AFRICA RISING RESEARCH PROGRAM
FINAL TECHNICAL REPORT FOR THE JUMPSTRAT PROJECTS

Evidence-Based Scaling-Up of Evergreen Agriculture for Increasing Crop Productivity, Fodder Supply and Resilience of the Maize-Mixed and Agro-Pastoral Farming Systems in Tanzania and Malawi

By
Anthony A. Kimaro, Sileshi G. Weldesemayat, Mathew Mpanda, Elirehema Swai, Heri Kayeye, Betserai I. Nyoka, Amos E. Majule, Joseph Perfect, and Godfrey Kundhlande

10th October, 2012

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

NARRATIVE SUMMARY

Declining soil fertility, climatic extremes, high costs of inputs and poor extension services are critical problems in Sub-Saharan Africa and are strongly associated with declining agricultural productivity and increasing rural poverty. Increasing population has also led to conflicts between farmers and pastoralists as crop production continues to encroach on tradition grazing areas. Intensification of agriculture is one of the options to address these problems. Development of a sustainable agro-ecosystem requires an integration of productive (e.g. crop yield & fuelwood supply) and ecological functions of agro-ecosystems as well as enabling policies and markets. Trees/shrubs are an integral component of small-scale farming systems in the region, often retained or planted by farmers and thus contributing to increase production and resilience of farming systems. However, the contribution of tree/shrub-based technologies to sustainable agricultural intensification has not received due attention. To fill this gap, this project was conducted to evaluate Evergreen Agriculture as an agroforestry model for the integration of sustainable farming practice to increase and maintain food crop production under the Africa RISING research program in Eastern and Southern Africa. The goals of the project were to generate research-based information to demonstrate the role of trees/shrub in sustaining increasing food crop production, fodder and biomass energy supply, and for reduced land degradation, and to identify evidences for scaling up evergreen agriculture technologies to provide these benefits. Major findings of this work are summarized below using the format proposed by the Africa RISING Research Coordinator.

1. Purpose, objectives, planned outputs

1.1. Research Objectives

The objectives of this project were to: 1) carry out socio-economic and biophysical baselines of Evergreen Agriculture practices, 2) establish the infrastructure for supplying tree seed and seedlings to be integrated into maize-legume-livestock systems based on farmers' needs, and 3) strengthen the capacity of farmers to use Evergreen Agriculture technologies for sustaining maize and livestock production, and to collect, interpret and use weather information to make climate smart farming decisions.

1.2. Planned Outputs

- Socio-economic, cultural, and policy factors influencing the success of Evergreen Agriculture evaluated.
- Biophysical factors underpinning the success of EGA documented
- Models to sustainable tree seed and seedling supply systems analysed
- The capacity of farmers to practice EGA and use weather information analysed

2. Project Partners

- **ICRAF**: Overall coordination of the projects, collect baseline information to identify constraints and opportunities for agricultural intensifications, conduct tree inventory and document ecological and socio-economic values of trees in the agricultural landscape. ICRAF Malawi office led the analysis of models for supplying tree/shrub seed and seedlings to farmers based on their on-going work in the country.

- **SUA** (Sokoine University of Agriculture): Analysis of Land cover and land use change to indicate land degradation and possible interventions for addressing the problem.
- **ARI (Agriculture Research Institute)-Hombolo**: Carried out the baseline in collaboration and prepared the report in collaboration with ICRAF-Tanzania.
- **IRA** (Institute of Resource Assessment, University) of Dar-es-Salaam: Analyzed access and use of use weather information by farmers in making farming decisions.
- **Others**: The field visit to select site for this jumpstart identified the following partners who will be actively involved during data collection: District Agricultural and Livestock officers (DALDOs) and extension officers in Kongwa, Kiteto and Babati.

3. Achievements and deliverables against plan

This research focused on identifying constraints to sustainable agricultural production and evaluated the potential of evergreen agriculture to address the problems in the context of maize mixed and agro-pastoral farming systems in Eastern and Southern Africa. Key deliverable for each research outputs are summarized below and detailed in the appended technical report.

3.1. Output 1: Socio-economic and Policy factors:

It was established that 50% of the population has large families, with 5-8 people per family. Similarly a greater proportion (60%) of the population owns small land holdings (1- 4 ha per household) which produce (1-1.5t/ha) below the farmer-estimated maize yield potential of 4.5t/ha. Current maize yield as estimated by farmers (1-1.5t/ha) was in line with the long-term maize yield data from FAO for Tanzania and Malawi. Low productivity, small land holdings and large family size are one of the major factors contributing to food insecurity in the study site, as noted by 60% of respondents who experience food deficit in 1-9 months in a year. The impacts of these factors on crop productivity are exaggerated further by low levels of inputs, especially fertilizer and/or manure, despite high percentage (60%) of individuals who keep livestock. Only 17% of respondent use fertilizer or manure and less than 10% indicated that they use improved seeds obtained from agro-dealers or quality declared seed (QDS) sources. This analysis suggests that, the focus of sustainable intensification research under the Africa RISING would be to minimize the identified crop yield gap as a one of the pathways out of higher. Both Tanzania and Malawi have enabling policy environment for scaling up evergreen agriculture and other sustainable intensification options for this research program. Thus evergreen agriculture technologies, utilizing tree/shrub-based options have the potential role to play as highlighted in subsequent outputs.

3.2. Output 2: Biophysical factors

There is a high level of land degradations and farmers attributed this degradation mainly to soil erosion (34%), overgrazing (25%) and depletion of soil nutrient or organic matter (11%). Rapid soil fertility rating also indicated that nutrient and organic matter levels in the soils, ranging from 0.02 to 0.11 % for total nitrogen, 0.91mg/kg to 25 mg/kg for extractable P (Bray -1 P) and 0.22 to 1.50% for organic matter. Although surveyed areas have high potential for maize production in the country, it was noted that such high yield on apparently impoverished soils like these were at the expense of clearing more land for agriculture. Over a period of 23 years (1987-2010), cultivated land in Kongwa and Kiteto districts increased by 31% while the areas under forest and shrubs/thickets declined by 38.8%. Consequently sustainable food crop production in these soils would require replenishment of soil nutrients and organic matter to restore soil health and productivity as well interventions to minimize forest degradation in the area. Apart from supplying nutrient, replenishing soil organic matter has the advantages of improving other soil properties, such as bulk density, nutrient and water retention capacities and infiltration capacity; which contribute to increasing use efficiency of soil nutrients and moisture by plants. These mechanisms have been demonstrated to increase rain water and stabilize maize yield against climate variability in the ICRAF-led research in Southern Africa and have practical applications to the Africa RISING research on sustainable intensification of cereal-legume and livestock farming systems. Grazing on farmland after crop harvest is a challenge to sustainable crop production and tree planting in Africa RISING sites. This is critical when grain or shrub legumes like pigeonpea and *Tephrosia* are used as fallow species for providing land cover and replenishing nutrients and/or soil organic matter. Farmers, however, acknowledged that participatory land use planning safeguard the interest of various stakeholders; enforcement of acts, bylaws, and regulations related to the judicious use of village lands; destocking to manageable rates, and public awareness or education on sustainable land use practices may help to address this problem. Other approaches like improving pasture management through establishing woodlot or grazing land reserves for fodder and fuelwood supply also need to be considered to provide integrated options to conserve the natural resource, especially soils, required for sustainable crop production.

3.3. Output 3: Evaluating models for sustainable supply of tree seeds and seedling

The sustainable supply of high quality agroforestry tree germplasm is fundamental to the successful establishment of productive agroforests by farmers. National Tree Seed Centres (NTSC) that were established initially to supply seed for plantation development and later revamped in the 1990s to supply quality tree seed to farmers have had challenges in reaching many farmers due in part to their central location. Equally, the resource-constrained smallholder tree planters and farmers also faced challenges, travelling long distances to the seed centres, only to buy small amounts of tree seed. The World Agroforestry Centre’s development strategy has been to develop and apply better methods of forecasting germplasm needs, and to help establish effective, low-cost, sustainable, germplasm production and distribution systems. A sustainable seed supply system for agroforestry tree species is the one in which farmers have access to adequate high quality seed of the desired type (species and seed source) at the right time. Tree germplasm supply models are either centralized or decentralized in relation to ownership and control of (a) the seed source (production), (b) collection and procurement and (c) distribution. Any one of these three components (source of germplasm, procurement and distribution) can either be centralized or decentralized creating an array of permutations. Research has shown that there is no one-size fits all sustainable quality tree germplasm supply model. A combination that draws from the strengths of each has been shown to be the best approach to supplying high quality tree germplasm. The most widely used models are the government centralized model, NGO model, private sector model, community and farmer-to-farmer model depending on the species. A study in Malawi found that 40% of the farmers received germplasm from NGOs. Free germplasm has been blamed for stifling private entrepreneurs as noted by 74% of farmers in Malawi who received germplasm free. Although the demand of agroforestry tree seed has not been properly quantified, available statistics indicate that at least 50 metric tons of tree/shrub seed were distributed annually in Malawi through the formal distribution network between 2007 and 2009. In Malawi, the major players in the tree seed suppliers, the Land Resources Centre (LRC), National Tree Seed Centre (NTSC) and ICRAF source respectively 100%, 65% and 46% of their seed from smallholder farmers respectively. Farmers may act individually or in groups (community) in both the tree seed and seedling production. This model was used in Malawi to produce tree seed in Chikhwawa (*Gliricidia sepium*), Mangochi (natural stands of *Faidherbia albida*) and Dedza (*Tephrosia* spp.) districts during the implementation of the Agroforestry Food Security Programme (AFSP), the tree germplasm production under Community Agroforestry Tree Seed (CATS) banks. The CATS bank approach was shown to be highly effective with precocious tree/shrubs species (*Tephrosia* and *Sesbania*), but may not be suitable for tree species that take longer to flower and fruit and also for those species with inherently low seed production potential. The control of tree germplasm is a challenge in both Tanzania and Malawi due to the absence of tree seed and seedling quality regulations. Opportunities of using voluntary certification and branding of germplasm are being explored.

3.4. Output 4: Analyzing the access and use of weather information by farmers in farming operations

The awareness of farmers on weather forecast information from the Tanzania Mateorological Agency (TMA) is low and farmers rarely use this information to guide their farming operations. Moreover the weather information generated is generalized and hence may not be very useful for planning site-specific activities. Farmers use local knowledge such as tree phenology with limited applications in predicting climate variability, which affects crop productivity in many semi-arid areas like Kongwa. The adaptive capacity of villagers to climate change in the study sites is low due to extreme poverty, limited alternative livelihood activities, and high environmental degradation. Interventions like the use of mobile phones to increase access to weather information and community weather stations where farmers can be trained to collect use and interpret weather data, could provide time and site specific information. This scientific information can be integrated with local knowledge to help farmers make climate smart decisions related to farming operations, such as the timing of site preparation and planting activities and the expected length of the effective rainy season. Climate Field Schools (CFS) programs are recommended for building the capacity of farmers to collect, use and interpret weather information effectively. These programs consists of a *socialization* phase, characterized by a series of meetings with farmers to increase their knowledge on climate and weather forecast information and to design cropping strategy, and the *institutionalization* phase where farmers practice what they learnt to build their capacity.

3.5. Recommendations

The following interventions are recommended to address key constraints to sustainable intensification of maize mixed and agro-pastoral systems in Tanzania and Malawi:

- Integrating fertilizer trees, manure and micro-dosing technologies, which fits very well into farmers' socio-economic conditions.
- Integrated soil and water management to address land degradation and moisture limitation to crop growth.
- Participatory land use planning to minimize land use conflicts and improve farm productivity
- Design and implement sustainable seed and seedling (trees and crops) supply systems.
- Capacity building for Climate-smart Agriculture to enhance the resilience of farming systems and increase the adaptive capacity of farmers.

4. Key Deliverable Deviation

- Given the short-duration nature of this project, the training aspect of research output 4 was revised at the inception workshop to focus on the analysis of access and use of weather information by farmers to assess training needs for further interventions. Also the completion of jumpstart contractual arrangements to start field work could not allow for the exchange visits and other planned experiential training Evergreen Agriculture as the season had advanced too much to see good practices in the fields. Such training, however, can be conducted in sub-sequent years of the Africa RISING research.
- Study sites (Kondoa and Babati Districts in Tanzania), which were pre-selected prior to the inception workshop, were changed to Kiteto and Kongwa districts to co-locate AfricaRISING activities with the Feed-the-Future action sites. This was a follow up of the recommendations from the visits of Jerry Glover to the USAID mission in Tanzania in June, 2012. For this reason, the Tanzania site for our jumpstart was changed to Kiteto and Kongwa districts.
- The start of field activities late in the growing season and changes in study sites could not allow for establishing tree/shrub nurseries and other infrastructure required for future work on building the capacity of farmers to produce tree seedling locally. As indicated in the report, there is a well-established and community-oriented tree seed and seedling supply system in Malawi. This system will provide a platform for starting tree seed and seedling productions within a short period when details of the action plan for the proposed research themes for year 2 are known.

5. List of geo-tagged locations/sites where activities took place

The geo-tagged locations are attached in separate files and have been submitted with this report.

6. Support of AFRICA RISING

Partnerships established during the implementation of this jumpstart project will be instrumental for the success of future work under Africa RISING. Similar interventions recommended by this report would be useful in designing the Africa RISING research projects for the East and Southern Africa.

7. Scalability

The candidate Evergreen Agriculture practices for sustainable intensification identified in this report are based on work conducted on-station and on-farm in areas with similar agro ecological conditions to the Africa RISING sites. Thus these practices can be evaluated for adoption in these sites.

8. Lessons learnt

The Africa RISING research program is all about integrations. Technologies and various disciplines from CG centers and national partners are integrated into packages to address challenges for sustainable intensifications of farming systems in Africa. The kind of partnerships developed from this approach is likely to last beyond the project lifecycle, but it has taken longer than expected to build a common vision among various partners and come up with a workable program. This delay also may have contributed to the following problems noted during the implementation of this jumpstart: 1) the change of action sites and limited involvement of research partners in this process as noted above, and 2) too short time to implement jumpstart projects, which was also complicated by delays in developing and signing of contracts and sub-contracts before fieldwork started.

9. Publicity

The interim and the final report for this project will be posted on the workspaces for public use and a summary of the final technical report will be posted on the ICRAF website. Results from this project will also be published as a journal article on tree stocking and use in farming landscapes and as the ICRAF working paper on evergreen agriculture technologies for sustainable intensification of cereal-based farming systems.

10. USAID indicators

Our target for USAID indicator No. 14 was to reach 1000 farmers. However, the project reached 600 farmers through household interviews (in four villages) and participatory rural appraisal (in eight villages) approaches used to collect data and though discussion on project activities with districts officials in the study sites. More farmers were expected to be reached through exchange visits which were not conducted because field activities started late in the season as mentioned earlier.

11. **Documentation of success:** A story was prepared in collaboration with the IITA communication Officer, Catherine Njuguna.

1. INTRODUCTION

1.1. Rationale for Evergreen agriculture

Evergreen Agriculture is one of several types of agroforestry, and it is defined as the integration of particular tree species into annual food crop systems in order to ensure greater production of food, fodder, fuel, fiber and enhance carbon storage both above-ground and belowground (Garrity et al., 2010). Evergreen agriculture emphasize on:

- Integration of trees and crop cultivars which are well adapted to local conditions, together with judicious application of agro-chemicals (e.g. supplementation with small dosages of fertilizer). This is aimed at maximizing synergy between organic and inorganic nutrient sources. It also helps to reduce use of external chemical inputs, which can have harmful impacts on soil and water quality, biodiversity, pollinators and human health; reduce erosion by wind and/or water;
- Integration of tree with conservation agriculture (CA) practices to increase soil cover (over and above CA), improve soil organic matter (SOM), provide a conducive habitat for soil biota and minimize erosion losses;
- Integration of trees in crop-livestock production systems to increases fodder resources (reduce overgrazing), avoids nutrient loss and greenhouse gas emissions by efficient recycling of nutrients.

The aim of evergreen agriculture is not necessarily to provide year-round “green cover” on the land, but to maintain vegetative soil cover that bolsters nutrient supply through nitrogen fixation and nutrient cycling and generate greater quantities of SOM, improve soil structure and increase the soils ability to capture rainfall, store water and make it available to crop plants. Maintenance of active soil biota communities (which also serve as the biological plough and ensure a healthy cycling of energy and matter in the soil) and conservation of above-ground biodiversity is another objective. The increased consideration of tree-based land use practices and the widening of the focus from the field to the landscape scale in agroforestry science have made links between agroforestry and the conservation of biodiversity more relevant and more obvious in southern Africa (Chirwa et al., 2008; Huang et al., 2002; Sileshi et al., 2007). In areas where the forest has been lost, indigenous fruit and timber trees may be grown on crop land as companion species to provide environmental services. Trees on farmland can provide habitat and food for other components of biodiversity, act as biological corridors, and as such support efforts to protect nature reserves. For example, in Tanzania Huang et al (2002) found a significant positive impact of agroforestry on the biodiversity conservation of nature reserves. In the face of increasing frequency of occurrence of extreme events, agroforestry can also be considered an adaptive strategy.

Agricultural development in Africa is often predicated on intensification of input use, notably application of inorganic fertilizers. However, fertilizer inputs alone cannot overcome the various challenges that African farmers are currently facing. Over the years, rapid growth of human population (3% per year), increasing pressure on the limited arable land have led to poor land use planning or inappropriate land use and unsustainable farming practices continue to subject agricultural land to increasing degradation and loss of its productive capacity. Land degradation, defined as the loss of the productive capacity of land to sustain life, is the most serious threat to livelihoods and the environment. Land degradation reduces biological diversity and ecosystem functions, and hence is a major component in the cycle of unsustainability and consequently the downward spiral of the poverty traps. It can exacerbate drought as the former affects water availability, quality, and storage.

According to the Land Degradation Assessment of Dry lands (LADA), deforestation, overgrazing, inappropriate agricultural practices (e.g. tillage) and overexploitation are the main cause of land degradation (UNEP, 1997). Vegetation denudation on farm land and deforestation through conversion of forests to farmland, slash and burn agriculture, charcoal burning, bush fires and harvesting of wood (for tobacco curing, smoking fish, timber, poles, etc.) are playing a key role in the modification and transformation of the forests in Malawi and Tanzania (Sileshi et al., 2007). Soil tillage can also have profound effects as it renders the soil more vulnerable to erosion and destruction of soil structure. For example, tillage with hand hoe, draught animal power or tractors and ploughs has been increasingly shown to provoke soil compaction, biological degradation and erosion.

Major forms of soil degradation include depletion of SOM and nutrients, soil acidification, loss of soil biodiversity, soil compaction, runoff and erosion, which are all conducive ultimately to desertification. The regular removal or loss of organic matter through biomass burning or tillage reduces soil fertility and soil surface stability. Bush fires are widespread and almost invariably started by people as land management tool in southern Africa (Ajayi and Kwesiga, 2003; Eriksen, 2007). Frequent uncontrolled fires are harmful both to vegetation and soil and biodiversity (Sileshi and Mafongoya, 2006a). Decline in SOM and associated unfavorable carbon to nitrogen ratio (C : N) and low soil nutrient status adversely affects water and nutrient availability and soil structure, resulting inevitably in loss of productivity. Soil acidity, either anthropogenic or natural in origin, is another major constraint for agricultural productivity. There are also signs of increasing soil acidity in some parts of Malawi as a result of continuous cultivation, prolonged use of inorganic fertilizers and biomass burning (Sileshi *et al*., 2012). Soil acidity is directly or indirectly conducive to other forms of land degradation. Continuous monoculture of crops with minimal rotation and reduction of agro-biodiversity has a tendency to deplete the soil and for crop pests to become endemic. This combined with the shortening of fallow periods and decline soil fertility has also been shown to increase the intensity of serious pests including the witch weeds, *Striga* spp., (Sileshi et al., 2006).

To create system sustainability requires that multiple concerns are addressed simultaneously. For example, combating desertification, conserving biodiversity, and mitigating and adapting to climate change are linked in many ways. This requires an operational shift in thinking and strategy that recognizes the broader working nature of managed landscapes, along with new ways of valuing their productive and protective functions. Evergreen agriculture offers opportunities for the implementation of such a strategy and ensuring sustainable land management (SLM). Traditionally, SLM is defined as the use of land resources (soils, forests, rangelands, water, animals and plants) for the production of goods to meet human needs while assuring the long-term productive potential. Investing in trees will support of SLM, and thus an essential and cost-effective way to deliver global environmental, social and private benefits. Evergreen agriculture has also been conceived as a strategy to address the often conflicting objectives of intensified agriculture, while maintaining and enhancing ecological and global life support functions of land resources.

1.2. The Farming System Focus

The main farming systems in the pilot areas were the maize mixed and agro-pastoral farming systems. The maize-mixed farming system is the most important food production system, extending across the plateau and highland areas where the climate varies from dry sub-humid to moist sub-humid in east and southern Africa. In this farming system, the main staple is maize and the main cash sources are migrant remittances, cattle, small ruminants, tobacco, coffee, and cotton, plus the sale of food crops (Dixon et al., 2001). Maize is now a staple crop supplying half of the calories consumed in some countries. Maize accounts for 60% or more of the cropped area in Malawi and Tanzania (Smale and Jayne 2003). Smallholders have readily adopted improved maize varieties in a number of locations and at various times (Byerlee and Eicher 1997; Smale and Jayne, 2003). Since the late 1990s, improved varieties have accounted for an estimated 58% in East and Southern Africa (Byerlee and Eicher, 1997, Morris 2001). However, the average grain yield has stagnated at around 1–2 t ha^{-1} (Fig. 1) despite the crop's genetic potential to yield up to 10 t ha^{-1} (e.g. in USA) and the availability of improved cultivars and such inputs as mineral fertilizer. This clearly indicates that bridging the yield gap needs more than just promoting improved varieties and fertilizer. Trends in total area harvested for 1961–2010 show increase in the maize area harvested in Tanzania. On the other hand, in Malawi it increased from 1960-2000 and has remained the same since then (Figure 1). This indicates that little or no suitable farmland remains uncultivated and that production cannot be increased by area expansion but will require productivity gains. Logically, the solution to this lies in sustainable land management.

The main sources of vulnerability in this farming system are drought, land degradation and market volatility. In fact, the whole system is currently in crisis because of the shortage or high prices of inputs (including seed and fertilizer). As a result, yields have fallen and soil fertility is declining—small holders are reverting to extensive production practices, which are not sustainable given the increase in population and decline in per capita land holding sizes. In most African countries, maize production per capita has not kept pace with population growth over the past 40 years (Smale and Jayne 2003). Therefore, the prospects for meeting food demand—which depends mainly on rain-fed, smallholder agriculture (Conway and Toenniessen 2003)—will likely remain bleak without major efforts to reverse current unfavorable trends in productivity.

