. OSFAC also provides a limited number of individuals the opportunity to participate in an internship programme. This programme incorporates both professional and academic degree-seeking interns who work with the OSFAC staff for up to 12 months.

OSFAC's programme to build higher-level capacity continues to evolve. Remote sensing to monitor forest cover is a highly technical and scientific exercise. Long-term exchanges and partnerships with scientific institutions are the only means to develop the level of expertise necessary to develop original forest cover change datasets. Since 2005, OSFAC has successfully promoted the studies of three students from the region in doctoral programmes in the US and Europe. OSFAC is also working to establish a pool of regional experts capable of generating functional products for decision makers and managers, using methodologies developed by top-level scientists. To meet this goal, OSFAC, UMD and SDSU plan to transfer capacity for these activities to OSFAC through an extensive training programme in the DRC.

Currently OSFAC's capacity for GIS is high and it maintains a reputation for delivering quality support and products. OSFAC engages in a wide variety of GIS and basic RS projects as part of its efforts to strengthen conservation and sustainable development initiatives by incorporating the use of spatial datasets. These initiatives build mapping capacity, provide OSFAC trainees with practical experience and contribute to OSFAC's long-term sustainability. Among the projects in which OSFAC has participated in are:

- A 2007 workshop co-hosted by WWF, the Minister of the Environment, ICCN, and

BOX 5. INSTITUTIONS AND PROTECTED AREAS THAT HAVE RECEIVED TECHNICAL TRAINING FROM OSFAC

- AWF
- Bombo Lumene Hunting Zone, DRC
- BCI (Bonobo Conservation Initiative)
- BEAU (Bureau d'études et d'aménagement urbain)
- CAMI (Cadastre minier)
- CENAREST (Centre national de recherche scientifique et technologique)
- CIB (Congolaise industrielle des bois)
- CICOS (La commission internationale du bassin du Congo-Oubangui-Sangha)
- CNIE (Cadre national de l'information environnementale)
- CNPN (Conseil national des parcs nationaux, Gabon)
- COHYDRO (Congolaise des hydrocarbures)
- Conkouati-Douli National Park, Republic of Congo
- CRGM (Centre de recherche géologique et minière)
- CTB (Coopération technique belge)
- CTCPM (La Cellule Technique de Coordination et de Planification Minière
- DGF (Direction de gestion forestière)
- ECODED (Economie et développement durable)
- ERAIFT (Ecole régionale d'aménagement intègre des forêts tropicales)
- FACAGRO (Faculté d'agronomie)
- Garamba National Park, DRC
- ICCN (Institut Congolaise pour la conservation de la nature)
- IPS (Inspection provincial de la santé)
- IRM (Innovative Resource Management)
- ITTO (International Tropical Timber Organization)
- Kahuzi-Biega National Park, DRC
- Lac Télé Community Reserve, Republic of Congo
- Lopé Reserve, Gabon
- MECNEF (Ministère de l'environnement, conservation de la nature, eaux et forêts)
- SNR/MECNEF (Service national de reboisement)
- MECNT (Ministère de l'environnement, conservation de la nature et tourisme)
- MEFE (Ministère de l'économie forestière et l'environnement, République du Congo)
- MINEF (Ministère de l'économie forestière, Gabon)
- Mikébé National Park, Gabon
- Nouabale Ndoki National Park, Republic of Congo
- OCHA/UN (Office for the Coordination of Human Affairs)
- Okapi Faunal Reserve, DRC
- PAIDECO (Programmes d'appui aux initiatives de développement communautaire)
- PARCAFRIQUE
- PNLTHA (Programme nationale de lutte contre la trypanosomiase humaine africaine)
- PROGEPP (Projet de gestion des écosystèmes périphériques du parc national de Nouabalé-Ndoki)
- Salonga National Park, DRC
- SPIAF (Service permanant d'inventaire forestier)
- SYGIAP (Système de gestion des aires protégées)
- TRIDOM (Dja-Odzala-Minkébé Tri-National)
- UNICEF (United Nations Children's Fund)
- UNIKIN (University of Kinshasa)
- UNILU (University of Lubumbashi)
- Virunga National Park, DRC
- WCS
- WRI
- WWF (World Wildlife Fund)

OSFAC to prioritize conservation areas in the DRC. Throughout the workshop, OSFAC provided technical support to create maps of priority areas.
- An initiative by the United Nations Educational, Scientific and Cultural Organization (UNESCO) to establish a permanent GIS lab at ERAIFT.
- Developing a methodology for monitoring land cover change as part of an environmental impact assessment for the World Bank PRO-ROUTES project.
- Partnering with WWF and WCS for a month-long field and lab-based GIS training centred on inventorying and mapping the Bombo Lumene Hunting Zone.
- A project to produce posters of all the RAPAC (Réseau des Aires Protégées d'Afrique Centrale) sites.
- Projects to map the Kisantu and Kinshasa Botanical Gardens.
- An inter-university project to map erosion in Kinshasa.
- A CTB project to map numerous communes in Kinshasa.

