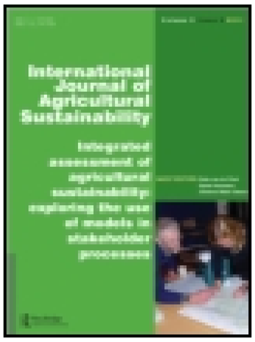

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Agroforestry Tree Products (AFTPs): Targeting Poverty Reduction and Enhanced Livelihoods*

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Agroforestry tree domestication emerged as a farmer-driven, market-led process in the early 1990s and became an international initiative. A participatory approach now supplements the more traditional aspects of tree improvement, and is seen as an important strategy towards the Millennium Development Goals of eradicating poverty and hunger, promoting social equity and environmental sustainability. Considerable progress has been made towards the domestication of indigenous fruits and nuts in many villages in Cameroon and Nigeria. Vegetatively-propagated cultivars based on a sound knowledge of 'ideotypes' derived from an understanding of the tree-to-tree variation in many commercially important traits are being developed by farmers. These are being integrated into polycultural farming systems, especially the cocoa agroforests. Markets for Agroforestry Tree Products (AFTPs) are crucial for the adoption of agroforestry on a scale to have meaningful economic, social and environmental impacts. Important lessons have been learned in southern Africa from detailed studies of the commercialisation of AFTPs. These provide support for the wider acceptance of the role of domesticating indigenous trees in the promotion of enhanced livelihoods for poor farmers in the tropics. Policy guidelines have been developed in support of this sustainable rural development as an alternative strategy to those proposed in many other major development and conservation fora.

Keywords: agroforestry, domestication, eco-agriculture, Green Revolution, indigenous fruits and nuts, novel crops

Introduction

Agroforestry is now being seen as an alternative paradigm for rural development worldwide, that is centred on species-rich, low-input agricultural techniques including a diverse array of new indigenous tree crops, rather than on high-input monocultures with only a small set of staple food crops (Leakey, 2001a, 2001b). This alternative paradigm addresses many of the global challenges highlighted by the UN Millennium Development Goals and environmental conventions (Garrity, 2004; Leakey *et al.*, submitted for publication). These challenges are associated with deforestation, land degradation, unsustainable cropping practices, loss of biodiversity, increased risks of climate change, and rising hunger, poverty and malnutrition (Figure 1). In the last 10–15 years, agroforestry tree domestication strategies, approaches and techniques, together with the commercialisation and marketing of agroforestry tree products (AFTPs), have become one of the 'pillars' of this new paradigm (ICRAF, 1997; Leakey & Simons, 1998; Simons & Leakey, 2004). Agroforestry tree domestication is aimed at promoting the cultivation of indigenous trees with economic potential as new cash crops.

Trees

The origins of tropical tree domestication

The domestication of many species for food and other products has been carried out for thousands of years in almost every part of the world, often arising from extractive uses by indigenous people (Homma, 1994). Current agroforestry tree domestication initiatives build on the efforts of smallholder farmers who, over a number of generations, have improved the size of some of the more important indigenous fruits, so providing the first steps towards domestication (Leakey *et al.*, 2004). Research programmes to

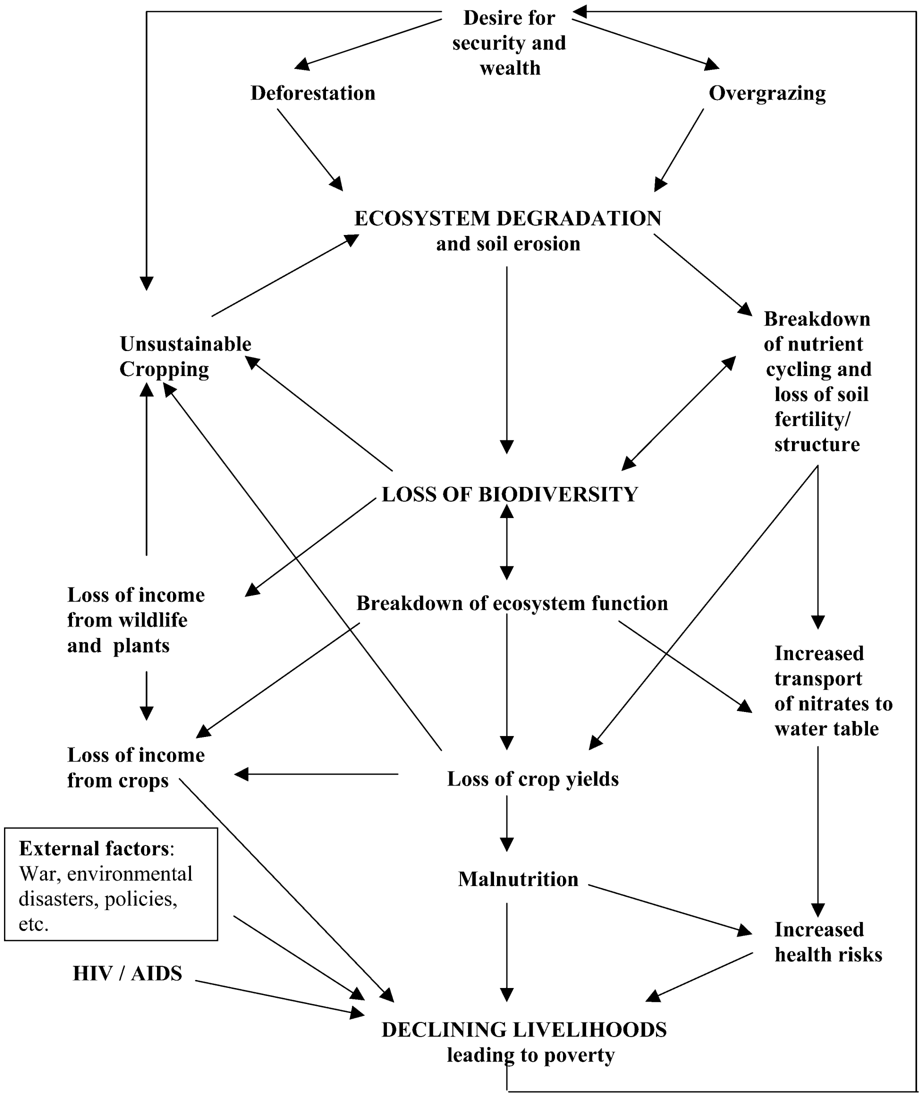

Figure 1 The cycle of biophysical and socio-economic processes causing ecosystem degradation, biodiversity loss, and the breakdown of ecosystem function, in agricultural land in many tropical countries

domesticate agroforestry trees, particularly for the production of non-timber forest products, was initiated in the 1980s (Leakey *et al.*, 1982; Okafor, 1980) and emerged as a global programme in the 1990s (Leakey & Newton, 1994a, 1994b; Leakey & Simons, 1998). In 1992, the term 'Cinderella species' was coined for all the tree species that have provided poor people with their everyday needs for food, medicinal and other forest products and which have been overlooked by science and the 'Green Revolution' (Leakey & Newton, 1994a). At this time agroforestry tree domestication was defined to encompass 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 (Leakey & Newton, 1994b). In agroforestry, domestication is not restricted to tree species, and a range of new herbaceous crops are also being developed (Smartt & Haq, 1997). Many indigenous vegetables are candidates for domestication (Guarino, 1997; Schippers, 2000; Schippers & Budd, 1997; Sunderland *et al.*, 1999) and can be components of multstrata systems, where there is a need for new shade tolerant crops. Agroforestry tree domestication has now been refined and expanded with emphasis on it being a farmer-driven and market-led process (Leakey & Simons, 1998; Simons, 1996; Simons & Leakey, 2004) and with emphasis on a participatory approach to the involvement of local communities (Leakey *et al.*, 2003; Tchoundjeu *et al.*, 1998). Additionally, it has been recognised that not just species, but also whole landscapes are domesticated when brought into cultivation (Wiersum, 1996).

In 1995, the International Centre for Research in Agroforestry (ICRAF) established a Tree Domestication Programme with projects in six ecoregions of the tropics, each of which developed their own species priorities (Jaenicke *et al.*, 1995, 2000; Maghembe *et al.*, 1998; Roshetko & Evans, 1999; Weber *et al.*, 2001). While the focus of this paper is on the development of marketable AFTPs from agroforestry trees, interest in tree domestication encompasses trees for other purposes such as soil amelioration, fodder, fuelwood, timber, boundary demarcation, etc. The implementation of sound domestication strategies for all species include the activities of: assessing the demand; evaluating the status of the resource; defining the purpose; objectives and strategy; germplasm collection, conservation and dissemination; reproductive biology; propagation techniques; tree improvement; tree breeding, etc. (Simons, 1996; Simons & Leakey, 2004).

The current concept of domestication of indigenous trees for AFTPs goes hand-in-hand with the commercialisation of the products and together, through agroforestry, they provide an incentive for subsistence farmers to plant trees in ways that achieve the Millennium Development Goals (Garrity, 2004; Leakey *et al.*, submitted), especially the reduction of poverty, and enhancement of food and nutritional security, human health and environmental sustainability (i.e. Goals 1, 3, 4, 5, 6, 7 and 8: see www.un.org/millenniumgoals/).

The participatory tree domestication approach – the case of west and central Africa

Participatory approaches to the domestication of agroforestry trees started with the involvement of many stakeholders in the germplasm collections of *Sesbania sesban* for improved fallow technologies (Ndungu & Boland, 1994) and the principles extended to collections of *Sclerocarya birrea* and *Uapaca kirkiana* for fruit production (Leakey & Simons, 1998; Ndungu *et al.*, 1995). This led to the development of guidelines for species priority setting in west and central Africa (Franzel *et al.*, 1996), where the top priority species were identified as *Irvingia gabonensis* (Ladipo *et al.*, 1996; Okafor & Lamb, 1994) and *Dacryodes edulis* (Kengue, 2002; Okafor, 1983; Tchoundjeu *et al.*, 2002a). Since then, it has expanded to a range of other species, including *Prunus africana* (Simons *et al.*, 2000b), *Pausinystalia johimbe* (Ngo Mpeck *et al.*, 2003a; Tchoundjeu *et al.*, 2004), *Ricinodendron heudelottii* (Ngo Mpeck *et al.*, 2003b), *Garcinia kola* (unpublished), etc. The approach has utilised, disseminated and refined a simple low-technology system for the vegetative propagation of tropical trees that is appropriate for use in small, low-cost village nurseries (Leakey *et al.*, 1990; Mbile *et al.*, 2004; Shiembo *et al.*, 1996a, 1996b, 1997), so that cultivars can be produced and multiplied by villagers. The trees for propagation have been identified by quantitatively examining the tree-to-tree variation in a range of fruit and nut traits to determine the potential for highly productive and qualitatively superior cultivars with a high Harvest Index (e.g. Anegbeh *et al.*, 2003, 2004; Atangana *et al.*, 2001, 2002; Leakey *et al.*, 2002, 2005c; Ngo Mpeck *et al.*, 2003b; Waruhiu *et al.*, 2004).

Together these developments result in a model participatory domestication strategy that is now being scaled-up to a regional level (Tchoundjeu *et al.*, 1998, in press), and encompasses 35 villages in southern Cameroon (about 2500 farmers), 11 villages in Nigeria (about 2000 farmers), three villages in Gabon (about 800 farmers) and two villages in Equatorial Guinea (about 500 farmers). The programme fulfils the criteria outlined earlier for agroforestry approaches to meet the Millennium Development Goals, and conforms to the Convention on Biological Diversity (Leakey *et al.*, 2003; Simons & Leakey, 2004; Tchoundjeu *et al.*, 1998), by recognising the rights of local people to their indigenous knowledge and traditional use of native plant species. However, ways have to be found to ensure that the investments made by community members in time and effort in developing cultivars can be protected through recognition of their rights in existing systems of intellectual property rights, and through the development of alternative '*sui generis*' ('of its own kind') rights systems for access and benefit sharing. Alternatively, ways may be found for indigenous communities and smallholder farmers to register 'plant breeders' rights'. If protection of these rights is not achieved, there is the danger that other people will reap the benefits of the pioneering work by villagers. Protection of this kind would then ensure that participatory domestication by local farmers could be recognised as a good model of Biodiscovery; an alternative to Biopiracy by expatriate or local entrepreneurs. There is however, a need for guidelines on how local communities can establish rights over cultivars, to ensure that they acquire royalties.

