Chapitre 7b : Agroforestry and Tree Domestication in the context of Central Africa

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Introduction

Central Africa is host to the second largest rainforest in the world—the Congo basin and equatorial African rainforests. These forests play a key role in global climate regulation and are also regarded as a biodiversity hotspot. In parallel, the forests are an important provider of employment from the timber industry, both formal (export oriented) and informal (domestic and regional), as well as of livelihoods and food for local populations including indigenous groups.

This region also harbours large rural populations, widespread poverty and extensive areas of low agricultural productivity due to steadily degrading natural resource bases, weak markets, and rights to forest and their products and high climatic risks. Meanwhile, most of these rural poor people are also dependent on forests, remnant woodlands, homestead trees, and on mixed agricultural and forestry production systems for their subsistence, fuel wood, food and fodder needs (FAO, 2009)

Overall annual deforestation rates are lower in Central Africa than other regions - 0.224 % between 2000 to 2010 compared to -1.32 % in humid West Africa (Word Bank, 2012). The main driver to deforestation in these areas is agriculture, which accounts for more than 80 % of forest cover loss in Cameroon (CARPE, 2005) just like in other countries in central Africa. This includes not only slash-and-burn shifting cultivation, long recognized as a key driver of deforestation in the dense forest areas (Ndoye and Kaimowitz, 2000), but also cash cropping with most notably cocoa (*Theobroma cacao)* (Sunderlin et al., 2000). Cocoa has been a major cash crop promoted by the government of Central Africa countries like Cameroon since independence up to the 1980s with considerable impact on forest integrity in Cameroon (World Bank, 2008 cited by Eba'a Atyi et al., 2009). According to the same report, cocoa cultivation was less profitable in the 1990s as a result of less attractive global market prices. However, with the current trend, Cameroon revitalized cocoa planting since 2005 at the expense of forests.

Demand for household energy is also an increasing driver of deforestation especially around rapidly growing urban centers like Kinshasa the second largest city in Africa with over seven million inhabitants. The sub-region also has important forests and woodlands outside the Congo Basin; out of DRC's forested area of 120 million ha, 40 million ha are dry land forests in the northeast and south. For instance, the eastern mountain forests, in the eastern provinces of DRC are densely populated just like the Western montane highland forest regions in Cameroon.

Land degradation is one of the most serious problems facing global agriculture as it affects two billion hectares (38% of the world's cropland). Consequently, many smallholder farmers in Central African countries in the humid tropics are trapped in poverty and hunger, together with malnutrition. With little, if any, land remaining for the expansion of farming, the only option is to use the available land

more efficiently. This therefore means that existing farmland has to be made more productive. The options are either to increase yields of existing good quality cropland or to rehabilitate degraded farmland and bring it back into production. In effect, this means either further expanding Green Revolution-like technologies (Borlaug, 2007) or seeking another solution. In temperate countries, where enough capital is available to invest, the first strategy is the most appropriate. In the tropics, there is a problem because although the Green Revolution has hugely improved yield potential and quality of a number of staple crops, poor farmers have often been unable to access seeds, fertilizers and/or pesticides which are at the core of the Green Revolution approach. According to Leakey (2012), adopting and implementing agroforestry technologies will improve the productivity of staple food crops by improving soil fertility and promoting agro-ecosystem functions. In addition, the domestication of agroforestry trees producing marketable products would then intensify the agroforestry system and lead to marketable food and tree products, increasing trade and business opportunities that improve farmers' livelihoods. Together, these steps would provide what the same author terms 'a generic and adaptable model for more sustainable agriculture in the tropics, which builds on the success of, and enhances the outputs of, the Green Revolution'.

Agroforestry and Tree Domestication Technologies

The inclusion of trees within farmland has been a tradition going back to the ages. Agroforestry has been defined as the set of land use practices which involve the deliberate combination of woody perennials and herbaceous crops and/or animals on the same land management unit, in some form of spatial arrangement or temporal sequence, such that there are significant ecological and economic interactions between woody and non-woody components (Sinclair et al., 1994).