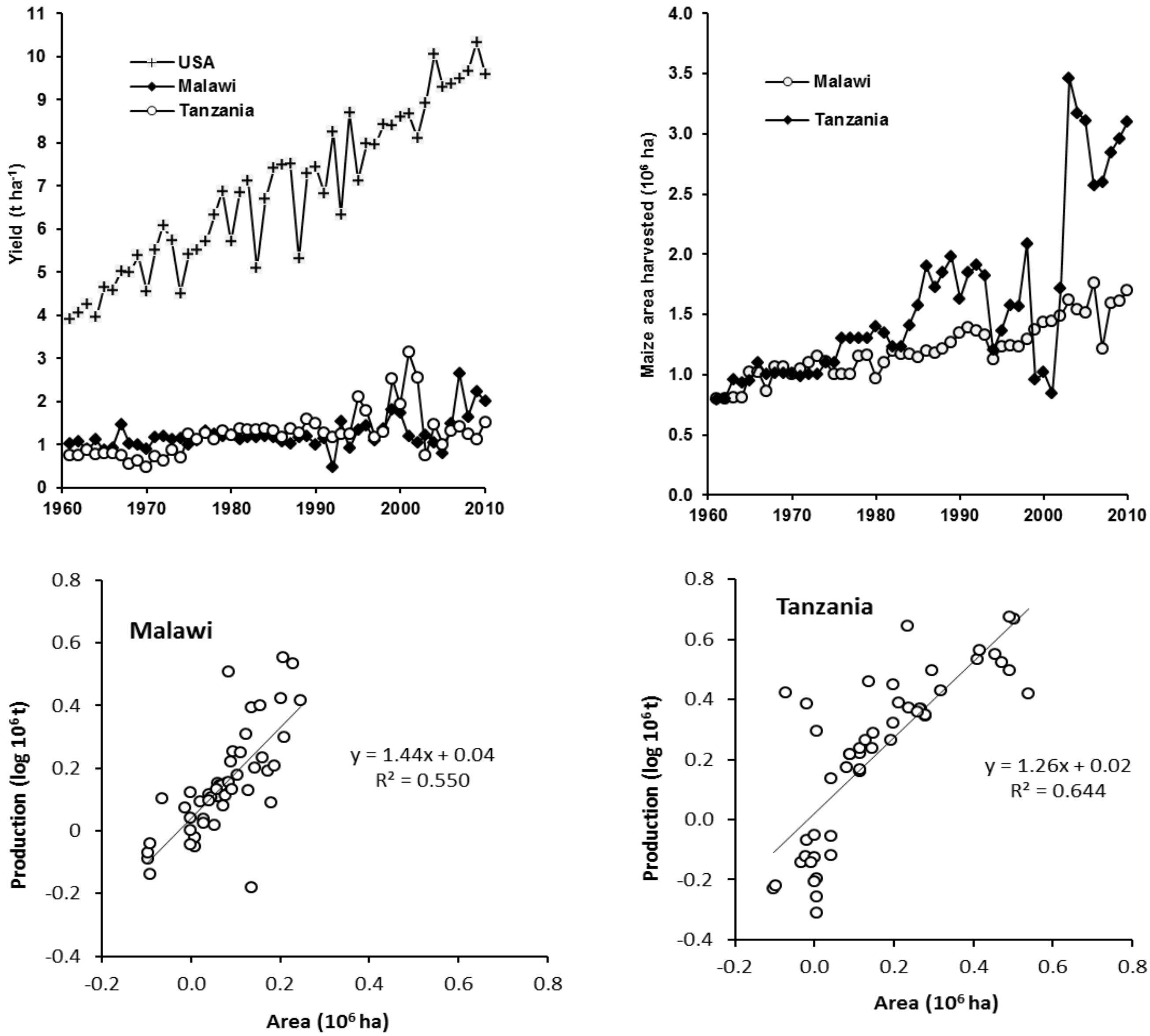

Figure 1: Maize yield, area harvested and the relationship between production and area harvested in Malawi and Tanzania

In the agro-pastoral farming system, rain-fed sorghum and pearl millet and livestock are the main sources of food and income (Dixon et al., 2001). The main source of vulnerability in this farming system is drought, which leads to crop failure, weak animals, and the distress sale of assets. Insufficient and erratic rainfall leads to low crop yields and the abandonment of traditional cropping systems. Soil-fertility problems are increasing in some areas because of shortened fallow intervals and long periods of continuous cultivation. Land shortage is a problem in the densely populated areas where soils are more fertile. Moreover, pressure on resources is expected to intensify in coming decades with the growth of human and livestock populations in the system. In addition to drought and declining soil fertility, crop-related constraints include weed infestation in cereals (e.g. the parasitic weed *Striga*), pests and diseases in cowpeas and groundnuts, and the high cost and general lack of credit for cotton inputs. Shortage of dry-season grazing and the weak condition of draught animals at the time of greatest physical effort are also a serious constraint.

1.3. Research Objectives and outputs

The main objective is to build an evidence base for scaling up evergreen agriculture to increasing crop productivity, fodder supply and resilience of the maize-mixed and agropastoral farming systems in Tanzania and Malawi. Specific objectives are to: 1) provide a synthesis of state-of-the-art knowledge on evergreen agriculture, (2) establish socio-economic and biophysical baselines of evergreen agriculture practices, 3) establish the infrastructure for supplying tree seed and seedlings to be integrated into maize-legume-livestock systems based on farmers' needs, and 4) strengthen the capacity of farmers to use evergreen agriculture technologies for sustaining maize and livestock production, and to collect, interpret and use weather information to make climate smart farming decisions. To achieve these objectives, the project was organized to deliver the following research outputs:

- Synthesis of existing knowledge on socio-economic, cultural, and policy factors influencing the success of evergreen agriculture
- Documentation of biophysical factors underpinning the success of evergreen agriculture
- Analysis of capacity and models to sustainable tree seed and seedling supply systems
- Analysis of the capacity of farmers to practice evergreen agriculture and use weather information

2. METHODOLOGY

2.1. Study site

2.1.1. Tanzania sites

This research was carried in Kongwa and Kiteto districts in Tanzania. Kongwa district (4041 km^2) is located between latitude 5˚30' to 6˚0' South and longitude 36^o 15' to 36^o East. It borders with Kilosa district in the East, Chamwino district in the West, Kiteto district in the North and Mpwapwa district in the South. The elevation of Kongwa District ranges from 900 to 1,000 meters above sea level. Generally the district lies on the leeward side of Ukaguru Mountains. The rainfall is ranging between 400 - 800 mm per annum. The rainfall pattern in the zones is bi-modal with short rains commencing November/December to January and long rains falling from mid-February to May. The annual temperature varies from mean minimum of 18^oC to a maximum of 34^oC. The characteristic vegetation of the district is of bush or thicket type. Kiteto District (16,685 km^2) is bounded by Simanjiro District in the North, Kilindi District in the East, Kilosa and Kibaigwa Districts in the South, Dodoma rural and Kondoa Districts in the west. It lies between latitude 40° 31 and 6º 03's and longitudes 36° 15' and 37° 25'E. The District is generally considered to be arid to Semi – arid. The District lies between 1,000m – 1,5000m above sea level. The low land areas rise from 1,100m – 1,300m`while the high land areas rise from 1,300m – 1,500m.The average day and night temperature is 22°C. Kiteto receives an average of 350mm - 700mm of rainfall. There is only one rainy season which is between the months of January and April. The terrain is characterized by plains with scattered ridges or rows of hills. The District is characterized by edaphic Savannas the Soil of which have developed from local geological condition and where soil moisture plays a key role in plant growth. Large areas are seasonally flooded and this restricts the growth during the intervening dry season due to deficiencies arising from leaching of soil nutrients. Thin story Soil dominate on the upper slopes while the lower slopes have red or grey sand soil which are usually poor in nutrients and prone to soil erosion (http://www.manyara.go.tz/wilaya.php?page=kitetoMain)

2.1.2. Malawi sites

Kasungu and Ntcheu districts in Central Region of Malawi were selected for this pilot study. Kasungu is part of the Lilongwe Plains and borders with Zambia to the west. The land is predominantly flat, and most important landforms include the Kasungu National Park, the Mchezi, Chimaliro and Kasungu hill with the highest peak (1272 m above sea level) in the District. The main rivers are Bua and Dwangwa. Rusa, Lingadzi, Milenje, Luwelezi and Lupache are secondary rivers. All these rivers drain their water into Lake Malawi. Ntcheu district boarders with Mozambique to the west, Dedza to the north, Neno to the south, Balaka to the southeast and Mangochi to the northeast. The terrain in Ntcheu is divided into Bwanje valley and the Kirk Range. Bwanje valley is located in the eastern part of the district and has alluvial soils. The Kirk Range is an upland area that lies along the Malawi-Mozambique border.

2.2. Data collection and Analysis

2.2.1. Sampling procedures and socio-economic data collection and analysis

A multi-stage sampling design was used to select the sampling units for this study. In consultation with IITA and USAID Feed the Future program two districts of Kongwa and Kiteto were purposeful selected. In consultation with respective district agricultural officers, four wards from each district were selected and thereafter one village from each ward was selected. The criteria for the wards and districts took into account areas with higher production potentials of cereal crops and those which are marginal. In total four villages were selected in Kongwa (namely Manungu, Sagara B, Lenjulu and Leganga) and three villages from Kiteto (Njoro, Dosidosi and Matui).

Household interviews using a structured questionnaire adopted for collected socio-economic data. Close-ended and open-ended questions as well as tabular questions were developed based on the research objectives. About 365 farmers were interviewed in Kiteto and Kongwa districts, representing approximately 10% of the population for each village. Four villages were purposefully selected for socioeconomic data collection to represent high and low potential maize producing areas. These include Njoro and Matui, in Kiteto district, and Lenjulu and Manungu, in Kongwa district. Representative from four villages were randomly sampled from village register to participate in household questionnaire survey. Randomization was done following the order of alphabet and consideration of sub-villages. The target respondent for the research was community members (villagers) aged 18 years and above who are aware with farming enterprise and other information of the household. Data collected was processed (coded, entered and verified) and then analyzed using Statistical Package for Social Science (SPSS) software. The analysis involved the use of descriptive statistics and content analysis. Following statistical analysis, the results were summarized in tables and figures of frequencies and percentages of respondents.

2.2.2. Soil fertility rating

Composite soil samples were collected from each village of study at a depth of 0 - 15 cm (plough layer) and 15 – 30cm (root zone area). The mapping units where soil samples were collected were identified by village communities through participatory mapping of major soil types existing in their respective villages. During soil sample collection village was represented by famers who have known to understand different locations of soils types. The soil was air dried, followed by grinding and sieving through 2-mm sieve. Soil chemical analyses were done in the department of soil science, Sokoine University of agriculture (SUA). Soil pH, in a 1:2.5 soil water suspension, was measured using a pH meter. Organic carbon was determined by the wet oxidation method of Wakley-Black. Total Nitrogen was determined by the semi-microkjedahl. Cation exchange capacity and exchangeable bases were extracted using neutral Ammonium Acetate extract and then determined in the atomic absorption spectrophotometry. Total phosphorus was determined by Bray-1 method. All analyses were carried out using standard laboratory procedures as described in Anderson and Ingram (1993).

2.2.3. Land Use and Land Cover Changes halt

Current and past year's satellites images were used for Mapping of land-cover and land-use in order to establish land use and cover changes of the Kiteto and Kongwa districts and corresponding given wards. Land-cover and land-use results are expected to provide a clear situation of the land degradation and types of land use exist in the areas. The satellites images used were Landsat of year 1987 and Landsat of 2010. Determination of the land-cover and land-uses parameters of the area was done using remote sensing techniques whereby ERDAS Imagine 9.1 Software was used. The unsupervised classification was applied first in order to determine natural signatures difference on the satellites images, and then followed by supervised classification with maximum likely hood classifier. The ground trothing was done by using randomly GPS points and GPS Transect route in the farms in order to justify the land covers existing in study areas. The land cover of the study areas obtained were closed forest, Woodland, Shrubs/ Thickets, seasonal river and gullies, water bodies and cultivated areas. The fallow, grassland and the cultivated areas were added together because of similarity in terms of signatures and fallows is the farm left for some times for regeneration and recovery in terms of soil fertility as shown in the table for land uses in each wards.

2.2.4. On-Farm Tree Stocking and Use

Participatory village land mapping was done using focused group discussions comprised of village government leaders, women, farmers, youth and other groups represented in the meeting. Various areas were identified and mapped according to land use such as agriculture, residence, forests, grazing land, watershed and others. Areas identified to be under cultivation of cereal crops were chosen to establish transects for tree inventory and soil mapping and sample collections. Furthermore, information on availability of trees, uses and energy requirement were probed. Furthermore, statistical information readily available from village government archives were retrieved and shared in the discussions. Information pertaining to agricultural fields was drawn on board, labeled and consensus was reached on major crops cultivated, proportional size of the area and soil types. Furthermore, consensus was reached on the uses of some dominant trees on farm and energy sources and requirements. Therefore, this information was directly analyzed in participatory manner.

Transects were laid ranging from 1 – 5km traversing along the longest side of the crop farming areas. Depending on the size and accessibility, transects were laid to cover the maximum area and passing through different soil mapping units as identified during focused group discussions. Plots were demarcated systematically after every 100 m along the established transect. Plot size of 50m x 20m were laid where all trees ≥ 10cm DBH (Diameter at Breast Height) were measured (DBH), and identified by means of local people (Mathew *et al*. 2011). Other additional information collected includes crop varieties and historical land use management. Data on tree inventory were summarized, coded and analyzed to determine stocking parameters per each district and also taking into account areas considered to have higher and lower potentials in cereal production in the two districts. Basic calculation for number of trees basal area per hectare and tree volume was computed using the following equations;

$N = \sum i / (a * n)$;………………………………………………………………………………...(i)
$G = \sum gi / (a * n)$; and ……………………………………………………………………...……....(ii)
$V = \sum gi * Ht * f / (a * n)$,……………………………………………………………………………..(iii)

Where:

Dbh = diameter at breast height (cm), Ht = height (m), Ln= natural logarithm, R = coefficient of determination and SE = standard error, a = plot area; f = form factor; Ht = height of tree; gi = basal area of a tree= (π * Dbh2) / 40,000); i = Individual tree; n = number of plots; N = number of stems per hectare; G = basal area per hectare; and V = volume per hectare. Form factor of 0.5 is traditionally used for natural forests in Tanzania without distinction of the vegetation type involved (Chamshama *et al*., 2004; Luoga, *et al*., 2005).

3. RESULTS AND DISCUSSION

3.1. Socio-Economic and Policy Factors

3.1.1. Demographic Characteristics and Population Migration

In the pilot sites in Tanzania, the proportion of male (83.2 %) and female (16.9%) respondents was highly unbalanced, suggesting that there are more men in the study villages than female because respondents were randomly selected from the village registry (Table 1). Similar result was noted for the elderly (51-60 and above 60 years) whose percentage was 25.9% compared to 74 % for respondent in the 18-50 years group. Hence special attention needs to be given to women and the elderly in all interventions so as to accommodate interests and rights of these age groups. These results also indicate that the majorities (53.1 %, 18-40 years) of interviewed farmers are in the most active category. Therefore, there is a need to continue motivating young people to engage in modernized agriculture which take into account the best bet practices for enhancing crop productivity. About 75.4 % of interviewed respondents were head of household. Considering that interviews targeted household heads or individuals older than 18 years, these results indicate that information collected are relevant for designing appropriate interventions for sustainable intensification of agriculture in the study area.

The length of time people have lived in the study villages ranged from 10 years or less (20% of respondents), 11 to 25 years (29.4 %), 26 to 40 years (34 %), 41 to 55 years (10 %) and above 55 years (6.2 %). Migration of people into study villages was relatively higher in Njoro and Matui in villages in Kiteto (80%) compared to 41 % of respondents in Lenjule and Manungu villages in Kongwa districts. These results suggest there may be more livelihoods opportunities in Kiteto than Kongwa districts, especially for Matui village where majority relocate to engage in commercial agriculture (Fig. 2). Other reason for migration into the study villages include: family related matters (31. 1 %), casual labor (3.6 %), problem of water shortage (2 %) and the villagilization policy which was implemented in 1970s (Fig. 2). This policy was part of the socialism ideology that moved people into villages (called "*Ujamaa villages*" is Swahili) to facilitate provisions of social services.

Table 1: General household characteristic by village

Variable to measure	Category	% of respondents by villages				Average
		Lenjulu (n= 102)	Manungu (n = 62)	Njoro (n = 100)	Matui (n = 101)	
Age of respondent	18 -40	50.0	37.1	51.0	74.3	**53.1**
	41- 50	28.4	17.7	26	11.9	**21.0**
	51 - 60	12.7	24.2	11.0	5.0	**13.2**
	>60	8.8	20.9	12.0	8.9	**12.7**
Sex of respondent	Male %	83.3	85.5	81.8	82.0	**83.2**
	Female %	16.7	14.5	18.2	18.0	**16.9**
Marital status	Married	96.1	92.0	85.8	89.1	**90.8**
	Divorced/ separated	1.0	4.8	5.1	3.0	**3.5**
	Widower	2.9	3.2	7.1	4.0	**4.3**
	Single	1.0	0.0	2.0	4.0	**1.8**
Household size	<4	24.5	33.9	44.9	34.0	**34.3**
	5- 8	45.1	56.5	45.9	56.0	**50.9**
	>8	30.4	9.7	9.2	10.0	**14.8**
Education	None	41.2	19.4	12.1	26.7	**24.9**
	Primary	57.8	80.6	85.9	67.3	**72.9**
	Form IV	1.0	0.0	2.0	5.0	**2.0**
	Other education	0.0	0.0	0.0	1.0	**0.3**
Head of household	Yes	80.4	83.9	77.8	59.4	**75.4**
	No	19.6	16.1	22.2	40.6	**24.6**
No of years lived at current location	<10	10.2	5.6	26.4	38.0	**20.1**
	11 - 25	29.5	14.8	33.3	40.0	**29.4**
	26 - 40	37.5	40.7	37.9	21.0	**34.3**
	41 - 55	15.9	22.2	1.1	1.0	**10.1**
	> 55	6.8	16.7	1.1	0.0	**6.2**
Person migrated into current location		41.1	27.9	81.8	87.6	**59.6**

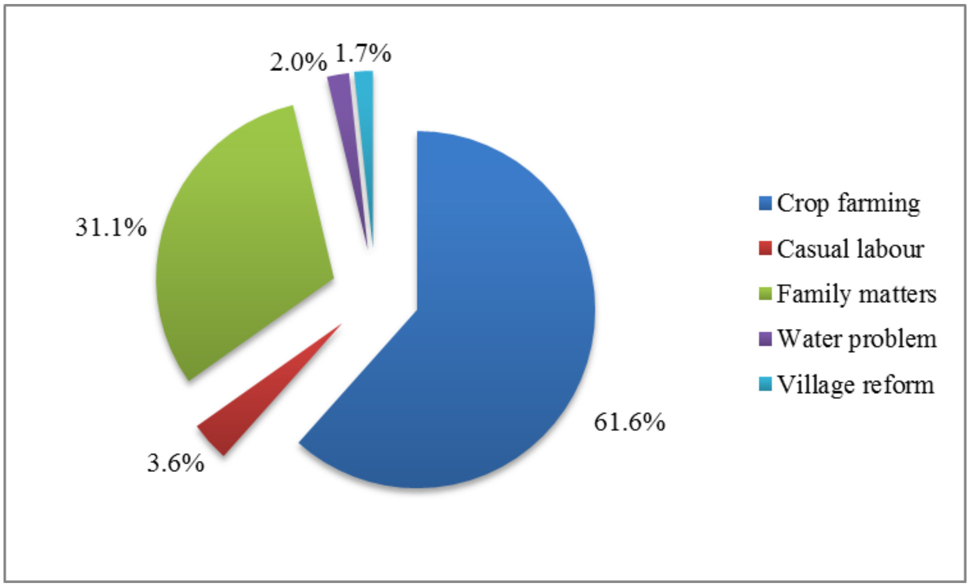

Figure 2: Reason for migrating into current locations

3.1.2. Household Assets, Labor, and Income

Land and livestock ownership: More than 70 % of land committed for farming enterprise is owned by nuclear family and or clan for Manungu and Lenjulu villages. In contrast, 69.3 % of respondents in Matui village rent land for farming (Table 2). About 60.9 percentages of respondents owned between 1.2 and 4 hectares (Table 3). Since majority of respondents own 1.2 to 4 hectares continuous cultivation on the same piece of land is a common practice across study area. As a result fallowing or rotating crops is rarely practical because of scarcity of land. However, majority of respondents in Njoro village with over 8 ha of land, have a large part of this land is out of cultivation due to cultivation-induced land degradation. Such area could be targeted for conservation farming practices such tree/shrub fallowing or rotations and Conservation Agriculture to restore productivity or increase land cover or converted for grazing areas for livestock. About 60.7 % of respondents interviewed keep livestock. Out of these, respondents keeping livestock were 81.4 percentages for Lenjulu, 71.0 percentages for Manungu, 53.7 percentages for Njoro and 36.6 % for Matui of sampled population.

Table 2: Land ownership by villages

Land ownership	**Percentage of respondents by villages**				**Mean**
	Lenjulu	Manungu	Njoro	Matui	
1.Nuclear family/Clan	74.5	80.6	42.0	13.9	**52.8**
2.Leased	13.7	19.4	39.0	69.3	**35.3**
3.Village government	69.0	0.0	14.0	6.9	**6.9**
4.Others	3.9	0.0	4.0	9.9	**4.5**

Table 3: Acreages owned by village

Land size (ha)	Percentage of respondents by villages				Mean
	Lenjulu	Manungu	Njoro	Matui	
0.4 – 0.8	9.9	6.5	4;9	17.8	**9.8**
1.2 - 4	62.7	66.1	51.2	63.4	**60.9**
4.4 - 8	13.2	19.4	11.0	8.9	**13.1**
> 8	14.3	8.1	32.8	10.0	**16.3**

***Household source of labor*:** Above 67 % of labor required for different undertakings relies mostly on use of nuclear family with exception of charcoal making in which about 57.6 % of labor required for charcoal making rely is hired labor. These findings indicate that nuclear family is a main source of labor for various household undertakings. Therefore, the introduction of labor saving technologies is inevitably needed particularly for time bound activities such as land preparation, planting and weeding.

Household income: Total household income per year ranged from TZS 200,000 to over TZS 500,000 with majority (52 %) falling in the range of TZS 200,000 – 1000000/= (Table 4). Annual income was found to be a combination of many sources (Table 5), including income obtained from crop production alone (44.6 %), combination of crops, casual labor and livestock (24.7 %); a combination of crops, casual labor and small business (22.1 %); and a combination of crops, livestock and small business (7.4 %). The contribution of crops-based sources of income varied among crops noted by respondents for: maize (40.4 %), sunflower (28.4 %) and pigeon pea (13.3 %), sales of chicken (4.1%), sales of cattle (3.6%) sales of goat (3.2%) (Fig. 3). These results reflect high poverty levels in the area and hence sound strategies which will improve crop farming through sustainable intensification are important.

