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DOCUMENTATION OF THE LESSONS AND THE BEST PRACTICES FOR CLIMATE SMART SMALL-SCALE AGRICULTURE

[FINAL REPORT]

CCAP PARTNERS

LENGALE Consulting Company LTD

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FOREWORD

This report presents the final technical report that draw lessons on best practices for small-scale climate smart agriculture to be shared with stakeholders for the purpose of influencing policy and policy practices at all levels. The report is based on literature review and filed visits to Kilosa and Chamwino Districts.

ACKNOWLEDGMENT

Lengale Consulting Company wishes to thank ActionAid and its members. Special thanks to the Staffs of the Project Office in Kilosa and Chamwino that did its utmost to facilitate the team on logistical arrangements. This was invaluable in allowing Lengale to carry out the study in as complete a manner as possible. Hopefully we've listened and observed well, our findings are grounded in reality, and our suggestions are realistic and practical.

To all of the stakeholders within and outside the project who took time from their long, busy day to participate in the interview, validation workshop and provision of their experiences and secondary information, it is our hope that the proposed interventions provided by the study team will be actively used to develop and improve small scale climate smart agriculture within the project area that will increase household income, food security and livelihoods to targeted beneficiaries.

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ACRONYMS AND ABBREVIATIONS

AEZs	Agro-Ecological Zones
AWD	Alternate Wetting and Drying
ASDP	Agriculture Sector Development Programme
CA	Conservation Agriculture
CC	Climate Change
CASARD	Conservation Agriculture and Sustainable Agriculture and Rural Development
CGIAR	Consultative Group on International Agricultural Research
CSA	Climate Smart Agriculture
CT	Conventional Tillage
ESSP	Earth System Science Partnership
FAO	Food and Agriculture Organization
FFS	Farm Filed Schools
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IFAD	International Fund for Agricultural Development
IFT	indigenous fruit tree
IRRI	International Rice Research Institute
LVIA	Lay Volunteer International Association
MDG	Millennium development goal
MICCA	Mitigation of Climate Change in Agriculture
MJUMITA	Community Forest Conservation Network of Tanzania
MVIWATA	*Muungano wa Vikundi vya Wakulima Tanzania* (Farmer's Network of Tanzania)
NFP	National Forest Programme
NT	No Till
NGOs	Non-Governmental Organizations
OPV	Open Pollinated Varieties
PFM	Participatory Forest Management
REDD	Reducing Emissions from Deforestation and Forest Degradation
RELMA	Regional Land Management Unit

RWH	Rainwater Harvesting
SACCOs	Saving and Credit Community Organizations
SOM	Soil Organic Matter
SSCSA	Small Scale Climate Smart Agriculture
SWC	Soil Water Conservation
TDBP	Tanzania Domestic Biogas Program
URT	Unite Republic of Tanzania
VEC	Village Environmental Committees

1 EXECUTIVE SUMMARY

ActionAid has been working in agriculture and food security in Tanzania since 1998 and has played a major role in promoting farmers cooperatives. ActionAid in collaboration with MJUMITA, MVIWATA, TFCG and TOAM – are implementing a project "Climate change, agriculture and poverty alleviation: putting small-scale farmers at the heart of policy and practice" in two districts of Kilosa and Chamwino. The Goal of the project is to reduce poverty and GHG emissions from agriculture through SSCSA.

ActionAid and the four partners believes that there are alternative approaches to land use and food production that would bring 'wins' in terms of CC adaptation and mitigation, but lack of awareness to small-scale farmers and policy makers on the adaptation and mitigation to CC has been the problem. Lengale Consulting Company was thus awarded a consultancy to document and draw lessons and best practices for climate smart small-scale agriculture internationally and from within Tanzania; Provide appropriate recommendations on the best practices for climate smart small-scale agriculture to be scaled up/adopted by farmers; and Provide relevant policy recommendations in relation to the climate smart small-scale agriculture to farmers in Tanzania.

Field research on climate smart agriculture intervention in the 2 project sites in Kilosa and Chamwino; Intensive Desk review of various literatures; Analysis of expert opinion, and a Validation workshop were used to collect information need to address the terms of reference.

International and Local Best Practices on SSCSA includes Conservation agriculture, Crop diversification and cropland management, Soil and water conservation/erosion control and Resilient food crop and risk insurance. Other SSCSA includes Soil fertility management, Agro forestry and Crop and tree product diversification and value addition. These SSCSA techniques and technologies vary depending on where they are applies.

Several lessons have been lent with respect to successful implementation of SSCSA. These include:

- Awareness among farmers increases successfulness of SSCSA. Thus availability of extension services is essential in scaling up SSCSA.
- Land tenure system plays a major role in adoption of various SSCSA. It has been showed farmers with no assurance of land are less likely to use inorganic fertilizers.
- Labor is one of the opportunity and variable costs affecting scaling up of SSCSA. Technologies with less labor intensiveness are favored by most farmers.
- Gender affects adoption of SSCSA in a way that female headed households were reported to be more constraints in adoption of new technologies because of lack of confidence, isolation in farmers groups and less contact with extension services.

The best practices for SSCSA to be scaled up/adopted by farmers in Kilosa and Chamwino are based situation analysis of the two districts. For Chamwino at landscape level it is recommended

to: Put in place land use planning -demarcate settlement areas, grazing and farming land; improve grazing land and consider developing pasture and fodder harvesting. It is also recommended to establish forests and beekeeping.

At farm level it is recommended to: Conserve soil moisture and control erosion; reduced tillage using magoye rippers and *In situ* RWH: chololo/zai pits, crop residue strips, earth bunds stabilized with vegetation (grasses, pigeon peas). Crop cover or soil cover – by intercropping with legumes like groundnuts, cowpeas, or lablab; Adaptive crops selection – drought tolerant varieties and crops -sorghum, millet, sunflower and groundnuts are recommended.

Kilosa district AEZ varies ranging from semi-arid to humid climate with four major AEZ (plains and plateau, low altitude to strong dissected uplands, flat alluvial plains and strong dissected mountains with steep slopes).

For Kilosa at landscape level it is recommended to improve and maintain land uses – Kilosa district have in place land use plan. At farm level it is recommended to emphasis bench or ladder step terraces especially in highlands and steep slope farms.

It had been shown it is very challenging to get the impact of CC correctly. This is due to variation in farming systems, specificity of local characteristics, and presence of multitude of stressors. This makes getting policies right for SSCSA a big challenge. At the global context CSA is supported and promoted by UN and WB as part of solution to climate change problems. At the local context Small scale CSA and even CSA in general does not feature in policy directly, although indirectly it can be traced. Both the land policy, the national climate change strategy, agricultural support development programme, are not explicit in addressing SSCSA. There is thus a need for SSCSA to be embedded in national policies and strategies.

2 INTRODUCTION

2.1 Background to the Study

ActionAid is an international anti-poverty agency working in over 40 countries in Africa, Asia, America and Europe, taking sides with poor people to end poverty and injustice together. In Tanzania, ActionAid has supported communities in Chamwino with food aid and improved drought tolerant seed varieties as one way of adapting to climate change. Exchange visit has also been undertaken for farmers to learn from their fellow farmers on the improved agricultural practices that adapt to climate change.

Recently ActionAid Tanzania, Community Forest Conservation Network (MJUMITA), the Farmer's Network of Tanzania (MVIWATA), the Tanzania Forest Conservation Group and the Tanzania Organic Agriculture Movement received funding from AcT for implementation of the project titled "Climate change, agriculture and poverty alleviation: putting small-scale farmers at the heart of policy and practice" in 2 districts of Kilosa and Chamwino.

Development of this project is based on the fact that the majority of people in Tanzania are smallholders and depends on agriculture for their livelihood. When it comes to climate variability, it is small-scale farmers who are hit first and hardest by the climate change (CC). It has been realized that land use changes particularly deforestation as a result of shifting agriculture, is the largest source of greenhouse gas (GHG) emissions in Tanzania. Investment in agriculture and agricultural policies and practices are prioritising a shift to more mechanised, fossil fuel dependent, larger scale agriculture with the aim of increasing productivity and commercializing smallholder production. Whilst this approach may increase short-term yields, it risks making small-scale farmers poorer and more vulnerable to CC.

ActionAid and the four other partners believes that there are alternative approaches to land use and food production that would bring 'wins' in terms of CC adaptation and mitigation, but lack of awareness to small-scale farmers and policy makers on the adaptation and mitigation to CC has been the problem.

2.2 Objectives, Scope and Output of the Assignment

2.2.1 Aim of the Study

The aim of this study to produce a comprehensive technical report that draw lessons on best practices for small-scale climate smart agriculture which will be shared to the stakeholders for the purpose of influencing policy and policy practices at all levels.

2.2.2 Objectives of the Study

1. To document and draw lessons and best practices for climate smart small-scale agriculture internationally and from within Tanzania.

2. Provide appropriate recommendations on the best practices for climate smart small-scale

agriculture to be scale up/adopted by farmers in Chamwino and Kilosa districts according to their agro ecological zones

3. Provide relevant policy recommendations in relation to the climate smart small-scale agriculture to farmers in Tanzania.

2.2.3 Scope of the Aassignment

Based on the Terms of reference the consultants were expected to investigate and report on the following issues that are relevant to the small-scale climate smart agriculture:

1. Assess existing coping mechanisms used by small-scale farmers (both own innovations and acquired knowledge and skills) to adapt and mitigate the impact of climate change (locally at project site, nationally and internationally)

2. To assess existing interventions that are being carried out by other stakeholders to address the small-scale climate smart agriculture

3. Mapping out key stakeholders who have been or are supporting small-scale farmers on climate change adaptation and mitigation and learn from their successes and failure

4. Assess what interventions on climate change adaptation and mitigation have worked in different agro ecological zones

5. Understand policy context at both local and national levels to see whether they are supportive of the best practices for small-scale climate smart agriculture identified from within Tanzania

6. Earmark possible opportunities for scaling existing mechanisms or best practices on small-scale climate smart agriculture by farmers

7. Look on what is existing in the literature about smallholder climate smart small-scale agriculture (empirically and theoretically) to compare different cases, link with local context to support your findings and recommendation

8. Recommend the best, appropriate and workable best practices regarding the climate smart small-scale agriculture for scale up by farmers in selected villages of Chamwino and Kilosa districts.

In addressing the objectives of this assignment and the proposed recommendations for climate smart small-scale agriculture, the Lengale Consultants took into account the following key questions:

1. Lessons learned and the best practices in terms of scaling up climate smart small-scale agriculture practices. Look into how have other initiatives successful moved beyond those trained directly by the project,

   a. Assess why others adopted the innovations and other not

   b. How can we avoid such constraints for farmers to adopt the innovations or technologies

2. Lessons learned and the best practices in terms of establishing broader support mechanism for small-scale farmers including linkages with private sector, government, research institutions

3. Lessons learned in terms of the importance of secure land tenure in improving climate smart small-scale agriculture

4. Lessons learned about how to ensure that both women and men become more resistant to climate change i.e. a consideration of gender in the context of climate smart small scale agriculture

5. Lessons learned in terms of how to identify and integrate traditional practices or local knowledge that enhances adaptation and resilience to climate change whilst also avoiding increased emissions.

2.3 Output

The major output of the study is this comprehensive technical report covering lessons learned and best practices on climate smart small-scale agriculture.

3 METHODOLOGY

To address the activities elaborated in the terms of reference (ToR) document for this assignment, four main approaches were used. (i) Field research on climate smart agriculture intervention in the 2 project sites in Kilosa and Chamwino. (ii) Intensive Desk review of various literatures. Documents reviewed included published papers, policy documents, evaluation/project reports, etc. (iii) Analysis of expert opinion, and (iv) Validation workshop.

Field research was done to document and analyse various intervention undertaken by farmers in collaboration with their partners (District leaders, elected representatives, project implementers). The consultants visited Kilosa and Chamwino where the project is being implemented. Key informants interview were conducted. The interviews among other things identified challenges and potential solutions and opportunities to achieve the goals of the project. Field observations were done for ground verification of various interventions. Validation workshop enabled the consultants to present the result of the study and receive valuable comments from participants. Comments from the validation workshop and other received from earlier version of the work have been addressed in this final report.

4 GLOBAL AND NATIONAL CONTEXT ON CLIMATE SMART AGRICULTURE

4.1 Global Context on Climate Smart Agriculture

Agriculture is an important sector for production of food and supporting of livelihood of many people in the world. In many developing countries agriculture was a target for achieving Millennium development goal number 1 (MDG 1) to reduce hunger and poverty by 50% (to less than 420 million people) by 2015. However, the numbers of hungry and poor people increased sharply to 1 billion people an increase of 250 million people during the period from 2008 to 2009 (FAO, 2009a; HLTF, 2011). The sharp increase in hunger and poverty is attributed to increased land degradation compounded by climate change impact. Decrease in agricultural food production and increased oil prices, decreased agricultural land for food production resulted in increased food prices and famine in the world (Fan, 2011). Contrary, world population is increasing, which increases the demand for food further exacerbating the food crisis and poses a threat to the ability of agriculture to feed the growing population. This global food crisis calls for attention to address climate change impact in agriculture and calls for interventions to ensure adaptation to climate change impact.

To respond to threat of not attaining MDG 1 by most countries in Sub Sahara Africa and South Asia (FAO, 2009a; Fan, 2011), which could not maintain 7% increase in GDP to achieve 50% poverty reduction (Clements and Moss, 2005), FAO (2009b) urged on focus to improve small scale agricultural systems. This is because 75% of chronically hunger and malnourished, and poor people live in rural areas of developing countries and their livelihood depends on agriculture directly or indirectly (FAO, 2009b).The extreme weather and increase in global temperature above 2^{o}C (a critical tolerance level) and increase in population with chronic hunger raise attention to consider agriculture in climate change agenda. Thus FAO developed "climate smart agriculture" (CSA) which aimed at mainstreaming climate change in agriculture (FAO, 2010) and presented in the *Global Conference on Food Security and Climate Change*, in The Hague, Netherlands in November 2010.

Climate smart agriculture is a revolutionary term that aimed at integrating climate change in agriculture and make agriculture adapts to climate change and to reduce emissions (or mitigation) that causes climate change. According to FAO (2010) climate smart agriculture is the agriculture that i) sustainably increased productivity, ii) reduce climate change vulnerability (enhance adaptation), iii) reduce emissions that cause climate change (mitigation), while iv) protecting the environment against degradation and v) enhancing food security and improved livelihood of a given society. The need to increase productivity and ensure food security for the growing population has been challenged by degradation of natural resources and recently hit by climate change impact (drought, seasonal variability, floods) (Headey, 2011).

Other initiatives to push the integration of the climate change agenda in agriculture focused on three themes: 1) Sustainable intensification and climate-smart solutions – enhancing food production while reducing greenhouse gas emissions, 2) Overcoming the barriers to climate-smart agriculture, and 3) Managing volatility and risks – technical and social-economic options for climate-smart risk management, which was presented by Wageningen University and Research Centre, to the *Global Science Conference on Climate-Smart Agriculture* co-organized by The Netherlands, the World Bank and FAO in preparation for COP 17 in Durban, South Africa in December 2011 (Wageningen Statement, 2011).

Other initiatives includes "Hunger for Action", The *2nd Global Conference on Agriculture, Food Security and Climate Change,* Hanoi, Viet Nam in May 2012, where participants (ministers, representatives of countries, practitioners, scientists, civil society, private sector) called for investment of developed countries and other partners to developing countries in implementation, scaling up, research, and technology dissemination on CSA (Hanoi Communique, 2012). Consultative Group on International Agricultural Research (CGIAR) and the Earth System Science Partnership (ESSP) emphasized on exploring how agriculture can contribute to a reduction in atmospheric greenhouse gases and at the same time, provide enough food for the global population. Therefore, the global perspective to CSA is to make agriculture resilient to climate change, contribute to mitigation and ensure food security through increased investment in agriculture and climate change.

The current system of industrial agriculture and international trade, though increased global food production has left about 1.3 billion people in rural areas in chronic hunger and poverty (Hoffmann, 2011), which necessitate inclusion of small scale agriculture system if MDG 1 is to be realized. Scaling up of CSA to achieve food security and poverty reduction, especially to the most vulnerable population require focus on smallholder farmers and rural development. According to HLTF (2011), efforts to increase small scale farmers' food productivity is a potential immediate need to reduce vulnerable food insecure population. Promotion of technologies to improve productivity and agricultural investments that include small scale farming has greater potential to make agriculture a vibrant economic sector to reduce poverty (HLTF, 2011). Therefore, globally, the position and importance of involving small scale farming system in CSA is highly recognized if adaptation and mitigation of climate change through agriculture is to be realized while achieving global food security.