Identification, capture, retention and protection of genetic diversity

Domestication has been defined as human-induced change in the genetics of the species to conform to human desires and agroecosystems (Harlan, 1975). It is not surprising therefore, that much of the work to domesticate agroforestry trees has focused on the identification of intra-specific genetic variability of the priority species, and the vegetative propagation techniques to capture the combinations of genetic traits found in superior individual trees. One of the key findings of the characterisation studies done in a number of species (*D. edulis*, *I. gabonensis*, *S. birrea*) is that each trait shows continuous variation, but that high values of one trait are not necessarily associated with high values of another trait: thus large fruits are not necessarily sweet fruits, and do not necessarily contain large nuts or kernels. This means that the variability between trees is increased the more traits there are that are of interest. This multi-trait variation, coupled with the extent of the variability of each individual trait, results in very considerable opportunity for selection of trees with good combinations of traits. Obviously, the more traits that are simultaneously screened the more unlikely it is that a tree with good values for all traits will be found. Thus, large numbers of trees have to be screened to find the rare combinations of traits. This rapidly becomes a major task and very expensive. Consequently, the practical approach is to seek trees, which have particular, market-oriented, trait combinations – such as big, sweet fruits for the fresh fruit market (a fruit ideotype); big, easily extracted kernels for the kernel market (kernel ideotype), etc. (Leakey & Page, in press). Following this logic, the kernel ideotype can then be sub-divided into those meeting the demands of different markets, such as for food thickening agents (Leakey *et al.*, 2005), or other products, such as pectins or oils for food or cosmetic industries (Kalenda *et al.*, 2002; Kapseu *et al.*, 2002; Leakey *et al.*, 2005b). In the three species studied to date, the screening of only 100–300 trees has successfully identified a number of trees of interest for each ideotype. This approach to genetic selection can result in substantial improvement in crop quality and productivity for a relatively small level of investment, especially when implemented in participatory mode with farmers, rather than through research institutions.

Building on the ideotype concept, little has been done to look at the genetic variability in nutritive value or sensory analysis in any of the new AFTP producing crops. In Cameroon, a start has been made to examine variability in flavour, taste and aroma in samples of *Dacryodes edulis* (Kengni *et al.*, 2001), demonstrating that organoleptic evaluation on a tree-to-tree basis should be possible. Studies of this sort also need to be linked to any processing to extend shelf-life and/or create new markets. The limited evidence available indicates that nutritive value of indigenous fruits is as variable as the other characteristics. In *Sclerocarya birrea*, for example, the tree-to-tree variation in the skin and pulp of fruits from just 15 trees was found to be 30.1–112.6 g per fruit for protein content, and 1.3–3.2 mg per fruit for vitamin C content (Thiong'o *et al.*, 2002). The oil content of kernels was not so variable (44.7–72.3%), but oil yield per nut was even more variable (8–53 g per nut) because of the variation in kernel mass per nut (Leakey *et al.*, 2005b). Characterisation studies with another indigenous fruit of southern Africa, *Strychnos cocculoides*, are underway and again finding significant differences in fruit traits, e.g. fruit mass, between sites (Mkonda *et al.*, 2003).

In *Irvingia gabonensis*, a study of the physical properties of the polysaccharide food thickening agent from kernels again found very extensive tree-to-tree variability in two independent traits of considerable potential market importance: viscosity (34.0–124.1 SNU[1]) and drawability (0.26–3.65 SNU). *I. gabonensis* kernels also varied in oil content (37.5–75.5%) and in protein content (Leakey *et al.*, 2005c). All of the above suggests that more detailed study of these characteristics affecting the food value and acceptability of ATFPs from different cultivars of different species is a high priority for future research.

Much of this variability in nutritional quality is also likely to affect the potential for food processing and different markets, so there is an urgent need for agroforesters to work closely with the food and other industries to optimise the domestication/commercialisation partnerships (Leakey, 1999a). Some studies have been initiated in *D. edulis*, for example, to formulate nutritious biscuits (Mbofung *et al.*, 2002). Research on the nutritional value of AFTPs has important implications for the alleviation of nutritional insecurity and health (Millenium Development Goals 4, 5 and 6). One aspect of the potential health benefits of agroforestry is the fortification of the immune systems of HIV/AIDS sufferers through the selection of especially nutritious cultivars of indigenous fruits and nuts (Barany *et al.*, 2001, 2003); something that requires further investigation as an output from agroforestry (Swallow *et al.*, in press). In this connection it is interesting to note that the tree-to-tree variation of B-sitosterol, the major sterol component, of the medicinal product from the bark of *Prunus africana*, used to treat benign prostatic hyperplasia, ranges from 50–191 μg/g (Simons & Leakey, 2004).

Another aspect of domestication needing further work is selection for production traits, such as yield, seasonality and regularity of production, reproductive biology and reduction of susceptibility to pests and diseases which can reduce productivity or quality (Kengue *et al.*, 2002). Interestingly, evidence from South Africa indicates that the yield of 'marula' (*Sclerocarya birrea*) in South Africa, is increased five to 15-fold by cultivation in homestead plots and fields (Shackleton *et al.*, 2003a). Mean fruit size is also greater from trees in these farms, again with some evidence for domestication by farmers (Leakey, 2005; Leakey *et al.*, 2005a, 2005b). High yield is obviously a desirable trait in any cultivar but, within reason, may not be as important in the early stages of domestication as the quality attributes. Many wild fruit trees have phenological variability, resulting in a fruiting season of two to four months, with individual trees differing in their period of ripening and fruit drop. Within this general pattern, there can be a few trees which fruit outside the normal season, or which fruit more than once per year. Cultivars derived from these trees can extend the productive season for farmers. Seedlessness is another very desirable trait in cultivars of fresh fruit producing species and trees with a high pulp:kernel ratio have been identified in *D. edulis* (Anegbeh *et al.*, 2004; Kengue, 2002; Waruhiu *et al.*, 2004).

Having identified the superior trees with the desired traits, the capture of tree-to-tree variation using techniques of vegetative propagation is relatively simple and well understood (Leakey, 1985, 2004; Leakey *et al.*, 1990, 1994; Mudge & Brennan, 1999), although the numbers of people with the appropriate skills may be a constraint to its widespread application in the future (Simons & Leakey, 2004). Typically, the techniques of grafting, budding and air-layering (marcotting) are used to capture superior fruit trees and to multiply them as cultivars. This is because mature tissues with the capacity to flower and fruit can only be propagated by cuttings with great difficulty (low multiplication rates). It is unclear to what extent this is a function of their ontogenetic age (state of reproductive maturity) or their physiological age (Dick & Leakey, in press). However, propagation by juvenile leafy cuttings is very easy, with high multiplication rates, for almost all tree species (Leakey *et al.*, 1990). Because of the ease of propagating juvenile tissues by cuttings, this is currently the preferred option for participatory domestication in village nurseries (Mbile *et al.*, 2004; Mialoundama *et al.*, 2002; Shiembo *et al.*, 1996a; Tchoundjeu *et al.*, 2002).

Having indicated above the great opportunities arising from the identification and capture of intraspecific genetic diversity, it is important then to consider the retention and protection of this genetic diversity (Leakey, 1991). Domestication is generally considered to reduce the genetic diversity of the species that has been domesticated. This is probably true in situations where the domesticated plant replaces or dominates the wild origin, but is probably not the case at the current level of domestication of agroforestry trees. For example, the range of fruit sizes in on-farm populations of *D. edulis* and *I. gabonensis* has been increased by the early stages of domestication (Leakey *et al.*, 2004). Nevertheless, it is essential that domestication activities are undertaken with the realisation that it is important to retain and maintain as much diversity as possible. Modern molecular techniques are useful in the development of a wise strategy for the maintenance of genetic diversity. Within the geographic range of a particular species they can be used to identify the 'hot-spots' of intraspecific diversity (e.g. Lowe *et al.*, 1998, 2000), places which should if possible be protected for *in situ* genetic conservation, or be the source of germplasm collections if *ex situ* conservation is required. In addition, when developing cultivars, it is highly desirable that they originate from unrelated populations with very different genetic structure. It is foreseen that this is one of the benefits of the participatory domestication model being developed in Cameroon, as each village is developing a different set of cultivars, which should retain a wide cross-section of the existing diversity. This raises the question as to how many cultivars/clones each village should produce to achieve their production objectives and, importantly, ensure that there is still a high level of genetic diversity in the cultivated population to minimize the risk of pest and disease epidemics. In the first instance each village may produce 10–15 cultivars for each species, and these will probably have been selected for a number of different attributes. While this number will be reduced as the cultivars are tested, it is hoped that new cultivars will be developed as a result of further screening of wild trees. In due course, seeds perhaps derived from cross-cultivar pollinations will create a new generation of trees for screening and selection. These approaches conform to published strategies for clonal selection and deployment and the wise use of tree improvement techniques (Foster & Bertolucci, 1994; Leakey, 1991; Libby, 1982).

Cultivation and the growth of cultivars

The final stage of the domestication process is the integration of selected plants into the farming system in ways that make effective use of natural resources (light, water, nutrients), and have positive socio-economic and environmental benefits (Leakey & Newton, 1994a, 1994b). In African farmland, a wide range of densities and configurations are grown (Gockowski & Dury, 1999; Kindt, 2002). A study of the fruit tree component in villages with varying mean farm size (0.7–6.0 ha) in Cameroon and Nigeria found that fruit tree density was inversely related to area, with small farms having the greatest tree densities (Degrande *et al.*, in press). Of these trees about 50% were indigenous species for AFTPs, and, in Cameroon, 21–57% of these indigenous fruit trees are *D. edulis* (Schreckenberg *et al.*, 2002). Agroforestry is expected to provide positive environmental benefits on climate change and biodiversity (Millennium Development Goal 7). Evidence is also growing that there are biodiversity benefits arising from the introduction of indigenous trees producing a wide range of marketable products into smallholder farming systems (Bignell *et al.*, 2005; Schroth *et al.*, 2004). However, research is needed to determine the impacts of such diversity on agroecosystem function (Gliessman, 1998; Leakey, 1999b; Mbile *et al.*, 2003); carbon sequestration (Gockowski *et al.*, 2001) and trace gas fluxes; and on the sustainability of production and household livelihoods. However, the domestication of agroforestry trees is only just reaching the point where the density and configuration of cultivars in the farm is becoming a research topic. This information will be fundamental to understanding the processes determining positive impacts of agricultural diversification on biodiversity, land degradation, livelihoods and income (Simons *et al.*, 2000a). Evidence is also required to determine whether the domestication and commercialisation of AFTPs provides incentives for farmers to diversify, as suggested by Leakey (2001a, 2001b). The importance of agricultural biodiversity and traditional food crops is increasingly being recognised internationally for their value in human nutrition and income generation (Frison *et al.*, 2004).

Markets

The linkage of tree domestication with product commercialisation was the focus of a conference at ICRAF in 1996 (Leakey & Izac, 1996; Leakey *et al.*, 1996). To be effective this linkage requires the involvement of the food, pharmaceutical and other industries in the identification of the characteristics that will determine market acceptability (Leakey, 1999a).

The term Agroforestry Tree Products (AFTPs) is of very recent origin (Simons & Leakey, 2004) and refers to timber and non-timber forest products that are sourced from trees cultivated outside of forests. This distinction from the term non-timber forest products (NTFPs) for non-timber extractive resources from natural systems is to distinguish between extractive resources from forests and cultivated trees in farming systems, and hopefully will avoid some of the confusion in the current literature (Belcher, 2003). Nevertheless, some products will be marketed as both NTFPs and AFTPs (depending on their origin) during the period of transition from wild resources to newly domesticated crops. Consequently, both terms are used in the following sections.