Table 4: Total household annual income by villages

Income categories (TZS)	Percentages of respondents by villages				Mean
	Lenjulu	Manungu	Njoro	Matui	
< 200,000	24.4	18.6	5	8.7	**14.2**
200,000 - 500,000	34.4	37.3	19	22.8	**28.2**
500,001 - 1,000,000	20	30.5	18	27.7	**24.1**
1,000,001 - 2,000,000	12.2	10.2	29	20.8	**18.1**
2,000,001 - 5,000,000	5.6	3.4	22	13.9	**11.2**
> 5,000,000	3.3	0	7	5.9	**4.2**

Table 5: Combination of household income sources

Main sources of household income	Percentage of respondents by villages				Mean
	Lenjulu	Manungu	Njoro	Matui	
1. Crops, casual labor and livestock	33.7	34.4	19.5	11.9	**24.7**
2. Crops, casual labor and small business	13.5	27.9	13.0	33.7	**22.1**
3. Crops, livestock and small business	7.9	13.1	5.2	4.0	**7.4**
4. Crops alone	43.8	23.0	61.0	49.5	**44.6**
5. Livestock alone	-	-	-	1	**0.7**
6. others	1.1	1.6	1.3	-	**1.2**

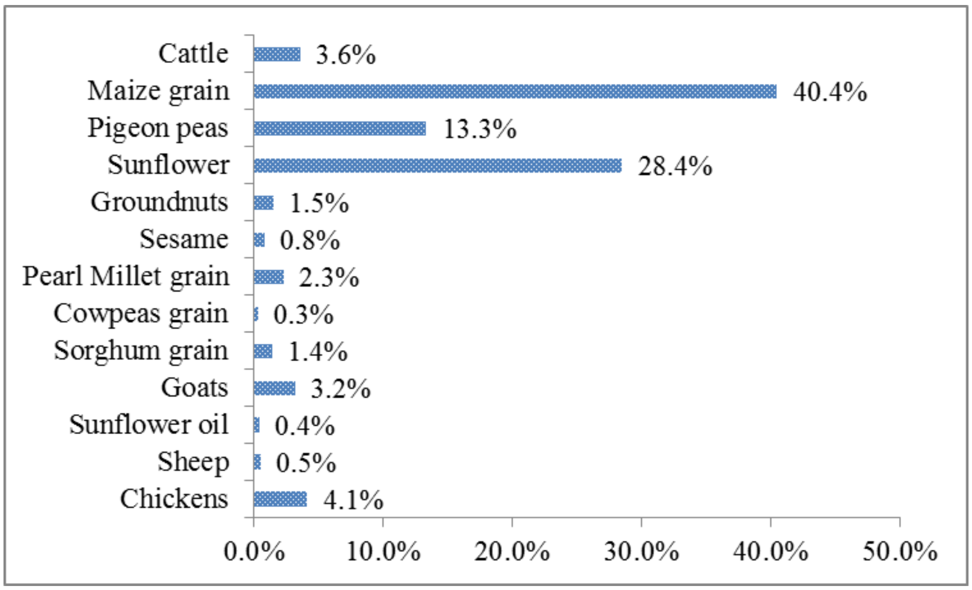

Figure 3: Main sources of income

3.1.3. Crop Production and Crop Management

Land preparation methods: More than 50 % of interviewed farmers in Lenjulu and Manungu villages in Kongwa District use ox-drawn plough tillage implement for land preparation (primary tillage). The use of tractor mounted disc plough was above 65 % for Matui and Njoro villages in Kiteto district. About 36.1% of respondents practice the slash and burn tillage method, locally called *"kuberega"*. The use this land preparation method normally generate high surface run-off from cropland because of reduced infiltration rate since the soil is not loosen properly before planting. Also burning may lead to the loss of soil organic matter and other nutrients, especially N volatilization. We also noted that there is a limited use of conservation tillage implements notably ridges and ripper for conserving soil and water.

Access to improved seeds: Common crops grown in the study areas include maize, pigeon pea, pearl millet, sorghum, sunflower, groundnuts, beans and cowpeas (Fig. 4)**.** The use of local seeds ranged from 83.6% for maize to 100% for sweet potatoes, beans, sesame and cowpeas. The limited use of improved seeds may contribute to extremely low crops yields in the study areas.

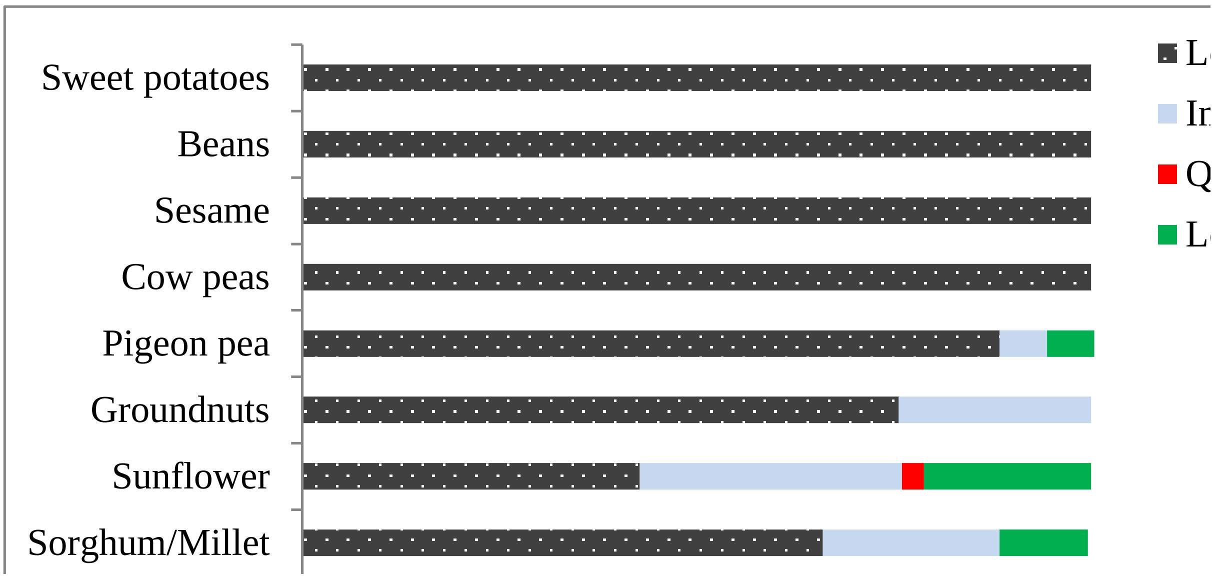

Figure 4: Percentages of farmers with access to improved seeds

Use of fertilizers: In general there is limited use of fertilizers across villages both organic, chemical and nitrogen fixing tree. Findings revealed that only 16.7 percentages of interviewed respondents used fertilizers among which 18.4 % used farmyard manure, 1.5 % used industrial fertilizers and nitrogen fixing trees and 0.3 % used both industrial and manure fertilizers. Interestingly, of four villages surveyed Lenjulu Njoro and Matui villages were beneficiaries of subsidized inputs namely chemical fertilizers (DAP, Minjingu Rock Phosphate (MRP) and improved high yielding seeds. Nonetheless farmers who received chemical fertilizers did not apply in their fields because they were scared of destructing the soils. Also they were not sure if the "*Kilimo Kwanza*" initiative (i.e. Agriculture First) will be sustainable method to receive inputs subsidies. Low crop yields (1 – 5t/ha of maize) estimated by farmers during the PRA could be partly attributed to the high nutrient mining through crop harvest because of no or little efforts to replenishment soil nutrients.

3.1.4. Household Food Security

Food availability and household coping strategies: Overall 41 % of respondent in the surveyed villages had sufficient food for 10-12 months in a year while the rest (59 %) experienced food deficit in 1 – 9 months. Similar trend was observed in all villages, except for Manungu and Njoro in which the number of respondents with sufficient food in 10-12 months was 31 % and 50 %, respectively (Table 6). These results suggests that about 60% of the population in the study villages may be food insecure for more than 3 months in a year and may require assistance to address the problem. The common strategies for coping with food shortage in Kongwa district include exchange of labor for food. Usually, few rich people in the village, called "Wagoli in plural and "Mgoli" in singular, play an important key role in terms of providing food aid to the needy mainly through the exchange of labor for food. Conversely, in Kiteto district, food insecure households usually accessed food from few people with surplus. Usually the agreement is to exchange one bag of grain, mostly maize, received during time of deficit with two bags (equivalence to 100% interest rate) during harvesting next season. This practice is locally known as "*Songoleda*".

Table 6: Months with sufficient food by villages

Month with sufficient Food supply	% of respondents by villages				Mean
	Lenjulu	Manungu	Njoro	Matui	
1 - 3	8.3	21.2	14.1	11.0	**13.7**
4 - 6	26.7	26.3	16.2	21.4	**22.7**
7 - 9	22.1	22.0	18.8	28.6	**22.9**
10 -12	41.9	30.5	50.0	39.0	**40.8**

3.1.5. Tree-Crop-Livestock Interactions

Awareness on benefits of trees: Overall the knowledge of tree benefits in farmland is low, as noted by 62 % of respondents who were not aware of potential benefits of trees listed in the questionnaire (Table 7). Such low awareness of may be attributed to limited effort to sensitize farmers on the environmental benefits of trees in their villages. Only 11.1 % of respondents were involved in the promotion of tree planting, 6.3 % of respondents indicated that there has been government initiative to promote trees through government institutions and 1.6 % of respondent mentioned of initiatives from non-governmental organization**.** However, the majority of respondent valued trees for the provision of shade when working in the fields (89.6 %), attracting rain (52.9 %), protecting crops against wind (51.2 %) and controlling soil erosion (42.2 %). On the other hand, benefits with less than 40 % were fodder (33 %), security of land tenure (17.3%), weed suppression (17.3 %), carbon sequestrations (13.9 %) and aesthetics (11.8 %).

Table 7: Awareness on benefits of trees

Variable measured	Yes	No
1.Fooder	33	66
2. Security of land tenure	17.3	82.7
3.Attract rains	52.9	47.0
4.Control soil erosion	42.2	57
5. Improved soil fertility	29.0	71.0
6.Boundary demarcation	53.1	46.8
7.Shade	89.6	13.4
8.Wind protection	51.2	48.5
9.Weed suppression	17.3	82.7
10. Aesthetics	11.8	88.2
11.Carbon sequestrations	13.9	86.1
Mean	**37.4**	**62.7**

It was noted that the majority of respondent (74%) clear fell trees when opening a new site for cultivation, possibly because of low awareness of the benefits of trees on-farm (Table 8). However, the remaining percentage (26 %) of interviewed farmers retained trees on-farm for a number of reasons including: provision of shade (53.5 %), trees attract rain (14.0 %), protect crops from wind (10.1 %), control of soil erosion (7.4 %) and supply of firewood (5.6 %). Farmers who retained trees on-farm also indicated that tree in agricultural landscape benefits livestock by providing shade (72 %) and fodder (44 %).

Table 8: Tree retained on farmland during land clearing and reasons for tree retention

Variable measured	Category	Percentage of respondents by village				Mean
		Lenjulu	Manungu	Njoro	Matui	
1.Retention of trees during land clearing	Yes	20.8	19.7	33.0	29.7	**25.8**
	No	79.2	80.3	67.0	70.3	**74.2**
2.Reasons for retaining trees on farmland	1.Provision of shade	74.0	43.8	48.3	47.9	**53.5**
	2.Wind protection/wind break	2.7	10.4	18.8	8.5	**10.1**
	3.Provision of firewood	4.1	6.2	7.8	4.2	**5.6**
	4.Attract rainy	8.2	8.3	14.1	25.4	**14.0**
	5.Control of soil erosion	2.7	14.6	9.4	2.8	**7.4**

3.1.6. Access and Use of Cooking Energy

The main sources of fuel-wood and charcoal used in the surveyed areas were mainly from public forestry (44.9 %), farmland (24.0 %), purchase (21.6 %) and forestry reserve (9.0 %) (Fig. 5). Fuel wood collection from these sources is mostly done by female (42.5%), both male and female (39.5 %), and to some extent by male (22.7 %). Male involvement in fuelwood collection often occurs when fuelwood is brought from a distant place using draught animals, especially donkey and cattle (Fig. 6).

Table 9 shows the common cooking stoves used by sampled population. The most common type of stove used is three stones open stove as noted by 80 % of sampled population. The traditional charcoal and improved charcoal stoves were used by only 7.4 % and 4.9 % of respondents respectively. These results indicate that knowledge of farmers on the benefits of energy saving stoves is low. This may lead to degradation of public forests which were identified as the main source of fuelwood or charcoal (Fig. 5). As expected, the scarcity of fuelwood in the study villages is experienced by the majority of farmers who attributed it to the increasing expansion of agriculture land (42.7 %), deforestation (23.0 %) and settlement expansion (18.4 %) (Table 10). Fuel wood scarcity is also aggravated by lack of community woodland (6.3 %), lack of awareness on tree planting, occurrence of drought (2.7 %) and failure to observe forestry bylaws. Therefore coping strategy against energy insecurity in the study villages is needed to address this problem.

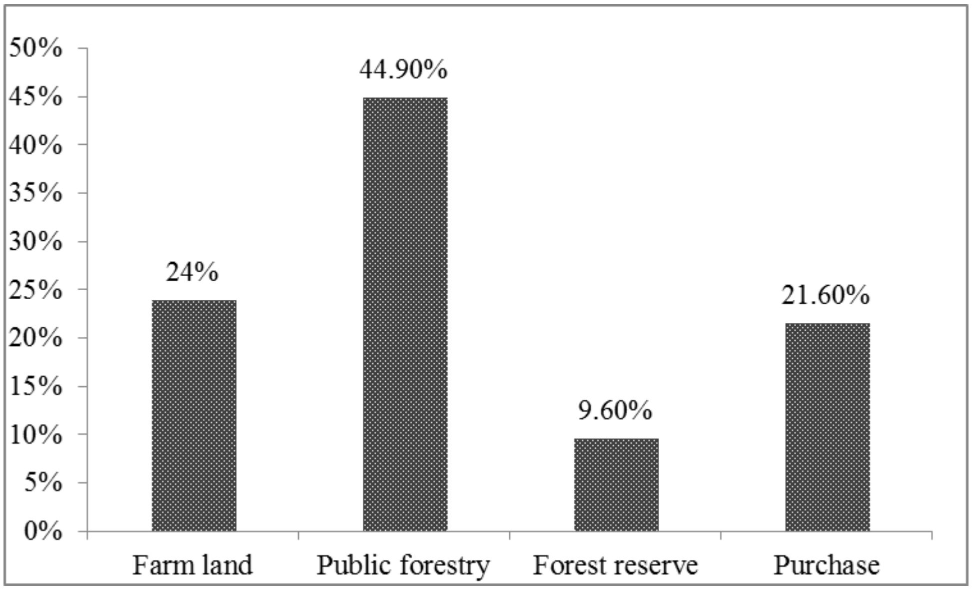

Figure 6: Sources of fuel-wood and charcoal used in the village

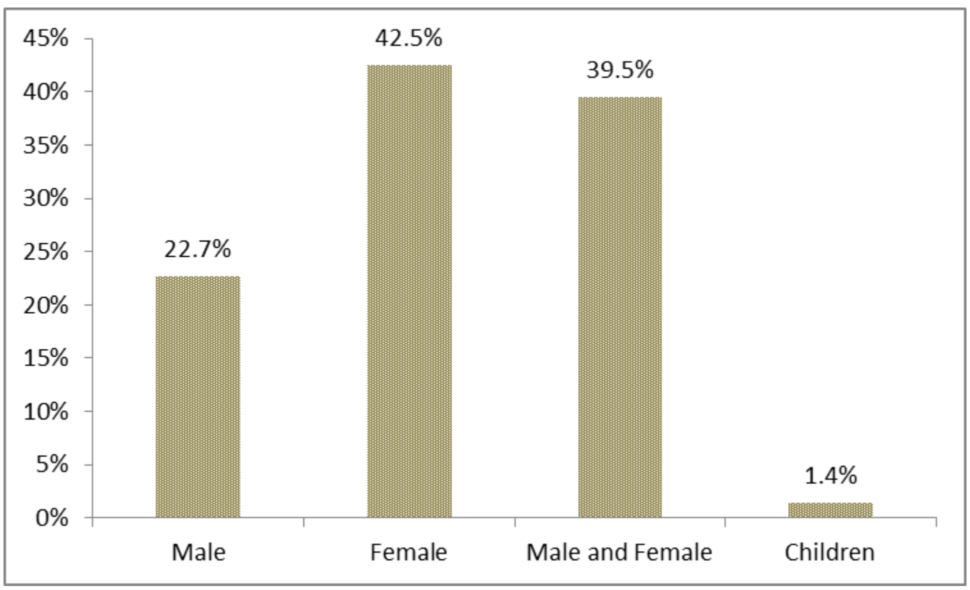

Figure 7: Person involved on fuel-wood collection

Table 9: Types of cooking stoves

Types of cooking stoves	Frequency	Percentage
1. Three stone open stove	311	85.2
2. Improved firewood stove	5	1.4
3. Traditional charcoal stove	27	7.4
4. Improved charcoal stove	18	4.9
5. Kerosene stove	4	1.1
Total	**365**	**100**

Table 10: Causes of fuel wood/charcoal scarcity

Causes of fuel-wood scarcity	Frequency	Percentage
1. Settlement	67	18.4
2. Expansion of agricultural land	156	42.7
3. Lack of community woodland	23	6.3
4. Deforestation	84	23.0
5. Occurrence of drought	10	2.7
6. Lack of awareness on tree planting	21	5.8
7. Forestry bylaws not observed	4	1.1
Total	**365**	**100.0**

Nonetheless, it was found that efforts undertaken to promote the use of improved charcoal were inadequate since only 4.9 % of respondents have been sensitized on the importance of using improved stoves. Key players identified for promoting the use of improved cooking stoves were government (2.7 %) and non-governmental organization (2.2 %). Incorporation of trees in farmland in various configurations, which are compatible to agro ecological condition of Kongwa and Kiteto (e.g. boundary tree planting, use of wider spacing and woodlots), would also help to minimize wood fuel scarcity and environmental degradation in the area.

3.1.7. Conflicts on the use of land resources

Overall conflict between farmers and pastoralists was reported by 75.7 % of respondents. Matui and Njoro villages in Kiteto district registered existence of conflict of about 97 % and 96 % (Table 11). About 20 % of conflict occurring in Lenjulu village is mainly exacerbated by shortage of land for crops and livestock grazing .Whereas conflict occurring at Njoro village is mainly attributed to the grazing on cropland before and after harvesting by pastoralist. Deliberate efforts focusing on the recommended stocking rate, through provision of education to pastoralist communities both Masai and Gogo tribes need to be advocated.

Table 11: Farmers opinion on resolving land conflict

Opinions on conflict resolutions	Percentage of respondents by villages				Mean
	Lenjulu	**Manungu**	**Njoro**	**Matui**	
1. Separate farmers from herders	18.8	21.6	22.7	25.3	**22.1**
2. Enforce bylaws	5.0	5.4	14.4	13.7	**9.6**
3. Introduce land use planning	40.0	29.7	33.0	45.3	**37.0**
4. Provide education on land use	13.8	27.0	4.1	3.2	**12.0**
5. Government should intervene	20.0	8.1	24.7	11.6	**16.1**
6. Put limitation to migrants	2.5	0.0	0.0	0.0	**0.6**
7. Improve livestock management	0.0	8.1	1.0	1.0	**2.5**

In order to reduce resource use conflicts, 37.0 % of respondents recommended the introduction of appropriate land use planning, 22.1 % separation of herders and farmers, and 16.1 % thought that government intervention on matters regarding land dispute resolutions is needed. These recommendations are reflected in the following views gathered from respondents:

- Separation of livestock keeper from farmers engaged on crop production as a main source of livelihood.
- Enforcement of bylaws which prohibits livestock keepers from grazing into cropland.
- Introduce village land use planning to safeguard the interest of various stakeholders.
- Education on best practices which focuses on protection of cropland through afforestation, agroforestry and natural resource management.
- Government interventions with special emphasizes on land dispute, provision of experts on land, controlling large land owners, provision of land lease.
- Put limitation to migrants
- Improvement of livestock management through keeping of less number that tally with existing grazing land.

This study, therefore, suggests that participatory land use planning and effective regulations for zonation of grazing land, cultivated areas and settlements would help to minimize such conflicts and soil degradation in farmland.

3.1.8. Policy Related to Evergreen Agriculture in Malawi

Malawi is a low income country with a fast growing population, and is experiencing rapid loss of valuable natural resources. The fast rate of natural resource degradation is due to several biophysical, social, economic, and political factors. The loss of trees is, for example, driven by demand for agricultural land and woodfuel (charcoal and firewood); while excessive soil erosion is as a result of the clearing of forests and woodlands and use of marginal lands in order to expanded agricultural land, and declining farm size and continuous cultivation of the land without replenishment of soil nutrients. The degradation of natural resources and the risks associated with increased climatic variability and changes pauses a serious threat to the sustainability of production systems and the livelihoods of large numbers of rural and urban households in Malawi. There is need for the development and promotion of production systems that will help smallholder farmers increase food production while protecting the natural resource base. Agroforestry based production systems have the potential for increasing agricultural productivity and to contribute to improved management of natural resources.

In Malawi, ICRAF and other stakeholders (e.g., the Government of Malawi, non-governmental organizations and farmers' organizations) have in the past three decades been carrying out research and promoting agroforestry based production systems among smallholder farmers. Examples of these interventions include the ADDFOOD project in the late 1980s which was funded by the European Union, the Malawi Agroforestry Extension (MAFE) project (1992-2002) supported by United States Agency for International Development (USAID), and more recently the Malawi Agroforestry Food Security Programme which was funded by the Irish Government and implemented by ICRAF. Households participating in the Malawi Agroforestry Food Security Programme and other agroforestry interventions obtain higher yields for maize and other cereal crops on fields planted to fertilizer trees (either as improved fallows or intercropping of the trees with maize and other cereal crops) compared to households not practicing agroforestry or fields without agroforestry trees (CIE, 2011; Sileshi et al, 2011). The increased cereal production helps to improve food security of the households. The increase in production and productivity is attributable to improvements in soil fertility and health. Fertilizer trees increase nitrogen (and other nutrients, e.g., phosphorous) content in the soil, while the resultant increase in soil organic matter when tree biomass is incorporated into the soil helps to improve its water holding capacity. Other benefits of trees on the agricultural landscape are reduced soil erosion and increased soil biological activity (Sileshi and Mafongoya, 2006b). These observations have implications for policies aimed at promoting both food self-sufficiency and crop and income diversification in low income settings, and for improved management of natural resources.

Agroforestry programs implemented in Malawi over the years have included a wide range of trees including fruit trees. The objective for promoting fruit production is to improve nutrition of households and income from sale of fruits (e.g., mangoes, citrus, avocado, pawpaw, guava, Uapaca). The diets of poor households are generally deficient in micro-nutrients and vitamins, and increased consumption of fruits can help alleviate this problem. Surplus fruits can be sold fresh in local, regional and national markets or to processors, thus providing households with an opportunity to earn extra income and to diversify sources of income. Assessments of agroforestry activities promoted by ICRAF and other organizations reveal that households who have trees already producing fruits reported an increase in fruit consumption and significant contribution to total household cash income from the sale of fruits (CIE, 2011). Lack of access to high value markets, high quality germplasm and product grading limits the amount of income farmers can earn from the sale of fruits.

Agroforestry programs in Malawi also encourage households to plant trees species that can provide firewood (e.g., *Acacia polyacantha*, *Senna spectabilis* and *Senna siamea*) in order to ensure adequate energy supplies and to help arrest the degradation of country's natural forests and woodlands. In addition to wood supplied by the firewood trees, the woody parts of fertilizer trees planted in improved fallows can also be used as firewood. Studies show that the energy security of households planting agroforestry trees is greatly improved compared to those that do not plant trees (CIE, 2011). Households also have the opportunity to earn additional income from the sale of firewood harvested from planted trees.

The benefits of agroforestry technologies to smallholder households and their contribution to improved environmental management are well documented. However, the challenge is that many households that could benefit from agroforestry technologies fail to take up the technologies, and often lack knowledge and access to information about the technologies. In addition, there are many other constraints restricting households from adopting and benefiting from agroforestry practices. In Malawi the farmer to agricultural extension officer ratio is very high (at about 1 officer per 3000 households), thus constraining the effective provision of rural advisory services. In addition, agricultural extension officers often lack knowledge on new agroforestry options that may be beneficial to farmers. This emphasizes the need to for improving information flows between research and extension and development, and for exploring other options for delivering more effective rural advisory services.

Agroforestry programs are often hampered by inadequate supply of quality germplasm that farmers demand. Tree seed for species that farmers prefer is often in short supply and where some seed may be available its quality is generally not known. Currently in Malawi fruit tree seedling production is very centralized. Much of the seedlings are production is limited to two government managed research stations in the southern and the central regions of the country. Farmers from more remote regions of the country face high costs of acquiring fruit tree seedlings, and this creates disincentives for investments in fruit production by smallholders. In order to facilitate widespread access and planting of fruit and other agroforestry tress it is important to support the development of sustainable systems (especially private) for the supply of agroforestry inputs.

