Domesticating Priority for Miombo Indigenous Fruit Trees as a Promising Livelihood Option for Small-holder Farmers in Southern Africa

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Abstract

Most countries in Southern Africa are experiencing acute malnutrition, food insecurity, and low income among the rural and peri-urban population, and these culminate in deforestation and loss of biodiversity. The Miombo woodlands are known to have over 75 indigenous fruit trees (IFTs), which bear edible fruits. The fruits are rich in minerals and vitamins, sold for cash income and constitute important food sources during famines and or emergencies. This paper provides an overview of some efforts to domesticate the IFTs identified by farmers and users as priority species, as an important step to provide opportunities for resource-poor farmers to cultivate and generate income from sale of fresh and processed products, and to conserve the genetic potential of these species. The approach used involves four basic steps: 1) identification of priority species by communities and other users, 2) participatory selection of superior trees and naming them in situ, 3) propagation and cultivation of trees as fruit orchards, and 4) dissemination and adoption. *Uapaca kirkiana, Parinari curatellifolia, Strychnos cocculoides* and *Sclerocarya birrea* have been identified by farmers and stakeholders as priority species for domestication in the southern Africa region. Germplasm of *Uapaca* and *Sclerocarya* were collected, exchanged among countries, and tested in multilocational provenance trials. Over 5000 farmers in four countries are involved in on-farm testing of IFTs in the field and homesteads. A new domestication strategy is developed for the participatory domestication of *Uapaca kirkiana*, using the rapid clonal selection approach. A strong network of stakeholders and farmers has shown strong enthusiasm, commitment, and participation in the domestication of IFTs. Creation of an enabling environment through policy reforms and market development will be essential to achieve socio-economic empowerment of the resource poor farmers in the region through domestication, utilization and commercialization of fruits and products. There is need for product development research, private sector involvement and strong policy support, in order to have tangible impact.

BACKGROUND

The world today faces urgent food and nutritional crisis, and the FAO Shah and Strong (1999) report has estimated as many as 840 million people face chronic or perpetual hunger and 19,000 of the 40,000 infants and children die of malnutrition (World Health, cited by CGIAR, 1999). A major preoccupation of the development and scientific communities in the last 50 years has been how to resolve the conflict between increasing demands for food and the degradation of the environment. The major challenge in the new century is in devising ways of integrating scientific breakthroughs with indigenous knowledge to develop tangible livelihood interventions that are applicable on farms, so as to ensure food and income security at the household levels and future prosperous small farming enterprises. Food security implies access to foods for a productive and healthy life (Shah and Strong, 1999), i.e. ability of households to produce, purchases, or acquire an adequate amount of food to meet biological requirements. It also means that people do not have to rely solely on staples such as maize, rice, cassava and potatoes. Development agendas must be set that will help farmers prosper and live a healthy life and not just to

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survive at subsistence level. Therefore the problems confronting rural poor is far more complex than simply increasing crop yields, it will also involve maintaining biodiversity and addressing the intransigent problem of poor health, especially in a region where HIV/AIDS still maintains a strong foothold (World Bank, 2000). The deficiency of vital micronutrients and vitamins in the dietary system are a form of '*hidden hunger*' that could be addressed through availability of fruits and fruit products. Vitamin deficiency has been reported to affect at least 125 million school children worldwide and has caused eye damage to about 14 million people (Shah and Strong, 1999). Approximately 85% of human food comes from only 20 species, which are currently undergoing serious genetic decline. Furthermore, it has been estimated that 24% of the existing 250,000 plant species are under the danger of extinction (Barbosa, 1996).

In Southern Africa a worsening crisis in the availability of food for the fast growing population is unfolding. The food production capacity in the region is being pushed to the limit, with resulting over-cultivation of fragile soils and loss of soil quality. Periodic droughts aggravate the situation, but even in years of favorable rainfall, most farm families cannot produce enough food to feed themselves. Many farmers in Malawi and Zambia had indicated that they exploited fruit trees as a coping strategy for hunger in the years of famine, as in 2001 and 2002 (Fig. 1), most of these were collected from the wild. IFTs have nearly disappeared in some regions making fruits and firewood difficult to obtain. The situation is predicted to become more severe in the coming decades. To address these daunting problems, a suite of technologies is needed including agroforestry.

One of the promising agroforestry technologies discussed in this paper is the domestication of indigenous fruits (IFs). The Miombo IFs are an important source of food and cash in Southern Africa region and they are widely consumed fresh as well as in processed form. The fruits are sold in both rural and urban areas. Over 50 fruit tree species have been identified in the Miombo woodlands, many of which bear widely used and marketed edible fruits (Maghembe et al., 1998). These under-exploited fruits are rich in sugars, essential vitamins, minerals proteins, oils and fiber, and serve as important food reserves for humans especially during seasonal food shortages (Saka and Msonthi, 1994; Saka et al., 2002; Kwesiga et al, 1998, Kwesiga et al, 2000). With such a valuable resource, IFTs can contribute to the local needs for food and other related products. As the rate of deforestation increases in sub-Saharan Africa with only 9.25% of the total area under forest (UNEP, 2001), IFTs are threatened with extinction. This means that the livelihood of the poor rural people who are largely dependent on this natural resource is also threatened. Therefore, considering the benefits offered by these fruits and the threat to their survival, there is strong justification to domesticate them.