Data accessibility

Since its inception, OSFAC has been committed to working with regional partners to assess and improve the state of spatial datasets in Central Africa as well as facilitate regional access to satellite data. OSFAC served as the sub-regional partner on the Mapping Africa for Africa (MAFA) initiative led by the Human Science Research Council and EIS (Environmental Information Systems)-Africa. The initiative aims to create a catalogue of available fundamental geospatial datasets and do a country gap analysis. Within the DRC, OSFAC is an active member of the GIS working group established by the UN Joint Logistic Committee. The working group provides a platform for stakeholders collecting and using GIS data in the DRC (including government institutions, UN agencies and NGOs), to harmonize data.

Through its affiliation with UMD, OSFAC has obtained hundreds of satellite images and maintains a database cataloguing all distributable imagery. OSFAC disseminates these data free of charge upon request. Poor internet access in the region means that having data available locally greatly facilitates access for many users. In addition to physically distributing data and providing technical assistance to individuals or organizations interested in using satellite images, OSFAC also maintains a website that provides users with information on different types of satellite imagery, remotely sensed products and details on data coverage across the region.

Future objectives

Building on its current capacity and ongoing activities, OSFAC remains focused on establishing its own sustainability and developing regional capacity to use satellite data in routine forest cover monitoring of the Congo Basin. OSFAC will be the primary conduit by which capacity for using the UMD/SDSU methodology is transferred to the region and hopes to establish itself as an independent organization with the capacity to monitor changes in forest cover. Once the capacity is established, OSFAC will work with local agencies to determine the accuracy of estimates and combine remotely sensed data with in-situ datasets. These data and derived products will be provided to forest managers and decision-makers directly and as part of the Observatory for the Forests of Central Africa (OFAC).

Table 3. Total number of individuals trained by OSFAC (June 2005–February 2008)

	Men	Women	TOTAL
Trainees	383	60	403
Interns*	19	9	28**
TOTAL	**402**	**69**	**471**

*includes both academic and professional interns
**16 were university students who worked with OSFAC to incorporate spatial data into their theses

Lessons learned in the use of satellite mapping and GIS

Regional initiatives such as topic-specific networks and technical bodies are fundamental mechanisms for creating rigorous forest monitoring systems.

Reaching a consensus on rates of forest cover change across the Congo Basin amongst different practitioners requires good communication. Regional networks provide practitioners a means to communicate and compare different monitoring methodologies to achieve a general consensus on estimates of change.

An independent technical body is necessary to assess the veracity of national forest change estimates. To be effective, the body will need to have the scientific capacity to develop accurate estimates as well as be officially recognized across the region as an independent assessor of forest change. In the Congo Basin one could imagine the Central African Forest Commission[4] establishing an independent body to carry out forest change assessments in close collaboration with a university.

Satellite remote sensing provides a comprehensive means for regional monitoring of forest cover. The convergence of change estimates derived from different RS methodologies demonstrates that a reliable representation of forest extent and forest change can be produced from satellite data. The wall-to-wall explicit mapping of forest cover change is more useful for CARPE's purposes than results obtained from a sampling methodology. However, it is useful to have simultaneous, overlapping monitoring activities to corroborate regional results.

Remote sensing provides a relatively low-cost solution for monitoring forest cover, but ultimately the derived products must be validated with ground-truth data. Implementation of a statistically valid Basin-wide field data collection campaign would be logistically and financially infeasible, since much of the Congo Basin remains relatively inaccessible. Plans are underway to collect field data for the validation of the DFCM products in at least one landscape. This will provide an opportunity to test and refine a field data collection protocol which can be disseminated to landscape partners to implement along with their other field activities. Establishing a mechanism whereby field and forest plot data can be shared, such as through a regional network, would benefit the development of reliable forest monitoring programmes.

There is an urgent need in the Congo Basin to transfer forest monitoring methods developed in the research domain into the operational domain.

The institutionalization of methods such as the DFCM is a current CARPE objective. Transferring these tools will require intensive long-term training to develop in-region technical capabilities. With increased capacity in the region, this method could be the foundation of an operational regional monitoring programme.

One of OSFAC's primary goals is to work with national forest monitoring agencies to use monitoring methods developed in the research domain to create useful products for forest management and decision making. This will require continuing to build the OSFAC network across the region and significantly increasing efforts to work with government agencies to understand their needs and communicate potential implications and possible applications of monitoring data.

Improved acquisition and free and open access to data would increase use of satellite data and support the development of sustainable forest monitoring systems in the Congo Basin Region.

