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Toward a biophysical carbon accounting in Africa and perspectives for REDD and CDM

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ABSTRACTS

Opening session:

The CarboAfrica Project: An overview on the Sub-Saharan Africa carbon balance

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This presentation is outlook on the carbon balance of Sub-Saharan Africa based on current available results from the project CarboAfrica is presented. Net ecosystem productivity, emissions from fires, deforestation and forest degradation were derived by field and model estimates, supplemented by bibliographic data and compared with national communications data to UNFCCC. Depending on the used methodology very different carbon balance estimates can be obtained. Even if the absolute value is still highly uncertain, a near carbon neutral or even sink values are shown. Therefore Africa could probably have a potential for carbon sequestration higher than expected. Further investigations are needed, particularly to better address the role of savannas and tropical forests and to improve biogeochemical models. The CarboAfrica network of carbon measurements could provide future unique data sets for better estimating the African carbon balance.

Keywords: The CarboAfrica Project; African Carbon Balance; Savannas; Fires; Deforestation.

Impact of vegetation fires on African GHG budget

A comparison of active fire detection and burned area mapping from satellite in the Congo basin

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Burned area product reports a smaller amount of fire-affected areas than the active fire products in forested ecosystems, where small fires caused, for example, by logging or clear-cutting can be easily omitted in burned area products due to obscuration of fires by dense vegetation and cloud cover. The MODIS active fire product (MOD14A2) and burned area product (MOD MCD45) are outlined and discussed for its advantages and limitations. This study presents the comparison between active fire and burned area products for the period 2000 – 2008 for the Congo basin. The active fire statistics have been reported for three countries on a regional and national scale: the Democratic Republic of Congo, Republic of Congo (Brazzaville) and Gabon. The comparison between the MODIS burned area product and active fire provides essential information on the accuracy and usefulness of the active fire product. The statistics show a greater number of hotspots than burned area for each country over the investigation period; the MOD14A2 registers many fires that are not detected by the burned area product. An analysis of hotspots and burned area per land cover type provides detailed information on the location and extent of fire activities in tropical rainforest. Comparing active fire detection and burned area mapping is essential to further assessing and analysing fire activity in Central Africa. Inter-annual variability in fire events in the Congo Basin can be explained by rainfall and NDVI patterns that have both been analysed to see if there are any correlations between these parameters and the hotspot counts. The discussion also highlights other factors that may have resulted in the variation of hotspot data.

A statistical burned area model for the use in dynamic vegetation models

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The simulation of current and projected wildfires is crucial for predicting vegetation as well as greenhouse gases released in the African continent. The most common approaches to model wildfires is either to prescribe them from remotely sensed data, model them dynamically by using a mechanistic approach i.e. simulate ignition and fire propagation, or to use a statistical approach relating burned area to its major drivers. The first approach which may, given recent advances in burned area detection be the most precise one has the disadvantage that reliable satellite data on burned area is only available for a relatively short time period and that such analyses can not be extended over the time period covered by the satellite data. The second approach which allows to estimate wildfire activity over longer time spans still has the disadvantage that it results in a highly uncertain result since the mechanistic ignition, as well as the fire propagation simulation relies on highly uncertain variables like wind speed and socioeconomic relations to estimate the ignition sources. Here we present a statistical approach to simulate burned area designed to serve as a tool for dynamic vegetation models and global circulation models. This limited the variable choice to variables that have global historical coverage and which are either inherently calculated by the dynamic vegetation model or for which projections are available. Though this modelling approach has a lower explanatory potential than analyses with a different focus, it still allowed us to simulate burned area with respect only to climatic and vegetation related variables and population density. The model correctly predicts the spatial distribution and extent of fire prone areas though the total intra- and inter-annual variability is underrepresented. Using projected future climate it also allows us to project spatial distribution as well as total areas of burned area.

Environmental indicators of climate vulnerability for Africa from remote sensing

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The African continent has been subject to environmental changes associated with both climate variability and unsustainable human activities. Thus, an assessment and monitoring of the vulnerability of natural resources to these drivers of change become a crucial issue for Africa.
A 10-year time-series of satellite data including the Normalised Difference Vegetation Index (NDVI) from SPOT-VEGETATION, rainfall (combination of FEWSNET and TRMM data)
and burned area (MODIS AQUA and TERRA product) was analysed for inter-annual anomalies and long-term trends. The result of the trend analysis indicated decreasing rainfall in the western part of Congo basin. Also several regions in the Sahel zone showed a decrease in fire activity at 90% confidence level. Spatial-temporal correlation between single variables illustrated that the variation in NDVI was controlled by the rainfall pattern for considerable part of the African continent; however, in some regions NDVI variability was controlled by fires. In this study, we also made a first attempt to integrate those three parameters into one environmental indicator reflecting the land condition. Environmental indicators can supply valuable information on environmental condition and may be used as a powerful tool to raise public awareness on environmental issues.
The results of this study provide a set of comprehensive environmental information for each administrative region that can be used to i) understand the mechanism leading the anomalous situation in the region, ii) to assess potential locations and needs for action and iii) to project future trends of environmental condition.

Terrestrial Carbon Observations in Africa and Ecosystem fluxes

Spatial and temporal variability of carbon fluxes in African ecosystems - a CarboAfrica synthesis study

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with data contributions by J. Ardö, A. Arneth, Y. Nouvellon, A. de Grandcourt, S. Archibald, J. M. Bonnefond, N. Boulain, N. Brueggemann, C. Bruemmer, B. Cappelaere, E. Ceschia, H. A. M. El-Khidir, B. A. El-Tahir, U. Falk, J., N. Hanan, Lloyd, L. Kergoat, V. Le Dantec, E. Mougin, M. M. Mukelabai, D. Ramier, O. Roupsard, F. Timouk, R. Valentini, E. M. Veenendaal, and C.A. Williams

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This study reports carbon and water fluxes between the land surface and atmosphere in eleven different ecosystems in Sub-Saharan Africa, measured by eddy covariance (EC). The ecosystems ranged in mean annual rainfall from 320mm (Sudan) to 1150mm (Republic of Congo) and include a spectrum of land cover types (savannas, woodlands, croplands and grasslands). Data were analysed across the network, in order to understand the driving factors for ecosystem respiration and carbon assimilation, and to reveal the different water use strategies in these highly seasonal environments. In addition to the spatial pattern, the temporal pattern that connects carbon fluxes with water relations in savanna ecosystems were studied in detail in a savanna ecosystem at Kruger National Park, South Africa and a miombo woodland in Western Zambia. Temporal variability: The regulation of canopy conductance was temporally changing in two ways: changes due to phenology during the course of the growing season and short-term (hours to days) acclimation to soil water conditions. The most constant parameter was water use efficiency. The regulation of canopy conductance and photosynthetic capacity were closely related. This observation meets recent leaf-level findings that stomatal closure triggers down-regulation of photosynthesis during drought. Our results may show the effects of these processes on the ecosystem scale. Spatial variability: The same pattern was found at large spatial scales. Maximum carbon assimilation rates were highly correlated with mean annual rainfall (r2=0.74) and were also positively correlated with satellite-derived fAPAR. Ecosystem respiration was dependent on temperature at all sites, and was additionally dependent on soil water content at sites receiving less than 1000 mm of rain per year. All the ecosystems studied that were dominated by C3-plants showed a strong decrease in the 30-minute assimilation rates at low humidity (VPD > 2.0 kPa), while ecosystems dominated by C4-plants did not.

