Adoption, Profitability, Impacts and Scaling-Up of Agroforestry Technologies in southern African countries

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1.0 Introduction

Due to a mix of agro-ecological factors (incessant drought, low soil fertility, environmental degradation) and other man-made problems (illiteracy, unfavorable development policies), southern Africa region faces several challenges including worsening poverty, food insecurity, low income base and more recently HIV/AIDS pandemic. Low soil fertility is identified as one of the greatest biophysical constraints to increasing agricultural productivity (Bekunda et al., 1997, Sanchez, 1999). The degradation of soils is caused by a breakdown of the traditional production systems resulting from shortening of fallow periods due to population pressure (Kwesiga et al., 1999). With the collapse of the erstwhile government support for the use of mineral fertilizer (e.g. through subsidies and distribution channels), in the 1990s, the ability of most smallholder farmers to purchase the same level of mineral fertilizers was reduced because the input became unaffordable to them. In addition, many countries in southern Africa are landlocked thus increasing the cost of transporting fertilizer from the ports. Howard and Mungoma (1996) estimated that the use of mineral fertilizer fell by 70% following an increase in the cost of the inputs. The sub-region also faces a rapid degradation of the miombo woodland, shortage of fodder and decreasing access to fuelwood supplies (Kwesiga and Beniest, 1998). For example, Chidumayo (1997) estimated that Zambia alone loses about 200 000 ha of forests per year. Some of the key avenues for overcoming food insecurity and rural poverty in southern Africa include reversing soil fertility depletion, intensifying and diversifying land use with introduction of high value products, and facilitating an appropriate policy environment for the smallholder farming sector. While mineral fertilizer is still one of the best options for
overcoming land depletion and increasing food production, the majority of the smallholder farmers are unable to afford and apply the fertilizers at the recommended rates and at the appropriate time because of high cost and delivery delays (Kwesiga et al, 2003; Akinnifesi et al, 2006). Low-cost technologies are needed on a scale wide enough to improve the livelihood of these farmers. This will require the adoption of new approaches to agriculture and rural development (Pretty, 1995). Agroforestry has proven to be one of such approaches. For the past fifteen years, farmers and researchers from different national and international institutions led by the International Centre for Research in Agroforestry (ICRAF), otherwise known as the World Agroforestry Centre have been combining their expertise and resources to develop agroforestry technologies and options to address some of these challenges facing smallholder agricultural production and the environment in the sub-region. The different types of agroforestry technologies address specific human and environmental needs in southern Africa. These include fertilizer tree systems for replenishing soil fertility, rotational woodlots for solving fuel wood problems, fodder banks to supplement feed for livestock and indigenous fruit trees for improving nutrition during the seasonal hunger periods and enhance the preservation of indigenous plant genetic materials.

2.0 Agroforestry technology options in southern African

The key agroforestry technologies that have been the focus of research and development efforts in southern Africa region in the past 15 years are listed below:
2.1 “Fertilizer tree systems”

This system is one of the pioneer agroforestry technologies in southern Africa region. Its development began in Zambia and it includes improved tree fallows (common in Zambia) and mixed inter-cropping technologies (popular in Malawi). The concept of intensifying land use for sustainable crop production by integrating nitrogen fixing trees and crops for soil fertility replenishment requires careful selection of agroforestry technologies and judicious management of limited available resources. The expectations of households and their preferences were important considerations in designing technologies and choosing appropriate species. The mechanisms for improved soil fertility in fertilizer tree systems are explained by the capacity of certain leguminous trees to fix large amounts of nitrogen from the air through rhizobia contained in their root nodules, and accumulate the fixed N, together with the native soil nutrients they draw from different soil horizons in their roots, stems branches and leaves as they grow, and the nutrients accumulated in tree biomass during growth. The tree biomass is then cut and the biomass is incorporated into the soil during land preparation. When the tree biomass decomposes, it releases nutrients to crops grown in the subsequent two to three years without adding external fertilizer but relying simply on the residual effect of the increased soil fertility. Fertilizer tree systems do not produce a similar instantaneous effect on crop yields as mineral fertilizers; trees need time and resources on their own to get well established in the field. The plant species used in fertilizer tree systems to overcome soil fertility problems in southern Africa include improved fallows based on *Sesbania sesban*, *Tephrosia spp.*, *Gliricidia sepium* and *Cajanus cajan* and relay fallow cropping with short rotation shrub and tree species. Results showed that two-year fallows with *Sesbania* can yield nitrogen biomass
in the range of 70-100 kg/ha is generally accumulated and can be applied as green
manure, resulting. Field trials show that maize yields obtained from such fertilizer tree
systems consistently reaches two or more times the yields from farmers’ practice of
continuous maize production without application of external mineral fertilizer inputs.
Further details of fertilizer tree systems are described elsewhere (Mafongoya et al., 2003;
Phiri et al., 2003)

2.2 **Biomass transfer**

Farmers have been growing vegetables widely during the dry season in wetlands (known
locally as *dambo*) but declining soil fertility has posed a major challenge. Biomass
transfer refers to cutting and carrying (“transferring”) nutrient-rich leaves of agroforestry
species (usually planted in the upland) to fertilize fields for the production of high value
vegetable crops and an extra maize crop in the *dambo* during the dry season. Biomass
transfer offers smallholder farmers the opportunity to supplement their incomes by
growing cash crops that fetch high prices in urban markets. In this system, nitrogen
fixing trees or shrubs are planted on a separate plot and the leaves are regularly cut and
used to fertilize neighbouring field plots in a cut-and-carry way, especially in the *dambo*.
It simply involves transferring of leaves and twigs of fertilizer trees from one part of the
farm to another. Farmers harvest trees planted at the upland to fertilize vegetables
cultivated in the *dambo* during the dry-season and use the coppices to fertilize their
maize during the main season, thereby having two full crops in a year. In Eastern
Zambia, *Gliricidia sepium* leaf mulches were used in combination with nitrogen
fertilizers. In a given season, the responses to *Gliricidia sepium* leaf biomass were
consistently higher than those of sole crop and mulch from other sources. It was
estimated that yield of 3 t/ha of maize could be achieved either through application of 52 kg/ha N or incorporation of 3.4 t/ha (dry weight) or 15 t/ha fresh weight of *Gliricidia* green manure.

