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Should We be Growing More Trees on Farms to Enhance the Sustainability of Agriculture and Increase Resilience to Climate Change?

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Introduction

The tree products of interest to foresters are both timber and non-timber forest products (NTFPs), with timber predominating in forest industries. NTFPs are important in the valuation of forest and as a resource for the livelihoods of forest people, but the term NTFPs has many meanings (Belcher, 2003). One issue is that a high proportion of NTFPs are actually harvested from farms, so there is grey line between whether they are really common property extractive forest products or privately owned farm crops. Distinguishing between these is important in terms of agricultural development and trade statistics (Simons and Leakey, 2004).

Looking first at the scale of the on-farm tree resource, recent data has shown that globally 46% of agricultural land (over one billion hectares) has more than 10% tree cover (Zomer et al., 2009), while 17% of farming land has more than 30% tree cover. This land with more than 10% tree cover is occupied by 31% of the people living in agricultural land (558 million) (Zomer et al., 2009). The products from these on-farm trees are important to the local people and the wider population for fuelwood, as well as many food and medicinal products.

While forests are still being severely degraded, the number of trees on farms is increasing (FAO, 2005) and interestingly, there are many examples where the rise in on-farm tree numbers occurs in areas where population densities are high and farm size is very small. This raises some questions. What role do trees play in farming systems? How important are they? What is the future of trees on-farm?

Trees in farming systems are found either in forest fallows within shifting cultivation systems; as relics from land clearance by slash-and-burn, or as a result of deliberate management and / or planting. The integration of trees in farming systems is the practice of agroforestry to provide environmental services and / or products that are either traded or used domestically to confer multiple livelihood benefits, especially for smallholder farmers in the tropics beset with poverty, malnutrition and hunger. Poverty (earning less than the purchasing power equivalent of US $2/day), malnutrition and hunger affect 3.2 billion, 2 billion and 0.9 billion people respectively. The scale of these problems is enormous despite the technical advances in agriculture over the last 50-60 years. Land degradation affects 1.9 billion hectares of land (38% of crop land) and 2.6 billion people (Eswaran et al., 2006).

Role of agroforestry

Agroforestry involves the cultivation and use of trees in farming systems and is a practical and low-cost means of implementing many forms of integrated land management, especially for small-scale producers. The World Bank (2004) has estimated that agroforestry practices are used by 1.2 billion people. Below we will briefly explore some of the main benefits arising from the integration of trees in farming systems, and then consider the question 'can trees play a bigger role in agriculture'?

The successful practice of agroforestry involves three steps (Figure 1) aimed at promoting more sustainable rural development:-

The first step involves the restoration of soil fertility in degraded farmland using nitrogen-fixing trees and shrubs in improved fallows. Over the last thirty years numerous experiments have been done in different countries and in different agroecosystems to study the benefits of growing nitrogen-fixing trees and shrubs to improve soil fertility (Buresh and Cooper, 1999). Now these 'Step 1' agroforestry practices are commonly implemented by farmers, and the Improved Fallow systems with *Sesbania sesban* and *Tephrosia vogelii* in particular are widely adopted (*e.g*. 66,000 maize farmers in Zambia in 2008) because maize yields are doubled or trebled. This represents a very important breakthrough for poor farmers locked in food insecurity and hunger (Sanchez, 2002; Sanchez et al., 2005). However, wider adoption / up-scaling of this is needed to address the land degradation affecting 1.9 billion hectares, and thus for the meaningful process of mitigating land degradation there is a need for very large scale efforts to disseminate and up-scale these now well researched and adoptable technologies. However, the reduction of land degradation alone does not have the potential to open up a pathway towards greater prosperity and better living standards for the rural poor.