It has become obvious, that greater integration of trees such as IFTs into farming systems could contribute towards achieving sustainable land use. According to Huxley (1999), regional and local self-sufficiency are likely to be important in the foreseeable future, and IFTs can contribute, especially to the local needs for food and related products. In the Miombo woodlands of southern Africa, the cultivation of more than 75 wild fruit tree species, which are eaten and sold, is hampered by limited knowledge of their biology, propagation and management (Maghembe et al., 1998). ICRAF and its partners in Southern Africa have instituted a systematic approach to bringing these indigenous but less-known fruit trees into wider cultivation by small-scale farmers in order to enhance their food security, human nutrition and cash income. In order to achieve this goal, ICRAF has been examining the constraints to domestication, identifying priority species and improving the germplasm of these fruit trees through provenance and traits selection and cloning for the benefit of small-scale farmers in the region.

This paper provides a regional state-of-the-art from experiences with one decade of research and development efforts on IFTs domestication and commercialization. It intends to highlight the achievements, constraints and the next steps.

BRINGING WILD FRUIT TREES INTO CULTIVATION

In the genetic sense, domestication can be described as an accelerated and human-induced evolution to bring wild or semi-wild trees into wider cultivation, the consequences of which are either an alteration, loss or gain of genes (Harlan, 1975). According to Simons (1996), people domesticate trees by bringing them into cultivation, adapting them to their needs and environmental conditions. The domestication and cultivation of wild and semi-wild indigenous fruit trees, have both economical and ecological impacts. During this process, adaptations in the plant may occur resulting in an increased adoption for specific uses. Tree domestication may not always be a conscious effort, as is the case with many useful trees that farmers grow as semi-domesticates around the homestead. Wiersum (1996) describes domestication as a man-plant evolutionary continuum which commences from extractivism or exploitation of trees products from the wild, followed by deliberate selection, retention or cultivation of semi-wild trees in enhanced environmental conditions (either to reduce risk or increase access), to commercial establishment of plantations of high-value trees, followed by genetic selection and or genetic improvement. Domestication occurs when the genetic makeup of a plant is altered or controlled, through the action of man, from gathering in the wild to breeding or improvement for desired traits, whereby wild trees are naturalized or conditioned to growing in a human-induced habitat (different from the progenitor), usually human settlement. This is a two-stage process of bringing wild plants into cultivation and subjecting them to some form of selection (or improvement) and management. Since about 83 to 93 % of the five top priority trees are found in the mountains and hills (Malembo et al., 1998), the challenge to agroforestry is how to bring this wild germplasm to wider cultivation in the fields, and within a reasonable time frame. ICRAF's approach to trees domestication is both market-driven and farmer-led. It has an implicit overall goal of achieving an improved germplasm (quality and quantity), conserve the genetic potentials and biodiversity of the useful, sometimes endangered high value tree species, that can help to reduce hunger and increase rural income, by so doing, effectively accelerate their adoption in the region.

The concept of domestication of indigenous fruits is not new. Kiwifruit (*Actinida deliciosa*), which originated in the upper Yangtse River region of China, was successfully domesticated to commercial scale in the New Zealand starting about 1903 (Berry, 1997). The kiwifruit domestication process was made possible through the availability of commercial cultivators who were also interested in selection (Berry, 1997), planting materials and growers' organizations, which facilitated awareness through dissemination. In West Africa, attempts to domesticate IFTs started by farmers retaining and selecting fruits of species such as *Dacryodes edules*, *Irvingia gabonensis*, *Chrysophyllum albidum*, *Garcinia cola*, *Artocarpus* species and other fruits which are now prominent in the regional trade. Many farmers in the Pre-Amazon and Amazon regions of Brazil are domesticating species such as Bacuri, Cupuacu, and *Artocarpus heterophylla* (Akinnifesi, unpublished). These semi-domestication efforts are rather slow and could be shortened by radical systematic domestication approaches. Comparatively, farmers in the southern Africa have little knowledge of tree propagation and cultivation of IFTs, hence selection and retention of trees in the field is a less conscious effort.

EFFORTS TO DOMESTICATE SOME INDIGENOUS FRUITS OF THE MIOMBO

The idea to domesticate the IFTs of the Miombo Woodlands started with collecting and establishing 24 IFT species in a nursery at Makoka, Malawi in 1990. The good performance including fast growth, early flowering and fruiting of a few species encouraged ICRAF to develop a strategy for domestication of IFTs of the Miombo (Kwesiga et al., 2000). In 1994, ICRAF organized a regional conference on the improvement of indigenous fruit trees of the Miombo Woodlands of Southern Africa. The domestication conference drew participants from various SADC countries and had reviewed the state of knowledge on the potential of cultivation and wide utilization of the fruits and their trees by small-scale farmers. It was agreed to develop a regional collaborative project for the domestication of IFs within the framework of the SADC-ICRAF agroforestry project. The responsibility of developing the project, evaluating priority species and seeking funding was given to ICRAF. In 1996, a proposal for funding the activities of domestication of IFs was submitted to BMZ in Germany. At the same time, funds from CIDA through SADC Tree Seed Center Network (STSCN) enabled ICRAF to train 30 germplasm collectors from Botswana, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia and Zimbabwe in October 1995. This facilitated the collection and exchange of 24 provenances of *U. kirkiana* and 40 provenances of *S. birrea* among 8 countries in 1996, and more than 10 tones of fruit were collected during the exercise.

