World Agroforestry Centre (ICRAF-WCA), Yaounde, Cameroon 2010

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Printing
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ICRAF West and Central Africa (WCA) Region has made giant strides in its research activities over the past years. This has been thanks to the emphasis on the quality of our science and the Centre's strong global strategy backed by continuous support from our donors.

2009 was a very successful year for the region. We were able to secure more funding to kick-start a number of projects and consolidated our achievements in many other areas, thereby confirming the leadership position of the World Agroforestry Centre in the domain of agroforestry. We were able to present results of our ten years of Agroforestry research during the Tree Domestication Days organized on 3rd February and 14th October 2009 in Yaounde and Kinshasa respectively.

This report is just a tip of the iceberg, of the huge research work carried out by ICRAF scientists and partners across the WCA region. We are working relentlessly to provide answers to some of the agricultural, climate and environmental problems facing the world today.

In the Sahel we focused our research on Land Degradation Surveillance and we registered interesting results in Burkina Faso, Mali, Niger and Senegal. Key International Public Goods (IPGs), which have formed the basis for the Africa Soil Information Service, include the proof of concept of soil health surveillance and digital soil mapping, and new algorithm for remote sensing of vegetation changes as an indicator of land degradation.

In Upper Guinea, we have been able to provide reviewed guidelines for co-management of forests and recommend how integrated biodiversity conservation practices and adoption of viable agroforestry incentives could improve livelihoods of rural populations.

The entire Congo Basin has an annual rate of deforestation of 0.42%, about 1.49 million hectares lost per year. Such statistics are scary, especially because these areas are confronted with increasing poverty. Through participatory tree domestication, we are beginning to break the yoke of poverty in certain communities in the region by integrating the selected high-value tree species in different cropping systems achieving the diversification which is crucial for the sustainable management of the Congo Basin.

The achievements would not have been possible without the sincere commitment of our partners in the frontline; the many NGOs and farmer organisations who work relentlessly to disseminate the results of our research. We express our deep gratitude to the main donors IFAD, USDA, the Belgian Development Cooperation, EU, CFC, DANIDA and BMZ for their continuous support. We are also grateful to our strategic partners particularly the NARS of Cameroon, Democratic Republic of Congo, Nigeria, Ghana, Niger, Mali, Senegal, Burkina Faso and different universities of the region for their great collaboration.
Introduction
Prosopis africana and Balanites aegyptiaca are native tree species in the West African Sahel. Rural communities use their durable wood for construction poles, handles for farm implements, firewood, charcoal and artisan products. Tree growth and wood density are key traits for these and other timber-tree species: growth determines potential wood volume, and density is an important indicator of wood quality properties. For example, denser wood has more lignin, which generally increases its strength, stiffness and calorific value. These in turn make the wood more valuable for construction wood and energy. Correlations between tree growth and wood properties are important in order to assess whether selecting faster-growing trees will have a positive, neutral or negative effect on the wood properties.

There are strong latitudinal and longitudinal gradients in rainfall in the West African Sahel. Therefore, one would expect genetic differences among natural populations as a result of natural selection along the gradients. The first provenance/progeny tests of P. africana and B. aegyptiaca were established in Niger. In the 2008 Annual Report, we reported that larger trees of P. africana tended to have denser wood, and that mean tree growth and wood density of P. africana provenances increased from the more humid to the drier parts of its sample region. In this chapter, we discuss and correlations between growth, wood density and calorific value of P. africana and B. aegyptiaca; and clinal variation in tree growth of B. aegyptiaca and wood calorific value of P. africana and B. aegyptiaca.

Materials and methods
Mean annual rainfall decreases in general from south to north and from west to east in Burkina Faso and Niger. The provenance/progeny tests, which include 24 provenances of P. africana from Burkina Faso and Niger and 12 provenances of B. aegyptiaca from Niger, were established at one relatively dry site in Niger. Tree growth (height, stem diameter over and under bark at 30 cm above soil level), wood basic density, and wood calorific value per kg (CVkg) and m³ (CVm³) were measured at 13 years. Details about the sample region, experimental design, variables measured, statistical analyses and data are provided elsewhere (see reference list).

Results and discussion

There were strong positive correlations between tree growth and wood density of B. aegyptiaca, as reported for P. africana. Given the general relationships between density and other wood properties, results suggest that tree domestication programmes could select faster-growing trees and/or trees with higher wood density of both species and thereby simultaneously increase wood volume, strength and stiffness, but this could also slightly increase the wood's volumetric shrinkage. Correlations between tree growth and wood calorific value of P. africana and B. aegyptiaca depended on the unit of measurement used for calorific value. In general, there were no significant relationships between tree growth and CVkg: the only significant correlation (positive) was observed among P. africana trees from provenances sampled in the drier parts of its sample region. However, for both species there were relatively strong positive correlations between tree growth and CVm³, especially in the drier parts of their sample regions. These results suggest that selecting faster gro-
wing trees would have little or no effect on wood calorific value per kg, but would increase wood calorific value per m3, especially in drier areas. The positive correlation with CVm3 partially reflects the fact that this value is the product of CVkg and wood density, and density is positively correlated with growth.

Wood density and CVkg of P. africana and B. aegyptiaca were not significantly correlated. These results illustrate that there is no simple and general relationship between wood density and calorific value. For example, wood with high density could have relatively low calorific value if the inorganic extractive content is high. The inorganic extractives are the minerals that produce ash when the wood is burned, and the content of inorganic extractives is negatively correlated with calorific value. General relationships could be determined by using chemical composition and moisture content of the wood as predictors of calorific value.