The second step builds on the common practice of small-scale farmers in the tropics to protect or plant trees producing traditionally important products (food, medicines, etc.) on their farms when land is cleared for agriculture. Tree domestication offers great opportunities to capture specific traits that are important for different market opportunities (Leakey, 1999; Leakey et al., 2005). In recent years an international initiative has implemented a programme to domesticate a wide range of indigenous tree species producing marketable food, fodder, and non-food products (Leakey et al., 2005). In this way, agroforestry tree domestication can be seen as a means to enrich and improve the 1 billion hectares of farmland with 10% tree cover. Tree products produced on–farm are known as Agroforestry Tree Products (AFTPs), to distinguish them from common property NTFPs (Simons and Leakey, 2004). Participatory tree domestication brings together agricultural science and technology with Traditional Knowledge as an integrated package which builds on local traditions and practices.

Currently, as a result of deforestation for modern farming systems, local communities no longer have access to all the traditionally important products formerly gathered from forests. Consequently, tree domestication is a means for farmers to rebuild the resource of species providing food, medicines and all their other products needed for everyday survival. This is particularly important in Developing Countries where most households do not have other sources of income or social support. Fortunately, however, there are many indigenous tree species that have the potential to produce marketable food, fodder, and non-food products (Leakey, 1999; Leakey *et al*., 2005) and some of these tree species are now the subject of tree domestication programmes to improve the yield and quality of their products (Leakey et al., 2003; Tchoundjeu et al., 2006). When a participatory approach to tree domestication based on local knowledge is used, the additional benefits include the empowerment of local communities towards greater food self-sufficiency and nutritional security (Leakey et al., 2003). However, this approach to agroforestry needs to be supported by Intellectual Property Rights agreements that comply with international law to give innovative Developing Country farmers protection from commercial exploitation (Lombard and Leakey, 2010). Many of these new tree crops can also play important ecological roles in the development of agroecological succession that greatly enhances the ecological functions of the agroecosystem (Leakey, 1996). In this way, the ecological services traditionally obtained by long-periods of unproductive fallow are provided by productive agroforests yielding a wide range of food and non-food products (Leakey, 1999), so further supplementing Step 1. Once again, however, the scale of adoption is grossly inadequate relative to the problems of malnutrition, hunger and poverty. In many areas, a lack of planting stock and poor nursery management skills are severe constraints to Step 2 agroforestry practices.

The third step is to promote entrepreneurism and develop value-adding and processing technologies for the new tree crop products, so increasing availability of the products throughout the year, expanding trade and creating off-farm employment opportunities; outputs which should help to reduce the incidence of poverty. In this way, rural people can generate income which can be used to improve their livelihoods and to begin the climb out of poverty, malnutrition and hunger. There is growing evidence that tree domestication can help rural communities to be self-sufficient, to support their families on an area of less than 5 ha and to contribute to the payment of childrens' school fees and uniforms (Schreckenberg *et al*., 2006; Degrande *et al.*, 2006). There is now some additional evidence from Cameroon which suggests that the development of over 300 village nurseries involving over 6000 farmers engaged in the domestication of indigenous trees producing AFTPs is generating income to help farmers meet specific income needs, as well as to attract young people to remain in their villages (Leakey and Tentchou, 2009; Tchoundjeu et al., 2010), reversing urban migration. Likewise, the local development of equipment for the processing, storage and wider trading of farm produce has starting to open improved opportunities for the marketing of AFTPs. This study has identified 31 positive impacts, including improved diet, increased income (rising to as high as US$10-20 per day), and improved livelihoods (Leakey and Tentchou, 2009). Other positive impacts included education, health and infrastructure developments (Tchoundjeu et al., 2010).

The integration of domesticated indigenous trees into productive agroforests is foreseen as an incentive for farmers to establish productive and profitable farming systems that provide the ecological services that used to be obtained by long-periods of fallow. To effectively reduce poverty in Developing Countries, where about 80% of rural households are engaged in agriculture, will involve the development of in-country processing and value-adding of agricultural produce and hence the diversification of the rural economy. Experience to date indicates that, by enabling market opportunities for these local resources, significant livelihood options for otherwise marginalised farmers and producers can be facilitated (Lombard and Leakey, 2010). Partnerships between producers and the local-to-global cosmetic, food, beverage, herbal medicine and pharmaceutical industries can be 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 (Lombard and Leakey, 2010). Through these partnerships it is possible to ensure long term relationships and supply agreements which ensure that the target producers remain in the value chain.