4.2 National Context on Climate Smart Agriculture

Rural communities that depend entirely on subsistence agriculture are the most affected population by climate change impacts (Mary and Majule, 2009). The population groups that are most vulnerable to climate change impacts are women, children, and the disabled. In Tanzania, like most African countries, women and girls are the ones that are involved in domestic works including fetching water and food preparation. Thus, water scarcity associated with drying up of water sources pose more stress to women and children. Moreover, women form the majority of rural dwellers and depend on subsistence rain fed-agriculture as their major source of livelihood (Shemdoe, 2013). Some studies suggest that climate change in East Africa could cause more rains in some parts (weAdapt, 2011). Otherwise, where rainfall will be less, fewer crops and lower yields will be produced, thus negatively affecting household food security. Low agricultural productivity will further exacerbate less interest of youth to engage in agriculture. Women, children and disabled are the most hard-hit by effects of climate change since their ability to adapt is relatively low compared to men and youths. Therefore CSA initiatives are especially useful to these vulnerable groups. Through this the communities will be able to utilise scarce land and water resources to sustain or improve livelihood.

Farming practices in Tanzania are variable. They are shaped by many things, among them being the existing variable agro-ecological characteristics as well as socio-cultural aspects associated with the particular > 120 ethnic societies. Under such circumstances it is not easy to choose a particular SSCSA as the most appropriate intervention in a particular area within a short while. There are various reasons behind this difficulty (see Whiteside, 2011). They include the interrelatedness of the practices; availability of enabling environment (markets, inputs and credits support, infrastructure, etc.); availability, spread and uptake of knowledge (localised research, establishment of Farmer Field Schools-FFS and local adaptation); and availability and sustainability of organisation steering (availability of NGOs, funding, etc.).

It is also important to avoid confusion of the farmers by changing of, not only types of projects/interventions; but also terminologies before they are done with the existing ones. So often different organisation implement differently programs (in most cases with similar broader goals of poverty reduction) to similar farmers using different approaches. Worse still is that the programs may last for a few years and the same organisations or different ones come in to work with the same farmers before the previous project has become successful. It is therefore critical for various sector policies to be made and implemented in such a way that conflicting interventions are avoided. Under those circumstances, the approach of working as a consortium of organisations same as ActionAid and partners are doing in Chamwino and Kilosa could turn out to be particularly useful.

4.3 Impacts of Climate Change on Small Holder Farmers and Pastoral Communities

Agriculture plays a key role in Tanzania's economy, and employs about 80% of the total population who are mostly small holder farmers (URT, 1997; Mary and Majule, 2009). The majority of agricultural output is by small-scale farmers, and much of it is low input agriculture carried out at a subsistence level (URT, 1997). Climate change impact on this sector is through reduced crop yields due to drought and floods, and reduced water availability, increased incidents and severity of pests and diseases, damage caused by floods, and increased evapo-transpiration as a result of higher temperatures (Levira, 2009).

Several studies have been undertaken on the impacts of climate change on the agricultural sector (Kalra et al., 2007; Mary and Majule, 2009; Mongi et al., 2010; GCAP, 2011) with a wide range of assumptions, models and results. Some studies predict very large negative impacts on the sector (Mongi et al 2010), while others (GCAP et al, 2011) predict that impacts will be fairly minor, and that climate change may even have positive impacts in certain areas. GCAP et al. (2011) conducted a study on maize production, which is highly vulnerable to the combined effect of rising temperature and decreasing rainfall. If rainfall does not decrease, then impacts would be expected to be minor or even positive. However, if rainfall decreases by 15% by 2030 as projected by some models for some areas, then production is expected to decrease in those areas by up to 16% (1 million tonnes/year), and losses of up to 25 – 35% (2 – 2.7 million tonnes) would be expected by 2050. In a worst case scenario this could lead to costs of up to $330 million per year in 2030 and $36 – 157 million in 2050. GCAP et al. (2011) have highlighted the fact that the actual impacts could be worse, since the existing studies do not take into account the impact of extreme events and variability, and the possible increase in pests and diseases.

Another study has shown an increase in yield of Mangoes and oil palms due to increased temperature. Climate change is most likely to have a negative effect on most of the major crops in Tanzania such as rice, sorghum, beans, potatoes and cassava through many ways such as emergence and increased incidents of pests and diseases (Levira, 2009; Rowhani et al., 2011). Some researchers have also suggested that climate change will reduce yields of maize but could favour the production of other crops such as wheat, rice and barley (IEED, 2009).

In a different study it was found that throughout Southern Africa and parts of East Africa the effects of climate change on crop productivity by the 2030s will be negative, except for rice (+8%). Most affected crops will be maize (-35%) and wheat (-22%). South African maize could be reduced by 8%. Predictions for the 2050_s for Southern Africa forecast halving maize and wheat productivity. Maize yield is expected to be reduced by 10-35% in Angola, Botswana, Madagascar, Malawi , Mozambique, Namibia, South Africa, Zambia and Zimbabwe, and increased by 26% in Lesotho. Sorghum in Botswana is forecasted to decrease by 10% and 36% in the Hard Veldt and the Sand Veldt Regions, respectively. In Swaziland sugarcane productivity is expected to increase by 15% if crop water requirements are satisfied. In Zimbabwe different planting dates and scenarios resulted in a positive effect on maize productivity at early and mid-planting dates in Gweru (+160% and +12-37%, respectively), and in Beit Bridge (up to 170%) at mid planting dates. Late planting was estimated to have severe negative impacts, reducing maize yield by 40-98% (Cranfield University, 2011).

The evidence above indicates that it is still complex to predict and or estimate the impacts of CC on small holder farmers. The effects of CC seem to express locality specificity and mode of intervention properties. Given that interventions, in particular here, SSCSA need not to wait; actions are needed sooner than later. Findings suggest that a combination of the various interventions, researching for location specific suitability as well as harmonisation of policy support can yield positive results (Whitefield, 2011).

For instance; there has been a shift of Agro-Ecological Zones (AEZs) that have favoured mango and oil palm production in areas which were not suitable in the past, the highland areas of the western plateau (Kangalawe et al., 2009; URT, 2013). The major challenge here is how to cope with and capitalise on such opportunities emerging with climate change. Climate smart agriculture studies are among the best entry points towards utilisation of such opportunities. Such studies need to be as local as possible because of the sensitivity nature of environment and the associated plants and local ecology.

Livestock production is also expected to suffer as a result of reduced water and forage, and more favourable conditions for pests and pathogens (Mwandosya et al. 1998). Although pastoralists already deal with climate-related stresses in arid and semi-arid lands, climate change is undermining the resilience and stability of these pastoral systems, subjecting significant impacts on pastoral livelihoods (GCAP et al. 2011).

Small holder farming communities in Tanzania do devise some means to cope with the challenges of climate change. A study by Kangalawe et al., (2011) conducted along the great Ruaha catchment showed that the changing climate has had negative impacts on, among other aspects, land use and water shortages for irrigation, livestock and domestic uses. This compelled riparian communities in the catchment to devise coping strategies including practicing irrigation to provide supplementary water to crops, using drought tolerant crop varieties, rationing of irrigation water in farmlands, wetland cultivation, and diversification to non-agricultural activities. Despite the existence of many indicators used for local climate forecasting, there are limitations to local adaptation, including among others, poverty, institutional aspects and limited integration of climate adaptation in various sectors. The bulk of indigenous knowledge could be integrated into formal adaptation planning, and save as an important components of SSCA at the local level.

Another study indicates that farmers in central Tanzania respond to climate change by diversifying their livelihoods such as livestock production, engaging in daily wage employment, seasonal migrations, selling crops, remittances and adopting farm practices such as switching crops, using drought tolerant species, intercropping and using early maturing varieties (More, 2009). Farmers need external help and support to effectively cope with changing climate and to adapt to current and future climate change. Direct and indirect financial help from government agencies through relevant policy environment are suggested as key in assisting small holder farmers. The study further suggests that an efficient and equitable marketing system would also benefit small holder farmers in Tanzania.

Therefore there is at least some evidence that small holder farmers and pastoralists are severely affected by climate change. They have and continue to devise various means of coping with the challenges. External support especially by imparting more awareness and supplementing the communities with coping technologies has been clearly emphasised. Climate smart agriculture initiatives are therefore of paramount importance. SSCSA is a basket of technologies and therefore careful and time to time testing of interventions suitable for specific localities is a requirement. Issues of improved flow of information, pricing, market access and transport infrastructure are very central to successful implementation of SSCSA in Tanzania. For instance the road to one of the project villages in Kilosa is impassable to almost all types of vehicles including 4WDs. The positive thing is that the government of Tanzania is intensifying its investment rehabilitation and maintenance of supply roads in rural areas. ActionAid and its partners can consider lobbying with the respective district councils so as roads to project villages are given priority in order for the SSCSA interventions under implementation to maximise success. Same is for markets and pricing of crop products. With good returns, adoption and externality rates will be expected to be high.

4.4 Policy and Strategy

Various sector policies in Tanzania are silent when it comes to CSA and so is small scale CSA. This is probably because CSA is a new concept. Therefore review and mainstreaming of climate change adaptation innovations into policies will act as a strong incentive to farmers' involvement. Revisions of policies related to SSCSA need emphasis to issues which relates to CC indirectly such as in exploiting market forces through giving small farmers market control and providing an 'enabling environment'. Non-governmental organisations are likely to play an increasingly important role in building awareness and delivering appropriate technologies to farmers

At the global level CSA has gained support and earned promotion as part of a solution to climate change problems (CCAFS, 2012). CSA has gained widespread support in organizations such as the UN Food and Agriculture Organization (FAO) and the World Bank, and was backed by a number of heads of states and the former UN Secretary General Kofi Annan at the United Nations Climate Change Conference (COP17) in Durban South Africa in 2011. The rationale for promoting CSA as part of a climate change solution is that the farming techniques increase the carbon retention capacity of the soils. It has also been claimed that CSA will boost the agricultural sector and benefit the small scale farmers through improved farming techniques, and by creating a market for soil carbon credits that can provide a direct financial income.

Small scale CSA per se does not feature in Tanzania policies, however as far as the contents of CSA are concerned the policy environment offers support. There is therefore room for successful implementation of small scale CSA while advocating for the idea to be incorporated into policies. For example; it is well known that CSA is an innovation which required investment at least in form of more labour. A small scale farmer who is poor and food insecure will most likely be reluctant to practice CSA innovations instead of solving the immediate problems. Whether more innovative farmers are more food secure, or whether food insecure farmers simply cannot invest in new technologies was analysed in a 2011 study of 700 randomly chosen farm households across five sites in Ethiopia, Kenya, Tanzania and Uganda (WAC, 2011). Despite the wide range of livelihoods, climate and institutional settings across these sites, their findings showed that both innovation and food security significantly influence each other. The policy implications for each situation differ. If food security is dependent to some extent on the ability or willingness to innovate, scaling up should consider existing innovations and the associated institutional, technical, management, finance and market setups. If food insecure farmers are unable to innovate then safety nets such as cash, credits, insurance products or other goods, will be essential before they can make significant changes to their farming practices (WAC, 2011; Kristjanson et al., 2010).

In Tanzania for instance through *Kilimo Kwanza* the government emphasise and injects significant amounts of money to support agriculture most of which run by small scale farmers. More extension workers have been sent to at least ward level, cooperatives have been revitalised to give farmers stronger marketing power and there are supportive environments for farmers to establish and manage their own financial institutions such as SACCOs. These are a few examples of policy environments in which a poor or food insecure farmer can get some relief and hence incentivised to invest in CSA innovations as suggested in the WAC, (2011) and so can be taped and used in Kilosa and Chamwino.

Some specific policy or government programmes and strategies with a relationship to CSA are highlighted below. Success of a SSCSA needs integration of approaches from many sectors and hence it is a good idea if advocacy issues involve a holistic strategy. The policies highlighted below are just a few and does not mean that the ones left out are not important.

4.4.1 The National Land Policy (1997)

This policy is considered key when it comes to climate change and adaptation, given the fact that all activities related to adaptation has to be implemented on land. SSCSA can be both an adaptation and a mitigation innovation. CSA is an investment on land and a requirement in this policy is an enabling environment for farmers to have tenure rights over land.

Tenure regimes in Tanzania and Africa in general are diverse and change over time. Some consider individual titling to be the best options (Feder, 1987), but there are possibilities for improved community managed individual schemes and limited access communal schemes. The positive gains from titling in Africa have often not materialised for poorer farmers. In Kenya for instance; smallholder agriculture (average 0.3ha) has shown it can be integrated into carbon finance. One such type involves mixed cropping systems across 86,000 hectares, using a registered association of 80,000 farmers as the aggregator. Tenure reform is sensitive, takes considerable time and must pay particular attention to the needs of the most vulnerable in rural areas i.e. women and the emerging youth generation. Small scale farmers would need assurance of right of ownership of land where they have to invest in CSA. For instance problems which come along with land grabbing in Tanzania is subjecting young villagers landless and causing conflicts in some areas (Nelson, et al., 2012).

4.4.2 The Agriculture and Livestock Policy (1997)

The Agriculture and Livestock policy signifies that agriculture is critically dependent on environmental resources such as land, water, forest, and air. There is no substantial voice about SSCSA in the agricultural policy. The policy shows that climate change has serious impacts on agriculture and livestock sectors and that agricultural practices could have a contribution on climate change through slash and burn practices. Through one of its objective which is to ensure food availability, the policy encourages more food production but it does not clearly warn doing this through area expansion which in many cases is done at the expenses of the existing vegetation cover (clearing vegetation) and extension of cultivation to the sensitive and marginal lands such as wetlands hence contributing to climate change as more carbon dioxide is added to the atmosphere. CSA needs to be incorporated into the policy to ensure that food production is done through methods which takes care of mitigation and adaptation of climate change while at the same time improving the livelihoods of the poor.

4.4.3 The National Climate Change Strategy

A national climate change strategy is in the final stages of preparation. The final draft of the strategy recognises that agriculture is the most vulnerable and severely affected sector of the country's economy to climate change (URT, 2013). The strategy notes that the effects of climate change on agriculture includes crop failure, increased incidents and severity of pests and diseases as well as shifting agro-ecological zones (AEZs). The strategy proposed interventions are among the tools found in the climate smart agriculture package. As highlighted in the strategy they include: promoting conservation agriculture technologies e.g. minimum tillage and efficient fertilizer utilization, promoting best agronomic practices, promoting integrated nutrients management and addressing soil and land degradation by promoting improved soil and land management practices/techniques. It will be quite important if climate smart agriculture come out clearly in the agricultural sector policy.

The awareness of the farming community on the impacts of climate change and their ability to adapt needs to be supported (Levira, 2009, Rowhani et al., 2011). Therefore, strong guides such as policies and strategies to help carrying out appropriate farming interventions and practices such as climate smart agriculture are needed. Small scale CSA is not specified in the strategy. This is important to feature since most of Tanzanians are small holder farmers. In an Annual General Meeting (AGM) for MVIWATA held at SUA in Morogoro, the issue of the possibility of small scale farmers to be forgotten in the *Kilimo Kwanza* campaign was strongly warned (ESAFF, 2009). Such advocacy and voicing is still needed from various stakeholders for small scale CSA to not only feature in policies but also be implemented at the farmers' level.

Another issue of interest in the strategy is the fact that financing of climate change interventions is largely by external/international resources. Local funding is outlined just as potentially available from the government's collective basket. There is a need to strengthen local financing in order to locally designed priorities based on needs. The government in collaboration with the industry and business can mobilise funds if enough awareness is created alongside a strong policy guideline.

4.4.4 The Tanzania Agriculture Sector Development Programme (ASDP)

This programme was formulated from 2002-2005 and attempts to address issues such as enabling farmers to have better access to and use of agricultural knowledge, technologies, marketing systems and infrastructure. In so doing, ASDP contribute to higher productivity, profitability, and farm incomes. Promoting private investment in partnership with public sector based on an improved regulatory and policy environment. It is well known that agriculture will be one of the hardest-hit sectors by climate change (NAPA, 2007). Therefore ASDP should mainstream climate change, particularly adaptation and mitigation measures. But analysis shows that climate change was not integrated in this programme. This shortcoming is amplified by the ASDP review conducted in 2008, which indicates that climate change was found to have significant impact on crop production, water availability for irrigation and other uses (ASR/PER report 2008). However, integration of adaptation to climate change in planning and implementation of ASDP interventions has not been well covered.

4.4.5 The National Forest Programme (NFP, 2001-2010)

The NFP is an instrument meant to implement the National Forestry Policy. This was developed in order to address the challenging responsibilities and to increase the forest sectors contribution to the national economy and more so in poverty reduction. The NFP document discusses crosscutting issues, linkages and implications and underscores the need for formal cross-sectoral coordination. Similarly, the NFP document stresses that the government of Tanzania has realized that more comprehensive approaches are needed to ensure sustainable forest management in the country. However, climate change is not discussed and addressed comprehensively. The document only outlines obligations, opportunities and implications of international initiatives to Tanzania's forest management in the context of the international treaties and initiatives such as United Nations Framework Convention on Climate Change (UNFCCC), the UN Conference on Environment and Development (UNCED) and the Convention on Combating Desertification (CCD), but without providing a clear roadmap on how climate change related issues would be addressed. This is a notable shortcoming given the clear linkages between forestry resources and climate change; and so is with agriculture.

