Research Application Summary

Contribution of agroforestry to natural resources management, food security and climate change mitigation: Experiences from Tabora region, western Tanzania

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Abstract

Food insecurity, natural resources degradation and climate change are among the most critical challenges facing Tanzania and indeed, the developing world today. There is decreasing agricultural productivity as a result of increasing land degradation, reduced ability of forest resources to provide goods and services due to deforestation and forest degradation. There is also growing evidence that climate change is impacting on forests and forest ecosystems and therefore livelihoods of forest dependent communities as well as national economic activities that depend on forest products and services. Agroforestry which is a land-use system where woody perennials are grown in association with crops, pastures or livestock can support growth of more food and biomass for fuel while sustainably managing agricultural landscapes for the critical ecosystem services they provide. Agroforestry can serve as a means of curbing greenhouse gas emissions by slowing forest conversion to farmland and sequestering more carbon in trees on farms. Different agroforestry technologies have been tested by agricultural Research Institutes and Universities in Tanzania in collaboration with International Research Organizations including the World Agroforestry Centre. These technologies include; use of nitrogen fixing trees to contribute to increased crop yields, food security and rural incomes, Agroforestry based rotational woodlots to supply fuelwood, charcoal and livestock fodder requirements and to generate substantial income and Agroforestry based farming systems to contribute to use of restoration of degraded lands, increase carbon sequestration and thus contribute to climate mitigation. Research has for example, shown that *Sesbania sesban* and *Gliricidia sepium* can increase maize yield by 1.5t/ha and 1.0t/ha respectively when compared to no fertilizer treatment. Studies on thornless Australian acacia trees showed that *Acacia crassicarpa* grown on acid sandy soils produced as much as 24 to 77 tons of wood per hectare within four to five years. A maize crop grown after cutting down this tree fallow yielded as much as 29 to 113 per cent more maize than that grown on a nearby natural fallow. This paper discusses the contributions of these agro-forestry technologies towards increasing food production, improving farmers' livelihoods as well as mitigation of climate change in Tanzania and suggests strategies for scaling up.

Key words: Agroforestry technologies, climate change, food security, natural resources management, Tanzania

Résumé

L'insécurité alimentaire, la dégradation des ressources naturelles et le changement climatique figurent parmi les défis les plus critiques auxquels fait face la Tanzanie en particulier et en général, le monde en développement actuellement. Nous remarquons la baisse de la productivité agricole comme résultat de la dégradation croissante des terres, la capacité réduite des ressources forestières pour fournir les biens et services en raison de la déforestation et de la dégradation des forêts. Il existe des preuves que le changement climatique produit un impact sur les forêts et les écosystèmes forestiers et donc sur les moyens de subsistance des communautés dépendant des forêts ainsi que les activités économiques nationales qui dépendent des produits et services forestiers. L'agroforesterie qui est un système d'utilisation des terres où des plantes vivaces ligneuses sont cultivées en association avec les cultures, les pâturages et le bétail peut soutenir la croissance de plus de nourriture et de la biomasse comme combustible tout en gérant durablement les paysages agricoles pour les services écosystémiques critiques qu'ils fournissent. L'agroforesterie peut servir comme un moyen de réduire les émissions de gaz à effet de serre par le ralentissement de la conversion des forêts aux terres agricoles et par la séquestration de plus de carbone dans les arbres sur les exploitations agricoles. Les différentes technologies d'agroforesterie ont été testées par des Instituts de Recherche Agronomique et des Universités dans le pays, en collaboration avec les organisations internationales de recherche, dont le Centre mondial d'agroforesterie. Ces technologies comprennent: l'utilisation des arbres fixant l'azote pour contribuer à l'augmentation des rendements des cultures, la sécurité alimentaire et les revenus ruraux, les boisements rotationnels basés sur l'agroforesterie pour fournir du bois de chauffe, la braise et les besoins en fourrage du bétail et pour générer des revenus substantiels et les systèmes agricoles basés sur l'agroforesterie visant à contribuer à la REDD et grâce à la restauration des terres dégradées afin d'augmenter la séquestration du carbone et de contribuer à atténuer les changements climatiques. La recherche a, par exemple, montré que *Sesbaniasesban* et *Gliricidiasepium* peuvent augmenter le rendement du maïs jusqu'à 1.5t/ha et 1.0t/ha respectivement par rapport au traitement sans engrais. Les études sur les arbres sans épines d'acacias australiens ont montré qu'*Acacia crassicarpa* planté sur des sols sableux acides a produit autant de tonnes de bois allant de 24 à 77 tonnes par hectare dans quatre à cinq ans. Du maïs cultivé après l'abattage dans la jachère de cet arbre a donné un rendement de 29 à 113 pour cent de plus de maïs que celui cultivé sur une jachère naturelle à proximité. Le présent article examine les contributions de ces technologies d'AF dans le but d'augmenter la production alimentaire, d'améliorer les moyens de subsistance des agriculteurs ainsi que d'atténuer le changement climatique en Tanzanie et suggère des stratégies d'intensification.