Mean tree growth of B. aegyptiaca provenances increased in general from the more humid to the drier parts of its sample region, as reported earlier for P. africana. This suggests that provenances from drier zones appear to be better adapted genetically to drier environments. However, unlike P. africana, mean wood density of B. aegyptiaca provenances did not vary significantly with latitude or longitude: the lack of clinal variation could reflect the relatively small sample region.

In contrast to tree growth, mean wood calorific value of P. africana and B. aegyptiaca provenances increased in general from the drier to the more humid parts of their respective sample regions (illustrated for P. africana in Figure 1). The lack of correspondence between the cline for CVkg and those for tree growth and wood density reflects the fact that CVkg was not significantly correlated with growth and density. Further research is needed to understand why calorific value tends to be greater in humid zones.

Based on this research, concerns of rural communities about the increasingly hotter and drier conditions currently being experienced and projections of some climatic models, we recommend that tree domestication programmes select P. africana and B. aegyptiaca germplasm from the drier zones for planting and conservation on farms in the West African Sahel. Specifically, we recommend that germplasm should only be transferred from the drier to the more humid zones in the region, and that selection criteria should emphasize increasing tree growth, survival and wood density. These recommendations are based on the geographical clines and the positive correlations between tree growth and wood density. Because density and other wood properties typically have higher heritability than growth traits, we recommend that selections be carried out primarily on wood density (using non-destructive methods). Clines in these studies indicate that calorific value is greater, in general, in the more humid zones in the sample regions of both species. However, given the concerns about climate change, it would be prudent to increase the drought tolerance/resistance of planted populations by selecting trees in the drier zones for future reforestation.

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References


Introduction
The Congo Basin forest is the second largest contiguous moist tropical forest in the world and plays a key role in securing the livelihoods of Central African citizens. The forest also provides critical habitat for biodiversity conservation and supplies vital regional and worldwide ecological services. Unfortunately, the Congo Basin is also characterized by widespread and acute poverty. Nowadays, it is generally accepted that conservation efforts will only be successful in the long term if local populations find viable alternatives to current natural resource use patterns that degrade the environment (Yanggen, 2009). Therefore, conservation organisations are now promoting a 'people-centred approach' to sustainable natural resources management in conservation landscapes. This approach aims to decrease habitat destruction and loss of biodiversity, while also reducing levels of poverty and improving well-being of local communities. However, anyone addressing key livelihood concerns in those areas faces serious challenges in terms of lack of infrastructure; more specifically roads, bridges and markets, and inadequate individual and institutional capacities able to create alternative and additional sources of income. Designing suitable livelihoods interventions that meet conservation objectives remains therefore a daunting task.

Role of Agroforestry in Conservation Programmes
Throughout the tropics, agroforestry had become a popular means to minimize soil erosion, achieve soil conservation and improve agricultural production as well as to provide additional products and services to enhance the livelihoods of the poor (Ashley and Mbile 2005). Knowing that three of the principal causes of environmental degradation in the Congo Basin are bush meat hunting, slash-and-burn agriculture and harvesting of fuel wood from natural forests (State of the Forest, 2008), the application of agroforestry in conservation landscapes was thought to not only enhance on-farm production but to also provide products and services that would otherwise be extracted from protected areas. For example, in the case of slash-and-burn agriculture, improved soil fertility management can allow longer use of a given piece of land and decrease agricultural expansion into the forested areas. In addition, improved seed and other productivity-enhancing practices can allow farmers to produce more using less land and thereby reduce deforestation. This is what is referred to by Yanggen (2009) as a threat-based linkage between livelihoods and conservation. On the other hand, developing livelihood activities that depend on the conservation of the natural environment (called interdependency linkages) such as NTFP enterprise development is another way in which agroforestry can contribute to conservation. The third type of livelihood-conservation linkage is through quid pro quo agreements. In this case, a conservation project agrees to fund a livelihood activity in return for a local community agreeing to restrict their use of certain natural resources such as farming in a protected area. The provision of agroforestry training, improved germplasm and other agricultural inputs and small tools to communities who accept certain restrictions concerning natural resource use, can be seen as an example of this type of agreement.

Partnerships to support Livelihoods in Conservation Landscapes: Case of the Maringa-Lopori-Wamba consortium in the Democratic Republic of Congo
For the last 5 years, the World Agroforestry Centre (ICRAF) has joined forces with conservation organisations like the African Wildlife Foundation (AWF), the Worldwide Fund for Nature (WWF) and IUCN and other stakeholders with a view of integrating livelihoods interventions into conservation programmes in the Congo Basin.

The Maringa-Lopori-Wamba (MLW) landscape, one of the 12 landscapes supported by CARPE in the
Congo Basin, spans 74,000 km² and covers the four territories of Basankusu, Bongadanga, Djolu, and Befale in the Equateur province of the DRC. Equateur Province was severely impacted during six years of war and unrest (1998-2004) and today remains one of the poorest and least developed parts of the country. The MLW landscape boundaries are the watersheds of the Lopori and Maringa Rivers. Forests dominate over 90% of the landscape. Rural complexes, that is, human-dominated areas, mostly farms and plantations, comprise less than seven percent of the landscape. The ecological value of the MLW landscape is very high and globally significant as MLW is home to diverse important animal species. Population density is on average eight people per km². One of the principal threats to conservation in the MLW Landscape is subsistence agriculture, further exacerbated by inadequate agricultural policies and lack of market access. It is estimated that between 1990 and 2000, roughly 56,000 hectares (about 0.9%) of the forest was converted for the expansion of slash and burn agricultural activities. (Dupain et al. 2008)

With a view to leverage collective resources and expertise of partners to implement a landscape-wide sustainable natural resource management programme, a consortium was formed comprising AWF - leading on landscape planning and biodiversity conservation - and a range of international and national institutions. In this partnership, ICRAF brings its expertise in developing and promoting land use practices that increase land productivity through better soil fertility management. In addition, the domestication of high-value and threatened tree species, associated with the development of small NTFP enterprises, is expected to generate alternative sources of income in villages near protected areas where households have few other income generating opportunities.