### 2.3 Indigenous fruit tree crop system

Many miombo indigenous fruit trees are important for food and nutritional security, as well as being a source of income for rural communities in the Southern Africa, with women and children being the main beneficiaries (Akinnifesi et al, 2004; 2006). It has been estimated that, wild fruit trees represent about 20% of total woodland resource use by rural households in Zimbabwe (Campbell *et al*, 1997). Until recently there has been little effort to cultivate, improve or add value to these fruits. In complementing the earlier emphasis on soil fertility improvement, developing indigenous fruit and nut trees into tree crop system continue to be an important strategy to reduce poverty and hunger and to create employment opportunities in rural areas (Akinnifesi *et al*, 2004, 2006).

Domestication involves accelerated and human-induced evolution to bring species into wider cultivation through a farmer-driven and market-led process (ICRAF, 1997). The tree domestication initiative aims at building on the desire of rural communities to cultivate indigenous fruits and nuts meet their livelihood needs, especially food and nutritional security, increase household income, create employment and diversify farming systems and the rural economy (Akinnifesi *et al*, 2006). The domesticating of indigenous fruit trees will increase their quality and productivity, and can also create opportunities for marketing their products, so empowering smallholder farming communities to conserve and cultivate them. Tree crop development and commercialization of indigenous fruit trees from the miombo woodlands in southern Africa requires a long-
term, iterative and integrated strategy for tree selection and improvement, for the promotion, use and marketing of selected germplasm and its integration into agroforestry practices (Akinnifesi et al, 2006). Based on household surveys to identify the important traits for improvement, the four priority indigenous fruit tree species that were identified in southern Africa are *Uapaca kirkiana*, *Strychnos cocculoides*, *Parinari curatellifolia* and *Sclerocarya birrea*. More recently, the marketing and commercialization component of this programme is receiving more emphasis. Rural entrepreneurs have been trained in fruit processing and business skills. The dissemination of these innovations have involved farmer-to-farmer exchanges where successful farmers pass on their skills and experience to new farmers entering the business, as well as formal courses to train trainers. This bottom-up approach has ensured community ownership of the implementation of the business and dissemination skills, and a market driven tree domestication initiative and promises to have a significant effect in raising rural incomes.

2.4 Rotational woodlots

The problem of deforestation is high in southern Africa region, particularly in intense tobacco-growing countries such as Tanzania and Mozambique where farmers require high quantities of fuelwood to cure the leaves. Rotational woodlots are meant primarily to provide high quality wood biomass. Some of the woodlot species also helps to fertilize the soil and are therefore grown in rotation with food crops (Kwesiga et al 2003). The main woodlot species that have been promoted in the sub-region are Acacias especially *Acacia crassicarpa* and *Acacia polyacantha* and *Acacia auriculiformis*
2.5 Fodder banks:

This involves the growing, harvesting and preservation of browse of nutritious protein-rich leguminous trees leaves during the wet season and using them as protein supplement for ruminant animals during the dry season. Although commercial feed concentrate is available, smallholder farmers consider it expensive and many can not afford it. The research and development of this agroforestry technology has been much more emphasized in Zimbabwe where livestock production is more predominant. This agroforestry technology helps to reduce the cost of formulated animal concentrate feeds for smallholder farmers.

3.0 Adoption of agroforestry technologies

3.1 From technical feasibility to farmer adoption

In the past one and half decades, the biophysical performance and the relevance of the agroforestry technologies in southern Africa have been well demonstrated (Kwesiga and Coe, 1994; Mafongoya et al., 2003; Kwesiga et al., 2003; Nyadzi et al., 2003; Mithoefer and Waibel, 2003; Kuntashula et al., 2004). As this chapter shows, gradually the focus of agroforestry research has changed from purely biophysical and field trials to the incorporation of socio-economic and on-farm research to allow for studies of profitability and acceptability of the different agroforestry technologies to be carried out in a much more real-life context. Research and development activities on agroforestry have therefore expanded to include questions on farmer uptake, adoption and impact of the technologies. Farmer adoption and the impact of new farm technologies on adopters (and
non adopters) are some of the key measures of the overall success or otherwise of such innovations.

In general, the uptake of agroforestry technologies is more complicated than those of annual crops (Mercer, 2004; Scherr and Müller, 1991) because of the multi-components and the multi-years through which testing, modification and uptake of the technologies takes place. As a result, a precise definition of the “adoption” of agroforestry often poses a challenge. Some authors (e.g. Adesina et al., 2000; Franzel et al., 2002) distinguished between “testers”, “experimenters” and “adopters”. Other authors (e.g. Ajayi et al., 2003) regard the uptake of agroforestry technologies as a continuum and posit that farmers can be assigned positions in the continuum based on the extent of uptake of the different components of the technology. A recent study in Zambia (Ajayi, 2006) reveals that the key criteria that farmers use for assessing the level of “adoption” of agroforestry technologies are as follows: good management (timely weeding & pruning) of agroforestry fields, density and mix of trees species planted, number of years of continuous practice of agroforestry and, size of land area that a farmer cultivates to agroforestry. In a strict sense therefore, different degrees of “adoption” of agroforestry technologies can be identified.