Carbon, water and energy fluxes in a West African humid tropical ecosystem

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The Nigerian Micrometeorological Experiment (NIMEX) is an on-going collaborative research project between a consortium of universities in Nigeria that constitute the Atmospheric Research Group, ARG) and the University of Bayreuth (UBT), Bayreuth in Germany. NIMEX initially was designed to study the land surface-atmosphere mass and energy exchange processes at a humid tropical location.
NIMEX-1 and NIMEX-2 have successfully been conducted in 2004 and 2005 respectively, and major scientific results have been reported in the literature. The ARG is now set to conduct NIMEX-3 between March and April, 2010. Its objective is to expand the scope of the earlier field studies to include the monitoring of CO2 fluxes by an eddy covariance (EC) system, using an ultrasonic anemometer (Campbell Scientific model CSAT3) and a gas analyser (Li-COR model LI-7500). NIMEX-3 measurements will complete the gaps that were apparent in NIMEX-1 and NIMEX-2 datasets.
The sparse observational network in and around the African continent implies a knowledge gap in understanding contributions to the global carbon budget. NIMEX-3 is a first attempt of CO2 flux monitoring in Nigeria, in order to quantify

and understand ecosystem carbon, water and energy budgets. We believe that the ARG flux tower will contribute significantly to the CARBOAFRICA flux measurement network in Africa. Preliminary data will be presented and discussed. 3ARG is made up of scientists from the following institutions: Department of Physics at the Obafemi Awolowo University in lIe-Ife; the Department of Physics at the University of lbadan in lbadan; both the Departments of Meteorology and Physics at the Federal University of Technology in Akure (all in Nigeria).

Heterogeneity of carbon fluxes in miombo woodlands - revised analysis

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Carbon dioxide efflux from the soil was measured over a period of several months within a heterogeneous Brachystegiy spp. dominated miombo woodland in Western Zambia. The objectives were to determine spatial and temporal variation of soil respiration along a disturbance gradient from a protected forest reserve to a cut, burned and grazed area outside, and relate the flux to various abiotic and biotic drivers. The highest daily mean flux (12 micromol m-2 s-1) were always measured in the protected forest in the wet season and lowest daily mean fluxes (around 1 micromol m-2 s-1) in the most disturbed area during the dry season. Temporal variation of soil respiration was closely correlated to soil water content and soil temperature. There was a 75% decrease in soil CO2 efflux during the dry season and a 20% difference in peak soil respiratory flux measured in 2008 and 2009. Spatial variation of CO2 efflux was positively related to soil carbon content (10 cm depth) in the protected area but not in the disturbed places. Higher values in leaf area index were associated with higher efflux rates, suggesting a close connection between photosynthesis and respiration. Three different approaches to calculate total ecosystem respiration (Reco) from eddy covariance measurements were compared to two bottom-up estimates of Reco obtained from chamber measurements of soil and leaf respiration which differed in the consideration of spatial heterogeneity. The consideration of of spatial variability resulted in only small changes of Reco when compared to simple averaging. Total ecosystem respiration at the plot scale, obtained from eddy covariance differed by up to 30% in relation to values calculated from the soil- and leaf chamber efflux measurements but without a clear tendency.

Carbon sequestration, radiation use efficiency and water use efficiency of a tropical grassland annually burned in Congo

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In Sub-saharan Africa, grasslands occupy 14.5 millions of km2, representing two third of the surface area of Sub-saharan Africa (FAO 2001). This biome is directly affected by climate change that we are facing, in particular through changes in seasonal distribution of rainfall and the increase in temperature (Ojima et al. 1993). Few eddy-covariance sites are established in this kind of ecosystem (Verhoef et al. 1996, Hanan et al. 1999, Veenendaal et al. 2004, Scanlon and Albertson 2004), while the anthropic pressure tends to transform them in rangeland, fields or trees plantations. Our main objectives in this study were: 1) to quantify carbon sequestration (NEP) and ecosystem respiration (Reco) of a tropical grassland, taking care of the loss linked with the annual fire, 2) to study the seasonal variation of the water use efficiency and the radiation use efficiency of the grassland, 3) to identify the environmental factors driving the grassland functioning.

CO2 fluxes at the AMMA Sahelian sites: a comparison between agro-pastoral and pastoral Sahel

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Within the frame of the African Monsoon Multidisciplinary Analysis (AMMA) project, CO2 eddy correlation flux measurements have been performed since 2005 for dominant vegetation types of the Sahel. Located towards the northern limit of the area reached by the West African Monsoon, the Sahel experiences a single rainy season with most precipitation falling between June and September.
We analyze here the observations collected during 2 years at a shrub savannah site located in the pastoral zone in Northern Mali, and those acquired at fallow and millet sites in Western Niger. The considered period is 2005-2006 for the Niger sites and 2007-2008 for the Malian site. For each cover type, carbon fluxes variations are interpreted in relation to seasonal variations of meteorological variables, vegetation dynamics and soil moisture content.
Net Ecosystem Exchange (NEE) is found to be close to zero during the dry season. During the rainy season, the seasonal variation of NEE follows closely the herbaceous vegetation dynamics which is the main component of the vegetation cover. For the savannah site in Mali, maximum daily values of NEE observed in 2007 are strongly and linearly correlated to Leaf Area Index (LAI) except during the dry sequences that have punctuated the rainy season. In 2008, this relationship does not hold due to overall very dry conditions. Carbon uptake by photosynthesis (Gross Primary Productivity) contributes up to 60-80% of NEE. During the period of maximum LAI for herbs, Light Use Efficiency (LUE) is strongly related to the water content of the upper soil layer. At the Niger site, the two cover types show clear differences in CO2 uptake. Assimilation appears much higher in the fallow than in the millet field indicating that the fallow is a more significant carbon sink than the cultivated field. This may have important consequences on the regional carbon budget within the context of rapid crop expansion in Sahel.