Agroforestry in Action: Preliminary Results in MLW
ICRAF is using the 'rural resource centre' approach to disseminate agroforestry practices in the MLW landscape. Practically, this means that, in collaboration with local NGOs and dynamic farmer organisations, pilot tree nurseries and demonstration plots are established at strategic places. Farmers come to such places for information and training, before applying the techniques in their own groups and farms. The participatory approach puts emphasis on learning-by-doing and provides individuals with information, knowledge and skills on agroforestry techniques and enterprise development, as well as on group dynamics, leadership and conflict management.

To date, resource centres have been established in Basankusu, Djolu and Bongandanga and 8 farmer organisations now produce agroforestry trees in village nurseries. Over the period 2007-2009, about 16,800 trees have been produced and 38 plots (totaling 57 ha) planted with more than 20 different species (including Elaeis guineensis, Dacryodes edulis, Syzygium cumini, Synsypalium dulcificum, Chrysophyllum lacourtianum, Persea americana, Annona riticulata, Nephelium lappaceum, etc.). In 2009, 50 and 75 farmers have participated in study visits to the resource centres of Bongandanga and Basankusu respectively. Though it is too early to measure the impact of tree planting on household livelihoods, we can already notice increased self-reliance with the participating farmer groups which generally have a positive influence on the entire community.

Lessons Learnt and Way Forward
Since 2008 the World Agroforestry Centre is also collaborating with WWF in the Campo-Ma'an area, South of Cameroon to develop income generating activities based on bush mango (Irvingia gabonensis) and Njansang (Ricinodendron heudelotii) and establish village tree nurseries. In 2009, as part of IUCN’s Landscapes & Livelihoods Strategy, ICRAF identified potentially interesting income generating activities based on NTFPs, linked actors in promising NTFP value chains and established village nurseries in the North of Congo.

Experience so far has shown that the success of livelihood interventions in conservation landscapes very much depends on the ability of the communities to commercialise their increased production. Therefore, facilitating access to markets in the form of better roads and bridges, but also by enhancing links bet-

http://carpe.umd.edu/where-carpe-works/landscapes
ween producers and traders, is mandatory. On the other hand, the choice of the tree species for domestication and enterprise development should be guided by the typical remoteness of conservation landscapes; thus favouring products with high value, low volume and which are less perishable.

Another difficulty that slows down the dissemination of agroforestry innovations in conservation landscapes is the size of the intervention zones, coupled with the usual bad state of roads and bridges, implying enormous efforts in time and money to bring the skills and knowledge to farmers scattered all over the landscape. In this case, it is worthwhile focusing on areas where human activity constitutes an immediate or potential threat to conservation. For example, the MLW programme works with local communities to identify micro-zones for agricultural production outside of primary forest areas and farmers only receive livelihood support if they agree to limit their production to these agreed upon micro-zones. This is the case of the forest area in the Territoire de Befale which is identified as an area of major importance to ensure the connectivity between the Faunal Reserve of Lomako Yokokala and the Luo Scientific Reserve, where the groupings in the Territoire Djolu are mainly characterized by intensive agricultural activities.

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Introduction

The Adaptation of land-use to Climate Change in sub-Saharan Africa (ALUCCSA) project aims to develop climate change scenarios for the next 100 years on a regional/local scale for the sub-Saharan Africa and their impact on land use systems. ALUCCSA is a BMZ sponsored project and led by the Centre for Tropical and Subtropical Agriculture and Forestry (CeTSAF), Georg-August University, Gottingen.

The consortium aims to achieving ready-to-use scenarios and recommendations for agroforestry and silvo-pastoral ecosystems on a highly-resolved spatial scale. Soil-vegetation-atmosphere-transfer (SVAT) models for a global scale will be used to simulate plant competition for space, Photosynthetically Active Radiation (PAR) radiation, water and nutrients. The capacity of the plant to cope with different environments will be estimated by measured and modeled leaf water potential. Present vegetation structure band function will be determined by means of remote sensing and ground based measurements. Their future distribution will be delivered from their habitat requirements and climate scenarios. Current forms of agriculture and livestock husbandry practices will be evaluated in various regions and confronted with future climate conditions.

The World Agroforestry Centre (ICRAF-WCA/Sahel) and Institut de l'Environnement et de Recherche Agricole (INERA) are participating in the 'Adaptation of SVAT-models to local vegetation types' through managing the process of research project in terms of preparation, execution, and dissemination as shown in Figure 1. ICRAF will jointly conduct with INERA experimental research to generate site, soil and vegetation specific parameters necessary for a successful run of WaNuLCAS. Model parameters which are unavailable and impossible to measure under given local conditions should be obtained from scientific publications.

Experimental site areas

To model climate dependent scenarios for Burkina Faso on a national scale, a systematic field sampling frame with complete coverage was proposed. The sampling intensity approximates 53 reference areas (RA = 25 km²). However, for the intensive field measurements, ICRAF and INERA experiments will be established only on 3 representative sub-samples: Tougouri (North, RA 43) for the Sahelian sites, Noberé (Central plateau, RA13) for the Soudano-Sahelian Savanna, and Soukouraba (South, RA 4) for the Soudano-Guinean Savanna. Details of sampling areas are given in Figure 1. Model parameters and measurements will be collected from plots laid down taking into consideration land use types and following a toposequence gradient as well.

