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# Comparing the "Big Five": A framework for the sustainable management of indigenous fruit trees in the drylands of East and Central Africa

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**Abstract**

There are many fruit trees that could be integrated into dryland farming systems in Sub-Saharan Africa to support income and nutritional security. Fruit contains almost all known vitamins and many essential minerals. Five important fruit species that are cross-regional include: *Adansonia digitata*, *Tamarindus indica*, *Zizyphus mauritiana*, *Sclerocarya birrea*, and *Mangifera indica*. While these species are well integrated in the Sahel region, besides mango, they are generally absent from smallholder farms in East and Central Africa. Fruits of the species in this region are mostly harvested unsustainably from the wild communal areas. Unlike the situation in the neighboring Southern Africa region, where *S. birrea* is utilized extensively in the wine industry, there is virtually no use for the tree in this region, largely because of limited knowledge. *Z. mauritiana* use is also limited because of low quality germplasm—the hard stone clings to the flesh. An analytical framework based on five factors (site requirements, genetic variability, propagation methods, nutritional properties and utilization, and commercial potential) is used to compare knowledge status and gaps on the species in the region. While this analysis reveals the existence of considerable knowledge between and within the species, lack of improved germplasm and markets emerge as two key constraints limiting their conservation through on-farm planting. Key research and development needs identified are: (a) fostering cross-collaboration and knowledge exchange with other regions where the species are fairly well utilized, and (b) developing criteria and indicators for monitoring impacts and increased investments on the "Big Five" on livelihood of dryland communities and on biodiversity conservation.


*Keywords:* Nutrition; Germplasm; Agroforestry; Marketing; Livelihood; Conservation

## 1. Introduction

Food security and alleviation of poverty in rural communities in Africa can be improved by diversifying the farming systems (Leakey and Simons, 1998). Crop

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farming alone, without incorporating livestock production, horticulture, tree planting and embracing alternative livelihoods such as bee keeping, irrigated agriculture, indigenous fruits and marketing of non-wood products, would not improve the standard of living for farming communities in Africa (Sanchez, 1995). This is particularly important in the drylands of the East and Central Africa (ECA) region where frequent famine and droughts are increasing the incidence of hunger and poverty. Vast tracts of the ECA region are classified as drylands, with Kenya having the most, as a percentage of its land area.

Between cropping seasons, farmers in the drylands of the region rely on alternative food products that include trees, fruits, animals and sale of non-wood products to eke a living, especially during droughts (Muok et al., 2000; Chikamai et al., 2004). Farming with fruit trees, particularly mangoes, as an alternative source of food and nutritional security is increasingly becoming popular (Greisbach, 2003). Fruit contains almost all known vitamins and many essential minerals. Children and women are the major users of indigenous fruit trees (IFTs) which are mostly available in the dry seasons (Swai, 2005). Where commercialized exploitation of indigenous fruits occur, for example, in the west and southern Africa regions, indigenous fruits show great potential – as much as exotic fruits – in providing food, vitamins and income. In contrast, indigenous fruits have largely not been exploited commercially in the ECA region. This is in spite of the existence of a wide range of IFTs, including those present in the other dryland regions of Africa.

There is a considerable wealth of knowledge among farmers and rural communities on the value and uses of IFTs (Demel and Abeje, 2004). This knowledge has been used, to some extent, to prioritize species domestication and identify research and development needs (Muok et al., 2000). However, there is little planting of these trees, with the possible exception of mangoes. Most of what is used is collected from the wild. Unfortunately, many trees in the wild are being destroyed through processes such as charcoal production (an important economic product for many poor people) and expansion of agriculture (Maghembe, 1994). Studies by Mohamed (2005) in communal lands in eastern Kenya, for instance, found species density to be more abundant in sparsely populated areas due to less clearance from cultivation, fires and destruction of wildings by livestock. In Uganda, there is fear among farmers that fruits may attract birds that damage crops (Okullo, 2005). Existing legislature and taboos regulating the use of the trees are currently not adhered to and the knowledge of codified rules is disappearing with generational changes.

Reversing this situation requires integration of the IFTs into the farming systems of the area. At present, the observations of Leakey and Simons (1998) that inconsistency in product quality and limited access to markets are two key problems to commercialization of the non-timber forest products (NTFPs) holds true for the ‘‘Big Five’’ as well. Farmers typically do not plant indigenous trees but protect those that grow naturally for their own use (Muok et al., 2000). National tree seed centres often do not stock many indigenous species because, compared to the exotic species, there is little demand for them. This is a ‘catch-22’; farmers often plant only the tree seedlings available in local government or project tree nurseries rather than what they would have chosen. Also, there is limited extension materials developed from research on the IFTs (Muok et al., 2000). While the provision of improved germplasm may enhance the planting of IFTs, this must be accompanied by efforts to expand the markets so that farmers can increase returns from their investments (Cooper et al., 1996).