Agroforestry, though a somewhat relatively new subject of scientific study, it is a traditional practice with a long history in many parts of the tropics (King, 1968; Nair, 1989).What seems to be new is the greater involvement in trees for the production of diverse tree products, as opposed to simply providing environmental services, leading to the application of modern horticultural techniques of domestication to the trees within the agroforestry system (Simons and Leakey, 1996; Tchoundjeu et al., 2006).

The most recent definition of agroforestry, considers it as 'a dynamic, ecologically-based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels' (www.icraf.cgiar.org).

Agroforestry and Tree domestication technologies

Soil fertility management

Typically, farm sizes in central Africa are less than 5 hectares, often less than two hectares, so farming is focused on providing for household needs and seldom on providing food for sale. As a consequence, farmers cannot generate enough income and remain very poor. They are thus unable to purchase fertilizers and the other inputs that would maintain good crop yields. In addition, as the forests regress their farmlands are becoming more degraded with increasing loss of soil fertility. Similarly, there is a

decline in the range of living organisms that are essential for the maintenance of life processes, such as nutrient and carbon cycling, food chains and life cycles important for pest and disease control, pollination, etc. While modern agriculture has dramatically increased yield potential of many staple food crops, the consumption of a diet increasingly based on starch-based foods like cassava, cocoyams, maize and the reduced consumption of traditional foods lead to unbalanced diets, malnutrition and a greater susceptibility to disease is common place in many highly populated areas in Central Africa.

Agroforestry is a delivery mechanism of multifunctional agriculture (Leakey, 2010) as the latter allows to and actually does better address the issues of: declining soil fertility, the rehabilitation of degraded land; restoration of above and belowground biodiversity; sequestration of carbon; and protection of soils and watersheds. Agroforestry practices like improved fallows using leguminous tree and shrub species are well-known, widely tested and an increasingly adopted agroforestry technology for soil fertility improvement (Cooper et al., 1996; Kanmegne et al., 2003; Degrande et al., 2007). Between 1988 and 1998, ICRAF developed two improved fallow technologies. (i) The first technology was the **rotational tree fallow** with *Calliandra calothyrsus.* This technology increased crop yields, provided farmers cut back at 0.05 m above ground level and prune the trees twice during cropping. In addition to soil fertility improvement, *Calliandra calothyrsus* fallows displayed many additional short-term benefits such as reduced weeds, provision of fuel wood and stakes and attracted bees as so planted are apiaries as the *Calliandra* trees flower almost all year round. However, the trees have to occupy the land permanently and soil fertility improvement is only observed after a number of years. (ii) To overcome a number of the constraints with tree fallows, **a shrub fallow was designed, using *Cajanus cajan*** in a relay cropping system. According to a review by Degrande et al. (2007), farmers' response to this technology was positive due to higher crop yields, easier clearing of Cajanus fallows, and the shading out of weeds by the shrubs. Shrub fallows were particularly appreciated by women for its low labour demand and because these shrubs can be planted on land with less secure tenure. However, wider dissemination of tree and shrub fallows was constrained by lack of an adequate seed supply system and poor extension strategies. That notwithstanding, rresults from a wide range of sites in Cameroon displayed maize yield increases on average by about 70% (Degrande et al., 2007), and in some areas 3 or 4 fold gains were possible.

Participatory Tree domestication

In agroforestry, the domestication of underutilized and indigenous trees was initiated in the mid-1990s by the World Agroforestry Centre (ICRAF) and its partners. This programme aimed at improving the quality and yield of products from traditionally important species that used to be gathered from forests and woodlands. In addition to meeting the everyday needs of local people, these products are widely traded in local and regional markets. Underutilized crops therefore have the potential to become new cash crops for income generation and to counter malnutrition and disease by diversifying staple food/food energy sources and dietary uptake of micro-nutrients that boost the immune system among others. These indigenous tree species also play an important role in enhancing agro-ecological functions and, through carbon sequestration, can help to counter climate change.

