Forest Biomass and Land-Use Change in Central Africa
Reducing Regional Carbon Cycle Uncertainty

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INTRODUCTION

Central Africa contains the second largest block of tropical forest remaining in the world[1], and one of the largest carbon reservoirs on Earth[2,3]. The carbon dynamics of the region differ substantially from other tropical forests because most deforestation and land use is associated with selective logging and small-scale landholders practicing traditional "slash-and-burn" agriculture[1,4]. The region is quite unlike the Amazon and Southeast Asia, where large-scale agricultural operations and clear-cut logging, respectively, predominate.

Despite estimates of 1-2 PgC/year released to the atmosphere from tropical deforestation[3,5], the amount released from Central Africa is highly uncertain relative to the amounts released from other tropical forests. The uncertainty in carbon fluxes results from inadequate estimates of both rates of deforestation and standing stocks of carbon (forest biomass). Recent estimates of deforestation in tropical Africa vary by more than an order of magnitude, and estimates of carbon stocks in soils and biomass are of comparable variability[6].

Dzanga Bai, Central African Republic— Central Africa is rich in timber and wildlife. Unique from the Amazon and the Southeast Asian rain forest are its high concentration of large mammals, including forest elephants, chimpanzees, gorillas, and various kinds of antelopes.

Pokola, Republic of Congo— Clearings of forest for small-scale agriculture is a dominant land-use practice around population centers

RESEARCH QUESTIONS

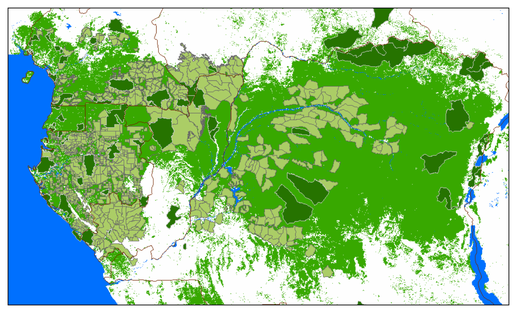
What are the recent trends (1960-2000) in carbon stocks and emissions in the tropical rain forest of Central Africa?

- What are the aboveground and soil carbon stocks?
- What is the net flux of carbon as a result of land-use changes?

OBJECTIVES

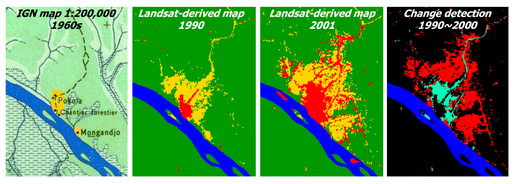
1. **Determine the rates of deforestation, forest degradation, and regrowth** using a remote sensing (RS)/Geographic Information System (GIS) approach;
2. **Estimate aboveground biomass at multiple scales and for different disturbance regimes** using land-cover maps from (1) and biomass calculated from field data;
3. **Calculate the annual fluxes of carbon from land-cover change** using a "bookkeeping model" and a spatial model (CARLUC); and,
4. **Develop a Central Africa Carbon Network (CAFCAN)** to promote research in carbon modeling for the region, to collect data for improving and testing these carbon models, and to facilitate the formulation of *Central Africa's National Communication on emissions as required by the United Nation Framework Convention on Climate Change* (UNFCCC).

Determining the rates of deforestation, degradation, & reforestation



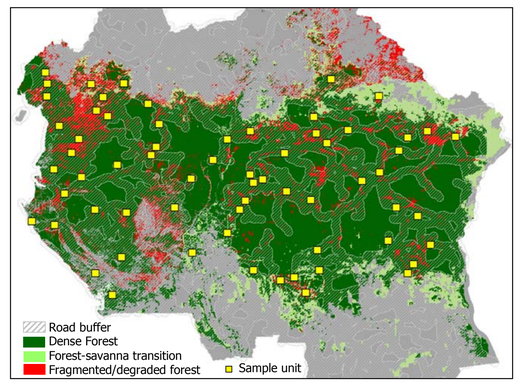
Distribution of timber concessions and protected areas in Central Africa: *Large-scale (industrial) logging and small-scale (non-industrial) agriculture are the main drivers of land-cover changes in the region.* (Background map: MODIS 500-m Global Percent Tree Cover[7]; concessions & park limits: various NGOs)