Scope for wider tree domestication

There are many wild species in natural ecosystems which produce products that have traditionally been collected and gathered to meet the day-to-day needs of people (Falconer, 1990, Abbiw, 1990; Villachica, 1996; de Beer and McDermott, 1996; Cunningham, 2001). Such products include traditional foods and medicines, gums, fibers, resins, extractives, as well as wood and timber for building materials, artifacts, etc. Many of these products are increasingly being marketed in local, regional and international markets (Ndoye et al., 1997; Awono et al., 2002) and so help to buffer the effects of price fluctuations in cocoa and other commodity crops (Gockowski and Dury, 1999). These species are all potential candidates for domestication and cultivation in small-scale farming systems. As well as indigenous species, small-scale farming systems commonly include exotic tree species producing useful products (Schreckenberg et al., 2002, 2006; Kindt et al., 2004) in ways that require little investment of cash and have low labour demands (Degrande et al., 2006).

In addition to meeting the domestic needs of small-scale farmers, domesticated agroforestry trees are producing products that have the capacity to produce new agricultural commodities and generate new industries. For example, species like *Prunus africana*, *Pausinystalia johimbe*, *Sclerocarya birrea*, *Vitellaria paradoxa*, *Canarium indicum* produce products of interest to pharmaceutical, cosmetic and nutraceutical industries. In addition, some AFTPs are sources of edible oils with market opportunities. In West Africa, for example, edible oils are extracted from the fruits/kernels of *Allanblackia* spp. (Tchoundjeu et al., 2006; Jamnadass et al., 2010), *Irvingia gabonensis* (Leakey, 1999), *Dacryodes edulis* (Kapseu et al., 2002), *Vitellaria paradoxa* (Boffa et al., 1996) and many other agroforestry species (Leakey, 1999). Unilever is investing in a new edible oil industry in West Africa, using *Allanblackia* kernel oil (Attipoe et al., 2006). In addition to the development of new fodder crops (Bonkoungou et al., 1998), there are opportunities for developing cattle cake from the by-products of species producing edible fruits and nuts (e.g. *Dacryodes edulis*, *Canarium indicum*, *Barringtonia procera*, etc). The nuts of *Croton megalocarpus* have been recommended as poultry feed (Thijssen, 2006). In Brazil, new agricultural commodities from community-based small-scale agroforestry systems are being used in the manufacture of products for the automobile industry (Panik, 1998). In the case of *Allanblackia* spp., Unilever is taking a similarly innovative and socially-responsible approach to developing a new industry. Rather than pursuing a large-scale plantation approach to oil production, they are working on the domestication and cultivation of *Allanblackia* species with local communities, seeing this as a new crop for Africa. In a different, but equally innovative development, Phytotrade Africa has taken out a patent on 'Maruline' a product from *Sclerocarya birrea* kernel oil, on behalf of a local women's group in Namibia (Lombard and Leakey, 2010). This emerging market orientation needs to be developed carefully as it potentially conflicts with community-oriented values and traditions. A series of "Winners and Losers" projects on the commercialization of AFTPs have examined these options (e.g. Leakey et al., 2005; Marshall et al., 2006).

Domestication techniques and strategies

Many of the above innovative developments have been made possible by the application of horticultural techniques and strategies to forest trees. For example, the development of robust vegetative propagation techniques have been used to overcome some of the critical barriers to rapid tree domestication, opening up the opportunities for clonal agroforestry and forestry (Leakey, 1987; Leakey, 2004). Techniques of vegetative propagation have existed for thousands of years, but many tropical trees were considered to be impossible to propagate by cuttings until the 1970-1980s, but now detailed studies of the many morphological and physiological factors affecting five stages of the rooting process in stem cuttings have resulted in some principles, which have wide applicability and explain some of the apparently contradictory published information (Leakey, 2004). Simple, inexpensive and low-tech methods for the rooting of stem cuttings have been developed for use by resource poor farmers in remote village nurseries (Leakey et al., 1990). These robust and appropriate techniques which do not require running water or electricity are now being widely implemented, most notably within participatory village-level development of cultivars of indigenous fruit/nut tree species in West Africa (Leakey et al., 2003).