For the full potential impact of agroforestry to be realized, there is need to ensure that agroforestry is given consideration in local, regional and national development, natural resources and environmental management strategies and that policies, regulations and other incentives do not discourage adoption of agroforestry technologies. In Malawi, a number of policies and strategies explicitly refer to agroforestry as a potential means for achieving policy objectives –e.g. improving household and national food security, poverty reduction, reducing land degradation, sustainable natural resources management, and adaptation and cushioning farmers from the negative impacts of climate change and variability. Agroforestry is included as a key component to the following policies: Malawi Growth and Development Strategy (MGDS), Agricultural Sector Wide Approach Paper (ASWAp), National Lands Policy and Act, National Forestry Policy, National Environmental Policy, Food Security Policy, National Energy Policy, National Water Policy, National Land Management Policy and Strategy, Agricultural Extension Policy, National Education Policy, National Livestock Development Policy, and National Adaptation Plan of Action.

The existence of a policy and institutional architecture to enable drawing on the potential benefits of agroforestry towards meeting the country's developmental and natural resources and environmental management goals is a positive start. It is however important to resolve potential contradictions in policies, laws, regulations and incentives that affect agroforestry. For example, emerging evidence on the impact of Malawi's Farm Input Support Programme (FISP) suggests that subsidized inorganic fertilizer may be having the unintended effect of discouraging investments in fertilizer trees and other inorganic fertilizers, and that there is an emerging shift in production systems in favor of simplified maize monocultures compared to the complex agroforestry based production systems (Holden and Lunduka 2012; Chibwana et al, 2010).

There still remain a number of other policy issues that affect agroforestry in specifically which will require special attention beyond the broad policy reform processes undertaken by various countries. These may include some national policies, laws, and regulations which impact more directly on the practice of agroforestry. For Malawi and other developing countries the following is a list of some issues which have been found to hinder the development and impact of agroforestry and where policy interventions are required: credit provision, tree insurance programs, marketing of agroforestry tree products, value adding, and mechanisms for paying farmers for the provision of ecological services.

3.1.9. Policy Related to Evergreen Agriculture in Tanzania

Tanzania government has prepared several policies, strategies, and initiatives to address challenges facing the agricultural sector with the aim of increasing the contribution of this sector to the country economy and the livelihoods of people. These include: The National Agricultural Policy (2011), the Poverty Reduction Strategy (2002), *Kilimo Kwanza* (Agriculture First), the Agricultural Sector Development Strategy 2001. The strategies are aiming at improving livelihoods of the rural poor whom account for over 80 percent of the population through poverty alleviation and food security. May I review these policy and initiative briefly and indicate the contribution of agroforestry.

The National Agricultural Policy revolves around the goals of developing an efficient, competitive and profitable agricultural industry that contributes to the improvement of the livelihoods of Tanzanians and attainment of broad based economic growth and poverty reduction. The Government is committed to bringing about a green revolution that entails transformation of agriculture from subsistence farming towards commercialization and modernization of the sector through intensification of crop production, diversification, technological advancement and infrastructural development. In this endeavor, agroforestry can contribute to intensification and diversification of crop production systems through the integration of trees (e.g., fertilizer and fruit trees) into the agricultural landscapes to enhance agricultural productivity, human nutrition and diversify income sources of farmers.

The National Strategy for Growth and Reduction of Poverty (NSGRP) is commonly known as *MKUKUTA*, the Swahili acronym for *Mpango wa Kukuza na Kufufua Uchimu Tanzania*. This strategy was developed to achieve the National Development Vision 2025, and the Millennium Development Goals targets. The NSGRPII has three clusters namely i) growth and reduction of income poverty, ii) improvement in the quality of life and social wellbeing, and iii) governance and accountability. Environment, conservation of natural resources and agroforestry feature as important development issues that cross cut the three clusters.

Various initiatives and programs have been initiated under each of the above *MKUKUTA* clusters to address the global and national challenges of climate change, poverty, malnutrition and declining livelihoods. Some of these initiatives include *KILIMO KWANZA*, the national Climate Change strategy, the national REDD+ strategy and the environmental action plan for agriculture. Other programs and projects include, the (Tanzania Agricultural Sector Investment Plan (TAFSIP) and the Southern Corridor Growth Initiative (SAGCOT).

KILIMO KWANZA: is a new Tanzania's Green Revolution initiative to transform its agriculture into a modern and commercial sector, to integrate programs and plans to increase agricultural productivity in to the government machinery, and to mobilize resources and the private sector to increase investment in agriculture and support in the implementation of this initiative. To date *KILIMO KWANZA* has been initiated in all districts of the country, providing a platform for scaling up and scaling out agricultural interventions. Some of the key activities under the *KILIMO KWANZA* program include promotion of proven agricultural technologies and practices, input supply, rural financing and capacity building. Agroforestry and its benefits contribute to the following pillars (works packages) of *KILIMO KWANZA*. Pillar No. 4 on paradigm shift to strategic agricultural production that seeks to identify strategic commodities, such as maize and legumes, for enhancing country's food sufficiency and also identify modalities for production of crops that can transform agriculture with minimal financial and technological requirements growing domestic or external market demand and employment creation potential. In this endeavor, tree and grain legumes that have been widely intercropped widely with maize holds promise to contribute towards attaining food sufficiency in Tanzania. Moreover, recent MAFSC-ICRAF initiative to develop the value chain of Cocoa and Allanblackia (details to be provided later), represents the commitment of the Tanzania Government to commercialize small-scale farming systems by developing market for high value agroforestry tree products.

Among other things, Industrialization for *KILIMO KWANZA* (Pillar No 7), aims to increase production and use of mineral fertilizers, especially phosphate fertilizers from locally available rock phosphate in Minjingu, Arusha and nitrogen based fertilizers using the available natural gas deposits. The Government re-introduced fertilizer subsidies in 2003/04 growing seasons for the grain producing areas on southern highlands. This program increased fertilizer use from 241,753 tons in 2005/2006 to 287,763 tons in 2006/2007. While we are proud of these results, we also realize that from the experience of green revolution in Asia and high inputs systems in developed countries that addition of mineral fertilizer alone is not sufficient to build a healthy soil and sustain agricultural productivity. Despite the huge success of the Farm Input Subsidy program (FISP) in Malawi, high implementation cost led to a 50% reduction in fertilizer subsidy. These examples underscore the need for promoting affordable and complementary approaches/practices to sustain agricultural productivity under *KILIMO KWANZA* in Tanzania. Strategic use of organic nutrient sources, such as fertilizer tree systems with mineral fertilizers is one of these options as it replenishes both nutrients and organic matter needed to improve soil chemical and physical conditions necessary for sustaining agricultural productivity.

Agricultural Sector Development Program (ASDP): The Government of Tanzania has adopted an Agricultural Sector Development Strategy (ASDS) which sets the framework for achieving the sector's objectives and targets. An Agricultural Sector Development Program (ASDP) Framework and Process Document, developed jointly by the five Agricultural Sector Lead Ministries (ASLMs), provides the overall framework and processes for implementing the ASDS. Development activities at national level are to be based on the strategic plans of the line ministries while activities at district level are to be implemented by Local Government Authorities (LGAs), based on District Agricultural Development Plans (DADPs). The DADPs are part of the broader District Development Plans (DDPs). This national framework developed under ASDP provides a platform for mainstreaming agroforestry intervention in central and local government development plans and mobilizing resources for scaling out activities.

***Initiatives by the Government of Tanzania to Scale Agroforestry Technologies*:** In November 2011, the Ministry of Agriculture Food Security and Cooperatives (MAFSC) in partnerships with the World Agroforestry Center (ICRAF), Novela Development Company, TechnoServe, embarked on three new initiatives to scale up agroforestry technologies (*Allanblackia*, Cocoa and Evergreen Agriculture) in Tanzania. These initiatives are based on agroforestry technologies developed within the country and elsewhere in eastern and Southern Africa as well as enabling policy environment and opportunities highlighted earlier. A summary of goals, target and expected outputs of each of each initiative is provided below.

Allanblackia spp, a new tree cash-crop for smallholder farmers in Tanzania: The goal is to domesticate *Allanblackia stulhmanii* for wide cultivation on-farm to diversity incomes sources of farmers and conserve natural forests, which are the main source of highly sought *Allanblackia* seeds for oil extraction. This initiative has four main outputs, namely: 1. selection of high quality planting material and developing and developing the appropriate propagation method(s), 2) develop sustainable supply systems for improved *Allanblackia* planting material, 3) strengthening capacity of farmers on nursery techniques for *Allanblackia* propagation, and 4) increased household income, rural livelihood and environmental sustainability through on-farm cultivation of *Allanblackia* and marketing of *Allanblackia* seeds.

Developing Cocoa Agroforestry Industry for Improved household income: Goal is increase the contribution of Cocoa to household income and national GDP by developing the cocoa value chain within and outside Tanzania. Outputs associated with this goal are: 1) increase production of Cocoa in Tanzania by expanding the area under cultivation and improving the quality germplasm, 2) promoting efficient market structures and sustainable financing mechanisms for the cocoa value chain development, 3) creating a supporting policy environment and institutional framework for the cocoa industry development, and 4) strengthening the capacity of farmers and other stakeholders on Cocoa production and marketing through training and/or applied research.

National Strategy for Scaling out Evergreen Agriculture in Tanzania: the goal is to facilitate adoption of Evergreen Agriculture interventions for improved food security, rural livelihood and environmental sustainability. This strategy set a target to reach at least 1 million households with Evergreen Agriculture technologies by 2017. The following outputs are expected under this strategy: 1) ensure adequate and sustainable supply of quality germplasm, 2) strengthening capacity of farmers, extension staff and other stakeholders for effective adoption of evergreen agriculture, and 3) assess the contribution of traditional and improved land use systems to climate change mitigation and adaptation.

3.2. Biophysical Factors

3.2.1. Land Degradation and Soil Fertility Status

Land degradation and constraints for increased agricultural productivity: Main causes land identified by interviewed respondents were soil erosion, overgrazing, declining soil fertility, deforestation and poor farming practices. Soil erosion took the lead with about 54.2% in Lenjulu, 33.8% in Matui, 25.8% in Njoro and 21.4% in Manungu village. In Kiteto district overgrazing contributed 45.2 % for Njoro village, 35 % for Matui village. The main indicators of land degradation identified by respondents include the presence of rills and gullies on cropland (38.8%), poor crop performance notably stunted growth and low yields (35.2 %).

Land degradation, reflected in form of the presence of rills and gullies on cropland (38.8%), poor crop performance notably stunted growth, and low yields (35.2 %); is probably one of major constraints to increased agricultural productivity in the studied villages. Apparently, the impact of land degradation is amplified further by drought, which was the factor most farmers (85.4%) associated with low crop yield. Other factors identified by farmers include: declining soil fertility (69.4%), limited access to improved inputs (57.4 %), limited access to market (50.0%), Limited capital (50.0%) and increased incidences of pest and diseases (46.7%).

The laboratory analysis of soil nutrients in the study area was in line with farmers observation that soil fertility decline was one of the major constraints to agricultural productivity (Table 1 and 12). As noted in Table 12, most of the nutrient levels in the top 30-cm depth were very low. The soil pH ranged from very strong acidic (4.69) to moderately alkaline (8.09) and decreased with soil depth. The electrical conductivity was less than 0.16 mS/cm which is below the salinity hazard. According to Landon (1991) organic carbon in the top soils range from very low (0.22 %) to medium (2.34%) and very low (0.29%) to low (0.79%) for sub-soils. There is irregular distribution of organic carbon in the two soil depths. Total Nitrogen across study villages varied between 0.04% and 0.11% for top soils and 0.02 and 0.08% for the 15 – 30-cm soil depth. According to Landon total nitrogen is rated very low or low for top soils very low for sub-soils (Landon, 1991). The relatively low levels of both carbon and total nitrogen are probably due to the land degradation due to soil erosion, continuous cultivation with little or no nutrient inputs, as mentioned earlier.

The topsoil phosphorus levels varied between low (1.46 mg/kg) and high (24.57mg/kg) for top soils. The sub soil phosphorus levels (0.91mg/kg) and 5.00 mg/kg) is low for Bray-1 P in soils with pH less than 7. Olsen P (in soils with pH greater than 7) varied from low (4.19 mg/kg) to high (78.39 mg/kg) in the top soils and low (3.67 mg/kg) to high (10.50 mg/kg) in the 15-30-cm soil depth (sub-soils). The subsoil phosphorus levels were generally low. Surface soils have relatively higher levels of phosphorus probably from decomposed vegetation deposited onto the soil surface. The low levels of phosphorus in the soils indicate a potential problem of deficiency to sensitive crops, especially legumes which requires soil P for N-fixation. Therefore any future recommendation on phosphorus based fertilizer in these soils should consider this factor. Across sampled sites there is gradual decrease of phosphorus with increased soil depth which suggests that the observed levels of phosphorus are associated with the organic matter.

Table 12: Selected Properties of the soils at Kiteto and Kongwa Districts, Tanzania

VILLAGE/LOCATION	Soil depth	Soil pH (1:2.5) (in H_2O)	EC mS/cm	Textural Class*	Total N (%)	OC (%)	Extractable P (mg/kg)		Exchangeable Cations (cmol/kg)		
							Bry-1 P	Olsen P	Ca	Mg	K
MANUNGU VILLAGE											
Kiegea	15 cm	8.00	0.14		0.09	1.22		9.13	7.65	1.84	1.22
	30 cm	5.32	0.02		0.04	0.29	2.03		0.74	0.96	0.50
Mlima Gatwa	15 cm	6.59	0.02	SL	0.04	0.22	1.61		1.62	0.87	0.42
	30 cm	8.16	0.12	SCL	0.07	0.60			5.41	1.68	1.15
Chinyika	15 cm	7.80	0.08	SCL	0.04	0.48		12.90	4.41	0.99	1.58
	30 cm	7.02	0.03	SCL	0.06	0.31	1.93		3.83	1.14	1.05
Manungu A	15 cm	6.40	0.05	SCL	0.06	0.54	2.71		3.09	1.38	0.90
	30 cm	6.07	0.03	SC	0.07	0.41	1.05		2.35	1.98	0.99
DOSIDOSI VILLAGE											
Gombelo	15cm	6.14	0.02	LS	0.07	0.32	2.38		0.88	0.59	0.28
	30 cm	6.01	0.01	LS	0.02	0.37	1.32		0.88	0.65	0.33
Sekondari	15cm	5.61	0.03	SL	0.05	0.39	2.61		0.88	0.52	0.42
	30 cm	5.17	0.02	SL	0.04	0.28	2.16		0.74	0.41	0.33
Mguli	15 cm	6.86	0.10	SCL	0.09	1.07	24.57		1.76	1.29	1.34
	30 cm	6.61	0.05	SCL	0.08	0.79	2.23		2.80	0.98	1.04
MATUI VILLAGE											
Ifughusa	15 cm	6.90	0.05	SCL	0.09	0.73	1.81		5.44	1.20	1.33
	30 cm	6.70	0.04	SCL	0.08	0.55	1.00		3.83	1.36	1.10
Juhudi	15cm	7.29	0.16	SCL	0.11	1.21		78.39	5.59	1.61	1.31
	30 cm	7.65	0.11	SC	0.07	0.72		10.50	4.27	1.59	1.36
Wazamtima	15 cm	5.54	0.04		0.06	0.58	2.64		1.33	1.13	0.70
	30 cm	5.32	0.03		0.06	0.48	2.84		1.49	0.97	0.68
SAGARA VILLAGE											
Igombo	15 cm	6.76	0.07	SC	0.09	0.98	19.81		4.41	4.04	1.19
	30 cm	7.30	0.05	C	0.07	0.69		5.82	9.41	6.12	1.24

Mahakamani	15 cm	8.09	0.09	SL	0.04	0.31		4.19	4.85	1.22	0.72
	30 cm	7.69	0.07	SL	0.05	0.47		3.67	3.97	1.67	1.27
Sogelea	15 cm	6.60	0.10	SC	0.08	0.69	10.31		7.32	3.96	1.20
	30 cm	6.73	0.06	SC	0.06	0.31	1.15		1.77	3.11	0.85
	15 cm	5.28	0.03	LS	0.04	0.39	3.31		0.59	0.54	0.30
Shuleni	30 cm	5.36	0.03	SCL	0.04	0.39	2.05		0.74	0.92	0.63
Kwambukwa	15 cm	7.00	0.05	SCL	0.08	0.66		18.58	4.71	1.51	1.08
	30 cm	6.90	0.04	SC	0.06	0.45	0.30		5.00	2.69	0.39
Lenjulu	15 cm	5.88	0.08	SC	0.09	5.49	1.46		5.74	3.16	0.96
	30 cm	6.49	0.03	C	0.07	0.56	0.91		6.91	4.41	0.24
LEGANGA VILLAGE											
Leganga	15 cm	6.84	0.06	SL	0.07	0.79	5.46		3.53	0.79	0.70
	30 cm	6.21	0.04	SCL	0.06	0.56	5.00		1.32	1.33	0.74
Lebendeli	15 cm	6.86	0.06	LS	0.07	0.70	3.37		1.62	1.35	0.62
	30 cm	6.73	0.03	SCL	0.07	0.56	1.62		2.21	1.35	0.74
NJORO VILLAGE											
Mwaire	15 cm	5.67	0.02	LS	0.04	0.34	3.34		1.03	0.57	0.38
	30 cm	6.60	0.02	SL	0.04	0.42	6.03		2.65	0.62	0.30
Kwamgua	15 cm	6.64	0.03	SL	0.06	0.56	4.14		2.80	1.09	0.41
	30 cm	5.45	0.02	SCL	0.06	0.49	0.85		1.03	1.89	0.47
Bwawani	15 cm	7.11	0.06	SCL	0.09	0.80		11.33	5.29	1.41	1.29
	30 cm	6.55	0.07	SC	0.06	0.48	1.01		4.71	2.47	1.34
Sek	15 cm	5.78	0.04	SL	0.06	0.60	3.84		2.50	0.59	0.60
	30 cm	5.47	0.03	SL	0.05	0.59	2.66		1.33	0.61	0.52
Sek Juu	15 cm	4.94	0.03	LS	0.05	0.42	3.20		1.33	0.57	0.28
	30 cm	4.68	0.03	SL	0.04	0.31	0.92		0.74	0.60	0.64
Majengo	15 cm	6.59	0.05	SCL	0.08	0.76	2.57		3.82	1.14	0.81
	30 cm	6.81	0.03	SC	0.06	0.49	0.60		2.21	1.31	0.62

*Textural Class Abbreviation: S = Sand, C = Clay, L = Loam

The exchangeable cations varied across villages and within the soil depth (Table 12). The exchangeable calcium and magnesium were low (0.59 cmol/kg for calcium, 0.54 cmol/kg for magnesium) to very high (7.65 cmol/kg) for calcium and 4.04 cmol/kg for magnesium on top soil. Low levels of calcium and magnesium (0.74 cmol/kg for calcium and 0.41 for magnesium) and very high (6.91cmol/kg for calcium and 6.12 cmol/kg for magnesium in the sub soils. The potassium for top soils range from low (0.28cmol/kg) to high (1.58 cmol/kg) and similar pattern was also noted for bottom soils. Soil levels were low (0.14 cmol/kg – 0.28 cmol/kg for top soils and low (0.17 cmol/kg) to medium (0.47 cmol/kg) and there is gradual increase of sodium levels with soil depth.

3.2.2. Land use and land cover types between 1987 and 2010

Land cover classification in Tanzania is yet to be standardized. This situation makes difficult to compare different studies and use previous studies as baseline for subsequent studies (Kikula, 1980). In this project on based on previous work (Kashaigili, 2006; Mbilinyi et al., 2005, Masudi, 2005) different land classes of land uses/cover were established by classification of satellite images.

Table 12 shows the area coverage of land use /cover types in the study area in 1987 and 2010. The spatial distributions of the land use/ cover types of Kiteto district are shown in Fig. 7. The table shows that the closed forest was the largest land cover in 1987 at Kiteto district with 65% (44376 ha). But it has been decreasing to 18% (12523 ha) in 2010. This decrease of the closed forest area is almost four times during the period of twenty three years of 1929 ha with a rate of 2.83% per year of the forest cover is removed. The woodland cover which were second largest cover in 1987 with 10.60% (7230 ha), have been decreased continuously to 0 % in 2010. This shows there is increased of population hence demand of land for cultivations and other resources. As cultivation land use increased from 7.3 % (5004 ha) in 1987 to 32 % (22274 ha).Others land cover/land use such as shrubs and thickets have been increased trends from 1987 as 10.19% (6954 ha) to 21% (14688 ha) in 2010. But water bodies and swamp areas have dropped from 6.87% to 0.013 % during the same interval, the settlements and seasonal river and gullies which were not present during 1987 they appear as 5.7% and 22.0% during year 2010 respectively as shown in Table 12. This shows that area was encroached by farmers and at that time it area was found intact. But by introducing farming cultivation all trees and natural vegetation and land was cleared and hence land degradations.

Table 12: Area coverage of land use at Kiteto District

Land uses	1987		2010	
	Area (ha)	Area(%)	Area (ha)	Area (%)
Cultivation	5004.63	7.3	22274.03	32.69
Forest	44376.453	65.02	12523.369	18.00
Shrubs/Thickets	6953.802	10.19	14687.61	21.5
Water	4686.203	6.87	8.85	0.013
Woodland	7230.26	10.60	-	0
Settlements			3744.28	5.7
Seasonal river/ gullies			15013.37	22.0
Total	68251. 342	100	68251.49	100

Source: Satellite Images classification of 1987 and 2010 by USGS (U.S Department of the Interior and U.S. Geological Survey)

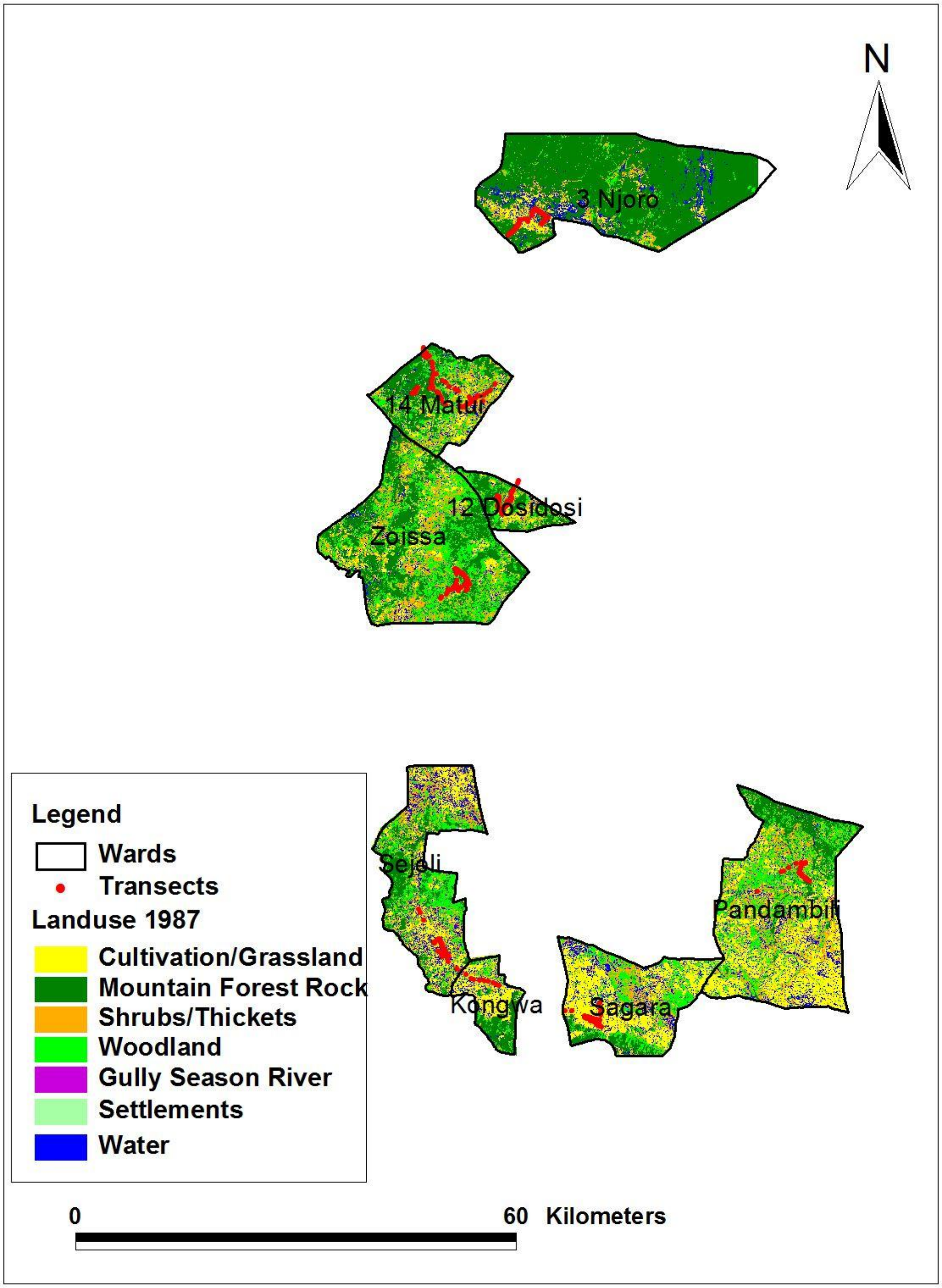

Figure 7: Land use Map of Kiteto and Kongwa in 1987

Similar situation is shown in Table 13 and Fig. 8 for Kongwa District, but the difference here is that at the cultivation was a major land use in Kongwa during year 1987 with 24.5% and it increased more than double in year 2010 up to 58.5%. Forest decreased from 22.3% up to 3.37%. Water bodies land use/cover also decreased from 10.39% up to 0%. New land use such as settlements and seasonal gullies which were not detected earlier appear with 0.43% and 22.0% coverage of all land uses/ land cover. The results in Table 13 also complement that there a big land degradation which occurred at Kongwa District due to increased poor cultivation practices.

