**Agroforestry: Participatory Domestication of Trees**

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### Glossary

- **Apical dominance** - The process which regulates branching in plants.
- **Circa situ conservation** - It is conservation through wise use.
- **Cultivar** - A cultivated variety.
- **Idotype** - The combination of a number of genetic traits that confer superiority in quality or yield.
- **Participatory rural appraisal** - Identification of the needs of local communities through dialog.

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### Introduction

The domestication of agroforestry trees is a technique for the intensification of agroforestry as a low-input farming system delivering multifunctional agriculture for the relief of poverty, malnutrition, hunger, and environmental degradation in tropical and subtropical countries (Leakey, 2010, 2012a).

In the past, tree products were gathered from natural forests and woodlands to meet the everyday needs of people living a subsistence lifestyle. With the advent of the Industrial Revolution and, more recently, the intensive modern farming systems of the Green Revolution, the resource of these trees has declined. This has been due to increased population pressures for agricultural land and the escalation of deforestation. To rebuild and improve this useful resource, the concept of tree domestication for agroforestry was proposed in 1992 (Leakey and Newton, 1994) and subsequently implemented by the World Agroforestry Centre (International Centre for Research in Agroforestry [ICRAF]) as a global initiative from 1994 (Simons, 1996). Great progress has been made in the first two decades of this initiative (Leakey *et al.*, 2005, 2012; Tchoundjeu *et al.*, 2006, 2008), which has encouraged local entrepreneurship in the processing and marketing of agroforestry tree products (AFTPs). This has had beneficial impacts on farmers’ livelihoods (Tchoundjeu *et al.*, 2010).

### Strategy

Domestication through cultivar development relies on three processes: selection, testing, and breeding. Selection identifies certain genotypes for cultivar development, testing exposes the new cultivars to appropriate environments, and breeding creates new genetic variability.

As in animals, plant domestication is a continuous process that, in crops like wheat, rice, maize, oranges, and apples, started thousands of years ago and continues today. In trees, two basic approaches are used to effect genetic improvement: the seed-based breeding approach typical of forestry and the clonal approach typical of horticulture, but the domestication strategies are not dissimilar. In agroforestry, Leakey and Akinnifesi (2008) have suggested a strategy based on the establishment of three interlinked tree populations (Figure 1):

- **Gene resource population.**
- **Selection population.**
- **Production population.**

The gene resource population is basically the wild population from which new selections can be derived. The selection population is the collection of selected provenances, progenies, or individual trees which are being tested and used to develop clonal cultivars or integrated within breeding programs to create the next generation of breeding stock. A wide range of genotypes may be kept in this population as long as each one has at least one characteristic of possible future interest. The production population consists of the highly selected clones, progenies, or provenances which are currently being planted by farmers.

In their strategy paper, Leakey and Akinnifesi (2008) specifically highlighted the development of a clonal approach to the domestication of high value trees, particularly the traditionally important indigenous fruits and nuts. However, the key element of the tree population strategy is equally applicable to less valuable tree species grown for their environmental services and propagated by seed. It is important to remember that the practice of domesticing a species is cyclical and thus continuous. For this reason, commercial plantings have to be made with whatever material is best at a given time, knowing that they will be superseded later.

The strategy being implemented by ICRAF and others to domesticate high-value indigenous trees for agroforestry, such as those producing marketable fruits and nuts, is based on participatory processes involving local communities. A participatory tree domestication strategy involves the consultation with and participation of farmers to (1) determine their priority species for domestication (Franzel *et al.*, 1996, 2008) (2) make an inventory of the natural resource, (3) implement a program of genetic selection and mass propagation aimed at the sustainable production of AFTPs for food, tree fodder, medicinals and nutriceuticals, timber, wood and fibers, etc., and (4) sell and trade the products in local traditional and new emerging markets further afield. Such strategies also recognize the importance of the wise use and conservation of genetic resources; the reduction of deforestation and restoration of degraded land. Participatory approaches have numerous advantages (Leakey *et al.*, 2003) such as building on tradition and culture and promoting rapid adoption by growers to enhance livelihoods and environmental benefits (Simons and Leakey, 2004). This participatory approach to domestication, therefore, differs from the more common scientific approach that has typically been implemented to develop most food crops. Therefore these approaches can be thought of as the ‘farm’ and the ‘research station’ pathways to domestication. In
agroforestry, these two pathways have been integrated (Figure 2) in a way that ensures that the participating farming communities can benefit from the close involvement of researchers as mentors both to the communities and the Nongovernmental Organizations (NGOs) implementing the domestication program.

**Biological Components of the Strategy**

**Propagation of superior trees**

The choice of mass propagation by the clonal approach has a number of advantages stemming from the use of vegetative propagation to capture and fix desirable traits, or combinations of traits, found in individual trees (Leakey and Simons, 2000). The main advantage arises from the fact that by taking a cutting, or grafting a scion onto a rootstock, the new plant which is formed has an exact copy of the genetic code of the plant from which the tissue was taken and is, therefore, genetically identical to the stockplant or ‘mother’ plant. The clone so formed can be mass produced by further vegetative propagation.

The capture of the first asexual propagule from proven and mature field trees that have already expressed their genetic traits is typically done in the field by air-layering/marcotting shoots on the mother tree or by collecting scions or buds from it for grafting or budding onto seedlings in the nursery.
Alternatively, the tree can be felled and the stump left to coppice to provide juvenile material for propagation by stem cuttings. The latter is preferable for clonal timber production from trees with a well-formed juvenile stem, whereas the former is more suitable for trees producing fruits on mature branches (Leakey and Akinnifesi, 2008). The advantage of propagating fruit trees from mature branches is that they already have the reproductive capacity to form flowers and fruits. This means that they are productive within a few years, thus reducing the time taken to produce economic returns. Plants propagated from mature tissues will also have a lower physical stature, making the harvesting of fruits easier (Figure 3).

Once the clone has been formed by one or other of the above techniques, the best strategy is to mass produce the clone, or cultivar, by rooting cuttings in the nursery. For this process, inexpensive and simple non-mist propagators have been developed (Leakey et al., 1990). This simple, low-technology strategy allows the process to be implemented in remote areas without electricity or running water. These propagators are also extremely effective and meet the needs of most developing country tree domestication projects in both the moist and dry tropics.