Priority setting exercises within the ECA region have identified a number of species in the drylands for domestication. Four species that typically are high are *Sclerocarya birrea* (marula), *Tamarindus indica* (tamarind), *Adansonia digitata* (baobab), and *Zizyphus mauritiania* (desert apple) (Chikamai et al., 2004). These species are keystone species in most landscapes of the drylands. In some areas, farmers protect them, especially if they have commercial value (Nyandoi, 2004). Besides these species, *Mangifera indica* (mango) is another key species on farmlands in the drylands. It has been naturalized in the region where it was introduced by Asian and Arab traders at the turn of the 19th century. Synthesis of knowledge on the five species, referred to as the ‘‘Big Five’’ in this paper, would provide insights for developing management options that enhance their conservation and contribution to food and the nutritional security of rural communities. This paper focuses on research and development efforts needed to get wide-scale planting, use and commercialization of the fruits and other non-timber products of the species.

A logical starting point is an analytical framework that helps assess the suitability of the species for use across the region. We do this by identifying the knowledge base and gaps for each species using five key factors of importance to producers and consumers: site requirements, genetic variability, propagation methods, nutritional properties and utilization, and commercial potential. We then highlight the extent to which the existing knowledge could be used to promote greater use of the species and identify critical gaps in the sustainable management of the species. The final section highlights the implications for research and development, taking into consideration the existing criteria and indicators proposed for sustainable forest management under the Dry-Zone Africa Initiative (Anon., 1999).

## 2. Approach

We used two approaches to determine the key factors that influence farmers' decisions to invest in fruit trees: (a) review of literature, within and outside our region of interest, and (b) consultations with key stakeholders—farmers, and the research and development community during a regional workshop on agroforestry in the drylands of the ECA that was held at ICRAF in September 2004 (Kassim et al., 2005). This was followed by a second regional workshop (Simitu et al., 2005) at a local market in the drylands of eastern Kenya where the sale of indigenous fruits is important (Muok et al., 2000). These efforts identified five factors of importance to users: site requirements, genetic variability and improvement potential, propagation methods, nutritional properties, and commercial potential.

The importance of these attributes has been underscored by others before (Demel and Abeje, 2004). For instance, on nutritional properties, Leakey (1999) observed that knowledge is important for engaging with the food industry. It forms the basis for guiding investments in research on domestication and genetic improvement. On germplasm, the call has been made for scientists to provide a regular supply of uniform and high quality germplasm before investors commit capital to the developing markets (Leakey and Izac, 1996). On commercialization, it is recognized that without an expanded or a new market, the incentives to domesticate intensively for self-use are not sufficient (Leakey and Simons, 1998). The absence of markets has limited research efforts so far to improve the productivity of the trees.

Synthesizing what is known about the "Big Five" along these factors provides a sound basis for their domestication and for developing criteria and indicators for monitoring their sustainable management on smallholder farms. The focus is on non-timber tree products (fruits, seeds and leaves), best relating to indicator 4.5 ('managed and sustainable extraction of non-wood forest products') of the Africa Dry-Zone sustainable forest management process (Anon., 1999).

## 3. The "Big Five": knowledge status and gaps

### 3.1. *Sclerocarya birrea (A. Rich.) Hoscht*

This is a dioecious multipurpose fruit tree that occurs in the semi-arid, deciduous savannas of Ethiopia, Eritrea, Sudan, Kenya, Uganda, Tanzania, Central Africa Republic and Democratic Republic of Congo (Kokwaro and Gillet, 1980; Hall and O'Brein, 2002; ICRAF, 2005a). Known as marula, its natural range in the region spreads from 0 to 1800 m above mean sea level, with habitat varying from dry and rocky hillsides to riparian environment, though it is most common on rocky sites with sandy to sandy clay soils.

Kenya and Tanzania have higher genetic diversity than other countries in the region (Kokwaro and Gillet, 1980; Muok, 2005), suggesting a wide gene pool that would be important for the development of improved germplasm. The genetic diversity observed includes the existence of a number of subspecies in specific sites. For instance, *multifoliolata*, *caffra* and *birrea* subspecies are widespread in the region (Mbuya et al., 1994; Maundu et al., 1999). Muok (2005) recently identified subspecies *multifoliolata* in Nyanza (Kenya) and Ruaha (Tanzania), subspecies *caffra* in Kwale (Kenya) and Morogoro (Tanzania) and subspecies *birrea* in Baringo, Mbeere, Kitui and Mombasa in Kenya. Genetic variation studies by Agufa (2002) of marula in eastern and southern Africa regions also

