FluxLetter

The Newsletter of FLUXNET

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Highlight FLUXNET sites
Hinda, Kissoko and Tchizalamou

Hinda, Kissoko and Tchizalamou flux tower sites
by Yann Nouvellon

Three main types of ecosystems are found in the South-Western Republic of Congo (Central Africa): secondary natural forests, savannahs, and eucalypt plantations (about 40000 ha) that have been established over savannahs since the 1970s for pulpwood and charcoal production. The Hinda (4°40'52"S; 12° 00'13"E) and Kissoko (4°47'29"S; 11°58'56"E) flux tower sites were established by CIRAD and UR2PI in these eucalypt plantations as part of a larger network of flux tower sites in tropical plantations (rubber-tree, coconut-tree, coffee and eucalypt plantations) managed by the CIRAD "Tree-based Tropical Plantation Ecosystems" research team (http://www.cirad.fr/ur/ecosystemes_plantations (in French only). The Hinda and Kissoko sites were operated successively for two years each, and the eddy-covariance system and meteorological station were then moved to a nearby savannah at Tchizalamou (4°17'21.0"S, 11°39'23.1"E), where flux measurements have been carried out since July 2006. The three sites are part of the CARBOAFRICA flux tower site network (http://www.carboafrica.net; see the "Carbon cycling in Sub-Saharan Africa" special issue in Biogeosciences for some early pub-

Figure 1: Closed-path (Li-6262+ sonic anemometer Young 81000V) and open-path(Li-7500 + 81000V) systems for flux measurements at the Hinda site (two years of measurements with the closed-path system, and one month with the two systems, for comparison)

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lished CARBOAFRICA results) and the French network F-ORE-T (http://www.gip-ecofor.org/f-ore-t/).

Measurements made at these sites aim at: i) quantifying and understanding the exchanges of water vapour (Fisher et al., 2009), CO_2 and energy between the ecosystem and the atmosphere, ii) identifying the main regulators of gross and net primary production (GPP, NPP) and net ecosystem production (NEP), and iii) parameterizing/ validating ecosystem process-based models for these two types of ecosystems. The seasonality of net primary production (NPP), soil CO_2 effluxes (Epron et al., 2004), fine root growth (Thongo et al., 2008), LAI and specific leaf area (Nouvellon et al., 2009) have been studied at these sites. At Kissoko, NEP has been assessed in two ways: 1) from eddy-covariance measurements of CO_2 net ecosystem exchange (NEE), and 2) from biometric NPP measurements and heterotrophic soil respiration (Rh) measurements (NEP=NPP-Rh). At the Hinda and Kissoko sites, canopy structure parameters, gap fractions, leaf gas exchange, and root CO_2 efflux (Marsden et al., 2008) have been measured in order to parameterize canopy or individual tree-based models (CANOAK, G'DAY and MAESTRA). Leaf gas exchanges measurements, and eddy-covariance measurements have both shown marked differences in the water-use efficiencies of the two studied eucalypt clones.

Figure 2: Coarse root CO_2 efflux measurement at the Kissoko site

At the Tchizalamou savannah site, soil CH_4 and N_2O effluxes are currently being monitored, as well as the seasonal dynamics of LAI and NDVI. These data are being merged with data obtained at other savannah sites of the CARBOAFRICA flux tower site network (in South-Africa, Botswana, Sudan, Mali, Niger, Benin, etc.; Merbold et al., 2008) in order to develop/validate "process-based" models simulating water vapour and CO_2 exchanges between savannas and the atmosphere, that will further be applied at the regional and continental scales, using remote sensing data, soil and vegetation cover maps, and meteorological data.

In the vicinity of the Hinda, Kissoko, and Tchizalamou flux tower sites, nutrient cycling at adjacent eucalypt and savannah ecosystems has also been studied: for 10 years soil water content and soil solution chemistry have been measured continuously down to a depth of 5 m, as well as nutrient fluxes between the soil and the plants (e.g. Laclau et al, 2005). This provides a unique opportunity to study the interactions between the carbon, water, and nutrient cycles. This is important since the response of African savannas to climate change is likely to be determined by the complex interactions between these three major cycles, and since savannas cover about two thirds of the sub-Saharan Africa surface. Another challenge in these studies is to assess the environmental impact of eucalypt plantations, and more specifically the effect of savannah afforestation on carbon sequestration, water resources, and soil fertility. Chronosequence studies have been carried out to assess the changes in carbon and nutrient stocks in the soil (D'Annunzio et al., 2008), and in the biomass (Saint-André et al., 2005) after savannah afforestation. Soil CO_2 effluxes after savannah afforestation (Nouvellon et al., 2008) and changes in the isotopic composition of soil C and of soil CO_2 effluxes have also been measured in order to investigate the dynamics of savannah-

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Hinda, Kissoko and Tchizalamou flux tower sites

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Figure 3: Soil CO_2 effluxes measurements at the Tchizalamou savannah site

derived, and newly eucalypt-derived soil C after savannah afforestation (Epron et al., 2009).

