Case study 3

Diversity of indigenous fruit trees and their contribution to nutrition and livelihoods in sub-Saharan Africa: examples from Kenya and Cameroon

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Introduction

In sub-Saharan Africa (SSA), growing both domesticated and wild fruit species on farms diversifies the crop production options of small-scale farmers and can bring significant health, ecological and economic revenues (Keatinge et al., 2010; Weinberger and Lumpkin, 2005). Dozens of indigenous fruit tree species (IFTs), although relatively unknown in global markets, are locally of large importance for food/nutrition security and income generation. Akinnifesi et al. (2008) showed the high potential of many wild fruit species from different African regions for undergoing domestication followed by successful on-farm production. Fruit markets in SSA are estimated to grow substantially due to economic and human population growth and increasing urbanisation rates, e.g. by 5.7 per cent per year in Kenya (calculation of ICRAF based on Ruel et al., 2005). Women are often strongly involved in and benefit from fruit processing and trade, particularly with regard to indigenous fruits (Schreckenberg et al., 2006). With appropriate promotion, the contribution of fruits to the livelihoods and health of African farmers and consumers could be substantially increased.

Currently, fruit consumption in SSA – with a daily average of only 36 g per person in Eastern and about 90 g in Western Africa (WHO, 2002) – is far below the recommended daily amount of 200 g per person (WHO, 2003). In sub-Saharan Africa about 30 per cent of inhabitants, most of them women and children, suffer from malnutrition (UNSCN, 2010). Fruits offer not only easily available energy, but also micronutrients such as vitamins and minerals necessary to sustain and support human healthy growth and activity (see examples below). There are, however, a variety of factors that constrain fruit consumption and production in Africa such as:

- Lack of consumer awareness on the health benefits of regular fruit consumption;
- Change of consumer preferences and loss of the traditional nutrition systems based on local agricultural biodiversity, which leads to erosion of both the plant genetic resources and the related traditional knowledge;

- Degradation of natural vegetation used for collecting indigenous fruits in the past;
- Lack of sufficient tree domestication techniques and their dissemination, especially of vegetative tree propagation methods;
- Lack of fruit processing facilities, which leads to high post-harvest losses;
- Poorly organised fruit marketing pathways along the value chain.

Indigenous fruit trees (IFTs) traditionally provide rural communities in SSA's drylands, where cultivation of exotic fruit species often is not possible, with nutritious fruits for self-consumption and sale. Wild fruits are mostly gathered from natural stands only, but IFTs are usually not cultivated on farms (Simitu et al., 2009). Climate change will most probably shift the natural geographic ranges, and reduce density and productivity of some wild fruit species (Dawson et al., 2011). Domestication of selected high value IFT species and their on-farm cultivation in agroforestry systems are prerequisites for enhanced production, processing and marketing of valuable indigenous fruits (Pye-Smith, 2010). In addition, cultivation of IFT species on farms will contribute to climate change mitigation and adaptation of farming systems. Trees such as fruit trees provide many other valuable environmental services (Garrity, 2004). Increased cultivation of IFTs will contribute to diversification of farming systems, improve connectivity of remaining natural habitats for biodiversity conservation and decrease the pressure on natural IFT stands, thus further contributing to conservation of genetic resources of these trees. In the following, the value of fruits for nutrition and income generation is described in more detail.

Fruits for health and food security

Deficiency of iron and vitamin A is prevalent in most parts of SSA. Low intake of vitamin A – around 50 million African children are at risk of deficiency – is considered to be Africa's third greatest public health problem after HIV/AIDS and malaria.[1] Vitamin C from fruits, on the other hand, is essential for absorbing iron, an important mineral that is present in significant quantities in green leafy vegetables. Indigenous fruits contribute to the vitamin and mineral supply of local communities, e.g. baobab (*Adansonia digitata*) for vitamin C, marula (*Sclerocarya birrea*) for vitamin A and white crossberries (*Grewia tenax*) for iron (Table C3.1). A child could cover 100 per cent of its vitamin C requirement by eating only about 10 g of baobab pulp a day. Concerning iron, consumption of 40–100 g white crossberries covers almost 100 per cent of the daily iron requirement of a child less than eight years old. In addition to micronutrients, fruits such as tamarind (*Tamarindus indica*) and baobab contribute much to energy supply due to their sugar content (Table C3.1). However, data on nutrient contents of many indigenous fruits are either unavailable or unreliable. The high variability of nutrient contents given in the literature (Table C3.1) may be caused by using different methods for analysis, but also by the fact that a very high variability

Table C3.1 Nutrient contents of selected indigenous and exotic fruits per 100g edible portion (high values are highlighted in bold).