Domestication is a complex process akin to evolution in which human use of plant and animal species leads to morphological and physiological changes that create a distinction between domesticated taxa from their wild ancestors (Purugganan and Fuller, 2009). Interestingly, the process of domestication has been conducted for more than 13,000 years (i.e., since the last ice age), and occurred independently in several regions (Gepts, 2002). In spite of the geographic and climatic diversity in the different regions, there is a remarkable similarity in the set of traits which were used to select completely unrelated types of crops.

In perennial crops, the selection of individuals under domestication is focused towards individuals with a more compact growth habit, having fewer and shorter branches as opposed to tall single stem wild relatives. All of these changes in plant growth habit have been reported to have a positive impact on the harvest index (ratio of harvested part to overall aboveground biomass) and size of the fruit or grain (Donald, (1968) cited by Gepts (2004)). Another feature that has been widely reported (Elias and Mckey, 2000; Gepts, 2004) to have change in crop evolution is the reproductive system. The latter authors emphasize that the reproductive system of most species under domestication has changed towards increase selfing (as in tomatoes and peppers) or a replacement of sexual reproduction by vegetative propagation in order to maintain trueness in type of cultivated individuals faced with possibilities of outcrossing with wild relatives. Waruhiu et al. (2004) reported that *D. edulis* fruits from trees on farms in Cameroon and Nigeria were 66% larger than those obtained from trees in the wild.

A tree is normally considered 'wild' when it grows spontaneously in self-maintaining populations in a natural or semi-natural ecosystem and when it can exist independently of direct human action (FAO, 1999). In contrast, it is considered to be domesticated when it has been selected purposefully for specific genetic characteristics, and when it is propagated and cultivated in managed agro-ecosystems (Leakey and Newton, 1994). Crop domestication has been limited to less than 0.05% of all plant species and about 0.5% of edible species (Leakey and Tomich, 1999). According to FAOStat (2010), out of a total of 400,000 flowering plants species, less than 200 have been domesticated as food and feed plants, and just 12 species provide 75% of the food eaten.

One of the main challenges in agroforestry is to address the lack of genetically superior seed sources for tree propagation (Simons, 1996). In this respect any domestication effort of a species has to involve making a decision as to whether to use sexual or vegetative propagation to achieve tree seedling production and improvement of tree, fruit and nut characteristics. When Simons and Leakey (2004) advanced a definition of domestication used for agroforestry trees, they proposed that it should encompass both the socio-economic and biophysical processes involved in the identification and characterisation of germplasm resources; the capture, selection and management of genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems.

Domestication is reportedly stimulated, when demand for certain species products exceeds supply (Leakey and Asaah, In press). This probably explains the recent interest in domesticating tree crops from wild forest species in the tropics, as deforestation has increased in proportion to population growth. In Cameroon for example, forest is being destroyed at an annual rate of 1% (FAO, 2007) as a consequence of unsustainable agricultural practices (slash-and-burn shifting cultivation). This accounts for more than

80% of forest cover loss (CARPE, 2005). This has made indigenous and culturally important species a scarce resource, even though they remain much in demand.

Interestingly, some innovative farmers have reacted to deforestation and rarity in the supply of traditional tree products by starting to select and manage useful trees or growing them within their farms. This approach to farmer-driven domestication in which species are brought into a managed environment through planting or retention, is indicative of the conviction that it is worth investing in indigenous fruit species. Asaah et al. (2003) and Leakey et al. (2004a) reported that farmers in Cameroon and Nigeria were selecting and multiplying *Irvingia wombolu* and *I. gabonensis* (bush mango) trees respectively, that have 44% large kernels over similar other trees of the same species (particularly in south-eastern Nigeria). Farmers in southern Cameroon have also been reported to select particular trees for their large fruit size as well as other characteristics such as taste and yield (Schreckenberg et al., 2006). Such selective planting by farmers in Cameroon and Nigeria, has been reported by Waruhiu et al. (2004) to result in *D. edulis* fruits from trees on farms being 66% larger than those obtained from trees in the wild.