Economic and social benefits from trading AFTPs

In west and central Africa, a number of indigenous fruits and nuts, mostly gathered from farm trees, contribute to regional trade (Ndoye *et al.*, 1997). In Cameroon, the annual trade of the products of five key species has been valued at US$7.5 million, of which exports generate US$2.5 million (Awono *et al.*, 2002). Perhaps because of this trade, evidence is accumulating that AFTPs do contribute significantly to household income (Awono *et al.*, 2002; Gockowski *et al.*, 1997) and to household welfare (Degrande *et al.*, in press; Schreckenberg *et al.*, 2002). For example, farm level production of three indigenous fruit and nut species in southern Cameroon has been reported to be worth US$355 (Ayuk *et al.*, 1999a, 1999b, 1999c), from an average farm size of 1.7 ha, and against an average annual expenditure of US$244 (Gockowski *et al.*, 1998). In Cameroon, farmers from four widely dispersed villages indicated that indigenous fruits represent 12.5% of their primary income, and 17% of their secondary income, while the equivalent income from exotic fruits was 6.8 and 3.5%, respectively (Degrande *et al.*, in press). In Nigeria, the equivalent proportions of income from indigenous fruits were 15% as primary income and 37.5% as secondary income, while exotic fruits had no value as primary income and only 2.5% as secondary income (Degrande *et al.*, in press). A crop of *D. edulis* fruits can be worth between US$20–150 per tree, depending on the quality of the fruits and the yield (Leakey *et al.*, unpublished). Thus, taking the number of *Dacryodes edulis* trees per household (Schreckenberg *et al.*, 2002), and a low estimate of the value of their fruits per tree (US$20) gives another estimate of annual income per household of US$380–2000. This result concurs with an economic analysis of farms in Cameroon with an average size of 1.4 ha, which found that when indigenous fruits are grown with cocoa they have a net present value/ha (over a 30-year period with a 10% discount rate) of about US$500 (Gockowski *et al.*, 1997; Gockowski & Dury, 1999). It seems that similar situations occur outside West Africa. For example, in South Africa, although the absolute income from *Sclerocarya birrea* fruits, kernels and beer was not as great as that from *D. edulis* in Cameroon, it was nevertheless in excess of the local wage rate (Shackleton *et al.*, 2003b). In Guyana, subsistence households were able to generate value added equivalent to US$288 per capita per annum, from utilisation of Andiroba oil and other forest resources (Sullivan, 2003).

What would be the impact of domestication on household income? It is anticipated that improved quality and market appeal from the domestication of these fruits would result in farmers getting higher prices, so long as supply does not exceed demand. At present there is high demand, but it is known that although the retail traders recognise the higher value of superior fruits, the wholesale traders do not (Leakey *et al.*, 2002). This is probably because a loaded truck of fruits from the current crop comes from a wide variety of trees of seedling origin and therefore includes the full spectrum of quality from very poor to superior. This would not be the case once farmers are planting recognised cultivars, as it would be possible for the wholesaler to obtain a loaded truck of superior fruits.

Different indigenous fruit species can vary in their seasonality, thus income opportunities can be spread across the year. Thus the overall household benefits from several different AFTPs, even without domestication, are almost certainly greater than the above examples suggest. To these benefits can also be added those that are derived from AFTP products used in domestic consumption, which represent a saving on expenditure. Evaluation of the economic benefits are further complicated by the fact that cash earned from AFTPs can potentially be invested in fertilisers, or in adding value to products, etc., so increasing the overall income derived from the sale of AFTPs.

Women are often the beneficiaries of this trade and they have especially indicated their interest in marketing *D. edulis* fruits because the fruiting season coincides with the time to pay school fees and to buy school uniforms (Schreckenberg *et al.*, 2002). It is also the women who are the main retailers of NTFPs (Awono *et al.*, 2002), with men being the wholesalers, and interestingly, it is the retail trade that recognises the market value of the tree-to-tree variation in size, colour, flavour, etc. (Leakey *et al.*, 2002). Evidence has also shown that some communities domesticate valuable species for the purposes of intergenerational security (Sullivan, 2003). Clearly these are social impacts of importance both to sustainable development in general, and in particular to the empowerment of women (Millennium Development Goal 3). Further work is, however, required to get a much better understanding of the market dynamics and potential for expansion. In the case of *D. edulis*, extending the season with early and late fruiting cultivars would be important (e.g. the Nöel cultivar, which fruits at Christmas); as would methods to extend their shelf life through simple fruit storage (bottling, canning, drying, freezing, etc.) and processing into paste, biscuits (Mbofung *et al.*, 2002), etc. Similar trends are emerging in southern Africa, where indigenous fruits have relatively new local and international markets (Brigham *et al.*, 1996; Shackleton *et al.*, 2000, 2002, 2003b).

The production and trading of AFTPs are based on traditional lifestyles, with many products used both for domestic consumption and/or sale depending on the household's cash and nutritional requirements. The ability to use household labour for harvesting/processing, combined with the low requirement for skills, capital and external inputs, makes it relatively easy for poor producers to adopt this approach to intensifying production and enhancing household livelihoods.

With HIV/AIDS now reaching up to 20–30% of the population in the worst hit countries (Swallow *et al.*, in press), one social benefit of special interest is potential health benefits which may accrue from a diet including more indigenous fruits and vegetables, many of which are rich in protein, oils, minerals and vitamins (Leakey, 1999a; Leakey *et al.*, 2005). The domestication of species producing these nutritious AFTPs is seen as a way to further enhance nutritional security and health, by strengthening the immune system of HIV/AIDS sufferers. This is seen as a critical component of an integrated natural resource management approach to improving the lives of poor people worldwide, especially in southern Africa (Barany *et al.*, 2003). Worldwide, medicinal products represent an annual international trade valued in excess of US$1 billion (Rao *et al.*, 2004). Many of these are herbs, which can be grown in the shade of agroforestry trees.

The linkages between the domestication and commercialisation of AFTPs

The success of domesticating agroforestry trees is very dependent on there being an adequate market for the products (AFTPs). In some instances, species currently being domesticated, such as *D. edulis, I. gabonensis* and *Gnetum africanum*, have local and regional markets, including exports to neighbouring countries (Awono *et al.*, 2002). In other cases, such as *Prunus africana* and *Pausinystalia johimbe* there are already established international markets in Europe and USA, in addition to local ones (Cunningham *et al.*, 2002). As already indicated, market-oriented domestication has the greatest likelihood of being adopted on a scale to have impact on the economic, social and environmental problems afflicting many tropical countries. This requires that agroforesters work closely with the companies processing and marketing the products (Leakey, 1999a). However, in doing this it is important to remember that smallholder farmers are the client of the research and development work and that there needs to be a functional production-to-consumption chain. This principle was apparently overlooked during recent domestication of peach palm in Amazonia (Clement *et al.*, 2004), resulting in the underperformance of the market. This failure has been attributed to a lack of understanding about the consumers' needs, and incorrect identification of the research client (i.e. the smallholder and not the entrepreneur).

In many cases the successful commercialisation of AFTPs is dependent on domestication, as frequently initiatives to develop markets for new products collapse (or do not expand to their potential) when supply does not meet the demand. This is especially problematic if the product has a seasonal production pattern, and the product is derived from many small growers, with minimal quality control. Another constraint to commercialisation can be the intra-specific variability that is so beneficial to the domestication process. This variability is a major problem when uniformity of quality (taste, size and purity) is important in the marketplace. Quality control is doubly important if there is any local level processing for value-adding, to extend shelf-life or to reduce the costs of bulk transport. Domestication is one way to increase the supply of high quality product, and through cultivar development can also greatly improve the uniformity of the product. Domestication can also lead to an extended season of production, making it easier to supply industries throughout the year. Good examples of coordinated domestication and commercialisation are kiwi fruit (*Actinidia chinensis*) and macadamia nuts (*Macadamia integrifolia*). Kiwi fruits were first grown commercially in New Zealand in the 1930s. By the 1950s there were a number of commercially grown cultivars and fruits were first exported in 1952. The Macadamia selection programme started in 1934, with considerable market interest.

In many domesticated crops, the market demand for the product has promoted large-scale mono-cultural production systems that frequently have been the cause of environmental degradation through deforestation, soil erosion, nutrient mining, and loss of biodiversity. Typically, these systems of farming have also resulted in social inequity and the 'poverty trap' for small-scale producers who are unable to compete in international trade with large or multi-national companies. Concerns about this have rightly raised many questions about the wisdom of domesticating and commercialising agroforestry trees. The key question that agroforesters have to address is whether or not agroforestry can prevent these negative impacts. In theory, agroforestry is beneficial to the environment and beneficial to the poor farmer. At the level of the individual farm there are many examples of these benefits being achieved. For example, extensive intercropping with trees and shrubs provides subsistence households in Amerindian communities with a significant degree of food security (Sullivan, 2003). The problem and the complexity of this issue is exacerbated by the need for agroforestry to be scaled up to the point when it reduces poverty and has environmental benefits at national, regional and global scales. So, what will happen if the domestication of AFTPs is so successful that the market-demand for one of them reaches the point when a company sees the opportunity to develop mono-cultural plantations as a cash crop either in the country of origin or in some overseas location with a similar climate and better access to markets? Will this undermine the whole purpose of developing new crops? The answer has to be a qualified – 'yes'. Having said that, what reservations or limitations can mitigate the problem? These issues were the subject of an ICRAF conference in 1996 (Leakey *et al.*, 1996) and it was concluded that, recognising the traditional role of non-timber forest products in food security, health, income generation, the potential benefits from domestication outweighed the risks. Nevertheless, many areas of market, social science and policy research were recommended by Working Groups. Important areas for more study are the complex issues surrounding commercialisation of genetic resources and benefit sharing (ten Kate & Laird, 1999) and traditional knowledge (Laird, 2002). Without markets there will not be the opportunity for subsistence households to increase their standard of living, while expanded market opportunities could lead to their exploitation by businessmen. Thus it is clear that commercialisation is both necessary and potentially harmful to small-scale farmers practising agroforestry (Leakey & Izac, 1996), and that as advocated by Dewees and Scherr (1996), policy scientists need to 'stretch their conceptual framework . . . and to consider more carefully the links between markets, the environment, household production and household welfare'. One risk alleviating strategy is to support the domestication of a wide range of tree species producing AFTPs, especially those with local and regional market potential. In this way, coupled with strong indigenous rights, it is very unlikely that the market demand will attract major companies and, even if products of a few species do become international commodities, there will be others that will remain only of local and regional importance.

In recent years there have been some very positive outcomes from the involvement of international companies in agroforestry. For example, Daimler-Benz has taken a small-holder, multi-strata agroforestry approach to producing raw materials for their C-Class Mercedes-Benz cars in Brazil, and in partnership with International Finance Corporation have been developing this as a new paradigm for Public/Private Sector Partnerships in Development (Mitschein & Miranda, 1998; Panik, 1998) Another example is the leadership being taken by Masterfoods within the chocolate industry, in support of sustainable livelihoods for small-holder cocoa farmers in Africa and Asia, through the diversification of cocoa farms into cocoa agroforests by the promotion of AFTP-producing trees. This development is building on the actions of the smallholder farmers themselves, who have integrated fruit trees (often indigenous species) into the cocoa farm so that the shade trees are also companion crops (Leakey & Tchoundjeu, 2001). This has been done as a risk-aversion strategy to provide new sources of income, in response to fluctuating market prices. Interestingly, cocoa is not the only former plantation cash-crop to now be an important agroforestry species. Rubber is perhaps the best example, especially in SE Asia (Tomich *et al.*, 2001), while tea and coffee are moving in the same direction. Taking these developments together, therefore, there are some good reasons for being positive about the potential impacts of commercialisation of agroforestry trees. A somewhat different, but interesting example of AFTP commercialisation is the case of marula (*Sclerocarya birrea*), a tree of dry Africa which is starting to be commercialised by subsistence farmers for traditional beer and for industrial processing as an internationally marketed liqueur 'Amarula' by Distell Corporation. Marula kernel oil is also breaking into international cosmetics markets. This species thus provides an opportunity to examine the impacts of different commercialisation strategies on the livelihoods of the producers, the sustainability of the resource and the economic and social institutions. In other words, who or what are the winners and losers arising from the commercialisation of indigenous fruits and nuts? This question has been the focus of the following study to investigate the impacts of commercialising both traditional and new products from emerging agroforestry tree crops.

Winners and losers: Impacts on livelihoods

The importance of non-timber forest products for the livelihoods of poor forest dwellers has been recognised for some time (Peters *et al.*, 1989; Sunderland & Ndoye, 2004; Vedeld *et al.*, 2004). A multi-disciplinary, multi-institutional study of the impacts of different commercialisation strategies for a number of different NTFP products from *Sclerocarya birrea* within farming systems and in structurally- and ethnically-different communities has provided very interesting insights as to who are the 'Winners and Losers' (Sullivan & O'Regan, 2003). The study was structured to examine the impacts of commercialisation on the five forms of Livelihood Capital (Human, Social, Financial, Natural and Physical). This review cannot do justice to this comprehensive study, but in brief it was concluded that to improve the livelihood benefits from commercialising NTFPs it is important to improve:

(1) The quality and yield of the products through:
   - domestication and the dissemination of germplasm;
   - enhancing the efficiency of post-harvest technology (extraction, processing, storage, etc.).