4.4.6 Climate Smart Agriculture and Governance

Tanzania has two spheres of government; central government and local government. In the central government, the roles of ministries are confined to the core functions of policymaking, regulation, and monitoring and evaluation of service delivery by local governments, service boards and/or executive agencies, NGOs and the private sector. Local government comprises of urban and rural authorities. The former are responsible for the administration and development of urban areas ranging from townships to municipalities and cities. Rural authorities, commonly known as district councils, form the second category. Both categories of local authorities are responsible for planning, financing and implementing development programmes within their areas of jurisdiction.

In Tanzania, District and Village authorities intervene environmental challenges though Village Environmental Committees (VECs). The committees are responsible in formulation and foreseeing various by laws. Before the bylaws are enacted, they must be approved by the village assembly where all villagers participate. Climate Smart Agriculture is a relatively new intervention in many parts of the country. The Kilosa District Agricultural Development Plans (DADPs) is yet to incorporate issues of Climate Smart Agriculture (CSA). It is only through the REDD project interventions by TFCG that some farmers in the project villages are aware of Conservation Agriculture (CA) and not CSA per see. In Chamwino, the District Council has in place a program to help farmers to cope with the harsh environment. It is the only District which produces and to provide farmers with improved seeds for the major crop, sorghum; at a subsidised price. In a way this helps farmers to cope with the problems of Climate Change. The District Plans in Chamwino includes training of farmers on the effects of climate change. However, as is in other Districts, it is high time Climate Change and in particular CSA issues are stepped up especially through practical implementations in the field.

4.4.7 Climate Smart Agriculture and REDD

The effect of climate change on agriculture and forestry has a relationship. This is especially so for small scale farming that tends to clear new lands for agriculture as soon as there is a decline in land productivity due to loss of soil fertility. Farmers will rush to secure farming plots close or inside forests where the environment is relatively cool often with natural streams available to irrigate their crops and with natural soil fertility (TFCG, 2012). FAO (2012) establishes that at the same time, the potential role of forests in reducing global greenhouse gas emissions and mitigating climate change is attracting considerable international interest.

Current negotiations to establish an international climate regime acknowledge the critical function that forests and other sources of biomass play in the global carbon cycle. By integrating forests and agriculture in global efforts to address climate change, the REDD+ mechanism seeks to maintain and even increase forest carbon stocks. The mechanism seeks to stop the current trends in deforestation and forest degradation and address all the drivers that contribute to deforestation and forest degradation. One of the ways it does this is by improving and strengthening sustainable land use policies in both the forest and agricultural sector.

Established in 2010, REDD+ is defined as an instrument that "encourages developing country Parties to contribute to mitigation actions in the forest sector by undertaking the following activities: (a) Reducing emissions from deforestation; (b) Reducing emissions from forest degradation; (c) Conservation of forest carbon stocks; (d) Sustainable management of forest; (e) Enhancement of forest carbon stocks, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances" (FAO, 2012).

Promising cases of implementation of REDD programs are reported from Bolivia where through reduction of slash and burn activities, over 1 million tonnes of carbon equivalent have been avoided in less than 10 years from a 800,000 ha land (Johns and Johnson 2008). Although successful; the project has been criticized for side-lining local farmers and revenues generated going to government agencies instead of forest communities. These are some of the issues which are expected to emerge as challenges in REDD project areas and therefore needing careful attention. For instance; without appropriate and significant compensation to the forest adjacent community, majority of them poor small scale farmers, the probabilities of leakages to increase are high. Studies from Indonesia (Noordwijk et al., 2008) suggests that REDD schemes must reward good performance and incentivize improved performance compared to reference scenarios, and adequately compensate agents that suffer losses from changed practices. Risks of leakage undermining the system can be minimised by increasing the scope of systems that track land use change and offer conservation incentives (Murray 2008) including small scale CSA.

It has been argued that the context about REDD is not new for Tanzania following successful implementation of Participatory Forest Management (PFM) and other components of REDD for many years (Milledge, 2009). The National Framework for REDD was launched in November 2009 and the REDD Strategy and Action Plan has been developed by the National REDD Task Force. Also Tanzania is one of the initial countries under the UN REDD programme which target to assist developing countries get "REDD ready" and support appropriate measures (Milledge, 2009).

In order to meet REDD carbon accounting needs, national forest resource assessment is currently being implemented countrywide by National Forestry Resources Monitoring and Assessment (NAFORMA). Other achievements in Tanzania include capacity building through UN-REDD Tanzania Program and learning from FCPF Readiness process (R-PP prepared); a National Carbon Monitoring Center (NCMC) was recently announced to be hosted at SUA (Norwegian Embassy-Dar es Salaam, 2013); process to have a National REDD Fund and process for PES with emphasis on H2O & Biodiversity values. The REDD policy is considered by the Government of Tanzania a viable option that can provide opportunities for the country to meet its obligations of managing her forests and woodlands on a sustainable basis and at the same time respond to poverty reduction initiatives accordingly (URT, 2009).

Therefore, successful implementation of CSA is strongly linked with REDD with potential to address some of the REDD and REDD+ initiatives challenges through calling for a multi-focussed approach that incorporates cross-sectoral model inputs. The priority of CSA is to explore adaptation and mitigation of climate change impact without compromising food security and peoples' livelihood. At a global scale, both intensification and extensification of farming are currently having a significant negative effect on the environment; depleting the natural resource base upon which we rely (MEA, 2005; IAASTD, 2009). The need to reduce the environmental impacts while increasing productivity requires a significant change in the way agriculture currently operates (WEF, 2010). Climate-smart agriculture has the potential to increase sustainable productivity, increase the resilience of farming systems to climate impacts and mitigate climate change through greenhouse gas emission reductions and carbon sequestration (FAO, 2010). It could be a good idea to recognise that small scale CSA is especially important for Tanzania due to the nature of majority of its farmer being small holder and poor.

5 ANALYSIS OF INTERNATIONAL AND LOCAL BEST PRACTICES ON CLIMATE SMART AGRICULTURE

A smarter outlook of doing agriculture is needed to ensure not only resilient of agriculture in productivity but also adaptation and mitigation of climate change impacts. To achieve CSA there is a need to ensure proper management of all resources needed in agriculture such as soils, water, genetic resources, pest and disease control that will promote increased productivity, protect the environment, adapt and mitigate climate change. The performance of these practices to achieve all four objectives of CSA will vary from place to place and sometimes crop to crop. The major threat to agricultural productivity and sustainability is land and soil degradation such as soil structure destruction, decrease SOM, nutrient mining and nutrient imbalances, reduced microbial activity and prevalence of pests, diseases, and weeds. Therefore, the crucial step towards CSA is sustainable land management and cropland management to increase productivity, reverse degradation and increase resiliency of agriculture to climate change. Below is an inventory of CSA best practices and technologies.

5.1 Conservation Agriculture

Conservation agriculture (CA) is a combination of wide range of tillage and cropping practices/technologies that aims at ensuring minimum soil disturbance, adequate soil cover, and mix or rotation of crops so as to reduce soil physical and chemical degradation (IIR and ACT, 2005). A combination of practices such as conservation tillage (reduced/minimum or zero tillage), mulching, intercropping, crop rotation are core in CA. According to (Bwalya, 2006) CA hold great promise to break vicious cycle of poverty due low productivity and food insecurity caused by land degradation that makes the society vulnerable and hence poor. The entry point to break the cycle is through CA's positive impact on preventing/reducing land degradation to form a sustainable and viable production system that will improve livelihood of many rural communities in Africa. The CA core technologies/practices include:

5.1.1 Soil disturbance/Tillage practices

The agricultural soil is usually disturbed by tilling or cultivating so as to loosen up the soil to enable easy root penetration and water infiltration for adequate crop growth. Other advantages of soil disturbance is discouraging weeds growth and reduce weed competition with crops at early stages of crop development. However, too much soil disturbance and inappropriate tillage methods has led to excessive removal of soil surface cover, destruction of soil structure and compaction, rapid losses of SOM and susceptibility to water and wind erosion during early stages of before full canopy cover.

Historically, invention of cultivation implements such as mouldboard in the 11th century in Europe, followed by agricultural mechanization using tractors with multiple implements by early 1900 enable intensive cultivation in many agricultural soils in Europe and America (Huggins and Reganold, 2008). However, between 1931 and 1939, a dust bowl era took away precious top soil, which was made vulnerable by ploughing, was witnessed in the southern plain of US resulting in farm degradation and crop failure (Huggins and Reganold, 2008). Thus, the need to reduce intensive cultivation and ensure soil cover was realized as early as in 1940's.

Conservation tillage: is the tillage system that achieve minimum soil disturbance and leave organic residue on the surface of the soil to ensure at least 30% of surface soil cover (FAO, 1993).

No till (NT) is conservation tillage achieved by no soil disturbance at all, i.e. zero tillage. Zero tillage is achieved by no tillage at all; hence planting is done by no-till planter capable of placing seeds at appropriate depth in the soil and ensures adequate seed-soil contact required for germination. The advantage of NT is that it ensures surface soil cover by leaving residue on the surface, conserve soil moisture, and increase SOM in the top soil. However, NT in compacted hinders root development after seed germination especially during first years of no till, and reduced infiltration at early stages of NT. Weed pressure is also a problem in case the surface mulching is low in NT system . In the zero tillage or NT practices weed control depends solely on herbicides.

Reduced tillage is another conservation tillage achieved by minimum disturbance of the soil in areas where seeds will be planted, either in rows or planting holes or small basins. Reduced tillage evolved in attempt to solve some disadvantages of NT systems, and improve root growth and penetration and water infiltration while maintaining surface mulch and slow down decomposition of organic residues. Reduce tillage can be achieved through:

Ripping - is the most popularly advocated conservation tillage technology in tropical soils. Ripping is achieved by using a ripper that breaks clogs along the planting rows, leaving the spacing between rows undisturbed. The ripped area also acts as micro-catchment to collect rainfall water and increase infiltration. Ripping can be done by using tractors or oxen.

Small Planting basin – is reduced tillage practices where the farm is cultivated in small fixed/permanent basins with 30-cm long and 20-cm deep, using narrow, deep and strong hand-hoes. The basins are cultivated at 70 cm spacing along the planting rows and 90 cm apart between rows to form rows of small basins. Seeding and fertilizer application is done in each basin. For maize 8, to 10 seeds are planted in a basin, while 10 to 20 seeds of beans are planted per basin. The basins are the only spot where soil is disturbed, hence helps to conserve soil and moisture. The basins also act as in situ rainwater harvesting and store water in the soil profile.

5.1.2 Successful International Best Conservation Tillage Practice and Lesson Learnt

In the early 1940's no tillage had a lot of challenges, but through other inventions such as herbicides, and jab/no-till planters made no-tillage practice widely adopted in the US and Brazil (Huggins and Reganold, 2008). Today USA, Brazil and Argentina have largest crop lands under no tillage or reduce tillage in the world. According to FAO statistics only 7% of the world crop land is under no-till, out of which 85% are in North and South America. No tillage has some challenges. No till has been reported to increase soil bulk density in the top soil at least in the short run. Studies in the US by Diaz-Zorita et al. (2004) and Amuri et al. (2008) demonstrated that there was increase in soil bulk density in the top 15 cm soil during the first two to three years under NT in silt-loam soils of Kentucky and eastern Arkansas, respectively, compared to conventional tillage (CT) by disking and harrowing.

However, the bulk density decreased more under NT than CT after third year of treatment in silt loam soil of eastern Arkansas (Amuri et al., 2008). Amuri and Brye (2008) reported greater increase in penetration resistance in the top 5 cm during the first 3 years under NT compared to CT in the silt loam soils of eastern Arkansas, USA. Logsdon and Karlen (2004) reported no differences in bulk densities between no tillage and ridge tillage system in deep loess soils of western Iowa. These results suggest that soil compaction due to NT is a short term trade off, that may be overcome in the long run due to increased aggregation and soil organic matter. Verkler et al. (2008) reported slower decrease in soil moisture under NT than CT after irrigation and rainfall event in the silt loam soils of eastern Arkansas, USA. These results show that conservation tillage helps to improve soil structure and conserve moisture by slowing down evaporation losses.

Photo 1: No till maize planted on wheat residue in Ohio, USA. Wheat residues provide soil cover and suppress weeds.
Source: Ohio State University

In Zambia, conservation farming, ripping using *magoye* ripper is done during dry season (soon after harvest) using oxen or tractor. Ripping is done along the rows where seeds will be planted; leaving the space between rows undisturbed, and covered with surface crop residues. Ripping helps to loosen compacted soil, reduce erosion, reduce evaporation moisture losses, provide soil cover, harvest rain water in the rows/basin and ultimately increase crop yield. Ripping is also performed in combination with accurate measurement of fertilizers and liming application along the ripped rows and reported to increase maize yield to 7.0 t/ha compared to 2.8 t/ha under conventional tillage (Aargaard, 2009).

The major limitation to ripping as practiced in Zambia is that it is done during dry season; hence it is laborious and difficult for women, making the practice being mostly men work. Another limitation experienced in Zambia is minimal surface residue cover due to competitive demand and use of residue for feeding/grazing livestock. Therefore, to ensure surface soil cover and increased SOM other strategies to provide feed for livestock should be in place.

Small planting basin technology has also been successful in Zambia conservation farming for maize and cotton production. The small planting basins are prepared during dry season. The major limitation of making planting basins during dry season is labour requirement that limits use of this technology among women.

Photo 2: A narrow, deep bladed and strong hand hoe (*chaka hoe, or ngwamba*) used to dig small planting basins.

Source: Conservation Farming Unit (CFU), (2007)

5.1.3 Successful National Best Conservation Tillage Practices and Lesson Learnt

In Tanzania, like many African countries indigenous tillage practices has been no till or reduced tillage such as *kuberega*, preceded by burning of crop residues to reduce weeds and other pests. Burning of crop residues makes traditional *kuberega* unsustainable practice and contributes to GHG emissions. Agricultural revolution in Tanzania soon after independence advocated tillage practices to produce very fine seed bed and increase water infiltration using hand hoes, mouldboard plough, which was replaced by disc plough. These conventional tillage practices are still widely practiced to date. The conventional tillage practices contributed to soil erosion and excessive moisture losses due to lack of soil surface cover (by crop residues) and loss of SOM due to fast decomposition of incorporated organic residues during cultivation. Excessive moisture losses due to excessive soil disturbances are the most serious problem in semi-arid areas or low rainfall areas.

In Tanzania, NT was introduced in 1980's in Arumeru district Arusha by SCAPA program in collaboration with Regional Land Management Unit (RELMA) and continued through early 1990's by Conservation Agriculture and Sustainable Agriculture and Rural Development (CASARD) with support from FAO in Arumeru, Karatu, and Bukoba. Effort put in conservation tillage by these programs fetched limited adoption due to lack of, and high cost of NT implements such as NT planters and high cost and unavailability of herbicides by then (Sheto and Owenya, 2007). This shows the need to link input suppliers as one of stakeholders involved in farming implement value chain. The remaining challenge in NT system is heavy reliance in use of and effectiveness/quality of herbicides that can potentially results in shift of weed diversity and development of herbicides resistance.

Case study: CA a labour saving technology in Babati and Karatu, Tanzania by BishopSambrook et al., 2004

Conservation tillage was introduced in Babati and Karatu in the late 1990s by and focused on vulnerable households. Two principle components of CA introduced were reduced tillage and cover crops (RTCC). It was revealed that it is possible to make significant savings in labor inputs with RTCC technologies and practices. Labour saving can be achieved shorten time taken for a particular task, and the need for fewer people to operate and fewer draught animals. The labor saving benefits were gender specific,. For example, men benefi t from time saved with using draught animals or tractors more efficiently while women benefited from draught animal-no-till or ripper planter that reduce planting activities and women also benefited from reduction of time spent in weeding. However, both were perceived to be expensive in comparison to conventional tillage implements. It was concludes that although CA was driven by land degradation labor saving is also crucial especially when the impact of HIV and AIDS on severe labour shortages are considered.

Kuberega – has potential to be best practice if the weeds slashed are not burnt, and seeds are planted with no-till, which is analogous to FAO no till with at least 30% residue cover (SUSTAINET, 2010). Later at early stages of crop development the soil may be disturbed by cultivations or use of herbicides to remove weeds. *Kuberega* is an indigenous technology common in eastern and central zones (Shetto, 1999). Non-burning of organic/plant residues can conserve soil and moisture due to residues form a surface mulch to cover the soil while non-burning reduce GHG emission (Mendoza and Samson, 1999; Amuri et al., 2008). Weeding should be done when there is adequate soil moisture if needed because weeding by cultivation harness drying of soil (Owen et al., 2007). In presence of enough mulch to cover the soil weed germination will be suppressed.