### 3.2 Factors affecting the adoption of agroforestry

Several empirical studies have been carried out to gain insights into the adoption of agroforestry in southern Africa region. The specific studies investigated the types of farmers who adopt (do not adopt) agroforestry (Kuntashula et al., 2002; Phiri et al, 2004; Gladwin et al., 2002; Ajayi et al 2006b). Other studies examined the factors that drive the
adoption of agroforestry; why do some farmers continue to adopt more than others (Ajayi et al., 2003; Place et al., 2002; Franzel and Scherr, 2002; Ajayi and Kwasiga, 2003; Keil et al., 2005; Ajayi, 2006; Jera et al., 2006; Thangata and Alavalapati, 2003).

Table 1: Factors affecting farmers’ decision to adopt fertilizer tree systems in Zambia.

<table>
<thead>
<tr>
<th>Study (and number of households involved)</th>
<th>Weal th</th>
<th>Age</th>
<th>Sex</th>
<th>Educ ation</th>
<th>Labor / Househ old size</th>
<th>Farm size</th>
<th>Uncultivate d land</th>
<th>Use of fertili zer</th>
<th>Off-farm income</th>
<th>Oxen ownership</th>
<th>Village exposure to improved fallows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors affecting farmers’ decision to plant fertilizer tree fallows for the first time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Franzel, S. 1999 (157 households)</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phiri et al. (2004) (218 households)</td>
<td>+</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kuntashula et al. 2002 (218 households)</td>
<td>+</td>
<td>N</td>
<td>N</td>
<td>+</td>
<td>N</td>
<td>N</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ajayi et al. 2006 (305 households)</td>
<td>N</td>
<td>+,N</td>
<td>N</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Peterson et al. 1999 (320 households)</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factors affecting farmers’ decision to continue to plant fertilizer trees</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Keil 2001 (100 households)</td>
<td>+/-</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Place et al. 2002</td>
<td>+</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:** +: positive association with planting improved fallows  -: negative association  N: no association, +/-: positive or negative depending on the value  Blank means the variable was not tested in the specific study.

Access to about information on agroforestry, training opportunities, good quality seeds, property rights on land, size of available land, flexibility and compatibility of agroforestry to existing farming systems among others are important factors affecting adoption of agroforestry (Place and Dewees, 1999, Place, 1995). The result of specific
empirical studies to assess the factors influencing the adoption of agroforestry (fertility tree systems) in Zambia is summarized in table 1. In general, the factors which influenced farmers’ adoption decision with regards to agroforestry technologies fall within four broad categories. These are those which exert (1) positive influence on farmers’ adoption decisions, (2) negative impacts (3) ambiguous or no direct effect (4) systemic influence on all types of households in a given community and spatial locations.

3.3 Socio-anthropological perspective for understanding farmers’ adoption of agroforestry

A number of surveys to investigate the actual and potential adoption of agroforestry technologies have focused primarily on the influence of different household and farm characteristics on the adoption by farmers. However, the inevitable implication that measuring the influence of household and farm characteristics in itself may provide insufficient explanations and thus there is need for different approaches. The process of adoption is complicated, dynamic and the various factors are likely to influence each other – hence they should not be treated in isolation, ignoring their mutual interdependencies and reducing the adoption-decision to a zero-sum game, as is frequently done. If individual household and farm characteristics are singled out, where one study considers a certain characteristic to have a positive influence on adoption, another study may view the same characteristic as having a negative influence. The differences can sometimes very well be clarified from the institutional and social contexts of the specific respective study areas. Such qualitative research methodologies compliment quantitative research approaches, provide insights into farmers’ adoption patterns and improve the understanding of the process of adoption of agroforestry
technologies from the perspective of farmers. The qualitative methodologies may enable
the comprehension of the process of adoption on the basis of diversity as found amongst
informants and generating the relevant variables in the course of interviewing and
observation (see e.g. van Donge et al., 2001). This qualitative approach was used to study
the history of interventions and the present-day consequences for agroforestry adoption in
southern Malawi. Given the complex process of decision making by farmers, an adjusted
research methodology is necessary to gain a better understanding of the process of
adoption, which needs to be contextualized, both within the socio-economic context of
the farm and family enterprise and in time.

4.0 Financial profitability and returns to investment in agroforestry
technologies

Profitability analyses that were carried out in southern Africa region show that the various
agroforestry technologies are profitable relative to conventional production practices
where trees are not grown (Franzel, 2004; Ajayi et al., 2006a; Place et al., 2002).
The results of a recent study in Zambia to assess the financial profitability of five soil
fertility management technologies—Sesbania sesban, Gliricidia sepium, Tephrosia
vogelii, continuous maize production with fertilizer and continuous maize production
without fertilizer show that over a five-year period, agroforestry-based soil fertility
management technology (“fertilizer tree fallows”) are more profitable than farmers’
practices of continuous maize production without external inputs but, it is less profitable
than full fertilizer application (Ajayi et al, 2006a). The 50% government subsidy on
mineral fertilizer particularly enhanced its superior financial performance over
agroforestry-based options. However, when valued at its market price, the magnitude of
the differences in the profitability of agroforestry option and mineral fertilizer option decreases by 30%, and the net present value of fertilizer ($349) is very close to one of the agroforestry options (NPV of $309). The mineral fertilizer option has a lower benefit cost ratio (BCR) implying that the higher net benefits obtained in mineral fertilizer option was achieved through a relatively higher investment cost.