For each sample block, we will develop maps of land cover and land-cover change and quantify rates of change from logging (degradation), agriculture (deforestation), and regrowth (after logging and crop abandonment). For the period of 1980-2000, a multi-temporal database of Landsat (Earthsat Geocover 1980 & 2000 orthrectified products) and ASTER images will be used for analyses. For the period of 1960-1980, we will combine the 1960s Institut Géographique National (IGN) land-cover maps and the 1980s satellite-derived maps in a GIS to compute change statistics.

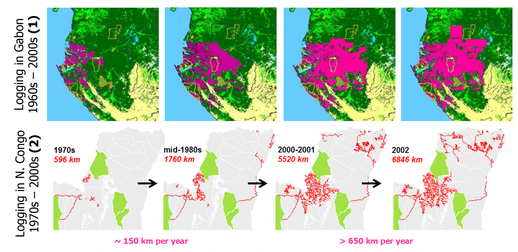


A simplified version of land cover and land-cover change mapping: *Pokola, a logging town in the northern Republic of Congo*[4]

We will determine the average annual rates of land-cover change by random stratified sampling. Deforestation in Central Africa is highly correlated to distance from human settlements and transportation corridors[8,9]. We plan to sample 2 % of the forest domain located within 20 km from major roads and population centers. Individual sample blocks of 20 km x 20 km will capture the spatial configuration of deforestation typical to the region.



A simulation of the random stratified sampling scheme
(Background map: modified from the AVHRR 1-km GACLAC map for Central Africa[1])



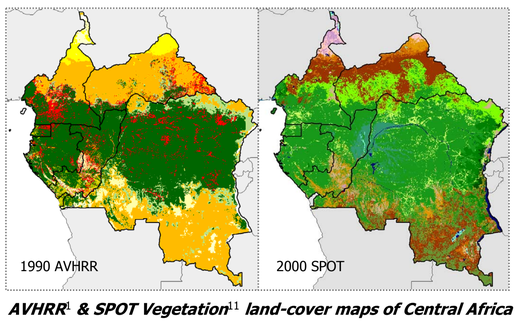
Reconstructing changes of forest cover due to industrial logging: ***(1) Historical data*** *compiled by Global Forest Watch and Forest Monitor* ***(2) Observations from Landsat imagery*** *enabled the mapping of logging roads and logging progression*[10]

Estimating aboveground biomass at multiple scales and for different disturbance regimes

Indirect estimation

Commonly referred to as the "classify and multiply" method, indirect biomass estimation assigns land-cover specific estimate of biomass to each land-cover type. Biomass associated with each land-cover type is compiled from literature and/or from *in situ* measurements, and land-cover mapping is done separately.

At the regional level, we will use the 1990 land-cover map produced from AVHRR[1] and the 2000 Global Land Cover product derived from SPOT Vegetation[11], both at 1-km resolution, as the bases for "multiplying." At the local level, biomass will be mapped for northern Congo only, where we have already produced a detailed vegetation map as part of our previous GOFC-GOLD activities[4].



AVHRR[1] & SPOT Vegetation[11] land-cover maps of Central Africa

To account for spatial heterogeneity of biomass for each class, we will combine logging history with edaphic and climatic variables in a GIS.