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Table 1
Selected nutritional composition of the fruits and kernels of the "Big Five" in Kenya

| Species | Plant part | Energy (kcal) | Protein (g) | Fat (g) | Vitamin C (mg) | P (mg) | Ca (mg) | Fe (mg) | K (mg) |
|---|---|---|---|---|---|---|---|---|---|
| *M. indica* | Fruit | 265 | 0.5 | | 30.0 | | | 0.5 | |
| *A. digitata* | Fruit | 1229 | 2.7 | 0.2 | 20.9 | 76.2 | 335 | 2.65 | 2409 |
| *A. digitata* | Kernel | 1803 | 33.7 | 30.6 | | 5.12 | 273 | 6.55 | 1275 |
| *A. digitata* | Pulp | 1214 | 2.2 | 0.8 | 270 | 118.0 | 284 | 7.4 | |
| *A. digitata* | Leaves raw | 289 | 3.8 | | 50.0 | | 400 | | |
| *S. birrea* | Flesh | 225 | 0.5 | 0.4 | 194 | 11.5 | 20.1 | 0.5 | 317 |
| *S. birrea* | Fruit raw | 126 | 0.5 | 0.1 | 68.0 | 19.0 | 6.0 | 0.1 | |
| *S. birrea* | Kernel | 2703 | 28.3 | 57.3 | | 808 | 118 | 4.87 | 601 |
| *T. indica* | Fruit dried | 1130 | 5.0 | 0.6 | 9.0 | 190.0 | 166 | 2.2 | |
| *T. indica* | Fruit raw | 285 | 2.0 | 0.2 | 8.0 | 97.0 | 60.0 | | |
| *T. indica* | Fruit pulp | | 3.1 | 0.4 | | | | | |
| *T. indica* | Seeds | | 16.0 | 5.5 | | | | | |
| *Z. mauritiana* | Fruit semi-dry | 1005 | 3.7 | 0.1 | 35.0 | 64.0 | 170 | 3.1 | |
| *Z. mauritiana* | Fruit dried | 1201 | 4.3 | 0.1 | 24.0 | 210 | 56.0 | 3.0 | |
| *Z. mauritiana* | Fruit dry | 565 | 1.2 | 0.3 | 400 | | 110 | | |

*Source*: Maundu et al. (1999); Greisbach (2003).

identified significant variations between subspecies and populations within them. Studies by Agufa (2002) also indicate that random amplified polymorphic DNA (RAPD) can determine, fairly well, the genetic variation of marula populations and guide germplasm collection for evaluation and conservation. This high provenance variation has been attributed to environmental stresses such as water stress, salt stress and flooding (Muok, 2005), although genetic factors could also be involved.

Marula is rarely planted by farmers; instead farmers leave trees they want during land preparation. It can, however, be established from cuttings although the rooting success is low (Hall and O'Brein, 2002). Vegetative propagation such as grafting can also be used to conserve desired traits. There are no reports on whether or not supplementary watering during the dry seasons is necessary. Flowering occurs between September and December and fruiting between December and March (Kokwaro and Gillet, 1980). These periods, particularly the latter, coincide with dry season and hence the hunger period. Information on yield is scarce. According to one study from Kenya, a single marula tree could produce between 21,000 and 91,000 fruits in a heavy fruiting season (Thiong'o and Edje, 2002). The fruit can be stored in the open, reaching maximum maturity after 7 days (Leakey, 1999). Storage life of the fruit can be delayed for a week at 12.8 °C. After 21 days, 89% of fruits rot.

Although there is considerable variation, the fruits are rich in vitamin C (Table 1), about five times higher than that of the citrus fruit (Leakey, 1999). The fruit pulp are eaten fresh, boiled to a thick black consistency for sweetening porridge or fermented to make alcoholic drinks of both local and commercial value (Maundu et al., 1999; Leakey, 1999; Agufa, 2002). In famine years, the kernel is locally roasted and eaten. At 96% dry matter; the kernel is 57.3% fat, 28.3% protein, 6% total carbohydrates, 2.9% fibre, and rich in phosphorus, magnesium and potassium (Glew et al., 2004). The fruit is also used to make juice, jam, jellies and as a cosmetic agent (Leakey, 1999; Shackleton et al., 2002). The leaves and bark have medicinal properties (Kokwaro, 1976).

Marula has acquired significant commercial importance since its fruits and other products entered local, regional and international trade in the Southern Africa region (Shackleton et al., 2002; Phofuetsile and O'Brein, 2002). The pulp is used to extract popular commercial alcoholic drinks sold under different trade names. The fruit is edible and contains an exclusively hard endocarp with 0 to 4 kernels (Leakey, 2005) that have considerable commercial value in the South African region as nutmeat. There are no reports on commercialization of the species in the ECA region.

There is, indeed, considerable knowledge on marula that can guide its greater use and production. The Southern Africa region's advances in commercialization can guide the same in the ECA region.

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Market prospects must, however, be determined before large investments in product development are made. This will also determine its potential to contribute to socio-economic conditions, a key principal of the sustainable management of dryland forest (Anon., 1999). Meanwhile, much could be done to create awareness of the food and nutritional value of the marula fruit. Use as nutmeat is particularly exciting, and would make use of the large production that currently goes to waste. This could improve the food security of the rural poor. To encourage on-farm production and in situ conservation, practical solutions need to be developed for the dioecious reproductive nature of the species, where many seedlings raised will be male and unable to contribute directly to fruit supply upon reaching maturity (Phofuetsile et al., 2002).