Carbon sequestration, water-use, and water-use efficiencies in eucalypt plantations in Congo

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Tropical eucalypt plantations provide an increasing share of the global wood supply. High yields on weathered tropical soils and their ability to grow as coppice are the main reasons for their success. However, their future will also depend on their ability to sustain high yields and to preserve soil fertility, and on their impact on water-resources, especially in areas where large amounts of water are needed for agriculture or other human activities. Our main objectives in this study were: 1) to quantify water-use (actual evapotranspiration, AET) by eucalypt plantations in Congo, and to compare it to the AET measured in more productive eucalypt plantations in Brazil; 2) to compare the wood production (WP), carbon sequestration (NEP), AET, and water-use efficiency (WUE) of two eucalypt clones (UG and PF1) planted in Congo; 3) to identify some of the most important factors explaining observed clonal differences in WP, NEP and WUE. AET measured by eddy-covariance was low in Congo (≈700 mm/yr) compared to that measured in Brazil (≈1300 mm/yr), despite similar annual rainfall (≈1200 mm/yr in Congo versus 1380 in Brazil). These differences were mostly explained by

differences in net radiation (≈2740 MJ/m2/yr in Congo versus ≈3830 in Brazil), and LAI (1.4 and 2.4 for PF1 and UG clones in Congo versus 3.2 m2/m2 in Brazil), and were associated with differences in WP (higher in Brazil). There were strong differences in WP and NEP between the two clones in Congo, despite low differences in AET, resulting in strong
differences in WUE, that were observed at both the canopy scale (eddy-covariance) and the leaf scale. These differences were mostly due to differences in leaf conductance. There were also strong differences in LAI, leaf turnover, leaf inclination, fraction of NPP allocated to wood, which all contributed to the observed differences in WP and NEP.

Measuring fluxes over a *Colophospermum mopane* savanna

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Colophospermum mopane grows throughout most parts of southern Africa, including South Africa, Zimbabwe, Mozambique, Botswana, Zambia, Namibia, Angola, and Malawi. It's specially suited to grow in hot, dry, low-lying areas. Where *C. mopane* trees occur, they are usually the dominant tree species in the landscape, although they are often found together with *Combretum* and *Terminalia* species. This paper gives the results of a year-long campaign at the Malopeni flux tower, near Phalaborwa, South Africa, which experiences some of the highest temperatures in the country and has a relatively low mean annual rainfall. These results are compared to flux measurements obtained during seasonal week-long campaigns at a *C. mopane* site further north in the Kruger National Park. If savanna systems in southern Africa become drier and hotter, it is likely that the geographic distribution of *C. mopane* will expand, and therefore understanding the carbon dynamics of *C. mopane* woodlands will help us to predict the consequences of such a change.

The carbon cycle in an African tropical forest

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Ecosystem CO_2 exchange, biodiversity, leaf area index, biomass and soil organic carbon content in an African evergreen tropical rain forest (Ankasa, Ghana) were analysed. Cumulated NEE (Net Ecosystem Exchange) indicates a carbon sequestration during the dry season of -178.65 g C m^{-2}. The extrapolation of the C balance to annual scale yields an amount of -5.87 t C ha^{-1} yr^{-1} absorbed from the atmosphere. The stock of carbon in the mineral soil to a depth of 1 m was measured to be 151±20 Mg C ha^{-1}, a similar value in magnitude to the one of the aboveground biomass being 138–170 Mg C ha^{-1}, including live and dead wood. Surface litter C is roughly 10% of the C in the biomass and soil. 38 families, 114 genera and 184 species were found in total within the sampling area. A total of 1898 plants with a diameter at breast height> 5 cm was found with an average density per hectare of 950 plants. The estimated LAI was 6±1. The Ankasa forest is a big reservoir of carbon, however the potential of African tropical forest to act as a carbon sink has been so far not adequately studied and should be further considered by future projects.

Keywords: biodiversity, biomass, carbon fluxes, oil carbon, tropical African forests.

Impact of seasonal drought and age-related changes in litter inputs on the temporal trends in soil CO_2 efflux after afforestation of a tropical savannah

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Soil CO_2 efflux (Fs) is a major flux in the global carbon (C) cycle, and an important determinant of the soil C balance. Land use changes, such as savannah afforestation with eucalypt might impact on the soil C balance, since vegetation influences both the rates of Fs and of C inputs to the soils. Few studies have examined the dynamic of F*s* and its components according to stand age. Our main objectives were: 1) to evaluate the seasonal and age-related variations of Fs during the first rotation after savannah afforestation in Congo; 2) to investigate the effect of soil water content (SWC) on Fs at three stand ages; 3) to study the dynamic of litterfall and litter accumulation on the forest floor, as stands mature, in order to estimate the contribution of litter decomposition (Fl) to Fs for increasing stand ages. Fs was measured for one year at 3 adjacent stands that were 1, 4 and 14-yr-old. Litterfall and litter accumulation on the forest floor were quantified over a chronosequence. Equations were derived for estimating Fl as a function of stand age. Annual Fs decreased from 5.8 to 4.6 tC/ha/yr from age 1 to age 4, and then increased up to 7.4 tC/ha/yr at the 14-yr-old stand. The high Fs during the first year after afforestation, compared to the 4-yr-old stand, was mostly due to the decomposition of savannah residues. The increase in Fs from age 4 to age 14 was partly due to Fl which increased from 1.6 to 3.2 tC/ha/yr. An empirical model relating Fs to SWC explained 79, 89, and 72% of the seasonal variability in Fs for the 1, 4 and 14-yr-old stands, respectively. Fs saturated rapidly with increasing SWC in the 4-yr-old stand but not in the 14-yr-old stand.

Using remote sensing to map forest cover change in savanna woodland: A case study in Malawi

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Malawi is one of the poorest countries in the world. Projections based on primary forest loss experienced between 1990 and 2005 suggest that all primary forest in Malawi will be degraded or deforested by 2020. Because of this, there is much interest in forest resource mapping and assessment, particularly with regards to implementing any proposed Reductions in Emissions from Deforestation and Degradation (REDD) mechanism. Remote sensing provides a unique opportunity to monitor and map forest cover change on spatial and temporal scales not otherwise possible. In order for REDD to work in Malawi, there is a need to first understand what forest cover (and therefore biomass) change is taking place in order to calculate baselines for any carbon credits or ecosystem services payments. Preliminary results of biomass mapping using ALOS PALSAR imagery and published biomass-backscatter relationships will be presented. The results of these analyses will be used to aid the determination of the most appropriate methodology for national and regional biomass and
forest cover change mapping across Malawi and form part of the REDD Horizon Project (_http://www.geos.ed.ac.uk/research/eeo/REDDHorizon/_). The results can also be used as a benchmark to help quantify the success of future carbon offsetting schemes, improve protection of forest reserves and national parks through specific targeting of resources, and be used in conjunction with other socio-economic data to help monitor the success of the National Forest Programme.