Photo 3: Slashed residues left on the soil surface to dry before burning and cultivation during farm preparation in moderate to steep slope areas of Kilosa District.

Photo by N Amuri 2013

Ripping has also been effective in Tanzania, especially in semi-arid areas of Dodoma and Karatu since its introduction in 1990s using oxen (Tumbo et al., 2011). Lay Volunteer International Association (LVIA) introduced ripping in Chamwino district. Therefore, in areas where rainfalls are low and unreliable there is great potential for adoption of this technology. Mkoga et al. (2010) reported greater ability of conservation tillage (ripping and crop residue cover) ability to reduce the acute and long intra-seasonal dry spells and increase productivity than conventional tillage in semi-arid area of Mbarali, Mbeya region. Because climate change projections shows reduced rainfalls in Tanzania due to increase in temperature (NAPA, 2007), reduced tillage especially ripping should be disseminated to wide areas. In Karatu and Arumeru district ripping in combination with cover crops (lablab or pigeon pea) gave higher maize yield (1.9 to 2.0 t/ha) than direct seeding with jab planter (No till) which gave 1.7 t/ha, while ox-ploughing gave lowest yield of 1.3 t/ha (Mkomwa et al., 2011). About 61% of farmers in Karatu and Arumeru preferred ripping and cover crop over no-till with direct planting by jab planter (Mkomwa et al., 2011). This shows that ripping has great potential for adoption among conservation tillage practices.

Photo 4: Cleared farm with all surface residues removed and burned in slope areas of Kilosa District.

Photo by N. Amuri 2013

Another conservation agriculture practices in semi-arid area of Karatu District Tanzania using ripping and cover crops [lablab and pigeon pea (Cajanus Cajan)] with neither inorganic nor organic fertilizers reported to increase maize yield over three years from 2.0 in the first year, to 7.2 in the second year and 4t/ha in the third year (Mariki, undated). In this project the conservation tillage was done by ripping using rippers, while planting was done by either jabber or Draught Animal Planter, and maize and cover crops were inter cropped. The conventional tillage in the area was ploughing twice, and intercropping maize with common beans and pumpkins. Both maize and legume seeds (lablab and pigeon peas) were harvested. Although there was increase in yield over three years, the non-use of fertilizers especially P fertilizers may lead to decline in yield in the long run due to P mining which will induce P deficiencies in soils. The Leguminous cover crops will supply N through biological N fixation especially is used as green manure. Harvesting of legume seeds will export significant amount of P and other nutrients and may result in yield decline in the long term.

Both no-till and reduced tillage will provide maximum benefit in terms of increased crop yield if done in conjunction with residue management (Kaumbutho and Kenzle, 2007). Before adopting no-till or reduced tillage it is important to break the hard pan, if any. Conservation tillage and appropriate residue management benefits that merits high productivity includes reduced soil erosion, improve soil-water retention, and/or reduced excessive water evaporation, and increase SOM due to reduced rate of decomposition of organic residue (Kaumbutho and Kenzle, 2007; Sheto and Owenya, 2007; Six et al., 2000). Adoption of CA in the project areas was reported to be low mainly due to lack of training, poverty and land ownership (Kaumbutho and Kenzle, 2007).

To achieve these benefits efficient weed management by herbicides and other pest and diseases is required (Shetto and Owenya, 2007). Weather condition has also reported to affect the performance of tillage practices, both conventional and conservation tillage (Mkoga et al., 2010), where in seasons with rainfall greater than 770 mm crop yield under conservation tillage was lower than under conventional tillage and there was no differences in soil moisture between the two tillage practices. Contrary, in low rainfall season yield was greater under conservation tillage than conventional tillage (Mkoga et al., 2010). Thus, conservation tillage has ability to resolve intra seasonal dry spell. These results shows the need to use integrative approach combining more than one CA technologies to reduce erosion, conserve moisture and enhance soil fertility to make agriculture adoptive to climate change.

Case study: Conservation Agriculture in Laikipia District, Kenya as documented by Kaumbutho and Kienzle (2007):

Laikipia is a low rainfall semi arid area with red volcanic soils located on the leeward site of Mt Kenya. In this district the CA was introduced in 2000 through 2003 by the Semi-Arid Rural Development Programme (SARDEP), while Kenya Agricultural Research institute (KARI) introduced legume cover crops, and CA-SARD project, which started in 2004 focused on conservation agriculture. All programs/projects targeted small scale farmers

Small scale farmers conventional practices includes use of hand hoe to cultivate and weeding and crop rotation, but did not have any planned rotation; crop rotated/intercropped includes beans, maize, vegetables – cabbage, tomatoes and other leafy vegetables. Choice of crops to rotate/intercrop depends on availability of land or ability to hire land, availability and affordability of seeds. When they intercrop, the legumes are harvested earlier by uprroting the palnt and threshing is done at home. The residues are either burned or fed to animals. Thus do not add any fertility to the soil.

Large scale farmers' crops include wheat, barley and canola, and conventional practice was disking with tractors. One successful large scale farmer used to cultivate ha out of 2000 ha he had, and expericned decline in soil fertility and high fertilizer requirements, high costs of production due to high oil prices, increased soil erosion, development of hardpan, and decline in wheat prices in the Common Market for East and Southern African (COMESA) countries.

Adoption of CA
Farmers adopted one or more element of CA. Conservation tillage was mostly adopted by large- and medium- scale farmers because of reduced costs of production.

***Small scale farmers** were slow in adoption of CA practices, which was attributed to their slow response to market dynamics, due to being poor, with no awareness of enterprise returns and poor record keeping. Thus, it was difficult to convince small scale farmer not to plough or weed even after years of intervention of promoting CA in Laikipia.*

***Large scale farmers** saw the Australian No-till planter from a friend in 2002 and acquired information on how to get one. In 2003, the farmer acquired no till planter and started practicing NT in 615 ha in 2003 and expanded to 1927 ha in 2004. The farmer acknowledges that the benefit of NT was not realized immediately, until the soil cover was enough. After adopting NT, the farmer did not allow grazing in the field, but allocated portion of land for grazing and started balling fodder. Weeds were controlled by glyphosate herbicides soon after emergence and before flowering to reduce weed seed bank. Sub-soiling to break hard pan was done every after 4 to 5 years.*

Benefit of CA realized by large-scale farmers:

- *Reduced cost of production by 55% due to reduced fuel power for cultivation by tractor*
- *Increased crop yield due to accumulation of resides that increased moisture retention and yield variability due to erratic rains*
- *Other crops such as sorghum and sunflower were included to increase crop diversity, and noted sorghum does better with NT*

Challenges of CA experienced by large scale farmers:

- *Frequent insects and diseases infestation in NT that before due to crop residues cover, and hence increased frequency of spraying pesticides*
- *Herbicides resistance of couch grass (Cynodon dactylon) and Amaranthus spps, which necessitate cultivation to control them, hence disrupt some benefits of NT*
- *Emergence of new weeds due to increased soil moisture*

5.2 Crop Diversification and Cropland Management

Cropland management includes all technologies that utilize crop diversity to ensure soil cover using cover crops, resiliency to climate change and minimize the adverse effect of mono-cropping, especially build-up of pests and diseases. A number of options to diversify crops are:

Cover crops are crops planted with the aim of providing soil cover during and after growing season of the main crop so as to minimize soil erosion and conserve moisture. These crops are usually creeping crops that will not compete for light with the main crops. The cover crops are usually intercropped with the main crop and can be left to cover the soil even after harvesting the main crop. The use of legume cover such as lablab and *mucuna*, has additional advantage of adding nitrogen in the soils especially when used as green manure. However, other nutrients such as P should be supplied to avoid nutrient completion with the main crop such as maize (Carlo Acosta, 2009).

The use of cover crops help to loosen up the soil (reduce compaction), conserve moisture, reduce soil erosion, reduce labour, and assumed to increase N in the soil (Mariki et al., 2011). The challenges in using cover crops is when the cover crops cannot be used as food crop or if have no any other uses, it provide less incentive for adoption. Also the seasons can be challenging especially in areas with only one short rain season, the cover crops may not provide soil cover throughout the year. However, even in these areas the soil will be covered at least during the growing season.

Crop rotation: is another crop diversifying practice. To sustainably manage cropland, crop rotation is recommended to achieve crop diversity, reduce incidences of pest and diseases of particular crop (SUSTAINET, 2010). Choice of crops to rotate should consider differences in growing habits, nutrient requirement, and disease and pests susceptibility/resistance to ensure maximum benefit of crop diversity (Table 1). A difference in root growing habits (tap roots and fibrous roots) is important to achieve natural tillage due to difference in rooting depth among crops rotated.

Table 1: Potential N-Fixing Cover Crops and Their Ecological Adaptation

Types of cover crops	Ecological adaptation	Nitrogen added*	OM added	Reference
Lablab (*Lablab purpureus* (L.), Synonyms: *Dolichos lablab* L	Tropical legume, tolerate low fertility, adapted to wide range of soil types, tolerate drought once established	220 kg N/ha	2.5 t/ha	Valenzuela, 2002
Velvet bean (*Mucuna pruriens*)	Tropical legume originated from India	150 kg N/ha	35 t/yr	Carlo Acosta, 2009
Cowpea (*Vigna unguiculata*)	Tropical legume, hot moist climate, slightly tolerant to low fertility, shade, heat, and dry conditions	130 kgN/ha	2.8 to 5.1 t/ha/yr	Valenzuela, 2002)

*when used as green manure

5.2.1 Successful International Best Cover Crop Practices and Lesson Learnt

The use of cover crops in farming system benefited farmers in semi-arid areas of Western Kenya. Two season experiment in striga infested semi-arid areas of Western Kenya showed that cover crops using *lablab* and velvet beans *mucuna (Mucuna pruriens)* in combination with reduced tillage gave significant greater maize yield of 2.37 to 2.96 t/ha compared to no cover crop and conventional tillage which yielded 1.75 t/ha (Nzabi, undated). The advantage of yield increase is due to reduced moisture stress, erosion and *striga* infestation in maize grown under cover crops compared to conventional tillage with no cover crops.

In Zambia crop rotation is practiced in combination with conservation tillage, where the farm of a household is divided into 3 or 4 fields, where cereals such as maize or sorghum or millet is planted in the first field, legumes (common beans, soybeans, cowpeas, green grams, groundnuts, sun hemp-as fallow crop) is planted in another field, and commercial crops such as cotton, sunflower or sesame is planted in the third field. In the following year, the cereals will be planted in the legume field, and legumes will be planted in the cereal and non-legume plot (Aargaard, 2009).

Experience has shown that although crop diversity reduces risks of crop failure, it has not lead to increase in soil organic matter and crop residue cover due to nature of crops rotated. Rotation with cotton that require burning of residues removes all the residues accumulated from previous rotation. Alternative and competing use of crop residues to feed/grazing livestock is the major challenge to maintain crop residues to cover the soil. Use of low biomass crops like maize, and legume is another factor limiting increase in residue cover and SOM in the farming systems where they are practiced (Amuri et al., 2008; Havlin et al., 1990). Thus, to achieve soil cover and increase in soil organic matter crop rotation must consider the amount of biomass produced by a given crop and alternative strategies to feed/grazing livestock.

Best agronomic practices are crucial to ensure crop productivity and benefits from soil and water, and soil fertility management. Agronomic practices such as timely planting, plating at right spacing and timely weed control and integrated pest management should be adopted, if increased yield to ensure adaptation to climate change is to be realized. One of successful and promising IPM technology using biological stem borer and moth control is push-pull technology (PPT) using insect repelling (PUSH) and attracting (PUSH) plants to minimize excessive use of insecticides in maize as illustrated in Box 3. However, before wide dissemination of push-pull technology, adaptability of desmodium and napier grasses in the targeted areas in Tanzania need to be tested.

Box 3 Biological pest control: Push Pull technology by Biovision (2010):

A push-pull technology for pest management is a biological pest control using desmodium plants (Pennisetum purpureum), a legume fodder and an aromatic plant that repel (PUSH) egg-lying stem borer in maize inter cropped between maize rows and nappier grass that attracts stem moth away from maize (PULL). The technology is environmentally friendly and cost effective compared to reliance on heavy use of pesticides to control these pests in maize production. Additional advantage of push-pull is biological N fixation, increased availability healthy fodder for feeding livestock using both desmodium and nappier grasses, which in turn and increase manure that can be used to improve soil fertility (Khan et al., 2008) in addition to increased animal productivity. Thus, push pull enhance adaptation and resilience of small scale farming to climate change impact.

This technology is being disseminated to small scale farmers around Lake Victoria in Kenya using farmers field school and extension products. The provision of starter seed (desmodium and naiper grasses) and required instructions was adapted by this project to minimize variable, and transaction costs, as the desmodium was not common in the farming systems around Lake Victoria.

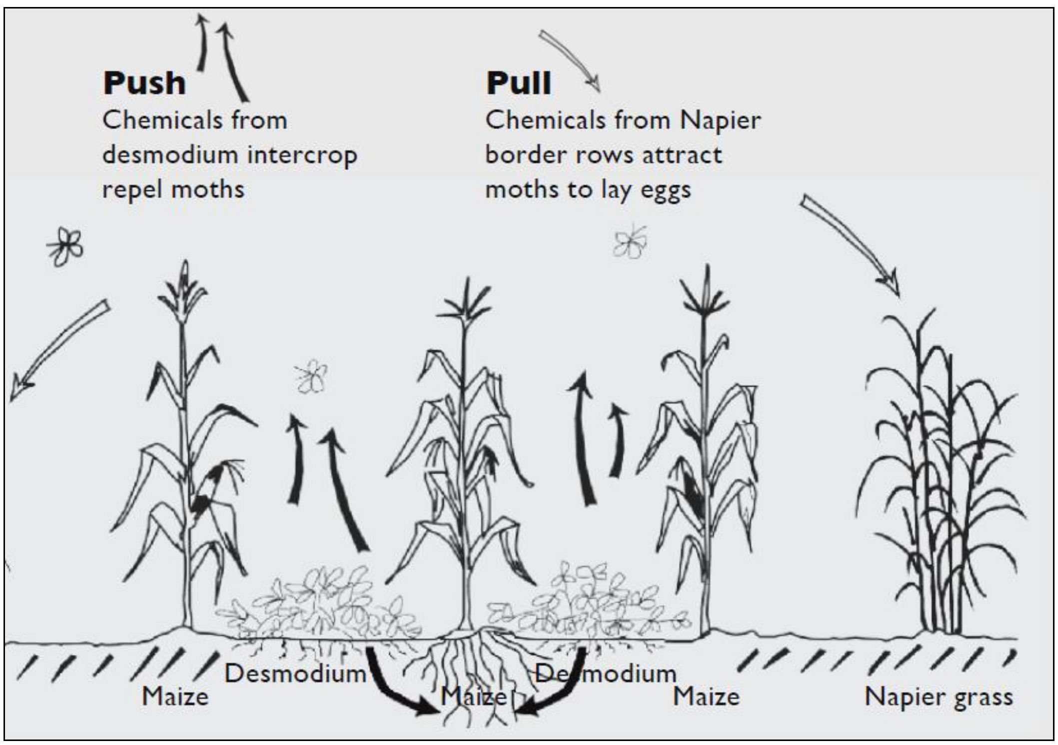

Figure 1: Intercropping of maize, desmodium, and napier grass in the push and pull technology (PPT) to control stem borer and moth in maize.

Source: Khan et al., 2008.

5.2.2 Successful National Best Cover Crop Practices and Lesson Learnt

Several studies reported better performance of *lablab* in low rainfall than high rainfall areas, while better performance of *mucuna* in high rainfall areas than in low rainfall areas of Bukoba and Dodoma (Ndamugoba, 2006; Tumbo et al., 2012). This is because lablab has minimum water requirement especially after development (Tumbo et al., 2012). When the cover crops residues are left on the surface or incorporated in the soil will help to re-cycle nutrients and increase soil organic matter, hence contribute to long term productivity of the soil.

5.3 Soil and Water Conservation/Erosion Control

Rainwater harvesting (RWH) is important in areas with water shortage and more important in this climate change era. Rain water harvesting is the collection of runoff from rain water for various purposes. Rain water harvested can be stored in the soil profile (in situ) or collected in reservoirs.