The above strategy of capturing the genetic superiority of mature trees in the field may not always be possible or acceptable, making it necessary to develop clones from seedling plants in the nursery. Basically, this adds an additional genetic selection step to the overall domestication program, which can take many years to complete. Nevertheless, there are three reasons why the use of seedlings may be preferable (Leakey and Simons, 2000):

1. The population of mature trees can be dysgenic (genetically depleted) because the elite specimens have been removed by loggers or farmers. In this case, the seedling progeny...
derived from such populations will probably have a better array of genetic variation during reproduction due to the remixing of genes during the segregation phase of meiosis.

2. The felling of large numbers of the most desirable mature trees for the purpose of generating cultivars may not be acceptable to the owners. In addition, felling the mature trees may not be environmentally acceptable.

3. The use of seedlings allows the screening of far larger populations, with much more diverse origins, thus maintaining genetic diversity among the cultivars.

Through the improvement of tree yield and product quality, tree domestication becomes a strategy for the intensification of agroforestry (Leakey, 2012a), something which is further enhanced when many of the different trees within the farming systems are domesticated in parallel.

**Genetic resource issues**

One of the important requirements of an appropriate strategy is to conserve a substantial proportion of the genetic variability for future use in selection programs and, subsequently, through breeding to broaden the genetic base of the cultivars in the Production Population. This also serves as a risk aversion strategy should it be necessary in the future to breed for resistance to pests and diseases. There are three actions which each contribute to genetic conservation:

- Establishing a Gene Bank (*ex situ* conservation).
- Protecting some wild populations (*in situ* conservation).

*Ex situ* gene banks containing randomly sampled populations from across the natural range of the species should be replicated within a site and across a number of sites. This replication is both for security and to ensure that the sites embrace any climatic or edaphic variation within the region. They should also be located in areas offering long-term protection from external threats, for example, deforestation and wild fires.

Regarding *circa situ* conservation and the wise use of genetic resources, it is important to recognize that there is a trade-off between accuracy of genetic value estimation and intensity of selection (i.e., greater accuracy generally comes at the expense of reduced numbers of families, individuals per family, or clones). In long-lived tree crops, there is also the problem that many of the traits on which selection is based are not visible until the trees are nearing their productive age at the end of a long period of growth. Consequently, in timbers trees, for example, much selection is done on early rates of growth and assumptions that this will relate to yield. In the case of the West African tree *Triplochiton scleroxylon*, a Predictive Test was developed on the basis of apical dominance (the process controlling the formation of branches) in very young plants in the nursery. This was to take advantage of a strong relationship between this physiological process and branching frequency in the nursery and then between branching frequency in the field and stem volume or timber yield (Leakey and Ladipo, 1987). A quick and early test like this allows much larger populations to be screened than would be either practical or economically justifiable through long-term field trials.

The trade-off between the intensity of selection and number of plants also affects the diversity of the genetic base – the gene resource population. This diversity should be rigorously enforced as one of the objectives of a domestication program. This, therefore, involves a good sampling protocol both of the natural population as well as for any existing provenances and progenies from a breeding program. In this respect, it is important to remember that it is not uncommon for there to be a few elite trees in provenances and progenies which may, however, on average, be poor. This is especially important if a clonal domestication program is being developed, as these elite individuals from poor populations may be genetically unique.

As the selection process intensifies with time, new traits will be introduced into the domestication program (e.g., seasonality of production, early fructifying, disease and/or pest resistance, drought tolerance, etc.). After the initial phases of clonal selection, the opportunity will arise for controlled pollinations between proven elite clones as has been done in *Ziziphus mauritiana* (Kalinganire et al., 2012) in the Sahel and *Dacryodes edulis* in Cameroon (Makueti et al., 2012). In this way, it should be possible to take advantage of specific-combining ability in unrelated superior clones and to produce progeny with heterosis in desirable traits that exceed what is found in the wild populations. The vegetative propagation of these new genotypes can become a second clonal generation.

**Environmental Components of the Strategy**

Different agroforestry practices typically involve a range of different species producing environmental/ecological services such as soil fertility enhancement, erosion control, or different products ranging from low-value fuel wood to high-value marketable products for food, cosmetic, and pharmaceutical industries. Different approaches to domestication will probably be followed for these different species. Likewise, these
different species will probably fill different spatial and temporal niches in the landscape and be planted in different configurations and densities within farming systems. This is all part of the diversification of the agroecosystem which is an important component of enhancing agroecosystem functions for the rehabilitation of degraded farmland (Leakey, 1999a, 2012b).

The domestication of indigenous trees producing high-value products, such as traditional foods and medicines, is one component of a novel strategy for the intensification (Leakey, 2012a) and diversification (Leakey, 2010) of smallholder farming systems in the tropics and subtropics through agroforestry. In environmental terms, the diversification with long-lived perennial plants is important because it is the way to rebuild the ecological functions of agroecosystems and landscapes. Soil and land rehabilitation is crucial if agriculture is to use land already cleared of forest rather than abandoning it and cutting down more forest (Leakey, 2012b).

Tree domestication and the commercialization of tree products also create incentives for farmers to plant agroforestry trees as they generate income and promote business, trade, and employment opportunities. When added to agroecosystem rehabilitation, tree domestication can be seen as step two in a generic model of how agroforestry can deliver environmentally desirable multifunctional agriculture (Leakey, 2010; Leakey, 2013; Figure 4) – a model with high adaptability to different climatic and edaphic situations (Leakey, 2012b).

Social Components of the Strategy

Many of the biological components described in the Section Biological Components of the Strategy are not specific to Participatory Domestication and would apply to more centralized and top-down programs led by research scientists. In
contrast, the social components are central to the philosophy of Participatory Domestication.

The prime objective of the participatory approach is to involve the target communities in all aspects of the planning and implementation of the program so that they fully understand it and can ‘buy-in’ and have ownership of the program. In addition, the purpose of this strategy is also to ensure that all engaged members of the community, whether male or female, are empowered by the program and are the beneficiaries of the outputs of their own initiatives and labor. This should enhance the livelihoods of the community members in general and promote social equity.