Species	*Energy (Kcal)*	*Protein (g)*	*Vit C (mg)*	*Vit A (RE) (mg)*	*Iron (mg)*	*Calcium (mg)*
Indigenous fruits						
Adansonia digitata	340	3.1	150-**500**	0.03–0.06	1.7	360
Grewia tenax	N.A.	3.6	N.A.	N.A.	7.4–**20.8**	**610**
Sclerocarya birrea	225	0.5	68–**200**	**0.035**	0.1	6
Tamarindus indica	270	**4.8**	3–9	0.01–0.06	0.7	260
Ziziphus mauritiana	21	1.2	70–165	0.07	1.0	40
Exotic fruits						
Guava (*Psidium guajava*)	68	2.6	**228.3**	0.031	0.3	18
Mango (*Mangifera indica*)	65	0.5	27.7	0.038	0.1	10
Orange (*Citrus sinensis*)	47	0.9	53.0	0.008	0.1	40
Pawpaw (*Carica papaya*)	39	0.6	62.0	**0.135**	0.1	24

Sources: Indigenous fruits: Freedman (1998) Famine foods. http://www.hort.purdue.edu/newcrop/faminefoods/ff_home.html (accessed 13 August 2012); Fruits for the Future Series, ICUC; Fineli (http://www.fineli.fi/, accessed 20 July 2012), etc.; Exotic fruits: Lukmanji & Hertzmark (2008) Tanzania Food Composition Tables.

naturally occurs among different populations of the same species as long as the species is undomesticated.

Tree crops such as fruit trees are contributing not only to nutrition security, but also to food security. Due to their extensive and deep rooting systems, fruit trees are less sensitive to droughts as compared with annual staple crops and give a harvest even when the staple crops fail. Not only during droughts, but especially during the pre-harvest periods of annual staples characterised by food shortages ('hunger gap'), fruits from some IFT species may be ready for harvest to serve as emergency food or to be sold, thus contributing to food and nutrition security (see case study 1 from Kenya and Figure C3.1 from Malawi and Zambia). By combining site-specific portfolios of different exotic and indigenous fruit species for cultivation, a year-round supply of fruits can be achieved.

Fruits for income generation and integrated rural development

Fruit tree cultivation offers great potential for income generation if farmers are (i) linked to markets to reduce input costs and improve prices for their produce, (ii) trained in best on-farm management of existing fruit trees; and (iii) in cultivating improved, high value varieties and species, which best fit present and future market demands (see above). When farmers have access to improved grafted planting material, they can expect a relatively quick return from their

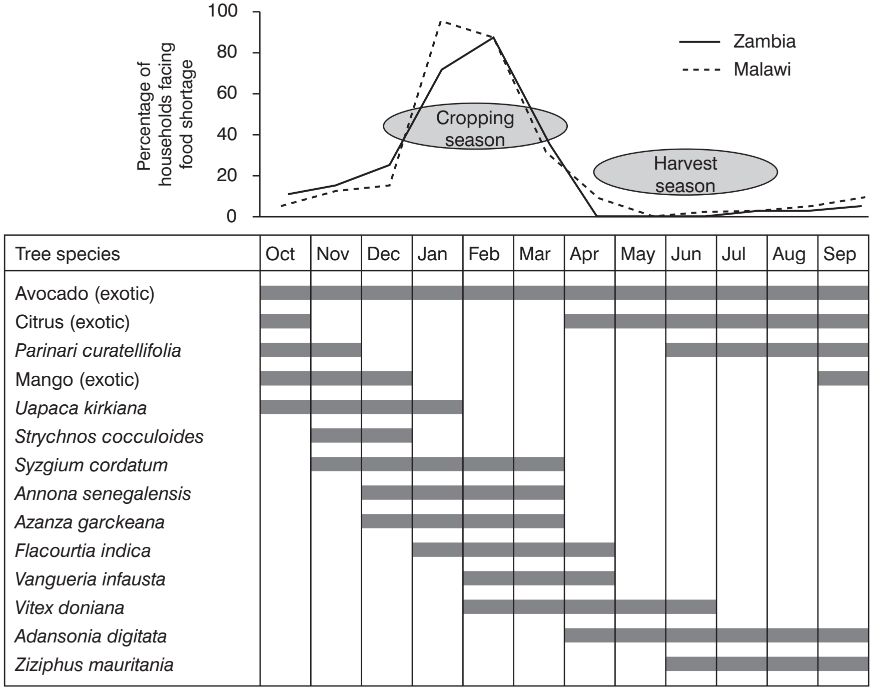

Figure C3.1 Prevalence of food shortage in rural households of Malawi and Zambia and the harvest periods of different exotic and indigenous fruit species of the same region. During the cropping ('hunger') season, fruits of one exotic and four indigenous species are continuously available, fruits of three more species are partly available (data collected by World Agroforestry Centre (ICRAF) staff in the region)