Table 2: Profitability of maize production per hectare using tree fallows and *subsidized* fertilizer options over a five-year cycle in Zambia

<table>
<thead>
<tr>
<th>Type of production system</th>
<th>Description of land use system</th>
<th>NPV</th>
<th>NPV (US $)</th>
<th>BCR ($/$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous, NO Fertilizer</td>
<td>Continuous maize for 5 years</td>
<td>584,755</td>
<td>130</td>
<td>2.01</td>
</tr>
<tr>
<td>Continuous + Fertilizer (subsidized at 50%)</td>
<td>Continuous maize for 5 years</td>
<td>2,243,341</td>
<td>499</td>
<td>2.65</td>
</tr>
<tr>
<td>Continuous + Fertilizer (at non-subsidized market price)</td>
<td>Continuous maize for 5 years</td>
<td>1,570,500</td>
<td>349</td>
<td>1.77</td>
</tr>
<tr>
<td><em>Gliricidia sepium</em></td>
<td>2 years of <em>Gliricidia</em> fallow followed by 3 years of crop</td>
<td>1,211,416</td>
<td>269</td>
<td>2.91</td>
</tr>
<tr>
<td><em>Sesbania sesban</em></td>
<td>2 years of <em>Sesbania</em> fallow followed by 3 years of crop</td>
<td>1,390,535</td>
<td>309</td>
<td>3.13</td>
</tr>
<tr>
<td><em>Tephrosia vogelli</em></td>
<td>2 years of <em>Tephrosia</em> fallow followed by 3 years of crop</td>
<td>1,048,901</td>
<td>233</td>
<td>2.77</td>
</tr>
</tbody>
</table>

- Market price for fertilizer include a 50% subsidy by the government
- Figures are on one hectare basis, using prevailing costs & prices and an annual discount rate of 30%

Table 2 shows that that for every unit of money invested into maize production, the farmer gains an extra 1.65 units through mineral fertilizer option, an extra 1.91 units of money if *Gliricidia* fallow option is used, an extra 2.13 units of money in *Sesbania*.
sesban fallow fields, an extra 1.74 units of money in Tephrosia fallow fields and a 1.01 unit of money if farmers’ conventional maize production practice is followed. Due to the challenge of HIV/AIDS pandemic and its possible effect to degrade the quantity and quality of labor supply in farm households, it is hypothesized that the returns to labor will become an increasingly important factor in the acceptability of agricultural production technologies to farmers and the decision to adopt them in the future. Analysis shows that the returns to a person labor-day is $3.20 for mineral fertilizer option and $2.50, $2.40, and $1.90 respectively for the three agroforestry-based options that were investigated. By comparison, the return to labor for the unfertilized maize system was only $1.10, while the daily agricultural wage is around $0.50. Thus, while the recommended dose of fertilizer option is the highest performer at current subsidized rates, at the full economic cost, the tree fallow options are only slightly less economically attractive. In areas where transport costs of fertilizer are high, the tree fallow options may outperform the fertilizer option. Sensitivity analysis shows that different price and other policy scenarios affect the financial profitability of different production systems. In general, the prevailing price of the staple crop (maize), cost of capital (interest rate), cost of including subsidy on fertilizer and the wage rate of labor are key determinants of the relative financial attractiveness and the potential adoptability of the production systems even when agronomic relationships between inputs and outputs remain the same.

**Rotational woodlots**

The financial analysis carried out in Tanzania regarding rotational woodlots shows that despite higher costs and longer payoff, rotational woodlots generate a net present value
(NPV) of US$388 per hectare, which is six times higher than the net benefit obtained in conventional maize fallow systems (Franzel 2004). Rotational woodlots consistently maintained its superior financial performance over conventional maize systems even when maize prices and labor cost changes up to 50%.

5.0 Scaling-up of agroforestry technologies

5.1 Approaches and methods for scaling-up

Following the successful demonstration of the potential of agroforestry technologies to make positive impact on the livelihoods of smallholder farmers in southern Africa, various agroforestry research and development institutions have been focusing efforts in scaling up these technologies to reach a greater number of resource-poor smallholder farmers who could potentially benefit from the technologies. Scaling up is expected to bring more quality benefits to more people over a wider geographic area, more quickly, more equitably and more lastingly. Due to the complexities of factors that affect scaling up, going to scale requires vertical and horizontal processes. The vertical process represents efforts to influence policy makers and donors and is generally institutional in nature. The horizontal process (also referred to as scaling out) refers to the spread across communities and institutions and geographic boundaries (IIRR 2000). Both processes characterize scaling up interventions of agroforestry. Agroforestry partners have focused efforts on a process of institutionalizing agroforestry in the research, extension, and development and education arenas in order to get policy makers, researchers, extension workers, development workers, educationalists and farmers to forge their efforts jointly to address the factors that influence going to scale. At the policy level, each country has a
National Agroforestry Steering Committee (NASCO) charged with the responsibility to facilitate the institutionalization of agroforestry in the relevant sectors. Specifically, the NASCOs’ roles include identifying priority agroforestry research and development areas and guiding donor support accordingly.

Three major interrelated and mutually enforcing strategies employed in the scaling up of agroforestry technologies in southern Africa are capacity building, partnerships and networking and promoting policies more conducive to adoption with the central focus being strengthening of local capacities to innovate as a way of ensuring sustainability of technological enhancement (Böhringer et al. 2003). Among the key interventions characterizing these strategies are the following: farmer-centred research and extension approaches, establishment of strategic partnerships, knowledge and information sharing, establishing viable seed systems, developing market options, local institutional capacity strengthening, diversification of agroforestry technologies and influencing policy at different levels. In building farmer capacity and providing them with management and problem-solving skills through learning by experience in the field, a mixture of approaches are used to reach farmers and improve their lives through agroforestry. These approaches have been pursued within a framework of a scaling up concept initially comprising the following four prongs:

*Training of farmer trainers and local change teams*: This approach involves direct training of farmers as trainers with the ultimate goal being that the farmers trained will in turn provide training in agroforestry to fellow farmers in a given locality.