Mots clés: Technologies de l'agroforesterie, changement climatique, sécurité alimentaire, gestion des ressources naturelles, Tanzanie

Background

Tanzania has about 88.6 million hectares (ha) of land suitable for crop and livestock production. Of these, only about 7 million ha are used for rain fed agriculture and 24 million ha for livestock production. Food crop production accounts for 55% while livestock accounts for 30% of the agricultural GDP for Tanzania. Production and productivity of both crops and livestock is generally very low. For example, average maize yield is 1.4 tons/ha while the potential is 4.0 tons/ha. The low agricultural productivity is due to use of inefficient and poor farm implements like hand hoes, low soil fertility, poor marketing systems and poor rural infrastructure. Low soil fertility is mainly due to continuous cropping without external inputs and due to erosion intensified by post harvest overgrazing.

Traditionally, farmers used shifting cultivation farming practices with 10 – 20 years natural fallow periods as a measure to improve soil fertility and increase crop yields. This is no longer possible due to high population pressure and related land use conflicts. Consequently, continuous cropping or very short (1-3 years) natural fallows are used resulting in low farm productivity. This translates into poor nutrition, hunger and ill health. The majority of farmers in Tanzania cannot afford expensive farm inputs like inorganic fertilizers. Most farmers still practice poor crop husbandry due to inadequate and poor extension services. Agro-forestry (AF) interventions can sustainable improve soil fertility in addition to providing households with other products.

Literature Summary

A review of the status of Tanzania's agricultural sector (for the Agricultural Sector Development Programme) notes that the country is lagging in achieving its targets on reducing poverty and food insecurity and in achieving the Millennium Development Goals targets (URT 2006). Tanzania has a challenge of revitalizing her agricultural sector by improving the natural resource base, i.e., soil, water and biodiversity. Agroforestry can offer robust options to improve productivity and achieve environmental sustainability.

Leakey (1996) defines agroforestry as "*a* dynamic, ecologically based, natural resources management system that, through the integration of trees in farmland and rangeland, diversifies and sustains production for increased social, economic and environmental benefits. The major components of agroforestry systems are trees and/or shrubs (woody perennials, including bamboo) deliberately retained or planted on the farmland; agricultural crops, including food and cash crops (some of which are herbaceous annuals or perennials); and livestock. There are many biological, ecological and economic interactions among the components, which makes it a resilient land use practice to mitigate and adapt to climate change, halt land degradation and enhance biodiversity conservation. Agroforestry is therefore a powerful tool for tackling the emerging global and local challenges. Research in Eastern and Southern Africa has shown that agroforestry has great potential in improving the livelihoods of people in terms of providing food, fuel, fodder for livestock and at the same time conserving the environment by mitigating climate change effects (Kwesiga *et al*., 1999; Tunu *et al.*, 2002; Nyadzi *et al*., 2003; Gama *et al*., 2004; Wambungu *et al*., 2006).