new trees as grafted trees will start fruiting two to three years after planting. Small-scale processing groups, particularly of women, benefit from improved fruit cultivation and help to reduce post-harvest losses. Still, there is a high unexploited potential for enhanced employment, business development and income generation through processing of both exotic and wild or domesticated indigenous fruits. For example, a feasibility study of small-scale juice concentrate processing enterprises calculated a potential net profit of about 28 per cent of the gross production value in Malawi (Jordaan et al., 2008). Domestication of IFTs includes: identification and characterisation of the available genetic diversity of a species; capture, selection and management of the genetic resources; propagation of superior materials and sustainable cultivation of the species in managed agro-ecosystems (Simons and Leakey, 2004). Vegetative propagation methods such as rooting of stem cuttings, grafting and marcotting warrant early fruiting and ensure that the desired traits of superior mother trees are passed to the offspring. Successful projects on domestication of IFTs, for example in Cameroon (see below), show that fruit cultivation and processing have significant impacts on rural development and transforming people's lives.

Case 1 Kenya: High on-farm IFT species diversity, but low consumption of fruits in the drylands

In Kenya, about 400 indigenous fruit tree species occur (Chikamai et al., 2004), which are said to contribute much to livelihoods of rural communities, particularly during the frequent periods of food shortage. However, detailed studies on diversity of IFTs and their consumption in Kenya are scarce. A case study was thus performed by Simitu et al. (2009) in the drylands of Mwingi District, Eastern Kenya, where 104 households were randomly selected to collect data on IFT abundance on farms and fruit consumption data of adults (26 male and 26 female respondents) as well as of children (26 boys and 26 girls < 18 years). All fruit tree species occurring on the farm of the respondent were identified and the individual trees counted. A combination of a semi-structured questionnaire and visual aids were used to collect detailed and reliable data on fruit consumption over a period of one year. A food-frequency questionnaire (FFQ) developed after Agudo (2004) with the names of all available fruit species was used to determine which species were consumed in the periods of the year, when the species could be harvested and how often the respondents consumed the respective fruit during that time. Typical household measures and photos of standard portions were used to help respondents estimate the usual amount of fruits consumed per meal and to calculate mean consumption per day for each of the species.

A total of 57 IFT species were mentioned as being consumed by the respondents; 36 of these species were found on the 104 surveyed farms, 21 species were exclusively collected from the wild. Thirty-three of the species found on farms were maintained from natural regeneration (e.g. trees protected during field clearing, new seedlings spared during weeding), of which 17 species were never planted and 16 species were both protected from natural regeneration and actively planted by respondents. The remaining three species out of the 36 on-farm species were exclusively planted. The most frequent species were *Balanites aegyptiaca* (desert date) occurring on 58 per cent of the surveyed farms, *Adansonia digitata* (baobab; 50 per cent) and *Berchemia discolor* (50 per cent). However, a large proportion of species were each found only on one or two of the surveyed farms. With regard to individual tree numbers, only 1.3 per cent of the counted 4,048 trees on the surveyed farms were actively planted by the respondents, e.g. some tamarind (*Tamarindus indica*) trees. Two crossberry species (*Grewia villosa* and *G. tembensis*) were the most abundant species, representing 20 and 16 per cent of the recorded tree individuals, respectively. Thirteen species were very rare, represented by less than 10 individuals each.