Evaluating commercial forest inventory data to report on forest carbon stock and forest carbon stock changes for REDD+ under the UNFCCC

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In context of the post-Kyoto discussions on reduced emissions from deforestation and degradation (REDD), it is important to provide reliable data on the spatio-temporal variation of aboveground biomass (AGB) in tropical forests. Obtaining sufficient ground-data to do so is an expensive and time-consuming task. There exists a particular gap in this information for Central African rainforests and specifically for Gabon. This paper seeks to provide an assessment on the use of commercial logging inventories to estimate AGB. The data presented in this study comes from five logging companies, covering ten logging concessions and 675 hectares of inventoried plots in total, dispersed over Gabon. The method used is a network of 0.3 hectare plots in which three subdivision are made. We find that the average AGB in the concessions ranges from ~ 153 ± 70 Mg/ha to 269 ± 132 Mg/ha, which is at the lower range of previous studies. The number of 0.3 ha plots put in place by the study bureau, Sylvafrica, for the management inventories is in all cases above the 10 % accuracy level and in some cases above the 5 % precision level. Using this inventory data, the forests were classified into three forest types based on family abundance. There exists a significant variation in AGB between these forest types which can be correlated to coarser ecological zones in the country. An overview of the caveats of using this type of data is presented together with how the AGB information produced from this data could be used in the UNFCCC REDD+ context. Finally it is suggested that that commercial logging companies should be involved for a successful REDD+ process in this region in terms of data sharing and expertise.

On the causes of the recent greening of the Sahelian vegetation: a synthesis of research results

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We present a synthesis of the main research results that have been gathered about the recovery (coined "greening") of the Sahelian vegetation after the droughts of the early 1970's and the mid 1980's. Various studies based upon field surveys or remote sensing observations suggested that since the 1980's droughts, vegetation cover has become denser. Some argue that this "greening" signal (which is dominated by the evolution of the herbaceous layer) could be concomintant to an increase in ligneous cover. The greening trend of Sahel is analyzed in the context of a region that is subject to a very high rainfall variability over a broad range of time scales (with a persistance of dry and humid anomalies over several years and decades that seem to be much more pronounce than in other semi-arid zones) and where the desertification-paradigm lexicon has been developed. In the following, evidence for a greening trend over Sahel is summarized and discussed. An overview is provided of attempts that have been made to identify which fraction of this evolution can be attributed to natural variability of the precipitations as compared to other driving forces along a presentation of the existing prospective studies.

Keywords : Greening, Vegetation Precipitation Feedbacks.

Soil and Vegetation: Carbon and GHG emissions in Africa

Evaluating Vegetation-Climate-Soil Complexes to explain FAPAR IAV across Sub-Saharan-Africa

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Despite the obvious controls of vegetation interannual variability such as rainfall and temperature little emphasis has been put on the effect of Vegetation-Climate-Soil-Complexes (CVS). Especially Africa's extended grasslands are thought to be under the strong influence of such complexes. Here we use different spatial datasets at continental scale to evaluate the complex combinations between climate, vegetation and soils using novel machine learning techniques. Results show that CVS can explain roughly 75% of the vegetation variability, but climate alone has the same explanatory potential. Soils alone explain almost 50% variability resulting also in a strong impact. We discuss several analysis within the study framework and future research directions.

Assessing forest structure and biomass from canopy aspect analysis on metric resolution remotely-sensed images

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The objective of our project is to propose a validated and operational methodology allowing the quantification of the forest structure as a starting point to assess biomass and carbon stocks and to monitor forest degradation in support of the REDD implementation. The approach is based on the textural characterization of metric resolution optical canopy imagery, in particular via the Fourier transform textural ordination (FOTO) method already tested at broad scale in the neotropics. Case studies have revealed good correlations between stand structure parameters (e.g. quadratic mean dbh) and canopy texture indices. Simulated stand structure and a radiative transfer model (DART developed at CESBIO, Toulouse) are also being used, to test model inversion and help minimize instrumental effects (such as acquisition angles of the satellite scenes). A partnership has been initiated between IRD, the French Institute for Development (ex ORSTOM), Forêt Resource Management (FRM) a forestry consulting society, and a software development society (Nevantropic), to test the approach on very large forest inventory datasets and to provide the end-users easy to use plugging functions compatible with the most popular GIS software. This project is part of a broader effort from IRD to address the consequences of global change on biodiversity, resources and health in central Africa.

Keywords: Canopy texture, Image simulation, Metric resolution, Remote-sensing, Forest structure

Carbon, Nitrogen and Phosphorus Budget in Land Management Systems involving *Acacia senegal* in drylands of North Kordofan, Sudan: *Flow and Balances*

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Average, optimistic and pessimistic balances of organic carbon (OC) nitrogen (N) and Phosphorous (P) in pure and intercropped sorghum, roselle and gasses with *Acacia senegal* at low- and high-tree density (LD 266 and HD 433 trees ha^{-1}) were investigated over three cropping seasons, in drylands of western Sudan. Nutrient inflows are OM from trees; gum Arabic; crop roots; atmospheric deposition, and N-fixation. Outflows are harvested products; crop residues; leaching, and wind erosion. Average balances were positive in grass systems, but negative in pure sorghum and roselle. Large variations exist between intercropped sorghum and roselle systems. Average balances were positive in poor cropping season (2002), while negative in good season (2003). Nutrient depletion was severe for studied

nutrients in pure sorghum and roselle, P depletion was severe in all roselle systems. High negative optimistic and pessimistic balances were in pure sorghum and roselle, due to high outflows and low inflows. At low productivity, P severely mined in intercropped roselle; while at high productivity, P was severely mined in sorghum and roselle at HD and LD. For all systems, phosphorus availability is the major determinant of sustainability. The study demonstrated that OM is essential for positive nutrient balances. Hence, intercropping is an appropriate option to enhance soil fertility.

Keywords: optimistic; pessimistic; nutrient balances; sustainability; nutrient depletion

Biogeochemical Modelling

Estimating Primary Production for Africa -satellite or ecosystem model?