*Training of project partners*: This involves agroforestry research institutions making available training to the staff of development partners and NGO projects who works at
the grassroots level. The major objective for this type of training is to enable partners to implement training for farmer trainers in their own project areas.

*Farmer-to-farmer exchange visits:* This approach involves exposing farmers to agroforestry by facilitating their visits to farmers in other locations who have been practicing agroforestry for some time and have started to get benefits from adoption of the technologies. As benefits accruing from agroforestry technologies take long, especially the soil fertility improvement options, exposure of farmers to benefits realized by those farmers who have adopted the technologies has proven to be a very effective way of promoting adoption.

*Support to national research and extension initiatives:* This involves support to existing government initiatives on sustainable farming, particularly extension work at the field level. One of the major challenges in implementing agroforestry has been underinvestment in the public research and extension systems, manifested in severe logistical as well as methodological limitations.

From 2004, other methodological approaches to scale up agroforestry have been developed. These include the use of exiting local institutions (and consultants) to conduct training on agroforestry, providing technical and logistics supports to agroforestry networks, the establishment or strengthening of school community links and sensitizing policy-makers about agroforestry benefits by producing policy briefs and use of public media channels and events (local radio, TV programs, documentaries, field days, agricultural shows etc). These policy shapers include parliamentarians, cabinet ministers, provincial and district administrators, and village councilors, traditional authorities that could help catalyze adoption of agroforestry /F in their respective constituencies.
5.2 *Number of farmers reached through agroforestry technologies*

As a result of these scaling up efforts, the number of farmers who have been reached with different agroforestry technologies in the five southern Africa countries has increased from a few hundred farmers in the early 1990s to 417,000 farmers as at 2005 (ZBAFP, 2005).

Table 3: Numbers of farmers reached through different agroforestry technologies in five southern African countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Methodological approach employed to reach farmers</th>
<th>Country totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Training of farmer trainers and local change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>teams</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Training of partner institutions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support to national research and extension</td>
<td></td>
</tr>
<tr>
<td></td>
<td>initiatives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>School-community linkages</td>
<td></td>
</tr>
<tr>
<td>Malawi</td>
<td>15,476</td>
<td>110,701</td>
</tr>
<tr>
<td>Mozambique</td>
<td>4,491</td>
<td>4,491</td>
</tr>
<tr>
<td>Tanzania</td>
<td>15,000</td>
<td>233,728</td>
</tr>
<tr>
<td>Zambia</td>
<td>15,387</td>
<td>61,583</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>-</td>
<td>7,000*</td>
</tr>
<tr>
<td>Prong totals</td>
<td>50,354</td>
<td>417,503</td>
</tr>
</tbody>
</table>

Source: ZBAFP, 2005

Note: The breakdown of the figure for Zimbabwe is not available.

Several factors contribute to the increases recorded in the number of farmers who has been reach through agroforestry technologies. First, it is the deliberate effort by several institutions to focus on the scaling up of the technologies using the different prongs described above. Several institutions that were interested in promoting natural resource management options provided added impetus to disseminate information on agroforestry innovations among farmers. Such institutions include the World Vision Integrated Agroforestry Project in Zambia (ZIAP), Soil Conservation and Agroforestry Extension...
(SCAFE) in Zambia, Malawi Agroforestry and Extension (MAFE) and the Eastern Province Development Women Association (EPDWA). These were complemented by interests in agroforestry technology through organizations such as Plan Zambia and Kehitysyhteistyön Palvelukeskus (KEPA), a Finnish-based Service Centre for Development Cooperation. In partnership with ICRAF, these institutions assisted in reaching a nucleus of farmers through direct training and provision of initial tree seed to farmers. The period coincided with the increasing emphasis by ICRAF on development programs aimed at accelerating the scaling up/out agroforestry technologies trees among farmers in the sub-region. Second, in the development of agroforestry technologies in southern Africa region, a constructivist approach was actively encouraged, i.e. farmers were encouraged to try the technologies, then modify and re-adapt them based on their experiences and desires to make them more acceptable to their circumstances. Third, some private sector organizations found a niche in agroforestry to fulfill their goal for a responsible corporate citizenship by being responsive to the environmental and natural resource implications of their activities. Among these are tobacco companies who are training their contract farmers on the use of poles from fertilizer tree species to make sheds for curing tobacco to avoid further deforestation associated with tobacco curing operations.

5.3 **Constraints to the scaling up of agroforestry**

A recent global review of the adoption of agroforestry show that the level of diffusion of such agroforestry technologies has generally lagged behind scientific and technological advances attained in such technologies thereby, reducing their potential impacts (Mercer 2004). The experience with regards to the adoption of agroforestry technologies in
southern Africa has not been too different from the global trend. Although agroforestry is financially profitable and there has been an increasing trend in the uptake of the technologies by farmers, the widespread adoption of agroforestry technologies by many more smallholder farmers is nonetheless constrained by several challenges such as local customs, institutions and policies at the national level. Some of the constraints are highlighted below:

**Local and national policies:** some local customary practices and institutions prevailing in the sub-region (especially incidence of bush fires and browsing by livestock during the dry season, and absence of perennial private right over land) limits the widespread uptake of some agroforestry technologies. The animals destroy the trees after planting either by browsing the leaves and removing the biomass or by physically trampling over the plants. Community’s institutional regulations for fruit collection, land and tree tenure all affect individual farmer’s decision to invest in establishing an indigenous fruit tree orchard. However, agroforestry institutions have been working in collaboration with traditional rulers, government officials, community-based organizations, NGOs, and national partners to resolve these institutional bottlenecks (Ajayi and Kwesiga, 2003).