Mean daily consumption of indigenous fruits was 19 g per person, being a little higher for children (about 23 g) than adults. Adults view many indigenous fruits as food for children and consume only fruits from certain, higher valued species such as baobab, tamarind, *Berchemia discolor* or *Lannea alata*. When exotic fruits (which were available only on market days) were included in the calculations, the mean daily consumption increased from 19 g to 28 g of fruits

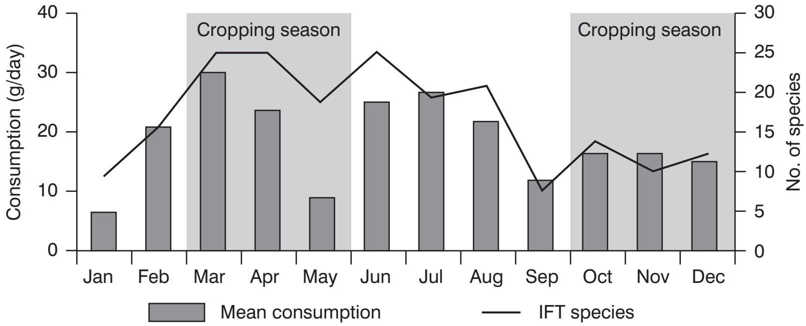

Figure C3.2 Availability of IFT species ready for harvest and mean daily fruit consumption per person during the course of the year in Mwingi district, Eastern Kenya

per person. This is still far below the recommended daily intake of 200 g per person (WHO, 2003). During the course of the year, fruit consumption varied among seasons (Figure C3.2), but 10–25 IFT species were ready for harvest even during the 'hunger gaps' of the two cropping seasons (March to May and October to December). Lean fruit seasons with mean daily consumptions of less than 10 g per day were in January and May, peak consumption seasons with more than 20 g per day in February to April and June to August. Mean daily consumption in a month was positively influenced by number of IFT species ready for harvest in the respective month ($R^2 = 0.543$, $p = 0.006$) (P. Simitu, 2008, pers. comm.). For example, in September, only eight IFT species had mature fruits for harvesting and daily fruit consumption was only 12.8 g per person in the same month, whereas in March 25 species were ready for harvest and the daily consumption was almost 30 g (Figure C3.2).

The study in Kenya showed the urgent need for awareness creation among rural communities about the value of fruit consumption for improved nutrition and health. Many IFT species were available, but they were not used efficiently. Domestication of priority species will help to increase the number of planted IFTs on farms and to improve the perception of IFTs in the rural communities from 'food for children' towards 'valuable fruits for health and wealth'. The first steps of a participatory species priority setting in Kenya resulted in the preliminary selection of *Tamarindus indica, Adansonia digitata, Sclerocarya birrea, Ziziphus mauritania* and *Balanites aegyptiaca* (Chikamai et al., 2004) as well as *Vitex payos* (Muok et al., 2000), *Berchemia discolor* and *Carissa edulis* (Teklehaimanot, 2005). However, species priority settings should also consider regional preferences, nutritional value of fruits, market and value addition potentials, seasonality of fruiting and adaptability of species to climate change and should involve not only farmers, but also fruit traders, processors and exporters, agricultural extension officers, and scientists from several disciplines such as agricultural economics, agronomy, natural resources conservation, ecology, ethno-botany, health and nutrition (Franzel et al., 1996).

Lessons learned and way forward

So far, both government extension services and NGOs in Kenya neglect the value of indigenous fruits for improved livelihoods of rural communities and, instead, focus on the promotion of exotic fruits, such as mango and passion fruit. Integrating the health sector and involving the educational segment in future programmes as well as analysing and developing value chains for indigenous fruits may help to mainstream IFT cultivation, processing, marketing and consumption in Kenya and beyond.

Case 2 Cameroon: Successful participatory fruit tree domestication improved livelihoods of rural communities

Farmers in humid West and Central Africa depend mainly on cacao and coffee cultivation for income generation, but have suffered from low and fluctuating prices for these commodities since the 1980s. Against this background, there was an urgent need to diversify farmers' livelihood options through the development of sustainable poverty reduction strategies, including agroforestry and tree domestication. In agroforestry systems, a combination of annual crops and useful tree and shrub species fulfils diverse production and service functions (Garrity, 2004). Many of these functions were once provided by natural forests, which are declining in Cameroon and elsewhere. The related decline in availability of important forest products such as food, medicine, fodder, timber and fuel wood with its negative impact on traditional diets, health systems and income generating opportunities for the local communities can at least be partly offset by promoting diverse agroforestry systems.

In 1995, the World Agroforestry Centre (ICRAF) conducted a farmers' species preference survey in the humid tropics of West and Central Africa. The priority species identified for domestication and improvement by research were mainly indigenous fruit, nut and medicinal species with a high value for nutrition and income generation such as *Irvingia gabonensis*, *Dacryodes edulis, Ricinodendron heudelotii, Chrysophyllum albidum, Garcinia kola* and different *Cola* species (Franzel et al., 1996). Contrary to the situation in Kenya (case 1), indigenous fruits are highly valued by farmers and consumers in Cameroon and have a ready market. The combined harvesting seasons of the mentioned species offered a year-round supply with produce for home consumption and sale (Figure C3.3). Fruits and nuts of some of these species are highly nutritious and contribute much to energy, protein and mineral supply of consumers (Table C3.2).