Table 13: Area coverage of land use at Kongwa District

Land uses	**1987**		**2010**	
	Area (ha)	**Area(%)**	**Area (ha)**	**Area (%)**
Cultivation	33512.1	24.5	79958.1	58.5
Forest	30566.5	22.4	4601.1	3.37
Shrubs/Thickets	25514.3	18.7	15517.7	11.35
Water	14200.5	10.4	-	0
Woodland	32917.2	24.0	24510.9	17.7
Settlements			583.6	0.43
Seasonal river/ gullies			11538.3	22.0
Total	136710.535	100	136710.535	100

Source: Satellite Images classification of 1987, and 2010 by USGS (U.S Department of the Interior and U.S. Geological Survey)

Table 14 below illustrate the trends behaviour of each land use/cover tentatively at Kongwa and Kiteto District respectively. The last column is the total change of land use changes in both districts. The closed forest have decreased from 1987-2010 by (61818 ha) which is about 30% of the total area. The total forest cover reduction in a span of twenty five years is 30 % (61818 ha). This forest cover decline is critical since farmers are still clearing bushes and thickest for agricultural expansion, which was found to increase by 31 % (63715 ha) over the same period (Table 14). This is probably due to population increase as well as looking for fertile land accompanying by shifting cultivation. The open forest seems to be remaining constant during these two windows because clearing of closed forest lead to open forest and improvement of bush and thickets and woodland resulting to the open forest. That is reason for the deforestation into cultivation lands is due to open up more land for cultivation from untouched lands.

The emerge of seasonal river and gullies in both district shows that there is large deforestation and land degradations in accompanying by increasing of settlements as shown in Table 14 and Fig. 8. The green colour of forest from Fig. 7 has been almost replaced by the yellow colour for cultivation. This sudden increase in cultivation without monitoring is a threat to land degradations as noted by farmers earlier and it may lead to a semi desert condition from semi-arid and wetlands condition depicted in year 1987 (Fig 8).

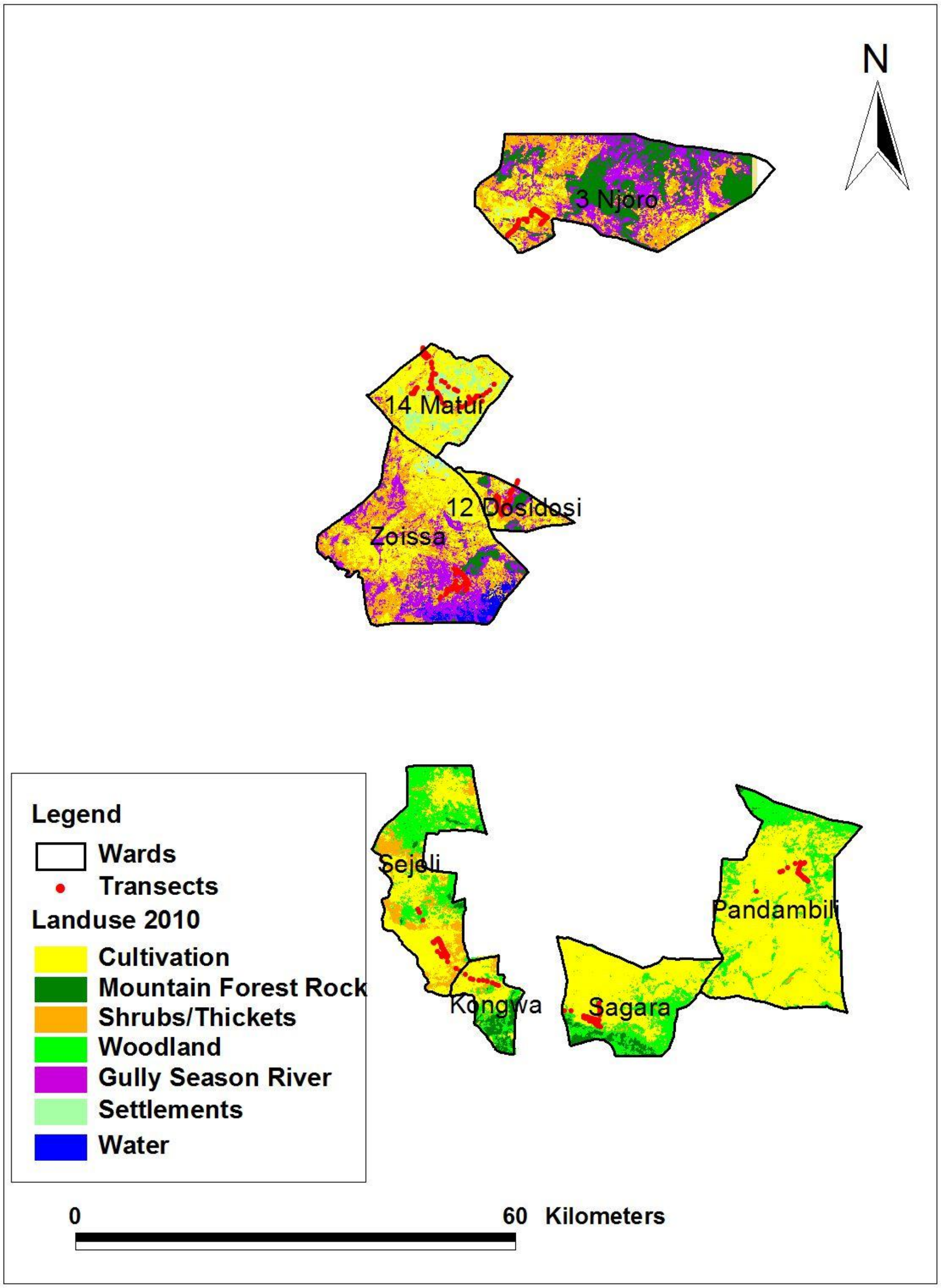

Figure 8: Land use Map 2010

Table 14: Changes in land use/cover types in Kongwa and Kiteto from 1987 - 2010

Landuse/cover	Kiteto District (years) (1987-2010) (ha)	Change (%)	Kongwa District (years) (1987-2010) (ha)	Change (%)	Total Change (ha)	Total Change (%)
Cultivation	+17269.4	25	+46446.0	-34.0	+63715	+31.1
Forest	-31853.1	-46	-29965.4	-17.0	-61818	-30.2
Shrubs/Thickets	-7733.8	-11	-9996.5	-7.30	-17730	-8.6
Water	-4677.4	-6	-14200.5	10.4	-18877	-9.2
Woodland	-7230.3	-10	-8406.3	6.14	-15636	-7.6
Settlements	+3744.3	+3.8	+583.9	0.04	+4327	+2.1
Seasonal River	+15013.4	+21	+11538.2	8.50	+26551	+13.0
Total	**68251.342**		**136710.535**		**204961**	

3.2.3. On-farm Tree stocking and Use

Most of trees found in the crop farming land had multiple uses. Charcoal making and fuelwood were the main uses, even threatening existence of few remaining trees on farm (Table 15). Wood fuel (charcoal and fuelwood) accounts for higher percentage of the energy sources for cooking and heating in the study area (Table 16). Major collections of woodfuel are done from surrounding forests and woodlands, and also to some extent from farms. On average the distance from the homestead to where the major collections occurs ranges from 3 to 9 km, taking a minimum of 4 hours to collect a head load. In most cases women play greater part in the collection of the fuelwood in the bush, while transporting is mainly done by women (if it is a head load) and by men when oxcart or bicycle is used.

Consumption of fuelwood at household level is almost 3 days per head load, while a volume of ox-cart can take between 2 and 3 months. It was further revealed that normally the pieces of fuelwood differ, where those carried by oxcart and vehicles are larger (i.e. pole to log sized) compared to those carried by head (i.e. withies to sapling sized).

Despite highly dependence on wood energy, fewer trees are found in the agricultural lands or in at homestead. Furthermore, it was noted that there was little effort to plant trees or allow for natural regeneration of trees in these land uses. This is attributed to several factors, including inadequate awareness on environmental conservation and poor farming practices, which led to fewer numbers of trees (Table 17) in farmland and thus exposing the land to degradation.

Table 15: Trees and their uses in Kongwa and Kiteto district, Tanzania

Local name	Scientific name	Charcoal	Fuelwood	Fruits	Construction	Timber	Others
Kongwa district							
Melea	*Melia azedarach*		xxx			xxx	Shade
Mijohoro	*Senna seamea*					xxx	Shade
Mikungugu	*Acacia tortilis*	xxx	xxx				Ropes, Paliro, Fodder, Shade
Minyara			xxx				Boundary
Mibuyu	*Adansonia digitata*			xxx			Vegetables
Mikololo							Animal fruits
Mikawea							Boundary, vegetable
Miumbu	*Senna singueana*		xxx	xxx			Shade, Environmental amelioration
Capparis sp.			xxx				Shade
Michalala			xxx		xxx		Shade
Misada	*Vangueria* sp.			xxx			'Kipekecho'
Miswagalalenga	*Albizia petersiana*		xxx				Shade
Misele	*Delonix elata*		xxx				
Mikole	*Grewia* sp.			xxx			
Msanza				xxx			
Kiteto district							
Michala/Miswagamalenga	*Albizia petersiana*		xxx				
Mikungugu	*Acacia tortilis*	xxx			xxx		
Mikeregembe		xxx					
Misewa		xxx					
Misanza		xxx		xxx			
Migunga	*Acacia polyacantha*	xxx	xxx		xxx		
Capparis sp.	*Capparis* sp	xxx			xxx		Spice
Mikongoro	*Commiphora ugogensis*		xxx				Bee hives, stools
Mikole	*Grewia* sp.		xxx				Sticks

Table 16: Trees, energy source and utilization in Kiteto and Kongwa District

Description	Kiteto			Kongwa		
	Njoro	**Dosidosi**	**Matui**	**Leganga**	**Lenjulu**	**Sagara B**
Main energy source	NA*	• Fuelwood (90%) • Charcoal • Crop residuals • Magunzi	• Fuelwood • Charcoal • Crop residuals	• Fuelwood • Charcoal • Magunzi	• Fuelwood • Charcoal	• Fuelwood • Charcoal • Crop residuals • Magunzi
Major source of energy	NA	• Farms • Nearby forest	• Nearby Namelock and Izava village	• Farms • Village forest	• Grazing areas within the village	• Farms • Bush around the mountains
Distance to the source of energy	• 3 – 4 km	NA	NA	NA	• 9 km	NA
Household consumption	NA	• Headload (3 days) • Ox cart (3 months)	• Bicycle (7 days) • Ox cart (2 months)	• Headload (3 days) • Oxcart (2 months)	• Headload (3 days) • Oxcart (One month) • Lorry/tractor (4 months)	• Headload (4 days) • Oxcart (2-3 months)
Price of woodfuel	NA	• Headload (2,000/- TZS) • Ox cart (10,000/- - 15,000/- TZS)	• Bicycle (5,000 TZS) • Oxcart (30,000/-TZS) • Lorry/tractor (150,000/- TZS)	• Headload (1,000/- TZS) • Oxcart (10,000/- TZS)	NA	• Headload (1,000 – 1,500/- TZS) • Oxcart (15,000 – 20,000/- TZS)
Time taken to collect woodfuel	• Headload (six hrs) • Bicycle (two hrs) • Ox cart (3 days)	• Headload (4 hrs) • Oxcart (3 days)	• Bicycle (7 hrs) • Oxcart (3 days) • Lorry (10 days)	NA	• Oxcart one day	• Headload (4 hrs)
Who (by gender) is responsible for fuelwood collection	NA	• Headload (women) • Oxcart (women)	• Headload (women) • Oxcart (women)	• Headload (women) • Oxcart (women)	• Headload (women) • Oxcart (women and men)	• Headload (women)

*NA = Not available

Tree stocking parameters in relation to crop farming intensification**:** On average the stocking number of stems per ha (N), basal area (G) and volume of tree on farm were low in Kiteto and Kongwa district (Table 17). Generally, the low potential areas for crop farming were found to have higher values than those in high potential areas, which can be attributed to the land fallowing practice in marginal areas to allow for natural regeneration to restore soil productivity and vegetation cover. Furthermore, most marginal areas especially in Kongwa district have higher number of baobab trees (*Adansonia digitata*). These large trees cannot be removed easily and do not supply fuelwood and charcoal, which are highly demanded energy source in the area. Thus they tend to dominate farmland where farmers use their fruits for domestic and commercial purposes. Recent works in the Sahel, however, suggest that light shade of baobab trees have positive facilitative effects on the yield of associated millet crops (Sanou et al., 2011), implying that ecological values of this tree on farm is more that fruits production as previously thought. Most tree and shrub species that are currently found in the cropland are those which do not have immediate use by local people and are not known to improve soil fertility. This is contrary to the southern highlands of Tanzania where farmers retain higher number of *Faidherbia albida* on farm which is associated with the benefits of soil fertility improvement and fodder supply.

Table 17: Mean for stocking parameters in Kongwa and Kiteto districts

Block	Parameters	Mean	SE
Kongwa (*n = 43*)	N ($no.ha^{-1}$)	20	0.00
	G (m^2h^{-1})	86.2	0.05
	V (m^3ha^{-1})	259.7	0.15
Kiteto (*n=20*)	N ($no.ha^{-1}$)	12.5	0.00
	G (m^2h^{-1})	1.17	0.001
	V (m^3ha^{-1})	4.67	0.008
Potential (*n=26*)	N ($no.ha^{-1}$)	15.3	0.00
	G (m^2h^{-1})	1.45	0.00
	V (m^3ha^{-1})	6.12	0.00
Marginal *(n = 37*)	N ($no.ha^{-1}$)	18.9	0.00
	G (m^2h^{-1})	99	0.08
	V (m^3ha^{-1})	300	0.23

Generally the results of this section indicate that, there is less tree cover on the cropland which subjects the land to degradation, such as wind erosion. The contributing factors include current farming practices which removes trees from the field to enable easy maneuvering of tractors and ox-plough. Furthermore, overexploitation of trees and shrubs for energy has also been suggested to accelerate clear felling of trees on farm. Opening up of land for grazing areas as well has increased land degradation and limit nutrient recycling. Overgrazing has also limited natural regeneration of the indigenous tree and shrub species. Encroachment of virgin woodlands to open up farms has been done with excessive tree cuts. Absence of tree and shrub germplasm for planting on-farm has been one of the bottlenecks in regenerating cover in the farmland. Compounded by low awareness on importance of trees on the improving environmental resilience, little have been done to plant trees on farm. We propose the following approaches in order to take full advantage of tree benefits note in this study:

- *Creating environmental awareness*: It is vital to increase awareness to smallholder farmers where suitable tree and shrub species can be left on farm will be vital in improving the agricultural landscapes of Kiteto and Kongwa district. Managing farms with trees in which semi-mechanized techniques can be used in possible, what is needed is proper land management planning.
- *Improving tree and shrub species germplasm supply*: Lack of germplasm and poor seed and seedling supply systems has hindered efforts to increase vegetation cover on farm. Despite enormous demand that prevails, only limited number and species are readily available to smallholder farmers making it difficult to significantly increase tree cover.
- *Enhancing natural regeneration:* Protecting emerging seedlings on farm land by limiting access by animals and mechanical removal by tractors and ox-plough will ensure reasonable increase of tree cover.
- *Improving fallow systems:* Most of indigenous species found in Kiteto and Kongwa districts have ability to rapidly regenerating once a farm is left for three to four years. This will ensure that most desirable tree and shrubs species are left to grow avoiding yearly clearing.

3.3. Sustainable Seed and Seedling Supply System

3.3.1. Why a sustainable tree germplasm[1] supply system

The sustainable supply of high quality agroforestry tree germplasm is fundamental to the successful establishment of productive agroforestry enterprises by farmers. Cost effective and sustainable tree germplasm supply systems are critical for a sector that in some countries has not yet attracted private sector participation. The lack of high quality tree planting material was identified as a major constraint to the success of agroforestry (Simons, 1997; Aalbæk, 2001). Besides quality tree germplasm, the low seed replacement rate for trees and the small seed requirements of smallholder farmers provides further challenges to private germplasm suppliers. National tree seed centers (NTSC) that were established in Tanzania and Malawi to supply quality tree seed have had challenges in reaching many farmers (Aalbæk, 1997) due in part to their central location. It has also been a challenge for the resource-constrained farmers to travel long distances to the seed centers, only to buy small amounts of tree seed.

The World Agroforestry Centre's development strategy has been to develop and apply better methods of forecasting germplasm needs, and to help establish effective, low-cost, sustainable, germplasm production and distribution systems. For agroforestry tree species, a sustainable seed supply system is one in which farmers have access to adequate high quality seed of the desired type (species and seed source) at the right time. This definition is largely consistent with that for crop seed (Scowcroft and Polak Scowcroft, 1999). Fig. 9 illustrates a generalized tree seed supply model.

One of the most important concerns scaling-up tree planting programs such as evergreen agriculture is the absence of sustainable tree germplasm supply (Aalbæk 2001; Ajayi *et al*. 2008). Tree seed, like non-hybrid seed of agricultural crops, is viewed as unprofitable for some species, due in part to: uncertainty and fluctuating demand; competition from farm-saved seed; low seed multiplication rates (e.g. for *Gliricidia sepium*); lack of transportation and storage difficulties; and lack of strong regional and international markets (Nyoka *et al*., 2011a).

3.3.2. No one-size-fits-all:

Lilleso et al. (2011) described tree germplasm supply models broadly as either centralized or decentralized in relation to ownership and control of (a) the seed source (production), (b) collection and procurement and (c) distribution. Any one of these three components (source of germplasm, procurement and distribution) can either be centralized or decentralized. Results and experience has shown that there is no one-size fits all sustainable quality tree germplasm supply model. A combination that draws from the strengths of each has been shown to be the best approach to supplying high quality tree germplasm. In Malawi and Tanzania the different array of tree germplasm supply models have been tested and employed all centered around the Government, the NGOs and farmers (Fig. 9).

[1] Germplasm in this context refers loosely to planting material (seed or seedlings) used to propagate the trees

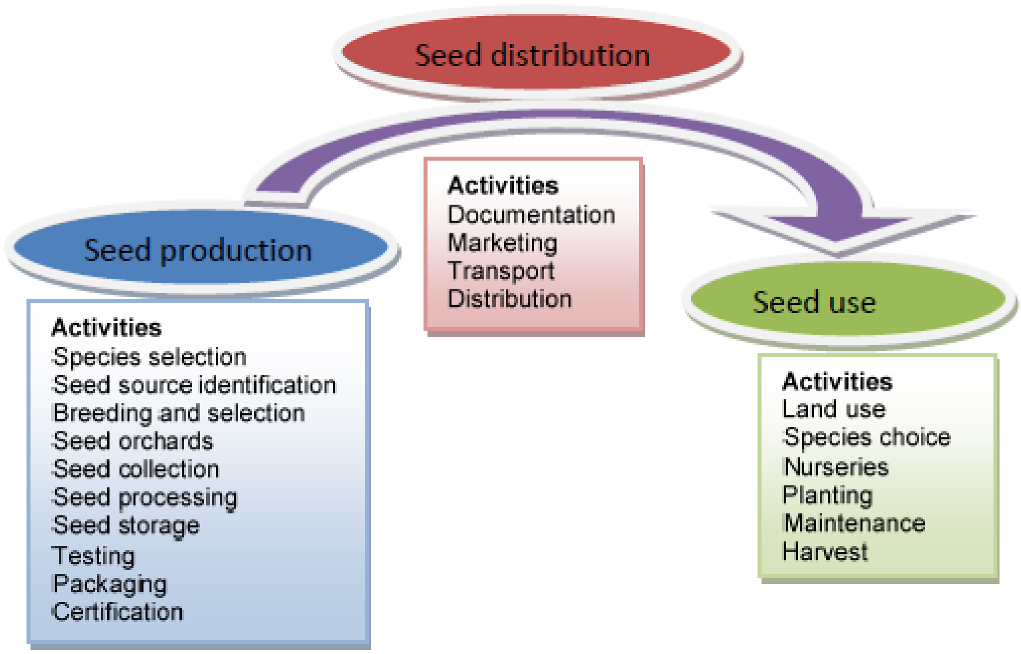

Figure 9: Generalized Tree seed supply model. Adapted from Schmidt (2007)

3.3.3. Centralized supply models

Government supply model: Under the complete centralized supply model, government usually has full control over the ownership of the seed source, collection and distribution depending on the species (Fig. 10). In Malawi and Tanzania although the source of germplasm of some tree species is often controlled by the government (e.g. fruit trees, some exotic timber species, and indigenous species found in protected forests) the distribution is usually undertaken by NGOs due in part to financial constraints on the part of government. Also depending on species, the collection of germplasm is often contracted out to smallholder farmers. Neighboring communities are often allowed access to the forests to collect non-destructive things such as seed under joint management. The greatest advantage offered by the centralized supply model is on germplasm quality, but this is countered by the major drawbacks: the cost of the germplasm often becomes very expensive for the farmers unless subsidized; and the germplasm is often accessible to only a few nearby farmers. In Malawi for example, good quality germplasm of fruit trees is only available from government agricultural research stations and to a very limited extend on private entrepreneurs. The National Tree Seed Centre in Malawi (NTSC) and the Tanzania Tree Seed Agency (TTSA) have the mandate for supplying tree germplasm nationally but due to their location and centralization often fail to reach many farmers.