(2) The marketing and commercialisation processes by:
   - diversifying markets for existing and new products;
   - investing in marketing initiatives and campaigns;
   - promoting supply contracts with equitable distribution of benefits, opportunities in national and international cuisine that build on indigenous knowledge and cultural heritage, improved sensory characteristics (taste, aroma, etc.), market chain investments, trading partnerships in local businesses with plans for sustainability (including exit strategies), commercialisation pathways that recognise the role of women, health and nutritional benefits.

The analysis from this study identified the factors that determine who/what are the Winners and the Losers under different circumstances (Table 1). The following lessons were learnt for NTFP commercialisation from the study of *Sclerocarya birrea* (abridged from Shackleton *et al.*, 2003b), that apply equally to AFTPs:

- NTFPs are most important for poor and marginalised people, and make up income shortfalls but do not significantly alleviate poverty. How domestication may change this still needs to be determined.
- Engagement in NTFP commercialisation and the extent of benefits is variable even amongst the poorest households. Households are far from homogenous in their levels of engagement. Entrepreneurship, labour availability, personal drive and choice play a pivotal role in determining whether or not households take up opportunities. So too do the levels of organisation within a community, the availability and quality of information about markets, access to transport, and the extent to which a producer is 'networked'. Benefits of NTFP commercialisation must be weighed against the negative social and cultural costs of commercialisation: there are trade-offs, which need to be recognised, between the preservation of traditions, cultures and social norms, and the benefits derived from increased income.
- Land and usufruct rights must be clear, government intervention pitched at the appropriate

Table 1 The characteristics of Winners and Losers among: (1) people and enterprises, (2) marketing, and (3) natural resources, that are due to the commercialisation of non-timber forest products (after Shackleton *et al.*, 2003b)

Winner Qualities	***Loser Qualities***
(1) People and enterprises	
• Individuals organised as a group	• Poorly organised group structure
• Well informed about markets	• Poorly informed of markets
• Good access to transport	• Poor access to transport
• Coordinated production	• Uncoordinated production
• Small 'Input cost: Revenue received' ratio	• Large 'Input cost: Revenue received' ratio
• Consistently good quality products	• Variable quality products
• Skilled in bargaining	• Unskilled in bargaining
• Well networked with good partnerships	• Poorly networked
• Easy and equitable access to resource	• Uncertain and restricted access to resource
• Fits with other livelihood strategies and socio-cultural norms	• Competes with other livelihood strategies and socio-cultural norms
(2) Marketing	
• Commercial opportunities	• Undeveloped/poor market interest
• Diversity of end markets	• Limited markets
• Diversity of end products	• Fad or single niche products
• Positive marketing image	• No or negative marketing image
• Unique characteristics of product	• Many other substitutes
• Raw product quality well matched to market	• Raw product requires processing
• Many buyers of raw materials and products	• A monopsony – only one buyer of raw materials
• Many sellers of raw materials and products	• A monopoly – only one seller
• Buyers aware of product or brand	• Buyers ignorant of product or brand
(3) Natural resources	
• Abundant resource	• Rare resource
• Plant part used is readily renewable	• Slow replacement of harvested product
• Harvesting does not destroy the plant	• Destructive and damaging harvesting
• Easily propagated	• Difficult to propagate
• Genetically diverse with potential for domestication	• Genetically uniform or little potential for selection
• Multiple uses for products	• Narrow use options
• High yield of high quality product	• Low yielding and/or poor quality product
• Valuable product	• Low value product
• Consistent and reliable yield from year to year	• Inconsistent and unpredictable production
• Already cultivated within farming system	• Wild resource which is difficult to cultivate
• Already being domesticated by local farmers	• Totally wild resource
• Fast growing	• Slow growing
• Short time to production of product	• Long time to production
• Compatible with agroforestry land uses	• Competitive with crops; labour intensive, etc.
• Hardy	• Sensitive to adverse environmental conditions
• Widely distributed	• Only locally distributed

level, and political support for the NTFP industry secured: insecure land tenure and resource rights can have a range of negative economic, social and ecological outcomes, and can severely jeopardise efforts to successfully commercialise NTFPs. The commercialisation of marula illustrates the central role that can be played by customary law in NTFP management. The findings argue for greater integration of customary and local law in places where traditional systems have eroded, and minimal governmental intervention in areas where customary law is adequate to deal with the pressures of commercialisation.

- NTFP commercialisation can lead to improved management and conservation of the resource in certain circumstances. This depends on the particular product, the species, the presence of a conducive policy environment, the feasibility/desirability of cultivation, and the potential for participatory domestication by interested communities.
- An abundance of 'winner' qualities (see Table 1) need to be in place or developed amongst the participants in the trade, and across the resource and markets. NTFP cultivation needs to be community-owned and driven: communities harvesting products and domesticating the species, need assistance and support to guarantee their ownership of germplasm and knowledge, and to ensure they are the beneficiaries of future commercialisation initiatives.
- Benefits can be accrued at the local level: value adding increases the returns to labour, but does not have to be large scale or aimed at external markets e.g. marula beer, in which traders can earn greater income per hour than the suppliers of fruit and kernels to other markets.
- Communities are generally poorly placed to benefit from intellectual property rights: intellectual property rights (IPRs) can play both a potentially positive and negative role in protecting the interests of primary producers, but to realise positive effects communities need substantial finance and support. There is an urgent need for IPR systems that promote poverty alleviation, food security and sustainable agriculture as NTFPs make the transition to AFTPs.
- Models of commercialisation based on partnerships between producer communities, NGOs and the private sector are most likely to succeed: partnerships between different players can allow for mutually profitable arrangements (e.g. CRIAA SA-DC marula oil model). Most important is the retention of ownership and control of the enterprise at producer level.
- Diversified production and reduced dependence on a single product: The diversification of species used, products produced, markets traded, and players involved, is an extremely important strategy to minimise the risks of NTFP commercialisation for rural communities. Often it is best to build on what exists at the local level rather than aiming for new high value, specialised markets.
- Scaling up and introducing new technologies can shift benefits away from women and the most marginalised producers: the increased commercialisation of NTFPs inevitably entails a shift from small-scale to large-scale, male-dominated activities.
- NTFPs form only part of a far broader ecological, economic, social and political landscape: NTFPs are harvested and used within the context of broader development and land-use pressures. For example, continued land clearance, the need for biomass energy, and woodcarving can be a greater threat than the commercialisation of a fruit product.
- NTFP trade and industries are dynamic in space and time: there are seldom permanent winners and losers in the NTFP trade and producers' relationships with the resource base, other role players, the industry and the markets will be constantly changing and adapting in response to a range of internal and external drivers and processes and policy contexts.

The conclusion from this on-farm study was that NTFP/AFTP commercialisation can create both Winners and Losers, but positive outcomes can be maximised if the importance of community involvement is appreciated by external players and if the communities themselves work together and use their own strengths to manage and use their resources effectively. This provides encouragement and some endorsement that the approach being developed for the participatory domestication of agroforestry trees is appropriate. This is supported by the findings of a study investigating the role of tree domestication in poverty alleviation (Poulton & Poole, 2001). Nevertheless, to ensure the farmers engaged in participatory domestication are Winners, there is the need to resolve the current difficulties facing farmers wishing to protect their rights to the cultivars that they are producing.

Features of this Agroforestry Approach to Rural Development

This paper has focussed on the role of agroforestry trees to reduce poverty and to enhance smallholder livelihoods. However, in rural development, the problems of poverty, land degradation, loss of biodiversity, social deprivation, malnutrition and hunger, poor health and declining livelihoods are all inextricably linked and cyclical (Figure 1). Consequently any attempts to alleviate the problems have to target a number of different points within the cycle. Agroforestry is advocated as a means of meeting these global challenges (Figure 2). Leakey and Sanchez (1997) estimated that 1.8 billion people in the world (many of them in urban centres) make some use of agroforestry products and services. Thus potentially the domestication of agroforestry trees and the commercialisation of their products, should be able to have positive impacts on the lives of many of the 50% of the world population (currently 6.4 billion) who are living on less than US$2 per day.

Regarding the above objectives, the features of this AFTP-approach to agroforestry and rural development are that it is based on:

- Traditional knowledge and culture (Cunningham, 2001).
- Participatory techniques to ensure relevance to local people (Franzel *et al.*, 1996). This empowers subsistence farmers to control their own destiny and decentralise business opportunities to the villagers and create employment in processing and marketing.
- Doing research and development directly with communities (Leakey *et al.*, 2003) rather than a 'top-down' approach with national or international institutions. This promotes early adoption and impact.
- Indigenous perennial crops and foods (Leakey, 1999a) which:
  - have a reduced requirement for soil tillage;
  - create ecological niches and habitat for wild species above- and below-ground so enhancing biodiversity and agroecosystem processes;
  - enhance food security, so reducing hunger;
  - promote nutritional security and dietary quality, so enhancing health and reducing malnutrition and diseases. This addresses

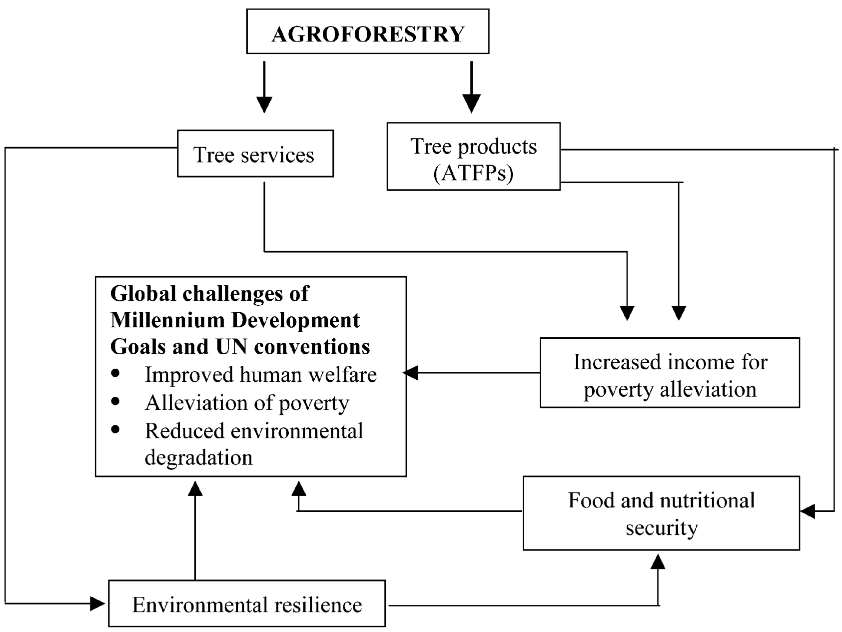

Figure 2 The relationship between the two functions of agroforestry trees and their potential to mitigate global problems arising from unsustainable landuse (after Leakey & Tomich, 1999)

  - food insecurity and micronutrient deficiencies through natural products and systems rather than biofortification;
  - create opportunity for income generation, reducing poverty and improving rural and urban livelihoods;
  - can be developed as new agricultural commodities to diversify the market economy and buffer commodity price fluctuations;
  - can substantially increase the numbers of crop plants available to farmers, adding those of local importance traditionally, culturally and ecologically.
- Integrated natural resources management and sustainable land use (Leakey, 1999b), based on diversifying the farming system at the local and landscape scale, enhancing agroecological function and watershed services. This enhances international public goods and services by reducing trace gas emissions that impact on climate change and by minimising the loss of biodiversity.
- Low-input polycultures rather than high-input monocultures (Leakey, 2001a, 2001b) i.e. working with nature rather than against it.
- Knowledge of the natural resource (Shackleton *et al.*, 2003a).
- Local germplasm and appropriate technology (Simons & Leakey, 2004).
- Market specialisation for a number of niche products with local and regional acceptability, rather than on globalisation and exposure to commodity price fluctuations in world trade.

The potential of this approach of course comes with some risks (Figure 3), of which the three most important are the dangers of:

- Reducing intra-specific genetic diversity and losing resistance to pests and diseases; losing genes that may have importance for future developments, etc.
- Losing the traditional and cultural values associated with indigenous species.
- Losing the sustainability of production systems by over-emphasis of high input, monocultural practices (Leakey & Izac, 1996), which would also undermine the markets supporting small-scale agroforestry producers.

There is one negative aspect of the domestication of AFTPs. It is likely to result in a reduction in the market-share of wild-harvested NTFPs. This would probably disadvantage landless rural people. However the number of people benefiting from this domestication probably greatly outweighs those who would be disadvantaged.

There is also one problem that needs to be overcome to implement this major paradigm shift in rural development. Extension services in many countries are virtually moribund, although to some extent they have been replaced by NGOs and CBOs. There is therefore a need for policies to create an extensive new network to transfer agroforestry technologies to farmers. These would need to extend into remote and marginal areas.