Study Description and Research Application

Agroforestry Technologies. Research carried out at Tumbi Research Institute, Tabora and Shinyanga in western Tanzania and other research institutions in Tanzania for over 20 years has identified a number of technologies that now benefit resource poor farmers in terms of food security and incomes. These include improved fallows using tree and shrub species, rotational woodlots, fodder banks mainly for zero grazed dairy cattle and use of indigenous fruits for food and income generation.

Improved fallows. Agroforestry offers different options for soil fertility replenishment, which are more affordable than inorganic fertilizers. These include improved fallows, intercropping and relay cropping of crops with nitrogen fixing trees and shrubs like *Sesbania sesban*, *Tephrosia vogelii*, and *Gliricidia sepium.*

In a field trial in Tabora, Tanzania (Gama *et al*., 2004), maize yields following 2-years of *S.sesban, T. vogelii*, natural grass fallows, and continuous maize (i.e. maize monocrop) with the recommended rate of fertiliser (100 kg N ha^{-1}, 17.6 kg P ha^{-1} and 33.2 kg K ha^{-1}) and without fertiliser were assessed in seven villages in 10 researcher-managed and 52 farmer-managed trials. Results (Table 1) show that maize grain yields were 2164, 1725, 1004, 882 and 780kg ha^{-1}respectively for fertilised maize>maize after *S. sesban*>maize after *T. vogelii*> maize after natural fallow> unfertilised maize options. Maize yields after natural fallow and *T. vogelii* and under no fertiliser did not differ significantly while yields under *S. sesban* fallow were consistently higher compared with the natural fallows. *S. sesban* fallows can therefore complement application of expensive inorganic fertilisers in Tabora.

Table 1. Maize yields in rotation with sesbania, tephrosia or natural fallow and in monocrop system averaged over 10 farmer – managed trials in Tabora district, Tanzania.

Treatment	Maize grain yield Kg ha^{-1}
Sesbania sesban	1725
Tephrosia vogelii	1004
Natural fallow	882
Fertilised	2253
Unfertilised	780
SED	157.6

SED = Standard error of difference of means.

In a similar study involving *Gliricidia sepium* and *Sesbania sesban* fallows and fertilised and unfertilized treatments, it was shown that *Sesbania sesban* and *Gliricidia sepium* fallows were superior in terms of maize production when compared to the no fertilizer treatment (Fig. 1). These studies on improved fallows have shown the great potential of these tree species for maize production particularly for small resource poor farmers in the country.

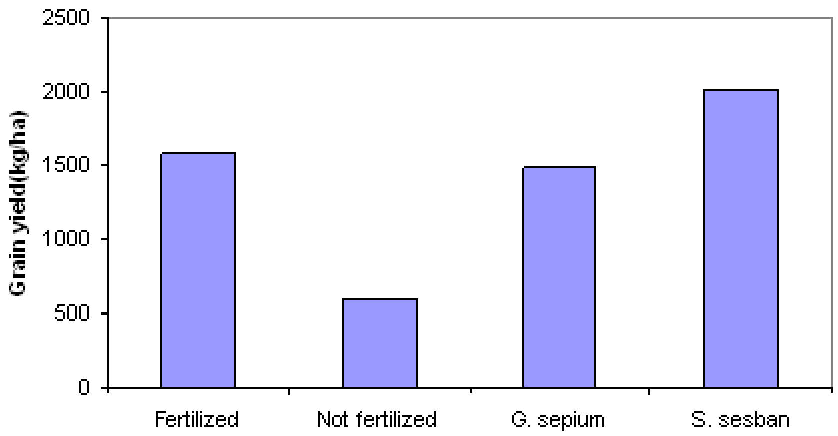

Figure 1. Effect of *S. sesban, G. sepium*, fertiliser and no fertiliser application on maize grain yield across 4 farmers' fields at Tumbi, Tabora 2002/2003 season.