### 3.2. *Tamarindus indica* L.

Tamarind is an evergreen fruit tree that occurs in the arid, semi-arid and coastal zones throughout the region. Its natural range goes from 0 to 1600 m above mean sea level and features prominently in riparian habitats (Dale and Greenway, 1961; Beentje, 1994; Mbuya et al., 1994; Maundu et al., 1999; Mohamed, 1999). It grows on a wide range of soils (Gunasena and Hughes, 2000). A study conducted on the ecological status of species in Tharaka district in eastern Kenya found its abundance, diameter classes and growth to be higher on farms than in natural woodlands (Nyandoi, 2004); suggesting farmers render some protection and conservation to the trees.

In terms of genetic diversity, sour and less sour varieties are reportedly found scattered within the region (Nyandoi, 2004). However, sweet varieties such as those found and commercialized in Thailand (Gunasena and Hughes, 2000) are absent from the region. The pulp is traditionally used to sweeten porridge by communities. The species germinates easily from seeds (by soaking in warm water for 24 h). It can be propagated from seedlings and wildlings (Maundu et al., 1999; Nyandoi, 2004; Mbabu and Wekesa, 2004; Omondi et al., 2004). However, if the seed is not well stored, especially with the pulp intact, it can be damaged by weevils. Short to long-term seed storage can be achieved under similar conditions to *S. birrea* (Omondi et al., 2004).

The flowering of tamarind varies by site and the seeds take 5–8 months to mature (Gunasena and Hughes, 2000). The fruiting season in Kenya is mostly from July to October (Omondi et al., 2004). Unless grafted, tamarind takes 10–14 years before fruiting (Gunasena and Hughes, 2000). Upon fruiting, the species is an abundant fruit producer with a single tree in Kenya providing between 150 and 300 kg per year (Kiambi, 1992; Nyandoi, 2004) for up to 50–60 years. This figure is three times higher than that of the West Africa region. One kilogram may contain 1500–2000 seeds. The fruit is brittle when ripe, containing a sticky brown edible pulp that surrounds brown seeds and can store up to 2 years. The pulp constitutes 30–50% of the fruit while the seed is about 25–40% (Gunasena and Hughes, 2000).

The fruit pulp has high levels of protein, fats and carbohydrates while the raw fruit also provides extra

Table 2
Ranking of indigenous fruit trees according to their potential to improve livelihoods in different regions of Kenya

| Species | Total ranking score based on farmers ranking in different sites of Kenya | | | | |
|---|---|---|---|---|---|
| | Baringo | Isiolo and Tharaka | Ukambani | Coast | Total score |
| *Tamarindus indica* | 2 | 1 | 1 | 1 | 1 |
| *Adansonia digitata* | – | 2 | 1 | 2 | 2 |
| *Balanites aegyptiaca* | 1 | – | – | – | 3 |
| *Bercemia discolor* | 4 | 5 | 6 | – | 4 |
| *Vitex doniana* | – | 2 | 4 | – | 5 |
| *Saba comorensis* | – | 14 | – | 3 | 6 |
| *Zizyphus mauritiana* | 3 | – | – | 4 | 7 |
| *Carissa edulis* | – | 4 | – | – | 8 |
| *Lannea alata* | – | 11 | 3 | – | 9 |
| *Sclerocarya birrea* | 8 | 6 | – | – | 10 |

*Source*: Mbabu and Wekesa (2004).

ready energy, vitamin C and minerals (Table 1). The pulp can be stored at room temperature for over 6 months without getting spoiled. The seeds have high oil and protein content (Table 1). The young leaves, flowers and immature pods are used to season rice, fish or meat in curries, soup and stews. It is little wonder that the tree is highly valued by local communities in the drylands of Kenya (Table 2).

The pulp is widely sold and used as a flavour in culinary preparations such as curries, chutneys, juice concentrate, and pulp powder juice. This is particularly so among communities of Asian and Arab origin. In Asia, the uses are greater, and include tamarind pickle and jam, syrup, candy, sauces, sweets, ice cream and sherbet (Gunasena and Hughes, 2000). Tamarind seeds yield amber colored oil, which could be used for making varnishes, paints and burning in oil lamps.

There is considerable commerce of tamarind in the region. In Kenya, for example, middlemen purchase it from farmers and traders in rural markets, and then sell it to other traders down the value chain. The main consumers are communities of Asian and Arab origin. Unfortunately, farmers have little to no information on the market prices. As a consequence, there is considerable price differential between farmgate and distant markets, as studies in eastern Kenya by Nyandoi (2004) reveal.