In Cameroon, participatory priority species selection showed a high demand for fruit and nut species such as bush mango (*Irvingia gabonensis*) and African plum (*Dacryodes edulis*). Until the start of the tree domestication programme in 1995, these species were mainly found in forests, from where the fruits were collected for home consumption, processing and sale. However, the number of these valuable trees was decreasing due to deforestation and over-exploitation, among other reasons (Tchoundjeu et al., 2006). After the critical strategic decision

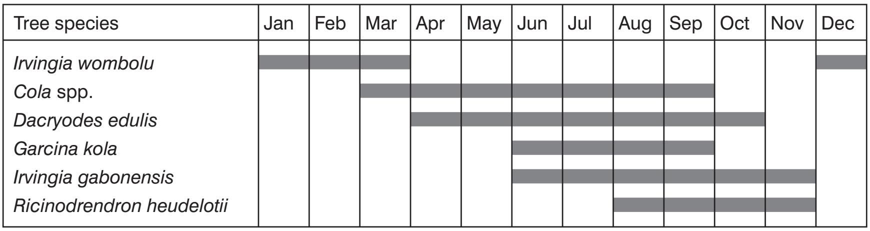

Figure C3.3 Harvest periods of selected priority indigenous fruit and nut species of West and Central Africa

Table C3.2 Nutrient contents of selected indigenous fruit and nut species of Central Africa per 100g edible portion.

Species	*Energy (Kcal)*	*Protein (g)*	*Vit C (mg)*	*Vit A (RE) (mg)*	*Iron (mg)*	*Calcium (mg)*
Dacryodes edulis (fruit flesh)	263	4.6	19	N.A.	0.8	43
Irvingia gabonensis (fruit flesh)	61	0.9	74	N.A.	1.8	20
Irvingia gabonensis (kernels)	697	8.5	N.A.	N.A.	3.4	120
Ricinodendron heudelotii (kernels)	530	21.0	0	0	0.4	611

Sources: Leung W.T.W., Busson F., Jardin, C. (1968) Food composition table for use in Africa. FAO, Rome, Italy; Platt B.S. (1962) Tables of representative values of foods commonly used in tropical countries. Special Report Series 302, Medical Research Council, London, UK.

to implement participatory tree domestication rather than the conventional research station approach, the first step of the domestication programme in Cameroon in 1999 was to develop propagation methods for the priority species based on appropriate low-tech methods that did not require running water or electricity and that was adapted to farmers' capacity and competences in remote rural communities (Leakey et al., 1990). In parallel, pilot farmers in selected rural communities – assisted by teams made up of scientists and extension staff from both government and non-governmental organisations – selected superior mother trees with the desired traits (e.g. many large and sweet fruits, early first fruiting) based on simple techniques for the characterisation of tree-to-tree variation developed by the team (Atangana et al., 2002; Tchoundjeu et al., 2006).

In the second step, innovative farmers managing pilot nurseries were trained in participatory tree domestication techniques and their nurseries were upgraded to 'Rural Resource Centres' (RRCs) (Asaah et al., 2011). RRCs manage community-owned nurseries for the production and distribution of high quality tree planting materials, but have additional functions as hubs for the development of propagation techniques and for training of nursery managers, farmers and small-scale processors (Figure C3.4). Also, RRCs serve as collection points and marketing centres for tree products. Each RRC is equipped with a

Figure C3.4 Appearance and activities of Rural Resource Centres (RRCs) in Cameroon. Left: entrance to an RRC; middle: farmers are trained in grafting techniques; right: women marcotting a fruit tree (photographs by Charlie Pye-Smith (left and centre) and Julius Atia (right))

Box C3.1 The fruits of success

If you had visited Christophe Missé in the 1990s, on his small farm some 40 kilometres north of the Cameroonian capital, Yaoundé, you would have heard a story of hardship and poverty. "My cocoa crop yielded an income for just three months a year," he recalls, "and even with the extra cash I earned as a part-time teacher, we struggled to make ends meet." Then, in 1999, Missé attended a training session held by the World Agroforestry Centre in Nkolfep, West Region. It was, he says, an experience that changed his life. He learnt about the techniques used to develop superior varieties of indigenous fruit trees. "As soon as I'd completed the training, I realised that it would help me to transform my farm," he says. He set up a nursery with his neighbours and is now selling over 7,000 trees a year. He has also planted hundreds of indigenous fruit trees on his farm such as bush mango and African plum, which now grow besides his main cash crop, cocoa. The African plums are particularly impressive, with some of his most fruitful trees earning 10,000 CFA francs (US$22) a year, five times as much as his individual cocoa bushes. Apart from enhancing the nutrition and food security of his family, Missé has substantially improved his livelihood with the additional income generated from fruit cultivation. "With the money I've made I've built a new house," he says proudly, "and I can now pay for two of my children to go to private school."