In the longest-running example of participatory domestication in agroforestry trees, the researchers have fed their outputs to NGO partners through training-of-trainers courses and by acting as mentors to the NGO-managed farmer-training schools (or Rural Resource Centers) established in pilot villages (Tchoundjeu et al., 2002, 2006, 2010; Asaah et al., 2011). As it will be seen in the Section Techniques, the farmers in this partnership have contributed their knowledge about the use and importance of local species, the range of variation in different traits of relevance to genetic selection, and their traditional knowledge (TK) about the role of these species in local culture and tradition. They have also contributed their time and labor. Furthermore, and crucially, they have also made available some of their trees for research and training in domestication techniques.

In implementing this strategy, it is of great importance to recognize the legal and socially important communal rights of local people to their TK and local germplasm (Lombard and Leakey, 2010) and to ensure that they benefit from their use and are rewarded for sharing them for the wider good. Because of the sensitivity arising from past commercial exploitation of these rights by individuals, companies, academics, international agencies, and government, it is very clear that the partners in domestication programs have to earn the trust of local communities before TK and germplasm is made freely available. Ideally, to ensure that benefits flow back to the farmers and communities, the recipients of TK and germplasm should enter into formal ‘Access and Benefit Sharing’ agreements (ICRAF, 2012) in which the rights of the holders of knowledge and genetic resources will be legally recognized.

**Commercial Components of the Strategy**

With poverty alleviation as one of the objectives of the domestication of agroforestry trees, it is clear that incentives for and approaches to income generation are important in the overall strategy. Consequently, improving and expanding the markets for agroforestry trees and their products are central to the strategy.

The first opportunity is the creation of demand for agroforestry trees, whether for environmental and ecological services or for AFTPs. This, certainly, involves the dissemination of the importance of agroforestry for soil fertility replenishment, watershed protection, reduction of erosion, demarcation of boundaries, as well as for the production of wood for fuel and other uses, timber, extractives, medicines, fodder, food, and numerous nonfood products (Leakey, 2012b). The experience of the past 10–15 years indicates that the first income stream from agroforestry projects is derived from the sales of plants from village nurseries to neighboring communities, especially the sale of seedlings of nitrogen-fixing or the so-called ‘fertilizer’ trees (Asaah et al., 2011; Leakey and Asaah, 2013). This is because the loss of soil fertility due to frequent cropping without access to artificial fertilizers is recognized as one of the main constraints to agricultural production. In addition, the benefit flow from these trees is obtained relatively quickly (1–3 years). However, it generally takes longer to obtain returns from the production of AFTPs.

The strategy for increased income generation from AFTPs is, in the first instance, to build local markets and trade. This is particularly important in the case of traditional foods and medicines as local people are familiar with the use of these products and the demand typically exceeds supply. In the longer term, however, some of these products may have regional and even international markets, firstly with expatriates from tropical countries living in Europe and America, and then as products become more widely known or better processed with global customers.

A secondary reason for focusing on local and regional rather than international markets is that if the demand expands too fast there is a risk that large-scale entrepreneurs may enter the marketplace and outcompete local business people (Leakey and Izac, 1996) thus, undermining the use of tree domestication as a development strategy. Having said that there are a few interesting and potentially very important initiatives in which multinational companies are becoming engaged with local communities in tropical countries in Public–Private Partnerships (Leakey, 2012b). These are generally operating in a way that is contrary to the trend of globalization in which all the economic benefits flow to industrial countries rather than at least some remaining in the tropical country.

Some tree products, notably fruits, are produced seasonally and have a very short shelf life. To overcome this constraint to year-round marketing, it is necessary to investigate opportunities for processing and value adding. This can take many forms such as drying and airtight packaging; preservation in oil, brine, or syrup; and freezing, etc. Generally, this involves the need for a level of scale outside the capacity of a smallholder farmer, although ‘cottage’ industries can be a possibility. If this approach to extending the marketing season has to involve industrial companies, then new issues arise. One of these is to involve the companies in the domestication process so that traits which are important in the processed product are included in the genetic selection program (Leakey, 1999b). Later, issues of trading agreements that also result from the involvement of processing companies in marketing will be considered.

An alternative approach to processing can be to seek the generally rare plants that flower and fruit outside the normal seasonal pattern and then to develop these as cultivars. Although this can be quite simple to achieve, these out-of-season plants may not have quality or yield traits that are as good as those fruiting within the normal season. In this case, developing cultivars which expand the productive season may need to also involve a breeding program.

As the commercialization process involves more players and becomes more complex, the risks that the producers will
be exploited and inadequately rewarded for their products and innovations increase. Entering into any market will expose suppliers to competition. Commentators have suggested that this will undoubtedly jeopardize the rights of farmers or communities in the supply chain. To shut out casual and opportunistic competitors, it is obviously important to do as much as possible to ensure that the supply chains leading up to the manufacture of the products are efficient, competitive, and as well protected as possible. Innovative approaches to ensuring that farmers and local communities are rewarded for their innovations have been developed by PhytoTrade Africa (Lombard and Leakey, 2010). It has been engaged in addressing the sustainable commercialization of natural products produced by indigenous plants, especially the trees of the Miombo woodlands. PhytoTrade Africa believes that the risks of exploitation can be minimized if the primary producers are able to secure long-term access to the markets developed for their products. Thus, they have worked to ensure that markets can be secured so that supply chains can emerge so that as wild harvesting leads to domesticated or farmed sources, the initial producers are protected as much as possible. The approach involves working with indigenous communities and helping them to secure long-term access to local and even international markets in ways which reward them and protect their intellectual property rights. Experience to date indicates that these approaches can result in critically important supplementary income of otherwise poor and marginalized farmers and producers. This, in turn, significantly improves their livelihoods.

This partnership approach between producers and the local-to-global cosmetic, food, beverage, herbal medicine, and pharmaceutical industries is based on four areas of intervention aimed at the prooor commercialization of the traditionally important products:

- Product development.
- Market development.
- Supply chain development.
- Institutional development.

Such partnerships are developed by carefully constructing commercial agreements with leaders in the relevant sector. Critically, this involves the establishment of strong and viable trade associations that are forward thinking and market oriented. Through these partnerships, it is possible to ensure long-term relationships and supply agreements which ensure that the farmers and local community producers remain in the value chain. The achievement of this can, under certain circumstances, also create a barrier to entry for plantation developers who might wish to outcompete small-scale producers and farmers.