Tamarind has probably been a commercial product in the region for much longer than the other species. Nevertheless, it has not received significant research and development efforts. For instance, unlike marula, there is a lack of knowledge on the extent and distribution of genetic variation within and between fruit tree populations of tamarind. At present, production fruits are collected largely from the wild and from scattered natural trees within farmlands. It is rarely planted, unlike the situation in south and Central America and Asia where the tree has been established in plantations. Given the widespread use and commerce of the species, greater investment in germplasm and market development could enhance its production and conservation on farmland. Collaboration with India, where trade and product development of tamarind is advanced, would enhance progress in the ECA region. Its fruit production during the dry season could also be explored to improve food and nutritional security of dryland communities.

### 3.3. *Adansonia digitata L.*

Baobab is a deciduous fruit tree with immense girth and can reach heights of up to 25 m. It is common at the coast and in the semi-arid, deciduous savannahs in Ethiopia, Somalia, Eritrea, Sudan, Kenya, Tanzania, Central Africa Republic and Congo (Sidibe and Williams, 2002). Its habitat ranges from 0 to 1700 m above mean sea level on variable sites, from rocky to sandy coastal environments (Sidibe and Williams, 2002). In drier climatic zones, baobab is not common on hilltops (Beentje, 1994; Mbuya et al., 1994; Maundu et al., 1999; Wekesa et al., 2006) and below rainfall of about 400 mm per year its population decreases (Sidibe and Williams, 2002).

There are few studies on the ecological status of this species in its natural environment. Studies by Mohamed (2005) in the Kibwezi district of Kenya reported that the species density ranges from 0 to 60 stems per hectare in the natural woodlands and reduces to 0 to 2 trees per hectare on farms. This is attributed to the free grazing of wildings and fires. Knowledge on genetic variability within the region is also limited. In the Sahel, however, four types of baobab are recognized physically but not genetically. They are black bark (reported to have mild tasting fruits); red-bark (have most delicious fruits); grey/white-bark (used for fibre rather than having the best fruits) and dark-leaf baobab (preferred as a leafy vegetable) (Leakey, 1999; Sidibe and Williams, 2002).

Baobab can be propagated from seeds and wildlings. Short to long-term seed storage can be achieved under similar conditions as those of *S. birrea* (Omondi et al., 2004). Flowering in eastern Kenya occurs in October and November (Omondi et al., 2004). The seeds take 8 months to mature. The fruits are harvested from May to October (Nkana and Iddi, 1991; Omondi et al., 2004).

The species is widely used by local communities in the region to improve their nutrition and income (Chikamai et al., 2004). The fruits, rich in vitamin C, are used in porridges and as snacks, particularly by children. There is some limited use and sale of the pulp as a refreshing drink after it is sweetened with sugar and dyed. The leaves are rich in vitamin A, calcium, energy, carbohydrates and minerals (sodium, phosphorus, magnesium, iron and potassium) (Table 1). With the exception of one community in northern

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Tanzania (Nkana and Iddi, 1991), the leaves are rarely used in the ECA region compared to West Africa where they are used as vegetables in various sauces almost every day (von Maydell, 1986; Sidibe and Williams, 2002). Because of this use, research efforts have recently promoted production in home gardens through vegetative propagation (ICRAF, 2003). This reduces risks associated with climbing large trees. It also makes the vegetable available year round; the tree drops its leaves during the dry season. The seeds have higher oil content than the fruit pulp (Table 1). But they are not used as food or for other purposes in the region.

Unlike the situation in West Africa where the tree is planted and protected for its multiple uses, some farmers cut it down in favour of crop cultivation in this region (Mohamed, 2005). In the process, ‘‘plus trees’’ that would be sources of cultivars for superior fruits and kernel production are being lost. From experience, except for the protection of a few trees, farmers do not plant it. The fruits are typically collected from the wild and from scattered natural trees within farmlands. This would suggest the need to put conservation measures in place.

Based on the uses of the tree in West Africa, it is evident that it is underutilized in the ECA region. Training the local communities on its food value would be a starting point towards its greater utilization and conservation. This would trigger research needed to provide quality germplasm. At present, there is a lack of knowledge on the extent and distribution of genetic variation within and between the fruit tree.

### 3.4. *Zizyphus mauritiana* Lam.

Ber, also known as Jujube, is common at the coast and in the semi-arid areas of the region (Maundu et al., 1999). It is a fast growing wild fruit tree reaching 12 m high. Its habitat ranges from 0 to 1800 m above mean sea level and prefers growing along rivers, water-courses and floodplains (Dale and Greenway, 1961). There are no reports on the genetic diversity in the region. This is in contrast to the situation in India where many varieties are known and cultivars developed for commercial purposes (Pareek, 2001). Ber can be propagated from seeds, seedlings and suckers. The flowering period varies with site. For instance, it is reported to flower from September to October in Turkana, Marsabit and Lamu districts of Kenya, and from March to April in Kilifi district of Kenya (Maundu et al., 1999).

The species is ranked high by local communities (Table 2) for its nutritional value (Chikamai et al., 2004). Though the nutrient contents of the fruits vary, they are known to be rich in vitamin C and minerals especially phosphorus and calcium (Table 1). The fruits are mostly liked by children and eaten raw. The fruits are also boiled with rice and millet and stewed or baked or made into jellies, jams, chutneys or pickles. They have moderate levels of energy, protein and carbohydrates, rich in sugars, protein, carotene and magnesium (Leakey, 1999).