Figure 1. Systematic Sampling Grid, total area of Burkina Faso app. 270,774 km²
Fieldwork procedures

Establishment of permanents plots
The plots and subplots will be randomly taken from those established by vegetation inventory methods team. Firstly in each site and for each land use/cover (LUC) unit, 3 subplots will be considered for data collection to study vegetation response to meteorological and land use conditions. Secondly, along transects of the gallery forest, a toposequence site-species matching assessment will be done. Moreover, a par-kland management experiment will also be conducted.

Measurement of weather and vegetation parameters

A) Weather data (hourly and or daily)
Weather informations to be collected from each site for WaNuLCAS are:
- Minimum temperature
- Maximum temperature
- Rainfall (intensity)
- Solar radiation
- Net radiation
- Dewpoint temperature
- Average daily wind speed and wind direction
- Photosynthetically Active Radiation (PAR)
- Humidity.

B) Vegetation data
Study 1: Vegetation response to meteorological and land use conditions
In addition to morphological parameters (height, diameter at breast height (DBH), crown diameter, Leaf Area Index (LAI), and the species composition assessed by the team of inventory, the following parameters will be collected in each plot:
- Soil profile describing the soil layers and sampling the soil for each layer for physico-chemical analyses
- Root density of the vegetation according the different soil horizons described. This will be done at maximum proportion of vegetation biomass (example of assessing root biomass in Figure 2). Two sampling positions will be chosen randomly within each plot and cores will be taken with a corer at 10 cm intervals. Using a sub-sample of know volume, roots will be washed using a root washer (Root Washer, Delta-T, UK) in order to separate soil from roots. Roots will be sorted into two categories: tree/shrub and grasses. For both grass and tree/shrub roots only fine roots (d 2 mm) will be retained for the purpose of the present study. Root length of trees and grasses will be estimated using the line intercept method described by Tennant (1975) and derived using the following formula:

\[ L = \frac{ND}{4} \]

Where:
- \( N \) = number of counts,
- \( D \) (cm) = grid size, and
- \( L \) (cm) = root length

When samples are very small (less than 30 intercepts on a 1 cm grid), direct measurement of length will be made using a ruler. Then root length density (RLD) will be obtained by dividing root length by the volume of soil used for root extraction. After length measurement, root samples will be dried in an oven at 70oC for 48 hours and weighted. Root weight density (RWD) will be obtained by dividing root weight of each sample by its volume.

Biomass production. This will be done at maximum proportion of vegetation biomass. Ten sub-plots a 1x1 m will be and 5 circular plots of 15 m radius, both types as described by the inventory team, will be totally harvested for grasses and shrubs respectively. The biomass will be weighed, air dry and weight again when well dried. FBA method (Van Noordwijk and Mulia, 2002) will be applied to the above ground part and to the below ground part for the trees and the below ground part for shrubs. Biomass of stems, branches, and coarse roots were estimated from DBH (cm) and tree height (H, in m) following the allometric relationships derived the measured data (Van Noordwijk and Mulia, 2002). Physiological parameters including specific leaf area (SLA), leaf weight ratio (LWR), and light extinction coefficient (k) will be measured.

Study 2: Gallery forest sampling
Along the intersect line used for sampling design of gallery forests will be laid out four plots going from the top to the bottom of the toposequence. Each plot will be replicated 3 times at each of the four points of the toposequence. On these plots, the following parameters will be collected as described above:
- Soil profile describing the soil layers and sampling the soil for each layer for physico-chemical
analyses;
- root density of the vegetation according the different soil horizon described; and
- biomass production.

**Study 3: Parkland experiment**
In each "intensive site", fields with main crops will be sampled and crop production monitored. In addition soil profile study will be conducted on each plot where the crop production will be measured. The interactions of 3 main tree species with sorghum and millet (the two main staple food crops in all climatic zones of Burkina Faso) will be monitored.

The area around each of the sampled trees will be subdivided into four concentric zones:
- Zone A - from the trunk to half of the radius of the tree crown;
- Zone B - from half of the radius of the tree crown up to the edge of the crown;
- Zone C - from the edge of the tree crown up to 3 m away; and
- A control plot for crop only treatment for each sample tree - an area of 4 x 4 m situated at least 40 m away from the edge of the crown of the sample tree but unshaded by any of the surrounding trees at any time of the day throughout the cropping season.

The soil nutrients, light transmission and transpiration by trees will be measured under all sample trees. Soil samples under trees will be taken at two points in each concentric zone. The two samples from each concentric zone will be bulked and mixed thoroughly to make composite samples. The samples will be air dried for physical and chemical analyses.

Quantum sensors, type DRP-1B (Didcot Instrument Co. Ltd, UK), will be used for the measurement of PAR. The measurements will be made at one minute intervals and 10-minute mean values stored on a DL2e data logger (DeltaT Devices Ltd, UK). The measurement of PAR under each the selected sample trees will be made at three random positions, in the first three concentric zones (A, B and C) and a fourth sensor will be positioned in an area outside the influence of the surrounding trees as a control.

Crop phenology and crop root density will be also assessed in this study. At harvest, all crop plants in each concentric zone and the control plot will be assessed. Crop parameters to be measured are:
- total dry matter, and
- grain yield per unit area.