Source: Extract from Pye-Smith, 2010

nursery, meeting and training facilities, motherblocks and demonstration plots, and fruit drying/storage facilities, if appropriate. RRCs are also holding a register for newly-developed farmers' fruit tree varieties, in order that local domesticators can assert their rights over selected cultivars. Interested innovative farmers from the villages nearby are trained at the RRCs to become nursery managers and to start 'satellite nurseries' on their farms (Tchoundjeu et al., 2006; Asaah et al.,

Figure C3.5 Christophe Missé (left) has significantly improved his income by growing superior varieties of indigenous fruit trees, such as African plums on his farm in Cameroon, which are in high demand at the local markets (right) (photographs by Charlie Pye-Smith)

2011; see example in Box C3.1). The trainees are then equipped with a starter kit of high quality germplasm and will construct simple nursery structures with local material at their farms. By this decentralised approach, even farmers in remote locations have access to high quality planting material of fruit trees from the satellite nurseries. Asaah et al. (2011) reported that the programme currently works in seven RRCs with more than 200 farmer groups or associations. ICRAF researchers developed training packages and play a coordinating and mentoring role in managing the RRCs and the local government extension officers. The RRCs are under the day-to-day technical supervision and general management of 17 'relay organisations', which include local NGOs, community-based organisations or well-established farmer groups, sometimes complemented by the involvement of local government extension officers. The relay organisations were trained in different aspects to ensure quality delivery of innovative advisory services to farmers and of community capacity-building activities.

According to Asaah et al. (2011) and Tchoundjeu et al. (2010), the following outcomes of the project were reported:

- In 2008, seven RRCs provided advisory services to about 100 satellite nurseries (8–35 satellite nurseries per RRC) and produced 122,500 indigenous fruit and nut trees that have been planted on the farms (Figure C3.5).
- Annual incomes were about US$21,000 for one RRC (running for 10 years) and an average of US$7,350 for each of 35 farmer-managed satellite nurseries of the same RRC in 2009.
- Around 50 per cent of local adopters integrated 10 fruit trees on average in their farms and reported to have increased their fruit consumption, 30 per cent also mentioned increased income (see Box C3.1 for an

example). The stated increase in fruit consumption is supposed to be due to the enhanced accessibility of a diverse set of different fruit species planted on the farms that fruit almost year-round (Figure C3.3), but no quantitative data are yet available.

- Tree nurseries that had received technical support (e.g. training on propagation techniques, group dynamics, management and marketing techniques) from ICRAF's participatory tree domestication initiative supplied a wider range of fruit trees and propagated in more appropriate ways and with higher purchaser satisfaction than those nurseries that had not received assistance. After about five years of support, RRCs are usually able to generate sufficient income to sustain their activities independently.
- The RRC approach for integrating participatory tree domestication with a broader set of rural services (e.g. training in nursery management and sustainable farming, watershed protection, beekeeping and marketing, providing microfinance, linking farmers to markets) is recognised as one of the best examples of multifunctional agricultural development for the reduction of poverty through conservation of biodiversity, and was accordingly awarded an Equator Prize in 2010.[2]

Lessons learned and way forward

This domestication project and the RRC approach developed within the project proved successful in regard to sustainably improving livelihoods of rural communities. Similar projects were already applied in Nigeria and the Democratic Republic of Congo (Tchoundjeu et al., 2006). RRCs were found to be economically independent after about five years of technical support while producing significant incomes from production of high quality agroforestry seedlings and from providing services such as training of farmers, micro-processors and nursery managers. The same RRC model will now be tested for up-scaling in Kenya, Tanzania, Rwanda and Mali and for its suitability for tree domestication in drylands.

Notes

1 www.worldmapper.org, accessed July 2012.
2 http://www.equatorinitiative.org/index.php?option=com_content&view=article&id=597%3Aribaagroforestryresourcecentre&catid=175&Itemid=339, accessed July 2012.

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