Policy Guidelines

The features of this agroforestry paradigm for rural development will require some policy changes at national and international levels, especially to ensure the scaling up to the levels required to achieve the Millennium Development Goals (Leakey *et al.*, submitted for publication). An earlier review of the policy issues surrounding the domestication and commercialisation of trees producing AFTPs raised many questions (Leakey & Tomich, 1999), some of which have been elaborated above. Inevitably, however, in a new research area such as this, with only a short history, many questions remain unanswered, and indeed cannot be answered until the techniques and strategies outlined above have been in use for longer periods and on larger scales. Nevertheless, there seems to be growing confidence on the part of institutions like ICRAF and their donors, that this approach to agroforestry and the alleviation of poverty has merit (e.g. Poulton & Poole, 2002). This is emphasised by suggestions that these concepts have a role to play in the achievement of several of the Millennium Development Goals (Garrity, 2004; Leakey *et al.*, submitted for publication; Sullivan & O'Regan, 2003).

For agroforestry to assist with the achievement of the Millennium Development Goals, there is a need for a major international initiative to create the level of up-scaling that is required to bring domesticated AFTP-producing trees into millions of households every year before 2010. Garrity (2004) has, consequently, indicated that many agricultural R&D institutions around the world must be helped to develop new skills in the domestication of indigenous species and the processing/storage of their products, in market

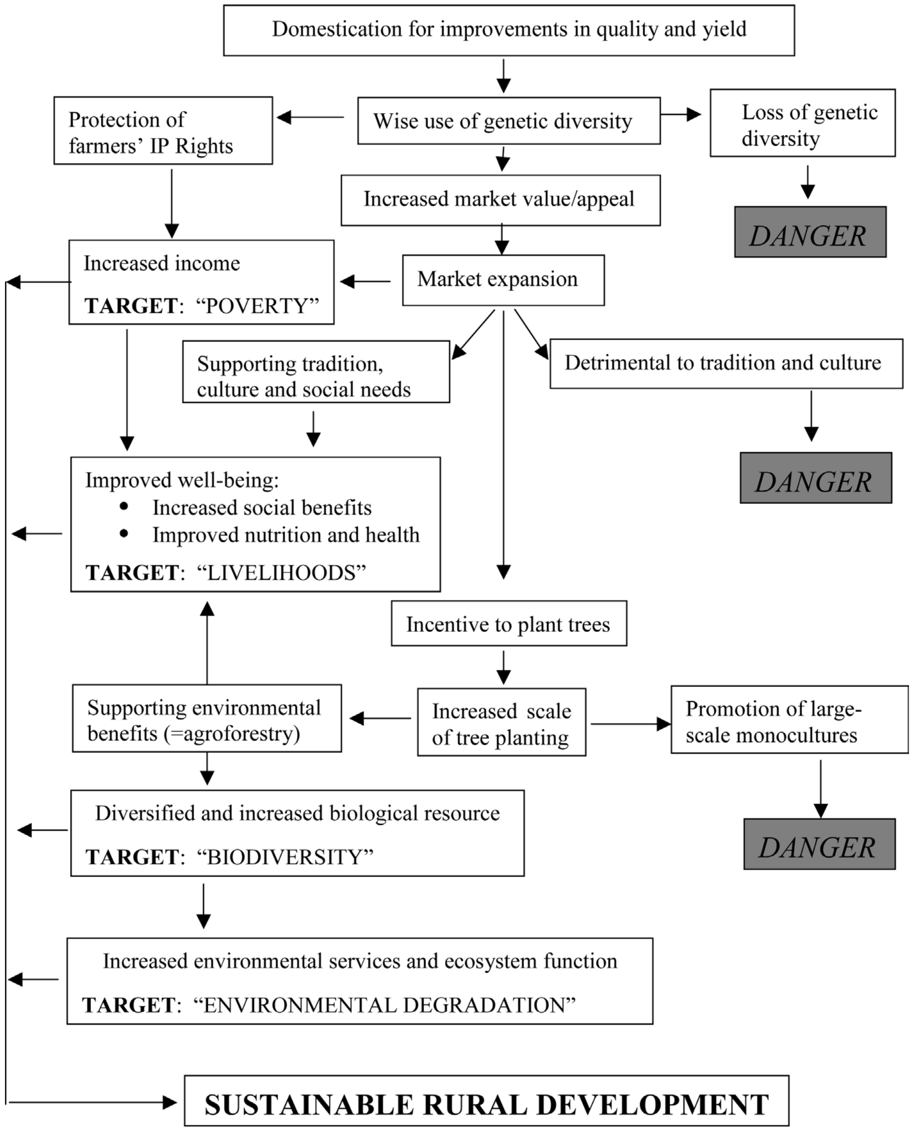

Figure 3 Potential impacts on sustainability of domesticating agroforestry trees

analysis and in developing market linkages. This level of up-scaling will also require high-level policy support to ensure a coordinated and coherent approach to domestication and commercialisation across government departments ranging from agriculture and forestry, education and training, infrastructure and transport, to rural development and trade.

The scaling up of participatory domestication to tens of millions of new households every year across the developing world is probably the biggest challenge. Currently participatory domestication is driven by the clients (the subsistence farmers) meeting existing local market demands which are more focused on quantity than quality, but as the process proceeds and supply meets these market demands, it will become increasingly important that new market opportunities are identified, with attention to product processing, adding-value and storage. These new markets are likely to be more interested in quality and thus markets are likely to start to drive the selection processes of domestication. This will require refinements in the identification of ideotypes that focus on the specific needs of a particular market: for nutritious food, medicinal products, cosmetics, etc. Matching these market demands with the domestication process and the supply chain will become a challenge, dependent on much better market information than is currently available.

The up-scaling of participatory domestication will be a challenge both in terms of the logistics of training and supervision, and in its adaptation to new species, environments and markets. In this connection, there is an urgent need to rapidly expand the pool of expertise in core techniques like vegetative propagation. Fortunately, the Commonwealth Science Council has published an excellent manual (Longman, 1993), with supporting videos (Edinburgh Centre for Tropical Forests, 1993) for 'training the trainers', which are appropriate for use by NGOs, etc. Associated with the development of vegetatively-propagated cultivars, an urgent issue to be resolved will be the acquisition and protection of 'plant breeder's rights' on the cultivars created by communities practising participatory domestication. The failure to achieve this will be a severe disincentive for villagers to invest their time, effort and limited resources to a venture, which could be taken away from them. This outcome would destroy the potential of agroforestry to enhance rural livelihoods and human welfare, and to meet the Millennium Development Goals. In this connection, policy makers should realise that IPR-protected participatory domestication represents a new and acceptable approach to biodiscovery – the antithesis of biopiracy.

As domestication becomes more widely implemented and the objectives more sophisticated it will become increasingly important to avoid the potential pitfalls of domestication (Figure 3), like the loss of genetic diversity. Thus the trainers and mentor organisations need to ensure that the communities understand the need to deliberately retain intraspecific variation for pest and disease resistance, environmental stress, etc., through germplasm conservation, and a rolling programme of genetic selection (Leakey, 1991). If attention is paid to genetic diversity issues, agroforestry with domesticated indigenous plants can serve a useful *circa-situ* conservation function. In addition, as commercial interests increase, it will be important to maintain a focus on diversified agroforestry production that should promote integrated pest management (Leakey, 1999b), rather than shifting to monocultures.

This risk of large-scale monocultural production is one that can develop in-country, or indeed overseas, the latter having particularly serious implications; and of course there are many precedents among the cash crop commodities. However, in this regard, it is encouraging that rubber, cocoa, coffee and tea are increasingly becoming smallholder crops, as the profitability of large plantations declines. The growing recognition of the suitability of smallholder production by large companies (Chrysler-Benz, Masterfoods, Bodyshop) is also encouraging. It is however clear from the above, that sound policy interventions will probably be needed to ensure that smallholder farmers are the beneficiaries of the domestication of AFTPs. As mentioned earlier, the desirability of starting to domesticate a wide range of new tree crops with local markets in each region, should keep the options open for farmers and so minimise the risks of monopolistic production companies. Policy makers tend not to think much about the differences between a monocultural approach to growing a new crop versus an agroforestry approach. This is illustrated by the recognition that 20 million trees can be grown by four farmers, or by a million farmers each growing only 20 trees. Clearly that latter approach has the greatest potential impact in terms of the Millennium Development Goals.

One clear policy message from many sources is the need to recognise the 'chicken and egg' relationship between domestication and commercialisation (Leakey & Izac, 1996) – and the folly of doing one without the other. However, it is clear that the relationship between domestication and commercialisation is delicately balanced, with both the lack of a market and the excessive growth of a market posing a threat. The latter is undesirable from two points of view: firstly an excessive market demand can result in low quality and non-uniform produce being placed on the market; secondly high market prices can encourage poor farmers to sell produce which should be used domestically to provide food and nutritional security, and thirdly, high market prices could encourage businessmen to embark on large-scale, monocultural plantations, which could undercut marginalised smallholder farmers practicing agroforestry, and so defeat the object of meeting the Millenium Development Goals. However, the complexity of marketing means that creating demand can also have positive effects. For example, the rise of large, multi-national 'supermarket' consumer companies (Reardon *et al*., 2003), may perhaps be an asset for the marketing of new food products.

These companies operate on a scale that may allow them to take a risk and to offer new products to consumers increasingly interested in the cuisine of other countries and cultures.

The following specific policy interventions are some of those recommended by recent studies on the domestication and commercialisation of agroforestry tree products. For example, following a study of the benefits and constraints of domestication of indigenous fruits in Cameroon and Nigeria (Ndoye *et al.*, 2005; Tchoundjeu *et al.*, 2005) have recommended that Governments and international agencies need to:

- Promote the participatory domestication of tree species fitting a variety of on-farm niches. Unlike institutional domestication programmes, participatory domestication empowers local communities, and maintains their rights over indigenous knowledge and germplasm, as proposed by the Convention on Biological Diversity.
- Focus domestication activities on the capture and use of intraspecific variation existing in wild/semi-domesticated populations and utilise the relatively quick economic and social returns from participatory domestication. These result from early fruiting and rapid improvements in productivity and product quality.
- Promote the local-level processing and marketing of indigenous fruits, nuts and other tree products in parallel with domestication to maximise adoption of diversified, sedentary farming (agroforestry).
- Recognise the very considerable training and extension needs of rural communities that are required to achieve the scaling up necessary to meet the Millennium Development Goals.

In a policy brief developed from a study of the commercialisation and potential domestication of marula fruits in South Africa and Namibia, Wynberg *et al.* (2003) have recommended 12 policy interventions, including the following:

- Governments should clarify land and usufruct rights to facilitate the successful and effective commercial development of AFTPs, recognising that Western approaches to titling may not be appropriate for indigenous resource tenure systems.
- Urgent efforts should be made to develop and implement systems to protect community-based cultivars (through participatory domestication) ... as part of legislative reforms for biodiversity management, indigenous knowledge protection, and plant genetic resource conservation and use.
- Through effective natural resource management, governments, traditional authorities and communities should ensure the continued use of a wide range of NTFPs, to support rural livelihoods. Commercial enterprises should promote the development of a wide range of products and markets.
- To ensure that local people capture a greater share of the benefits from commercialisation, basic management, financial and institutional capacities must be in place.

Together the above policy guidelines provide some direction on specific interventions to improve the likelihood that agroforestry will contribute substantially to the achievement of the Millennium Development Goals.

Development Issues for the Future

In the nine years that agroforestry tree domestication has been in progress, great advances have been made. This review has focused on progress in the humid zone of west and central Africa and in southern Africa, but similar programmes are underway in the Sahel, in East Africa, in Amazonia and in SE Asia, as well as in programmes outside the World Agroforestry Centre (ICRAF). Hopefully, the experiences reported here for agroforestry based on locally-relevant tree species and markets will be of great benefit to other areas of the world embarking on similar people-centred concepts for rural development.

After 25 years of agroforestry research, it has been argued that there are already many examples of modern approaches to agroforestry, achieving the objectives of the Millennium Development Goals at the household and community level (Leakey *et al.*, submitted for publication). Some of these examples include the enhanced production and marketing of AFTPs to raise incomes above US$2 per day. The challenge identified by these authors for the Millennium Development Initiative was how to scale up agroforestry between now and 2015 to reach the millions of poor rural families (60 million in the humid lowlands of West and Central Africa alone). Scaling up agroforestry is really more a matter of extension and community training than one of developing new technologies, although as is evident from this review, there is very considerable need to expand participatory tree domestication research, with locally relevant species, in very large numbers of communities throughout the tropics.