Insitu rain water harvesting refers to soil and water conservation techniques that trap rain water and prevent runoff within the cropland to flow out of the crop land and allow enough time for infiltration (Hatibu and Mahoo, 1999). The in-situ RWH technologies harvest water over short distance, stores water in the soil profile to ensure water supply to crops, and with catchment area: cultivated area of 1:1 to 1:3 (ADB, 2013). The in-situ SWH technologies are as follows:

Zai/chololo pits. These are examples of indigenous in situ rainwater harvesting (Figure 2). Zai pits are practiced in semi-arid areas of Burkina Faso, where a series of small, wide and shallow pits (30cm diameter and 15-20 cm deep) are dug in the farm to break the crusted surface. In each Zai pits farm yard manure is applied and 4 to 8 seeds can be planted, and rain water is collected in these pits (Munguambe, 2007). Chololo is another indigenous insitu rainwater harvesting developed and practiced in Dodoma Rural district, consisting of small pits of 22 cm diameter and 30 cm deep, dug along the line at 60 cm space between pits in a row and 90 cm between rows of pits. The chololo pits are made with soil bunds around the pit to help retain rain water, farm yard manure and compost, and 1 to 2 maize/sorghum/millet seeds can be planted per pit (Munguambe, 2007). Chololo pits have been reported to be effective in heavy soils rather than loamy soils (Tumbo et al., 2012).

Contour furrow is another in-situ RWH, where the furrow and ridges are made against the slope (along the contour) with furrow upslope and ridge down slope with approximate spacing of 1.5 m. The furrows are used to trap rain water and are tied at the end to prevent water flow out of the furrow at the end of the furrows. The contour furrow are suitable for inter cropping especially cereal and beans. Contour bunds are constructed by creating a ridge down slope by excavating a channel upslope (narrow terraces) at the interval of about 1 m between contours to cut off long steep slope. Contour bunds are laborious to construct and are usually used for production of high value crops such as vegetables. Generally contour farming is more effective in areas with slope of 4 to 6%, and all farm operations are done along the contour (Mati, 2007).

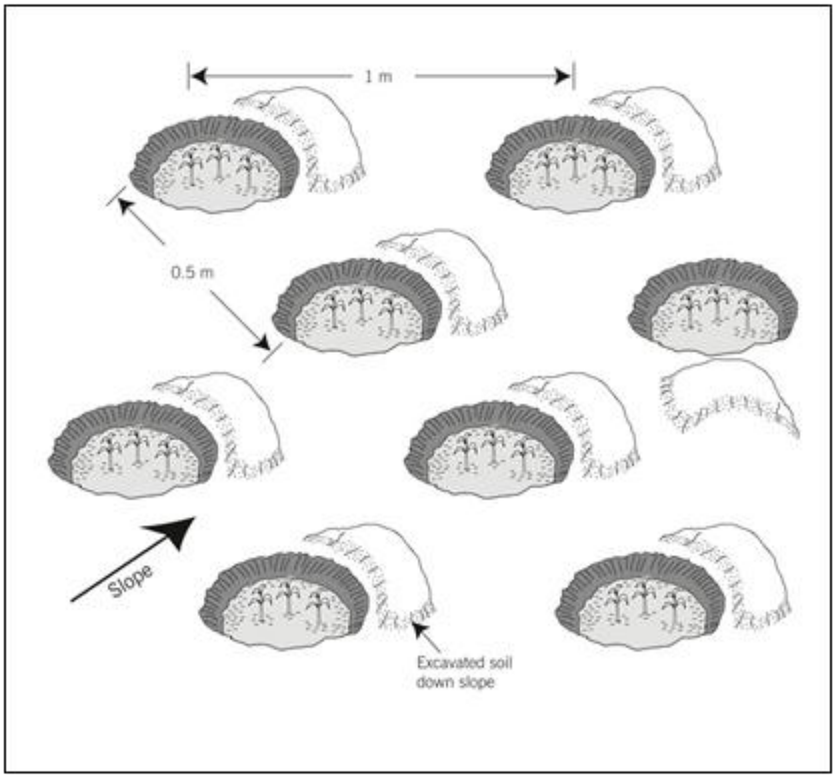

Figure 2: Chololo pits, from Chololo village, Chamwino District, Dodoma Tanzania.
Source: Sungula 2001.

Photo 5: Half-moon insitu catchment in Nakambe, Bukina Faso.
Source: WHaTeR Fact sheet (Photo by Issa, 2012)

Earth Basins/bunds. Earth basins are other in-situ rain water harvesting which can be circular, half cycle/moon, square or rectangle shaped with earth bunds intended to capture and hold rain water for plant use. Sunken basin formed by either ground level bunds or raised earth bunds are also traditional water harvesting techniques that has been practice in desert areas of North America and Mexico, especially for cultivating high value crops such as vegetables (Glanzberg, 1994).

Terraces: Terracing is another CA technology for soil and water conservation which is effective especially in steep slope areas (Tenge, 2005; Tumbo et al., 2011). Terraces are constructed by cutting off slope with bunds made of stones and soil with or without cut-off drains to form short distance land areas with relatively same slope along the long slope resulting in a large step-like structure. The construction of terraces is laborious at initial stages, but later the labour requirement is reduced as only maintenance is done when required.

Charco/malambo dams are small and simple excavated shallow pans/ponds (up to a maximum depth of 3 m) constructed in a flat area for collection of runoff water to be used primarily for livestock watering (Mati, 2007). The runoffs are received from the rangeland and contour bands are used to divert water to the charco dams. Therefore, in improved rangelands, constructions of charco dams need to be included.

Micro-catchment RWH on the other hand is the rainwater harvesting that collects rainwater runoffs either from the roofs or low infiltration grounds (concrete surface, rocky surface, plastic sheets, etc.) and concentrate them in reservoirs or dams for various uses including irrigation and livestock (Hatibu and Mahoo, 1999; Munguambe, 2007). The water collected in the reservoir can be used for irrigation using drip irrigation, bottle irrigation or furrow irrigation to convey water to the crop land. The water can also be for domestic use or livestock watering. This technology has great potential to take advantage of unreliable and erratic rainfall characterized by high intensity rainfall over short growing period. The micro catchment if well collected in salt-free reservoirs is unlikely to be influenced by high salinity as ground water. Salinity is the major challenge in irrigation water sources which is reported to increase under climate change due to depletion of ground water levels, especially in low rainfall areas (Yeo, 1998).

5.3.1 Successful National Best Soil and Water Management Practices and Lesson Learnt

In Tanzania sunken beds/earth bunds known as *majaruba* is common rain water harvesting technology used in rain fed flooded rice production in semi-arid areas especially in heavy clay soils (Hatibu and Mahoo, 1999). The contour bunds have been used on the steep slopes of Uluguru Mountain in Mgeta, where vegetable production is practiced. The success of contour bunds in Mgeta is due to physiographic characteristics – mountainous with very steep slopes (>40% slope) which are highly susceptible to soil erosion. The production of high value crop with more return has also helped wide use of contours. Chololo pits were disseminated by INADES in Mnase ward in Dodoma.

Terraces have also been widely used in highlands and steep slopes of Arumeru since its introduction by SCAPA in 1980's. Farmers practicing terraces alone in Arusha and Dodoma reported greater average yields of maize in maize (1.3t/ha) than minimum tillage alone (0.8 t/ha) (Tumbo et al., 2012). Overall the financial returns were greater in terraces alone or in combination with other CA techniques such as minimum tillage, cover crops, large pits and ridges) Tumbo et al., 2012). Stone terraces have been successful in Same and Lushoto districts in conserving soil and water. The benefits of terraces are greater in steep slope areas, where soil erosion due to run off down the slope is high due to low infiltration and high run off in steep slopes. In Lushoto the SWC technologies most adopted includes vegetation strips adopted by 55% of farmers, followed by bench terraces adopted by 26% and fanya juu which was adopted by 15% of farmers (Tenge et al., 2004). In Arumeru district in Arusha Terraces were more widely adopted (52%) because of bio-physical characteristics consisting of steep slopes (Tumbo et al., 2012). Terraces were least adopted in Dodoma because the problem is more on soil moisture deficit, hence rainwater harvesting technology such as chololo pit were more adopted (26%) (Tumbo et al., 2012). Adoption of SWC was high among female headed families because was annual crop farms are found in erosion prone areas and women are responsible for annual crop production (Tenge et al., 2004).

Photo 6: Stone terraces to conserve soil and water in Makanya, Same District.
Source: WHaTeR Fact sheet (Photo by Issa, 2012)

Photo 7: Cutting slope with residue bunds/strips as practiced in Southwest of Uluguru Mountain.
Source: MICC –FAO project

Adoption of soil and water conservation has been minimal due to top-down approach, which neglects farmers' knowledge and participation in planning (Tenge, 2005). This shows that adoption of soil and water conservation is slow because it requires knowledge and awareness of soil erosion. To enhance adoption of SWC a catchment/landscape approach that involve all stakeholders in a catchment or landscape from the planning stage regardless of individual farms boundaries should be used (Kizughuto and Shelukindo, 2003). Other consideration to facilitate adoption includes integration of economic factors (costs and benefits) into SWC plans, creation of awareness on long term benefits of SWC and effect of soil erosion among farmers, and development of various options of soil and water conservation measures for different farms in the landscape (Tenge et al., 2005). Perception of farmers on erosion as a major problem or not determine adoption rate. Tenge et al. (2004) reported that farmers who adopted SWC are the ones who considered erosion a major problem. Therefore to enhance adoption raising awareness on soil erosion problem is important.

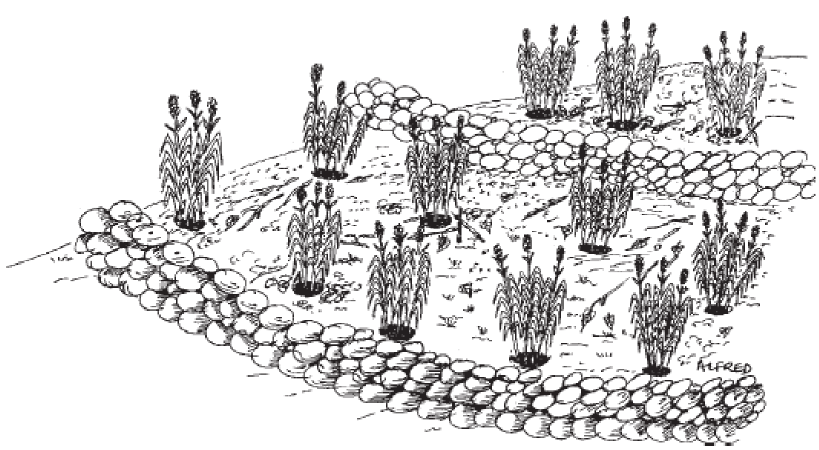

Figure 3: Stone line for soil and water conservation of sloping land.
Source: FAO Training Manual.

5.4 More Resilient Food Crops and Risk Insurance

Different crops and varieties differs in the requirement for water, and hence adaptation to different agro ecological zones. To ensure resilience of productivity, choice of crops and varieties is essential. Crops like sorghum and millet have minimum water requirement than maize and beans. Hence, such crops are more preferred in areas with rainfall less than 600 mm per year. However, maize is the most popular and marketable crop in Tanzania, to sustain its production there is a need for using maize varieties that are more adapted to low and un reliable rains. Early maturing and open pollinated varieties(OPV) (short varieties) of maize such as TMV1, Katumani, Kilima, Kito, and Staha should be used in low altitude areas and low rainfall areas over hybrid maize in low rainfall areas and TMV(Kaliba et al., 1998). In addition, these OPV are resistant or tolerant to maize streak virus and with yield potential range of 2.5 (Kito) to 6.25 t/ha Kilima (Kaliba et al., 1998). However, the major challenge of these locally bred improved OPV is quality of seeds, which tends to be not uniform and attributed to poor multiplication and handling of the then public seed company (TANSEED) (Kaliba, 1998). Most of hybrid maize seeds have yield potential of 4.5 to 8.0 t/ha are bred, multiplied and distributed by private companies, which are more efficient in distribution and quality control. However, the drawbacks of hybrid varieties are high price, poor storability, poor pounding quality, and unsatisfactory taste (Kaliba et al., 1998).

One of the climate change effect is changing of agro-ecological zones where the growing season has been reported to shrink, that is reduced rainfall at the beginning and at the end of growing season (Mongi et al., 2010). This change calls for more research to breed the most adapted crop varieties to even shorter seasons in the near future. Cassava is another crop which is more resilient under harsh conditions such as poor climatic conditions especially in low rainfall and low fertility areas. Other more drought tolerant and nutrient efficient crops include sorghum and millet (Reddy et al., 2013). Sorghum varieties such as Wahi, Hakika, and Macia are the drought tolerant and commonly used in Tanzania because of early maturity, and Wahi and Hakika are resistant to Striga (ASARECA, 2013) and yield potential range of 1.5 to 4.6 t/ha compared to 0.98 t/ha for local varieties (Moyo et al., 2004). The adoption of improved sorghum varieties is estimated at 80% in Dodoma (Moyo et al., 2004).

Another important drought tolerant crop is pearl millet, and its relatively new varieties are Okoa and Shibe released in 1994 with yield potential of 1.85 to 2.31 t/ha relative to 1.62 t/ha for local varieties (Moyo et al., 2004; ASARECA, 2013). Okoa is intermediate in maturity (about Three weeks earlier than most local varieties) but it can avoid excessive quelea damage, a major advantage of local variety (Moyo et al., 2004). Okoa is most popular pearl millet variety adopted by 30% of farmers in Tanzania after only 10 years after release while shibe remain unknown to most farmers (Moyo et al., 2004). Sweet potatoes also have considerable ability to tolerate dry conditions. Major reason for adoption of sorghum and pearl millet was early maturity, drought tolerance, good taste and high yield (Moyo et al., 2004). Recently released orange-fleshed sweet potatoes (OFSP) varieties rich in beta-carotene a precursor for production of vitamin A in human body and drought tolerant have great potential; to save as food security crop (supply calories and essential nutritional benefits) especially for women and children (Tumwegamire et al., 2004).

Cassava is an important food crop to bridge the household food deficit between the period of farm preparation and before next harvest or "lean season" (Aagaard, 2009). However, maximum benefit of cassava will be obtained if improved cassava varieties with high yields and disease resistant are used in the farming system. In Tanzania improved cassava varieties resistant in cassava mosaic disease (CMD) were released and about 27% of farmers in the Lake Zone adopted these varieties (Kavia et al., 2007). This adoption is low and was attributed to lack of information on technology package, bad taste and low starch contents (Kavia et al., 2007).

5.5 Fodder Development, Rangeland Management and Integrating Livestock and Crops

Grassland management practices have potential to contribute towards food security and agricultural productivity via increased livestock yield and minimize land degradation. The feed quantity and quality from pasture is determined by weather, fertility, stand density, and season. Pasture land can be improved by improving vegetation community through planting high productivity, drought tolerant and deeper rooted fodder grasses and/or legumes (Branca et al., 2011) such as Superior Brachiaria bred cultivars (Mulato and Mulato II) and Canavalia brasiliensis, (CIAT, 2013).

Controlled grazing through stocking rate management, rotational grazing, fallowing grazing to allow rejuvenation of grasses has been reported to improve grazing land, ensure surface cover, and reduced erosion while increasing fodder productivity (Branca, 2011). Thus rotational grazing is necessary in order to meet animal forage needs (Smith, 2010). Starting point to improved rangeland management can be allocation of land to pastoralists for grazing. Allocation of land to pastoralist will encourage them to manage it and practice control grazing (Tumbo et al., 2011). Improving pasture will indirectly help to improve agricultural land by reducing the demand for crop residue removal to feed livestock. In presence of managed pasture and grazing land, the crop residues removal from farms will be reduced and the soil will be protected by soil cover and build SOM in the long run.

Long term adaptation strategies for livestock keepers have been destocking or animal harvesting followed by migration and diversification (Tumbo et al., 2011). Animal harvesting is regular selling of animals to avoid overstocking, a common practice in Chamwino, Dodoma (Tumbo et a., 2011) In other semi-arid areas like Same, sale of animals (or destocking) is done due to drought that cause lack of pasture. Migration of livestock keepers is popular in Mvomero, where most pastoralists in the area are immigrants from Northern Tanzania and Lake zone (Tumbo et al 2011). Other adaptation actions include: purchase of pasture land, conservation and storage of forage, consulting veterinarians, building community dips, and keeping more animals of resilient species (Tumbo et al., 2011). Therefore, animal harvesting, improved pasture, improved breeds and ownership of land for grazing and pasture can be promoted to wider livestock keepers and contribute to achieve CSA.

Alternatively, integrating livestock and crop farming to recycle nutrient can be adopted. In this integrating system the waste of crop or livestock can be used as a resource for livestock or crops

(Rota, 2010). Thus, crop residues can be used to feed animals, and manure is returned to the farm to recycle nutrient, improve soil fertility and increase SOM. (Rota, 2010). The major limitation in this system is poor nutrient quality in crop residues and manure if not properly handled and manure inherent low nutrient content, which are insufficient for sustainable crop production (Rota, 2010). Thus use of leguminous tree pasture to improve animal nutrition and inorganic fertilizers to supplement nutrients for crop production is required. Therefore, Integrating livestock and crop farming helps to improve nutrition of household and diversify income generating activities, hence contributes to adaptation of climate change.