Prior to these exercises, the planting of fruit trees such as mangoes and oranges in upland fields and homestead was among the important agroforestry technologies that farmers were familiar with as alternative sources of food and cash income. The farmers thought that the native fruit trees were God's gift in nature and retained only the best in crop fields while other trees were cleared for cultivation.

As a follow up to the surveys conducted in 1986 to 1988, ICRAF carried out ethno-botanical surveys in Malawi, Tanzania, Zambia and Zimbabwe. The surveys aimed at characterizing indigenous multipurpose trees and shrubs with respect to their establishment and management, location and arrangement, market opportunities, uses and functions in farmer fields. In addition, there was a need to prioritize the IFT species found on farmers crop fields for further agroforestry research (Kwesiga and Chisumpa, 1992; Karachi et al., 1991; Maghembe and Seyani, 1992). Results of these surveys confirmed that IFTs are an important resource to rural communities. Farmers in the region identified about 50 indigenous fruit tree species, which they use for food in the form of leaves, fruits, pods, seeds and roots. Their fruits are available mainly during the rainy season when traditional crops are not yet ready for harvest, and hence they can contribute significantly to the diets of the rural people. The survey results also showed that most of the fruits are consumed raw, that is, very little processing is done at the household level. The fruits are collected from the forests and besides being consumed locally they are also sold in local and roadside markets. A study in Tanzania showed that in addition to the IFTs left in crop fields, farmers plant exotic fruit trees. The choice of the species favored is strongly influenced by market value of the fruits and the need (by the farmers) to supplement their diets (Karachi et al., 1991). However, due to lack of knowledge in propagation and establishment of seedlings, inadequate management skills and because of the free availability of the fruits from the forests, very few farmers had planted IFTs (Sambo, 1991).

The ownership and rights to fruit trees have been identified as issues that need to be addressed, most probably by policy mechanisms, with regard to their clarity and equity. In the three areas surveyed in Zimbabwe, respondents indicated that IFs are found in forests, fields and grazing areas as well as around homesteads. The ownership or control of access to these fruits was reported to be different depending on the place of occurrence of the fruit trees. Village chiefs as well as field and homestead owners play an important role in controlling access to the fruits.

SPECIES PRIORITIZATION AND TRAIT SELECTION BY FARMERS

The need for domesticating IFTs is determined by the potential markets, macro-economic climates and the perceived political environments. Since there is a wide range of IF species used by farmers in the southern Africa region, it is only feasible to work with a few species with wider potential impact on poverty alleviation and income generation. Priority setting requires understanding of user needs and preferences, technological opportunities and methodologies for ranking species. Species prioritization was undertaken following the procedures described by Franzel et al., (1996). The process involved seven steps: i) team building and planning, assessment of user needs, assessment of species used, ranking of major products, identification of priority species, valuation and prioritization of species, and final choice (Franzel et al., 1996).

Farmer surveys were undertaken to determine needs and preference of farmers and various stakeholders (Maghembe et al., 1998). A total of 469 households in 20 districts were involved in the survey, involving 28 households in Malawi, 70 in Tanzania, 153 in Zambia and 118 in Zimbabwe (Maghembe et al., 1998). In this multidisciplinary approach, user's objectives and constraints were also identified. Farmers, consumers and experts commonly preferred *Uapaca kirkiana*, *Parinari curatellifolia and Strychnos cocculoides* as the 'top-priority' IFT species for domestication in the region (Table 1). Country specific priority species were also recorded, including: *Azanza garkeana* and *Flacourtia indica* for Malawi; *Vitex* species and *Tamarindus indica* for Tanzania; *Anizophyllea boehmii* for Zambia; and *Azanza garkeana* and *Ziziphus* for Zimbabwe (Kadzere et al., 1998). Within country variations in farmers preference also occurred at the 8 districts sampled in Malawi (Malembo et al., 1998). It was also found that farmers have generally not planted IFTs for the following reasons: lack of planting materials, lack of knowledge on propagation, nursery and tree husbandry, uncertain markets and low price, unknown nutritional values and perception that they are abundant in the forests. Farmers' major concerns are the need for improvement of the precocity and fruit quality attributes such as better fruit sizes, more sweetness for fruit like *Strychnos cocculoides*, and smaller tree size for most priority species. According to farmers, tree precocity is by far the most critical attribute that needs urgent improvement, as seedling trees have to grow for more than 10 years before first flowering and fruiting.

Updating the priority list in Malawi, Zambia and Zimbabwe showed that the list of preferred species is different from the findings of Maghembe et al., (1998) (Table 1). However, *Uapaca* remains the most preferred species. It was also noted that in every country, exotic species are preferred before IFTs. For IFTs the preference was in the following decreasing order: *Uapaca kirkiana*, *Strychnos cocculoides*, *Parinari curateli-folia*, *Berchemia discolor*, *Adansonia digitata*, *Azanza garkeana*, *Vitex payos*, *Ziziphus mauritiana*, *Flacourtia indica and Diospyros mespiliformis.* The surveys suggest that the top species may change positions, depending on the timing, location and people interviewed. It is interesting that *Uapaca kirkiana* held the 4th position in the overall ranking when compared among all exotic and indigenous species, but ranked 1st of all IFT species (Table 2).