Long-term forest cover monitoring requires insti-

[4] The Commission des Forêts d'Afrique Centrale (COMIFAC), which consists of the forestry ministers of participating Central African countries, coordinates decisions, actions and initiatives pertaining to the conservation and sustainable management of the Congo Basin forests.

tutional support and access to a continuous data stream. While governments continue to support global and regional monitoring by developing and launching satellite-borne sensors, data are still under-used due to prohibitive data costs. Even when individual scenes are relatively inexpensive, cumulative costs can be high when data needs are intensive. Progressive data policies are required so that operational mapping organizations need not worry about problematic data cost or access policies[5].

The greatest return on investment in earth-observing satellite assets comes as information derived from sensor data in the form of value-added products. Limited data access limits the development and improvement of methods to derive useful products, limits the capacity for monitoring and limits the information available for making sound resource management decisions. An international strategy should coordinate data acquisition from different sensors to maximize the potential for obtaining useful data (e.g., cloud-free in the case of optical sensors) over the Congo Basin, and this data should be made freely available.

In the current limited satellite data access scenario, researchers use the data they can afford, not the data they truly need. For example, the DFCM method is robust, repeatable and could be modified to work with data inputs other than Landsat, if the data were readily available. Significant gaps remain in the products largely due to a lack of cloud-free Landsat data. While it is not possible to overcome historical failures of data acquisition and archiving, other data sources exist today that can compensate for Landsat limitations, either by increasing the available pool of cloud-free optical data or by providing data from other modes, such as radar.

The compilation and creation of geospatial data and products, as well as the results of geospatial analyses, contribute to CARPE's success. The dissemination of these data, products and results must continue to be fostered and improved.

The geospatial and RS data, and the derived products compiled and created under CARPE, are a significant contribution to forest management and planning for the Congo Basin, to the CBFP and to the State of the Forest reports in particular. The data, products and results need to be made available to CARPE partners, and to the wider community, in a timely manner.

The regional dissemination of RS data and derived products is problematic due to the large data volumes involved and limited internet capacity in the Congo Basin, therefore, OSFAC will continue to be an important regional node for data distribution. Internet dissemination of geospatial feature data is less of a problem, but for both feature and RS data, there is a need to ensure that geospatial data is shared among CARPE partners. There should be a routine transfer of satellite data to OSFAC and a systematic review of RS data available to CARPE partners. The ability to review, access and update geospatial datasets could be improved, perhaps by implementing an open-source geoportal.

The geospatial and RS data compiled and produced by CARPE are filling a regional data deficit and will have applications beyond their contribution to CARPE Strategic Objectives. The availability of these datasets should be brought to the attention of international environmental monitoring programmes, such as the UNFCCC's REDD initiative.

Map products in poster form are an effective means of communicating CARPE objectives and results. In particular, the maps based on RS image composites are useful for informing stakeholders, engaging local communities and for public education. Integrating the basic DFCM products with other geospatial datasets, such as national, landscape and protected area boundaries, conveys at a glance the forest cover and change dynamic within the Congo Basin. Maps

[5] The NASA/USGS Landsat data distribution policy ensures that data products are available at no more than the cost of fulfilling user requests (COSUR), meaning that there is no effort to recover costs of satellites, ground systems or other capital assets. This COFUR policy could be a model for other satellite data distribution programmes.

of this type tailored to specific regional needs should be produced by OSFAC.

Partnerships with academic institutions are essential to develop technical expertise and establish centres of excellence to meet the demand for high technical skills.

One of the keys to OSFAC's success has been its close relationship with academic institutions both within and outside Central Africa. Through CARPE, OSFAC has developed and maintained an active relationship with both UMD and SDSU in the USA. Both universities are highly scientific institutions with long-term commitments to using remote sensing to monitor forest cover and working with OSFAC to create a critical mass of RS experts in Central Africa. These partnerships have provided OSFAC with the day-to-day technical and financial support necessary to establish itself as a respected NGO concerned with mapping resources in the Congo Basin and have provided the best opportunity for OSFAC to continue to develop its capacity through a combination of higher-level training courses in the region and in academic exchange programmes.

Simultaneously, OSFAC has benefited by maintaining a close relationship with UNIKIN and its School of Agronomy. This partnership is critical to assure that capacity building in remote sensing and GIS will be institutionalized within the region and has put OSFAC in contact with a continuous pool of motivated and skilled candidates for training. Working through the local university system has allowed OSFAC the opportunity to partner with supplementary initiatives to establish more permanent training institutions such as ERAIFT. Additional centres of excellence are necessary to meet the demand for high technical skills.

OSFAC will only succeed if it can attain a measure of sustainability, including establishing secure funding mechanisms and building management capacity.