What about leaf area? Tree transpiration rate, which is an expression of water use by the tree, will be estimated from sap velocity measured using Thermal Dissipation Probes (TDP) type SV1 (DeltaT Devices Ltd, UK). Measurements will be made every 1-minute and 10-minute mean values stored on a DL2e data logger (DeltaT Devices Ltd, UK). Then transpiration rate per tree will be calculated from the adjusted sap velocity and sapwood cross sectional area of each tree. Mean sapwood cross sectional area per tree will be obtained by taking wood cores with an increment borer at two opposite positions in the trunk of each sample tree.

Tree root density will be assessed as described in study 1. This will be done at maximum proportion of vegetation biomass. Two sampling positions will be chosen randomly within each concentric tree influence zone and cores will be taken with a 7 cm inner diameter corer at 10 cm intervals. Using a subsample of know volume, roots will be washed using a root washer in order to separate soil from roots. Roots will be sorted into three categories: tree, crop and weeds.

FBA method (Van Noordwijk and Mulia, 2002) will be applied to the above ground biomass and to the below ground biomass at the end of the experiment to avoid disturbing the plots. Physiological parameters including specific leaf area (SLA), leaf weight ratio (LWR), light extinction coefficient (k) will be measured.
**Preliminary Results**

Different land use/cover were identified and field experiments established on permanent plots. Only parkland was considered in Tougouri site as the all area of the village is almost under cultivation and the non cultivated area is bare land. In Nobéré, three land uses (parkland, fallow and classified forest) were identified while two were considered in Sokouraba (parkland and fallow). The aim was to work on the same tree species across the country but it in the field it was impossible to find three common species with the required conditions (density, spacings) on farmed field. Therefore, in Vitellaria paradoxa (karité) and Parkia biglobosa (néré) were encountered in a sufficient number in Tougouri site to be included in the experiments. The tested species were V. paradoxa and P. biglobosa and Adansonia digitata (baobab) whereas at Sokouraba the species were V. paradoxa and P. biglobosa. Therefore, there is one common species to the three sites. In each site and for each species 8 individuals were selected and the experiment design laid out around each tree as described in the research protocols. Permanent plots were also established in fallows and classified forest land use units.

A number of data have been collected and will be used to run WaNuLCAS model for its adaptation to the local vegetation types. Tree transpiration and light transmission were only measured at Nobéré because the equipments dedicated for the measurement of these parameters were not delivered on time. Two sets of this equipment are now available and will be used during the 2010 cropping season allowing the measurement of the same parameters on the three sites. Soil samples will be collected during the dry season as soil profile is much easier to realize during that period than during the rainy season. FBA method to assess the below ground biomass will be applied at the end of the three-year period experiment to avoid disturbing the plots.

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**References**


Farmer perception about climate change adaptation and mitigation in rain forest and western highlands zones of Cameroon

Alain Tsobeng, Charlie Mbosso, Ann Degrande, Ebenezer Asaah and Bertin Takoutsing

Introduction
Cameroon, as many other countries of Sub-Saharan Africa faces many challenges; a rapidly growing population (from 1.93 to 2.19 % between 2005 and 2009), expanding urban areas (urban population has increased from 0.79 to 4.75, in Cameroon), unsustainable agricultural and forest exploitation practices (the annual net loss of forest area between 2000 and 2005 was 7.3 million hectares/year in Sub-Saharan Africa) that lead to land degradation and potentially climate change. The potential negative impacts of climate change would add other constraints to agricultural production if nothing is done. In effect, countries need to respond to the challenges posed by climate change. Therefore, access to information on climate change and involvement of rural populations in particular can improve adaptation and mitigation strategies.

The objectives of this research were as follows:
- to assess farmers’ awareness on climate change and their perception on recent variations in some key climate elements;
- to identify problems related to climate variation faced by farmers at field and household level; and
- to inventory measures taken by farmers to adapt to and mitigate the effects of climate variation.

Methodology
Two agro-ecological zones in Cameroon were chosen for the study: the humid forest with bimodal rainfall (1 600 mm), and the western highlands with unimodal rainfall (2 000 mm) (Fig. 1). Though these zones are generally considered as less vulnerable than drier areas, significant variations in climate have been observed recently.

In these zones, 117 farmers randomly selected from the different groups that collaborate with ICRAF and distributed as follows, were interviewed.

<table>
<thead>
<tr>
<th>Agro-ecological zone</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid forest</td>
<td>29</td>
<td>25</td>
<td>54</td>
</tr>
<tr>
<td>Western highland</td>
<td>36</td>
<td>27</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
<td>52</td>
<td>117</td>
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Fig. 1: Agro-ecological zones in Cameroon (Ambassa, 2000)

Key results
Farmer awareness and perception of climate change

Fig. 2: Duration of observation of climate change according to zone and gender
Independent of gender and agro-ecological zone, 99% of the farmers interviewed were aware of what climate change is all about. Most of these farmers have observed a change in climatic conditions over the last 5 years. In the humid forest zone, about 12% of farmers interviewed have observed a change in climatic conditions over the last 10 years (Fig. 2).

The elements of climate affected by climate change are rainfall, wind and temperature. The majority of respondents in both zones affirmed that the rainfall has become more irregular. However, more farmers have noticed a decrease in rainfall in the highlands than in the humid forest zone (fig. 3). More than half of the respondent noted that winds have become more irregular, while increased wind speed has been stated more in forest than in highland zone (fig. 4). In general, temperatures have increased in both zones.

Farmers have identified six species for which yields seem to be less negatively affected by variations in climate; namely Dacryodes edulis, Cola spp., Persea americana, Mangifera indica, Ricinodendron heudelotii and Adansonia digitata. Respondents reported that D. edulis and M. indica are the most resistant in humid forests and western highlands (fig. 5). Farmers could not determine differences between propagule types in terms of tolerance to climate change. Resistant farming systems identified by respondents include home gardens and cocoa or coffee based systems (Fig. 6).