**Training:** Agroforestry technologies are generally incipient technologies and relatively new phenomenon compared with conventional agricultural practices that farmers have known, been used to and have received training for a much longer period. Unlike annual crop production technologies and conventional soil fertility management options, fertilizer trees systems require skills in terms of management of the trees. Capacity for doing this need be built at the national level. The costs of providing information greatly
decrease over time, but they are critical when helping farmers get started with the practice.

**Seed and germplasm:** One of the greatest constraints of some agroforestry technologies is the lack of access to quality seeds. Unlike the seeds of annual crops in which established institutions exist to promote them and private sector organizations have been engaged in their multiplication and distribution, there is little or no institutional structure to make the seeds of agroforestry available “off the shelf”.

**Awareness:** Over several years, there have been structural shifts towards “quick fixes” and technologies that render immediate benefits. The opportunity of agroforestry technologies to provide some medium and long term benefits to individuals and the public simultaneously is not as yet well communicated to many stakeholders.

**Human resource capacity:** The human capacity, infrastructures and institutional supports for agroforestry are not as well developed as for annual crop technologies. Such missing supports include well developed input and output market to enhance access of smallholder farmers to ensure that they get the price premium for their crop produce.

### 6.0 Impact of agroforestry technologies

Agroforestry technologies have multiple impacts on both adopters and non-adopters, on food security and the environment as presented in Table X. The impacts of agroforestry that are most pronounced are on improved soil fertility (hence food security), more income and increased firewood supply. Some of the costs and benefits identified in Table 4 occur simultaneously in the same agroforestry field depending on the type of tree planted. The Table is based on the several studies that were carried out in the region coupled with personal observations of the authors over several years of research and
development work on agroforestry in the region. Some of the costs and benefits require a more rigorous study to quantify their economic value. Despite the existence of negative spillovers of some aspects of agroforestry (for example, incidence of fire and grazing), we expect the overall effect of the technologies to be positive.

Table 4: Types of impacts of agroforestry technologies in southern Africa

<table>
<thead>
<tr>
<th>Cost</th>
<th>Individual</th>
<th>Public at large</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Land</td>
<td>• Land</td>
<td>• Incidence of <em>Mesoplatys</em> beetle pest (restricted to specific species only)</td>
</tr>
<tr>
<td>• Labour</td>
<td>• Labour</td>
<td>• Reduction of free grazing area during dry season</td>
</tr>
<tr>
<td>• Tree seeds and nursery establishment</td>
<td>• Tree seeds and nursery establishment</td>
<td>• Risk of uncontrolled fire outbreak</td>
</tr>
<tr>
<td>• Pest control (some tree fallow species only)</td>
<td>• Pest control (some tree fallow species only)</td>
<td></td>
</tr>
<tr>
<td>• Working equipments</td>
<td>• Working equipments</td>
<td></td>
</tr>
<tr>
<td>• Risk of uncontrolled fire outbreak</td>
<td>• Risk of uncontrolled fire outbreak</td>
<td></td>
</tr>
<tr>
<td><strong>Benefit</strong></td>
<td><strong>Benefit</strong></td>
<td><strong>Benefit</strong></td>
</tr>
<tr>
<td>• Yield increase of subsequent crops</td>
<td>• Yield increase of subsequent crops</td>
<td>• Carbon sequestration</td>
</tr>
<tr>
<td>• Opportunity for farm diversification (e.g. compatible with fish</td>
<td>• Opportunity for farm diversification (e.g. compatible with fish farming</td>
<td>• Suppression of weeds</td>
</tr>
<tr>
<td>farming and growing of high-value vegetables)</td>
<td>and growing of high-value vegetables)</td>
<td>• Improved soil infiltration and reduced runoff</td>
</tr>
<tr>
<td>• Increase in fodder and maize stubble (for livestock)</td>
<td>• Increase in fodder and maize stubble (for livestock)</td>
<td>• Enhanced biodiversity</td>
</tr>
<tr>
<td>• Fuel wood- available in field, and so reduces time spend</td>
<td>• Fuel wood- available in field, and so reduces time spend searching for</td>
<td>• Serves as wind breaks</td>
</tr>
<tr>
<td>searching for wood</td>
<td>wood</td>
<td></td>
</tr>
<tr>
<td>• Use of tree leaves (<em>Tephrosia vogelii</em>) as “pesticides” to</td>
<td>• Use of tree leaves (<em>Tephrosia vogelii</em>) as “pesticides” to remove ticks from</td>
<td></td>
</tr>
<tr>
<td>remove ticks from livestock.</td>
<td>livestock.</td>
<td>livestock.</td>
</tr>
<tr>
<td>• Suppresses the growth of weeds</td>
<td>• Suppresses the growth of weeds</td>
<td></td>
</tr>
<tr>
<td>• Potential to mitigate the effects of drought during maize season</td>
<td>• Potential to mitigate the effects of drought during maize season</td>
<td>• More fuel wood available to reduce deforestation</td>
</tr>
<tr>
<td>• Stakes for tobacco curing</td>
<td>• Stakes for tobacco curing</td>
<td>• Serves as wind breaks</td>
</tr>
<tr>
<td><strong>Source:</strong> Ajayi and Matakala (2005)</td>
<td><strong>Source:</strong> Ajayi and Matakala (2005)</td>
<td></td>
</tr>
</tbody>
</table>

**6.1 Impacts on yield and food security**

Fertilizer tree systems increase the yield of maize (the staple food crop in the region) by two or more times compared with the usual smallholder farmers’ practice of continuous
maize without nutrient inputs (Kwesiga et al., 2003; Akinnifesi et al., 2006). One way to assess this impact is in terms of food security - by determining the number of days of additional food they provide to a household. Using the present average fallow plot area of is 0.20 hectares, and the per capita maize consumption, the systems generate between 57 and 114 extra person days of maize consumption per year (Ajayi et al 2006a). The total monetary value of the nitrogen fixed by fertilizer trees in the region is estimated at US$ 5.7 million per annum. This is however assuming that all 150 kg N would be available to the maize (during the following production seasons), but it is likely that some will be lost due to leaching or gaseous emissions, thus reducing this figure accordingly. Depending on distance and condition of the roads, the cost of transportation of fertilizer bags from the shops in the major town/cities to farmers’ village ranges between 10-25% of the purchase cost of fertilizer.