New research (planned but not yet funded) will focus on carbon, water, and nutrient cycles in the secondary natural forests.

Our research is carried out in collaboration with scientists from INRA, University of Nancy, CNRS (ESE and CEFE), Second University of Naples (S. Castaldi and A. Rasile; N_2O and CH_4 flux measurements), and scientists from other research Institutes involved in CARBOAFRICA (Max Plank Institute, W. Kustch; CSIR, B. Scholes; DISAFRI, R. Valentini, etc.).

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Further Reading

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Why is it so hard to sustain a flux network in Africa?

Bob Scholes

The processes which eddy co-variance equipment measures – transpiration and carbon assimilation – are fundamental to many of the practical ecosystem management issues in Africa. Furthermore, the rising profile of the UN Framework Convention on Climate Change and the potential for the trading of carbon credits means that the carbon cycle itself is of interest to researchers and policymakers in Africa. But the present global distribution of flux measurements is massively skewed towards the northern hemisphere, developed, extra-tropical countries. Any global synthesis of flux-derived data runs the risk of large biases as a result. Therefore it is easy to make a case for why there should be many more flux measurements in Africa. But moving from this agreement to an implemented, operational, self-sustaining network has proven to be much harder. This article discusses some of the obstacles, in order that we can realistically work out how to surmount them.

I have been the co-investigator at the Skukuza flux site since 2000. This is probably the longest flux record – patchy as it is – anywhere in Africa. I work for a large scientific organisation in one of the most technically-advanced countries in sub-Saharan Africa. If it is so hard for my team to keep the Skukuza site functioning, how much harder is it for researchers elsewhere in Africa?

The most obvious - but not necessarily the greatest - obstacle is funding. Very few African countries have national competitive research grant programmes – and when they do, the awards are far too small to establish and maintain a flux site. African researchers can access various international funds, but the entry barriers are daunting. The first is simply the knowledge, experience and confidence to write a winning proposal. The second is that these awards are often very large - and the home institutions of the African researchers are not equipped to satisfy the accounting rules for disbursing them effectively. The third is that the international funds inevitably require international partners – not a bad thing in itself, but hard for an African researcher to set up unless they are already part of the club.

The biggest single barrier, in my experience, is the shortage of skilled technicians. Running a flux site successfully requires a good working knowledge of electronics, instrument maintenance, calibration and trouble-shooting, data handling and telecommunications, as well as some basic micrometeorology and ecological knowledge. Finding this package of skills in a single individual, and then being able to retain this relatively highly-skilled person under difficult field conditions on an uncompetitive salary is a great challenge.

A related challenge is finding African students with the necessary mathematical skills to deal with complex flux data, and the

"...The biggest single barrier, in my experience, is the shortage of skilled technicians. ."

"...A related challenge is finding African students with the necessary mathematical skills to deal with complex flux data, and the interest in doing so in a 'marginal' field such as ecology"

Figure 1. The CarboAfrica training workshop on flux site characterisation, held at Phalaborwa, South Africa in March 2008. The fifteen researchers, from all parts of Africa, were learning how to collect information to satisfy the basic FluxNet package of information on vegetation, soils and climate. Bob Scholes is explaining how to record tree height; the workshop organiser Rudzani Makhado looks on from the left. Behind him is an armed game guard, because the field practicals took place in the Kruger National Park. Werner Kutsch and Lutz Merbold (third from the left) of the Max Plank Institute at Jena were part of the training team.

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Why is it so hard to sustain a flux network in Africa?

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interest in doing so in a 'marginal' field such as ecology. South Africa, with its recent *apartheid* history of poor maths and science education for black Africans, is particularly crippled in this regard, but the problem is widespread in Africa – the brightest students are siphoned off into banking, commerce and government. The majority of African PhDs end up working outside their fields, and outside of Africa.

To purchase and service flux site instruments in Africa is at least 50% more expensive than in Europe or North America. The equipment suppliers work through a system of local agents, who add a mark-up, but do not have the capacity to supply much technical support. The import process often involves punitive taxes and substantial delays. Currency fluctuations make budgeting a gamble.