**Effects of climate change**

Independent of agro-ecological zone and gender, the following negative effects of climate change on tree performance were identified: decrease in tree yields due to abortion of flowers, increased prevalence and virulence of pests and diseases, irregularity in yields and change in fruit characteristics (colour, size, taste...). These factors, according to interviewees, negatively affect the household through increased malnutrition and reduced revenue. Consequently, the level of education and the purchasing power of hou-
seholds (for basic commodities like salt, spices ...) have reduced, while health has deteriorated. The major diseases attributed to climate change include cough, skin diseases, rheumatism, typhoid, amoeba and intestinal worms.

However, some positive effects of climate change have been noticed as well. Some farmers said that because of lower and irregular production, agroforestry products are scarce in the market and thus fetch higher prices.

**Fig. 7: Perception of production and fruit characteristics in the two zones**

**Fig. 8: Perception of climate change effects at household level**

Measures taken to adapt to and mitigate climate change

Some major actions have been taken by farmers to adapt to and mitigate climate change. These actions are both active and passive. Active actions include: intensification of tree planting, change in eating habits, diversification of sources of revenue [fishing, hunting, livestock rearing (fish, pig, chicken ...)], intensification of tree based systems, increase in exploitable field size and fight against bush fire.

In the forest zone, diversification of income sources was mentioned by 90% of respondents followed by intensification of tree planting (65%) and change in eating habits (54%). Passive actions characterized by prayers and complaints to researchers cannot be neglected. In the western highland zone, up to 70% of the farmers interviewed put their hope in God and count on researchers to find a solution to climate change. The fact that none of the respondents in the highlands mentioned increasing field size as a coping strategy can be explained by the scarcity of arable land in this zone.

Women tend to be more passive towards climate change than men (fig. 9). The study did not look specifically at possible reasons for this, but it is likely that women are less informed about climate change because of their lower level of education. More sensitization is thus needed to increase farmers’ and particularly women’s awareness on climate change and possible actions to adapt to this phenomenon.

**Fig. 9: Perception on measures taken against climate change**

**Conclusion**

It could be concluded that climate change is a reality in the western highlands and humid forest zones of Cameroon. The landscape, the fruit trees and the livelihoods are all negatively affected. The study has shown the consequences of climate change and identified some measures already taken for mitigation and adaptation. Those actions have to be further encouraged.
This study should be seen as an exploratory research and information gathered could be used to formulate research hypotheses. For example, 10 years’ data on yields of Dacryodes edulis and Ricinodendron heudelotii, and on growth of Irvingia gabonensis, Garcinia kola and Irvingia wombolu in ICRAF demonstration plots should be analyzed against the meteorology within the same period to confirm the evolution of yield and growth with climate variation. On the other hand, farmers should be provided with logbooks to record actual yield data for some key tree species in the light of further studies.

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Cameroon's western highlands and its challenges
The Western Highlands (West and North West regions) of Cameroon cover a surface area of about 3.1 million hectares. The topography is undulating and the vegetation is predominantly savannah with patches of gallery forest and montane forest containing a variety of agroforestry tree species. The soils are highly variable, ranging from andosols that are generally fertile and rich in organic matter on the high plateau (2000-2700 m) to ferralitic soils, often deep and impoverished by intensive cultivation in the valleys (1400-1500 m; Figure 1). Rainfall (1,800 to 2,200 mm per annum) is unimodal with a peak in September. The dry season runs from mid-November to mid-March. Daily temperatures vary from 10 to 28 oC and the average is 20 oC. The population density is quite high with an average of 90 - 300 inhabitants km-2. The most striking feature of this region is the high cultivation intensity; smallholder farms average 1.8 ha. About 40-75 percent of the total area is planted with annual and perennial crops - cereals, legumes, root crops, market gardening, fruit trees, cash crops like coffee, cocoa, tea and oil palm.

Homesteads are scattered, each family residing in the middle of the homestead enclosed by tree hedges of indigenous and exotic tree species: e.g. kola (Cola spp), bitter kola (Garcinia kola), safou (Dacryodes edulis), black fruit (Canarium schweinfurtii), country onion (Afrostyrax lepidophyllus), groundnut spice (Monodora myristica), avocado (Persea americana), mango (Mangifera indica), apple (Malus domestica), prunus (Prunus africana), voacanga (Voacanga africana), Eucalyptus spp and Podocarpus mannii.

As a result of population growth and agriculture expansion, few forests are remaining and they are highly degraded, causing losses in traditionally-important nutritious foods, medicines and other useful products. Furthermore, soil fertility has drastically fallen with fallows shortening and even disappearing to make place for continuous farming.

This paper describes how agroforestry technologies can be applied to reverse these trends. Particular reference is made on technologies to slow down land degradation and on the domestication of indigenous tree species. In addition we illustrate how farmers have applied tree domestication techniques on a naturalized variety of a temperate fruit - apple which can be integrated in the current participatory tree domestication programme.

Using agroforestry options to reverse land degradation
Soil fertility management
Improved fallows using leguminous tree and shrub species have been widely tested in the western highlands of Cameroon (Degrande et al., 2007) and are increasingly becoming adopted for soil fertility improvement. Results in Cameroon have shown that subsequent maize yields have increased by 70% (Degrande et al., 2007). Furthermore, doubling of maize and potato yields have been obtained through the use of improved fallows in the study area (Asaah et al., 2010).