Fodder and fodder banks improvement. One of the major constraints to livestock production is shortage and poor quality feed, particularly during the dry seasons. Agroforestry research in Tabora and Shinyanga has identified suitable fodder trees and legumes that have improved fodder quality and quantity. The fodder bank technology and improved *Ngitilis*, using fast growing fodder trees and shrubs such as *Leucaena pallida; L. diversifolia, L. collinsii, Acacia angustissima* and *Gliricidia sepium* has shown great potential to meet the needs of livestock feed in the dry seasons (Wambugu *et al.*, 2006). For example, supplementation of dairy diets with 2 - 4 kg of Leucaena leaves resulted in 30% increases in milk production in Shinyanga. Table 2 shows the effect of supplement feeds on milk production. It was observed that tree leaves could be substituted for the expensive and unaffordable cotton seed cake.

Table 2. Effect of feed supplements on milk production (n = 38).

Type of Supplement	Quantity/day (kg) (average)	Milk/day (litres) (average)
Cotton seed cakes	3	12
Cotton hulls	4	8
Maize bran and fodder leaf	6	11
Maize bran (no supplements)	4	7

Rotational woodlots for fuel wood production. The use of fuel wood as a major source of energy for the majority of Tanzanians has resulted in high pressure on natural forests. In 1999, 95% of the wood consumption in the country estimated at 42 million cubic metres was fuelwood. In order to offset fuelwood demand from natural forests, several technologies were developed and tested. These included: woodlots (pure stand and rotational), alley cropping, boundary planting and wind breaks. Rotational woodlots have shown greater potential in alleviating fuelwood shortage. Rotational woodlots involve three phases; a tree establishment phase (2 – 3 years), where trees are planted with crops; a tree fallow phase; and a post fallow phase. Fast growing and high yielding tree species suitable for rotational woodlots have been identified. Some of these include: *Acacia crassicarpa, Acacia julifera, Acacia leptocarpa, Senna siamea, Leucaena leucocephala, Acacia polyacantha* and *Acacia nilotica.*

Studies at Tumbi Tabora and Shinyanga (Nyadzi *et al*.,2003) showed that on acid sandy soils at Tabora, *Acacia crassicarpa* A. Cunn. ex Benth. grew faster and produced 24 to 77 tons ha^{-1} of wood in four to five years (Table 3.) On alkaline Vertisols at Shinyanga, seven years old woodlots of *Acacia polyacantha* Willd. and *Leucaena leucocephala* (Lam.) De Wit. produced 71 and 89 tons ha^{-1} of wood, respectively (Table 4). Intercropping of maize between trees was possible for two years without sacrificing its yield. The first maize crop following *A. crassicarpa* woodlots gave 29 to 113% greater yield than the crop after natural fallow. *Acacia polyacantha* and *L. leucocephala* woodlots also increased the subsequent maize yields over a three year period. The increase in crop yields after woodlots was attributed partly to accumulation of greater amounts of inorganic N in the topsoil compared to the traditional fallow, and partly to other effects. Thus medium-term rotational woodlots are likely to contribute to meet the wood requirements of rural people and thereby help protect the natural woodlands in Tanzania and the system should be disseminated and scaled up and out in many parts of Tanzania. A National Agroforestry

Table 3. Growth characteristics of *Acacia crassicarpa* in 4- or 5-year old woodlots planted on-farms at different slope positions at Isikizya, Tabora, Tanzania.

Landscape position	Age (years)	Height (m)	DBH (cm)	Wood (t ha^{-1})	Total biomass (t ha^{-1})
Lower	5	15.7	17.9	56.4	71
Middle	4	14.3	21.5	77.4	95.8
Upper	4	11.3	14.7	24.3	31.4
SED	0.59	1.31	1.31	11.52	15.5

SED = standard error of difference and DBH= diameter at breast height.

Table 4. Growth and biomass of three tree species planted as woodlots at the age of three and seven years at Shinyanga, Tanzania.

Woodlot species	3 years		7 years		
	Survival (%)	Biomass (t ha^{-1})	Height (m)	Wood (t ha^{-1})	
				Un pruned	Pruned
Acacia nilotica	78	2.5	3.9	8.4	6
Acacia polyacantha	76	7.8	5.8	70.9	49.7
Leucaena leucocephala	80	15.4	7.7	88.9	34.6
SED	7.2	1.34	0.64	23.5	-

SED = standard error of difference between means.