These techniques allow clonal approaches to the genetic improvement of tree species which can result in large improvements in yield and quality traits, based on ideotypes resulting from a good understanding of the 3-10-fold intraspecific variation in all traits of importance for selection and improvement to meet many different market opportunities (reviewed by Leakey et al., 2005). Interestingly, this variation is greatest at the village level, while the variation between villages is only modest, indicating that genetic diversity at the species level can be maintained by village-level domestication. In addition to selection for yield and quality traits, it is possible to develop cultivars that are productive out of season and whose fruits sell for prices 10-fold higher than those obtained in the peak fruiting season.

Agroforestry for the delivery of multifunctional agriculture

The philosophy of 'Multifunctional Agriculture' recognizes the 'inescapable interconnectedness of agriculture's different roles and functions' in sustainable rural development and the need for agriculture to be more socially, economically and environmentally sustainable (McIntyre *et al.*, 2008 – see also Figure 2). This paradigm is based on the view that agriculture is at a 'crossroads' and in need of redirection (Kiers *et al*., 2008) because of the unresolved issues of poverty, malnutrition, hunger and natural resources degradation. The concept recognizes the need for more socially-relevant, pro-poor, approaches to agriculture that relate to production, livelihoods, and ecosystem service functions, and the need to revitalize farming processes and rehabilitate natural capital to achieve simultaneous impacts at different points in the land degradation cycle (Figure 3).

To build on the positive outcomes of the last 60 years of agricultural research and to rehabilitate degraded farm land it is important to find ways of restoring soil health by enhancing fertility and the biodiversity necessary for agroecosystem function at the plot and landscape level, so reducing dependency on purchased inputs; integrating the improved crop varieties and livestock breeds into more diversified, risk averse, farming systems, which include perennial vegetation to help to counter climate change and provide environmental services. Diversification should also increase the number of niches in the agroecosystem in ways which make them less damaging to the environment and which are additionally compatible with the culture of the farming community. Ideally through diversification with new tree crops, the farming system can also produce traditionally-important products to meet the everyday needs of local people, as well as to generate income.

Fortunately, there are examples from around the world of low-input, socially-relevant, pro-poor, approaches to rural development that relate to production, livelihoods, and ecosystem service functions. Some of these approaches are based on an understanding of agroecology and soil science but, currently, few of them provide a complete package. Many of these low-input resource-conserving technologies are based on integrated management systems such as reduced- or no-tillage, conservation agriculture, ecoagriculture, agroforestry, permaculture and organic agriculture. Of these, agroforestry seems to be particularly relevant to the delivery of multi-functional agriculture. Like the other systems, it addresses the issues of soil fertility management; the rehabilitation of degraded farming systems; loss of biodiversity above and below ground; carbon sequestration; and soil and watershed protection. However, in addition, agroforestry also provides three crucial outputs that are not provided by the other systems, namely: (i) useful and marketable tree products for income generation, fuel, food and nutritional security/health and the enhancement of local livelihoods; (ii) complex mature and functioning agroecosystems akin to natural woodlands and forests; (iii) linkages with culture through the food and other products of traditional importance to local people. Consequently, based on the information summarized in this paper, it has been suggested that agroforestry can be seen as a delivery mechanism for multifunctional agriculture (Leakey, 2009).

Agroforestry and the mitigation of climate change

All increases in the carbon content of agricultural soils have beneficial impacts by reducing CO_2 emissions to the atmosphere. Longer-term and more effective sequestration occurs when carbon is stored in woody plants; hence agroforestry has greater benefits than other farming systems. Studies suggest that through agroforestry carbon sequestration could be increased from 2.2. up to 90-150 tonnes of carbon per hectare over a potential area of 900 million ha worldwide (World Agroforestry Centre, 2007).