GERMPLASM IMPROVEMENT THROUGH PROVENANCE SELECTION

It is still not certain as to whether or not phenotypic selection, based on tree characteristics in the field is effective. Relatively low genetic gain may be expected in one cycle of selection for a trait, such that less than 60% progeny-parent similarity may be obtained (Simons, 1996). In order to determine the genotype x environment interactions in selecting superior genotypes, sixteen provenances of *Uapaca kirkiana* and twenty of *Sclerocarya birrea* are being evaluated at four sites in the region for genotype x environment interactions for trees grown from seed. Tree growth assessment at 30-42 months after establishment (MAE) showed that the best-performing provenances (based on height growth) was Phalombe for Malawi, Murewa for Zimbabwe and Chipata provenance for Zambia. The Choma provenance from Zambia ranked among the top three superior provenances in the three sites, indicating higher adaptive performance. Survival for *Uapaca* at 30-42 MAE ranged between 51 and 81% at Makoka, 22 to 62% at Masupe and 74 to 96% at Domboshawa. In Malawi, the trees attained 2-3 m at 36 to 42 months after establishment. In Zambia, there was high variability in height growth ranging from 41 cm to 78 cm. Tree performance was poor in Domboshawa due to annual frost damage. It is not known whether tree growth will correlate with precocity and fruit traits in these trials. Analysis across sites showed that height growth of the provenances was better near the origin of mother trees than other sites. The geographic and climatic variables were significantly correlated with height, e.g. Lat x ht (r=0.71). Analysis also showed a significant G x E interactions in height growth in three countries, implying adaptation to local environments (local optimality). In addition, trees planted at the lower elevations in the field seemed to have performed poorly compared to those at the middle or upper slopes, suggesting that *Uapaca* is better adapted to well-drained soils. This may explain why 93% of *Uapaca* is found in the mountains and hills (Malembo et al., 1998). From a pomological standpoint, the trials will be more important when the trees have started fruiting.

It was recently noted that some of the 10-year old trees planted at Nauko have started to produce fruit, indicating that at least 8-10 years is required for trees established from seed to produce fruit. Some provenances of *Sclerocarya birrea* in Magochi have started to produce fruit 7 years after establishment. Compared to fields established in Makoka, which produce seeds after about 10 years, few provenances would be considered to be relatively early fruiting. In order to shorten the period of waiting before the first fruiting (precocity) and to reduce hybrid variability, vegetative propagation approaches have been explored.

VEGETATIVE PROPAGATION AS A TREE DOMESTICATION TOOL

The use of vegetative propagation is based on the '*totipotency*' of living cells in plant, i.e. capacity of a tissue to regenerate to a whole and identical plant as the mother tree. Therefore, clones produced from the same mother plant are genetically identical, unless rare somatic mutations occur (Hartman et al., 1990). Vegetative propagation allows the tree domesticator to rapidly multiply, test, select from and use the large genetic diversity in wild tree species. After superior genetic individual tree(s) have been identified in natural stands, one option is to test these in multilocational screening or provenance trials, or the planting materials can be vegetatively propagated and released to farmers.

Although, sexual reproduction by seeds provides opportunity for variation and evolutionary advancement, it seems to offer little appeal for IFT domestication, due to the long waiting period for conventional breeding to yield desirable results. Further, most IFT species are out-breeders, maintaining considerable genetic variations, such that seeds from an individual tree usually are not 'true-to-type'. Vegetative propagation is the key to preserving genetic resources of high value species threatened by extinction in the wild, obtain uniform tree products, and accelerating fruit production by reducing the time to fruiting compared to trees produced from seed regeneration. Although earlier enthusiasts have opinioned that probably over 90 % of tropical trees are amenable to propagation by juvenile stem cuttings (Leakey, 1991), experience with the Miombo fruit trees indicate that stem cutting is not feasible, at least for the four regional priority Miombo fruit trees, i.e. *Uapaca, Parinari, Strychnos* and *Sclerocarya*. Propagation by root cutting seems to be promising for *Parinari*, a tree with poor seed germination (< 10% regardless of scarification efforts). Research is underway to explore rooted cuttings of *Parinari* as rootstocks for grafting. Experience from many tropical fruit crops worldwide, such as mango, avocado, orange, etc. indicates that grafted stock is an efficient way to rapidly effect plant propagation in fruit trees (Ndungu et al., 1995).

Airlayers was promising for *Uapaca kirikiana*(63%), but not successful for *Parinari* and *Strychnos* species. It is evident from our work that with further improvement, *Adansonia digitata, Uapaca kirkiana, Sclerocarya birrea,* and to some extent *Strychnos cocculoides,* are quite easily amenable to grafting. There was a problem with graft survival after potting and grow was slow in the field. A significant improvement in graft take (80%) has been recorded for *Uapaca kirkiana* (Table 2), compared to less than 10% reported by Jaenicke et al., (2001). Graft takes of *Adansonia digitata* (83%) and *Vangueria infausta* (79%) compared favorably with exotics, such as mango, in the same trial. Both grafting and air-layering set during November – December gave the best result. Top-wedge and whip methods were the most successful for grafting. The success of any vegetative propagation technology is, however, affected by several factors, which includes the species, tree physiology, timing, growing media, and or plant hormones used, especially for cuttings (Hartman et al., 1990). Our experience in Makoka also showed that the skill of grafters, timing of scion collection and, to a lesser extent, storage method could affect the graft take in a dramatic way. Interestingly, rooting hormone did not improve the rooting of *Uapaca* airlayers. A bottleneck in grafting *Uapaca* has been that of matching the scion with the rootstock. Seedling growth is very slow and requires a year's growth before a pencil size rootstock could be attained for grafting. The growing shoot of *Uapaca* is usually very thick and vigorous. With use of appropriate soil media, Uapaca seedling could attain pencil size thickness in one year (Mhango, unpublished). Grafted *Strychnos cocculoides* and *Vangueria infausta* flowered in the nursery six months after propagation. Precocity in these species may compare with mangoes when vegetative propagation is used. In Botswana, Vield products research, an NGO, has shown that grafting can reduce the juvenility period of *Sclerocarya birrea* from 8-10 years in the wild to 4-5 years in grafted plants (Taylor et al., 1996).