Since its inception, OSFAC has benefited technically and financially from the support of USAID and partnering academic institutions. This support is critical in these initial stages; however, in its aim to establish itself as a local organization, it is imperative that OSFAC continues to develop its own management capacity and financial sustainability. OSFAC supplements its USAID funding by engaging in short-term income-generating mapping projects, but this income covers less than 25 percent of OSFAC's operating costs. The aim is to increase this percentage but it is acknowledged that if OSFAC is to have a role in regional forest monitoring, it will continue to require additional sources of support, either through donor agencies or through a commitment from national agencies.

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Appendix I.

Acronyms

ALOS – Advanced Land Observing Satellite
ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR – Advanced Very High Resolution Radiometer
AWF – African Wildlife Foundation
CAMP – ESA/EC Central Africa Mosaic Project
CARPE – Central African Regional Program for the Environment
CBERS – China Brazil Earth Resources Satellite
CBFP – Congo Basin Forest Partnership
CTB – Coopération Technique Belge
DFCM – Decadal Forest Change Mapping
DRC – Democratic Republic of Congo
EC – European Commission
EEA – European Environment Agency
ERAIFT – Ecole régionale d’aménagement intègre des forêts tropicales
ERS – European Remote Sensing satellites
ESA – European Space Agency
ESRI – Environmental Systems Research Institute
ETM – Enhanced Thematic Mapper
FAO –Food and Agriculture Organization of The United Nations
FRA – FAO Forest Resource Assessment
GIS –Geographical Information System
GLC – Global Land Cover
GOFC-GOLD – Global Observation of Forest and Land Cover Dynamics
GRFM – Global Rain Forest Mapping
HRVIR – High Resolution Visible and Infrared
ICCN – Institut Congolaise pour la conservation de la nature
IGBP – International Geosphere-Biosphere Programme
IRS – Indian Remote Sensing Resource-1 Satellite
JRC – European Commission Joint Research Centre
MDGLS – NASA/USGS Mid-Decadal Global Land Survey
MERIS – Medium Resolution Imaging Spectrometer
MODIS – Moderate Resolution Imaging Spectrometer
NASA – National Aeronautics and Space Administration
NDVI – Normalized Difference Vegetation Index
NOAA – National Oceanic and Atmospheric Administration (USA)
OSFAC – Observatoire Satellital des Forêts d’Afrique Centrale
PALSAR – Phased Array type L-band Synthetic Aperture Radar
RED – Reducing Emissions from Deforestation and Degradation
RS – Remote Sensing
SAR – Synthetic Aperture Radar
SDSU – South Dakota State University (USA)
SLC – Scan Line Corrector

SPOT – Satellites Pour l'Observation de la Terre satellite series
TREES – Tropical REsources and Environment monitoring by Satellite
UCL – Université Catholique de Louvain (Belgium)
UMD – University of Maryland (USA)
UNEP – United Nations Environment Programme
UNFCCC – United Nations Framework Convention on Climate Change
UNIKIN – University of Kinshasa
USAID – United States Agency for International Development
USGS – United States Geological Survey
WCS – Wildlife Conservation Society
WRI – World Resources Institute
WWF – World Wildlife Fund

Earth Observing Satellites with Vegetation Mapping Applications

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

[6] For CARPE purposes, regional corresponds to the entire Congo Basin and local corresponds to the CBFP Landscape level.
[7] The primary purpose for this sensor is meteorological.
[8] High Resolution Charge-coupled Device (CCD) camera, Infrared Multi-Spectral Scanner, Wide Field Imager
[9] Linear Imaging Self Scanner, Advanced Wide Field Sensor
[10] Thematic Mapper/Enhanced Thematic Mapper
[11] High Resolution Geometric
[12] Advanced Land Imager
[13] Revisit frequency depends on mode and incidence angle.
[14] Advanced Synthetic Aperture Radar

Case study 4 - Monitoring of Wildlife Populations : Lessons Learned from Central Africa