Conclusions

We have seen that the numbers of trees in farmland is very considerable, and that they can contribute to:- (i) the restoration of lost productive capacity in farm land, especially infertile degraded land, through the rehabilitation of agroecosystem functions (ii) the creation of new opportunities for greater and more diversified production with enhanced utility and profitability through the domestication of indigenous tree species conferring nutritional and health benefits, and (iii) the promotion of local enterprise, value-addition, entrepreneurism and job creation in rural communities through the commercialization of AFTPs. Thus the expansion of the on-farm tree resource through the up-scaling of agroforestry and tree domestication could lead to a reduction of poverty, malnutrition, hunger and land degradation, as well as contributing to the reduction of climate change.

There are many tree species producing timber and non-timber products with potential for domestication using rapid horticultural approaches to cultivar development. This illustrates a role for tropical foresters to engage in urgently needed work in support of more socially, economically and environmentally sustainable tropical agriculture.

This raises two questions: ‘When forests are so vulnerable to deforestation, should we be growing more trees on farm for timber and non-timber products’? If so, should this be a goal for ISTF?

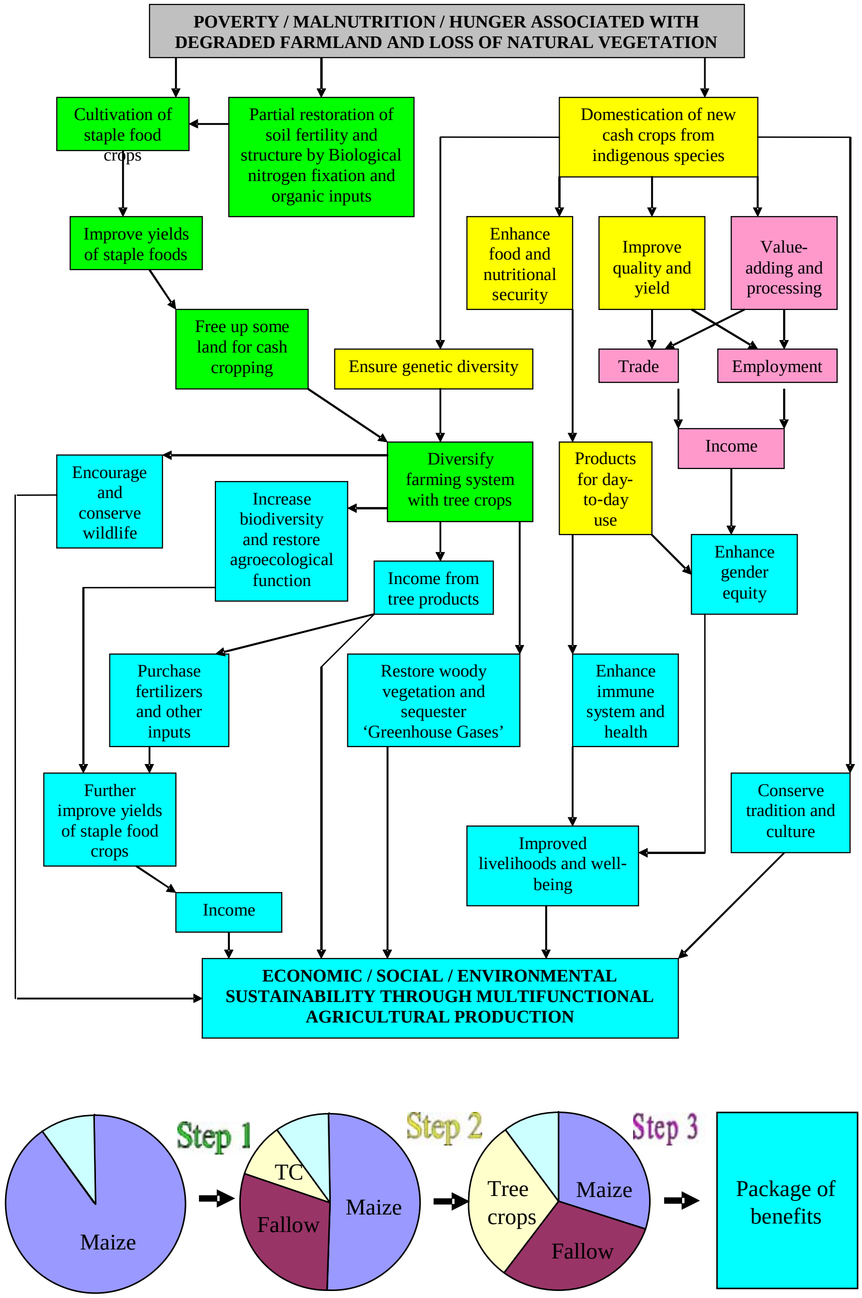

Figure 1. Three steps (1 = green; 2 = yellow; 3 = pink) to effective agroforestry (After Leakey, 2009).