5.5.1 Successful International Best Pasture Management and Lesson Learnt

Pasture fertilization using organic or mineral fertilizers is necessary for improved pasture and grazing land. Nitrogen fertilization is common in pasture, while P and K fertilization may be necessary in degraded or long term grazed pasture soils low in P and K (Barnhart et al., 1997). Nitrogen fertilization rate of 68 to 136 kg N/ha and about 30 kg P/ha has been reported to increase different types of grasses pasture yield and be profitable in Iowa silt loam soils (Barnhart et al., 1997). Successful pasture management in the US is in areas with adequate rainfall/irrigation water and controlled grazing.

Pasture fertilization is not a common practice among small holder farmers in Tanzania, except in intensive livestock keeping and where grazing land is scarce. For pasture fertilization to be advocated in the targeted areas, specific land allocation for pasture has to be demarcated, grazing if has to be done must be controlled. Pasture can also be considered as a commercial crop for farmers and sell to livestock keepers.

5.6 Soil Fertility Management

Soil fertility management has been and will continue to be an integral part of sustainable crop and livestock production. Climate smart agriculture technology requires soil fertility management that is compatible to the environment without compromising soil productivity. Therefore soil fertility management strategies that will ensure efficient nutrient cycling without over exploitation of natural fertility through excessive nutrients or nutrient mining are needed. Soil fertility Initiative (SFI) of FAO recommended getting away from blanket uniform fertility management packages and change to specific package for a given situation facing a given production constraint (FAO, 2001; FAO, 2006; GPNM, 2010).

The first step in achieving climate smart agriculture in soil fertility management is participatory soil fertility status evaluation, to determine the type and rate of nutrient to be applied to ensure balanced fertilization to increase nutrient use efficiency (FAO, 2001). Participatory soil fertility evaluation and management was done by African Highland Initiative (AHI) project in Kwalei village, Lushoto, integrating both indigenous knowledge and modern methods that lead farmers to adopt combination of farm yard manure and Minjingu rock phosphate (Mowo et al., in press). Another project invested in soil fertility evaluation is NAFAKA project for rice production in Kilombero and Wami valleys (Massawe and Amuri, 2012) that for the basis for scaling out NPK + S and micronutrient fertilizers in partnership with YARA fertilizer company. Soil fertility evaluation will also provide information on the need for any other soil amendments such as gypsum or lime. Integration of organic and inorganic fertilizers will provide both soil organic matter and nutrients at required quantity in the soil.

The most important plant nutrient to ensure climate smart agriculture is nitrogen. Nitrogen is the most limiting nutrient in the soils but required by most plants in large quantities, and poses great potential to contribute to GHG emissions through emission of nitrous gases (NOx) if mismanaged in agricultural soils. Nitrous emissions from agricultural soils are estimated to contribute about 3% of GHG emissions due to N fertilization using both mineral fertilizers and animal manure (Flynn, 2009). Therefore, nutrient management to increase N use efficiency through maximizing N uptake by crop is essential to achieve CSA (Future Faming, 2008).

Nitrogen use efficiency can be improved by first ensuring adequate supply and balance of P, K and S, because deficiency of these nutrients reduces NUE. Accurate estimation of amount of N fertilizer needed as per crop demand is essential to avoid excess that may lead to build up of NO_3^- in the soil and increase potential for NOx emissions (Flynn, 2009). Timely application match the period of crop demand is critical for rapid uptake of soluble N from most mineral fertilizers (Semoka et al., 2010). Adequate SOM content and ensuring adequate soil pH is also critical to minimize N losses and ensure uptake by crop (Future Farming, 2008). Choice of sources of nutrients should also be carefully considered, and utilization of available organic resources and supplementation of inorganic resources is recommended while taking consideration of balanced nutrient availability. Utilization of controlled or slow release N fertilizers such as Urea super granules and coated N fertilizers or nitrification inhibitors should be explored (Flynn, 2009).

Phosphorus is the second most limiting nutrient in agricultural soils (Havlin et al., 2005; Semika et al., 1996). Phosphorus availability enhance nutrient uptake through its influence on root growth and development (Havlin et al., 2005) and hence contribute to improved nutrient use efficiency. Low P content in manures and supply of plant biomass from tree fallows and legume rotations has been reported as the major reason for inability to reduce P deficiency on highly P-deficient soils (Buresh et al., 1997). Therefore, to solve P deficiencies in soils and integration of organic-based systems and agro forestry with inorganic P-fertilizers has great potential to increase availability of soil P to plants for crop production (Buresh et al., 1997; Ikerra et al., 2006).

The current challenge in fertilizer recommendations in Tanzania is that the national recommendations are too old, focusing on only N or N and P recommendations for most crops. Due to non-use of fertilizers and long term cultivation hence nutrient removal by crops and soil erosion multiple nutrient deficiencies has been reported in many agricultural areas of Tanzania (Amuri and Semu, 2006; Massawe and Amuri, 2012). Deficiencies of Zn, B, and K are now observed in Dakawa and Kilombero (Massawe and Amuri, 2012), with possibility of wide spreading in similar rice, maize, and beans growing areas in Tanzania.

Fertilizer use is essential for replenishing nutrient removal by harvested crops. Although high costs of inorganic fertilizers is considered a major limitation to fertilizer use in small scale farming, lack of knowledge and poor fertilizer market development are major determinant of success of subsidies for sustainable food production (Druilhe and Barreiro-Hurlé, 2012). To enhance use of fertilizers by small scale farmers, training to raise awareness and change negative perception on fertilizers is required along with the subsidies programs to reduce cost of inorganic fertilizers.

Small scale farmers believe that inorganic fertilizers will destroy their land. Training in the use of both inorganic and organic fertilizers should be included to achieve sustainable soil fertility management. Training in manure handling, storage and application is also important for maximum benefits in crop production. Combination of organic and inorganic fertilizers at half-half nutrient recommendation has great potential to increase yield and soil health (Onyango et al., 2000). Practical training through FFS and demonstration plots should be used to demonstrate not only the performance of both organic and inorganic fertilizers but also appropriate use and timing of application, and indeed inorganic fertilizers use may lead to economic losses and nutrient imbalances if not properly used. Increased availability of organic fertilizers such as composting using N-fixing leguminous plants and other organic domestic wastes can be explored especially in areas where livestock keeping is not common.

5.7 Agro-Forestry

Integrating perennial trees/shrubs plants in agricultural lands both crop production and grazing has been documented to improve soil cover, and ensure green cover during off season. In so doing trees/shrubs in agricultural land helps to curb land degradation and conserve biodiversity to create a resilient land use that adapt and mitigate climate change (Kitalyi et al., 2011). This technology when integrated in crop land has to be done in such a way that light competition or shading effect between trees and crops is avoided. Thus, careful selection of trees with low shading effect and planting at the border of the farms preferably on the south-north borders is recommended. Trees can also be planted in areas of the farms that are highly vulnerable to soil degradation such as on steep slopes, soil bunds of terraces, and near water sources. Alley cropping can also be done, where trees are planted in alleys between crop fields.

Fertilizer trees capable of fixing atmospheric nitrogen and with multipurpose use such as *Sesbania sesban, Crotalaria grahamiana and Tephrosia vogelii* are recommended and have been successful used in Kenya and Tanzania (Kitalyi et al., 2011). The World Agroforestry Center has developed four fertilizer trees options to improve soil fertility in the crop land. These fertilizer tree options includes fertilizer trees during fallow in rotations with cereal crops, intercropping fertilizer trees as coppiced fallow and cereals, intercropping shrubs in annual allay with cereals, and harvesting *Gliricidia* or *Tithonia* trees/shrubs leaves and apply them in crop land as mulch, green manure or compost (biomass transfer) (ICRAF, 2011). Fertilizer trees have also been reported to contribute to mitigation of climate change by above ground C sequestering of about 2.5 to 3.6 tons of carbon per hectare per year (Nyadzi 2004).

5.7.1 Successful International Best Agro Forestry Practices and Lesson Learnt

One of the outstanding agroforestry technology has been reported in Zambia using Musangu tree (*Faidherbia albida*), an indigenous, deep root, drought tolerant tree of leguminous tree that fix N and shade leaves during the rainy season, providing organic residues, nutrients (up to 75 kg N, 27 kg P_2O_5, 19 kg K_2O, 183 kg CaO, 39 kg MgO and 20 kg S under the canopy) and light penetration for crop production (Aargaard, 2009). The Musangu tree can be adapted in many areas with similar agro-ecological zone with Miyombo wood land like Chamwino and Kilosa. The *Musangu* can be planted within the field at spacing of about 10 m by 10 m, and spacing may be increased to 20 by 20 when the trees grow bigger. In between *Musangu* trees field crops such as maize, millet, sorghum, beans can be planted without problem of shading.

Niger, a country frequently afflicted by droughts, revised its forestry regulations to give farmers the right to decide how to manage trees on their land. Following that policy, farmers responded by encouraging the natural regeneration of *Faidherbia albida*, a tree which improves soil fertility by shedding its nitrogen-rich leaves during the rainy season. Other indigenous tree species which provide a free source of soil fertility, fruit, fuel wood and livestock fodder were also preserved. Today about 5 million ha of land in Niger are covered by *Faidherbia* and other indigenous species. The yield of annual crops (sorghum and millet) in these agroforestry systems have increased significantly as well as farmers' incomes.

5.7.2 Successful National Best Agro Forestry Practices and Lesson Learnt

Other successful traditional agroforestry systems in Tanzania includes Ngitili (Sukuma land) and Olalili (Maasai), a silvi-pasture system consisting of trees/shrubs/pasture in multi layers system with a mixture of perennial and annuals plants like natural ecosystem (Kitalyi et al., 2011). These traditional agro forestry systems can serve as range land and reduce pasture scarcity in dry lands and is more suitable in mid latitude plains. The major limitations to these traditional agro forestry systems are land tenure system, and their sustainability has been seriously hampered by over grazing beyond their carrying capacity (ICRAF, 2011).

5.8 Diversification and Value Addition to Crop and Tree Products

In order to enhance adoption and benefits of climate smart agriculture in Chamwino and Kilosa, enabling the farmers to diversify crops and trees they grow as well as equipping them with processing and marketing skills can be done. *Sclerocarya birrea* is an extremely valuable indigenous fruit tree (IFT) naturally growing in these areas but remain potential due to lack of awareness by farmers and other related stakeholders in the country.

A study has developed an unsophisticated grafting methodology which local farmers can perform easily using local equipment and attain fruiting within two years instead of the normal 10 to 15 years (Woiso, 2011). Fruits from *Sclerocarya* trees are used to develop valuable products which can be traded in the local markets, urban centres and even internationally. Such products include a variety of cosmetic oils (selling up to USD 80 per 2 ounces), shoe polish, highly rated cooking oil, biofuel, beverages (such as the popular amarula cream sold worldwide and available in stores in Tanzania for about TSh. 20,000 per bottle).

Other important agroforestry IFT species for dry land areas are *Adansonia digitata* (Baobab or *Mbuyu* in Swahili) and *Tamarindus indica* (Tamarind or Ukwaju in Swahili) whose fruits can be sold locally or in cities like Dar Es salaam to domestic consumers of processors who makes products like juice and jam from them. Cash and food crops can also be diversified and processed and marketed to fetch more profit per effort. In climate smart agriculture it is important that yield and income per unit area is maximised in order to use much of the land for conservation.

Livelihoods diversification, market access and value addition can be participatory formulated and implemented to target communities in collaboration with some relevant private sectors such as lending institutions, processors and business. It should be done to increase awareness of the role and importance of markets, not only once production is completed or harvested, but also in the selection of activities to be undertaken, including the selection of product focused by stakeholders, increasing the value of local production, whether through timing of output, packaging, storage or transformation or through the creation of market links directly with end users (processors, institutional buyers, exporters, etc.).

6 CLIMATE SMART AGRICULTURE PRACTICES

6.1 Mitigation of Climate Change in Agriculture (MICCA) Uluguru Mountain

Mitigation of Climate Change in Agriculture (MICCA) in south-western side of mountain Uluguru is one of the first pilot projects implementing integration of climate change and agriculture. MICCA is carried as a continuation of Hillside Agricultural Conservation Project (HICAP) by measuring C accumulation and emissions (Besa et al., 2012). The MICCA project implements CSA through conservation agriculture, agro forestry and crop rotation, which were already practiced in the area and monitoring GHG emissions and C storage. The approach used is group learning using farmer field school and participatory approach in all planning and implementation of project activities. The project allow introduction of farmers own knowledge in management and land uses and introduction of new crop rotations (Besa et al., 2012). The major challenges faced in this project are slow adoption of CA, land tenure systems and knowledge gap in CSA. It is learned that strong partnership with the government and other stakeholders is critical for success of the CSA related projects.

6.1.1 Reducing GHG Emissions in Rice System

Paddy rice, especially irrigated system emits GHG's including nitrous oxide and methane. The successful CSA in paddy rice is to use a water-saving technology known as Alternate Wetting and Drying (AWD), designed by the International Rice Research Institute (IRRI) and partners in the Philippines. In this technology the use of irrigation water is optimized. The AWD has helped farmers on Bohol Island to maintain crop yields and reduce methane emissions by an estimated 48% compared to continuously flooded rice fields (Pye-Smith, 2011). The AWD also helped farmers to adapt to possible shortages of water caused by climate change.

6.1.2 Adaptation to Climate Change through Livestock Insurance and Biogas Plants

In Kenya the International Livestock Research Institute (ILRI) launched an index-based livestock insurance scheme for pastoralists in Northern Kenya and payment depends on the lack of pasture due lack of pasture. The ILRI project monitor vegetation changes by satellite image and provides early warning to pastoralists to avoid degradation due to overgrazing (Pye-Smith et al., 2011). The major challenge and complains from beneficiaries of the insurance scheme is that payment is not based on actual number of livestock that died due to drought (In Guangxi Province, China livestock keeper reduce GHGs from livestock by generating biogas for cooking through the support by the International Fund for Agricultural Development (IFAD) (Pye-Smith, 2011). In turning GHG into energy, these farmers have also reduced forest degradation by reducing firewood consumption. In Tanzania, biogas plant construction and use of biogas is implemented in Arusha and Njombe by Tanzania Domestic Biogas Program (TDBP) where zero grazing livestock keeping is practiced.

6.2 Situation Analysis and Best CSA Practices Options for Chamwino District

Chamwino is a semi-arid area receiving less than 600 mm rainfall per year. The landscape of Chamwino is mainly gentle slope extensive plains with few hills. The area has relatively strong winds. Farming and livestock keeping are dominant agricultural practices. Chamwino agro-ecological condition is highly susceptible to both wind and water erosion. Being semi-arid area moisture deficit problem is a dominant factor affecting crop productivity and vegetation cover or regeneration. Overgrazing is the second dominant contributor to soil erosion. Gully and rill erosion are common features observed in agricultural land and along the roads in several villages Chamwino including Chololo, Manchali nearby other villages. Compacted land due to overgrazing is widely common, and to a great extent reduced land area for cultivation. Because most farmers are agro pastoralists, there is advantage of availability of manure for soil fertility improvement. However, agro-pastoralist pose challenges for competition of crop residues between animal feed and soil cover to control erosion and build soil organic matter.

At landscape/catchment level the following are recommended:

- Put in place land use planning to demarcate settlement areas, grazing land and farming land
- Improve grazing land by reducing overgrazing and consider developing pasture/fodder during rainy season to provide feeds during dry season and allow grazing land to regenerate
- Highly erosion susceptible areas should be left for forest establishment and beekeeping using modern bee hives can be integrated as alternative source of income

- Erosion control strategies to slow down runoffs using crop residue strips, divert runoffs to reservoir points, contract cut off drains and stabilize with grasses along the village roads, paths and grazing route to reduce, prevent and hill gullies and rills.
- Use stone to slow down runoffs in the plains and helps to retain eroded soil particles within the plains to help vegetation regeneration

At farm level the following technologies to conserve soil and moisture can be used:

- Reduced tillage using *magoye* rippers – to reduce evaporation losses and conserve moisture and acts as insitu water harvesting, especially in compacted farms
- *In situ* water harvesting and erosion control options to be used: chololo/zai pits, crop residue strips, earth bunds stabilized with vegetation (grasses, pigeon peas) to reduce erosion within the farm in loamy soils.
- Crop cover or soil cover – intercropping with legumes live groundnuts, cowpeas, lablab
- Adaptive crops selection – drought tolerant varieties and crops should be grown in this area, such crops include sorghum, millet, sunflower and groundnuts.
- Irrigation using fresh water (non-saline water) should be done for high value crops (vegetables) and for other crops when moisture deficit. In these areas fresh water can be obtained from rainwater harvesting and runoff collection in mini reservoirs/dams to conserve water for irrigation during rainy season. This is because dry spells during rainy season are common in these areas and expected to be more frequent and with long duration under increasing temperatures in climate changing conditions.
- Agro-forestry – using fertilizer trees that can act as wind breaks to reduce erosion and excessive moisture losses and supply residues to apply in farms as soil cover and fertilizers and fodder.
- Biogas production and utilization will have great potential to generate energy for cooking and to manage manure and reduce GHG emissions from manure, while producing slurry/composted manure for crop production

Apply the following practices to improve soil fertility

- Soil fertility evaluation survey to give general soil fertility status is conducted to give an indication of type of fertilizers to be used.
- Integration of organic and inorganic fertilizers for crop production, application of these fertilizers at the right time and rate as per crop requirement is essential. Farm yard manure can be used in combination with phosphate fertilizers during planting and N-containing fertilizers at low rates can be used as top dressing. Maximum benefit of

inorganic fertilizers will be realized in these areas if soil-water conservation technologies are practiced, as they require moisture to solubilise and taken up by plants roots.