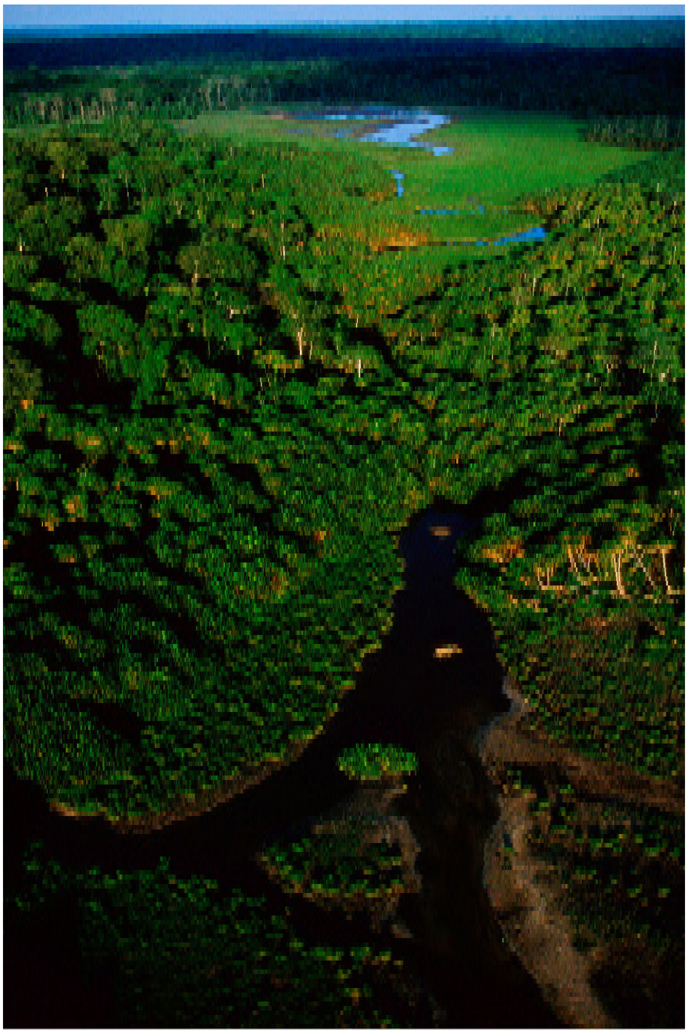
Fiona Maisels

Introduction : The need for standardized wildlife monitoring

The biodiversity within the humid tropical forests of the world is typically about 50 percent of the global total, although they cover only 15 percent of the earth's surface. The Central African block is the second largest of these forests after Amazonia, and much of it is still unlogged, closed canopy tracts with continuous cover. These forests contain important populations of large, endangered mammal species such as forest elephant, gorilla, bonobo and chimpanzees, plus medium-sized mammal species including monkeys, forest antelopes, pigs and buffalo. In addition, the individual trees within these forests are often many hundreds of years old, and maintain a myriad of smaller species of fauna and flora, often endemic to small areas within the main forest block (although the degree of endemicity varies tremendously over the area). There have been long cycles of forest retreat and regrowth, caused by climatic cycles; at present the cycle is approaching its maximum for forest cover and would eventually take over the savannah islands within the block if not held back, up to a point, by burning.

Archaeological record

People have lived in these forests for many thousands of years. The archaeological evidence suggests that the vegetation was not always simply affected by the climatic cycles, but was also greatly changed by people's activities. There seems to have been extensive habitation, clearing and cultivation in the Congo Basin between about 1000 BC to about 400 AD, followed by a human population crash. In the Gabon area (the Ogooué basin), a similar human population crash seems to have occurred in about 500 AD, after an intensive period of 800 years of iron working, which would have required a great deal of forest