Unlike the situation in India, there are no significant commercialization activities of the species in the region. An important constraint is the quality of the germplasm available—the fruits produced are small and a hard seed clings to them. To get farmers enthusiastic about planting ber, the provision of quality planting materials is absolutely essential. Towards this, there is a need to introduce the improved and almost seedless varieties developed in India (Pareek, 2001). This has happened in West Africa where Pomme de Sahel as it is called is now promoted widely by both research and development programs (ICRISAT, 2004).

### 3.5. *Mangifera indica*

Mango, an evergreen tree that grows up to 15 m high, is indigenous to South and South East Asia. It was brought by early Indian and Arab traders to the ECA region and has now naturalized (Noad and Birnie, 1992; ICRAF, 1992). It grows well from 0 to 1500 m above mean sea level, does not tolerate flooding and prefers well-drained, deep sandy-loamy soil and areas (Mbuya et al., 1994; GTZ-ITFSP, 2000). Although it is drought tolerant, it requires some supplementary irrigation in order to produce high quantity and quality fruits in dry areas Greisbach, 2003).

Greisbach (2003) provides a comprehensive review of the varieties that are commercially available in the region, including their propagation and management needs. Over 30 different varieties of mangoes have been introduced into Kenya in the 1980s. Only a few of them do well under dryland farming conditions. For example, Sabre and Peach are the most drought tolerant varieties, but their fruits are fibrous, small in size and easily perishable. Improved varieties, especially Apple and Ngowe, are increasingly becoming popular and are highly marketable in world markets. Good mango fruits are without fibres and do not smell of turpentine (Noad and Birnie, 1992; Mbuya et al., 1994).

The scions of improved varieties such as Apple and Ngowe have to be grafted or budded onto the rootstocks of any of the outstanding polyembryoic varieties including Sabre, Peach, Batawi, Boribo, Dodo, Carabao, Chino, Golek, Heart, Kensington, Madoe, Matthias and Ngowe (Greisbach, 2003). The drawback of growing a mango from seed is the long wait for fruit production to start while a grafted one can fruit within 3 years.

In the dry zones of Kenya, mango generally flowers from July to November and the fruit is harvested from December to March (Greisbach, 2003). Although the yield per tree varies from 200 to 500 fruits per year, up to 1000 fruits have been recorded on a mature tree. The fruits are rich in vitamins (Table 1) (Mbuya et al., 1994; Greisbach, 2003). However, when compared with the indigenous fruits discussed here, the protein content is generally low (Table 1).

Despite the existence of improved varieties, most farmers plant unimproved local varieties such as Sabre and Peach that have a lot of fibre and are not easily marketable. Supply of improved materials is limited and often beyond what poor farmers can afford. Other important challenges facing integration of the species in the farming systems of the region include the high cost of pest and disease control and inadequate knowledge in the processing and marketing of quality germplasm.

## 4. Towards sustainable management

Notwithstanding the limited development of the ‘‘Big Five’’, the information available so far provides insights for mainstreaming them into smallholder farming systems in ways that improve the welfare of dryland’s communities while at the same time contributing to biodiversity conservation. Assessing impacts requires identifying appropriate criteria and indicators, and the guidelines in Dry-Zone Africa Initiative for sustainable forest management (Anon., 1999) provide a useful starting point. Given that most of these guidelines are for native forests, there is a need to adapt (or include) the indicators for agroecosystems such as agroforestry, at least initially before large-scale mono-culture plantations emerge. Indicators of relevance at the farm-level are productivity and associated profitability, and the resilience of the biodiverse systems as a whole to various shocks that farmers face (e.g., drought and associated crop failures, and loss of crops from outbreaks from pest and diseases).

The observations of Leakey and Simons (1998) that inconsistency in product quality and limited access to markets are two key problems limiting the commercialization of the NTFPs is, indeed, valid for the ‘‘Big Five’’ as well. Like most other indigenous trees of the region, there is a lack of knowledge on the extent and distribution of genetic variation within and between fruit tree populations. This is essential for determining appropriate genetic management strategies, both for utilization and conservation purposes (Leakey and Simons, 1998). From farmers’ perspectives, issues of importance include propagation techniques, yield level, time to fruiting, length and seasonality of fruiting and availability of markets (Maghembe, 1994; Muok et al., 2000). Early fruiting is a feature that farmers appreciate; it enables them to harvest as the tree grows. Early fruiting species should be given priority for planting on farms. However, species that fruit late in the dry season would also be useful as this is the time of food shortages. As noted for Zimbabwe, this is when communities typically depend more on indigenous fruits from the wild (Campbell, 1987).