- Improve handling and quality of manure and reduce greenhouse gases: Manure should be kept under shade, protected from direct sunlight and rainfall to reduce Nitrous emissions. The manure should be kept and allowed to decompose and cool before applied in the farm for maximum benefits. When applied in the farms FYM should be covered by soil or mixed with soil to reduce further emissions and N losses.

- Micro-catchment rain water harvesting and water storage in reservoir to provide water for irrigation during prolonged dry spell and for production of high value crops such as vegetables

- Agro forestry using leguminous trees, *Faidherbia albida,* and other indigenous fertilizer trees which are adapted in Chamwino agro ecological condition should introduced/encouraged

6.3 Situation Analysis and Best CSA Practices Options for Kilosa District

Kilosa receive rainfall ranging from 400 to 1400 mm per year, the district have several agro-ecological zone differing in land characteristics, rainfall and temperature. The major agro ecological zones includes gently undulating to rolling plains and plateau, rolling plains at low altitude to strong dissected uplands, flat alluvial plains, and strong dissected mountains with steep slopes. The district is rich in many river networks. Kilosa resident communities mainly practice crop farming only, while most livestock keeping in the district are practiced by immigrants from pastoralist communities (Maasai and Sukuma).

The common and also traditional farming is by clearing land by burning residues followed by direct seeding, and cultivation is done after germination to control weeds. In both lowland and highlands farming is practised, where in lowlands crops such as rice, vegetables and maize are dominant. Irrigation is practiced in rice production and vegetable production during dry season. Common beans, potatoes, vegetables and maize are common crops in highlands.

Most villages in Kilosa have in place land use plan to demarcate land for settlement, farming, reserved forests, and grazing. However, the challenge is to improve and maintain land uses. Soil and water conservation is minimal in the area even in those areas with steep slopes. Similar landscape/catchment and community participatory approach to introduce and implement CSA as in Chamwino should be used in Kilosa. Therefore, the CSA technologies recommended for Kilosa are:

Climate smart agricultural technologies options in highlands and in steep slope farms

- Bench or ladder step terraces - These can be done by stone terraces, *fanya juu*, or residue strips across the slope to reduce distance of runoff and capture eroded particles on the stone line, earth bund of *fanya juu* or residue strips, which over time develop a ladder-like step terraces.

- Contours – can be contracted by furrow and soil bunds up the hill (*Fanya juu*) on the relatively same altitude.
- Mulching – in Kilosa the biomass production is greater than Chamwino, hence there is abundant biomass that can be soil cover through mulching instead of burning
- None burning of residues - burning should be discouraged to reduce GHG emissions and loss of biomass to build SOM.
- Reduced tillage should be practiced to help increase in SOM
- Crop diversity to include crops other than maize and beans should be encouraged. Crops such as potatoes, peas, etc. In the highlands, cover crops establishment at the end of growing season to protect soils during dry season can be done taking advantage of residue moisture.
- Integrated soil fertility management and agro forestry using fertilizer trees
- Bee keeping in conserved areas
- Irrigation should be practiced using available river water during rainy season in case of prolonged dry spell.

6.4 Scaling up CSA

Scaling up technology aimed at achieving sustainable and wide adoption and use of a given technology that ensure continuous realization of benefit from a particular organization. SUSTAINET divided scaling up into four types: 1) quantitative up scaling – where a large number of farmers either from same village or from different villages are directly or indirectly enabled to adopt a technology, 2) functional up scaling – where same technology or a new activity is adapted to suit a new situation, which is particularly relevant in technologies such as CSA that are related and dependent on other aspect like socio-economic benefits e.g. value addition, diversify farming activities 3) political scaling up – influencing how government provide services or changing policies to favor adoption and use of technology, this can be achieved at local (through by-laws, village committees), national (through policy briefs, conferences/workshops) , regional, or international level, and 4) organizational scaling up – increasing capacity in governance and management; human resource development; and communication to make organization more efficient, e.g. build capacity of staff, increase number of technical staff, strategic planning.

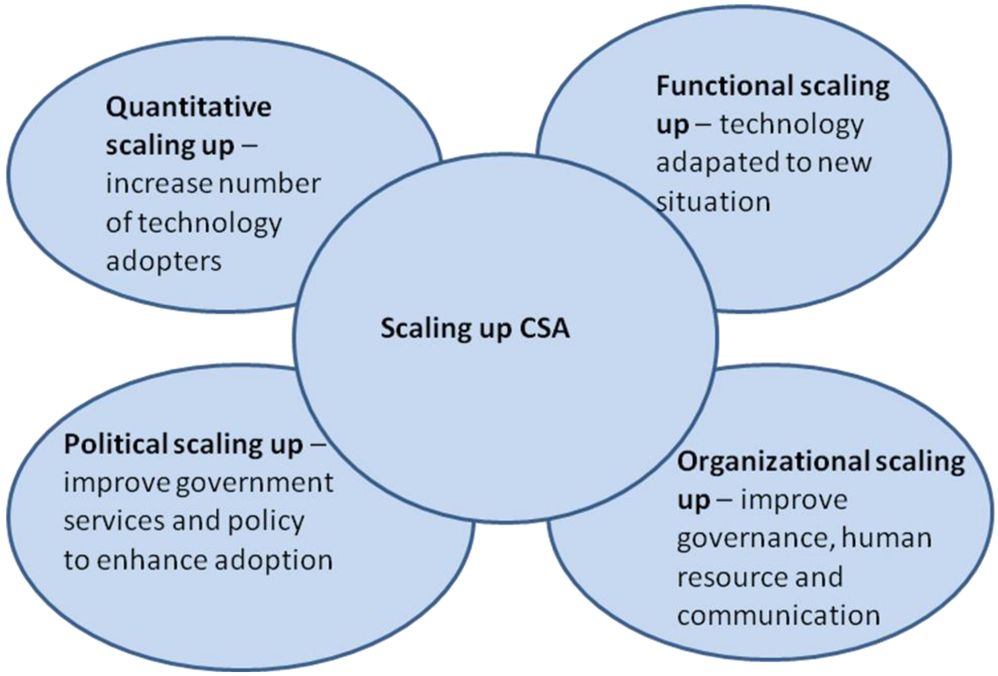

Figure 4: Scaling up levels (Adapted from SUSTAINET)

Achieving agricultural resilience to climate change and improved productivity requires that improved CSA technologies and SLM have to be adopted by farmers and at vertical scale to institution and policy level. Reducing emissions also require both the widespread diffusion and adoption of currently available low-carbon technologies (Stern, 2008). However, low adoption of sustainable land management, which is a key to CSA has been due to various factors that can be grouped into five categories: investment cost, variable and maintenance costs, Opportunity costs, transaction costs and risks costs (McCarthy et al., 2011).

The investment costs are those associated with cost to purchase equipment, machinery, or materials and labor to build on farm structure for CSA and SLM as in the case of low adoption of CA discussed above. It was revealed that poor households defer or postpone the purchase of assets including farming tools during times of hardship (Bishop-Sambrook et al., 2004). Hence any technology that requires new or specialized equipment will have low adoption by these poor households (Bishop-Sambrook et al., 2004). Unavailability of equipment required for particular equipment/implements also add investment cost and hinder adoption as documented in jab planter availability and low adoption of No till in Tanzania (Sheto and Owenya, 2007).

The Variable and maintenance costs includes the expenditures for consumables required to either carry on CSA and SLM, these includes improved seeds, fertilizers, additional labor, labor for maintance of conservation structures, payment of credit if secured (Mc Carthy et al., 2011; Kaliba et al., 1997). Low use of fertilizers and improved seeds in many parts of Tanzania, like other sub-sahara countries has been attributed to high variable costs beyond small scale farmers' capacity to afford them (FAO, 2001).

Opportunity costs include costs of alternative factor of production allocated by individual farmer relative to implementation of CSA and SLM such as labor, land, materials for other activities versus CSA related activities. The opportunity costs can be of short term or long term. **Transaction costs** are expenditures associated with searching for information on new technologies, bargaining and negotiation, time spent in and monitoring and enforcement (McCarthy et al., 2011). **Risks costs** due to absence or imperfect insurance market or mechanisms associated with uncertainty to realize benefits of CSA. The assurance of private benefits such as increased yield, income, food security tends to attract farmers to adopt CSA rather than public benefits C sequestration, reduced GHG's, increased infiltration, and erosion control such as which are usually long term benefits (McCarthy et al., 2011).

Box 4 Up scaling Approach a Case of Himo Environmental Management (HEM), in the foot slopes of Mt. Kilimanjaro (SUSTAINET, undated)

Up scaling approach starting with training to impart skills and raise awareness of local village leaders first proved to be successful in enhancing adoption of CA in Kilimanjaro region. The training includes a combination of classroom training and practical training using demonstration plots at HEM center. HEM used multi-sector approach by providing technical services in agriculture, natural resources, livestock, water, and community development to enhance CA adoption. Training village leaders first helped to sensitive these leaders, who are in a better position to influence villagers in CA and created a demand for CA and erosion control technologies.

After sensitizing the village leaders, HEM team were invited in the villages for further discussion on erosion control and CA with the villagers. The initial step adapted by HEM was rural participatory appraisal to identify major problems facing farming community in selected villages, which are poor yields, low crop productivity, and soil erosion were identified. The villages formed committees that includes village extension worker as a member of the committee. The committee is under the village local government with the task of sensitizing farmers their village to raise awareness and convincing farmers to adopt CA and erosion control technologies, planning, implementing. Therefore, scaling out of was trained and committee farmer to farmers approach. Furthermore, each village elected one farmer to receive extra training and become farmer extension worker. The village extension staff and farmer extension staff received one month technical training on tree nurseries, agroforestry, rehabilitation of irrigation furrows, soil and water conservation, zero grazing, improved stoves, and training methodologies to enable then train farmers effectively.

Up scaling – landscape level

The implementation approach of landscape level soil and water conservation is "Kazi jumuia", where each member of the village is required to work one day a week on community activities, like road maintenance, repairing an irrigation canal or building check dams on a stream or school building as agreed by farmers, organized and re-enforced by village leaders. For the Kazi jumuia approach to be effective, strong village leadership is necessary.

CA benefits in Kilimanjaro

Conservation agriculture enabled farmers who adopted it increase maize yield from 1.3 to 2.6 t/ha (6 to 12 100-kg bag per acre), sunflower yields from 0.6 to 1.1 t/ha (5 to 9 100-kg bag per acre), and bean yields from 0.7 to 1.2 t/ha (3 to 5 bags per acre). The agro forestry using leucaena, calliandra and croton and grasses such as Napier grass, desmodium, setaria and Pallida to stabilize soil bunds increased availability of fodder for cows, which increased milk production from 4 to 7 litres a day for improved breeds and 0.5 to 2.5 litres for local breeds.

6.5 Lesson learned on importance of acquisition of knowledge and raising awareness

Successful reduced tillage in the US is Virginia where acreage under conservation tillage increased among crops from 48.2% in 1989 to 67.6% in 2007 (Reiter, 2009). The positive trend is attributed to increase awareness among Virginia farmers on the benefits of low and no-tillage regimes and is consistently improving their production systems to move towards sustainability. Similarly, adoption of CA by large and medium scale farmers in Kenya has been possible due to understanding of befits despite the challenges of CA as presented in the case study above (Kaumbutho and Kienzle, 2007). In Kilimanjaro, a combination of classroom and field practical training on CA was used to impart knowledge to farmers, village leaders, and extension staff to enhance adoption of CA, where 67% (760 farmers) of trained farmers were the first to adopt CA (SUSTAINET, undated). After realizing the benefits of CA from fellow farmers, other 6500 farmers adopted (SUSTAINET, undated). Therefore, a combination of classroom and practical training is important to up scaling technologies. A study using The Tanzania National Panel Survey (TZNPS) and the TNS-Research International Farmer Focus (FF) showed that inorganic fertilizers use among small scale farmers in Tanzania is strongly and significantly determined by availability of extension services (Stahley et al., 2012), indicating the importance of imparting knowledge and advice in adoption of inorganic fertilizer use and most likely other agricultural technologies.

6.6 Lesson learned on importance of land tenure and labour

Land tenure system has greatly affected wide adoption of various CSA discussed above. Bishop-Sambook et al (2004) reported weak, cumbersome and uncertain outcome in process to obtain and claim land rights among poorest farmers and hinder them from adopting reduced tillage and cover crop technologies in Babati and Karatu district Tanzania. Tumbo et al. (2011) revealed that low adoption of young generation to CA was mainly attributed to lack of land ownership. Discussion with key informant in Kilosa revealed that land owners can even dictate the farming practices to be used by the person renting the land. A study using national statistics showed that farmers with no assurance of land are less likely to use inorganic fertilizers (Stahley et al., 2012).

6.7 Lesson learned on how labour affects adoption of CSA

Labor is one of the opportunity and variable costs affecting scaling up of technologies. Technologies with less labor intensiveness are favored by most farmers (Tumbo et al., 2011). The high peak labor requirement in agricultural system is during land preparation and weeding (Bishop-Sambrook et al., 2004). Availability of labor has double impact on reducing adoption of conservation agriculture especially reduced tillage. To wealthier farmers cheap labor gives no incentive for extra benefit of reduced tillage in saving costs, while to poor farmers adoption of reduced tillage would mean reduced opportunity to sell labor and hence extra income (Bishop-Sambrook et al., 2004). In such cases, sensitization and awareness creation is needed. Where possible incentives to reduce tillage should be created for compensation for public benefits in increased C sequestration or reduced erosion and improve infiltration needs to be factored in to attract more farmers to adopt conservation agriculture in form of carbon credit. Alternatively, conservation agriculture should be done in conjunction with other income generating activities to compensate for lost income from causal labor.

6.8 Lesson learned on how gender affects adoption of CSA

Men and women have different roles in farming activities, where men are responsible for land clearing and seed bed preparation, while women take role in planting, weeding, post-harvesting handling (Carl and Hartl, 2010). It has been observed that women's specific needs and access to resources are the major drivers to women's technology-adoption rates (Rathgeber, 2011). Female headed households were reported to be more constraints in adoption of new technologies because of lack of confidence, isolation in farmers groups and less contact with extension services (Bishop-Sambrook et al 2004). However, female headed households have great potential to adopt any labor saving technologies because labor is their major problem, and are enthusiastic to learn when reached by extension service programs and projects (Bishop-Sambrook et al., 2004). Female headed household had already realized the importance of crop diversity especially intercropping maize with pumpkins and sweet potatoes to suppress weeds and produce food (Bishop-Sambrook et al., 2004).

A study among farmers in Malawi showed that women farmers were quicker to adopt a new kalmia bean variety because of variety's lesser time requirement for cooking and good taste (Masagano and Miles, 2004). Contrary, in Kenya, fewer women adopted use of inorganic fertilizers because fertilizers are expensive and most women lack of financial resources (Rathgeber, 2011). Farmers groups are effective in dissemination of agricultural technologies and helped women to build confidence and be able to speak out, hence actively participating in decision making (Rathgeber, 2011). Young people prefer to cultivate cash crops and fodder crops for dairy production in Kenya (Jonsson, 2012). The preference of dissemination pathway also differed among gender groups, where young and educated farmers prefer receiving information through print materials such as booklets, fliers, extension manuals (Murage et al., 2010). Therefore, gender issues should be mainstreamed from all aspects related to technology implementation, products and pathways of technology dissemination.

6.9 Lesson learn on how to integrate IK to enhance adoption of CSA

Most often, agricultural research and extension tends to overlook the existing technical knowledge (indigenous knowledge) of farmers in particular area, which is based on generation of experience and field testing. Taking advantage of existing knowledge and experience related to agriculture tends to enhance adoption of improved version of indigenous. Experience showed that adoption of conservation tillage by rippers is relatively high in areas with experience in drought animal power to prepare seed bed (Bishop-Sambrook et al., 2004) than to farmers using oxen than hand hoes. To some farmers reduced tillage such as No till may implied unprogressive practice and against modern agriculture, and hence may limit the adoption unless there is a change in mindset.