6.2 Impact on the environment

In addition to increase in food production, agroforestry has positive impacts on the conservation of the natural resource base and the in the protection of the environment. For example, the fertilizer tree systems can provide up to 10 tons of wood biomass per hectare (Kwesiga and Coe 1994). This greatly reduces the burden of carrying firewood over long distance and the time spent searching for wood energy (especially by women). Agroforestry provides “live barns” and alternative source of stakes for curing tobacco and thus has great potential to contribute to the reduction of the deforestation of the miombo woodland. Deforestation is an important economic problem in the southern Africa region. In Zambia alone, it is estimated that the miombo is being deforested for development purposes at a rapid rate of between 200,000 and 300,000 hectares per year. To the extent
to which farmers are able to source for fuel and other wood requirements for their households from improved fallow fields, cutting of wood from communally owned forests and hence deforestation may be reduced. A recent study in southern Africa show that carbon stored in agroforestry fields varied between 2.5 to 3.6 tons ha\(^{-1}\) year\(^{-1}\) (Paramu Mafongoya, personal communications, 2005). The trees have overall net positive impact on the soil invertebrates and also perform important ecosystem functions that can affect plant growth (Sileshi and Mafongoya, 2006). In addition to improving soil fertility and food security, some agroforestry technologies improve the physical properties of the soils. This is because in agroforestry fields, the soil aggregation is higher and this enhances water infiltration and water holding capacity (Phiri et al., 2003). The improvement in soil aggregation and water holding capacity could contribute to minimizing the risk of productivity loss during drought years. Some fertilizer tree system species (e.g. *Sesbania sesban*) reduce the incidence of noxious weeds (*Striga hermothica*) which generally thrive under conditions of low soil fertility in the region (Kwesiga et al., 1999). This aspect of fertilizer trees provides a big incentive for women who are often responsible for weeding the family’s fields.

### 6.3 Impact on income generation and diversification of livelihood

Several studies indicate that rural communities can increase their incomes by utilizing and marketing tree products from forests and horticultural tree crops grown on-farm (Campbell, 2000; Akinnifesi et al., 2006; Mithofer, 2005; Schreckenberg et al., 2006). Indigenous fruits contribute on average about 42% of the natural food basket that rural households rely on in southern Africa (Campbell et al., 1997). In 2002, a household food security survey found that about 60-85% of rural households in the “Chinyanja Triangle”
(i.e. Malawi, Zambia and Mozambique), lacked access to food for three to four months per year, and 26-50% of the respondents had relied on indigenous fruits for sustenance during this critical period (Akinnifesi et al., 2004). In Malawi, wild fruits are most important in the areas where rural people frequently face annual food shortages and the deforestation rate is high. The home consumption and marketing of these fruits contributed substantially to household livelihoods and cash income, and enabled households to live above the poverty line during the critical famine periods. An ex ante analysis in Zimbabwe showed that indigenous fruits contributed to a poverty reduction of up to 30% and an income above the poverty line throughout the year, and households marketing fresh fruits have been able to maintain income flows above the poverty line throughout the year (Mithofer et al., 2006). The benefits from selling indigenous fruits come at a critical time when income is generally low, and provides nutrition and food when agricultural labour demands are high.

Feasibility assessments and business plans have been completed for fruit enterprises in four countries (Malawi, Zambia, Zimbabwe and Tanzania). These efforts, which have produced profits of 15-28% for fruit concentrate, have provided women groups with a 40% of the market share. As a result of simple production processes, low capital investment and low fixed costs, an average internal rate of return of 34% was attainable on inputs (Joordan et al., 2006). In Tanzania, six women groups who received training and supports had increased their average income from less than US$ 200 to US$ 911/person/year from processed fruit jam, juice and wine. Rural communities in Zimbabwe, Zambia and Tanzania were able to move from being ‘price takers’ to ‘price givers,’ by increasing their income through processing and sale of indigenous fruits. These pilot activities are now at
take-off point, and have provided valuable lessons as a strong platform for scaling up to other tree products and areas.

### 6.4 Other impacts

Biomass transfer technology enables farmers to grow high value crops (ginger, garlic, cabbage and onion) in the wetlands (*dimbas*) thereby offering the opportunity to enhance food production and diversify farmers’ income. Crop production takes place during off-season when farm produce attracts higher prices. The farm enterprise using biomass transfer is highly profitable and net profit ranges between $700 and $1000 per ha compared with $366 for control plots (Kuntashula et al., 2004). In Zimbabwe, farmers who adopt fertilizer tree fallows (*Sesbania sesban*) obtained an increase in cash which they use for discretionary spending (Muhdara et al., 2003). In Zambia, agroforestry helps farmers to purchase necessary daily commodities and clothing, and use the additional money earned from increased crop yield to pay their children’s school fees, attend to health care for their family members and to buy higher value food like meat and fish (Keil, 2001; Schuller et al., 2005).