Except for mangoes, the germplasm used by farmers is, at present (2006), largely unimproved. It is for this reason that improved mango remains top among species preferred by farmers (Greisbach, 2003). Its production is increasingly becoming profitable with many local firms now making mango juice (Boersma, 2005). Based on our observations, annual incomes could be in excess of US$ 7500 per hectare from age 10 when the trees are in full production. For the other species, the provision of a regular supply of uniform and high quality germplasm is needed before investors commit capital to developing the markets and farmers start large-scale production. Leakey and Izac (1996) make similar observation on the commercialization of indigenous trees in general. Another preferred condition is fast growth rate. Farmers

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typically prefer the exotic over the indigenous species that are felt to be slow growing. Contrary to conventional thinking, IFTs can grow fast and fruit early, as Maghembe (1994) reports for many species native to the miombo woodlands of Malawi.

Ber's use as food and planting on farms is probably limited at present by the poor quality of germplasm available in the region. Introduction of the Pomme du Sahel varieties would improve the use and conservation of the species, since the native materials would form the rootstocks for grafting. For mangoes, the challenge is the provision of the already available commercial varieties to rural farmers. Rural nurseries should carry grafted seedlings of the improved varieties and be sold at a price poor farmers can afford. From our observations, a grafted mango seedling costs between US$ 1 and 1.5 within ECA region when compared with ungrafted ones that cost less than US$ 0.5. To address marketing problems [a major problem with mangoes (Boersma, 2005)], farmers should also be encouraged and assisted in forming marketing associations that can take advantage of scale.

From a conservation perspective, baobab and tamarind are two top priority candidates. This is because they are being utilized for both commercial and domestic needs without any commensurate planting or conservation programs. Farmers tend to clear baobab in favour of other crops when preparing land for agriculture (Mohamed, 2005). For tamarind, there is some conservation on farms and less in the wild, where farmers derive some financial benefits from the trees (Nyandoi, 2004). Given the high nutritional value of their pulp (Table 1), the greater utilization of tamarind could contribute significantly to food and nutritional security in the ECA region. The same applies to baobab, especially if there was greater use of it as a vegetable during the dry season when production of other vegetables is limited. Marula's development would benefit much from the linkages with South Africa's beverage industry that has commercialized beer from the fruit pulp. This would provide incentives for plantings on farms.

## 5. Implications for research and development

Despite their importance to the livelihoods of rural communities, IFTs have not been fostered by agricultural and forest policies, an observation also made by others elsewhere in Africa (Campbell, 1987). Investments in the ''Big Five'' provides a unique opportunity for sustainable production that could help reduce the spread of subsistence agriculture, and thus contribute to maintaining the integrity of the drylands ecosystems. This could occur through three interlinked mechanisms: (1) by diversifying and increasing tree cover in the emerging agricultural systems that are dominated by annual crops; (2) by binding the labour force of local communities and farmers on a smaller area and allowing them to use it sustainably, thereby reducing the need to convert remaining woodlands and forests into agriculture or for extraction of charcoal and other wood products; (3) by creating a landscape 'matrix' for dryland forest reserves that preserves the integrity of dryland ecosystems, while allowing humans and wildlife to co-exist better than under annual crop systems. Testing these hypotheses should be an important component of research and development efforts to expand the production of the ''Big Five''.

Improving markets would be a big driver for greater investments by farmers and the private sector in the production and commercialization of the ''Big Five''. Without an expanded or a new market, the incentives to domesticate intensively for self-use are not sufficient (Leakey and Simons, 1998). As suggested by Leakey and Tomich (1998), market prospects must be analyzed at the earliest stage of identification of candidate species for domestication, well before significant scientific resources have been committed. This should include local, regional and global markets. For instance, Boersma (2005) observed growing demand for mangoes within urban populations, thus opening up new marketing opportunities for smallholder farmers. The mango marketing chain in Kenya is fairly well developed and could provide insights on how to do the same for the other species (Mungai et al., 2000). For marula, developing market links with the marula beverage industry will be essential to develop the use of this species in the region.

To sustain any markets, product quality must be improved and consistency of supply assured. At present, productivity is highly variable between and within species. While this occurrence provides an opportunity for selecting and improving their production, it does not favour investment in large-scale production. Once improved varieties are obtained, the commercialization of the fruits could be easily planned and promoted. For instance, mango production has been more heavily adopted and marketing the produce is increasingly expanding with the advent of improved varieties. In spite of this, most smallholder farmers are still planting unimproved local mango varieties that have a lot of fibre and that are not easily marketable. This is dissemination and not a research problem, and could be addressed through public–private investment in the production of improved germplasm. Regional collaboration is also needed to ease the movement of improved germplasm across countries. Towards this, ICRAF has recently assisted private sector nurseries to move grafted mango seedling from Kenya to countries in the region (Ethiopia, Rwanda and Uganda) to help start orchards for improved germplasm (ICRAF, 2005b). In 2005, Kenya was the leading mango producing country in Africa (Boersma, 2005).