NGOs supply model: In both Malawi and Tanzania, most NGOs do not have control over the ownership of the seed source so the NGO supply model is never a completely centralized. NGOs however tend to centralize the procurement and distribution of tree germplasm (Lillesø *et al*., 2011). They usually either buy the seed from the NTSC and from government research farms in the case of fruit trees or will buy directly from farmers who collect it from trees on their farms. The major drawback with the current NGO approach has been that of wholesale free distribution of germplasm

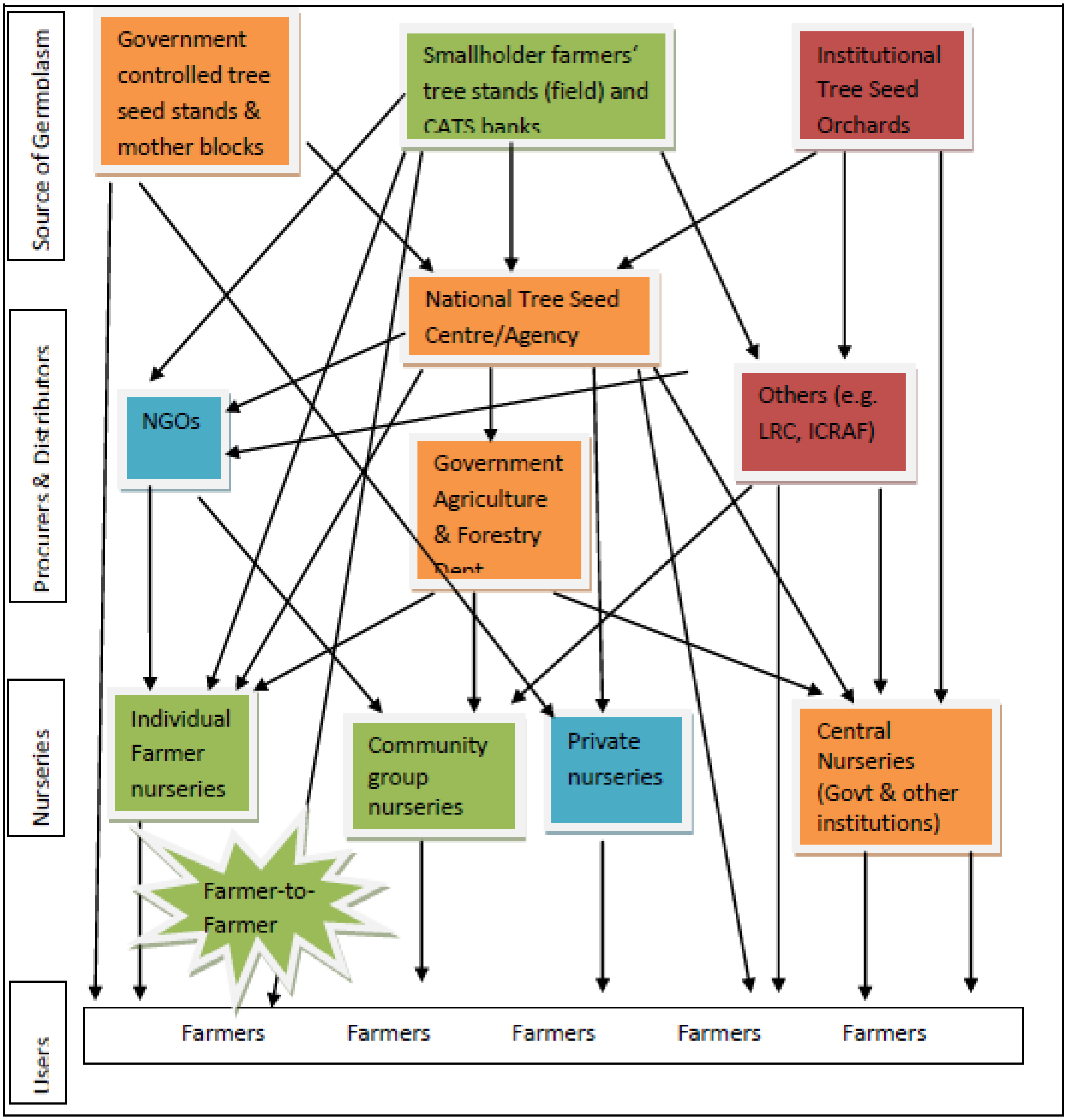

Figure 10: Major pathways through which tree germplasm flows in Malawi and Tanzania

to any farmer regardless of their ability to pay for the planting material. This is widely believed to be *crowding out* private entrepreneurs, who are also critical in the long term. Furthermore, some of the NGOs inadvertently (perhaps due to lack of staff competent in tree germplasm issues) distribute germplasm sometimes of very poor quality resulting in farmers having unproductive agroforestry enterprises resulting from the poor tree growth and tree deaths due to maladaptation. Despite these shortcomings, NGOs remain a vital cog of any good germplasm supply system for resource-constrained farmers. Successful germplasm delivery will require the participation of NGOs to distribute germplasm: perhaps freely to only those farmers who cannot afford it, and also bringing the germplasm closer to the communities where it is required, thereby improving farmer accessibility to germplasm. Because blanket distribution of free germplasm to every farmer, regardless of willingness and ability to pay has been shown to be unsustainable, NGOs will need to target specific farmers rather than the wholesale distribution that characterize germplasm distribution in Malawi and Tanzania in previous efforts. Between 2007 and 2009, 89% of the germplasm that was bought from the major procurers (LRC, NTSC and ICRAF) in Malawi was destined for NGOs and donor-funded projects while the remainder of 11% was shared by the departments of Agricultural Extension (1.4%) and Forestry department (0.4%) and by CBOs (4.3%) and individual farmers (4.6%) (Nyoka *et al*., 2011a).

3.3.4. Decentralized tree germplasm supply models

Community/individual tree seed banks and tree seedling nurseries (Figs 11 & 12): Some farmers own and control some sources of germplasm especially farmland seed source (Lilleø et al., 2011) while other farmers have access to seed sources on protected forests and woodlands. In these cases, the farmers play a pivotal role in the production of tree germplasm. In Malawi, the major tree seed procurers LRC, NTSC and ICRAF source respectively 100%, 65% and 45% of their seed from smallholder farmers, with the remainder being own collection from seed orchards and seed stands (Nyoka *et al*., 2011a). Farmers may act individually or in groups (community) in both the tree seed and seedling production. This model was used in Malawi to produce tree seed in Chikhwawa (*Gliricidia sepium*), Mangochi (natural stands of *Faidherbia albida*) and Dedza (*Tephrosia* spp.) districts during the implementation of the Agroforestry Food Security Program (AFSP), a 4-year scaling-up program funded by the Irish Aid to supply tree germplasm of fertilizer trees, fodder, firewood and fruit trees in eleven districts (AFSP, 2008, 2009, 20010). The model was also tested under the tree germplasm production under Community Agroforestry Tree Seed (CATS) banks, a 3-year project funded by the Flemish government (Akinnifesi, 2008; Sosola et al., 2011). About 231 CATS banks (125 in Malawi) were established in two districts in Malawi (Kasungu and Mzimba) and also two districts (Tsangano and Angonia) in Mozambique. There were a total of 9,031 farmers participating in the project and annual production averaged 25kg per farmer from which they realized an average of MK6,250 ($38) from seed sales. The approach was shown to be highly effective with precocious tree/shrubs species (Tephrosia and Sesbania) but may not be suitable for tree species that take longer to flower and fruit and also for those species with inherently low seed production potential.

Community or group nurseries and individual nurseries have been extensively used in scaling-up agroforestry and evergreen agriculture in both Tanzania and Malawi (Böhringer *et al*., 2003; AFSP, 2008, 2009, 2010). A survey of community group and individual nurseries revealed that, invariably, the former appeared to be inefficient – producing far less seedlings per farmer compared to individual farmer nurseries (Böhringer *et al*., 2003). This was attributed to either poor planning at the start of the nursery or quarrelling among group members particularly on allocation of duties that affected production of these group nurseries. Community and individual nurseries operators in Tanzania and Malawi were found to face a host of challenges that include pests damaging tree

Figure 11: Some of the notable successes of the CATS bank project in Malawi and Mozambique

Figure 12: Community group nurseries - low cost mass tree seedling production systems were employed in Malawi.

seedlings, scarcity of water, lack of adequate space for nurseries and damage by livestock (Böhringer and Ayuk 2003).The community and individual farmer tree seed and seedling supply model has shown great promise in meeting the increasing demand of agroforestry tree seed. The major challenges faced by community tree seed banks include marketing of the seed and ensuring quality. Voluntary certification of tree germplasm and accreditation of nurseries has now been proposed for experimenting on in Malawi as this has already been tested in other countries that include Uganda, the Philippines and Indonesia. There is also scope to consider branding some of the germplasm to improve quality as well. Branding of either nurseries or seedlings has been shown to be effective in improving germplasm quality in Indonesia (Roshetko *et al*., 2008) and in the Philippines (Harrison *et al*., 2009).

Private sector supply model: The private sector tree germplasm supply model although theoretically, the most efficient when viewed based on the hybrid crop seeds of field crops, still faces many challenges in developing countries including Tanzania and Malawi. With the exception of small-scale nursery operators focusing mainly on high value fruit trees and ornamentals, there are no private sector players on tree seed. The market for the fruit trees seems to be that created by NGOs who often buy fruit trees to distribute freely to farmers. High income people living in the urban areas are also a significant market for the small-scale nursery entrepreneurs. There is scope to involve the private sector initially focusing on those tree species (fruit trees) on which they already have a comparative advantage in production and marketing by extending their distribution reach.

Farmer-to-Farmer supply model: The farmer-to-farmer model of germplasm supply, on paper has all the attributes of a sustainable germplasm supply but in practice is a said to very slow and inefficient (Lillesø *et al*., 2011) and therefore perhaps not suitable for a short term programs. The farmer-to-farmer model has been shown to be effective with field crops i.e. annual crops. In trees, the farmer-to-farmer diffusion of tree germplasm is only useful when using germplasm of those species and seed sources that are already on the farmers' fields (Brandi *et al*. 2007; Mvula and Lillesø 2007; Namoto and Likoswe, 2007) or to precocious species such as *Sesbania* and *Tephrosia*.

3.3.5. Quality Control of Tree Germplasm:

Certification and Branding: In Malawi and Tanzania, the control of tree germplasm quality is not currently being regulated by the central government (Fig. 13). Consequently, the quality of the germplasm being used by farmers is often of poor quality resulting in poor germination, poor tree growth, low tree survival, low biomass (wood or leaf) yields, all a consequence of maladaptation. The result is often unproductive agroforestry enterprises. Calls and attempts have been made in Malawi to develop and implement compulsory certification of both fruit trees and forest trees (DARS, 2007; Pedersen and Chirwa, 2005). Our experience is that compulsory certification often takes long to develop and implement and requires active government participation and ultimately resources to enforce it – in a region where laws and policies only exist on paper. Consequently voluntary certification of germplasm or accreditation of nurseries and seed production areas could be a pragmatic approach in Malawi and Tanzania. Nyoka *et al*. (2011b) recommended voluntary certification of tree germplasm in those countries where compulsory certification face logistical challenges in implementation in the absence of a legal framework. Voluntary certification is currently being practiced in Uganda on nurseries (www.sawlog.ug/index.php) and the Philippines (Danilo, 2010; Gravoso *et al*., 2010).

Besides certification, other approaches such as branding have also been used to improve the adoption of practices that enhance the production of high quality germplasm. In Indonesia, Roshetko *et al*. (2008b) used the approach of branding nurseries that met a set criteria of quality termed *Nurseries of Excellence* (NOEL) while in the Philippines they branded the high quality seedlings as *Q-seedlings* (Gregorio *et al*., 2010) as a way of differentiating the seedlings from the traditional ones that were often of low quality. There is scope in testing these approaches to producing high quality tree germplasm in Malawi and Tanzania.

Figure 13: Tree seed quality control - extraction and processing to ensure purity

Value Chain Analysis of Agroforestry tree seed and seedling sector

As more farmers, adopt agroforestry practices, more and more tree germplasm will be required for the establishment of agroforests. With this realization, the CATS bank project commissioned a study to conduct a value chain analysis of the agroforestry tree seed and seedling subsector in Malawi. The objectives of the study were among other things to:

- Determine the annual production and demand trend of AF tree seeds,
- Identify potential actors and their roles in stimulation of the growth of AF tree seed and seedling sector,
- Determine the opportunities and challenges faced in the production to consumption stages of AF tree seed sector,

The study was conducted by the Centre for Independent evaluations (CIE) in nine districts in Malawi including Kasungu which is part of the Africa RISING project. The many findings of the study were that 81% of the farmers prefer the fertilizer trees for soil fertility replenishment, 10% preferred trees and the remainder preferred fruit trees (CIE, 2011). The study found that 40% of the farmers received germplasm from NGOs while 74% indicated that the germplasm was given to them for free. Although the demand of agroforestry tree seed was indicated as very high it was not possible to ascertain the actual volumes going through both formal and informal routes. Between 2007 and 2009, Nyoka *et al*. (2011a) estimated that at least 50 metric tons of agroforestry tree seed was distributed annually in Malawi through the formal distribution network. The major players in the tree seed business in Malawi are the Land Resources Centre (LRC) and FRIM's National Tree Seed Centre (NTSC) who all source their germplasm from smallholder farmers in addition to their own collection. LRC, NTSC and ICRAF source respectively 100%, 65% and 46% of their seed from smallholder farmers respectively. In Tanzania the equivalent of NTSC is the National Tree Seed Agency. The key recommendations of the study were:

- Investigate mechanisms for improving the supply of agroforestry tree seed in Malawi.
- Explore opportunities for commercializing the agroforestry tree seed sector
- Explore options for monitoring and regulating the quality of agroforestry tree germplasm

3.3.6. Tree germplasm markets

Competitive germplasm markets are important for agroforestry development as they ideally offer farmers and other germplasm suppliers, opportunities to earn income from engaging in trade of germplasm. Many farmers and nursery operators often engage in seed and seedling production for income generation. A responsive market is key to the development of a sustainable tree germplasm supply system. The tree germplasm market in Malawi and Tanzania comprise mostly of smallholder farmers and donor or government funded programs. Where smallholder farmers form the bulk of the market, there is a need to determine whether these resource-constrained farmers are able and willing to pay for the tree germplasm. This information is currently missing in both countries. There is a need to undertake market research to determine whether farmers are willing and able to pay for tree germplasm of their choice. There are two key but related approaches to the supply of tree germplasm that could threaten the evolution and development of vibrant markets. If the state becomes a major actor in the supply of tree germplasm, private germplasm suppliers may be *crowded out*. This has been observed in other countries such as Nigeria, Philippines and China (Harrison *et al*., 2008b; Babalola, 2008; He *et al*., 2012). In Tanzania and Malawi, the distribution of tree seed by NGOs has to be regulated and targeted to only those farmers who cannot afford to buy or access the germplasm otherwise the private sector will not compete effectively against free germplasm. The practice of giving free seed creates an artificial market which is not sustainable when the NGOs pull out (Nyoka *et al*., 2011b). The subsidized inorganic fertilizer in Malawi is also targeted.

The size of the market for tree germplasm is also important. There are very few studies that have focused on determining the potential market size of the tree germplasm in Malawi and Tanzania. While the potential market is said to be large (CIE, 2011), this appears to be based on the current germplasm supply approaches in which the germplasm is mostly supplied for free. The entry of private sectors players is likely to occur only when commercial opportunities are evident. The sporadic markets arising as a result of donor funded programs are not likely to entice companies to invest in agroforestry tree germplasm. A shift in government policy (from inorganic fertilizer subsidy to organic i.e. fertilizer trees (or even 50% organic +50% inorganic fertilizer subsidy) in Malawi could potentially create a market for germplasm of fertilizer trees in excess of 600 metric tons.

The other factor that could potentially reduce interest of private companies on agroforestry tree germplasm is the lower seed replacement rate because most tree species are not established annually as with field crops. Kugbei and Bishaw (2002) believe that small-to-medium enterprises (SMEs) are best suited to trade in such seed that has a limited appeal to large companies. The other challenge that is faced by potential entrants to the seed supply system is the strong seasonality of both production and demand that implies that large stocks of seed have to be carried over. Tree seed yields vary greatly from year to year meaning that investment in adequate storage facilities is required. When this occurs to farmers and small-scale entrepreneurs, it tends to tie up their already small working capital.

3.4. Capacity Building in the use of weather information for Making Climate Smart Farming Decisions

3.4.1. Background

The United Republic of Tanzania is among the 49 Least Developed Countries (LDCs) in the world. The country's main economic activity is agriculture, a climate change fragile activity that employs about 80 percent of the total population. Agriculture in Sub Saharan Africa and Tanzania in particular is facing enormous challenges, including how to increase yields, replenish nutrients in depleted soils and to adapt and mitigate climate variability and change (Garrity et al., 2010). African Union (AU) and Donors (notably Norwegian Government) are calling for a continental effort on Evergreen Agriculture as a flagship program to address these challenges (Garrity et al., 2010). Besides, adverse impacts of climate change and variability call for mainstreaming climate change adaptation and mitigation in development and investment processes. This is clearly stipulated in country's NAPAs (National Adaptation Program of Actions) and different strategies are in place including some programs aimed to build capacity of individuals, institutions and organizations to adapt to climate change and variability.

Furthermore, climate change and variability in Tanzania is affecting the accuracy, precision and reliability of seasonal rainfall prediction. Relevant interventions are therefore needed to address these challenges to improve productivity of agricultural sector and achievement of newly launched agricultural policy under the theme "*KILIMO KWANZA*". The newly launched "*KILIMO KWANZA*" initiative put agricultural sector as the number one priority in all development activities in Tanzania, with the purpose of enhancing agricultural productivity and improved quality in agricultural produce through the use of good and modern agronomic practices. However, since agriculture activities in Tanzania are mainly rain fed, productivity of crops to large extent depend on the appropriate and effective decision on when , where and what to plant, which in turn will depend much on the accuracy, precision and reliability of seasonal rainfall forecasting. Officially, Tanzania Meteorological Agency (TMA) is the Agency responsible for monitoring and predicting weather and climate in Tanzania, including seasonal rainfall forecasting. Conventional weather and climate prediction is normally done using statistical and dynamical methods (Gissila et al., 2004). In spite of the slight improvement in forecasting accuracy, the present forecasting accuracy, which is 75%, is still not sufficient and the challenges are still numerous due to the strong spatial and temporal variability nature of rainfall (Zorita and Tilya, 2002). Recent climate change projection indicates increased climate variability in the context of climate change over most part of the world (IPCC, 2007).

3.4.2. Major issues relating to weather and climate farming decisions in Kongwa and Kiteto districts, Tanzania.

There are no deliberate initiatives to provide precise and accurate weather information to farmers in Kiteto and Kongwa. Few villagers are aware of climate forecast by TMA through RADIOs and TVs. Those few who can access climate forecast information from TMA claimed not to use such information to plan farming decisions. Besides, climate forecast information issued by TMA is not informative due to low level of understanding of the users such as farmers and pastoralists and also their ability to use climate (forecast) information for supporting farming activities. Specifically, weather information by TMA is too general covering large areas with little or no information specific to sub units such as districts, divisions, wards and villages. TMA forecasts are not that accurate spatially and temporally (Chang'a *et al.*, 2010).

The semi-arid areas of Tanzania i.e. Kiteto and Kongwa districts, receive low and erratic rainfall which varies in both seasons and from year to year resulting in food insecurity. Most smallholder farmers living and farming in the semi-arid areas are food insecure and get a good crop yield in two out of five years because of low and erratic rains (Nyamudeza, 1998). Climate, including weather, is an important variable that influences crop production especially in the semiarid areas (Rao, 2005). Information on the onset of the main rains, quality (rainfall amounts), cessation of the main rains, temporal and spatial distribution of the main rains, timing and frequency of active wet and dry spells assists farmers make better informed decisions regarding the type of crop to grow, variety to choose and crop management practices that respond well to the season. Hence, farmers place a lot of importance on the prediction of the attributes of the season.

Scientific (conventional) forecasts provide the quantitative rainfall in probabilistic mode for season climate and determine the amount for medium range weather; it does not support farmers' needs in terms of onset and distribution of rainfall (Rengalaskshmi, 2004). Therefore, scientific forecast prepares the farmers in terms of the quantity of the rainfall while the traditional prediction helps farmers know the possible onset of the rainfall. Rengalaskshmi (2004) concludes that it is possible to establish a continuum between scientific and traditional forecast, which combines the scale, and the time of the onset of rainfall. Most farmers in the semi-arid areas do not have access to seasonal climate forecast and cannot interpret it where it is available because of poor literacy levels. Apart from this, TMA do not assist the local farmers in making decisions on cropping patterns because they make long range predictions for the whole nation. Therefore, farmers resort to using indigenous meteorological beliefs and knowledge in making seasonal.

3.4.3. Indigenous knowledge in weather forecasting

Indigenous knowledge systems are generally defined by Boef et al (1993) as the knowledge of people of a particular area based on their interactions and experiences within that area, their traditions, and their incorporation of knowledge emanating from elsewhere into their production and economic systems. Indigenous knowledge systems that have evolved through observation and experience over a time period are adapted to local conditions and needs unlike scientific forecasts that are formulated at a much larger scale, diverting with local needs. Indigenous knowledge systems are a body of knowledge, or bodies of knowledge of indigenous people of particular geographical areas that they have survived on for a very long time and passed on from one generation to the other (Mapara, 2009). The local weather and climate is assessed, predicted and interpreted by locally observed variables and experiences using combinations of plant, animals, insects and meteorological and astronomical indications (Boef et al.1993). Likewise, before the establishment of conventional weather and climate forecasting, older generations especially in the rural areas in Tanzania have largely relied on Indigenous Knowledge to predict weather through observation and monitoring the behavior of animals, birds, plants and insects (Mhita, 2006).

Villagers in Kongwa and Kiteto districts don't use TMA forecasts to plan farming activities, they use local knowledge i.e. phenology of trees miombo '*Brachystegia spiciformis'*, miembe 'Mango tree' and michumbu. It is therefore imperative that efforts to improve accuracy and reliability of indigenous seasonal forecast will need to be enhanced. Systematic documentation and subsequently integration of Indigenous Knowledge (IK) in seasonal rainfall forecasting is one of the promising initiatives that need to be explored. Historically and to date traditional local communities in semi arid areas of the world have continued to rely on IK to conserve the environment and deal with natural disasters. The communities particularly those in drought and flood prone areas have generated a vast body of Indigenous Knowledge on disaster prevention and mitigation through early warning and preparedness (Anandaraja et al., 2008). The use of contemporary and indigenous climate forecasts information for farm level decision in Tanzania, Mozambique and Kenya is described in Chang'a (2010), Lucio (1999) and Ngugi (1999) respectively.

In spite of all these benefits, IK in weather and climate prediction is under threat of disappearance due to: lack of systematic documentation of the knowledge; lack of coordinated research to investigate the accuracy and reliability of IK forecasting and finally when old people who are the main custodians of the knowledge pass away, the knowledge which has been accumulated for many years is lost. In this study, it is argued that IK can provide significant value and boosts in the improvement of forecasting accuracy and reliability if it will be systematically documented, researched and subsequently integrated in conventional forecasting system. The documentation of IK will be a good resource for the establishment of IK forecasting database in Tanzania and will be an important resource in the establishment of effective adaptation strategies to lessen the impacts of climate change. Most of the respondents in Kiteto and Kongwa districts acknowledged the existence of traditional methods of weather and climate forecasting in their communities and acknowledged using traditional weather and climate forecasts in their agricultural activities.

However, increased climate variability have significantly reduced the accuracy and the reliability of indigenous forecasting and it is also one of the challenge faced by TMA experts in their efforts to improve forecast accuracy and reliability, underlining the need for integrated approach in seasonal rainfall forecasting. Since IK is mainly based on relative experience and local experience, lack of benchmark makes it difficult to be harmonized and integrated into conventional forecasting system. Systematic documentation, quantification and subsequent integration of IK into conventional weather forecasting system is therefore recommended as one of the strategy that could help to improve the accuracy and reliability of seasonal forecasting information under a changing climate. Tanzania Meteorological Agency (TMA) currently is working with other institutions namely Sokoine University of Agriculture (SUA) and University of Dar es salaam (UDSM) on the project to document existing indigenous knowledge which together with scientific information can be integrated in adaptation and mitigation of effects of climate change. Basing on the experimental results to test the accuracy and reliability of IK forecasts, appropriate recommendation on how IK and Conventional weather forecasting system can be integrated will be established by this project.