These are strategies developed by farmers in order to be self-sufficient for food, micro-nutrients, medicines and all their other day-to-day needs (Tchoundjeu et al., 2008). These actions by farmers to retain natural seedlings on farms and in homegardens, and to eliminate trees with products (fruits/nuts) with less desirable attributes as they open up land to cultivate other crops, as well as the parallel sowing and/or dispersal of seeds of the more delicious fruits they eat close to the homestead, has been suggested to be a form of 'commensal' domestication (Leakey and Asaah, In press). This commensal approach to domestication constitutes one of the building blocks of the pathway to participatory tree domestication. Participatory tree domestication combines agricultural science and technology with traditional knowledge as an integral package (Tchoundjeu et al., 2006). The domestication of agroforestry trees could therefore be considered as a necessary step to promote sustainable agriculture through diversification with species which generate income in local and distant markets, improve diets and health, meet domestic needs, and restore functional agro-ecosystems, as well as empowering local communities (Leakey, 2012).

Work to domesticate agroforestry species started in Cameroon in 1997 to improve the yield and quality of their products, with a focus on the species identified as the farmers' priorities (*Irvingia gabonensis*, *Dacryodes edulis*, *Ricinodendron heudelotii*, *Garcinia kola*, *Cola* species, *Pausinystalia johimbe,* and *Prunus africana*). The techniques and strategies employed: vegetative propagation, characterization of genetic variation, tree selection, and cultivar development have been extensively reported elsewhere (see reviews by Tchoundjeu et al., 1998; 2006; Leakey et al., 2005; 2008). Uniquely, the approach developed in Cameroon was to work directly with local communities and to promote the use of local knowledge (Tchoundjeu et al., 2006; 2010). Through this research, techniques and strategies for participatory tree domestication were developed with the aim of empowering local communities, promoting food self-sufficiency, generating income and employment and enhancing nutritional benefits (Asaah et al., 2011). This participatory approach brings together agricultural science and community empowerment. There is now growing evidence that in this way agroforestry can help rural communities to be self-sufficient and to support their families on an area of less than 5 ha (Schreckenberg et al.,

2006; Degrande et al., 2006). Consequently, the domestication of indigenous fruit and nut trees is increasingly being recognized as an important component of agroforestry and has started to demonstrate meaningful impacts in rural development contributing to the alleviation of poverty, malnutrition and hunger (Asaah et al., 2011, Tchoundjeu et al., 2010).