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Primary production of terrestrial vegetation can be estimated by several methodologies, including dynamic vegetation models and remote sensing based models as well as various combinations of these two methodologies. This study compare MODIS based estimates of GPP and NPP (MOD17A2, MOD17A3) with estimates from the Lund Potsdam Jena (LPJ- GUESS) global dynamic vegetation model.
The product MOD17A2 provides 1-km spatial resolution and 8 day temporal resolution composites of global NPP and GPP based on the light use e_ciency (LUE) concept assuming a conservative relationship between plant productivity and absorbed photosynthetic radiation. LUE is biome speci_c and scaled with temperature and vapor pressure de_cit when these factors are assumed to limit productivity.
PJ simulates potential vegetation as a mixture of plant functional types (PFTs) defined by growth form, phenology, life-history characteristics and bioclimatic limits for establishment and survival. The simulated plant type assemblage depends on the outcome of the intraspecic competition which is shaped by the environmental conditions. Main drivers are air temperature, precipitation, incoming radiation, but also disturbance events like _res which are prescribed from remote sensing are taken into account. LPJ-GUESS was executed with a spatial resolution of 1 x 1 degree and a daily time step.
Differences in spatial and temporal resolution of the methodologies are explored and compared. Comparisons between LPJ-GUESS and MODIS estimated GPP and NPP are stratified per vegetation type and quanti_ed using correlation, root mean square error and bias. Spatial variability of the 1 km resolution MODIS estimates within each 1 x 1 degree LPJ grid cell are described with standard deviation and range.
Results regarding the spatial & temporal di_erences and similarities of MODIS versus LPJ-GUESS based estimates of GPP/NPP are presented and discussed. Avenues of interaction of the process intense vegetation model with the more data intense satellite product are explored and discussed.

E-Dendro. A soil-plant model operating at stand scale to assess the impact of sylviculture on the biogeochemical cycles of planted forest ecosystems

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Tropical plantations are often established on poor soils, characterised by low reserves of available nutrients. There are then concerns about the sustainability of such fast growing plantations because an intensive management is carried out resulting in the removal of large quantities of biomass every 7 to 8 years (very short rotations) and leading to high risks of soil nutrient deficiencies. In this study, we present an innovative chain of models combining a growth and yield approach

for tree and stand growth; a wood properties module to assess volumes and biomasses (above and below ground); a biogeochemical module estimating within-tree content of nutrients (N, P, K, Ca, Mg), litterfalls and litter decomposition; and finally a soil-plant interaction module which controls the impact of fertilisation and slash management on the growth module. Currently, this chain is calibrated for eucalyptus plantations in Congo and the soil-plant interaction is only driven by nitrogen which is the main limiting factor in these plantations. After a description of all equations involved (including the results of calibration and validation for the different modules), we present some runs of simulations of different slash management options over several rotations. Estimates are then compared to the measurements currently done in a field trial (two rotations of the same treatments).

A comparison of data- and process-oriented models for Africa

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Uncertainties of the spatial distribution and temporal evolution of carbon and water fluxes of the African continent are very large. We use globally distributed eddy-covariance measurements of carbon and water fluxes (FLUXNET) integrated with remote sensing information in a machine learning framework to estimate key biospheric fluxes in a spatially and temporally explicit way. Results from this data-oriented approach are compared with the ensemble of process model runs from the CarboAfrica Model Intercomparison. We identify robust patterns that emerge independently from both modelling approaches, and identify and discuss divergent patterns.

CDM and REDD in Africa

Carbon Market in Africa

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IDEV-ic, Dakar Sénégal

After a brief description of the legal basis of carbon transaction, the paper describes the different aspects of the flexibility mechanism with a special attention on clean development mechanisms and voluntary carbon market. The present share of Africa is given with an analysis of barriers of African countries in this market. These barriers are linked to weak capacity, complexity of methodologies with respect to afforestation and reforestation. New perspectives offered by REDD and AFOLU are also discussed.

Keywords: Africa, carbon, Clean development mechanism, Kyoto protocol, REDD, AFOLU, voluntary market

Capabilities of Remote Sensing for Biomass Estimation and REDD in Tropical Africa: the Case Study of Uganda

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Aboveground biomass of vegetation for the year circa-2000 is retrieved at national scale in Uganda using Landsat ETM+ images, a National Land cover dataset and field data with an object-oriented approach.
A regression tree-based model (Random Forest) produces satisfactory results (cross-validated R^2 0.81, RMSE 13 T/ha) when trained with a sufficient number of field plots representative of the vegetation variability at national scale. The empirical model captures the non-linear relationships between satellite data and

biomass density and is able to use categorical data (land cover) in the regression. Independent comparison of biomass estimates with Lidar height metrics indicates a strong positive correlation between the parameters.
Optical data provide an effective way to spatialize field biomass measurements and produce estimates at national scale required for REDD-related monitoring and reporting. Saturation appears at high biomass density (150 – 200 Mg ha^{-1}) and cloud coverage limits satellite data availability. Consequently, the phenologically consistent Landsat mosaic created for Uganda with images acquired in the dry season during 1999 – 2003 does not contain multi-temporal information. The addition of land cover data increases model performance mainly because land cover contains phenological information missing in the Landsat mosaic. On the other hand, Landsat data present higher spatial and thematic resolution compared to land cover, which allow the computation of detailed and continuous biomass estimates. Fusion of satellite and ancillary data improves model results but, to avoid error propagation, accurate, detailed and updated ancillary data are necessary for biomass prediction.
When compared with the reference biomass map of the Forest Department of Uganda, our product performed better than other three published regional biomass maps derived from satellite or land cover data. The comparison also highlights the importance of using local (forest inventories) versus biome-average (IPCC Tier 1) biomass reference values and national versus global land cover data.

Variability of carbon stocks in sub-Saharan Africa

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Understanding climate change and identifying mitigation actions depends on our comprehension of the carbon cycling in terrestrial ecosystems. While sub-Saharan Africa is the most vulnerable continent to climate change it is also the less known. Several attempts tended to develop continental or regional estimates of carbon stocks but they were limited by the numbers of available data and by heterogeneity in data quality and domain of validity. The aim of this study was to estimate the variability of carbon stocks in sub-Sahran Africa. The first georeferenced database on harmonized carbon stocks was built for this continent. Integrating the data with land cover and tree cover continental products allowed the development of continental carbon maps using several biome classifications. The results illustrates the variability of carbon stocks which are found in the various ecosystems and biome types but also the impact of forest definitions and biome classifications in assessing carbon stocks. Integrating biophysical georeferenced data allowed the development of a model that could be used to predict carbon stocks in natural ecosystems of sub-Saharan Africa. The derived products could be used to predict the cost of forest inventory, the available fuelwood and bioenergy, calibration or validation of biogeochemical models and climate studies.