Have your cables been chewed by a hyena, or your solar panels trashed by a grumpy rhinoceros? Admittedly, the Skukuza site has been deliberately located in the Kruger National Park, and those are the risks you take. But in general, the natural hazards faced by flux sites in Africa are quite extreme. The tower is a magnet for lightning, which regularly fries our delicate electronics. Instruments fail when the temperatures climb into the high forties (Celcius). Vegetation fires, an ecological feature of savannas, can be expected every year or two. Vandalism or theft is a continual problem where the tower is within reach of human populations.

"..Filling the data gaps in Africa will require genuine, long-term partnerships with developed-country researchers, a substantial amount of money (largely from outside Africa), well-targeted and sustained capacity building (including in such non-traditional areas as proposal writing, paper publication and technician training), and above all, patience. .."

Poor infrastructure is probably the single greatest developmental challenge in Africa. Getting a bottle of calibration gas to a remote site often doubles or trebles its cost. When an instrument fails, it usually takes months to get it to a service agent, have it repaired and then reinstalled. Communications bandwidth limitations prevent the large raw flux data files from being regularly transmitted and analysed, meaning that problems are often only detected long after they have occurred.

Having overcome these hurdles, the proud operator of a new African flux site is still not home and dry. For a whole range of reasons, it is hard for African researchers to get their work published in the international literature. When flux measurements in developed countries were in their start-up phase two decades ago, it was possible to publish a short or imperfect flux record in a good journal. That is no longer the case. Acceptance now requires a long record, lots of supplemental information, and some new angle (simply being in an under-represented ecosystem or region is not enough). There are no African journals that are suitable, and which might be more supportive. But without the endorsement of peer-reviewed publications, the African researcher cannot continue to compete for the international funding needed to sustain the work. A classic catch-22.

The above litany of woes is neither a complaint nor an excuse. But it is an appeal for understanding, and a request for thoughtful assistance. Filling the data gaps in Africa will require genuine, long-term partnerships with developed-country researchers, a substantial amount of money (largely from outside Africa), well-targeted and sustained capacity building (including in such non-traditional areas as proposal writing, paper publication and technician training), and above all, patience.

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Celebrating the first year of FluxLetter

Rodrigo Vargas and Dennis Baldocchi

The FLUXNET office has been editing FluxLetter as a quarterly newsletter to present news, sites, results, and opinions of interest to the FLUXNET community. With this issue we celebrate our first year of this effort and we continue working to make FluxLetter a powerful information, networking, and communication resource for the community. To date we have published four issues of FluxLetter which are available on-line at two websites: (http://www.fluxnet.ornl.gov/fluxnet/newsletters.cfm or http://bwc.berkeley.edu/FluxLetter/). We have highlighted five graduate students and six young scientists from all over the world to show the diversity in research and personality among the community. In addition, we have highlighted FLUXNET sites in Asia, Africa, America, Europe, and Oceania to show specific examples of research done in this growing network.

During this past year it has been a pleasure to interact with all the collaborators that have supported and contributed for the published issues of FluxLetter. The success of this newsletter is only possible because of the invaluable support that we have received from FLUXNET scientists around the world. Thank you very much for your contributions and support!

FluxLetter is starting its second year with this issue that highlights opinions, sites, students, young scientists and research done in African ecosystems. We invite scientists around the world to propose new sections, send opinions and contribute with highlight research and FLUXNET site sections. Our goal for the following issues is to create a space to show the diversity of research, study sites and opinions along the network.

If you want to contribute to any section of FluxLetter please contact Rodrigo Vargas (rvargas@nature.berkeley.edu) or Dennis Baldocchi (baldocchi@nature.berkeley.edu)

THANK YOU!!

Highlight Graduate Student

Sally Archibald

My interest in environmental science started with an interest in botany – specifically the evolution of life-history traits, but I soon became fascinated in broader issues. Punctuated by a brief period as a news reporter I went from a Masters Degree at the University of Cape Town - where I investigated how fire and grazing interact to control vegetation - to a job at the CSIR in Pretoria. At the CSIR I have the opportunity to work on my PhD which is looking at the drivers of fire regimes in Africa. Specifically I am interested in identifying the limits of climate and human control of fire in Africa, and the extent to which fire regimes can be manipulated.

Switching from a purely ecological to a more biogeochemical and systems approach has been illuminating for me; and changing my view of fire as something that affects plants and animals, to

Figure 1 - Sally Archibald

something that is an integral part of a larger vegetation-fire-climate system has been an exciting intellectual journey. Especially when one adds humans into the picture.