Within the framework of the Agricultural and Tree Products Projects funded by the United States Department of Agriculture (USDA) and executed by ICRAF in the Western Highlands from 2007-2010, 45 local trainers (21 women and 24 men) were trained in soil fertility management. In 2009, they worked with 85 farmer groups (representing 1,500 farmers) to set up 147 improved fallow demonstration plots and 93 composting heaps. In addition, 79 seed-banks for the continuous production of planting material of soil fertilizer species were established.
Domestication of tree crops for home use and markets

Recognising the traditional importance of indigenous tree products for food and nutritional security (Leakey, 1999) and the declining availability of these species, the World Agroforestry Centre (ICRAF) initiated a programme to domesticate indigenous tree species in 1995. In Cameroon, tree domestication started in 1997 and aimed to improve the yield and quality of species identified as farmers’ priorities (Irvingia gabonensis, Dacryodes edulis, Ricinodendron heudelotii, Garcinia kola, Cola spp, Pausinystalia johimbe, Prunus africana). The techniques and strategies used include vegetative propagation, characterization of genetic variation, tree selection, and cultivar development (Waruhiu et al.; 2004, Leakey et al., 2007). Uniquely however was the idea to work directly with local communities and to promote the use of local knowledge (Leakey et al., 2003; Tchoundjeu et al., 2006; 2010), resulting in an approach currently referred to as ‘participatory tree domestication’. The approach empowers local communities, promotes food self-sufficiency, income generation and rural employment, and provides nutritional benefits (Schreckenberg et al., 2006). Domestication of indigenous trees is therefore increasingly recognized as having meaningful impacts in rural development with application in the alleviation of poverty, malnutrition and hunger (Asaah et al., 2010; Tchoundjeu et al., 2010), resulting in an approach currently referred to as ‘participatory tree domestication’. The approach empowers local communities, promotes food self-sufficiency, income generation and rural employment, and provides nutritional benefits (Schreckenberg et al., 2006).

Farmer application of tree domestication techniques to a naturalized temperate fruit - apple

Among the many fruit species found in the area are apples (Malus domestica). Though the history of apple cultivation in the western highlands of Cameroon is neither clear nor documented, Pa Njolai, a retired agricultural technician and renowned apple farmer in Kumbo, recounts that he bought four pink apple fruits in the then 'Lucas Fru & Sons Shop' in Bamenda in 1976. After eating the fruits he nursed 16 seeds on a seedbed besides his house. Four of the seeds germinated and were transplanted. Only one of the plants survived and grew to a mature tree that started bearing in 1981. Later, Pa Njolai transplanted many wildings from below the tree to populate his farm, while others were sold to interested farmers.

Pa Miamo has a commercial orchard of apples and is among the most enterprising smallholder apple farmers in the area. The orchard now has about 300 apple trees but it all started with 16 seedlings of sucker origin bought from Pa Njolia. Both Pa Njolia and Miamo do not have any knowledge on the husbandry of apples. Therefore their trees are not managed and consequently suffering from pest and disease problems resulting in sub-optimal growth and productivity. However, they have sold several thousands of apple seedlings from sucker or seed origin to clients both from within the western highlands and beyond. During the fruit maturity period these far-
mers virtually become guards to protect their fruits from thieves. The fruits are sold to traders, missionaries and patients in hospitals around Kumbo at 100 fcfa to 250 fcfa (20-50 US$ cents) each, depending on size.

Pa Maimo is now an affiliated member of the Riba Agroforestry Resource Centre in Kumbo, where he first heard about participatory tree domestication. After the training, Pa Miamo experimented vegetative propagation techniques on apple trees which gave him very satisfactory results. Since 2008, Pa Miamo produces and sells grafts and marcots of apples that are tree-to-type and have early fruiting. Apple seedlings are sold at 250 fcfa (US$ 50 cents) but grafts easily fetch prices 4 folds more, while prices of marcots can go up to 1500 fcfa (US$ 3).

Apples are attracting the interest of scientists of ICRAF because there is a major information gap with regards to the cultivation requirement of this species in this part of the world; thus offering a unique opportunity to carry out adaptive research.

**Conclusion**

Species' preferences are much of a cultural phenomenon as they are agroclimatic or physiological. The western highlands of Cameroon combine a mixed topography of undulating hills with cold high tops and warm valleys ideal for growing most indigenous and exotic fruit trees species. This climate also offers the chilling and hot summer-like requirements ideal for temperate fruits like apples pears, and grapes. In addition the soils are well drained, relatively deep, fertile (especially in the valleys) and are well aerated. The current adaptive research on indigenous tree species, when extended to other naturalized exotics species in this region, will increase the array of fruit species that have long been recognized to provide many of the vitamins and minerals required to complement the predominantly starchy diets of rural households.

The Rural Resource Center approach to promote technological innovations is self supporting and is increasingly becoming an integrated rural development philosophy, proven to encourage strong local participation and to ensure the sustainability of a diverse set of activities that may benefit rural household nutrition, local economies and overall farmer physical health, as well as preserve the environment.

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Introduction
In Sierra Leone, the degradation trends combined with forest cover loss have been increasingly alarming as forest cover reduction went from 70% to barely 5% (UNDP/CBD, 2003). According to the same report, the main threats eroding ecosystems resources in the country are due to anthropogenic activities such as deforestation, land degradation, overgrazing, wild bush fires, slash and burn agriculture and urbanization. The ten-year war further threatened and accelerated the extinction of some of the biodiversity. As the threats are increasing under the exacerbation of climate change, it becomes crucial to identify natural resources management strategies and policy inadequacies that could lead to the better integration of community needs at local level, but could also target increased communication and collaboration between decision makers, researchers and natural resource managers across protected areas to enhance biodiversity conservations efforts.