The up-scaling of improved short-term fallows (Buresh & Cooper, 1999), especially in the maize belt of southern Africa, has been one good example of how to promote the adoption of agroforestry. Using this example, Leakey *et al.* (submitted) have argued that the benefits of short-term fallows on maize yields can be the catalyst for a further advances into agroforestry based on indigenous fruit trees, which in turn can allow smallholder farmers to make the transition from subsistence into a cash economy. In this, as in other examples, the small amounts of cash generated by selling AFTPs can allow farmers to purchase agricultural inputs, to achieve higher yields from their staple foods, and so create an opportunity for further advances into cash cropping (Leakey *et al.*, submitted for publication), and increase the returns from the investment in the Green Revolution (Leakey, 2001b; Leakey & Tomich, 1999).

The realisation of this vision would be a 'Really Green Revolution' (Leakey, 2001b; Leakey & Newton, 1994a). It is an alternative to some of the other approaches being advocated for rural development (e.g. McCalla & Brown, 1999; Serageldin & Persley, 2000), but has synergies with others (e.g. InterAcademy Council Report on African Agriculture, 2004 – www.interacademycouncil.net), the World Summit on Sustainable Development's Water, Energy, Health, Agriculture and Biodiversity initiative (http://esl.jrc.it/dc/wehab/WEHAB_indicators.htm) and the proposals for Ecoagriculture (McNeely & Scherr, 2003).

From this review, it is suggested that the domestication of new tree crops provides an incentive for farmers to implement agroforestry practices which target intervention points in the cycle of agroecosystem degradation (Figure 1) and that by so doing, it is possible to reduce land degradation, hunger, malnutrition, disease and poverty and so move towards the achievement of the ambitious targets set by the Millennium Development Goals. This approach to rural development in the tropics will, however, require fundamental changes in the attitudes of many national government and international development agencies and in their policies. Such changes are beyond the scope of this paper.

Notes

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1. 1 SNU = 12 mPa.s.

References

Anegbeh, P.O., Usoro, C., Ukafor, V., Tchoundjeu, Z., Leakey, R.R.B. and Schreckenberg, K. (2003) Domestication of *Irvingia gabonensis*: 3. Phenotypic variation of fruits and kernels in a Nigerian village. *Agroforestry Systems* 58, 213–218.

Anegbeh, P.O., Ukafor, V., Usoro, C., Tchoundjeu, Z., Leakey, R.R.B. and Schreckenberg, K. (2005) Domestication of *Dacryodes edulis*: 1. Phenotypic variation of fruit traits from 100 trees in southeast Nigeria. *New Forests* 29, 149–160.

Atangana, A.R., Tchoundjeu, Z., Fondoun, J-M., Asaah, E., Ndoumbe, M. and Leakey, R.R.B. (2001) Domestication of *Irvingia gabonensis*: 1. Phenotypic variation in fruit and kernels in two populations from Cameroon. *Agroforestry Systems* 53, 55–64.

Atangana, A.R., Ukafor, V., Anegbeh, P.O., Asaah, E., Tchoundjeu, Z., Usoro, C., Fondoun, J-M., Ndoumbe, M. and Leakey, R.R.B. (2002) Domestication of *Irvingia gabonensis*: 2. The Selection of multiple traits for potential cultivars from Cameroon and Nigeria. *Agroforestry Systems* 55, 221–229.

Awono, A., Ndoye, O., Schreckenberg, K., Tabuna, H., Isseri, F. and Temple, L. (2002) Production and marketing of Safou (*Dacryodes edulis*) in Cameroon and internationally: Market development issues. *Forest, Trees and Livelihoods* 12, 125–147.

Ayuk, E.T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki-Manga, T. and Zenkeng, P. (1999a) Uses, management and economic potential of *Dacryodes edulis* (Burseraceae) in the humid lowlands of Cameroon. *Economic Botany* 53, 292–301.

Ayuk, E.T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki-Manga, T. and Zenkeng, P. (1999b) Uses, management and economic potential of *Garcinia kola* and *Ricinodendron heudelotii* in the humid lowlands of Cameroon. *Journal of Tropical Forest Science* 11, 746–761.

Ayuk, E.T., Duguma, B., Franzel, S., Kengue, J., Mollet, M., Tiki-Manga, T. and Zenkeng, P. (1999c) Uses, management and economic potential of *Irvingia gabonensis* in the humid lowlands of Cameroon. *Forest Ecology and Management* 113, 1–9.

Barany, M., Hammett, A.L., Sene, A. and Amichev, B. (2001) Non-timber forest benefits and HIV/AIDS in sub-Saharan Africa. *Journal of Forestry* 99, 36–42.

Barany, M., Hammett, A.L., Leakey, R.R.B. and Moore, K.M. (2003) Income generating opportunities for smallholders affected by HIV/AIDS: Linking agro-ecological change and non-timber forest product markets. *Journal of Management Studies* 39, 26–39.

Belcher, B.M. (2003) What isn't an NTFP? *International Forestry Review* 5, 161–168.

Bignell, D.E., Tondoh, J., Dibog, L., Huang, S.P., Moreira, F., Nwaga, D., Pashanasi, B., Pereira, E.G., Susilo, F.-X. and Swift, M.J. (2005) Belowground biodiversity assessment: Developing a key functional group approach in best-bet alternatives to slash and burn. In C. Palm, S. Vosti, P. Sanchez and P. Ericksen (eds) *Slash and Burn: The Search for Alternatives* (pp. 119–142). New York: Columbia University Press.

Brigham, T., Chihongo, A. and Chidumayo, E. (1996) Trade in woodland products from the miombo region. In B.M. Campbell (ed.) *The Miombo in Transition: Woodlands and Welfare in Africa* (pp. 137–174). Bogor: CIFOR.

Buresh, R.J. and Cooper, P.J.M. (eds) (1999) The science and practice of short-term fallows. *Agroforestry Systems* 47, 1–358.

Clement, C.R., Weber, J.C., van Leeuwen, J., Domian, C.A., Cole, D.M., Lopez, L.A.A. and Argüello, H. (2004) Why extensive research and development did not promote use of peach palm fruit in Latin America. *Agroforestry Systems* 61, 195–206.

Cunningham, A.B. (2001) Applied ethnobotany: People, wild plant use and conservation. *People and Plants Conservation Manual* (300 pp). London: Earthscan.

Cunningham, A.B., Ayuk, E., Franzel, S., Duguma, B. and Asanga, C. (2002) An economic evaluation of of medicinal tree cultivation: *Prunus africana* in Cameroon. *People and Plants Working Paper 10* (35 pp). Paris: UNESCO.

Degrande, A., Schreckenberg, K., Mbosso, C., Anegbeh, P.O., Okafor, J. and Kanmegne, J. (in press) Farmers' fruit tree growing strategies in the humid forest zone of Cameroon and Nigeria. *Agroforestry Systems*.

Dewees, P.A. and Scherr, S.J. (1996) *Policies and Markets for Non-timber Tree Products.* EPTD Discussion Paper No. 16, IFPRI, Washington DC, USA, 78 pp.

Dick, J.McP. and Leakey, R.R.B. (in press) Differentiation of the dynamic variables affecting rooting in juvenile and mature cuttings of cherry (*Prunus avium*). *Journal of Horticultural Science*.

Edinburgh Centre for Tropical Forests (1993) *Multiplying Tropical Trees: Vegetative Propagation and Selection.* 5 Video Programmes, ECTF, Edinburgh, Scotland, UK.

Foster, G.S. and Bertolucci, F.L.G. (1994) Clonal development and deployment: Strategies to enhance gain while minimising risk. In R.R.B. Leakey and A.C. Newton (eds) *Tropical Trees: The Potential for Domestication and the Rebuilding of Forest Resources* (pp. 103–111). London: HMSO.

Franzel, S., Jaenicke, H. and Janssen, W. (1996) Choosing the right trees: Setting priorities for multipurpose tree improvement. ISNAR Research Report (pp. 8, 87).

Frison, E.A., Cherfas, J., Eyzaguirre, P.B. and Johns, T. (2004) Biodiversity, nutrition and health: Making a difference to hunger and conservation in the developing world. *Seventh Meeting of the Conference of the Parties to the Convention on Biological Diversity (COP7)*, International Plant Genetic Resources Institute, Rome, Italy.

Garrity, D. (2004) World agroforestry and the achievement of the Millennium Development Goals. *Agroforestry Systems* 61, 5–17.

Gliessman, S.R. (1998) *Agroecology: Ecological Processes in Sustainable Agriculture*. Chelsea, USA: Ann Arbor Press.

Gockowski, J., Tonye, J. and Baker, D. (1997) Characterisation and diagnosis of agricultural systems in the Alternatives to Slash and Burn forest margins benchmark of southern Cameroon. *Report to ASB Programme*, IITA, Ibadan, Nigeria.

Gockowski J., Baker D., Tonye J., Weise S., Ndoumbe M., Tiki-Manga T. and Foaguegue A. (1998) Characterisation and diagnosis of farming systems in the ASB forest margin benchmark of southern Cameroon. Mimieograph. Yaoundé, IITA Humid Forest Ecoregional Center.

Gockowski, J.J. and Dury, S. (1999) The economics of cocoa-fruit agroforests in southern Cameroon. In F. Jiménez and J. Beer (eds) *Multi-strata Agroforestry Systems with Perennial Crops* (pp. 239–241). Turrialba, Costa Rica: CATIE.

Gockowski, J., Blaise Nkamleu, G. and Wendt, J. (2001) Implications of resource-use intensification for the environment and sustainable technology in the Central African rainforest. In D.R. Lee and C.B. Barrett (eds) *Trade-Offs or Synergies? Agricultural Intensification, Economic Development and the Environment* (pp. 197–219). Wallingford: CABI.

Guarino, L. (1997) *Traditional African Vegetables.* Rome, Italy: International Plant Genetic Resources Institute.

Harlan, J.R. (1975) *Crops and Man*, Madison, WI: American Society of Agronomy/Crop Science Society of America.

Homma, A.K.O. (1994) Plant extractivism in the Amazon: Limitations and possibilities. In M. Clusener-Godt and I. Sachs (eds) *Extractivism in the Brazilian Amazon: Perspectives on Regional Development* (pp. 34–57). MAB Digest 18, Man and the Biosphere. Paris: UNESCO.

ICRAF (1997) *Annual Report 1996*. Nairobi, Kenya: ICRAF.

Jaenicke, H., Franzel, S. and Boland, D.J. (1995) Towards a method to set priorities amongst species for tree improvement research: A case study from West Africa. *Journal of Tropical Forest Science* 7, 490–506.

Jaenicke, H., Simons, A.J., Maghembe, J., and Weber, J.C. (2000) Domesticating indigenous fruit trees for agroforestry. *Acta Horticulturae* 523, 45–52.

Kalenda, D.T., Missang, C.E., Kinkela, T.T., Krebs, H.C. and Renard, C.M.G.C. (2002) New developments in the chemical characterisation of the fruit of *Dacryodes edulis* (G. Don) H.J. Lam. *Forests, Trees and Livelihoods* 11, 119–123.

Kapseu, C., Avouampo, E. and Djeumako, B. (2002) Oil extraction from *Dacryodes edulis* (G. Don) H.J. Lam fruit. *Forests, Trees and Livelihoods* 11, 97–104.

Kengni, E., Tchoundjeu, Z., Tchouangep, F.M. and Mbofung, C.M.F. (2001) Sensory evaluation of *Dacryodes edulis* fruit types. *Forests, Trees and Livelihoods* 11, 1–10.

Kengue, J. (2002) *Safou: Dacryodes edulis G. Don.* Fruits for the Future 3. International Centre for Underutilized Crops, Southampton, UK, 147 pp.

Kengue, J., Tchuenguem Fohouo, F.N. and Adewusi, H.G. (2002) Towards the improvement of Safou (*Dacryodes edulis*): Population variation and reproductive biology. *Forests, Trees and Livelihoods* 11, 73–84.

Kindt, R. (2002) Methodology for tree species diversification planning for African ecosystems. PhD thesis, University of Ghent, 327 pp.

Ladipo, D.O., Fondoun, J.-M. and Ganga, N. (1996) Domestication of bush mango (*Irvingia* spp.): Some exploitable intraspecific variations in west and central Africa. In R.R.B. Leakey and A.C. Newton (eds). *Tropical Trees: The Potential for Domestication and the Rebuilding of Forest Resources* (pp. 193–205) London: HMSO.