I am registered for my PhD at the University of the Witwatersrand in Johannesburg. One interesting result from my thesis work is that ignitions never seem to be limiting fire in Africa – and the extent to which a landscape burns depends to a large extent on the amount of fuel and the connectivity of the fuel bed. Currently people in Africa only seem to influence fire by decreasing its extent – not by increasing it as has been assumed in several global analyses. Whether this was always the case, when the human impacts on fuels and landscape connectivity were less, is not certain. I am involved in a theoretical modelling exercise to explore this question. I want to determine the impact humans have had on fire regimes over paleo-ecological time.

Some interesting thresholds appear in the relationships between fire, vegetation and climate. Very little fire is apparent at tree covers of 40% or greater – and it is also obvious that there are large parts of Africa which are being maintained at tree covers of < 40%. Currently I am visiting the Department of Ecology and Evolutionary Biology at Princeton University where I am working with other graduate students to model fire's role in these vegetation boundaries.

While at the CSIR I have the opportunity to be involved in several other research projects. The Skukuza flux tower in the Kruger National Park is one of a handful of towers which has long-term flux measurements for a savannah system. Data from this tower provide interesting insights into land-atmosphere fluxes in systems that are water-controlled – where most of the biological activity occurs in short bursts associated with rainfall events. The coexistence of two different life forms – trees and grass also results in interesting dynamics. We have recently published a paper looking at the drivers of inter-annual variability in this system.

I love the fact that my career means I can live and work in my home country, South Africa, but still interact with scientists from all over the world. I am excited to expand my research to a global scale when I finish my PhD.

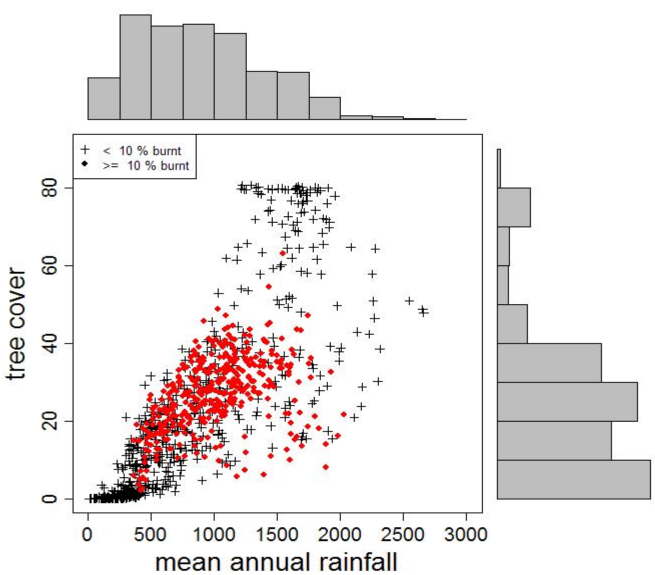

Figure 2 - The relationship between rainfall, tree cover and fire in southern Africa. Fires hardly occur above about 40% tree cover, but most of the region is also maintained at tree covers less than 40% - presumably largely due to the effect of fire.

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Highlight Young Scientist

Agnes de Grandcourt

I was born in Paris, France. As granddaughter and daughter of foresters I spent soon a lot of time outside, during the week-ends and the holidays. I started to help my father during forest inventories at 15, during the holidays.

At 16, I decided to have a job related to forests. After my *baccalauréat*, I made my first 4 years studying biology and ecology at the University Paris 11. It was a great place to study, with grasslands, forests and lakes inside the campus. So we could learn to recognize birds' songs or plants during the course, walking outside the classroom. It may sound obvious for a US student, but for a French and more a Parisian student, it was exceptional. At the end of these 4 years, the French students have to choose between research and engineering. To be able to choose, I decide to stop the university for one year to discover the world of the research with trainings. I started with a 6-months study in eco-physiology with Alexandre Bosc, who was a PhD student at INRA Bordeaux. I applied for the first time what I learned during my courses. It was exciting to have a question and to find how to answer to this question. I made my first respiration chambers… looking a little bit strange but airtight proof. After that, I succeeded in finding a job in French Guiana, in the tropical rainforest, which I wanted to see since years as a forest lover! I worked in the molecular biology lab of INRA for 2 months.

Figure 1: Agnes de Grandcourt in South Africa for the first CarboAfrica annual meeting.

After this year, I definitely choose to do research and spend my fifth year of my university studies at Nancy (east of France) studying Forest biology. During 10 months, I studied the growth and respiration of roots of tree seedlings at different light levels. I did my doctorate in French Guiana (at 4°N) on the acquisition and the utilization of phosphorus by forest seedlings associated with endomycorrhizas, in relation with soil phosphorus and light.