The development and promotion of some agroforestry technologies such as fertilizer tree systems resulted in several unintended extra benefits (positive externalities) to the farmer and the society on one hand and, some unintended problems (negative externalities) on the other. The negative externalities include *Mesoplatys* beetles attack on *Sesbania sesban*. Other social and institutional problems are browsing of the fertilizer tree fallow species by free ranging animals and, the incidence of bush fires destroying fertilizer tree fallow species especially during the dry season. In some cases, these incidents cause unintended social problems resulting from a conflict of economic interests among...
different sections of the community (Ajayi and Kwesiga, 2003; Ajayi, 2001).

Collaborative efforts by traditional chiefs, village headmen, farmers and research and development organizations and policy dialogues between the different stakeholders have resulted in various approaches to try and find ways of dealing with the problem of livestock browsing and fire.

7.0 Discussion and way forward

This chapter describes the adoption, profitability and impacts of agroforestry technologies with special reference to the southern Africa region. In doing this, a large amount of knowledge has been generated. A number of important lessons have also been learnt.

The first lesson is that while the technical characteristics of agroforestry technologies are important, they are neither the exclusive nor sufficient conditions to guarantee their adoption by smallholder farmers. Therefore, in addition to technological fixes, the adoption of agroforestry can be increased considerably by also focusing on understanding and influencing the processes of innovation, intervention and policy. Agroforestry technologies should therefore be socially situated, not only in bio-physical domains.

Second, adoption of agroforestry is not a simple direct relationship based on technology and farmers’ characteristics alone, but it is a mix of several factors. These include household-specific factors (e.g. age, education), technological factors (e.g. “waiting period” before farmers obtain benefits, quantity and distribution of labor inputs requirements to manage the technology), institutional and policy factors (e.g. land tenure system, agricultural subsidies, incidence of fire and grazing) and geographical factors (e.g. type and characteristics of soils which determine the bio-physical limits of
technologies, access to roads and markets, location of a village relative to institutions promoting agroforestry, etc).

Third, due to its long-term nature, the adoption of agroforestry may not take place in a policy vacuum. It is necessary that adoption of agroforestry be facilitated a conducive policy and institutional framework at both local and national level (Haggblade et al 2004). Recent profitability analysis (Ajayi et al 2006) shows that different “external” factors affect the financial attractiveness and potential adoptability of fertilizer tree fallows and other soil fertility management options even when technical relationships (e.g. yield coefficients) between inputs and outputs remain constant. Most households do not have direct control over the major factors that determine profitability and potential adoptability of soil technologies and as result, appropriate policies and institutions that are contributing to scaling up adoption of fertilizer tree fallows should be facilitated.

Fourth, the pattern of distribution of benefits (or costs) of agroforestry technologies among various sectors of a community are important factors that enhance (or inhibit) their widespread adoption (Ajayi and Kwesiga, 2003). Issues related to property rights are an important issue within farm communities. As a result, national policies need be complemented by institutional support at the local level to reduce current constraints of property rights and other institutional constraints affecting the adoption of agroforestry.

Fifth, inadequacy of tree seeds, seedlings and other planting material has repeatedly been identified as one of the most important constraints to the greater adoption of agroforestry. Successful scaling up is based on sustainable supply of germplasm of high physiological and genetic quality for a wide range of agroforestry species that can meet the needs and priorities of small-scale farmers. Adequate institutional and organizational mechanisms
that are conducive to large-scale production and distribution of agroforestry seed are also needed. ICRAF and other organizations that support agroforestry activities have been supplying large quantities of free seed to farmers. While it is appreciated that free seed should be part of the dissemination process in the initial stages of the program, continued free tree seed supplies make it difficult to determine the effective demand for agroforestry seed and undermine the establishment of a sustainable seed system (Mitti et al., 2004). A more sustainable seed and germplasm supply for smallholder farmers should be developed.

Sixth, due to the mix of groups of factors variables that influence farmers adoption decision of agroforestry, a single cross sectional data based exclusively on either of the groups of factors alone will most likely produce incomplete results at the best or even misleading results in some cases. As a result, beyond conventional adoption studies that are based exclusively on household surveys, more comprehensive geo-referenced studies that integrate variables from the different groups of factors identified above will provide more accurate insights into the adoption of agroforestry in the sub-region. An example of such studies is a on on-going multi-disciplinary survey presently being implemented concurrently in five countries in the sub-region (Malawi, Mozambique, Zambia, Zimbabwe and Tanzania) to evaluate the influence of household-specific, community factors and project-based scaling up activities on farmer adoption of agroforestry and, to estimate the number and proportion of households who are “testers” or “adopters” of key agroforestry technologies.

Seventh, a number of the studies on the adoption of agroforestry technologies have often been limited by lack of common methodologies. This has rendered cross-site
comparisons of the results difficult or sometimes impossible. Detailed characterization (much more comprehensive than hitherto available) of the causes, nature and severity and extent of deforestation, soil fertility and food security problems are required to provide information for diagnosis of the problems and evaluate opportunities through agroforestry options for solving them across temporal and spatial scales. Such detailed information will serve as a valuable resource for making informed decisions for targeting appropriate agroforestry technologies to suitable geographical locations and recommending appropriate policies for ensuring impact on the problems the sub-region faces.

Eighth, while most agroforestry technologies are profitable over time (i.e. they record positive net present values), one constraint is that a number of such technologies attain break-even point about 2 to 3 years after initial investment. This implies that farmers must commit to initial investment in terms of land, capital or labor and must absorb net losses for a couple of years before receiving profits from adoption. In low income countries where smallholder farmers have a low capital and savings base, significant levels of adoption of the technologies may be limited to farm households who are sufficiently well off to withstand these net losses. Other types of households may require targeted changes in policy and institutional framework that helps them cope through the “waiting period” for them to achieve a significant increase in the level of adoption.

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