Laird, S.A. (2002) *Biodiversity and Traditional Knowledge: Equitable Partnerships in Practice.* People and Plants Conservation Series. London: Earthscan.

Leakey, R.R.B. (1985) The capacity for vegetative propagation in trees. In M.G.R. Cannell and J.E. Jackson (eds) *Attributes of Trees as Crop Plants* (pp. 110–133). Abbots Ripton, Huntingdon: Institute of Terrestrial Ecology.

Leakey, R.R.B. (1991) Towards a strategy for clonal forestry: Some guidelines based on experience with tropical trees. In J.E. Jackson (ed.) *Tree Breeding and Improvement* (pp. 27–42). Tring: Royal Forestry Society of England.

Leakey, R.R.B. (1999a) Potential for novel food products from agroforestry trees. *Food Chemistry* 64, 1–14.

Leakey, R.R.B. (1999b) Agroforestry for biodiversity in farming systems. In W.W. Collins and C.O. Qualset (eds) *Biodiversity in Agroecosystems* (pp. 127–145). New York: CRC Press.

Leakey, R.R.B. (2001a) Win:Win landuse strategies for Africa: 1. Building on experience with agroforests in Asia and Latin America. *International Forestry Review* 3, 1–10.

Leakey, R.R.B. (2001b) Win:Win landuse strategies for Africa: 2. Capturing economic and environmental benefits with multistrata agroforests. *International Forestry Review* 3, 11–18.

Leakey, R.R.B. (2004) Physiology of vegetative propagation in trees. In J. Burley, J. Evans, and J.A. Youngquist (eds) *Encyclopaedia of Forest Sciences* (pp. 1655–1668). London: Academic Press.

Leakey, R.R.B. (2005) Domestication potential of Marula (*Sclerocarya birrea* subsp *caffra*) in South Africa and Namibia: 3. Multi-trait selection. *Agroforestry Systems* 64, 51–59.

Leakey, R.R.B. and Newton, A.C. (1994a) Domestication of 'Cinderella' species as the start of a woody-plant revolution. In R.R.B. Leakey and A.C. Newton (eds) *Tropical Trees: The Potential for Domestication and the Rebuilding of Forest Resources* (pp. 3–4). London: HMSO.

Leakey, R.R.B. and Newton, A. (1994b) Domestication of tropical trees for timber and non-timber forest products. MAB Digest No. 17, UNESCO, Paris, 94 pp.

Leakey, R.R.B. and Izac, A.-M. (1996) Linkages between domestication and commercialisation of non-timber forest products: Implications for agroforestry. In R.R.B. Leakey, A.B. Temu and M. Melnyk (eds) *Domestication and Commercialisation of Non-timber Forest Products* (pp. 1–7). Non-wood Forest Products No. 9, Rome: FAO.

Leakey, R.R.B. and Sanchez, P.A. (1997) How many people use agroforestry products? *Agroforestry Today* 9 (3), 4–5.

Leakey, R.R.B. and Simons, A.J. (1998) The domestication and commercialisation of indigenous trees in agroforestry for the alleviation of poverty. *Agroforestry Systems* 38, 165–176.

Leakey, R.R.B. and Tomich, T.P. (1999) Domestication of tropical trees: From biology to economics and policy. In L.E. Buck, J.P. Lassoie and E.C.M. Fernandes (eds) *Agroforestry in Sustainable Ecosystems* (pp. 319–338). New York: CRC Press/Lewis Publishers.

Leakey, R.R.B. and Tchoundjeu, Z. (2001) Diversification of tree crops: Domestication of companion crops for poverty reduction and environmental services. *Experimental Agriculture* 37, 279–296.

Leakey, R.R.B. and Page, T. (2006) The 'ideotype concept' and its application to the selection of 'AFTP' cultivars. *Forests, Trees and Livelihoods* 16.

Leakey, R.R.B., Last, F.T. and Longman, K.A. (1982) Domestication of forest trees: A process to secure the productivity and future diversity of tropical ecosystems. *Commonwealth Forestry Review* 61, 33–42.

Leakey, R.R.B., Mesén, J.F., Tchoundjeu, Z., Longman, K.A., Dick, J.McP., Newton, A.C., Matin, A., Grace, J., Munro, R.C. and Muthoka, P.N. (1990) Low-technology techniques for the vegetative propagation of tropical tress. *Commonwealth Forestry Review* 69, 247–257.

Leakey, R.R.B., Newton, A.C. and Dick, J.McP. (1994) Capture of genetic variation by vegetative propagation: Processes determining success. In R.R.B. Leakey and A.C. Newton (eds) *Tropical Trees: The Potential for Domestication and the Rebuilding Forest Resources* (pp. 72–83). London: HMSO.

Leakey, R.R.B., Temu, A.B., Melnyk, M. and Vantomme, P. (eds) (1996) *Domestication and Commercialization of Non-Timber Forest Products for Agroforestry.* Non-Wood Forest Products No 9. Rome: FAO.

Leakey, R.R.B., Atangana, A.R., Kengni, E., Waruhiu, A.N., Usuro, C., Anegbeh, P.O. and Tchoundjeu, Z. (2002) Domestication of *Dacryodes edulis* in

West and Central Africa: Characterisation of genetic variation. *Forests, Trees and Livelihoods* 12, 57–72.

Leakey, R.R.B., Schreckenberg, K. and Tchoundjeu, Z. (2003) The participatory domestication of West African indigenous fruits. *International Forestry Review* 5, 338–347.

Leakey, R.R.B., Tchoundjeu, Z., Smith, R.I., Munro, R.C., Fondoun, J.-M., Kengue, J., Anegbeh, P.O., Atangana, A.R., Waruhiu, A.N., Asaah, E., Usoro, C. and Ukafor, V. (2004) Evidence that subsistence farmers have domesticated indigenous fruits (*Dacryodes edulis* and *Irvingia gabonensis*) in Cameroon and Nigeria. *Agroforestry Systems* 60, 101–111.

Leakey, R.R.B., Shackleton, S. and du Plessis, P. (2005a) Domestication potential of Marula (*Sclerocarya birrea* subsp *caffra*) in South Africa and Namibia: 1. Phenotypic variation in fruit traits. *Agroforestry Systems* 64, 25–35.

Leakey, R.R.B., Pate, K. and Lombard, C. (2005b) Domestication potential of Marula (*Sclerocarya birrea* subsp *caffra*) in South Africa and Namibia: 2. Phenotypic variation in nut and kernel traits. *Agroforestry Systems* 64, 37–49.

Leakey, R.R.B., Greenwell, P., Hall, M.N., Atangana, A.R., Usoro, C., Anegbeh, P.O., Fondoun, J-M. and Tchoundjeu, Z. (2005c) Domestication of *Irvingia gabonensis*: 4. Tree-to-tree variation in food-thickening properties and in fat and protein contents of Dika Nut. *Food Chemistry* 90, 365–378.

Leakey, R.R.B. Attah-Krah, K.N., Clement, C.R., Garrity, D.P., Garrett, H.E., McNeely, J.A., Nair, P.K.R., Sanchez, P.A., Scherr, S.J., Shapiro, H-Y. and Swaminathan, M.S. (submitted for publication) Agroforestry: Scoring Millennium Development Goals. *World Development*.

Libby, W.J. (1982) What is the safe number of clones per plantation? In H.M. Heybroek, B.R. Stephan and K. von Weissenberg (eds) *Resistance to Diseases and Pests in Forest Trees* (pp. 324–360). Wageningen, The Netherlands: PUDOC.

Longman, K.A. (1993) *Rooting Cuttings of Tropica Trees, Tropical Trees: Propagation and Planting Manuals* (Vol 1). Commonwealth Science Council, London.

Lowe, A.J., Russell J.R., Powell W. and Dawson I.K. (1998) Identification and characterization of nuclear, cleaved amplified polymorphic sequences (CAPS) loci in *Irvingia gabonensis* and *I. wombolu*, indigenous fruit trees of west and central Africa. *Molecular Ecology* 7, 1771–1788.

Lowe, A.J., Gillies, A.C.M., Wilson, J. and Dawson, I.K. (2000) Conservation genetics of bush mango from central/west Africa: Implications from random amplified polymorphic DNA analysis. *Molecular Ecology* 9, 831–841.

Maghembe, J.A., Simons, A.J., Kwesiga, F. and Rarieya, M. (1998) *Selecting Indigenous Trees for Domestication in Southern Africa: Priority Setting with Farmers in Malawi, Tanzania, Zambia and Zimbabwe*. Nairobi: ICRAF.

Mbile, P., Tchoundjeu, Z., Degrande, A., Asaah, E. and Nkuinkeu, R. (2003) Mapping the biodiversity of 'Cinderella' trees in Cameroon. *Biodiversity* 4, 17–21.

Mbile P., Tchoundjeu, Z., Degrande, A., Avana, M-L. and Tsobeng, C. (2004) Non-mist vegetative propagation by resource-poor, rural farmers of the forest zone of Cameroon: Some technology adaptations to enhance practice. *Forest, Trees and Livelihoods* 14, 43–52.

Mbofung, C.M.F., Silou, T. and Mouragadja, I. (2002) Chemical characterisation of Safou (*Dacryodes edulis*) and evaluation of its potential as an ingredient in nutritious biscuits. *Forests, Trees and Livelihoods* 12, 105–118.

McCalla, A.F. and Brown, L.R. (1999) Feeding the developing world in the next Millenium: A question of science? *Proceedings of Conference on 'Ensuring Food Security, Protecting the Environment, Reducing Poverty in Developing Countries. Can Biotechnology Help?'* 21–22 October 1999, World Bank, Washington DC.

McNeely J.A. and Scherr S.J. (2003) *Ecoagriculture: Strategies to Feed the World and Save Wild Biodiversity.* Washington, DC: Island Press.

Mialoundama, F., Avana, M-L., Youmbi, E., Mampouya, P.C., Tchoundjeu, Z., Mbeuyo, M., Galamo, G.R., Bell, J.M., Kopguep, F., Tsobeng, A.C. and Abega, J. (2002) Vegetative propagation of *Dacryodes edulis* (G. Don) H.J. Lam by marcots, cuttings and micropropagation. *Forests, Trees and Livelihoods* 12, 85–96.

Mitschein, T.A. and Miranda, P.S. (1998) POEMA: A proposal for sustainable development in Amazonia. In D.E. Leihner and T.A. Mitschein (eds) *A Third Millenium for Humanity? The Search for Paths of Sustainable Development* (pp. 329–366). Frankfurt am Main: Peter Lang.

Mkonda, A., Lungu, S., Maghembe, J.A. and Mafongoya, P.L. (2003) Fruit- and seed- germination characteristics of *Strychnos cocculoides* an indigenous fruit tree from natural populations in Zambia. *Agroforestry Systems* 58, 25–31.

Mudge, K.W. and Brennan, E.B. (1999) Clonal propagation of multipurpose and fruit trees used in agroforestry. In L.E. Buck, J.P. Lassoie and E.C.M. Fernandes (eds) *Agroforestry in Sustainable Ecosystems* (pp. 157–190). New York: CRC Press/Lewis Publishers.

Ndoye, O., Ruiz-Perez, M. and Ayebe, A. (1997) The markets of non-timber forest products in the humid forest zone of Cameroon. *Rural Development Forestry Network*, Network Paper 22c. London: Overseas Development Institute.

Ndoye, O., Awono, A., Schreckenberg, K. and Leakey, R.R.B. (2005) *Commercialising Indigenous Fruit for Poverty Alleviation.* A policy briefing note for governments in the African humid tropics region. London: Overseas Development Institute.

Ndungu, J. and Boland, D. (1994) *Sesbania* collections in southern Africa: Developing a model for cooperation between CGIAR and NARS. *Agroforestry Systems* 27, 129–143.

Ndungu, J., Jaenicke, H. and Boland, D. (1995) Considerations for germplasm collection of indigenous fruit trees in the Miombo. In J.A. Maghembe, Y. Ntupanyama and P.W. Chirwa (eds) *Improvement of Indigenous Fruit Trees of the Miombo Woodlands of Southern Africa* (pp. 1–11). Nairobi: International Centre for Research in Agroforestry.

Ngo Mpeck, M.L., Tchoundjeu, Z. and Asaah, E. (2003a) Vegetative propagation of *Pausinystalia johimbe* (K. Schum) by leafy stem cuttings. *Propagation of Ornamental Plants* 3, 11–18.