PARTICIPATORY DOMESTICATION STRATEGIES

Germplasm improvement of IFTs entails the applications of silvicultural, horticultural and/or tree-breeding skills to obtain the most valuable domesticable fruit trees as quickly and inexpensively as possible. Therefore, germplasm improvement is a basic tool of tree domestication. It consists of the combination of the trees' parentage with silviculture to obtain the greatest overall genetic and commercial gains. The ICRAF agroforestry project adopted a participatory tree domestication approach that seeks to obtain a short cut to the conventional genetic improvement procedures and accelerated delivery of superior tree germplasms to farmers through participatory selection, propagation and dissemination. The approach is to involve farmers in the germplasm selection, production and dissemination, thus reducing the number of steps involved in the process, without compromising program quality. The domestication program is both market-oriented and farmer-led, but it has both research and developmental components also. All aspects are closely linked, but require different approaches and philosophies. As the program matures, the research activities will become increasingly dependent on the developmental component. The main goal of the developmental component is to obtain suitable trees that can give early returns to the farmers, thereby accelerating wider adoption. The research goal is to ensure a solid scientific basis for the domestication process, whereas, the production goal is to ensure proper exchange and delivery of germplasm to farmers.

The five basic steps of the SADC-ICRAF agroforestry project are:

- identification of priority species (by regional experts, farmers and the market);
- selection of superior phenotypes of individual trees from the wild and collection of germplasm
- raising the rootstock or vegetatively propagated planting materials in nurseries;
- management or cultivation (on station and on-farm);
- dissemination and adoption of planting materials and knowledge (training, publications).

Currently, the ICRAF programme is using vegetative propagation of plus trees and the use of seedlings from superior trees as rootstocks to select superior clones and cultivars of IFTs. Superior trees are identified directly with communities using PRA approaches involving traditional leaders, villagers, marketeers (roadside vendors, retailers and wholesalers), school children and experts, to determine superior fruit traits (sweetness, fruit size, fruit load, etc) for fresh market, processing and home consumption purposes. Trees that met the cut-off points are jointly identified with communities, named following a set procedure aimed at crediting trees to communities and individual farmer who manage them. For instance, a tree found in Mr. Majoni's farm in 2002, being the 54th tree selected in Malawi and 3rd copy of that clone, would be named: ICR02 MAJONI MW54/3 [ICR=ICRAF, 02= cloned in year 2002; Majoni = farmers' name; MW=Malawi; 54/5= a 3rd copy of 54th tree]. Genetic breeding and biotechnological options could be introduced at later stages of domestication to obtain improved cultivars for a mass dissemination programme (Fig. 1). Research is underway to graft mature male and female branches of *Uapaca* on one stock or top working, in order to overcome the problem of dioeciousness.

Farmers frequently blamed the lack of genetically superior germplasms as major bottlenecks to on-farm diversification of products and in tapping the hidden wealth of wild fruit trees. It is difficult to discuss gene conservation in the light of IFT conservation in a rational way, because sometimes the subject is emotionally charged. Many equate the need for gene conservation or genetic diversity with the necessity to prevent the extinction of an endangered species or a provenance of a species (Zobel and Davey, 1977), irrespective of the usefulness of such species to the farmer. Although, biological genetic conservation is not a direct area of priority of the domestication of the Miombo woodlands, it is considered pertinent to save the desired genes or gene complexes for future uses. Gene conservation is being established through conventional vegetative propagation of a few of the desired trees established ex situ in orchards or fields which can be crossed or cloned when desired. Conservation of natural forest areas is still essential for genetic resources and habitat even if these characteristics not presently understood or appreciated.

GAPS AND OPPORTUNITIES FOR ACTIONS

Biophysical Considerations

Several biophysical constraints still limit the domestication of IFTs at the farmer's level. These include lack of superior planting materials, lack of nursery management knowledge and perception that the trees are abundant in the forests. The following biophysical considerations are considered relevant to germplasm improvement in the region:

1. There is need to establish seed zones and seed transfer guidelines for collection of propagules between provenances distances, based on genetic and environmental criteria, in order to minimize risks of maladaptation of wild species in new niches. Germplasm collection needs to focus on superior traits and efforts must be made to credit the farmers and the local communities in whose custody these materials have been preserved for centuries.
2. There is little knowledge of genetic selection and improvement for IFs of the Miombo that may result in significant changes in fruit quality, harvesting and regeneration costs. Clonal selection and breeding approaches should be used to improve yield and quality.
3. Vegetative propagation techniques, especially grafting and to lesser extent air-layering, need to be given greater attention for priority species, especially *Vangueria infausta, Adansonia digitata, Uapaca kirikiana, Zizyphus mauritiana, Strychnos cocculoides, Sclerocarya birrea, and Parinari curatellifolia*, which appear to be amenable to grafting.
4. Molecular investigation is needed to understand the genetic factors controlling dioecy in Uapaca and *Sclerocarya*. A hermaphrodite variety for efficient fruit production would be desirable. Currently, the domestication challenge lies in the possibility of grafting male and female scions on the same individual tree, e.g. grafting male branches on a female tree. This requires identifying tree 'sex' at seedling or juvenile phase of growth or grafting male and female branches on the same tree. The best option for now is to select superior trees for rootstocks and use a scion of known sex, quality, age, and fruit traits as budwood.
5. Breakthroughs in improving tree precocity will be a major incentive for growing wild trees and catalyze their adoption by farmers. To develop both the fresh market and processing fruit qualities, superior phenotypes growing in semi-domesticated environments or in the wild should be selected and managed as orchard crops. The soil and water requirements and other management practices should not be seen as different from known exotics such apples and mangoes. Selection of early and late fruiting clones would help to extend the period of fruit availability.

SOCIO-ECONOMIC CONSIDERATIONS

Market and Product Development

Often questions are raised as to whether IFT cultivation and domestication (germplasm improvement and production) should come before product marketing or vice versa. This is clearly an 'egg and chicken' riddle (Leakey and Izac, 1996). The story of kiwifruit domestication and commercialization in many parts of the world was that of a perfect free-market model (Blanchet, 1997). In France, no commercial orchard existed until the 1960s, but production reached 70,000 tons annually by 1997 (Blanchet, 1997). The kiwi and mango domestication history serve as indication that market may not always be a precursor of domestication efforts. Domestication, product development and marketing should rather be seen as a cyclic process, without a clear starting or ending point rather than as triangular tripod stands. The market situation in most tropical countries seems to favor the well known exotic fruits, while native fruit trees are restricted to home consumption. There is need for product development research, and private sector involvement is strongly advocated. Although ICRAF is not rigorously involved in direct product development, it has helped to facilitate and catalyze the process of market development through effective partnership and strategic alliances with enterprise development partners and the private sector. Table 3 shows success stories in Malawi, Tanzania and Zambia, where local communities were trained by ICRAF staff and partners in pilot cottage processing of fruits from IFTs into juice, jam, wine, yogurts, and other products. A few months later the trained women groups had trained at least 5 to 10 other persons in processing (Saka et al., 2002).

An information gap is a common reason why some farmers have been unable to sell tree products. There is need for market information on product delivery pathways and market outlets. Millions of African rural people currently depend on forests for some income and employment. Domestication is pertinent to ensuring the contribution of IFs to income generation to the rural communities. This will ensure sustainable production, availability of raw materials, improve markets, technologies for processing and production, enhance local capacity/skills, improve markets and facilitate access to credit. The contribution and socio-economic impact of IFs still remain unknown. Further, economic gains and improvements should be quantified and subjected to benefit-cost analyses.

Recent studies have demonstrated that improved marketing and adding value to agroforestry products can increase 'small-holders' incomes. Major strides in market interventions are linked with improved access to market information, product development, identification of new markets, certification and labeling, collective action to assemble and market produce, and policy reforms to improve conditions under which farmers operate.

Local Perception and Constraints

Depending on the country, community perceptions and culture may affect germplasm improvement. Some trees are perceived as God-given, and 'can not be propagated', may not be grown near the dwellings because they are normally found in the mountains, while it is taboo to collect propagules from trees grown in certain areas, e.g. those growing around a burial ground, even if these are superior germplasms. Land-users were noted to have deliberately felled all trees marked or sampled for vegetative collection in Mangochi in Malawi, for suspicion that these may be special trees of interest that may rob them of their land or disturb their peace. In the same token, children, for sheer inquisitiveness have vandalized on-farm setting of air-layering, especially when these are found close to the roads or homesteads. Community members must be fully involved with tree domestication programmes to ensure success. Recent involvement of communities in identification and capturing of superior *Uapaca* trees, using grafting techniques, has proved successful because they were involved in the decision making process and actual implementation.

Institutional and Policy Gaps

IFTs have not been subjected to agricultural or forest policies (Tomich, 1996; FAO, 1989). Furthermore, the over-promotion of a very narrow range of exotic timber species and fruit trees (mango, guava, orange, avocado) by extension agencies has accelerated the neglect of domestication, utilization and marketing of IFT species (Maghembe et al., 1994). Neglect at the policy level has resulted in haphazard conservation strategies and genetic erosion of native fruits and other valuable germplasm products from the Miombo, through fire and clear-felling for agricultural land expansion to meet the needs of a rapidly growing population (Kwesiga and Mwanza, 1994). IFTs are very susceptible to failures in marketing when policies negatively impact free production and sale. Consequently, there has been limited interest in their conservation, production and improvement through selection and breeding. Policies need to achieve successful conservation, selection, multiplication, improvement and management. Further, since these fruits contribute to nutrition and cash economy of the rural households, national and regional policies should promote their processing and marketing.