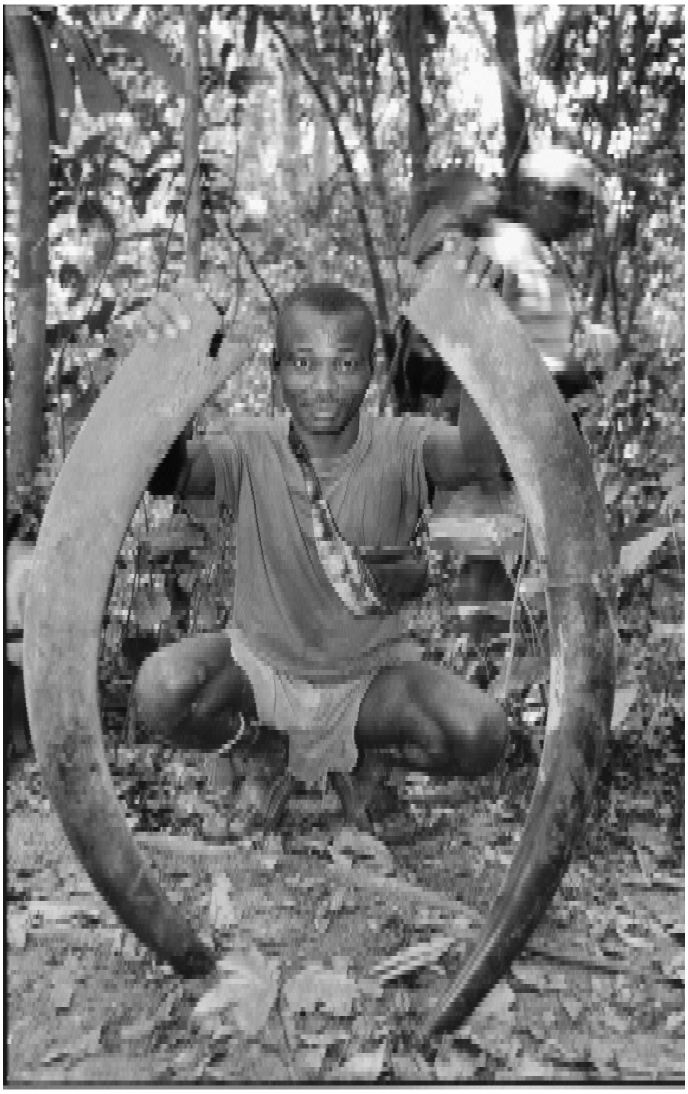


cover removal (Mbida et al., 2000; Oslisly, 2001; Willis et al., 2004; White, 2001). The forests then recovered, at least for a while. In the last few hundred years, and especially over the last hundred years, the rate of harvest of many species of wild plants and animals has far outstripped the rate at which they are replaced leading to a net decline in populations. This accelerated harvesting of wild species has been caused by three main factors: (i) great improvements in the technology of extraction (firearms, metal cables, chainsaws); (ii) rapidly growing human populations in the region (about 3 percent per year: UNDP (2006)), resulting in a doubling of the population every 20 years); and (iii) growing international markets for exotic goods such as ivory, tropical hardwoods, and even bushmeat. China is now the world's most important importer of ivory, tropical logs and sawn wood (ITTO, 2006; Milliken et al., 2007) and most of their ivory and much of their timber comes from the Central African forests.

Vulnerability

The vulnerability of any given species is a function of both its intrinsic rate of reproduction, and of its value to humans as a resource. General rules of thumb are that, for any given taxonomic group, the larger the individual, the slower it reproduces. For example, hardwood timber trees can take many decades to reach maturity and to set seed, and even then some species only fruit once every few years. Small herbs, by contrast, are often annuals. The same is true for animals – the slowest to reproduce are the apes and elephants, which can take up to 15–20 years to reach maturity, and even then only give birth to one young every four years. Contrast this with rodents, many of which reach maturity in a matter of months and can produce litters of several animals more than once a year. Likewise, the commonest small antelope in these forests, Blue duikers, can reproduce after one year and give birth to one offspring annually.

The value of certain products also leads to overharvesting. Overexploitation of most of the valuable hardwood species currently on the international tropical timber market has led to most of them being placed on the IUCN Red List – for example most of the central African mahogany species (all the Entandrophragmas, Afrormosia, Wenge, African mahogany, Bossé), plus Okoumé, Moabi, Azobe, Bahia and a great many others are all now either considered Endangered or Vulnerable (IUCN Red List, 2006). The value of ivory has led to a sharp decline in elephant numbers across the world, and most recently in Central Africa (Blake et al., 2007). Wild meat is considered a traditional luxury in modern Central African cities and it is often served on important occasions (marriages, funerals, etc.). Although it is more expensive than domestic meat in cities, people are prepared to pay the higher prices if they can afford to (Wilkie et al., 2005).



Relevance to management

What does this mean for the more vulnerable plants and animals of the Congo Basin? Outside protected areas (i.e., national parks and reserves), it is likely that most of the large mammals will be hunted out of the forests within the next few decades, unless rapid and effective wildlife management strategies are undertaken immediately. Indeed, in many areas, especially those in countries with high human population density, this has already happened, especially around towns and larger villages. Even some protected areas in the region have effectively no real protection and exist only on paper. For the vulnerable plant species (mostly the hardwood trees), only truly sustainable logging will result in the long-term survival of their populations. By "sustainable" we mean harvesting at or below the rate of recruitment of young trees into the reproductive population, implying protection of seed trees, maintaining long felling rotations, and maintaining the seed disperser agents, most of which (80 percent) are mammals and large birds in this region.

Monitoring and evaluation

In order to verify whether the chosen management strategies are actually having the desired effect on maintaining the vulnerable, slow-reproducing, large species (elephants, apes, large trees) plus the smaller but targeted species such as forest antelopes, pigs and monkeys, monitoring programmes are essential. Over the last two decades, many different bodies including governments, professional researchers and conservation organizations have realized that a continuous, permanent monitoring programme across the whole Congo Basin is necessary to follow changes in the extent and quality of the forest itself, the species living within it, the distribution and abundance of its fauna, and the distribution, abundance and activities of its human populations. Forest-cover monitoring is generally most cost-effective using remote sensing, and this has been and continues to be successfully carried out in the Congo Basin (see Chapter 9, CBFP: State of the Forest 2006 and Chapter XX in this series of Lessons Learned). By contrast, there remains an important need for monitoring of wildlife and human population distribution and abundance within the forest itself. In order to be able to detect change over such a wide area and over long periods of time, the methods of data collection and reporting have become standardized, and the indicators for animal and human populations are basically the same throughout not only the Congo Basin, but in all tropical humid forests worldwide.