After my PhD, my vision of ecophysiology changed of scale and gained height. I was chosen by Dr Jean-Pierre Bouillet and CIRAD (a French agricultural research centre working for international development) to follow the CarboAfrica project in Congo (still at 4°, but 4°S this time). This CIRAD team is working on the plantation ecosystems, and three other eddy-covariance sites are running on eucalyptus (in Brasil), hevea (in Thailand) and coffee (in Costa-Rica). I arrived in Congo in June 2006. I am associated with UR2PI, a research center focused on plantation productivity. At UR2PI, we are around 30 members, 8 researchers (3 Congolese and 5 French) and 7 PhD students (6 Congolese and 1 French). I am in charge of an eddy-covariance station, measuring the exchanges above a grassland at the Tchizalamou site at 75 km of Pointe Noire, the town where I live (more or less 2 hours of car, on road and sand track). I also conduct research on vegetation dynamics (above-ground and below-ground). This grassland is very poor and no big herbivores can live here. Unlike some other sites in Africa, we have no problem of vandalism caused by the elephants! There is nothing bigger than jackals. But the jackals sometimes eat the connectors of the soil humidity probes!! We also have to manage the fire, as villagers burn the grass every year. The guardians at the site make a great job to avoid the eddy-covariance station to be roasted!

After more than 2 years of survey of the grassland, we hope to follow the impact of the change of land use, as the grassland is supposed to be planted with eucalyptus. The plantation was supposed to be done last October, but it has to be postponed by the eucalyptus plantation owner, because of the world financial crisis. There are 40.000 ha of eucalyptus around Pointe Noire and this eddy-covariance

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station was previously above an eucalyptus plantation.

The fluxes measured at the Tchizalamou grassland site are sent to the CarboAfrica database. With studies in 11 sub-Saharan countries, CarboAfrica aims to quantify and predict the GHG budget of Sub-Saharan Africa and its associated spatial and temporal variability. More locally, I want to analyze the differences of functioning between the grassland and the eucalyptus plantation.

My data has been sent to the FLUXNET database. I was pleased to participate in the workshop at LaThuile in 2007, where I met a lot of very interesting researchers. It was a great chance for me, as a beginner at the eddy-covariance research, to meet all these persons and to understand better all the challenges around this topic.

The CarboAfrica project allows me to start cooperation with other laboratories. Especially, the Department of Environmental Sciences (DSA) of the Second University of Naples (SUN) (Simona Castaldi and Americo Rasile) and I decided to study the impact of the termites on the GHG emissions (methane). I really love to study the interaction of the plants with other biotic factors such as fungi during my doctorate, or termites during my post-doc.

Figure 2: Agnes de Grandcourt harvesting aboveground biomass. The living and dead biomass is separated by species and organs.

Work in Congo is a great experience, even if it is quite hard to find spares quickly (no big drugstore around) and the internet connection can be really slow! I will be sad to leave the Congo at the end of the year, as my post-doc will finish in October. I hope to see all the CarboAfrica participants at Pointe Noire for the final conference before I leave. All the Fluxnetters will be welcome to our final conference.

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Figure 3: Map of Central Africa

Highlight Young Scientist — *Christopher Williams*

My name is Christopher A. Williams, and I'm pleased to have been invited to introduce you to some of my work in African ecosystems. In general, my research focuses on assessing environmental controls on ecosystem structure, function, and distribution; inferring what this means for water, carbon, and energy exchanges; and exploring the likely effects on ecosystems and the resources they provide.

Over the years my work has become a loose combination of field data, remote sensing, and process-based modeling. Flux tower data continue to provide one of the central data constraints, and I have had the good fortune of working with outstanding colleagues at multiple flux tower sites (e.g. South Africa, Botswana, Blandy and UVA Experimental Farm and Forest; Duke Hardwood and Pine Sites; Sardinia, Italy; and SMACEX of Ames, Iowa), as well as in Botswana and South Africa.

Figure 1: Chris with daughter Chloe

Highlights from Africa

My focus on African ecosystems was intiated by doctoral research under John Albertson, CEE at Duke Univ. We took two flux towers to sites in the Central Kalahari (Ghanzi, Botswana), and set them up in contrasting land cover types for a short intensive field campaign. Not surprisingly we found that soil water is a dominant control on evaporation, plant productivity, and respiration (Williams & Albertson WRR 2004).