One important consideration in developing these partnerships is the selection of appropriate species. It is critical that the abundance of the resource, and the ownership over the resource by the target producers, is sufficient to ensure sustainable and reliable supply of the products. To date, small-scale producers have depended on wild harvesting to supply the local markets. Although this provides a supply-related barrier to large scale trade that favors small-scale producers, it also imposes constraints to the market expansion that is needed to raise these producers out of poverty. For example, wild products are highly variable in quality, often with unreliable levels of production. However, the focus on naturally occurring wild resources is now changing with the recent emergence of highly compatible prooor participatory domestication technologies for indigenous fruit and nut trees. This offers great opportunities to improve product quality through tree selection and cultivar development. Creating these new crops should also greatly increase the supply of very marketable produce. Thus, by realizing the importance of ‘commercialization for domestication’ and ‘domestication for commercialization,’ there is considerable opportunity for agroforestry to alleviate poverty, malnutrition, and hunger in marginalized agricultural communities of developing countries. Thus, the symbiotic relationship between domestication and commercialization is a very important aspect of the strategy needed to ensure real impact on the big socioeconomic issues affecting the world. The overall outcome of such developments arising from improved agricultural production and enhanced livelihoods should, therefore, be improved access to clean water, better diets, healthcare, education, etc. Just as it is seen above regarding adaptability to different environmental situations, this model case has great adaptability to different socioeconomic situations (Leakey, 2012b).

Thus, in conclusion, when the social and commercial components of the strategy that have been developed for participatory domestication strategy are added to the agroecosystem benefits from the adoption of agroforestry for land rehabilitation, the emergence of a three-step generic model for the delivery of a socially and economically desirable multifunctional agriculture by agroforestry can be seen (Figure 4, Table 1).

Before moving on, however, it is important to recognize that the trade in some new products will require regulatory approval for European Union (EU) and American markets. It is, however, possible to tie the approval of these products to the target producers, as has been achieved by PhytoTrade Africa's successful application to have Baobab fruit approved as a novel food ingredient in the EU under Regulation (EC) 258/97 and by Unilever Deutschland GmbH for *Allanblackia* seed oil (European Food Security Authority No EFSA-Q-2007-059).

**Techniques**

**Biological Components of the Techniques**

**Genetic selection**

The domestication process is basically about the cultivation of plants with superior genetic traits. In trees, two techniques can be used to assist in the identification of superior mature trees (sometimes called 'elite' or 'plus trees') producing timber and wood, indigenous fruits and nuts, or otherwise useful everyday domestic products. In forestry for timber and wood production, genetic improvement is typically done by selection of a population with inherent genetic quality (a provenance) and by making seed collections from that population. Alternatively, when more is known about the genetic quality of individuals within a population, seeds (a progeny) are typically collected from the best mother tree(s). The same
Some traits of different trees which can be combined to genetic variation that 5 tons ha\(^{-1}\) (accessed 16.09.12).

Leakey, 2012b with nitrogen-
et al. given below as to how to en-
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Step 1: Adopt agroforestry technologies such as two year or enhance the indigenous knowledge approach by
et al.
Step 3: Promote entrepreneurship and develop value-adding and processing technologies for the new tree crop products, thus increasing availabilit
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developed for the breeding of cereals has been an Ideotype.

Addressing the causes of land degradation, food/nutritional insecurity and poverty: A new approach to agricultural intensi

approach is used in agroforestry when cultivating trees for soil fertility enrichment or for wood products such as poles or wood fuel (i.e., environmental services or low-value products). However, in agroforestry, trees are also cultivated for high-value useful or marketable products like fruits, nuts, medicines, or other chemical ingredients. In this case, domestication is often done using vegetative propagation to develop cultivars or clones, and participatory approaches involving local communities are appropriate.

In the participatory domestication of trees producing indigenous foods two approaches to genetic selection can be adopted. The first is to seek the knowledge of local people about which trees produce the best products (see ‘social components of the techniques’ given below as to how to ensure that their traditional rights are recognized). The second, more scientific, technique involves the quantitative characterization of many traits of fruits, kernels, and leaves, which are associated with size, flavor, nutritional value, etc. This characterization also determines the extent of the tree-to-tree variation. This more scientific approach can be used to ‘backstop’ or enhance the indigenous knowledge approach by adding new knowledge about marketable or commercially important traits to enrich the indigenous knowledge. Over the past two decades, much scientific knowledge has been acquired to support the participatory domestication initiatives being implemented around the world (see review by Leakey et al., 2012; Leakey, 2012b).

In the scientific approach to selection, modern laboratory techniques are being increasingly used to examine traits which are not visible to the naked eye. For example, to quantify genetic variation in the chemical and physical composition of marketable products such as polysaccharide food-thickening agents, nutritional content (protein, carbohydrate, oils, fiber, vitamins, minerals, etc.) by proximate analysis, medicinal factors like antiinflammatory properties, the composition of essential oils and fatty acids, the determination of wood density, strength, shrinkage, color, calorific value, and other important wood properties correlated with tree growth (Leakey et al., 2012). In addition, molecular characterization of the genetic code is being used to determine the structure of genetic variation in natural, managed, and cultivated tree stands and to devise appropriate management strategies that benefit users (Jamnadass et al., 2009). This information is used to determine the proportion of a species’ genetic variation that is available at a local geographical scale, whether or not cultivated stands are of local or introduced origin, and to ensure that domesticated populations have sufficient genetic diversity to avoid future problems from inbreeding (Pauku et al., 2010).