Presently, national policies seem to favor urban over rural interests, concentrate rather that distribute wealth/incomes, systematically displaces labor and promote cash crops or industrial trees to the complete destruction of food crops including IFs. A broader and more flexible policy framework is desirable to incorporate food and income needs of local people in the overall forest policy. This will entail expanding forest planning and management practices to include greater involvement of local people. Any legal and other institutional hurdles, which impede the domestication process, should be identified and removed to provide a legal basis for production and marketing of IF fruit products. This should include genetic and intellectual property rights. Employment creation will result from cottage-level and intermediate forest industries. This could be facilitated by development of rural infrastructure such as roads, transport and marketing channels. Policies and financing of such infrastructures are needed before large-scale domestication can be profitable.

Furthermore, since deforestation results in loss of genetic material and biodiversity, their conservation is thus important in the domestication process. Loss of genetic diversity is both locally and internationally important. Governments need to strongly support and finance conservation of the indigenous trees. National and regional policies should therefore provide for their protection and conservation, while avoiding measures that restrict the genetic base. The policies also should provide for the control of dangerous introductions, such as invasive species, which may lead to extinction of local resources.

Policy-makers and stakeholders, must look for environmentally appealing, economically efficient, and socially just and forward-looking ways of increasing the food-basket through research, extension, infrastructure and policies. The central message in this paper is that improved domestication through, cultivation, utilization and marketing of indigenous trees are a venture worth investigating and supporting by stakeholders and policy makers. Supportive policies can help influence the direction of national programmes and projects in order to optimize their impact on food security. This will entail modifying existing institutional approaches and arrangements, especially the traditional focus on forestry and horticultural training, such that efforts can address the task of improving household income and meeting food and nutritional security objectives through IFTs.

Future Outlooks

The process of transforming farming practices and rural livelihood systems through domestication of IFTs remains challenging. Two clear opportunities for institutional involvement were foreseen. The first is to re-orient national research institutions and agricultural extension systems to support participatory domestication of IFTs through awareness creation, sensitization and dissemination of agroforestry technologies, involving fruit trees, in the region. This may involve reinforcing, not only, parental participation in knowledge-intensive fruit trees domestication and marketing process, and capacity building, but also in preparing the next generation of IFT cultivators through rural school children involvement in the process of 'bringing out trees from the wild'. The dissemination process will be accelerated, if farmers and group of farmers can become engaged, on their own volition, in the testing and adapting of fruit trees domestication options. This will require the development of simple domestication guidelines for extension workers and farmers.

The high local demand for exotic fruit trees indicate clearly the urgency and need to provide fruits throughout the year to supplement food requirements. Thus, given the diversity of IFTs, they will fill this role, especially for their unique taste and flavors. The policy and commercialization components will ensure realization of social benefits through nutritional and food security, poverty reduction and employment as well as environmental benefits. The development of suitable technology for processing, construction of efficient marketing channels, and promoting effective extension and dissemination systems will help stimulate production, utilization and marketing of IFTs.

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Tables

Table 1. The five most preferred indigenous fruit tree species for domestication by farmers.

Rank[†]	Malawi	Tanzania	Zambia	Zimbabwe	Overall
1	*Uapaca kirikiana* (77)[††]	*Strychnos cocculoides* (64)	*Uapaca kirikiana* (85)	*Strychnos cocculoides* (78)	*Uapaca kirikiana* (74)
2	*Parinari curatellifolia* (55)	*Uapaca kirikiana* (53)	*Parinari curatellifolia* (80)	*Uapaca kirikiana* (70)	*Parinari curatellifolia* (62)
3	*Strychnos cocculoides* (32)	*Vitex mombassae* (46)	*Anisophyllea boemii* (75)	*Parinari curatellifolia* (57)	*Strychnos cocculoides* (55)
4	*Flacourtia indica (29)*	*Parinari curatellifolia* (43)	*Strychnos cocculoides* (52)	*Azanza gackeana* (52)	-
5	*Azanza gackeana* (20)	*Tamarindus indica* (33)	*Syzygium geineense* (39)	*Vitex payos* (34)	-

[†] Exotic fruit tree species were omitted in the survey;
[††] Figures in brackets indicate percentage of household mentioning the species.
Source: Maghembe et al., 1998

Table 2. Graft take of selected fruit trees in Makoka nursery, Malawi.

Species[†]	**% Graft take (n=40)**
Adansonia digitata	83
Parinari curatellifolia	23
Sclerocarya birrea	52
Strychnos cocculoides	37
Uapaca kirkiana	80
Ziziphus mauritiana	90
Mangifera indica	97

[†]Top wedge used for all species except *Ziziphus mauritiana* in which T-budding was used

Table 3. Training of processors of indigenous fruits in Tanzania, Zambia and Malawi.