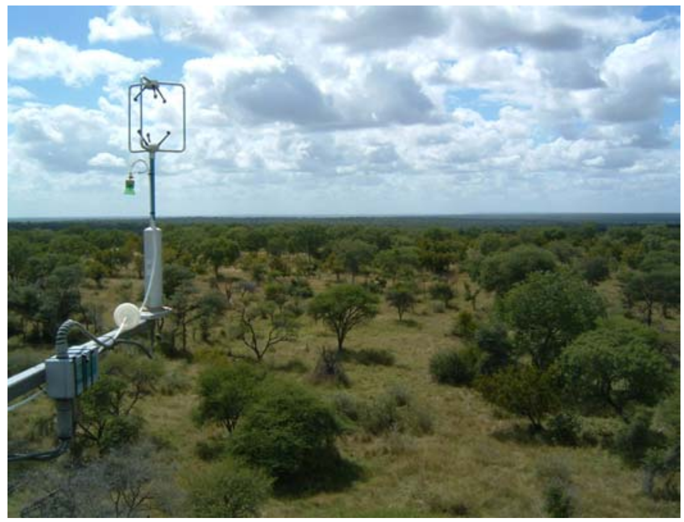

Figure 2: Skukuza, South Africa view

Based largely on these field observations, I coded up a simple mechanistically-based numerical model for the study of multi-decadal interactions between soil, vegetation, and climate (Williams & Albertson WRR 2005). Somewhat unconventionally, we found that the annual surface water balance is largely insensitive to vegetation type and abundance for a wide range of dryland conditions. Instead, vegetation largely tracked annual rainfall, which emerged as the dominant control on annual plant production.

Continuing with the modeling of dryland vegetation dynamics, I examined how the interannual correlation of rainfall (long-period modes) and variability in annual rainfall may degrade grass forage resources for a range of climate and grazing settings (Williams et al. GCB 2006), by advancing a classical model of equilibrium dryland dynamics. …In other words, we took about a month of flux tower data from a relatively remote location in Botswana and used it as a basis to comment on interannual vegetation dynamics of savannas. Needless to say, we could use a bit more observational data…

This brings me to postdoctoral work with Niall Hanan, Colo. State's NREL. Though tasked with unraveling the roles of climate, vegetation dynamics, fire, and land use in driving diurnal to interannual variability in Africa's carbon cycle, I continued to explore site-based results by analyzing canopy-scale observa-

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tions from the Skukuza, South Africa tower. We've found some interesting lags in productivity responses to rainfall pulses and uncovered hysteresis in the temporal evolution of evapotranspiration, productivity and respiration (in review).

Keeping to the continental scale of the funded project (African Carbon Exchange, NASA + NOAA), Niall and I synthesized estimates of the major fluxes in the African and global carbon cycles (Williams et al. CBM 2007), shedding light on the vast fire but slight fossil emissions. Then, using Simple Biosphere, I diagnosed physiological and structural limitations on photosynthesis across Africa (Williams et al. 2008). Most recently, we have explored how climate oscillations induce interannual fluctuations in rainfall and productivity (in review).

With all of this modeling work, I can't help but long to get back in the field, and so perhaps soon you'll see another dot on the global flux tower map. That said, and to state the obvious, a long-term record of high quality, semi-continuous measurements at a site in Africa would require international collaborations and I welcome continued dialogue along those lines.

Figure 3: Ghanzi, Botswana field site

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Figure 4: Eddy covariance site during intensive campaign in Ghanzi, Botswana

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Flux-measurements in a Miombo woodland in Western Zambia in relation to deforestation and forest degradation

Werner L. Kutsch, Lutz Merbold, Mukufute Mukelabai, Maurice Muchinda

Figure 1: Kataba Forest Reserve during the wet season as seen from the fluxtower. (Picture by W. Kutsch)

Miombo woodlands cover the transition zone between savannas and rainforests in Southern Africa. Since they are located in semi-arid areas with a distinct dry season, they belong climatically to savannas; however with about 800 – 1000 mm of annual precipitation the tree coverage can be more than 60 % which is commonly defined as threshold between savannas and woodlands. Miombo woodlands cover about 3 million km^2 in southern Africa.

The fact that almost nothing is known about Miombo woodlands in terms of fluxes (the only data that are available are three weeks of eddy-covariance data measured during the SAFARI-2000 campaign by Scanlon & Albertsen 2004) motivated us to choose the Kataba Forest near Mongu, the capital of the Western Province of Zambia as one of the core sites of CarboAfrica. Figure 1 shows the Kataba Forest Reserve during the wet season.

The forest is located East of the Zambezi floodplain on an area that is part of the Kalahari Sands. The satellite picture in Figure 2 shows that the reserve is embedded into a landscape highly affected by land use change. The light areas are former woodlands that are converted into agricultural land or clear-cuts that have not regenerated yet.