The above scientific inputs to the understanding of genetic variation can then inform the process of farmer selection and help to provide guidance of how best to meet the needs of different market opportunities. To achieve this, the concept of ‘ideotypes’ developed for the breeding of cereals has been modified in order to assist tree selection (Leakey and Page, 2006). An ideotype is the ideal combination of traits for a cultivar to produce a product that meets the needs of a particular market (Figure 5). So, for example, an ideotype for a fresh fruit would have a lot of flesh (and small seeds/nuts/kernels), be sweet, juicy, tasty, nutritious, and look attractive.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The 3-step model for multifunctional agriculture</th>
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<td>• Step 1: Adopt agroforestry technologies such as two year ‘Improved fallows’ or ‘Relay cropping’ with nitrogen-fixing shrubs that improve maize yields from approximately 1 ton ha(^{-1}) per hectare up to approximately 4–5 tons ha(^{-1}). This allows the farmers to both improve food security and reduce the area of their holdings planted with maize and thus make space for other crops, perhaps cash crops which would generate income. An additional benefit arising from improved fallows with leguminous shrubs is the reduction of parasitic weeds like Striga hermonthica and the reduced incidence of insects pests like the stem borers of maize.</td>
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<td>• Step 2: Diversify the farming system by the inclusion of species producing marketable products or fodder for livestock. The adoption of participatory approaches to the domestication of traditionally important food plants is a good way to rapidly create new cash crops that generate income, improve nutritional security through diversified diets, enhance gender equity, provide diversified diets rich in micronutrients, empower communities toward self-sufficiency in products of day-to-day domestic importance, and maintain culture and traditions. The sale of these products would allow the purchase of fertilizers and thus, potentially, the increase of maize yields up to 10 tons ha(^{-1}). Consequently, the area under maize could be reduced further to allow more cash cropping. The integration of fodder trees and livestock into a farm is one of the elements of diversification that could be part of this step.</td>
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<td>• Step 3: Promote entrepreneurship and develop value-adding and processing technologies for the new tree crop products, thus increasing availability of the products throughout the year, expanding trade, and creating employment opportunities. All of these are outputs which should help to reduce the incidence of poverty and enhance gender equity.</td>
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Figure 5 Some traits of different trees which can be combined to form the ideal tree for fresh fruit or kernel production – an Ideotype.
However, a nut ideotype would have a large kernel(s) (and probably little flesh), have a thin shell so that it is easily cracked, be rich in edible oil with an appropriate fatty acid profile, or have other characteristics meeting the needs of the cosmetic or pharmaceutical industries. In both instances, these quality traits are ideally associated with a high yield of fruits or nuts, so that the cultivar can be said to have a high 'harvest index' – a large amount of 'ideal' harvestable product.

An obvious trait for inclusion in the selection of all cultivars for food products is their nutritional quality. Although it is known that the tree-to-tree variation is substantial in these traits, and indeed in antinutritional factors such as phenolic content, there is a lack of knowledge on the extent of this variation in most species. Instead, most researchers have published the average values per species. This allows some comparison between species but is not useful when seeking to select cultivars from within a species. Likewise, there is very little information about tree-to-tree variation in taste, but again it is known that tree-to-tree variation is substantial in these species (Kengni et al., 2001).

**Vegetative propagation and stockplant management**

The vegetative propagation of elite trees is central to the domestication strategy for indigenous trees producing valuable and marketable products (Leakey and Akinnifesi, 2008). A key element of this strategy is that the domestication is done by local people in their communities so that they are the beneficiaries of their work. This means that the vegetative propagation techniques have to be appropriate for implementation in remote villages by people with little, if any, formal education. For this reason, the techniques must be simple, robust, and must not be dependent on an electricity supply or running water. The achievement of this has been described by Leakey (this volume and 2004). One aspect of this is the way in which stockplants are managed. Thus, the long-term success of a cloning program is heavily dependent on the nursery management and the skills of the nursery staff.

**Nursery management**

Good nursery management involves many skills and attention to detail. The process starts with acquisition of high-quality germplasm of known origin (accession records) and recorded genetic quality, supported by documents recognizing the rights of the supplier (Access and Benefit Sharing agreements) – for example, see the Agroforestry Tree Genetic Resources Strategy of the World Agroforestry Centre (ICRAF, 2012). Furthermore this germplasm must have been appropriately stored and handled to avoid loss of viability. Germplasm can be of two types: seeds and vegetative propagules. Seeds also are of two main types: those that can be stored by drying or freezing (orthodox) and those which cannot be (recalcitrant). Both the latter and the vegetative propagules are short lived (from a few days to at most a few weeks). They have to be very carefully and rapidly handled to avoid water or temperature stress and any physical damage.

Accession records must be stored safely and the origin of every plant in the nursery must be labeled or in some other way traceable back to these records. Plants of unknown origin are of zero importance in a domestication program.

Successful plant production is dependent on rapid germination of seeds and propagation of vegetative propagules and their subsequent growth in good, free-draining potting compost well supplied with nutrients and organic matter. During early growth, some shade is usually desirable to prevent wilting and water stress. Usually, daily watering is required during dry weather. Once growing in the nursery, potted plants must be regularly maintained so that they do not become root bound and consequently the roots do not escape from the pot into the soil below (if this happens, it is very difficult to subsequently establish this plant as its roots will be left in the nursery). Plants should not be kept in the nursery so long that their root systems become coiled. Attention should be paid to weeds and pests.

Plants which are poorly managed in the nursery usually struggle to perform well once planted out in the field. The standards of nursery management are clearly visible to a visitor and are an excellent indicator of the interest and enthusiasm of the nursery staff and manager. Consequently, they are also a good indicator of the likely success of the subsequent planting program.

**Predictive test for domestication of timber trees by vegetative propagation**

One of the difficulties facing anyone involved in tree domestication is their longevity and long regeneration cycle. Many trees do not reach sexual maturity for 10–20 years and especially in the case of timber they do not display their yield potential and commercially important qualities until they are large trees. This makes tree breeding a slow business, but it also means that clonal forestry is difficult as juvenile trees which have not had time to display their potential are the easiest to propagate by cuttings. To get around this problem, large trees can be felled and allowed to develop coppice shoots, although this too is less likely from very old trees.

In *Triplochiton scleroxylon*, a West African timber tree conforming to Rauh's Model of branching architecture, a technique to predict which seedlings in a given population were more likely to grow to form the trees with the best form (branching frequency) and yield has been developed (Leakey and Ladipo, 1987; Ladipo et al., 1991). This is based on the fact that the trees developing the greatest stem volume had been found to be those producing a few branches in each branch whorl and no branches between whorls – so allocating biomass to stem rather than to branches. The technique is based on an assessment of the 'strength' of apical dominance, the process regulating the formation of branches, by decapitating young seedlings and following the pattern of sprouting and the reassertion of dominance by the upper shoot (Ladipo et al., 1992). This nursery-based screening technique in seedlings on 3–6 months old allows the rapid selection of those likely to produce the best stems to enter a program of clonal propagation. Conversely, because the leaves of this species are eaten as a vegetable by local people in Nigeria, the trees producing the most branches can be selected and managed as a hedge for leaf production.