Outcomes of Agroforestry and Tree domestication

Biological and Environmental outcomes/impacts

As a glaring consequence of agroforestry, 'fertilizer trees', such as *Calliandra calothyrsus*, *Acacia angustissima, Sesbania sesban, Tephrosia vogelli,* and *Cajanus cajan* that fix atmospheric nitrogen and restore soil fertility are being planted and promoted in most countries in Central Africa with varying levels of adoption. However, more farmers adopted the practice in high populated and less forested savanna ecosystems (Degrande et al., 2007). In the western highlands of Cameroon for instance, Rural Resource Centers (RRC) promote the planting of over 52,500 fertilizer trees annually (Asaah et al., 2011) for soil fertility management, apiculture, fodder banks and fuelwood. RRCs are defined as knowledge and demonstration centres (hubs) and act as an interface between research institutions/projects and farmers for the promotion and diffusion of technological innovations within a target area. In 2007-08 in one of such RRCs - RIBA Agroforestry Resource Center (RARC)- the number of farmers planting fertilizer trees rose from 208 to 360 (Asaah et al., 2011). These improved fallows have become a well-accepted technology in most of the communities engaged in the practice and farmers are reporting that their crop yields have doubled or tripled. This significant increase in staple food crop productivity is a great contribution towards reversing observed tends of food insecurity in some rural areas in Cameroon. It could be postulated that, this increased yield could allow farmers to plant smaller area of food crops while at the same time making space available for other types of crops, to meet other needs. Leguminous trees and shrubs also attract bees. Many communities therefore have opted to the practice of apiculture, which implies more access to honey which is a better substitute to refine sugars from a health perspective. The RARC is located on a 7 hectare piece of land that was completely bare, degraded, and had been abandoned by farmers. Today, the soils have been rehabilitated through agroforestry and the yields of wheat, maize, beans and potatoes have doubled. Furthermore the site has been planted with a diverse range of tree species serving different purposes such as: providing fuelwood, boundary trees that act as windbreakers, woodlot on the hilltop providing fodder for livestock and forage for bees. Moreover, increased tree cover, arranged along the contours of the hillsides, also protect the soil and reduces the risks of soil erosion while protecting watersheds.

With respect to tree domestication, the outcomes include new tree crop types (cutting, marcots, grafts) and cultivars of indigenous fruit/nuts species with improved product quality and greater market demand. This is going on in many countries in Central Africa, (Cameroon, Equatorial Guinea, Republic of Congo, DR Congo) on several dozens of species. However, participatory tree domestication is most advanced in Cameroon, where improved cultivars have been developed through vegetative propagation techniques by local farmers for cultivation in their different farming systems aimed at meeting their

household needs. Currently, as the demand for tree products like bush mango kernels (*Irvingia* spp) and Eru/Okok leaves (*Gnetum africanum*) supersedes supply, it is hoped that the supply of these products would increase in the coming years due to the different improved cultivars integrated into various farming systems. According to Tchoundjeu et al. (2010), Asaah et al.(2011) and Leakey (2012), the tree products will be sold – at first locally and then more widely – regionally within Central Africa countries and in Europe and America.

The integration of these potential 'new cash' crops in diverse farming systems is resulting in more stable and healthier agro-ecosystems. Diverse systems, either as mixed crops or as land use mosaics, apparently improve the agro-ecosystem functions and could reduce the incidence of pest and diseases. According to McNeely and Schroth (2006), agroforestry systems are more supportive of biodiversity than mono-crop systems, although there are no substitutes for natural habitat on whose proximity they may often depend for high levels of wild biodiversity. In a recent study, Asaah, (2012) and Asaah et al. (2010; 2012), reported that trees of vegetative origins allocated their biomass differently, with less fine roots and more primary roots and shoots, suggesting that clonal cultivars are more likely to be less competitive with annual crops. In parallel, the perennial nature of trees makes them suitable biological sinks of carbon for the mitigation of climate change. Available evidence suggests that vegetatively propagated cultivars could store double fold carbon in their shoots and primary roots than seed propagated trees – an unexpected benefit of tree domestication (Asaah, 2012).

Commercial and social outcomes/impacts

Amongst the outcomes of agroforestry and tree domestication, is the expected restoration of soil fertility status of degraded land and the improvement of livelihoods of smallholder farmers by encouraging and enabling them to increase their use of trees in agricultural landscapes. This will help to improve food security, nutrition, income and health; provide shelter and energy; and lead to greater environmental sustainability and better equity to improve the lives of women and youths. According to Asaah et al. (2011) and Degrande et al. (2012), rural resource centres are now delivering both education and training in agroforestry and tree domestication, as well as in business management, so that farmers can earn money from the sale of plants and their tree products.

One of the very impressive outcomes of tree domestication is the development of tree nurseries and their income-generating potential from the sales of superior cultivars of indigenous fruit trees. Normally, it is from year 3 that income starts streaming, after which there is rapid growth.