Methodology of wildlife monitoring

Monitoring of elephants and large ungulates in the grasslands of Africa has been carried out for decades using direct counts of individuals or herds during foot surveys, counts from off-road vehicles or from small aircraft. All these methods assume that most of the animals can actually be seen! In the savannahs this is mostly true and methods have improved over the last 20 years to calculate the numbers of animals likely to have been missed during the surveys. However, animals living in a closed canopy forest are not so easily counted. Firstly, they cannot be counted from an aircraft, because of the tree cover. Secondly, counts cannot be made from vehicles, as the distance one can see into a forest is a few metres, and animals move away from the sound of an approaching car and are hidden by vegetation. Finally, even people walking through the forest can see only a short distance, and animals usually detect their presence and move away before they can be recorded. This has led to the development of methods that do not require that the animals themselves are detected, but rather that the signs they leave behind are the units of census.

Since biologists began working in the region, we have been producing maps of where the different species occur. Population size estimates for some species such as elephants and apes followed. These estimates ranged from "best guesses" based on interviews with local hunters or foresters at remote sites, through sample-based methods aimed at estimating a mean density across a large area, to, in the case of some populations, fairly accurate head counts which assumed that most of the animals in an area of interest were known individually. This latter approach was really only possible with small ape or elephant populations which were the subject of intensive study and where individuals are distinctive. However, it is neither feasible nor cost-effective to monitor multiple groups over a large landscape. Sampling methods had to be developed which work under the forest canopy. Over the last 20 years, the methods for monitoring large mammal abundance and distribution in lowland tropical forests have become standardized. The methods are based on calculating the density and/or abundance of the animals themselves, or certain signs (such as nests or dung) which are produced at a fairly uniform rate by each individual animal, and which are visible no matter what the substrate (unlike footprints). Surveys carried out using these methods between about 1983 and now have allowed alarm bells to be rung for the great apes in Central Africa (Walsh et al., 2003) where it was realized that half of all apes had died over a twenty-year period due to a combination of Ebola and hunting. Similarly, the international elephant monitoring programme of IUCN/CITES (MIKE, or Monitoring the Illegal Killing of Elephants) showed that even in what had been believed to be the stronghold of forest elephants in central Congo, there were a mere handful remaining (MIKE, 2005; Blake et al., 2007). These types of surveys were also used to inform the Regional Action Plan for the Conservation of Chimpanzees and Gorillas in Western Equatorial Africa (Tutin et al., 2005) and the revision of the status of the western lowland gorilla from Endangered to Critically Endangered (Walsh et al., 2007).

Lessons learned

Avoid bias

Much of this work has been spearheaded by groups of wildlife mathematicians, who have examined the sources of bias caused by pitfalls into which one can easily fall (Buckland et al., 2001, 2004; Hedley and Buckland, 2004; Sanz et al., 2007; Sutherland, 1996; Walsh and White, 1999; Walsh et al., 2000, 2001; and many others). One of these pitfalls was that people would often walk along existing roads to collect animal or human data. It was much easier, much faster, and avoided wetlands and other habitats difficult to traverse. Of course this resulted in an overestimation of human signs and an underestimation of animal signs, as hunting and trapping was usually more intensive near roads. Another bias was to carry out an intensive survey of one small area and then extrapolate to a much larger area without good knowledge of different habitats or hunting pressures that might be present in the areas not surveyed. . For these reasons, modern surveys now try to cover the entire area of interest, using an evenly spaced sampling plan, so that the sampling is representative of the whole site (whether it is a protected area, a logging concession, a community forest, or a combination of these and other land-use types).

Don't jump in and do an intensive survey right away

In general, any wildlife monitoring programme goes through a series of steps. A short site visit is made to assess logistics, contact local communities, and hear peoples' perceptions of wildlife in their forests. This is often followed by a pilot study consisting of walking for a week or so in the forest, and if wildlife seems to be relatively abundant, by a few pilot transects distributed evenly throughout the area of interest (straight lines along which wildlife signs and human activities are recorded and georeferenced). The results of the pilot transect are used to decide whether to do a survey where the objective is to estimate animal density or whether simply to map relative abundance of the target species (and of human activity). For estimating density, a comprehensive survey design is set up over the whole area, which will have enough samples and enough overall effort to estimate animal density with an acceptable degree of precision (a measure of the intrinsic variability of the data across the area). The results provide an estimation of animal (or sign) density, plus the data is set to create distribution maps.