**Nursery management strategy**

Farmers who manage tree nurseries can adapt their management to best meet their needs. For example, if their priority is to meet their own domestic food demands, they can plant the majority of the trees they produce in their own farm rather than selling them or multiplying them up by harvesting successive batches of cuttings or scions. Alternatively, if income
generation through the development of a tree nursery business for the sale of plants to other farmers is the priority, they can take 3–4 crops of cuttings off every plant per year for a few years and so very rapidly build up a large stock of plants for sale. This strategy should result in the greatest income generation in the long term but has the disadvantage that there are no financial returns in the first few years. An even longer term commercial strategy would be to do a long period of plant multiplication before large-scale planting. In addition to these individual strategies, there are, certainly, many possibilities of intermediate or mixed options.

Environmental Components of the Techniques

As a low-input farming system based on long-lived perennial trees, agroforestry provides many environmental benefits. Tree domestication is normally an approach to make these farming systems more productive and more profitable – in other words to intensify the agroforestry system. Many aspects of this will also have indirect environmental benefits in more rapid cover of the soil, greater root penetration, and lateral spread with consequently better protection and improvement of the soil and agroecosystem function. Rapid tree growth is associated with high water use. Although this may have negative impacts on the growth of associated crops, it can also reduce the impacts of salinization by lowering the water table.

Recent data in *Dacryodes edulis* show that vegetatively propagated cultivars have lower fine root density in the crop rooting zone and hence are more likely to be less competitive with crops (Asaah et al., 2012). In addition, the perennial nature of trees also assists in carbon sequestration for the mitigation of climate change, and emerging evidence suggests that vegetatively propagated cultivars store more carbon than seed propagated individuals in their primary roots and shoots – an unexpected benefit of tree domestication (Asaah, 2012).

One important aspect of these environmental impacts is their quantification. This requires Baseline surveys based on randomized controlled trials – described by Barrett et al., (2010) as providing solutions to development economics issues with weak causal factors. If applied to agroforestry, this approach should help to determine the scale of the impact at the plot, farm, landscape, and regional level.

Social Components of the Techniques

To maximize the social and economic benefits flowing from tree domestication, a participatory approach has been taken by the World Agroforestry Centre and some other organizations and their local partners to identify the farmers’ preferences in terms of the tree species they would like to cultivate. Interestingly, in most of the places around the world where this has been done, the farmers have identified indigenous fruits, nuts, and leaves for uses as foods or medicines (Franzel et al., 2008). As mentioned in the Section Social Components of the Strategy, participatory domestication has typically followed the identification of priority species, with farmers contributing their knowledge about the traits they would like to see incorporated within a selection program and the usefulness of the tree products to local households.

To encourage and assist the farmers, the agroforestry scientists and NGO partners in Cameroon have provided training and knowledge through specially constituted Rural Resource Centers in pilot villages in different regions of the country (Tchoundjeu et al., 1998, 2006, 2010; Asaah et al., 2011). These Rural Resource Centers provide opportunities for hands-on training in critical nursery management, vegetative propagation, agroforestry practices, and enterprise development in a community nursery (Figure 6). The focus of this training is that it is appropriate for implementation in often remote village nurseries without piped water and electricity. The farmers are then encouraged to set up similar facilities in their own farm or community, thus creating satellite nurseries which help to spread the techniques and concepts to neighboring communities. To encourage this kind of farmer-to-farmer technology transfer, exchange visits, demonstrations, and competitions covered by radio and television are organized. In time, these village and community nurseries become self-sufficient and independent.

In recent years, the range of topics presented in training programs has been expanded to include the wise use of microfinance and financial management, product marketing, business development, infrastructure development, and community organization. In parallel to this, artisans in neighboring towns have been trained in the fabrication of simple equipment and tools for product drying, processing, and packaging, whereas entrepreneurs and women’s groups have been helped to develop businesses in food product processing and value adding aimed at improving the quality of products for the marketplace and increasing market demand. As these processes expand, it is expected that some people will cease to be farmers and producers and instead enter the cash economy as business men and women providing employment to others and developing new enterprises.

Although much progress has been made in developing, implementing, and expanding the participatory domestication of a wide range of agroforestry trees and commercializing their products, there is still much to do to quantify the socio-economic impacts. A critical component of this is the establishment of statistically viable baseline surveys so that accurate assessments can be made in years to come as the concepts are disseminated and scaled up to new communities. This process...
has begun, but to date, the results are preliminary. Likewise, it is still too early to say much about the implementation of work to recognize and protect the rights of farmers and rural entrepreneurs to their innovations.

**Commercial Components of the Techniques**

Ultimately, as it can be seen from Figure 4, it is the commercialization of the sustainably grown products that potentially delivers the really important impacts from agroforestry and multifunctional agriculture. However, it is also recognized that commercialization can pose the greatest risks affecting the success or failure of the overall initiative. One study (Wynberg et al., 2003) has examined the ‘Winner or Loser’ qualities of different approaches to the commercialization of an indigenous fruit (*Sclerocarya birrea* – Marula) in southern Africa (Table 1). It basically found that bottom-up community initiatives had the greatest chance of being Winners, although top-down commercialization involving large multinational companies could also be Winners if the company recognized the importance of buying raw products from local smallholder producers, rather than from large-scale plantation growers.

Focusing first on tree domestication can encourage the positive aspects of commercialization from producers practicing agroforestry. The expansion of markets beyond the traditional market or roadside stall (Figure 7) requires increased product quality, uniformity, and regular supply. The longer the value chain from local to global market, the more important are the attributes of quality, uniformity, and regularity of supply (Figure 8). Hence, the development and cultivation of vegetatively propagated cultivars selected for year-round

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**Figure 7** A market stall in Makanéné in Cameroon, selling *D. edulis* fruits.

**Figure 8** The increasing importance of domestication in the value chain of an agroforestry tree product.
production and other commercially desirable traits makes a quantum leap in the marketability of the products, as it means that traders and wholesalers can purchase a large volume of uniform, high-quality product from a recognized and named cultivar. In return, hopefully the producer will receive a higher price, as it is clear that consumers are willing to pay more for the more desirable varieties (Figures 9 and 10).