Ngo Mpeck, M.L., Asaah, E., Tchoundjeu, Z. and Atangana, A.R. (2003b) Strategies for the domestication of *Ricinodendron heudelotii*: Evaluation of variability in natural populations from Cameroon. *Agriculture and Environment* 1, 257–262.

Okafor, J.C. (1980) Edible indigenous woody plants in the rural economy of the Nigerian forest zone. *Forest Ecology and Management* 3, 45–55.

Okafor, J.C. (1983) Varietal delimitation in *Dacryodes edulis* (G. Don) H.J. Lam. (Burseraceae). *International Tree Crops Journal* 2, 255–265.

Okafor, J.C. and Lamb, A. (1994) Fruit trees: Diversity and conservation strategies. In R.R.B. Leakey and A.C. Newton (eds) *Tropical Trees: The Potential for Domestication and the Rebuilding of Forest Resources* (pp. 34–41). London: HMSO.

Panik, F. (1998) The use of biodiversity and implications for industrial production. In D.E. Leihner and T.A. Mitschein (eds) *A Third Millennium for Humanity? The Search for Paths of Sustainable Development* (pp. 59–73). Frankfurt am Main: Peter Lang.

Peters, C.M., Gentry, A. and Mendelson, R. (1989) Valuation of a tropical forest in Peruvian Amazonia. *Nature* 339, 655–657.

Poulton, C. and Poole. N. (2001) *Poverty and Fruit Tree Research: Issues and Options Paper.* On WWW at http://www.nrinternational.co.uk/forms2/frpzf0141b.pdf. DFID Forestry Research Programme, Wye College, Ashford.

Rao, M.R., Palada, M.C. and Becker, B.N. (2004) Medicinal and aromatic plants in agroforestry systems. In P.K.R. Nair, M.R. Rao and L.E. Buck (eds) *New Vistas in Agroforesty: A Compendium for 1st World Congress of Agroforestry.* Agroforestry Systems 61, 107–122.

Reardon, T., Timmer, C.P., Barrett, C.B. and Berdegue, J. (2003) The rise of supermarkets in Africa, Asia and Latin America. *American Journal of Agricultural Economics* 85, 1140–1146.

Roshetko, J.M. and Evans, D.O. (1999) *Domestication of Agroforestry Trees in Southeast Asia.* Farm, Forest and Community Tree Research Reports, Special Issue, Winrock International (FACT Net), Morrilton, Arkansas, USA.

Schippers, R.R. (2000) *African Indigenous Vegetables: An Overview of the Cultivated Species*. Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation.

Schippers, R.R. and Budd, L. (1997) *African Indigenous Vegetables*. Rome: IPGRI, and England: Natural Resources Institute.

Schreckenberg, K. (1999) Products of a managed landscape: Non-timber forest products in the parklands of the Bassila Region, Benin. *Global Ecology and Biogeography* 8, 279–289.

Schreckenberg, K., Degrande, A. Mbosso, C. Boli Baboulé, Z., Boyd, C., Enyong, L., Kanmegne, J. and Ngong, C. (2002) The social and economic importance of *Dacryodes edulis* (G. Don) H.J. Lam in southern Cameroon. *Forests, Trees and Livelihoods* 12, 15–40.

Schroth, G., Da Fonseca, G.A.B., Harvey, C.A., Gascon, C., Vasconcelos, H.L. and Izac, A-M.N. (2004) *Agroforestry and Biodiversity Conservation in Tropical Landscapes.* Washington, DC: Island Press.

Serageldin, I. and Persley, G.J. (2000) *Promethean Science: Agricultural Biotechnology, the Environment, and the Poor.* CGIAR, 1818 H St, Washington, DC 20433, USA, 41 pp.

Shackleton, C.M., Dzerefos, C.M., Shackleton, S.E. and Mathabela, F.R. (2000) The use of and trade in indigenous edible fruits in the Bushbuckridge savanna region, South Africa. *Ecology of Food and Nutrition* 39, 225–245.

Shackleton, S.E., Shackleton, C.M., Cunningham, A.B., Lombard, C., Sullivan, C.A. and Netshiluvhi, T.R. (2002) Knowledge on *Sclerocarya birrea* in South and Southern Africa: A summary. Part 1. Taxonomy, ecology and role in rural livelihoods. *Southern African Forestry Journal* 194, 27–41.

Shackleton, C.M., Botha, J. and Emanuel, P.L. (2003a) Productivity and abundance of *Sclerocarya birrea* subsp. *caffra* in and around rural settlements and protected areas of the Bushbuckridge lowveld, South Africa. *Forests, Trees and Livelihoods* 13, 217–232.

Shackleton, S.E., Wynberg, R.P., Sullivan, C.A., Shackleton, C.M., Leakey, R.R.B., Mander, M., McHardy, T., den Adel, S., Botelle, A., du Plessis, P., Lombard, C., Laird, S.A., Cunningham, A.B., Combrinck, A. and O'Regan, D.P. (2003b) Marula commercialisation for sustainable and equitable livelihoods: Synthesis of a southern African case study. In *Winners and Losers in Forest Product Commercialization, Final Technical Report to DFID, FRP R7795*, Appendix 3.5. Wallingford: CEH.

Shiembo, P.N., Newton, A.C. and Leakey, R.R.B. (1996a) Vegetative propagation of *Irvingia gabonensis* Baill., a West African fruit tree. *Forest Ecology and Management* 87, 185–192.

Shiembo, P.N., Newton, A.C. and Leakey, R.R.B. (1996b) Vegetative propagation of *Gnetum africanum* Welw., a leafy vegetable from West Africa. *Journal of Horticultural Science* 71 (1), 149–155.

Shiembo, P.N., Newton, A.C. and Leakey, R.R.B. (1997) Vegetative propagation of *Ricinodendron heulelotii* (Baill) Pierre ex Pax, a West African fruit tree. *Journal of Tropical Forest Science* 9, 514–525.

Simons, A.J. (1996) ICRAF's strategy for domestication of indigenous tree species. In R.R.B. Leakey, A.B.

Temu, M. Melnyk and P. Vantomme (eds) *Domestication and Commercialization of Non-Timber Forest Products in Agroforestry Systems, Non-Wood Forest Products* 9, 8–22. Rome: FAO.

Simons, A.J. and Leakey, R.R.B. (2004) Tree domestication in tropical agroforestry. *Agroforestry Systems* 61, 167–181.

Simons, A.J., Jaenicke, H., Tchoundjeu, Z., Dawson, I., Kindt, R., Oginosako, Z., Lengkeek, A. and Degrande, A. (2000a) The future of trees is on farms: Tree domestication in Africa. In *Forests and Society: The Role of Research* (pp. 752–760). XXI IUFRO World Congress, Kuala Lumpur, Malaysia.

Simons, A.J., Tchoundjeu, Z., Munjuga, M., Were, J., Dawson, I., Ruigu, S., Lengkeek, A. and Jaenicke, H. (2000b) Domestication strategy. In J.B. Hall, E.M. O'Brien, and F.L. Sinclair (eds) *Prunus africana*: *A Monograph* (pp. 39–43). Bangor: UNCW.

Smartt, J. and Haq, N. (1997) *Domestication, Production and Utilization of New Crops*. Southampton: International Centre for Underutilized Crops.

Sullivan, C.A. (2003) Forest use by Amerindians in Guyana – implications for development policy. In D. Barker and D. McGregor (eds) *Resources, Planning and Environmental Management in a Changing Caribbean*. Kingston: UWI Press.

Sullivan, C.A. and O'Regan, D.P. (2003) *Winners and Losers in Forest Product Commercialization*. Final Report to DFID Forestry Research Programme (R7795), Centre for Ecology and Hydrology, Wallingford, UK. On WWW at http://www.ceh-wallingford.ac.uk/research/winners/literature.html.

Sunderland T.C.H., Clark, L.E. and Vantomme, P. (1999) *Non-Wood Forest Products of Central Africa, Current Research Issues and Prospects for Conservation and Development*. Rome: FAO.

Sunderland, T.C.H. and Ndoye, O. (eds) (2004) *Forest Products, Livelihoods and Conservation: Case Studies of Non-Timber Forest Product Systems – Volume 2 – Africa*. Indonesia: CIFOR.

Swallow, B.M., Villarreal, M., Kwesiga, F., Holding, A.C., Agumya, A. and Thangata, P. (in press) Agroforestry and its role in mitigating the impact of HIV/AIDS. In *World Agroforestry and the Future*, *Proceedings of 25th Anniversary Conference*, 1–5 November 2003, Nairobi: ICRAF.

Tchoundjeu, Z., Duguma, B., Fondoun, J-M. and Kengue, J. (1998) Strategy for the domestication of indigenous fruit trees of West Africa: Case of *Irvingia gabonensis* in southern Cameroon. *Cameroon Journal of Biology and Biochemical Sciences* 4, 21–28.

Tchoundjeu, Z., Kengue, J. and Leakey, R.R.B. (2002a) Domestication of *Dacryodes edulis*: State-of-the art. *Forests, Trees and Livelihoods* 12, 3–14.

Tchoundjeu, Z., Avana, M.L., Leakey, R.R.B., Simons, A.J., Asaah, E., Duguma, B. and Bell, J.M. (2002b) Vegetative propagation of *Prunus africana*: Effects of rooting medium, auxin concentrations and leaf area. *Agroforestry Systems* 54, 183–192.

Tchoundjeu, Z., Ngo Mpeck, M.L., Asaah, E. and Amougou, A., (2004) A role of vegetative propagation in the domestication of *Pausinystalia johimbe* (K. Schum), a highly threatened medicinal species of West and Central Africa. *Forest Ecology and Management* 188, 175–183.

Tchoundjeu, Z., Degrande, A., Leakey, R.R.B. and Schreckenberg, K. (2005) *Participatory Domestication of Indigenous Trees for Improved Livelihoods and a Better Environment* (2 pp). A policy briefing note for governments in the African humid tropics region. London: Overseas Development Institute.

Tchoundjeu, Z., Asaah, E., Anegbeh, P., Degrande, A., Mbile, P., Facheux, C., Tsobeng, A., Atangana, A. and Ngo-Mpeck, M-L. (in press) AFTPs: Putting participatory domestication into practice in West and Central Africa. *Forests, Trees and Livelihoods*.

ten Kate, K. and Laird, S. (1999) *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit-Sharing*. London: Earthscan.

Thiong'o, M.K., Kingori, S. and Jaenicke, H. (2002) The taste of the wild: Variation in the nutritional quality of marula fruits and opportunities for domestication. *Acta Horticulturae* 575, 237–244.

Tomich, T.P., van Noordwijk, M., Budidarsono, S., Gillison, A., Kusumanto, T., Stolle, F. and Fagi, A.M. (2001) Agricultural intensification, deforestation and the environment: Assessing trade-offs in Sumatra, Indonesia. In D.R. Lee and C.B. Barrett (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment* (pp. 221–244). Wallingford: CABI Publishing.

Vedeld, P., Angelsen, A., Sjaastad, E. and Kobugabe Berg, G. (2004) *Counting on the Environment: Forest Incomes and the Rural Poor.* Environmental Economics Series No 98, World Bank, Washington DC, USA, 95 pp.

Waruhiu, A.N., Kengue, J., Atangana, A.R., Tchoundjeu, Z. and Leakey, R.R.B. (2004) Domestication of *Dacryodes edulis*: 2. Phenotypic variation of fruit traits in 200 tress from four populations in the humid lowlands of Cameroon. *Food, Agriculture & Environment* 2, 340–346.

Weber, J.C., Sotelo Montes, C., Vidaurre, H., Dawson, I.K. and Simons, A.J. (2001) Participatory domestication of agroforestry trees: An example from the Peruvian Amazon. *Development in Practice* 11 (4), 425–433.

Wiersum, K.F. (1996) Domestication of valuable tree species in agroforestry systems: Evolutionary stages from gathering to breeding, In R.R.B. Leakey, A.B. Temu, M. Melnyk and P. Vantomme (eds) *Domestication and Commercialization of Non-timber Forest Products, Non-Wood Forest Products* 9 (pp. 147–158). Rome: FAO.

Wynberg, R.P., Laird, S.A., Shackleton, S., Mander, M., Shackleton, C., du Plessis, P., den Adel, S., Leakey, R.R.B., Botelle, A., Lombard, C., Sullivan, C., Cunningham, A.B. and O'Regan, D. (2003) Marula policy brief. Marula commercialisation for sustainable and equitable livelihoods. *Forests, Trees and Livelihoods* 13, 203–215.