3.4.4. Improve access to weather information

Developing effective method for communicating climate (forecast) information to the end-users is important. There are successful examples such as Climate Field Schools (CFS) in Indonesia and provision of weather packages to farmers via mobile phones in India. Capability of farmers in Kiteto and Kongwa to use climate forecast to anticipate the events is very limited. On the other hand, climate forecast information issued by TMA is not informative due to low level of understanding of the users (local authorities, extension workers, and farmers) due to the terminology used and also their ability to use climate (forecast) information for supporting farming activities. The involvement of intermediaries in the process is very important. How climate information should be translated into farmer language is one of the most important aspects that need to be developed. The extension workers who are the main mediator for transferring new technology to farmers should be trained. Learning by doing process may be an effective process for transferring climate knowledge or climate information to farmers (Boer, 2010). Climate Field School (CFS) in Indonesia is a case in point. The field climate school was intended for (i) increasing farmers knowledge on climate and ability to anticipate extreme climate events for their farming activities; (ii) assisting farmers in observing climatic parameters and their used for supporting their farming activities, and (iii) assisting farmers how to translate the climate (forecast) information for supporting farming activities, in particular planting decision and cropping strategy (Boer et al, 2011).

CFS program consisted of two phases. The first was *phase of socialization*, that is a phase for CFS socialization to farmers carried out in eight months or two planting season (24 meetings, 12 meeting in dry season and 12 meeting in wet season). The second is *phase of institutionalization*, which is a phase for implementation or further activities in the form of field actions done by farmers as CFS participants. This phase was carried out after the Socialization Phase for eight or more planting seasons. The phase of socialization was intended to increase farmers' knowledge on climate and the use of climate (forecast) information for designing cropping strategy and the phase of institutionalization was intended to capacitate the farmers on how to practice the knowledge in their farming activities. In the Climate Field School, all modules were given in the form of game or simulation. This was intended to expose the participants to the process of learning by doing. In other word, the CFS is a continuous process, i.e. getting experiences from doing, discussing or explaining the experiences to colleagues, analyzing the experience together, taking conclusion, and taking action (implementing) and then get again new experience from the action taken etc (Boer et al, 2011).

Another successful example of provision of weather information to farmers is in India. Twice every week, the India Meteorological Department (IMD) prepares a weather package for farmers in each of the 600 districts across India and sends this package out through SMS text messages. These packages include a five-day forecast, a weekly outlook, maximum and minimum temperatures, expected rainfall, cloud cover and surface wind humidity. Farmers use this information to determine when to plant, water, fertilize, harvest their crops and increase their yields. At present, only 10 to 15 percent of the farmers are benefiting from the mobile phone services and about 24 perfect of farmers are aware of it. The economic benefit of these services, however, has been estimated by India's National Council of Applied Economic Research (NCAER) to be approximately US$10 billion. If the country's entire farming community were to tap this resource, that amount would more than quadruple, to approximately US$ 40 billion. Improved access and use weather information help farmers to make decisions which helps to adapt to the risk associated with climate variability

3.4.5. Adaptation of farmers to climate change and variability

Adaptation to climate change is a process used to reduce negative effects of climate change and utilize the opportunities provided by climate change and variability. Therefore, adaptation measures are not only relying on long term alternatives to address the impacts of climate change and variability but also prepare important strategies to increase the current adaptation capacity without degrading natural resources. Adaptation capacity is determined by level of development, access to resources and capacity in technology, information, skills, infrastructure, institutions, and equity. In most cases people adapted to the adverse effects of climate change basing on resources they have and their skills gained through experience for a long time on the climate system. Frequently they forced to address climatic extreme events such as drought, floods, strong wind and earth quark. Communities will not rely on experience only that cannot provide a reliable trend. This means that there is a need of a combined effort from the communities, scientists, expertises and policy makers.

The current adaptive capacity of villagers to climate change in Kiteto and Kongwa is low due to combination of factors: endemic poverty, limited alternative livelihood activities, environmental degradation, farmer herder conflicts, seedling and crop damage by livestock, inadequate technical capacities, poor infrastructure, poor access to markets and weak local institutions. These factors, in combination with climate change effects, undermine the community's capacity to adapt successfully. Women in Kiteto and Kongwa adapt climate changes by working for food, relief food, selling hand crafts, cooking and selling food i.e. mama ntilie, daily laboring –weeding and harvesting, some are recently planting *cajanus cajan* for protein , income and fodder by importing seeds from Babati district, Manyara region. Adaptation strategies for men include relief food, sell of livestock to get income, selling traditional medicine in neighboring towns, selling craftwork in towns in neighboring towns, look for jobs as watchmen or in women saloons in neighboring towns, daily laboring in different activities, including ox ploughing and harvesting, abandoning farms for sometime so as nutrients are replenished. However, these local adaptation strategies are not ecologically, socially and economically sustainable in face of long term climate change and variability.

Sustainable adaptive strategies in the face of climate change and variability in Kiteto and Kongwa should include: provision of farmers with short-term weather forecast data from the Tanzania Meteorological Department for farming decisions i.e. choice of plant varieties and time for farming activities; integration conventional weather forecasts with existing indeginous knowledge .i.e. phenology of mango trees, *Brachystegia spiciformis*, behavior of white broud coucal 'dudumizi' bird; extension services for conservation farming decisions i.e. Maize and Pigeonpea (*Cajanus cajan)* in Kiteto; capacity building for tree nursery management i.e. Agroforestry in Kiteto ; extension services for conservation of catchment forests for irrigated farming; extension services for agricultural water management (AWM) interventions i.e. Bill and Melinda foundation project in Tanzania. There are other several measures to address climate change and variability that include appropriate training and understanding of climate change and variability and technical strategies such as the use of drought tolerant crops and environment management. The climate trend for many communities has changed to be unreliable, there is need to make efforts on adaptation capacity basing on important sectors like agriculture, water and natural resources. In addition, the efforts to reduce greenhouse gases emission are needed. This includes stopping environment degradation, rehabilitation of affected areas and acquiring knowledge on adaptation to climate change and variability. The following documents provide trends and strategies to guard the process of adaptation and mitigation of climate change and variability. These documents are (a) Environment management Act of 2004; (b) National Adaptation Program of Action of 2006 (c) Land and water sources management Strategies of 2006. d) National Strategy on Reducing Emissions from Deforestation and forest Degradation (REDD) of 2012.

3.4.6. Innovation Systems for Climate Change and Variability

Definition of Innovation system**:** Innovation system is the network of organizations/ institutions, enterprises and individuals that aims to bring a new product, new process, and new appearance of organization on the use of economic, together with institution and policies that affects characteristics and prosperity. In short, innovation system is a group of institutions and people involved on providing, adopting and scaling up, and use important on socio-economic and managing institution on the relation and process. Fig. 14 indicates how this innovation system works through involvement of different stakeholders in order to improve farmer's household livelihood.

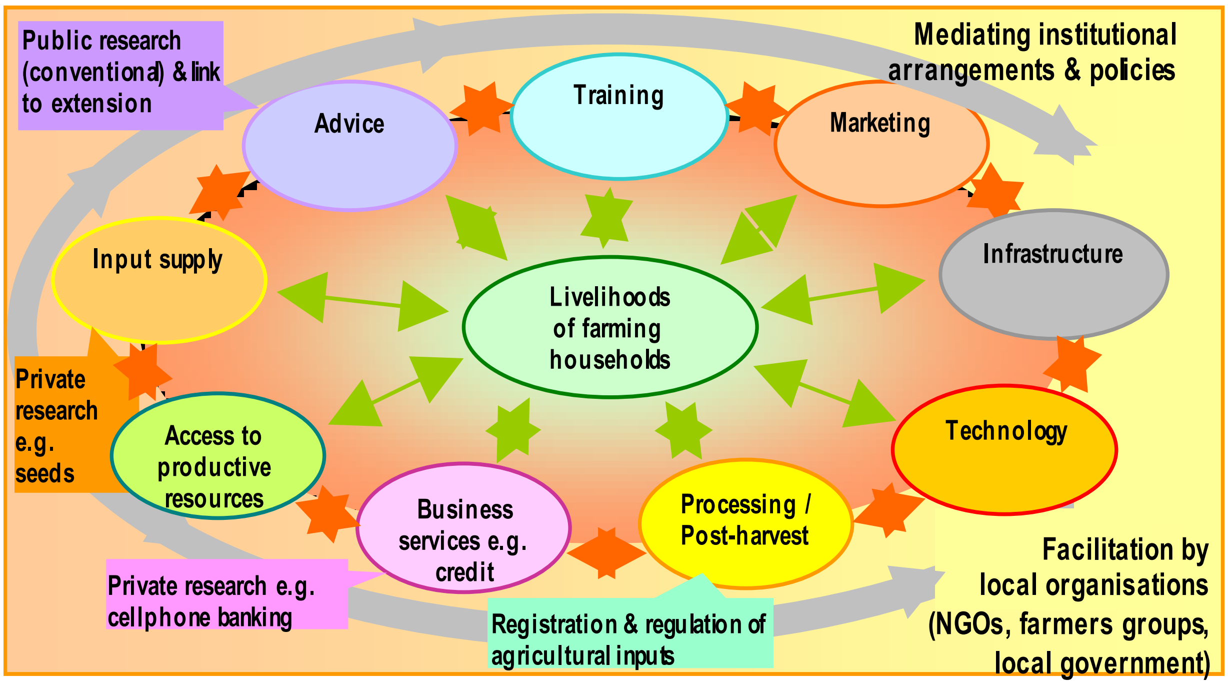

Figure 14: Agricultural innovation systems from farmers' perspective

3.4.7. Important of innovation system in adaptation to climate change and variability

Climate change and variability already affected the agricultural production system every place and increase fear of not producing. There is a need to improve resilience among the small holder farmers to mitigate impacts of climate change and variability. This include use of proper technology, experts knowledge, access to fertilizer and seed, security on land and access to information about markets, crops storage facilities and reliable transport. The use of different techniques in agriculture production is more effective in adapting to climate change. For example, CCAA project in Dodoma and Singida implemented by the Institute of Resource Assessment of university of Dar es Salaam has managed to increase production in smallholder farmers through this innovation system. Farmers managed to increase the use of organic fertilizer (farmyard manure and composite manure), using the recommended seeds, spacing and proper tillage practices for rainwater harvesting. Such strategies have reduced food shortage problem, increased income and contributed to environmental management. Innovation system is good strategy in adaptation to climate change and variability.

This strategy links agricultural expertise, farmers, researchers, stockists and other agricultural stakeholders in adapting to climate change.

3.4.8. Innovation system on technology and type and varieties of crop seeds.

Among the good things on the innovation system are technology, new production and storage methods and new crop types and varieties. For example in agriculture farmers and other stakeholders in agriculture, they may look on:

- Soil management strategies, for example tillage strategies that involve early tilling, rain water harvesting through tilling to allow water to penetrate in the soil. This will help deeper water penetration and conserve moisture and also tillage helps to reduce weeds that would reduce moisture and soil nutrients.
- Crops management, for example selection of crop to grow such as drought tolerant crops that reduce vulnerability to climate change and variability. Places with drought, drought tolerant crops are sorghum, finger millets, pigeon, Pulses, sesames and sunflowers. In addition, here we look on varieties and nutrient needs that increase production cost.
- Agricultural system, for example mixing cropping where by more than one crop is grown in the same field basing on measurement and type of crops. Example of crops cultivated under mixed farming and are drought tolerant include sorghum, pigeon peas and Pulses.
- Number of crops, here we look on optimal number of crops and proper measurement of plants/ crops. Nb: More crops grown do not mean more harvests.
- Weeding, weeds compete with crops water, and soil nutrients. In addition, weed attracts diseases and pests that can affect the plants. Early weeding helps to adapt to climate change and variability. Mulching that cover the soil helps on moisture retention on the soil, reduces rainwater flow, reduces weeds, adds composite, and soil fertility.
- Water management, soil water helps the biological, physical and chemical processes. Fertilizer to be absolved need water, therefore water management, will increase the capacity of soil to retain water, increase nutrients, and reduce diseases. Water management is good way of addressing drought Methods used include water and soil management, rainwater harvesting and good land use and crops. Every drop of water during drought can bring changes.

Based on the results of this study, we suggest that climate change adaptation for Evergreen Agriculture (EGA) should include the following:

- It is important to raise community awareness on climate change and variability issues, projections and potential adaptation strategies, so that communities can prepare themselves as much as possible for the upcoming impacts.
- Creating partnerships between farmers and weather/climate institutions such as the Tanzania Meteorology Agency for gathering and using accurate climate data.
- Developing effective method for communicating climate (forecast) information to the end-users i.e. farmers, pastoralists is important- Climate field schools (Indonesia) and forecasts through mobile phones (India)
- Using traditional knowledge and starting from what people are already doing on the ground when developing climate variability adaptation strategies i.e. weather forecast using phenology of miyombo '*Brachystegia spiciformis*', behavior of white browed coucal 'dudumizi' bird in Tanzania etc and integrate with conventional weather forecasts.

- Investing in ecosystem health to build community resilience and adaptive capacity to climate change;
- Improving information and knowledge sharing from pilot climate change adaptation activities;
- Moving from short-term coping towards long term adaptation so that the underlying causes which affect people exposed to climate change hazards and impacts are addressed in a timely manner
- Diversification of livelihood activities for communities, as people with diverse income sources tend to be more resilient to climate hazards.
- Integrating climate adaptation into development plans and policies.

4. POTENTAIL EVERGREEN AGRICULTURE FOR SUSTAINABLE INTENSIFICATION OF CEREAL-BASED FARMING SYSTEMS

The evidence for the benefits of evergreen agriculture practices in the pilot areas were elicited through review of literature for ICRAF's field experiments in Tanzania and Malawi. The results of these were also compared with the general literature from Sub-Saharan Africa.

4.1. Evidence from household surveys and on-farm trials

ICRAF staff and post-graduate students attached to ICRAF have been conducting household survey and on farm trials in order to establish the benefits and impacts of evergreen agriculture. Here we will summarize results of those from Kasungu and Ntcheu districts. In 2008, a total of 65 household in Kasungu were interviewed by Ann Quinion an MSc student attached to ICRAF. Farmers were selected on the basis of length of agroforestry use; having been adopters of technologies for at least five years. The results (Quinn et al., 2010) show that the most frequently reported technology in both districts was intercropping (85%), relay cropping (45%), improved fallows (45%) and biomass transfer (62%). Over 66% of respondents cited *Tephrosia vogelii* as the preferred agroforestry species for intercropping followed by *Gliricidia sepium* (26%). *Sesbania sesban* was the preferred species for relay cropping. Approximately 79% of those using improved fallows in Kasungu favored Tephrosia followed by Gliricidia (10%). Some 73% of those using biomass transfer reported using Sesbania followed by Gliricidia (Table 18).

Table 18. Percentage of respondents reporting using agroforestry technologies and preferred species in Kasungu district (Quinion et al., 2010)

Technology	% respondents	Number of respondents	Tephrosia (%)	Sesbania	Gliricidia	Faidherbia
Intercropping	85	55	66	2	26	7
Relay cropping	45	29	0	86	10	3
Improved fallow	45	29	79	7	10	0
Biomass transfer	62	40	0	73	28	0

4.2. Evidence from experimental results

4.2.1. Improved soil health

The improvement in soil health under evergreen agriculture is usually reflected in soil chemical properties (e.g. higher SOM, improved availability of N, P, K and improvement in basic soil cation contents and pH), biological (increased faunal activity) and physical properties (e.g. infiltration rates, water storage). Rapid soil fertility assessment (Table 12) and the response of farmers indicated high soil degradations in the study sites. This condition, however, can be mitigated by using tree/shrub-based technologies. Firstly, trees in cropping systems serve as both the source of SOM and protect it from loss through erosion. At several sites in Malawi, SOC was 3-30% higher under faidherbia canopy than in the open (Rhoades, 1995). At Makoka in Malawi, SOM, particulate organic matter (POM), POM-C and POM-N were 12, 40, 62 and 86% higher in the maize-Gliricidia intercrop compared to monoculture maize (Beedy et al. 2010). Increased SOC content, particularly in the light fraction, is known to improve aggregate stability and overall soil structure that resists breakdown and erosion. Improved aggregate stability may result in increases in soil porosity and hydraulic conductivity. For example, infiltration rates and water use efficiency were higher in the maize-Gliricidia intercrops than monoculture maize at Makoka in Malawi and Msekera in eastern Zambia (Chirwa et al. 2007; Sileshi and Mafongoya, 2006b)

The contribution of trees/shrubs to soil fertility also comes from N inputs via deep capture and biological nitrogen fixation (BNF). With evergreen agriculture innovations, the trees add significant amounts of nitrogen (N) and phosphorus (P). At Makoka in Malawi, Akinnifesi et al. (2006) estimated that the green leaf and twig biomass from Gliricidia adds up to 302 kg ha^{-1} N yr^{-1} and 21 kg P ha^{-1} yr^{-1}. P concentration in the top 0-20 cm soil layer was 90 kg ha^{-1} under Gliricidia-maize intercropping compared to 56 kg ha^{-1} in sole maize at Makoka in Malawi (Mweta *et al*., 2007). Nutrient uptake and recovery by associated maize crops was also shown to be higher under evergreen agriculture. For example, at Makoka N and P uptake by maize were 156% and 121%, respectively, higher in Gliricidia-maize intercropping compared to sole maize (Mweta *et al*., 2007). On several sites in eastern Zambia, earthworm densities were found to be significantly higher in maize grown after fallows of Sesbania and Tephrosia or when intercropped with *Acacia anguistissima, Caliandra calothyrsus*, gliricidia and *Leucaena collinsi* compared with fully fertilized sole maize (Sileshi and Mafongoya, 2006b; Sileshi *et al*., 2008b).

The ability of trees to improve soil physical properties has been widely documented in Tanzania, Malawi and elsewhere in Africa. One of the key improvements is improvement in water retention, storage and availability to associated crops such as maize (Nyamadzawo *et al*. 2012; Phiri, 2002). Soil water stored in continuously cropped fully fertilized sole maize was lower than in maize rotated with *S. sesban* especially during periods of water stress (Phiri, 2002). In parklands in Ethiopia, available water was 1.5 to 2 times more under faidherbia than outside the tree canopy (Kamara and Haque, 1992). Similarly, in Malawi, soil moisture in the 0-15 cm soil depth was 4-53% higher under faidherbia than outside the tree canopy (Rhoades, 1995).

Despite high promise to replenish soil nutrient and organic matter by tree/shrub-based technologies, it should be noted that in Phosphorus (P)-limiting site in Dodoma, these technologies will require mineral fertilizer supplementation (Kimaro et al., 2009). This is because the N-fixation process is limited in low soil P supply and unlike N; plant cannot fix P from the atmosphere. Rather plant's ability to improve P in the top soil is limited to the reserve in the sub-soils from which the tree/shrub roots take it. However, given the slight acidic to basic conditions noted in the Tanzania sites (Table 12) it is unlikely that P will be the most limiting nutrient for crop production. This suggests therefore that organic-based technologies, including the use of tree-shrubs technologies may be appropriate for integrated nutrient management under the Africa RISING research framework to improve soil health (chemical, biological and physical properties of soils) and productivity as discussed above

4.2.2. Control of pests

There is growing evidence that some agroforestry practices can reduce maize pests such as termites (Sileshi et al., 2005) and weeds (Sileshi et al., 2006) in southern Africa. Agroforestry increases plant diversity and structural complexity, with implications on pest population dynamics. It is an ecological maxim that diversity is closely related to stability because of structural and functional heterogeneity and genetic diversity regulate pest populations. However, simply increasing diversity will not necessarily increase the stability of all agro-ecosystems (Sileshi et al., 2007c).

4.2.3. Increased crop yield and yield stability

Increase in crop yields is one of the well-documented benefits of evergreen agriculture practices in Malawi, Tanzania and the rest of southern Africa (Table 19). Various studies also suggest complementary effect of tree biomass combined with small dosages (25-50%) of inorganic fertilizer on crop yields (Sileshi et al., 2012a, b; Kimaro et al., 2008; 2009). For example, at Chitedze in Malawi, Sileshi et al (2012b) recorded 43% and 84% increase in paprika yield using Gliricidia biomass alone and *Gliricidia biomas* + 50% fertilizer, respectively, over the no-input control. With the recommended rate of fertilizer the corresponding increase was 9.4%. Similarly maize yield after pigeonpea fallow + half recommended N and P fertilizers were similar to that of full rates (Kimaro et al., 2009), mainly due to the alleviated moisture competition via the sequential cropping arrangement under this practice (Isaac and Kimaro, 2011). Maize yield after a 5-year tree fallows of *Acacia polyacantha* and *G. sepium*, were similar to the yield obtained with full reccomendaed rate of N and P fertilizers in Morogoro (Kimaro et al., 2008). In a long-term (12 years long) trial conducted at Makoka Research Station in southern Malawi, average yield of maize was highest in maize-Gliricidia intercropping amended with 50% of the recommended N and P fertilizer, and this was comparable with yield recorded in monoculture maize that received inorganic fertilizer.

Table 19: Average maize yield and yield increase (t ha^{-1}) with fertilizer trees relative to the control (unfertilized maize grown continuously) in Malawi and Tanzania

Species	Country	Number of sites	Yield (t ha^{-1})	Yield increase (t ha^{-1})	Percentage increase
Gliricidia	Malawi	5	3.9	2.9	345.6
	Tanzania	2	2.3	0.8	55.8
Sesbania	Malawi	7	2.5	1.3	161.4
	Tanzania	2	1.2	0.7	171.4
Tephrosia	Malawi	9	2.0	1.1	232.7
	Tanzania	2	2.0	0.9	80.1

The increases in cereal yields recorded in Malawi and Tanzania (Table 19) are also consistent with data from across sub-Saharan Africa (Table 20) showing that on averaged maize yields can increase by 89-318% over the no input control. Robust estimates indicate that the 95% confidence intervals of maize yield increases with *Faidherbia* (2.0-2.7 Mg ha^{-1}), gliricidia (1.8-2.4 Mg ha^{-1}) and inorganic fertilizer (1.9-2.3 Mg ha^{-1}) completely overlap. An important gain that is usually under-reported is the stover yields, which is a critical input as livestock fodder in cereal-livestock mixed farming systems in Africa. An additional 0.2-2.0 Mg ha^{-1} yr^{-1} of stover can be produced using the fertilizer trees. This can contribute to availability of livestock feed during times when grass is in short supply.

4.2.4. Adaptation benefits

Temporal variability in crop yields has implications for sustainable crop production, particularly since greater fluctuations in crop yields are projected with climate change. In that sense, reliable cropping systems, i.e. those that combine high levels of mean yield and yield stability (low production risk) are needed. Evidence now exists that evergreen green agriculture practices hold a great promise. For example, stability analyses (Sileshi *et al*., 2011; 2012) of long-term trials in Malawi, Zambia and Nigeria has shown that maize yields are more stable in maize intercropped with leucaena and gliricidia than in fully fertilized sole maize. At Makoka in Malawi, maize yields remained more stable in maize-Gliricidia intercropping than in fertilized maize monoculture in the long-term although average yields may be higher with full fertilization (Sileshi et al., 2012).