Fast calibration of robust biomass equations. From the conceptual framework to the application using the Carboafrica database on allometric equations

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Working on both Fagus sylvatica in Europe and Eucalyptus in Congo, we demonstrated that species of similar traits (e.g., crown architecture, wood structure) exhibit the same biomass patterns. The basic fitted equation was biomass = $\alpha * d^2h^\beta$ making it possible to work with biologically meaningful parameters, where α encompasses both the form of the tree and the wood density, and β is the allometric exponent which gives the proportionality between biomass and volume increment. The allometric parameters were found to vary with stand age (decreasing for the crown and increasing for the trunk biomass), which significantly improved the performances of all aboveground biomass equations. This time-dependency was related to both changes in stem form and in wood density for the trunk; and to sapwood to area ratio and hydraulic conductance for the crown. All equations for Fagus sylvatica found in the literature failed to

accurately estimate the measured biomasses, mainly because they were fitted on a limited number of trees. However, using our model, we were able to homogenize most of these equations using the stand age given in each paper. Our proposed method opens the
opportunity to quickly calibrate accurate sets of biomass equations for different tree species using either published equation database or few sampled trees appropriately chosen. The recent Carboafrica
database gathering more than 800 published biomass and volume models opens rooms for developing robust and accurate equations for Africa. Combining the conceptual framework abovementioned and the predictions of several models to get more accurate biomass estimates could alternatively be done using Bayesian techniques for multimodel regression. These techniques will be sketched to show their potentiality when using the database on biomass equations for sub-Saharan Africa.

'Rules of the game' and 'game tactics': elements for a National Forest Inventory to support REDD+ implementation under the UNFCCC

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Countries that are willing to participate in the future mitigation mechanism of Reducing Deforestation and Forest Degradation (REDD+), will have to establish a Measurement, Reporting and Verification (MRV) system in order to assess anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks. A national forest inventory (NFI) is one component of such and MRV system. Following the UNFCCC's Subsidiary Body on Scientific and Technological Advice (SBSTA), the most recent Intergovernmental Panel on Climate Change (IPCC) guidance and guidelines should be used as a basis for estimating anthropogenic forest-related greenhouse gas emissions by sources and removals by sinks, forest carbon stocks and forest area changes. In this context, this paper has three objectives: (i) to briefly present the UNFCCC MRV framework and indispensable elements following IPCC guidelines in which a NFI for REDD+ implementation has to be developed; (ii) to present some non-exhaustive optional elements within this framework that a REDD+ country could consider and finally (iii) to apply the above two components to present a preliminary methodological approach for a NFI driven by aboveground biomass (AGB) estimates for the Democratic Republic of Congo (DRC) to assess and to report carbon stock changes on forest land at least at a Tier 2 level. Although there exists decades of experience in setting up traditional NFIs, developing a NFI that a country may use for REDD+ mitigation actions under the UNFCCC represents the development of a 'new game' in this field. It is hence urgent that the scientific community acquaints itself with the rules of this new game and possible game tactics, so that it may provide the scientific expertise and innovation which is needed so that REDD+ mitigation actions may be implemented successfully and with environmental integrity.

Demonstration projects and developing capacities in Africa

Root plasticity of two eucalypt clones under drought conditions in Congo

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In a context of climate change, adaptation of perennial plantations to water constraints becomes a major concern for wood productivity. Scenarios of climate change predict severe and longer dry periods, particularly on west coast of central Africa. During two years, root plasticity of young eucalypt plantation was characterized in drought conditions in Congo (3-4 month dry period), on two

contrasted improved clones (1-41 and 18-50, with low and high wood productivity levels, resp.). Three field conditions were compared: (1) “dry treatment” without irrigation corresponding to natural conditions, (2) “irrigated treatment” at field capacity during dry periods and (3) “recovery treatment” with no irrigation during the first year and irrigation during the second year. Root plasticity was studied through root architecture dynamics and root biomass distribution (top soil to depth) for coarse (D>1cm), medium (1cm<D<2mm) and fine roots (D<2mm).
Irrigation effect on root biomass production (all root types) was highly significant (4 to 6 times compared to dry treatment) on both clones but only during the first 6 months after plantation. Afterwards, this effect was not significant for both clones because of high recovery root growth during following rain seasons. However, 18-50 clone produce more root biomass under both watered and dry conditions than 1-41 clone probably because of its higher growth potential (1 to 2 meter higher than 1-41 at 18 month old). By contrast, 1-41 clone set up more root biomass in the 50cm deep horizon in dry treatment than 18-50 clone which tend to develop higher fine root biomass in top soil in same conditions. Recovery treatment confirm this result with a deeper fine root development in 1-41 clone during the first dry year and 18-50 clone exhibited the best recovering growth during the second watered year, with a complete catch up. Concerning dynamics of root architectural parameters, irrigation provide longer plagiotropic coarse roots (mainly 1-41) with no modification on their number and on the proximal root branching rate.
To conclude, 1-41 clone seemed to be more reactive to drought with a better root distribution in deeper soil and good recovery growth during wet periods whereas 18-50 clone, despite its higher growth and recovery potential, seemed to be more limited during dry period and less plastic than 1-41 clone.

A Mapping Tool for Sharing or why do big research projects deliver so little practical benefit?

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Large multi-partner research projects on natural resources / carbon management/ land management / climate change tend to suffer the following problems: - Initial ideas for collaboration, synergies and cross-disciplinary work are rarely followed through in practice - Projects tend to deliver isolated packages of outputs rather than a clear, integrated synthesis - Data sets are often lost (archived on physical had disks that are never retrievable by other research groups) - Experience and insights leak away once project comes to an end - Research outputs do not get taken up or used by policy makers (either because the institutions are not able or willing to digest this material or because researchers are unable to communicate to this audience, or because there are not sufficient resources or conditions to take up) - Outreach or dialogue with potential users is generally ineffectual (stakeholder meetings are nearly always a waste of time and nobody with any decision-making capacity ever goes to them). - Researchers have a limited understanding of how their research can be usefully used. - Project websites are nearly always terrible (mainly for internal communication) Our Ecosystem is a map based web-tool that helps address some of these problems by providing a shared interface to: - record what research is done where - display locations of sample plots - link to research network and results Above all it provides a map interface to communicate the significant results - e.g. carbon stocks at risk and can compare outputs of one project with another. By making data access and sharing easier, it builds the capacity of individuals, teams and organisations to turn data into results.