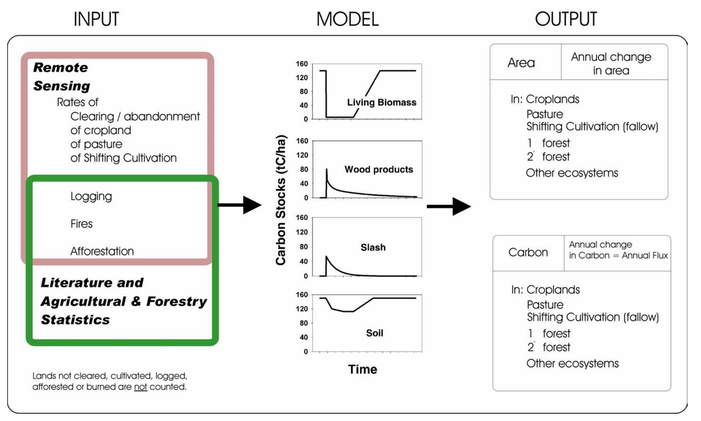
Direct estimation

The direct estimation "maps" biomass by establishing a statistical relationship between remote sensing variables and biomass derived from field data[12,13].

These field measurements include data collected by our collaborators from across the region and consist of both commercial and ecological inventories.

A the regional level, we will evaluate 3 MODIS products: the Surface-Reflectance Product (MOD 09), the Normalized Difference Vegetation Index (MOD 13), and the Enhanced Vegetation Index (EVI). At the local scale, we've selected three sites for evaluation: the Ituri forest in the Democratic Republic of Congo, the Sangha tri-national region in the northern Republic of Congo, and Korup National Park in Cameroon. We will first apply geometric and radiometric normalization to the fine-scale satellite images and then "compress" the original spectral bands into indices for regression analyses.

Integrating biomass and land-use data with carbon models



The bookkeeping model: *calculating sources and sinks of carbon from land-use change*

The Bookkeeping Model

Using the results from the first two components of the project, we will calculate the annual fluxes of carbon resulting from land-use change, starting with the "bookkeeping model"[14]. Annual per hectare changes in the carbon of vegetation and soil following a land-use change are defined for different ecosystems and land uses.

The bookkeeping model tracks the areas, not their spatial locations, of different land uses and the amounts of carbon held in living vegetation, slash, wood products, and soil. Changes in these pools from one year to the next define the annual net flux of carbon between land and the atmosphere. The total rates of land-use change are applied to specific types of ecosystems. The number of ecosystems included in the model will depend on the number of natural habitats with distinctly different biomass, which ideally would be distinguishable from remote sensing data.

The model calculates the flux of carbon that is attributable to direct human activities. It does not include the effects of increased atmospheric CO_2, increased deposition of nitrogen, or changes in climate. Rate of decay and growth vary across ecosystems in the model, but the rates are not affected by temporal changes in the environment. Ecosystems that are not altered are not included in the analysis.

The Carbon and Land-Use Change Model (CARLUC)

We had also proposed to estimate carbon flux using a modified version of the original CARLUC Model for the Amazon Basin[15]. CARLUC is a spatially explicit model that takes into account the rates of change in response to changes in environmental variables.

RELATED ACTIVITIES AND THEIR SIGNIFICANCE

We will initiate a Central Africa Carbon Network (CACN), coordinating with existing carbon-related networks such as Carboflux, AFRIFLUX, and GOFC-OSFAC. This will also help Central African countries to prepare more accurate and transparent reports of national carbon emissions. Results produced by the project will be disseminated to regional and global communities through a range of activities and media: direct collaboration and networking; workshop; a website under the current WHRC Africa Program; posters, brochures and publications. We expect that this project will improve the regional and thus global carbon budget and increase the Central African participation in carbon cycle science and regional conservation.

COLLABORATING ORGANIZATIONS

- Central African Regional Program of the Environment of the U.S. Agency for International Development & partners
  - Wildlife Conservation Society
  - Center for Tropical Forest Science at the Smithsonian Tropical Research Institute
- Global Observation of Forest and Land Cover Dynamics (GOFC-GOLD) of the UN Food and Agriculture Organization
  - Observatoire Satellital des Forêts d'Afrique Centrale (OSFAC)
- Winrock International
- Congolais Industrielle des Bois (logging company in N. Congo)

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