With climate change, increasing water stress and agricultural drought, which are frequently associated with rainfall variability, are likely to pose a serious challenge in rain-fed cropping systems. Agricultural drought is said to exist when water supply is insufficient to cover crop water requirements, and this is brought about by soil degradation as much as by climate. Much more than crop per drop" of water. Recent studies show that evergreen agriculture can reduce land degradation and thus increase water use efficiency. In a long-term trials in Malawi and Zambia, Sileshi et al. (2011; 2012a) analyzed rain use efficiency (RUE) defined as the mass (kg) of grain dry matter produced per unit area per mm of precipitation received during the rainy season (i.e. crop per drop). RUE is commonly used in dry land ecology and lower RUE values have been shown to indicate higher land degradation. The results (Fig. 15) show that fertilizer trees significantly increase RUE (thus crop per drop) as they increase the ability of the land to capture rainfall, store and make it available to crops. On the two Zambian sites, maize intercropped with Leucaena achieved 190-197% increase in RUE over the control (maize grown without nutrient inputs), which is the *de facto* resource-poor farmers' practice. On the Nigerian site, RUE was 202% higher in maize planted between Leucaena hedgerows supplemented with 50% of the recommended fertilizer, and 139% higher in maize grown between Leucaena hedgerows without fertilizer compared to the no-input control. On the other hand sole maize receiving the recommended fertilizer achieved only 85% increase in RUE over the control (Sileshi et al., 2011). A detailed analysis of a 14 years trial at Makoka (southern Malawi) revealed that unfertilized maize intercropped with Gliricidia achieved 402% increase in RUE over the control, and this was slightly better than fertilized sole maize. This indicates that evergreen agriculture can boost the soils ability captures and stores rainfall and make it available to associated crops. Relative to the no-input control, RUE further increased by 457 and 503$ when maize intercropped with Gliricidia was amended with 25 and 50% of the recommended dosage of fertilizer. This highlights the fact that organic resources in combination with small dosages of inorganic fertilizer can boost the crops' ability to efficiently convert stored water into yield.

Table 20. **Cereal yield response to fertilizer trees summarized from studies across sub-Saharan Africa (Sileshi, unpublished)**

Cereal crop	**Species**	**Number of studies (N)**	**Mean yield (Mg ha^{-1}±SE)**	**Yield increase (Mg ha^{-1}±SE)**	**Increase* (%±SE)**
Maize	Pigeon pea[1,2]	24 (69)	2.1±0.2	0.7±0.1	89.8±13.2
	Tephrosia vogelii[1,2]	28 (177)	2.1±0.1	0.9±0.1	206.3±42.6
	Leucaena leucocephala[2,3]	6 (78)	2.5±0.2	1.0±0.1	94.5±12.2
	Sesbania sesban[1,2]	42 (262)	3.0±0.1	1.7±0.1	318.1±82.5
	Gliricidia sepium[4]	15 (127)	3.2±0.1	2.2±0.1	295.9±27.8
	Faidherbia albida[5]	12 (88)	4.5±0.2	2.5±0.2	184.6±33.9
	Inorganic fertilizer	72 (384)	3.8±0.1	2.2±0.1	383.8±40.5
Sorghum	*Gliricidia sepium*[4]	4 (10)	1.5±0.1	-0.1±0.1	93.8±5.3
	Faidherbia albida[5]	5 (14)	1.0±0.2	0.3±0.1	144.4±22.8
	Sesbania sesban[1,2]	2 (24)	1.8±0.1	0.6±0.1	180.4±19.1
Millet	*Acacia* spp.[5]	3 (11)	0.7±0.1	-0.04±0.1	107.8±14.4
	Faidherbia albida[5]	5 (13)	1.2±0.1	0.4±0.1	149.3±14.4

N = number of data points representing either sites or years within a study
[1]Relay cropping; [2]Improved fallow; [3]Alley cropping; [4]Intercropping; [5]Parkland
* Increase over the no-input control

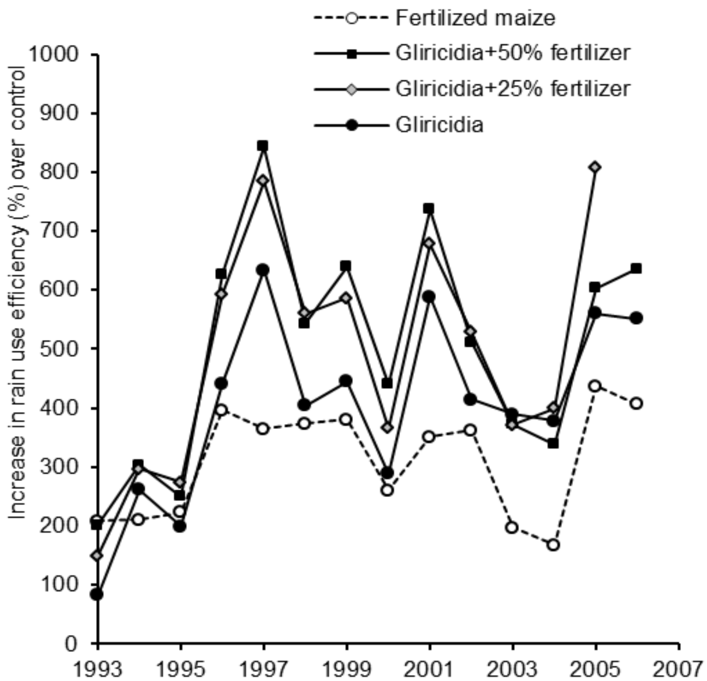

Figure 15: Improvement in rain use efficiency (%) by maize intercropped with Gliricidia and supplementary fertilizer (50 or 25% of recommended) over the sole maize control receiving no external inputs at Makoka, southern Malawi

Table 21. Means and 95% confidence intervals of RUE for Figure 15.

Treatment	% increase in RUE	95% CI
Gliricidia + 50% fertilizer	503	452-555
Gliricidia + 25% fertilizer	457	395-519
Gliricidia + 0% fertilizer	402	361-444
Fertilized sole maize	309	285-335

4.2.5. Climate change mitigation benefits

A growing number of studies have demonstrated that trees can facilitate C sequestration in the soil and plant biomass above-ground. For example, in 6-yr stand of *Faidherbia albida* in Tanzania accumulated 9.4 Mg C ha^{-1} in wood when planted at 5x5m spacing (Okorio and Maghembe, 1994). According to Kimaro *et al*. (2011) in Tanzania, SOC stocks within 0–15cm soil depth under 5-yr rotational woodlots of *Acacia* species (15.8–25.6 Mg ha^{-1}) were higher than in soils that had been continuously cropped for the same time period (13 Mg ha^{-1}). In addition, these species accumulated C at the rate of 2.3-5.1 Mg C ha^{-1} yr^{-1} in wood (Kimaro *et al*., 2011). In Malawi, Makumba *et al*. (2007) found that soil C in a Gliricidia–maize intercropping is roughly doubled after 7-10 years compared to sole maize. Recently, mitigation benefits of *Tephrosia* and *Gliricidia* in Malawi were analysed using the Small Holder Agriculture Monitoring and Baseline Assessment (SHAMBA) model developed by Edinburgh University (Berry, 2012). According to the model outputs, net emission removal over 20 years was -33 t CO_2 equivalent (95% ci: -27, -47) using Gliricidia-maize intercropping relative to the baseline of +36 t CO_2 equivalent. Similarly, the estimated emission removal with *Tephrosia* was -70 t CO_2 equivalent (95% ci: -48, -91) compared to the same baseline conditions. The carbon benefits from the trees are envisaged to accrue from land use changes (LUC) and/or reducing emissions from deforestation and forest degradation (REDD).

5. CONCLUSIONS AND RECCOMENDATIONS

This study evaluated constraints of agricultural productivity in the study areas and conducted a literature survey to show the potential of Evergreen Agriculture Technologies in sustaining and intensifying agricultural productivity for increased food security, fodder and biomass energy supply, and for reduced land degradation. The study established that low productivity, small land holdings and large family size are one of the major factors contributing to low productivity and food insecurity in the study site, as noted by 60% of respondents who experience food deficit in 1-9 months in a year. The impacts of these factors on crop productivity are exaggerated further by low levels of inputs, especially fertilizer and/or manure, despite high percentage (60%) of individuals who keep livestock. Only 17% of respondent use fertilizer or manure and less than 10% indicated that they use improved seeds obtained from agro-dealers or quality declared seed sources. Both Tanzania and Malawi have enabling policy environment for scaling up evergreen agriculture and other sustainable intensification options for this research program.

Kongwa and Kiteto are high potential areas for maize production in Tanzania, but soils in these districts are highly impoverished due to continuous cultivation with little or no inputs and extensive grazing. As a results crop yield per ha are very low and has been maintained at 1-1.5t/ha (for maize crop) since 1960s by expanding area under cultivation. This extensive form agriculture is associated with 38.8% decline in areas under forest and shrubs/thickets over a period of 23 years. These results suggests that sustainable intensification practices in these soils would require replenishment of soil nutrients and organic matter to restore soil health and productivity as well interventions to minimize forest degradation. Moreover, ICRAF-led work in the Southern region has indicated the potential for evergreen agriculture practices to increase rain water and stabilize maize yield against climate variability. This research may be useful for reducing the risk of climate change to farmers, given sporadic rainfall partners and low adaptive capacity of farmers in the study sites. Programs like Climate Field Schools (CFS) recommended below could be help build the capacity of farmers in planning farming operations to minimize the risk of climate variability on crops production.

The following interventions are recommended to address key constraints to sustainable intensification of maize mixed and agro-pastoral systems in Tanzania and Malawi:

- Integration of fertilizer trees and Micro dosing technologies to provide technologies for enhancing the use of inorganic and organic nutrient sources by farmers. This approach could be an entry point for encouraging fertilizer use by farmers as localized application of small doses of fertilizer (micro-dosing) or in-situ production of green manure by tress/shrubs or fallow species can provide nutrients sufficient for crop production at less cost and risky to farmers compared to full application rates. As a result the technology advocated will fits into farmers socio-economic conditions. As noted in this reported, combined use of tree/shrubs and fertilizer has shown high promise to improve crop yields. These works can be tested on-farm in the study sites to identify appropriate spatial and temporal arrangement and density of trees/shrubs and optimum N and P micro-dose levels and manure rates needed for sustaining cereal production in the study sites.

- Integrated soil and water management to minimize soil erosion and drought effects on crop production. Approaches like in-situ rainwater harvesting (RWH) will help farmers to minimize the risk of total crop failure and lack of crop response to fertilizer due to drought or sporadic precipitation patterns. Understanding of spatial and temporal soil moisture relation under different practices such as conservation Agriculture, Conservation Agriculture with trees (CAWT) and Improved fallow or relay intercropping with trees/shrubs, may help to design the interventions most appropriate to farmers. RWH technologies such as tied ridges and other tillage practices works well with tree/shrubs-based technologies in Malawi region and Mpwapwa, Tanzania (Shemdoe et al., 2009) and could be introduced in Kiteto and Kongwa.
- Participatory land use planning and promote technologies for sustainable pasture and fodder management such as fodder banks, community grazing reserve or woodlot establishment, can enhance livestock productivity while minimizing conflicts between farmer and livestock keepers.
- Capacity Building for Climate-Smart Agriculture is one of the cross-cutting issues to be considered under the Africa RISING research framework to increase access and use of weather information for making climate-smart farming decisions. Successful programs like Climate Field Schools (CFS) practices in Indonesia could be introduced to build the capacity of farmers in planning farming operation to minimize the risk associated with climate variability. Usually the CFS program consists of two phases. The first phase is a phase for CFS socialization to farmers carried out in two planting season (12 meeting in dry season and 12 meeting in wet season). The second is phase of institutionalization, which is a phase for implementation or further activities in the form of field actions done by farmers as CFS participants. This phase can be carried out for eight or more planting seasons. The phase socialization is intended to increase farmers' knowledge on climate and the use of climate (forecast) information for designing cropping strategy and the institutionalization phase intends to build the capacity of farmers on how to practice the knowledge in their farming activities.

6. REFERENCES

AFSP (2007, 2008, 2009, 2010). Agroforestry Food Security Program in Malawi: Annual report for 2007, 2008, 2009 and 2010. World Agroforestry Centre. ICRAF-Southern Africa Regional Program. Lilongwe, Malawi.

Akinnifesi FK (2008). Community Agroforestry Tree Seed (CATS) banks. Unpublished project proposal document. World Agroforestry Centre, ICRAF-South Africa Regional program, Lilongwe, Malawi.

Anandaraja N, Rathakrishnan T, Ramasubramanian M, Saravan P, Suganthi NS (2008). Indigenous weather and forecast practices of Coimbatore district farmers of Tamil Nadu. Indigenous J. Trad. Knowl. 7: 630-633.

Anderson, J.M. and Ingram, J.S.I. 1993. Tropical Soil Biology and Fertility: A Handbook of Methods, 2nd ed. C.A.B. International, 221 pp.

Babalola FD (2008). Assessment of Small-Scale Private Nursery Enterprises in Ibadan, Oyo State, Nigeria. Small-scale Forestry (2008) 7:263–273.

Boef,Wde., Kojo A., Kate Wand Anthony, B. (1993). *Cultivating Knowledge;GeneticDiversity, Farmer Experimentation and Crop Research.*London: Intermediate Technology Publications.

Boer R, Tamkani K, Subbiah A.R (2011) Communicating climate forecast to farmers through climate field school: Indonesia experience. Unpublished report

Böhringer A and Ayuk ET (2003). Farmer nurseries as a catalyst for developing sustainable land use systems in southern Africa. Part B: Support systems, early impact and policy issues. Agricultural Systems 77 (2003) 203–217

Böhringer A, Ayuk ET, Katanga R, Ruvuga S (2003). Farmer nurseries as a catalyst for developing sustainable land use systems in southern Africa. Part A: nursery productivity and organization. Agricultural Systems 77(3):187–201.

Centre for Independent Evaluations (CIE) (2011) Evaluation of ICRAF's Agroforestry Food Security Program (AFSP) 2007 – 2011. Report presented to Irish AID Malawi Country Office, Lilongwe, Malawi

Chamshama S.A.O., Mugasha A.G. and Zahabu E. 2004. Stand biomass and volume estimation for Miombo Woodlands at Kitulangalo, Morogoro, Tanzania. *Southern African Forestry Journal* **200**: 59–69.

Chang'a L, Yanda P and Ngana J (2010). Indigenous knowledge in seasonal rainfall prediction inTanzania: A case of the South-western Highland of Tanzania. Journal of Geography and Regional Planning Vol. 3(4), pp. 66-72

Chibwana C, Jumbe C, Mazunda J, Fisher M and Shively G (2010) Impact of Subsidies on Fertiliser Use, Land Allocation and Forest Pressure: Evidence from Malawi. BASIS Brief BB2010-07, University of Wisconsin, Madison, USA.

Danilo CC (2010). Pilot testing of the forest nursery accreditation system in the Philippines DENR region 10. *In*: (editors: Harrison SR, Bosch A, Gregorio NO and Herbohn JL) Proceedings from the Mid-term Workshop (ASEM/2006/091), Improving the Effectiveness and Efficiency of the Philippines Tree Nursery Sector, Visayas State University, Baybay, Leyte, the Philippines. 13 February 2009. pp 67-72

Garrity D, Akinnifesi F, Ajayi, Sileshi W, Mowo J, Kalinganire A, Larwanou B (2010) Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Sec. (2010) 2:197–214 DOI 10.1007/s12571-010-0070-7

Gissila T, Black E, Grimes DIF, Slingo JM (2004). Seasonal forecasting of the Ethiopian summer rains. Int. J. Climatol. 24: 1345-1358.

Gravoso R., Gregorio N. and Godoy J. (2010). Working with local government units in accrediting forest nurseries. *In*: (editors: Harrison SR, Bosch A, Gregorio NO and Herbohn JL) Proceedings from the Mid-term Workshop (ASEM/2006/091), Improving the Effectiveness and Efficiency of the Philippines Tree Nursery Sector, Visayas State University, Baybay, Leyte, the Philippines. 13 February 2009. pp135-139.

Gregorio N, Harrison S and Herbohn J. (2010). The Seedling Nursery Survey on Leyte Island, the Philippines. Annals of Tropical Research 32(2): 1–14

Gregorio NO, Herbohn JL and Harrison SR (2004) Small-Scale Forestry Development in Leyte, the Philippines: The Central Role of Nurseries. Small-Scale Forest Economics, Management and Policy 3(3): 337-351.

Harrison S, Gregorio N, Herbohn J, Mercado A Jr (2008b) Seedling production systems for smallholder forestry development: local practices versus national policies in the Philippines. Paper presented at the International symposium on small-scale rural forest use and management: global policies versus local knowledge Ge´rardmer, France, 23–27 June 2008.

He J, Yang H, Jamnadass R, Xu J and Yang Y (2012). Decentralization of Tree Seedling Supply Systems for Afforestation in the West of Yunnan Province, China. Small-scale Forestry (2012) 11:147–166.

IPCC (2007). Climate Change, The Physical Science Basis. http://www.ipcc.ch 22ND August 2012

Kashaigili.J. J. (2006). *Landcover dynamics and hydrological functioning of wetlands in Usangu Plains in Tanzania.* A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy of Sokoine University of Agriculture 256pp.

Kimaro AA, Timmer VR, Chamshama SOA, Mugasha AG, and Kimaro DA .2008. Differential response to tree fallows in rotational woodlot systems: Post-fallow maize yield, nutrient uptake, and soil nutrients. Agric Ecosyst Environ 125: 73–83.

Kimaro, A.A, Timmer, V.R., Chamshama, S.O.A., Ngaga, Y.N, Kimaro, D.A., 2009. Competition between maize and pigeonpea in semi-arid Tanzania: effect on yields and nutrition of crops. Agric. Ecosyst. Environ. 134: 115-125.

Kimaro, A.A., Isaac, M.E. and Chamshama, S.O.A. 2011. Carbon pools in tree biomass and soils under rotational woodlot systems in Eastern Tanzania, accepted. In Kumar, BM and Nair, P.K.R (eds) Carbon sequestration in Agroforestry: Process, Policy and Prospects. Advances in Agroforestry 8: 129-144.

Lucio FDF (1999). Use of contemporary and indigenous forecast information for farm level decisión making in Mozambique. Consultancy report. UNDP/UNSO p. 72.

Luoga E.J., Kajembe G.C., Shemweta D.T.K., Zahabu E., Mwaipopo C.S. and Kweka D.L. 2005. Assessment of Tree Stocking and Diversity for Joint Forest Management (JFM) in Nkweshoo Village Forest Management Area, Kilimanjaro, Tanzania. *Forests, Trees and Livelihoods* **15:** 259–273.

Masudi.H. K. (2005). Spatial temporal assessment of soil erosion using GIS, Remote Sensing and RUSLE : The case study of Mahenge village in Mbinga District. A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy of Sokoine University of Agriculture 256pp.

Mbilinyi, B.P., Malimbwi, R.E., Shemwetta, D.T.K., Songorwa, A., Zahabu,E., katani , J.Z. & Kashaigili, J.J. (2006) *A Forest Area Baseline for the Eastern Arc Mountains*. Forestry and Beekeeping Division, Ministry of Natural Resources and Tourism, Dar es Salaam, Tanzania.

Mhita MS (2006). Training manual traditional knowledge for nature and environmental conservation, agriculture, Food security and disaster management in Tanzania. http://www.unep.org/IK/PDF/TANZANIA%20IK%20TRAINING%20M ANUAL.pdf.
Mpanda M. M., Luoga E. J., Kajembe G. C., and Tron E. H. (2011). Impact of forestland tenure changes on forest cover, stocking and tree diversity in Amani Nature Reserve, Tanzania. *Forests, Trees and Livelihoods*, Vol. 20, pp. 215–230.
Mvula PM, Lillesø J-PB (2007) Tree seedling growers in Malawi: who, why and how? Development and environment no. 5. Forest and landscape. University of Copenhagen, Hørsholm.
Namoto M, Likoswe MG (2007) Case studies of nurseries in Malawi. Forest and landscape. Working paper no. 20. University of Copenhagen, Hørsholm, Denmark.
Ngugi RK (1999). Use of Indigenous and contemporary knowledge on climate and drought forecasting information in Mwinyi district, Kenya. Consultancy report. UNDP/UNSO p. 28.
Nyamudeza, P. (1998). *Water and Fertility Management for Crop Production in Semi-Arid Zimbabwe.* Unpublished PhD Thesis, University of Nottingham.
Nyoka BI, Ajayi OC, Akinnifesi FK, Chanyenga T, Mng'omba SA and Sileshi G, Jamnadass R and Madhibha T. (2011b). Certification of agroforestry tree germplasm in Southern Africa: opportunities and challenges. Agroforestry System 83:75–87.
Nyoka BI, Mng'omba SA, Akinnifesi FK, Ajayi OC, Sileshi G and Jamnadass R (2011a). Agroforestry tree seed production and supply systems in Malawi. Small-scale Forestry. 10(4): 419-434.
Pedersen AP, Chirwa PW (2005) Tree seed in Malawi. Organisational survey. Forest and landscape. Working papers no. 8–2005. University of Copenhagen, Hørsholm, Denmark
Rao, KCP. (2005). Enhancing Productivity of Water under Variable Climate. *The East African IntegratedRiver Basin Management Conference.*ICE, Morogoro, Tanzania, 7-9 March, 2005.
Rengalakshrni, R. (2004). Linking Traditional and Scientific Knowledge Systems on Climate Prediction and Utilization: Proceedings Of The Conference On Bridging Scales and Epistemologies: Linking Knowledge with Global Science in Multi Scale Assessments: Abstract. *filleniumIicosystem Assessment.* Alexandria, Egypt. March 17-"20.
Roshetko JM, Idris N, Purnomosidhi P, Zulfadhli T, Tarigan J. (2008b). Farmer Extension Approach to Rehabilitate Smallholder Fruit Agroforestry Systems: The Nurseries of Excellence (NOEL) Program in Aceh, Indonesia. Paper presented at the 4th International Symposium on Tropical and Subtropical Fruits 3-7 November 2008, Bogor, Indonesia. 8p
Sanou, J. Bayala, J. Teklehaimanot, Z., and Bazie P. 2011. Effect of Shading by baobab (Adansonia digitata) and nere (Parkia biglobosa) on yields of millet (Pennisetum glaucum) and taro (Colocasia esculanta) in parkland systems in Burkina Faso, West Africa. Agroforestry Systems
Schmidt Lars (2007). Seed Supply and Distribution. *In*: Tropical Forest Seed, Chapter 8. Tropical Forestry series: 323-363.
Scowcroft WR, Polak Scowcroft CE (1999). Developing a strategy for sustainable seed supply systems in sub-saharan Africa: policies, stakeholders and coordination. *In*: Proceedings of the regional technical meeting on seed policy and programs for sub-saharan Africa, Abidjan, Cote d'Ivoire 23–27 November 1998. Seed and plant genetic resources services, FAO plant production and protection paper no. 151, FAO, Rome, Italy, pp 175–190
Shemdoe, R.S., Kikula I.S., and Van Damme, P. 2009. Increasing Crop Yield in Water Scarce Environments Using Locally Available Materials: An Experience from Semi-arid Areas in Mpwapwa District, Central Tanzania. Agricultural Water Management, 96: 963-968.

Shisanya C, Kalumuna M, Makhoha MO, Kimani S, Tenge A (2007). Farmer tree nursery as a catalyst for developing sustainable best land use management. Journal Applied Science 7(13):1755–1761.

Sileshi G and Mafongoya PL (2006a). The short-term impact of forest fire on soil invertebrates in the miombo. *Biodiversity and Conservation* 15: 3153-3160.

Sileshi G and Mafongoya PL (2006b) Long-term effect of legume-improved fallows on soil invertebrates and maize yield in eastern Zambia. *Agriculture, Ecosystem & Environment* 115: 69–78.

Sileshi GW, Akinnifesi FK, Ajayi OC, Muys B (2011) Integration of legume trees in maize-based cropping systems improves rainfall use efficiency and crop yield stability. *Agricultural Water Management* 98: 1364–1372.

Sosola BG, Akinnifesi, FK, Muys B. Sileshi GW, Mng'omba, Mussa J. Kumwenda W. and Phombeya H (2011). Community Based Agrofrestry tree seed production: Lessons from Malawi. Poster presented at an ICRAF Science week meeting, Nairobi, Kenya.

URT. 2009. National Framework for Reduced Emissions from Deforestation and Forest Degradation (REDD). Dar es Salaam, Tanzania.

Zorita E, Tilya FF (2002). Rainfall variability in northern Tanzania in the march-may season (long rains) and its links to large scale climate forcing. Clin. Res. 20: 31-40.