In Zambia, as in many of its neighbouring countries, Miombo woodlands are affected by high forest degradation and deforestation mostly for charcoal production. Domestic burning has switched from fuelwood to charcoal during the past decade along with urbanization and population increase. The higher charcoal demands in urban areas have also changed the supply site. Whereas in rural areas firewood has been mostly produced in small amounts by the demanding households themselves, charcoal is produced in much higher amounts and traded over much bigger distances. This has changed the production as well as the resulting impact severely: charcoal production has become a full-time job of migrating workers that 'buy' the trees from local communities, produce charcoal and leave (Fig. 3). The price per tree we were reported was about 20 Eurocent. Since the buyers are not bound to the land and the ecosystem services that the Miombo woodlands provide, they do not care for

Figure 2: Satellite image of the area with the Zambesi floodplain on the left. (Courtesy of Google Earth)

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Flux-measurements in a Miombo woodland

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Figure 3: Some impressions of charcoal production and transport in Zambia. (Pictures by W. Kutsch and L. Merbold)

sustainable use of the woodlands.

According to the NGO Mongabay which provides detailed information about deforestation and other parameters of Zambia on its website (http://rainforests.mongabay.com/deforestation/2000/Zambia.htm), about 445,000 ha y^{-1} of woodland were deforested or degraded between 1990 and 2000, thereafter the rate has even increased. Each hectare of deforestation means a loss between 21700 (FAO) and >40000 kg (Chidumayo 2002) of woody biomass. This increases the Zambian per capita emissions between 1.6 and 3 tons CO_2 y^{-1}. The regeneration potential is almost unknown. Only one study by Chidumayo (2002) has reported about the carbon that is accumulated in the aboveground biomass within the first ten years of regrowth after a clearcut. On average it was 28 % of the biomass of undisturbed areas.

The high uncertainty in carbon fluxes related to deforestation, forest degradation and regeneration in Miombo woodlands has been another motivation for our research in Zambia. It played an important role in our experimental design, particularly, in designing measurements of ancillary data concerning soil carbon dynamics and regeneration potential of vegetation affected by logging for charcoal production. Three questions are crucial:

1.) How much carbon from the standing biomass and from soil is lost?

2.) How big is the sink that is lost?

3.) How big is the regeneration potential?

In this contribution we will give a preliminary answer on the second question based on a first year of eddy covariance measurement. I addition, we will describe our concept to derive data that will improve the data base to answer the other two questions.

Experimental design at Kataba Forest

In September 2007 the tower which was erected during the SAFARI 2000 campaign was equipped with an eddy-covariance system (open as well as closed path for comparisons), a CO_2 profile system and microclimate sensors that are powered by a photovoltaic system. The construction work (Figure 4

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Figure 4: Field work during tower instrumentation in September 2007. Left: Waldemar Ziegler as field blacksmith, centre top: Lutz Merbold working at the tower, centre bottom: Mukufute Mukelabai and Werner Kutsch at the control unit of the system, right: Olaf Kolle working at the solar power station. (Fotos by Lutz Merbold and Werner Kutsch)

shows some impressions) lasted about 4 weeks. The tower is located in the North-West corner of the forest reserve. The main footprint area lies in the almost undisturbed area within the reserve, because East and South-East are the prevailing wind directions (Figure 5).

In addition, we designed four inventory plots that are located along a disturbance gradient from outside to the centre of the reserve. In these plots we conduct inventory studies to get ancillary data on above and belowground carbon pools as well as soil carbon dynamics and tree growth. Since the area west of the tower was completely clear-felled during 2008 we decided to place another inventory plot in that area, too. Thus, future projects will be able to follow the regeneration during the next years.

First results

Since the first rains usually occur in October, we decided to set the beginning of the 'meteorological year' at Mongu on September 1st. The fingerprint (Figure 6) shows how strongly the system is driven by water availability: The first rains in October resulted in an increase in nighttime respiration, followed by a strong uptake rates from November on. During the peak growing season maximum net uptake rates were around -20 µmol CO_2 m^{-2} s^{-1}. They slowly decreased after the rains stopped in April.

Annual NEE for the first year of our measurements between September 2007 and August 2008 resulted in an uptake of about 5 g C m^{-2} y^{-1}. Thus, Kataba Forest in an example for an undisturbed old-growth forest that is carbon neutral which might contradict recent opinion based on mostly Northern hemisphere old-growth forests that were calculated to be carbon sinks.