Posters

Soil CO2 efflux in a congolese savannah: seasonal and interannual patterns, and comparison with eucalypt plantations

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The evaluation of the impacts of land use change, like afforestation of tropical savannah by eucalyptus, is needed to predict the potential for carbon sequestration in Sub-saharan Africa. Soil CO2 efflux (Fs) is one of the main components of ecosystem respiration and exhibits a high spatial and temporal variability. Therefore obtaining good estimates of Fs and understanding environmental control on the underlying processes are important to understand C cycling and sequestration in soils. In the present study, our objectives were to quantify and to analyse seasonal and inter-annual variations of Fs in a savannah and to compare it with eucalyptus plantation. Fs was measured from November 2006 to December 2009. It exhibited pronounced seasonal variations with lowest values below 1 µmol m-2 s-1 at the end of dry season and highest values of 5.5 µmol m-2 s-1 during the wet season. An empirical model describing Fs as a function of soil water content and temperature explained only 55% of the variability while the same model applied in eucalypt plantation explained between 72 to 89% of the variability depending on stand age. Adding absorbed photosynthetic active radiations increased the model predictability to 83%, underlying the importance of carbon allocations to roots and of the autotrophic component of Fs in savannah compared to eucalypt plantations. Cumulated fluxes over one year were higher in savannah than in eucalyptus plantation (1.22 kgC m-2 an-1 in savannah vs. 0.74 in eucalypt plantations). At the end of the wet season, grasses allocate most of assimilated carbon belowground. It may explain why savannah FS is less sensitive to the decline is SWC than Eucalyptus FS.

Keywords: soil respiration, savannah, eucalyptus

Soil carbon in miombo woodland has large spatial variability

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Even though Africa is the second largest continent on earth, very little is known of Africa's soil carbon pool. The dynamic processes leading to soil carbon changes need to be better understood to arrive at better estimates of the potential for carbon storage and sequestration in African soils. Soil carbon stocks are influenced by climate, geology, topography, vegetation, soil physical characteristics, and disturbance history, all of which vary spatially. Furthermore, the heterogeneity of the miombo woodland landscape makes soil carbon spatial sampling challenging.
A study into spatial variability across a miombo woodland landscape was carried out in central Mozambique, with the aim to answer (a) How do soil carbon stocks vary spatially in miombo woodland, and (b) What determines variation in soil carbon? In this study a one-dimensional cyclic sampling design was utilised, optimising plot distributions for geostatistical analyses, allowing quantification of spatial patterns in the landscape. Sampling took place along a 5.25 km straight line transect.
Preliminary results show that there is large variability in measured parameters across the landscape. Mean soil carbon ranged from 7-23 Mg C ha-1 in the top 5cm, and 29-111 Mg C ha-1 in the top 30cm, with large variability at short distances. Aboveground biomass similarly varied from 2-39 Mg ha-1 for tree stems less than 30cm diameter, and 8-90 Mg ha-1 for tree stems greater than 30cm diameter. We present our sampling technique with preliminary results, linking it with remote sensing imagery, showing the heterogeneity of the miombo woodland landscape.

Keywords: soil carbon, miombo, geostatistics, cyclic sampling, Africa

Using satellite radar to map biomass

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Regional-scale above-ground biomass (AGB) estimates of African savannas and woodlands are highly uncertain, despite their covering the majority of the land area of the continent, and their huge importance both as providers of ecosystem services and as a highly dynamic component of the carbon cycle. In response, we collated field inventory data from 253 plots at four study sites in Cameroon, Uganda and Mozambique, and examined the relationships between field-measured AGB and cross-polarized radar backscatter values derived from ALOS PALSAR, an L-band satellite sensor. The relationships were highly significant, similar among sites, and displayed high prediction accuracies up to 150 Mg ha−1 (±~20%). AGB predictions for any given site obtained using equations derived from data from only the other three sites generated only small increases in error. The results suggest that a widely applicable general relationship exists between AGB and L-band backscatter for lower-biomass tropical woody vegetation. This relationship allows regional-scale AGB estimation, required for example by planned REDD (Reducing Emissions from Deforestation and Degradation) schemes, and will enable the production of more accurate biomass maps, helping us to understand the carbon balance these dynamic ecosystems.
We also present an example from Cameroon of using this relationship between radar backscatter and AGB to quantify changes in AGB over an 11-year period by using L-band radar data from the JERS-1 satellite from 1996. This shows that radar data can be used to monitor changes in biomass, and repeat passes from the same sensor should enable deforestation, degradation and woody encroachment to be monitored accurately.

Using remote sensing to map sustainable forestry in Malawi

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Malawi is facing a forest loss crisis. Projections based on primary forest loss experienced between 1990 and 2005 suggest that all primary forest in Malawi will be degraded or deforested by 2020. Because of this, there is much interest in forest resource mapping and assessment. In order to manage this vital resource sustainably an understanding forest cover change is required. Results from a biomass map developed using ALOS PASAR imagery and a published backscatter/biomass relationship for African savannas have shown the potential of this technique for mapping forest cover change and biomass in areas where that have failed to find direct relationships between backscatter and ground truth data.

Analysis of biodiversity and biomass in the Ankasa Resource Reserve, Ghana

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Tropical rainforests play a crucial role for the biosphere and therefore are a natural reserves of biological diversity and store large amounts of carbon playing a major role in the global carbon budget.
This study conducted in the framework of CarboAfrica project, and was aimed at the ecological characterization of the Ankasa tropical forest. In particular the following issues were analyzed: biodiversity, leaf area index and biomass. Several biodiversity indices were calculated, including the Genetic Heat Index (GHI) for estimating the abundance of rare species in the forest population.
The aboveground biomass was estimated using allometrics equations.
38 families, 114 genera and 184 species were found in total within the sampled area of 20000 m^2. A total of 1898 plants with a diameter at breast height> 5 cm was found with an average density per hectare of 950 plants. The GHI resulted is 197. The basal area per hectare was estimated as 50 ± 11,5 m^2 ha^{-1}(average ±

dev.st.). The aboveground biomass was 271 t ha^{-1} with 135 t C ha^{-1} and 49.95 t C ha^{-1} stored in aboveground and belowground biomass, respectively. The estimated LAI was 6 ± 1.01 (average +/-dev.st.).
Due to the low level of secondary and pioneer species and the high rate of biodiversity, Ankasa reserve can be considered an undisturbed forest.
In light of these results it is clear that the African tropical forests, yet undergoing an impressive rate of deforestation should be considered with great attention to avoiding the biodiversity loss, and mitigating climate change.