Steering Committee (NASCO) can play a great role here in mobilizing different stakeholders in the process.

Indigenous Tree Fruits and other Non Wood Forest Products and services (NWFPs). Natural forests contain a variety of indigenous fruit trees and other non wood forest products (NWFPs) and services. The NWFPs are important for food and nutritional security, as well as a source of income for rural communities in southern Africa, with women and children being the main beneficiaries. They consist of game meat, medicinal plants, fodder, latex, beverages, dyes, fibres, gums, resins, oils, beeswax and honey, tannins and toxins. Ecosystem services which accrue from the forests include: watershed functions, maintenance of soil fertility, conservation of biodiversity, sustaining cultural values, carbon dioxide (CO_2) sequestration, climatic amelioration and eco-tourism. The natural forests providing these products and services are being degraded and therefore reducing their potential to provide these products and services. *In-situ* and *ex-situ* conservation would ensure sustainable supply. Research has demonstrated that incorporation of indigenous fruit and nut trees and other NWFPs into agro forestry farming systems can be an important strategy for providing a high nutrition diet, for reducing poverty and hunger during periods of drought and for creating employment and income generating possibilities in rural areas. For example, Ngitilis have been shown to benefit owners about 14 US$ per person per month, which is much higher than the average monthly spending per person in rural Tanzania (8.5 US$). The benefits gained were from products harvested from Ngitili, including fuelwood, timber, medicinal plants, fodder, thatch-grass for roofing, wild foods such as bush meat, edible insects, fruit, vegetables, and honey. In addition, restored vegetation through Ngitili has been reported to maintain water storage in reservoirs for domestic and livestock use. The free access to communal Ngitili for poor people provides a safety net for the poorer households who have no or very little individual ngitilis.

There is a growing interest in the carbon trade which would assist farmers to sell their carbon credits and generate incomes to improve their livelihoods. It is estimated that carbon could generate US$10 billion a year which would make a significant contribute to fighting poverty and deprivation in Africa. One of the key constraints preventing small farmers from taking advantage of emerging carbon markets has been the lack of knowledge about how to measure carbon stocks and how to access the markets.

Agroforestry innovations for climate change adaptation. A large and growing body of scientific evidence indicates that climate change impact is a major threat to sustainable development and achieving Millennium Development Goals (UK Government, 2006; IPPC, 2007). For Tanzania, predictions show temperature increase ranging from 2.1 to 4^{o}C, with central and western parts of the country showing higher changes. Predictions show that areas with bimodal rainfall pattern will experience increased rainfall of 5% – 45% and those with unimodal rainfall pattern will experience decreased rainfall by 5% – 15%. This shifting weather regime will have many adverse effects on agricultural productivity including more frequent droughts, changes in planting dates of annual crops, increased fungal outbreaks and insect infestations causing decline in crop yields, reduction in ecosystem integrity and resilience, and declining in biodiversity. The adverse effects of climate change and variability is reported in the MUKUKUTA 2006 Status Report and was given utmost importance in the Ministry of Agriculture 2008 budget speech. The Government and development partners are challenged on how best to work with local farmers to identify innovations that increase farming systems resilience and reduce farmers vulnerability. The national assessments (URT, 2006) describe the Central Plateau ecological zone of Tanzania as one of the most vulnerable to climate change and variability. This vast area of drylands (covering most of Central regions i.e. Dodoma and Singida as well as western regions of Tabora, Shinyanga, Kigoma and

Mwanza) falls in the priority areas for scaling-up of agroforestry technologies.

Concluding Remarks

A major challenge to national and international institutions working on agroforestry is on how best to scale up proven agroforestry technologies for more impact on poverty reduction, environment conservation and climate change adapation and mitigation. There are a number of social, insititutional and political barriers to scaling up, which require multi-insitutional and cross-sectoral collaboration.

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