Country	**1st Generation trained**	**Second Generation processors**	
	No. of women	**No. of Groups**	**No. of women**
Tanzania	198	43	2045
Malawi	120	150	1875
Zambia	115	5	77
Total	**433**	**198**	**3997**

Source: Saka et al (2002)

Figures

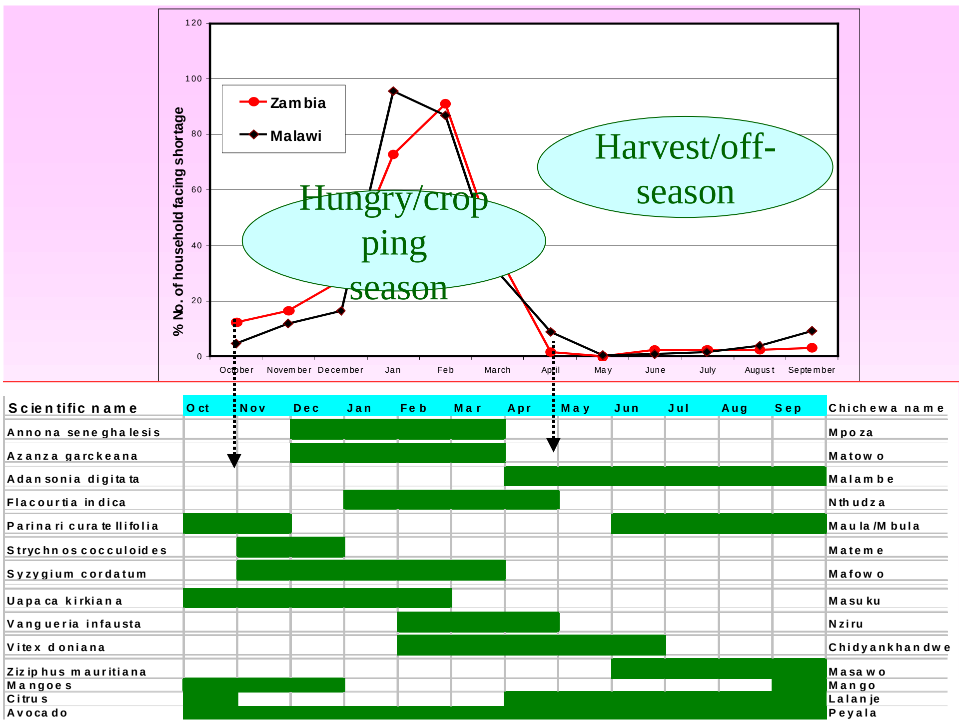

Fig. 1. Trends in maize shortage and ripening time of fruit trees in Malawi.

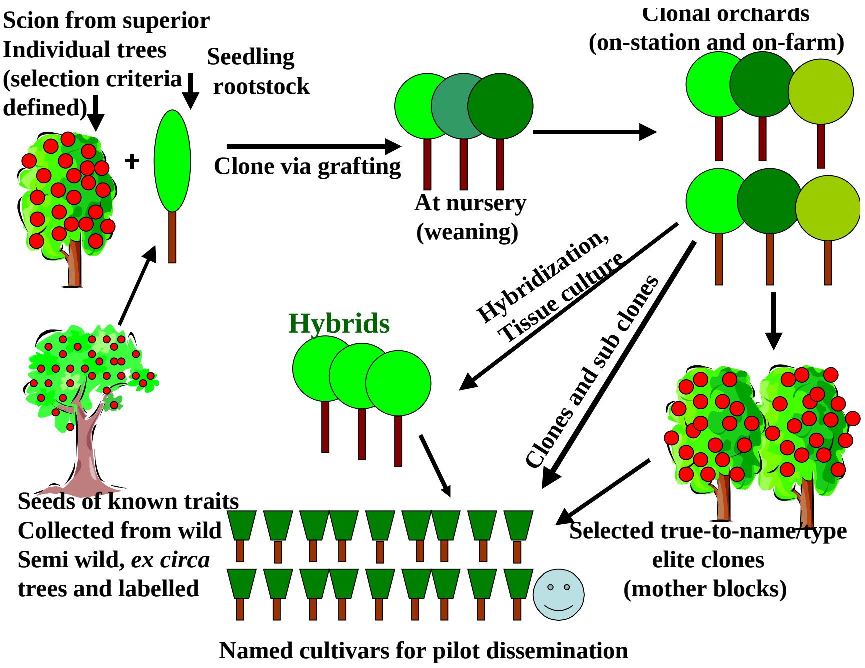

Fig. 2. New cultivar development of indigenous fruit trees using clonal propagation techniques.

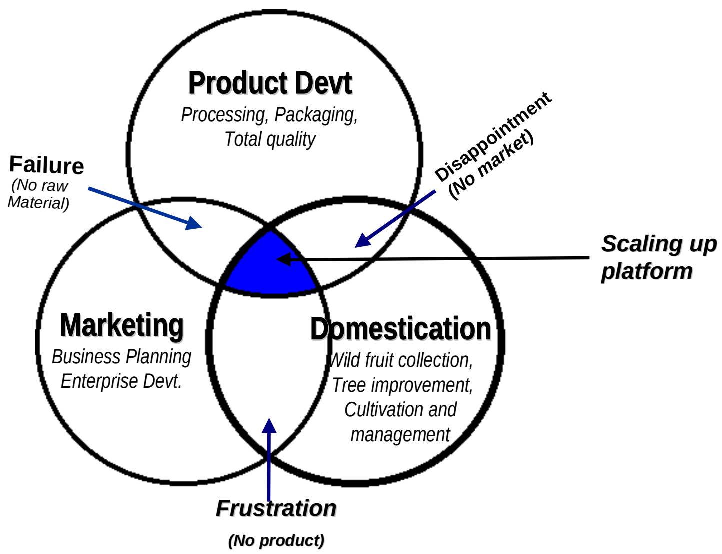

Fig. 3. Holistic horticultural domestication concept.