For example, one of the RRCs that adopted agroforestry and tree domestication over 10 years ago – MIFACIG in Northwest of Cameroon and its satellite network of nurseries, sold plants for over US$ 21,000 in 2009. About 35% of that income, i.e. US$ 7350, is going to the satellite nurseries owned by farmer groups. Plant-derived income from another RRC that had adopted agroforestry and tree domestication for over 5 years - GIC PROAGRO, in West of Cameroon in 2007 was estimated around US$1750 from the sales of soil fertilizer species. From 2008 this RRC laid emphasis on producing and selling of improved cultivars of indigenous fruit trees like Kola (*Cola* spp), Safou (*Dacryodes edulis*) and other adapted exotic fruits like Avocado (*Persea americana*) and their income rose to about US$ 40,000

in 2009 (Asaah et al., 2011). This suggests that cultivars derived from superior trees of diverse species could be amongst the biggest source of income in the nurseries developed by farmers. Soon, all of these communities will also be able to further increase their income by selling fruits from the cultivars already integrated into their agricultural landscape. According to Asaah et al. (2011), within the highlands of Cameroon some farmers were observed to be planting between 10 and 120 fruit trees on their farms. Availability of fruits and other tree products, in addition to income, would indirectly improve health and education opportunities with smallholder farmers. Furthermore, the overall package of farmer empowerment at community level allows for more self-sufficiency and so could transform their lives, giving them hope for the future. Early indications are that young people in the participating communities now envision a future for themselves if they remain in the village without having to migrate to more urban areas for a better life (Tchoundjeu et al., 2010; Asaah et al., 2011, Leakey et al., 2012). The resultant effect of this is that smallholder farmers are starting to generate income and gradually entering into a cash economy and so begin the climb out of poverty.

Challenges for Agroforestry and Tree Domestication Implementation in Central Africa

Political and Institutional challenges: need for reforms on rights and tenure

If agroforestry is to fulfil its full potential of livelihoods' improvement and provision of environmental services, then appropriate strategies, institutions and the necessary financial mechanisms need to be provided. In a recent study, Foundjem-Tita and Degrande (2012) made the following policy recommendations.

(i) *A comprehensive program needs to be put in place to develop, guide and implement agroforestry strategies*. Appropriate policies, policy instruments, strategies and implementation mechanisms are required to reap the full benefits of agroforestry. However this needs a concerted action between all ministries interested in tree planting. Such a strategy would define clear objectives and targets to meet. This requires adequate financial and sectorial affiliation.

(ii) *Distinction should be made between agroforestry products harvested from trees on-farm and non-timber forest products collected from the wild*. Most NTFPs with high economic value currently collected from the wild are likely to be planted on farmers' fields in the near future, partly thanks to recent advances in tree domestication research. Furthermore, development projects in the domain of climate change mitigation and adaptation (REDD and REDD+) most likely will encourage tree planting by farmers. Thus, there is need to develop criteria to distinguish agricultural and agroforestry products from forestry products and NTFPs, while products bounded by specific legislation need to be clearly defined. Since it is impossible to visually differentiate tree products harvested from the wild from those harvested on farmers' fields, certificates of origin may be useful.

(iii) *Facilitate access to land and secure ownership*. Obtaining land certificates should be simplified to allow farmers to secure ownership of the land and the trees they plant on that

land. On the other hand, strategies are needed to either encourage land markets or redistribute land to enterprising farmers in another manner.

(iv) *Additional incentives should be provided to encourage farmers to plant more trees.* Farmers have developed agroforestry as a traditional land use practice with minimal assistance from either government or NGOs. Nevertheless, policies that provide additional incentives for farmers could accelerate the adoption of agroforestry, amongst which: provide assistance to production and distribution of quality tree planting material; add value to tree products, for example through improved processing of tree products; disseminate appropriate tree propagation and tree management skills to farmers through vast extension programmes.

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