We can conclude from our preliminary results that deforestation and forest degradation in the Miombo woodlands do not result in the loss of a carbon sink. However, the carbon pools that are lost from the vegetation and the soil are enormous when the actual rates of deforestation are taken into account. According to a recent publication in the Biogeosciences Special Issue on carbon fluxes in Sub-Saharian Africa Canadell et al. (2009) showed that deforestation accounts for about 95% of Zambian carbon emissions. From our point of view the crucial question is: How is the regeneration potential of the woodlands affected? If full re-growth is possible (Chidumayo 2004 observed high resilience) and charcoal can be produced in a sustainable way, it might be a way to avoid fossil fuel burning. If re-growth is impossible due to the loss of soil fertility and seed bank decline Miombo woodlands should be-

Figure 5: Wind distribution during the first year and location of the inventory plots. The white triangle symbolizes the 50 % fetch area for the sector 90 – 120 °, which is the main wind direction.

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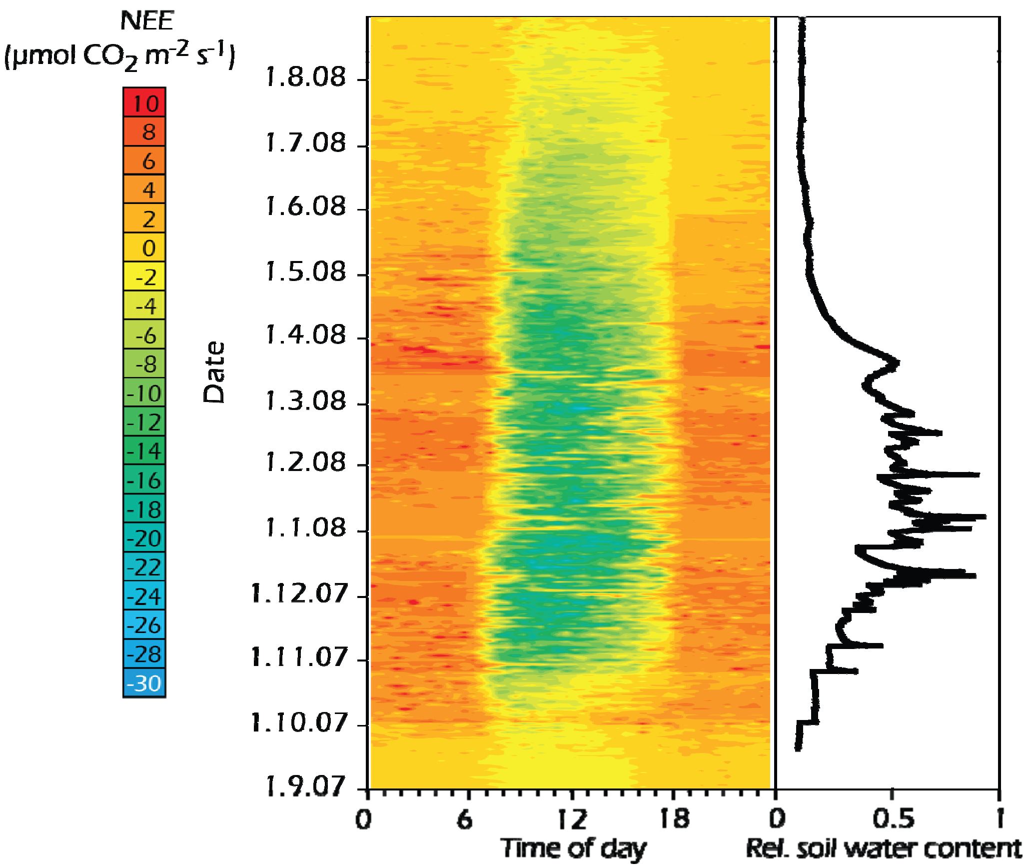

Figure 6: Fingerprint of the gap-filled EC fluxes between 1.9.2007 and 31.8.2008 and the relative plant available water for the upper 100 cm of the soil.

come part of actions like REDD (Reduction of Emissions from Deforestation and forest Degradation). The REDD mechanism is under negotiation for the post-Kyoto commitment periods. The basic idea is to pay compensation for not using the timber and protecting intact forest ecosystems. The crucial parameter will be whether the compensation will be high enough to generate alternative labour for people that produce charcoal and alternative energy for people that use charcoal. Thus, further studies are necessary and they have to include socio-economic aspects of the charcoal production, technical as well as income alternatives and studies about ecosystem services that are provided by Miombo woodlands. Unfortunately, CarboAfrica is coming to an end in September 2009 and we will have to stop our work at Mongu.

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We plan to make the FLUXNET newsletter a powerful information, networking, and communication resource for the community. If you want to contribute to any section or propose a new one please contact the FLUXNET Office. THANKS!!