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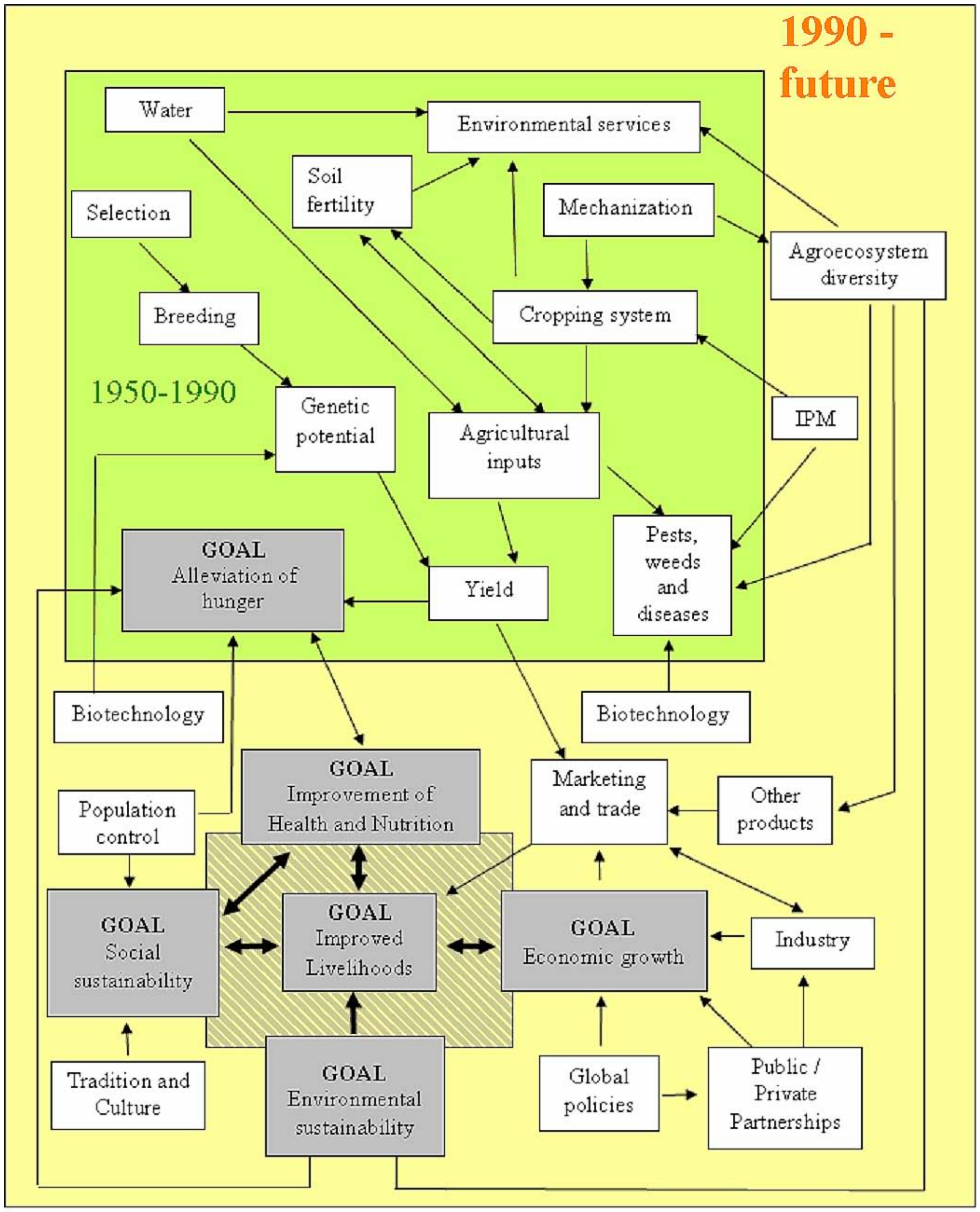

Figure 2. The interconnectedness of agriculture's different roles in rural development.