Keywords: Africa, tropical rain forests, Ankasa forest, biodiversity, Genetic Heat Index, biomass, allometric equations, emispherical photograph, LAI, carbon stock.

Effect of density, fertility and genetics on specific leaf area, leaf area index and carbon allocation to above-ground plant compartments in eucalyptus plantations in Congo

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In view of the sustainable management of 43,000 ha of Eucalyptus plantations near Pointe-Noire, powerful tools based on the understanding of ecosystem functioning are needed, to simulate tree, stand growth and to assess the impact of plantations on soil properties. Soils near Pointe-Noire are sandy (more than 90% of sand), chemically poor in K, total N and organic matter and are characterized by a low cation exchange capacity. Our research hypothesis is that an optimum combination of plantation density and fertilization regime can be found for each clone and each ecological situation, allowing simultaneous maximisation of wood production, carbon sequestration and soil fertility. Three factors are likely to affect soil-plant interactions and therefore wood production: 1) efficiency of light interception (fAPAR), which depends on both leaf area index (LAI, leaf biomass * specific leaf area, SLA) and canopy structure (leaf angles and canopy clumping); 2) light use efficiency (LUE), defined by the ratio of above-ground net primary production (ANPP) to absorbed light (APAR); 3) carbon allocation between tree compartments . The objective of this study was to assess the impact of genotype, fertilization, and stand density on leaf biomass, SLA, and LAI. The experimental site was set up in 2007. It includes two contrasted fertilization regimes, crossed with two contrasted clones (18-147 and 1-41) and two stand densities (833 and 10.000 trees/ha). LAI, leaf biomass and SLA were assessed destructively regularly during 2 years. The first results show an exponential decrease of the SLA over time with a strong seasonal effect (high during the first year and slighter during the second year). The changes are stronger in high density (10 000 trees per ha) and non-limiting fertilization conditions. The seasonal effect is more pronounced for the 18-147 clone than for the 1-41 clone, with a time lag for the latter.

Cocoa agroforest Carbon: an apportunity to mitigate climate change at a peri-urban area in South-western Cameroon

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The south-western Cameroon is the youngest and the most fruitful cocoa basin, and is an ecological zone with diverse characteristics compared with those of the Centre and South. A cocoa agroforest in this part of Cameroon presents cocoa trees and associated plants including timber trees, fruit trees and medicinal plants. This study evaluates carbon stocks in the cocoa agroforests at the periphery of Kumba, the principal town of the cocoa agroforest in south-western Cameroon. 10 cocoa agroforests in total were chosen according to their age (0-25 years, 26-40, and 40 years above). In each cocoa agroforest, 4 quadrats of 25 m x 25 m were measured and the DBH of all trees above or equal to 2.5 cm (Sonwa, 2004) were listed and identified using Vivien and Faure (1986) and with the assistance of an advisor resident of the village. The species which could not be identified on the spot were collected, treated and carried to the Systematic Ecology Laboratory of University of Yaounde I. The biomass of forest/fruit trees, Musa and Palm are evaluated using allelometric formula. Conversion to carbon stock was done using the recommendation from Nolte and Al. (2001). On average, cocoa agroforest around Kumba stores 74 tC/ha. In those agroforest, the main plant is cocoa tree which stores 53% of this quantity. Associated trees store 47%. Within associated plants, timber trees, edible (fruit trees) and other plants including medicinal trees

store respectively 45, 41 and 14%. Timber stores about half of carbon of the associated plants. These associated species in addition to the carbon stock have other socio-economic and ecological functions. And their presence offers opportunities to explore their role and contributions in the REDD+.

Representing in a Global Vegetation Model the constrated land-covers caracteristic of the crop/fallow succesion of the Sahelian region

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West Africa is a region where land/atmosphere interactions exert a strong feedback on regional climate. These interactions are mainly driven by local vegetation characteristics and dynamics. In this study we use ORCHIDEE, a dynamic global vegetation model (Krinner et al., 2005) that has been widely used for simulation of carbon and water fluxes of point locations, and in European and global applications (Ciais et al., 2005; Piao et al., 2007) and which the surface component of the IPSL Earth system model. ORCHIDEE has been applied by Piao et al. over Africa to simulate the variability of CO2 fluxes over the 20th Century, but not specific improvement were incorporated in that study for the West African vegetation. Specific representations of natural grassland savannas with light bush cover (savannah & fallow) and of croplands dry cereals cultivated in that region (sorghum/millet) have been implemented, in place of the single generic grassland parameterization used in the original version of the model for both plant types (with slightly different parameters). The modifications concern both the model structure (equations) and model parameters. Here, we compare the simulations performed with this the new version of ORCHIDEE against in situ eddy covariance flux data and biometric measurements from the AMMA Niger (Wankama «local sites»), in order to assess the ability of the landcover ecosystem-specific parameterizations of the model to capture the respective observed synoptic, characteristics seasonal and inter-annual variability of vegetation carbon, water balance and energy fluxes over diurnal to interannual time scales. We also discuss the ability of the model to account for the relative differences between crops and fallow at the same location in terms of land/atmosphere interactions.

Keywords : Land-cover, Phenology, Carbon and energy fluxes.

Analysis of the first year of atmospheric CO2/CH4 measurements at LAMTO, Ivory Coast

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The atmospheric CO2 and CH4 monitoring network is very heterogeneous, with a relatively high density of stations in North America and Europe, and almost none stations over large parts of the world like Africa, Siberia or South America. The poor density of the monitoring network over some continents is the main reason for the large uncertainties in the regional flux estimates based on the analysis of spatial/temporal gradients of atmospheric concentrations. As part of the European project CARBOAFRICA, we set up a new monitoring station at the Station de Géophysique de LAMTO, Ivory Coast (6.22°N, 5.03°W, 155masl) on August 2008. The site is located 160km North/West from Abidjan in an ecological reserve, where a couple of other long term observational programs are ongoing (CTBT seismic and infrasound network, IDAF network for wet and dry deposition fluxes). The instrument installed at LAMTO is the Picarro G1301 CO2/CH4/H2O analyzer, based on cavity ring-down spectroscopy. The continuous measurements are linked to the WMO international reference scale by using four calibration tanks calibrated at LSCE. The air is sampled on top of a 50m high tower, and is going through a suite of filters to protect the pump and analyzer from dust. At the moment, do drying system has been installed. The system is operational since August 29 and is now operated by the technical staff of the LAMTO station. The instrument has been working for almost one year without major failure. We will describe the observations characterized by a strong CO2 diurnal cycle (diurnal amplitude about 30ppm), and synoptic scale CH4 variations of the order of 50 ppb associated to either biomass burning or shift from southern to northern air masses.