In the cases where wildlife has been intensively hunted over a number of years, we simply cannot do enough transects to assess animal abundance without spending huge amounts of time (and thus money) which could otherwise be spent on activities which would reduce the hunting pressure. In these cases a survey design is drawn up which consists of lines across the area of interest, which are walked by field teams, but along which they collect a smaller set of data than on transects, and along which they move about four times as fast as on transects (so the cost of these surveys is about a quarter of that of those designed to assess density). The results of this type of survey, known as reconnaissance surveys, are expressed as the number of animals or animal signs (or human signs) per kilometre walked, and serve as the basis for maps of animal and human distribution and relative abundance over a landscape.

Training people takes time and has to be done well

Over time, we have realized a great deal of training is necessary for the survey teams to bring back meaningful data. In the early stages of work in the region (in the early 1990s), training courses of a week or two were given, after which teams carried out work for months without supervision. However subsequent examination of the results showed that they often made mistakes, got lost, or lost data. Since then training courses have been longer, with a great deal of practical work involved, and repetition of field tasks so that people get used to the different aspects of the field work.

Back up data and reports in several places!

The Central African region is a volatile one, to say the least. Most of the countries in the forest block have undergone either one or more full-blown civil wars or some kind of regionally restricted civil unrest in the last two decades. Apart from the loss of life, the long-term results are a general lowering of the standard of living for urban dwellers (food restrictions, loss of access to medical supplies and services, cuts in electricity and water supplies (very isolated rural populations are sometimes not so much affected)), and the deterioration of national infrastructure (railway lines, roads, public buildings such as schools, etc.). Importantly, the national documentary storage and/or scientific services are often pillaged during civil war. National herbaria, museums, ministries, and all offices that might contain computers have been broken into and all useful objects removed, including the paper on which herbarium specimens were mounted. This has important implications for long-term monitoring. All data and reports should be recorded electronically, copied, backed up, and kept in several places: at the site of origin, plus in the appropriate national ministry, plus (if they were produced by another body) at the local and offshore offices of the scientific or conservation institution which produced them. At present (2008), a monitoring database for Central Africa is being constructed (the FORAF project) which will be web-based and thus not subject to local unrest which has destroyed so much of the documentary evidence of past surveys.

Finally, as part of these "Lessons Learned", we present a Decision Tree which was originally designed as part of the IUCN Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations (Kuehl et al., 2008). The book will be mainly online and contains chapters on survey design, field practicalities, and training. It was written using a great deal of the experience gained in carrying out surveys and monitoring programmes in the Central African forests from 1990–2007. The Decision Tree is laid out like a botanical key, where successive questions lead the reader to a series of decisions as to how to

carry out the survey.

What to do when: A decision tree for wildlife surveys in forested environments

I. First let us assume you need to know how many animals are present in the population

Question 1. Are all animals in the population known individually and can they be found within a few weeks AND/OR are they relatively few in number, and found within a small area?
This is the case with very few animals. The Rwanda tourist gorillas come close!

a. Yes: carry out full count of known individuals, OR use a sweep sample to cover the whole of the area of interest.
b. No: go to Question 2.

Question 2. Is the rough encounter rate of nest groups or other signs that will be used to estimate density already known?

c. No: conduct pilot study consisting of a few transects throughout the area of interest in order to obtain a rough idea of encounter rate (this should only take a couple of weeks). Then go to Question 3.
d. Yes: go to Question 3.

Question 3. Decide on the target coefficient of variation you require for the survey. If the survey or series of surveys is to be used for monitoring purposes, then a power analysis should be conducted to estimate the probability of being able to detect a trend given the potential variability in the data and the given monitoring design (same can be said for methods based on mark-recapture, etc.). Using the encounter rate derived from the pilot study, calculate how many kilometres of transect you would need to estimate density of nest groups (use the formula found in Chapter 7, section 7.2.2.1. of Buckland et al., 2001). Is the number of kilometres feasible considering the time and resources that you have available?

e. Yes: design a transect-based survey using a combination of ArcView or ArcGIS and the DISTANCE program, and implement it using trained teams in the field; use the results to estimate the population of apes in the area surveyed.
f. No: go to Question 4.

Question 4. You cannot calculate density without enormous cost. Therefore you cannot estimate numbers of animals using transect methods. Given the practical constraints, are encounter rates too low to enable density calculations from transect methods?

g. Yes: if you have access to trained staff and a partner laboratory to process the information, consider designing a survey using genetic markers and implement it. (NB: A pilot study is advised – this may or may not be more costly than transect methods).

h. No: consider index methods (go to Question 5).

II. Either you cannot estimate how many animals are present in the population and/or you do not need to know at this point. However you can calculate area of occupancy (distribution maps) and relative abundance.

Question 5. Are there sufficient resources to cover the whole area using recce walks?

i. Yes: create a recce sampling design using a combination of ArcView or ArcGIS and the DISTANCE program and implement it using trained teams in the field. Results will provide a distribution map and relative abundance over the area.
j. No: consider interview-only surveys.

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