The National Park based biodiversity management strategy has limited impact especially in the trans-boundary areas due to uncontrolled uses of resources and illegal hunting and logging. Analyzing the present legal context and developing alternatives to reduce pressure on the remaining resources in the Ottamba Kilimi National Park (OKNP) could lead to effective and sustainable management of the landscape bordering the Guinean hedge end of Fouta Djallon contre-forts.

This report highlights the preliminary experience and lessons on policy related matters arising from communities and states services in course of forestry and wildlife acts reviewed undertaken in Sierra Leone.

Site profile

Map: Study Site located at the border between Sierra Leone and Guinea
This action research was conducted in Tambakha chiefdom which is the continuum of the transboundary landscape embedding Ottamaba Killimi National Park in Sierra Leone and Mamou and Madina Oula forests in Guinea (Map below). On the Sierra Leone side, the Tambakha Chiefdom is located in the North east of Bombali District, Northern Province of Sierra Leone, and this is a Guinea Savannah ecological zone predominantly dominated by lophira woodland with extensive patches of bolilands that are seasonally flooded. This is the largest chiefdom in Sierra Leone but sparsely populated, remote and less developed, hence a suitable factor justifying the establishment of the Outamba-Kilimi National Park (see Map below) as catalyst for development of the chiefdom. This area is found to have relatively undisturbed vegetation, a substantial number of variety of animal species and diverse avian life. The soil fertility is also relatively poor and cannot support agricultural practices for dependable yield that will support commercialization nor sustainable subsistence, but marginal areas such as inland valley swamps and seasonally flooded areas are suitable for subsistence farming. The park covers 112,825 ha of predominantly savannah woodland, and important wildlife species include elephant, a range of primates (chimpanzee, monkey species), hippopotamus, buffalo, giant forest hog, warthog, a variety of antelopes especially duikers, and profuse bird life.

Forestry and Wildlife related Policy Review process in Sierra Leone

The World Agroforestry Centre (ICRAF), CIFOR and PAGE have been involved alongside other key stakeholders in policy related debates over the past two years. An analysis of governance structures and issues was initiated early 2009 to determine constraints and gaps in the governance system that would influence implementation of co-management, and effective adoption of best practices for NRM in the Transboundary landscape. The first country to start reviewing its NRM related policies was Sierra Leone and this was launched in stakeholders’ workshop held in February 2009 in Freetown aimed to review the Forestry and Biodiversity policies and law. In Sierra Leone, the main weaknesses were identified in two categories: (1) Policy inadequacies and (2) Cross cutting issues beyond national forestry department.

Participants to the Freetown policymakers’ workshop interacting with Government ministers

National Forestry policy texts inadequacy
During the multi stakeholders meetings, existing legal texts showed that:
- Some titles in the existing acts and policy documents are no longer in use;
- No impact assessment was indicated before any public work or mining activities;
- The Minister was given immense power and this may lead to abuse;
- International conventions are not referred to in most cases;
- Governance related to forestry extraction and transboundary issues are absent in the texts;
- Coordination among relevant ministries is not clear; and
- The role of research seems not to be recognised anywhere in the policies.

Cross-cutting issues beyond national forestry department
Cross-cutting issues to be reviewed included:
- Decentralisation and Governance of Forest resources: Unclear decentralization mandates & schedule of devolution
- Weak and unclear mining activities regulatory framework especially in protected areas;
- Rewards and compensation mechanisms for classified forests stewardship.
- Transboundary cooperation through Mano river Union framework;
- Periodic national multi resource inventories;
Environmental Impact Assessment; and
Promotion of gene banks, herbarium and arboreta to ensure the survival of endangered species.

It was therefore proposed and agreed upon that the revised forestry act, and Forestry policy will take into consideration these emerging global concepts such as Co-management, climate change, payments for environmental services "PES", REDD and Agroforestry knowledge including for the very first time in the sub-region the transboundary areas management in conjunction with neighboring countries.

Lessons learnt
The main question emerging from high level policy makers, traditional rulers and research teams during the previous debates under Mano River Union ongoing meetings on NRM particularly for Guinea and Sierra Leone transboundary conservation area of OKNP was: How do we interest communities in forest reserve conservation? The preliminary answers derived from ongoing analysis of lessons learnt from the project were provided. In order to create and maintain communities' enthusiasm in forest reserve conservation, it appears important to work out a mechanism that tackles the following areas:

- Responding to practical needs of communities according to their priorities,
- Valuing local knowledge and traditional values (what is important to communities: money or other things? what has been going on before we got involved?),
- Empowering communities for collective actions towards Participatory Natural Resources Management (PNRM),
- Integrating appropriate biodiversity friendly technologies and management practices, and
- Setting up appropriate incentive mechanisms based mostly on non-cash options.

In conclusion, it was observed that there is strong political will to adapt existing texts and laws to the current global environmental debates especially addressing community livelihoods and rights to resources. This is demonstrated by the implication of a cross section of ministers respectively in charge of Agriculture, Forestry and wildlife, Environment and lands, town planning and public works. This has positively affected the review process. However, it was noticed the weak coordination among concerned stakeholders in policy development and implementation at ministerial levels. Additionally, the finalization of Forestry and wildlife review would be completed after sub regional consultation and harmonization the Mano River Union Multi stakeholders meetings to include all transboundary issues before enacting the new laws. This will require more donors' implications as additional grassroots linkages with traditional authorities and communities would benefit the process in the neighboring countries.

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