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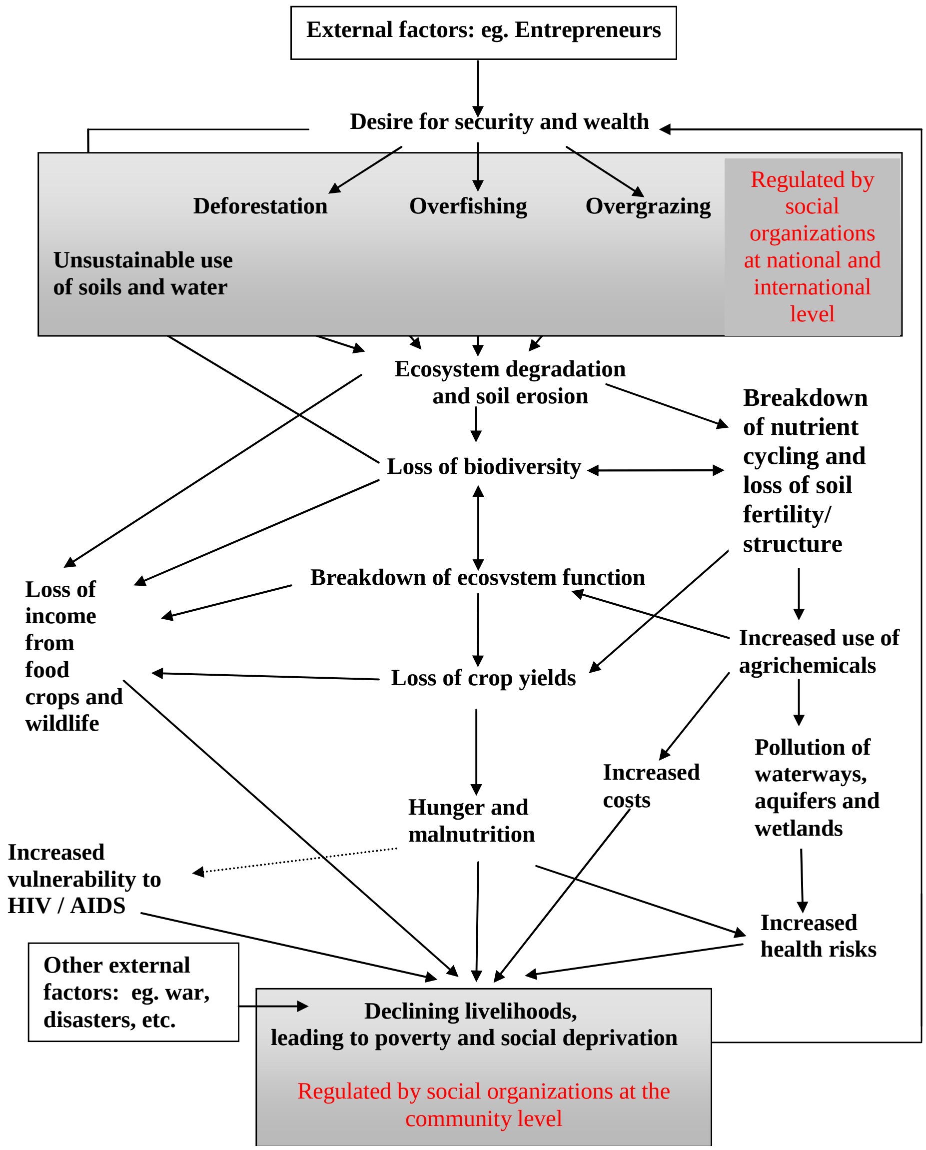

Figure 3. The cycle of land degradation (adapted from Leakey et al., 2005).

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