For marula, desert apple, tamarind and baobab, there is a need to determine their ecological niches and propagation techniques so that farmers can be guided on how and where to plant them (Leakey and Simons, 1998). Selection for taste, semi-processing and storage are areas that require development so that value can be added to fruit products. The large diversity noted within species, for example marula, allows the development and evaluation of fruit qualities such as fruit size, density, taste and fruiting patterns (Leakey, 1999). Screening can be done fast with the random amplified polymorphic DNA (RAPD approach) (Agufa, 2002) and the capacity of national programs to use it should be strengthened. Similarly, marketing strategies could be developed for marula, tamarind and baobab whose productivity per tree are known to be high (Gunasena and Hughes, 2000; Sidibe and Williams, 2002). Practical solutions need to be developed for species such as *S. birrea* that have a dioecious reproductive nature, where many seedlings raised will be male and unable to contribute directly to fruit supply upon reaching maturity (Phofuetsile et al., 2002).

Lack of skills by rural communities in processing and enterprise development is probably the biggest constraint to developing marketable products from the species. Rural communities should be supported in the establishment of indigenous fruit processing enterprises. Processing and marketing will include putting in place appropriate methods of harvesting, use, storage and processing, alongside market development (FAO, 1988). Developing the technical and business skills of the communities is essential given that production is generally seasonal and any changes in production will be difficult to bring about in the short term. Given the external benefits to society that may arise from increased domestication of indigenous fruits, including biodiversity conservation, it is justifiable to argue for public sector program sponsorship and support for the costs of adoption of these species as well as the required enterprise development skills of the smallholder farmers.

If the markets are lucrative, Leakey and Simons (1998) raise the possible danger that large company plantations could displace smallholder production. This has, indeed, happened in South Africa and Israel where the tree has been established in plantations (Leakey, 2005). To develop such policies and guide the engagement of the business community in the IFTs industry, it is important to understand the different steps in the market chain and the economic importance of each species at household, village, sub-national and national level. Essential data needed to develop decision support tools include the actual extent in number and size of the industry at national level and the types of offered. Others are information on yield (both levels and seasonality), inputs used (land, labor, purchased inputs, and other inputs), prices of both inputs and outputs, including capital costs. Since much of the production of the species is still from the wild (the exception being mangoes), analysts must be clear about the assessment and comparisons. At this point, ex-ante analysis is the most appropriate thing to do.

While the Dry-Zone Africa forestry indicators provide useful indicators for monitoring impacts on livelihood and on biodiversity conservation, they need to be adapted for trees managed in agroforestry systems. Indicators of importance include ease of establishment (drought and termite resistance), yield levels, returns to investments, and interaction with crops. Indicators also need to be matched with benchmarks and thresholds against which impacts can be measured. Both are lacking at present, and more so for thresholds, which Izac and Swift (1994) noted as needing the highest priority in research and

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development efforts aimed at developing sustainable land use systems. A starting point towards this effort is developing and strengthening, where they exist, national and regional information management systems on the uses and management of the ''Big Five'' as well as other IFTs. An example of such a system is a detailed database known as the 'Kenya Resource for Indigenous Knowledge' with over 800 indigenous food plants that is managed by the National Museums of Kenya.

Finally, the logical framework adopted in this paper identified fairly well the status and gaps of knowledge on the ''Big Five'' that is of importance for their utilization and conservation. It is evident that there is variation in knowledge and the level of development among the species, with ber being the least and mangoes the most. With the possible exception of mangoes, there is a need for additional information to be made available to allow them to better integrate the trees into the farming systems. This includes: ability to tolerate drought, termite resistance and control measures, age to fruiting and longevity of production, yield level of the various provenances suitable for different agro-ecological zones, pest and disease control, level of competition with crops, and consumers' preferences. These factors require further research that also engages the local community since they have valuable indigenous knowledge of the species as well as the food industry.

## 6. Conclusion

Development of the ''Big Five'' and other indigenous species in the ECA region is based on the concept of 'use it or lose it' and it is clear that economic incentives, focusing on household incomes, nutritional and food security, can be powerful motivators. There is continuing traditional importance of the ''Big Five'' throughout the drylands of the ECA region. Although there is limited trade in the tree products, at present (2006), there is extensive scope for commercial initiatives (Phofuetsile et al., 2002). These species have tremendous nutritional value and thus contribute to the health status of rural communities.

More research and development efforts are needed to harness the wide genetic diversity of fruit quality among provenances, while improving access to quality germplasm, fruit processing, storage and marketing. This requires improved research and capacity building amongst key stakeholders in the region. Capacity building and institutional development will involve training of research and development agents, and the provision of support to local communities and policy makers.

Quick gains can be made by: (a) strengthening collaboration with other regions, including India, the Sahel and Southern Africa, where the trees are already extensively utilized commercially; (b) developing information management systems for indigenous fruits that support research and investments decisions at international, national and regional levels. Such systems would help identify indicators and thresholds for sustainably managing the ''Big Five'' with the twin objectives of improving livelihoods and biodiversity conservation.

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