The above demand for uniformity and quality makes the ideotype concept more important, especially at upper end of the value chain where processing and value addition increase the value of the marketable products (Figure 11). With the increasing importance of the ideotype, the identification of the specific traits that confer market acceptability and market exclusivity and distinctiveness become more and more critical. This, therefore, is the reason for increasingly sophisticated research, mentioned in the Section ‘Biological components of the technique’ earlier, to determine the genetic variation found in different tree populations in the chemical, physical, and medicinal properties of the raw products. This, certainly, will lead to the need for stronger linkages between agroforestry researchers and partners in industry (Leakey, 1999b).

Food crop domestication over thousands of years has been credited with the advance of civilization as witnessed in industrialized countries (Diamond, 1997). However, domestication and commercialization are both part of this force for development, as one is considerably weakened without the other. Leakey (2012b,d) has recognized that in the tropics there is a need for a ‘new wave of domestication,’ but this too has to be supported by market growth along the value chain. Thus, one of the important components in this ‘new wave’ is the processing and value addition that extends the shelf life of products, expands market demand, and makes them more valuable. In Cameroon, the development of cottage industries to dry and package AFTPs has started (Asah et al., 2011), but this enterprise development and its up-scaling needs considerable expansion – recognizing the characteristics of Winners in the development process (Table 1). In this regard, one interesting development in recent years has been the involvement of a few multinational companies in Public–Private Partnerships with rural communities engaged in production of agroforestry products in tropical countries (Jamnadass et al., 2011; Leakey, 2012b). Although associated with risks, this also offers great opportunities for the future development of agroforestry tree crops if the strategies and practices can be developed appropriately.

**Outcomes**

To date, studies on the environmental and socioeconomic impacts of tree domestication have not been based on randomized controlled trials. Nevertheless, comparisons based on household surveys have indicated that integrated rural development based on agroforestry, tree domestication, and local market initiatives with small-scale enterprises have

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**Figure 9** Fruits of *D. edulis* from market stalls showing the retail price in Central African francs (CFA) and illustrating consumer preferences for fruits from certain trees. Reproduced from Leakey, R.R.B., 2012b. Living with the Trees of Life – Towards the Transformation of tropical Agriculture. Wallingford, UK: CABI, 200 pp.

positive impacts on the lives of farming households in participating communities (Figure 12 and Table 2). Together these impacts illustrate that agroforestry can deliver what the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) called Multifunctional Agriculture (Table 3). Currently, the impacts are only on a local/household/farm/village scale and there is much to be done to upscale and outscale the agroforestry initiatives before the scales are extended (Table 4).

Biological Components of the Outcomes

The major outcome of participatory tree domestication, as expected, is new tree crop cultivars with improved product quality and greater market demand. This is happening in many places around the tropics in more than 50 species but is most advanced in Cameroon, where these cultivars have been developed by local farmers for cultivation in their own farms to meet household needs. However, as the supply of product increases, it is expected that both these cultivars and their products will be sold – at first locally and then more widely (Tchoundjeu et al., 2010; Asaah et al., 2011; Leaky, 2012b). The cultivation of these new cash crops is leading to the diversification of farming systems and this is expected to result in healthier agroecosystems. Another biological finding with likely impacts on agroecosystems is that vegetatively propagated trees allocate their dry matter differently, with less in fine root and more in primary roots and shoots. Consequently, clonal cultivars are more likely to be less competitive with annual crops (Asaah, 2012; Asaah et al., 2010, 2012).

Environmental Components of the Outcomes

One important outcome expected from more sustainable land use systems that rehabilitate degraded land is better access to productive land for staple food crop production and hence the opportunity to diversify into other crops with market potential. This diversification either as mixed cropping or as landuse mosaics should improve the agroecosystem functions and thus lower the need for inputs such as pesticides. The increased tree
The perennial nature of trees also assists in carbon sequestration for the mitigation of climate change, and emerging evidence suggests that vegetatively propagated cultivars store more carbon in their primary roots and shoots than by seed-propagated individuals – an unexpected benefit of tree domestication (Asaah, 2012).

Social Components of the Outcomes

One of the original purposes of initiating participatory tree domestication was to improve the livelihoods of poor farmers, especially income generation to reduce poverty; food security to reduce hunger; better nutrition and diet to reduce malnutrition; and better equity to improve the lot of women and children in society. It was envisioned that indirectly this would also improve health and education opportunities and that the overall package would empower individuals and communities, allowing them to be more self-sufficient in order to transform their lives, giving them hope for the future. Early indications (Table 2) are that these outcomes are starting to emerge in the participating communities. Furthermore, when associated with microfinance, business training and access to simple equipment for the processing and packaging of raw products, there is now evidence of rural people engaging in small businesses either as entrepreneurs or as employees.

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

**Table 3** The impacts reported by farmers engaged in a participatory domestication program for agroforestry trees in Cameroon

<table>
<thead>
<tr>
<th>Positive impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased number of farmers adopting agroforestry and the domestication of indigenous trees</td>
</tr>
<tr>
<td>Increased production of tree products</td>
</tr>
<tr>
<td>Increased income from tree sales by nurseries</td>
</tr>
<tr>
<td>Increased income from sale of tree products</td>
</tr>
<tr>
<td>Increased income from better farming practices</td>
</tr>
<tr>
<td>Increased income from eligibility for microfinance</td>
</tr>
<tr>
<td>Increased income used for schooling and school uniforms</td>
</tr>
<tr>
<td>Increased income used for medicines and healthcare</td>
</tr>
<tr>
<td>Increased income used for home improvements – for example, installation of water and electricity in the home, new buildings, etc.</td>
</tr>
<tr>
<td>Increased income used for farm improvement – for example, livestock, wells, agricultural inputs, etc.</td>
</tr>
<tr>
<td>New employment opportunities from nurseries</td>
</tr>
<tr>
<td>New employment opportunities from processing both agricultural crops (such as cassava) and new markets for processed agroforestry products (fruits, spices, herbs, and medicinal)</td>
</tr>
<tr>
<td>New employment opportunities in the emerging workshops producing small tools and appropriate mechanized equipment to service the need for food processing equipment</td>
</tr>
<tr>
<td>New employment opportunities from marketing as traders of processed products and the food processing equipment</td>
</tr>
<tr>
<td>New employment opportunities in transport from producers to markets and to the processors of agricultural produce</td>
</tr>
<tr>
<td>Retention of youths in the villages due to career opportunities by domesticating trees in their village nurseries</td>
</tr>
<tr>
<td>Tree domestication has led to better diets and improved nutrition</td>
</tr>
<tr>
<td>Luxury food items consumed</td>
</tr>
<tr>
<td>Improved health from potable water</td>
</tr>
<tr>
<td>Piped water supplies for irrigation and use in nurseries</td>
</tr>
<tr>
<td>Increased livestock rearing due to tree fodder</td>
</tr>
<tr>
<td>Increased use of traditional medicines and better health</td>
</tr>
<tr>
<td>Increased honey production and processing</td>
</tr>
<tr>
<td>Reduced drudgery in women’s lives from not having to collect water from rivers and farm produce from remote farms, as well as from mechanical processing of food crops</td>
</tr>
<tr>
<td>Reduced drudgery gives more time to look after their families and engage in farming or other income-generating activities</td>
</tr>
<tr>
<td>Improved marketing for food and agroforestry products</td>
</tr>
<tr>
<td>Improved soil fertility from improved fallows has increased crop yields 2- to 3-fold with better weed control</td>
</tr>
<tr>
<td>Improved tree fodder for goats and cattle</td>
</tr>
<tr>
<td>Having more time as a result of better farming methods, farmers had more time for marketing and new farming activities</td>
</tr>
<tr>
<td>Community feeling empowered, stronger, and optimistic for the future in ways that they could sustain</td>
</tr>
<tr>
<td>Knowledge has empowered the Rural Resource Centers as an agent of change</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Negative impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased jealousy and theft</td>
</tr>
<tr>
<td>New roads lead to deforestation and land degradation as a result of the expansion of farming activities to more remote areas</td>
</tr>
</tbody>
</table>

Significantly, one of the outcomes mentioned by young people in the participating communities is that this now means that they can see a future for themselves if they remain in the village rather than feeling that they have to migrate to towns and cities for a better life (Table 2).

**Table 4** The characteristics of the participatory domestication of agroforestry trees important for the delivery of multifunctional agriculture

The features that agroforestry brings to multifunctional agriculture to enhance social, economic, and environmental resilience in agriculture and rural development are:

- Based on TK and culture
- Based on participatory techniques to ensure relevance to local people
- Based on integrated natural resources management and sustainable land use
- Based on knowledge of the natural resource

The above features mean that multifunctional agriculture can:

- Empower subsistence farmers to control their destiny
- Enhance food security and rural/urban livelihoods, reducing hunger
- Enhance nutrition security and health, reducing malnutrition and diseases
- Enhance opportunity for income generation, reducing poverty
- Diversify farming system at the local and landscape scale, enhancing watershed services and sustainable production
- Create new agricultural commodities
- Diversify market economy and buffer commodity price fluctuations
- Decentralize business opportunities to the villagers
- Create employment in processing and marketing
- Build social responsibility from the ‘grassroots’
- Enhance international public goods and services, reducing climate change and loss of biodiversity
- Offer opportunities for new policy interventions to combat deforestation, desertification, and land degradation
- Breakdown the disconnects between disciplines and organizations responsible for policy and its implementation in rural development

The characteristics of the participatory domestication of agroforestry trees important for the delivery of multifunctional agriculture are:

- Based on TK and culture
- Based on participatory techniques to ensure relevance to local people
- Based on integrated natural resources management and sustainable land use
- Based on knowledge of the natural resource

The important commercial outcomes have been the development of Rural Resource Centers that deliver both education and training in agroforestry and tree domestication, as well as in community development and business management so that the villagers can earn money from the sale of plants and raw products. This money is then being used to make infrastructure developments, such as roads and clean water supplies, as well as to reduce the drudgery of the women (Table 2). The consequence of this has been that poor farmers are starting to generate income and enter the cash economy and so begin to climb out of poverty (Figure 11). In bigger villages and small towns, local people are also developing cottage industries and engaging more in marketing and trade. This relationship between enhanced farm production and urban life is important for the rural economy and the overall alleviation of poverty. It is an example of farm production being the ‘engine of growth.’

**Commercial Components of the Outcomes**

In the long term, the application of these strategies should lead to benefits, which encompass many of the rural development goals of development agencies, as specified in the Millennium Development Goals of the United Nations. At the community
level, some of these goals have been achieved, but to date, it is still only talked about several thousand participating farmers. Achieving these benefits will, however, require the large-scale adoption of the techniques and strategies presented here in ways that will meet the needs of the farmers and those of new and emerging markets (Leakey et al., 2012). This makes it important to get the messages about good domestication strategies to policy makers (e.g., Wynberg et al., 2003).

Clearly, the challenge is to scale up the application of agroforestry and tree domestication to the huge numbers needed to have meaningful impact of national, regional, and global scales.

Biological Components of the Impact

The vision of what could be achieved with the widespread adoption of the domestication of trees and the associated trade of the products in numerous different industries is perhaps best exemplified by the domestication of the wolf to give large numbers of breeds of dogs of all sorts of shapes, sizes, and appearances, to be both pets and working partners with farmers, policemen, entertainers, blind people, etc. These dog breeds have arisen by breeders teasing out the genetic traits present in the wolf genome. If the same is done for trees, there could be a large number of different cultivars meeting the needs of many food, cosmetic, medicinal, perfume, fiber, and wood markets – not just in one species but in hundreds of species. This, in turn, would lead to a highly diversified, intensified, and more productive Multifunctional Agriculture (Leakey, 2012b).

Integrated Environmental, Social, and Economic Components of the Impact

The restoration of degraded land by Multifunctional Agriculture could make productive land available for an expansion of overall farm production to fill the Yield Gap (Leakey, 2012b) and meet the needs of a growing human population without the need for further deforestation and without future negative impacts on erosion, flooding, climate change, etc. A healthier environment could lower the risks of disasters due to flooding, drought, landslides, pest and disease epidemics, etc.

The achievement of even greater success than foreseen by the Millennium Development Goals could lead to greatly improved local and national economies and the gradual transition of developing countries toward developed countries.

References


Non-Wood Forest Products No. 9.


**Relevant Websites**

- [www.internationaltreefoundation.org](http://www.internationaltreefoundation.org)
- [www.worldagroforestrycentre.org](http://www.worldagroforestrycentre.org)
- [World Agroforestry Centre](http://www.worldagroforestrycentre.org)