Government support to IK also plays a significant role in adoption and scaling up of agricultural technologies. Farmers in Chololo district indicated that lack of government support on their efforts in adopting *chololo* pits, an indigenous CA technology (Tumbo et al., 2011). Other indigenous soil management such as slash and burn are practiced because of cultural beliefs (Zagst, 2012), hence in depth awareness creation is required to change peoples' mind set and turn it towards sustainable land management technologies such as CSA. Changing mindset can be achieved through emphasizing the importance of IK that are compatible with CSA, and supported with scientific knowledge in scaling up through communicating research findings on IK and through training.

6.10 Lesson learned on community participation in planning and budgeting CSA

Participatory dissemination methods involving farmers in problem analysis, setting extension priorities, and planning and obtain feedback from farmers are well recognized for its impact on technology adoption (Rathgeber, 2011). The community involvement in planning through demonstration plots and farmers field schools provides such platform for farmers participatory and feedback. The HEM project successfully used community participation integrated in the village local government through formation of village committees to sensitize, raise awareness, convincing farmers, train, plan, and implement CA and erosion control (SUSTAINET, undated). The village committee members that include village leaders and government extension staff, and the strength of leadership are considered key in success of HEM project. The implementation approach of landscape level soil and water conservation can be "*Kazi jumuia*" as in the case of Kilimanjaro (SUSTAINET, undated).

In this approach each member of the village is required to work one day a week on community activities, like road maintenance, repairing an irrigation canal or building check dams on a stream or school building as agreed by farmers organized and re-enforced by village leaders. For the *Kazi jumuia* approach to be effective, strong village leadership is necessary. Another successful community participation is a collective action mechanism to promote civil society involvement in water shed management through "The Converstatorio of Acción Ciudadana (CAC)" in Colombia. The CAC is a legal mechanism supported by the Constitution in Colombia used four-phase process that enhances the effectiveness of local participation: (1) awareness-raising, (2) capacity-building and preparation (3) CAC implementation, and (4) review and planning. The CAC mechanism has brought together diverse actors and fostered collective action across spatial and social scales. The approach enhanced organizational and political support for community and local NGOs through dialogue and networking activities that lead to higher-level organizations (i.e., sub national, national and international) linked up and working with lower-level organizations and communities (Cordoba and White, 2011), that is cross-scale collaboration. In so doing, CAC foster scaling up of sustainable land use to protect watershed.

7 DISSEMINATION APPROACH

Achieving scaling up of CSA requires appropriate dissemination pathways or approaches to ensure effective uptake especially among the smallholder farmers. This is because CSA is knowledge-intensive, in the sense that requires integration of climate change adaptation and mitigation, and wide range of best agronomic practices and integration of farm and off farm intervention. Therefore, choice of dissemination approach should consider both the ability to reach large number of farmers and preference by farmers for reliability and credibility, which are important in enhancing adoption (Murage et al., 2010).

Dissemination pathways documented to have impact in technology transfer and adoption includes farmer field school, farmer trainer (para-professional), field days, extension communication products (fliers, manual, and booklets), radios, classroom trainings to least few. Generally, the most preferred dissemination approach by small scale farmers are field days, farmer trainer, famers field school and fellow farmers whereas the least preferred is print materials, radio, and *baraza i.e.* village meeting (Murage et al., 2010). However, it has been urged that the preference of a pathway by farmers and hence positive impacts in adoption of a given technology depends on socio economic characteristics of farmers. Murage et al (2010) reported that farmers with low education level preferred field days, farmers in groups preferred FFS, farmers with small farm size prefers farmer trainer, while young and educated farmers preferred print materials.

The dissemination approach to achieve scaling up of CSA should take into consideration the following aspects to achieve quantitative, functional, political and organizational scaling up:

1. Community involvement and enabling legal environment, where farmers as end users are involved in planning and implementation of project activities. Community empowerment and facilitation to communicate their views and influence policies to improve land tenure, input access, communal, land management, at local and national level.

2. Capacity building to impart knowledge and awareness through training. Training should target both farmers and extension services. The extension service is acknowledged to have great contribution to technology transfer; hence their correct and accurate understanding of CSA is important to successful scaling up of CSA. Farmers training focusing on the benefits of CSA, change of mind set, entrepreneurship in farming business, and record keeping are essential for scaling up CSA.

3. Promote mechanism to improve access of required implements/equipment – promoting local manufacturing of equipment and maintenance/service of equipment or facilitating purchase of those equipment. Partnership/collaboration with institutions/companies like SIDO, CARMATEC etc. will be useful to improve access of required implements such as rippers, biogas plants, *ngwamba* hoe etc.

4. Introduce/promote secured land tenure systems in participatory approach in collaboration with village authorities and respective sector.

5. Improve market accessibility and efficiency to ensure smooth and fair prices for agricultural produces and enhance income generation and investment to CSA.

All these can be achieved through multi-sectoral, multi-stakeholder approach with public and private sector partnership. The CSA technologies and practices dissemination approach should be participatory after creating awareness of the need to go for CSA. There should be a common understanding among all stakeholders on the impact of soil erosion and soil fertility decline and the benefits of their control, both in short term. Creating awareness on the potential of CSA to increase agriculture adaptation and mitigation of climate change should also be emphasized. Once all stakeholders are awareness, landscape/catchment approach should be used in planning and implementing the following CSA technologies

8 CONCLUSIONS AND RECOMMENDATIONS

The major constraints in Chamwino and Kilosa are soil erosion, excessive loss of soil moisture, and loss of soil productivity. Therefore, climate smart agriculture technologies that conserve soil moisture, supply soil water (water harvesting), improve soil fertility, use of adaptive crop varieties and types are highly recommended. Implementation of these technologies at a particular site should base on land use planning depending on the potential of the land for particular use (forest areas, grazing land, crop land, and wetlands). The most erosion vulnerable areas should be conserved as forest areas, and income generation that conserve forest such as bee keeping should be promoted to discourage deforestation for charcoal making or agriculture as major source of livelihood.

Climate smart technologies such as reduced tillage, crop residue management to protect surface soil from erosion should be emphasized in crop land. These conservation technologies should go hand in hand with soil fertility management using integrative nutrient management. The livestock keeping should be integrated with crop production though development of fodder areas and grazing land fertility and soil management to discourage competition for crop residues between protection of soil surface and feeding livestock/grazing. Availability of fodder will not only increase livestock production but also increase availability of farm yard manure to improve soil fertility. Manure management technologies that protect exposure of manure to sun and rain should be emphasized to ensure quality of manure as source of nutrient, and also reduced emissions of GHG.

Land use planning and management for each village to allocate lands for farming, livestock grazing, wetlands and settlement is an institutional intervention that can be done at village level as required in the Tanzania Government plan. The village level land use plan according to government plan will be completed in 2030. In both implementation areas for ActionAid project Chamwino and Kilosa, land use planning is of priority due to existence of multiple land uses for crop production and livestock keeping.

In Kilosa, incidence of land use conflicts has been documented as being caused by lack of land use planning and inappropriate management of land for both crop production and livestock keeping that forced each land user to encroach marginal lands. Therefore, implementation of technologies and practices to ensure climate smart agriculture should be implemented based on the capacity of land for particular use.

Livestock are a key component of CSA, especially in Chamwino where manure fertiliser is highly relied upon. It is important though that livestock herd size is checked against the diminishing pastureland and the stress caused by climate change on the pasture itself. Intensification of zero grazing in sheds while using some of the land to intensively produce pasture could be one of the best options. This will reduce the effects of livestock on soils, reduce animal invasions on croplands and hence conflicts as well as simplifying collection of manure since it will be constricted in the shed. Zero grazing has been successful implemented in land scarce areas such as Kilimanjaro and the manure has played a big role in the success of the famous Chagga multi-storey agroforestry systems (IHDP, 2008).

In general terms the idea is appealing. If it works, it could bring benefits to farmers while at the same time leading to low carbon development pathways. However considerable challenges remain. One important concern is its mitigation potential. REDD initiatives are still being experimented, Kilosa being one of the pilot study Districts implemented by TFCG. The achievement of the mitigation component of climate smart agriculture is almost entirely dependent of the successful implementation of REDD.

Important questions surrounding REDD initiatives in Tanzania and elsewhere are over the amount of money to be paid or expected to be received by communities, availability and access to carbon markets, institutional bottlenecks such as corruption by implementing organs, etc. These questions are crucial and farmers needs to be fully aware of the answers before they invest their time and willingness in setting aside land and forests for REDD or any other payment for ecosystem service (PES) initiative. It is not strange therefore that doubts and concerns exists over the technical mitigation potentials, whether payments to farmers will be more than symbolic, and over the environmental consequences. Some argue the payment to farmers for carbon storage should be seen merely as an ‘added bonus’ to farmers, and that the main benefits to them will be productivity gains and increased resilience to climate stress. However, these are concerns not to be taken lightly.

On the issue of tenure and land planning, conflict between farmers and pastoralists in Kilosa and Chamwino should be given considerable effort for CSA to succeed. Pastoralists normally require a considerable amount of land compared to farmers. They often times invade cropland and forests destroying farmers crops and conserved species. Animal trampling is also a serious problem since it accelerates erosion substantially and hence negatively affecting soil conservation and hence CSA. Livestock keepers should be educated and empowered to maintain small but more productive herds. They also should diversify and add value to livestock products so as to maximise benefits. This venture requires expertise, cooperation as well as political support for implementation. If not handled conflicts between farmers and pastoralists will persist and destabilise CSA initiatives.

CSA in Tanzania is mostly rain fed agriculture. Major implications on rain fed agriculture are possible shrinking of the growing season, increasing moisture and heat stress to common food and cash crops, increased insects and pests and eventually low income and food insecurity. Studies have shown that there is strong evidence demonstrating the vulnerability of rain fed agriculture to negative impacts of climate change and variability (Mongi et al, 2010). It is suggested that there is a need for multi-level interventions on adaptation to climate change and variability taking into account a wide range of stakeholder involvement.

Finally and importantly it is to point out that, research has proved that farmers who obtain agricultural knowledge through extension/training seminars as well as those with secure land ownership are likely to adopt climate smart agriculture such as soil conservation technologies (Kalineza *et al*, 1999). Two broad policy implications emerge from such findings. The first implication is that there is a need to intensify extension education that demonstrates relative benefits of various climate smart agriculture technologies to stimulate their adoption (Kalineza *et al*, 1999; Bot and Benites 2001; Wondwossen Tsegaye et al. 2008; FAO, 2011). A good example of this is from the GALUP project in Gairo, Tanzania (Kalineza *et al*, 1999).

The second implication which emerges from the significance of land ownership in adoption of climate smart agriculture practices is the need for a clear land policy that provides rights of owning land among smallholder farmers. Secure land rights will promote investments on land such as adoption of soil conservation practices which conform to climate smart agriculture. An analysis by FAO, (2011) cited conservation agriculture, agroforestry, soil and water conservation as well as conservation grazing being a risk intervention where land tenure is insecure.

REFERENCES:

Aargaard, P. 2009. Conservation farming and conservation agriculture handbook for ox farmers in agro-ecological regions I and IIa. Conservation Farming Unit, Zambia.

African Development Bank (ADB). 2013. Assessment of Best Practices and experiences in rain water harvesting: Rainwater Harvesting Handbook. Available at: http://www.rwsn.ch/documentation/skatdocumentation.2009-02-16.6179799035/file accessed Feb 2013.

Agrawal S., Moehner A., Hemp A., Valst S. Smith J., Meena H, Mwakifwamba S.M., Hyera T and Mwaipopo O.U. (2003). Development and Climate Change in Tanzania Focus on Mount Kilimanjaro. Paris OECD

Amuri , N. and K.R. Brye 2008. Residue management practice effects on soil penetration resistance in wheat-soybean double-crop production system. Soil Sci. 173: 779-791.

Amuri, N., Brye, K.R., Gbur, E.E., Popp, J. and Chen, P. 2008. Soil property and soybean yield trends in response to alternative wheat residue management practices in a wheat-soybean, double-crop production system in eastern Arkansas. J. Integr. Biosci. 6(1):64-86.

ASR/PER, (2008). Agriculture Sector Review and Public Expenditure Review, 2008/09. Final Report, November, 2008.

Barnhart, S. K., Voss, R. D. and Geroge, J. R. 1997. Pasture fertilization. Agronomy: Crops, Soils Climate. Iowa State University Extension, Pm-869. Available at: http://www.extension.iastate.edu/Publications/PM869.pdf Accessed Feb 2013

Bezabih M., Chambwera M and Stage J (2010). Climate Change, Total Factor Productivity and the Tanzanian Economy: A computable General Equilibrium Analysis. Environment for Development. Discussion paper Series. June 2010 EfD DP 10-14.Tanzania

bFAO, 2009. Food security and agricultural mitigation in developing countries: Options for capturing synergies. Contributing Authors: W. Mann, L. Lippe, T. Tennikeit, N. McCarthy, and G. Blanca. Rome, Italy. Food and Agriculture Organization of the United Nations.

Bishop-Sambrook, C., Kienzle, J. Mariki, W., Owenya, M. and Ribeiro, F. 2004. Conservation Agriculture as a Labour Saving Practice for Vulnerable Households. A Study of the Suitability of Reduced Tillage and Cover Crops for Households under Labour Stress in Babati and Karatu Districts, Northern Tanzania. IFAD, FAO, 80p

Branca, G., McCarthy, N., Lippe, L. and Jolejole, M.C. 2011. Climate smart agriculture: A synthesis of emperical evidence of food security and mitigation benefits from improved cropland management. *Mitigation of Climate Change in Agriculture Series 3*, December, pp. 1-36.

Buresh, R.J., Smithson, P.C. and Hellums, D.T., 1997. Building Soil phosphorus Capital in Africa. in: Replenishing Soil fertility in Africa. American Society of Agronomy and Soil Science Society of America. Special Publication no. 51. Wisconsin, USA

Bwalya, M. 2006. Conservation Agriculture for Sustainable Agriculture and Rural Development (CA – SARD) and Food Security in Southern and Eastern Africa Project.End of Project Stakeholders Workshop on Enhancing Knowledge Generation and Experience Sharing, held in Nakuru, Kenya

Carlo Acosta, I.S. 2009. Promoting the Use of Tropical Legumes as cover crops in Puerto Rico. A thesis submitted in partial fulfillment of the requirements for the degree of Master In Sciences In Agronomy University Of Puerto Rico Mayagüez Campus. Climate change and variability in semi-arid Tanzania. African Journal of Environmental Science and Technology Vol. 4: 371-381

CIAT, 2013. Tropical forage program. Agrobiodiversity Research Area.

Clements, M. and T. Moss 2005. What's Wrong with the Millennium Development Goals? Center for Global Development Brief

Córdoba, D. and D. White. 2011. Citizen participation in managing water: Do Conversatorios generate collective action? An outcome evaluation of the CPWF project: Sustaining Collective Action Linking Economic and Ecological Scales in Upper Watersheds (SCALES/PN20). Colombo, Sri Lanka: CGIAR Challenge Program for Water and Food (CPWF). 66p. (CPWF Impact Assessment Series 06).

de Wit, M. and Stankiewicz, J., (2006). Changes in Surface Water Supply across Africa with Predicted Climate Change. Science 311: 1917-192

Diaz-Zorita, M.J., Grove, J.H., Murdock, L., Herberck, J. and Perfect, E. 2004. Soil structural disturbance effect on crop yields and soil properties in a no-till production system. Agron J. 96: 1651-1659

Druilhe, Z. and Barreiro-Hurlé, J. 2012. Fertilizer subsidies in sub-Saharan Africa. ESA Working paper No. 12-04. Rome, FAO

Ehrhart, C. and Twena, M., (2006). Climate change and poverty in Tanzania: realities and response options for CARE. Background report, CARE International Poverty-Climate Change Initiative

Fan, S. 2011. Overview: Major Food Policy Developments in 2011. 2011 Global Food Policy Report. IFPRI, Washington DC, USA. 1-10.

FAO (2012). Mainstreaming climate-smartagriculture into a broader landscape approach. The Second Global Conference on Agriculture, Food Security and Climate Change. Hanoi, Vietnam, 3-7 September 2012. Food and Agriculture Organization of the United Nations, 2012

FAO 2009a The State of Food Insecurity in the World Economic crises – impacts and lessons learned. WFP 61p

FAO, 1993. Soil tillage in Africa: needs and challenges. FAO Soils Bulletin. Available at http://www.fao.org/docrep/T1696E/T1696E00.htm Accessed March 2013

FAO, 2001. Soil fertility management in support of food security in sub-Saharan Africa. FAO, Rome, Italy

FAO, 2006. Fertilizer use by crop. FAO Fertilizer and Plant Nutrition Bulletin 17. Rome. Italy

Flynn, H.C. 2009. Agriculture And climate change: An Agenda for negotiation in Copenhagen For Food, Agriculture, and the environment. The Role of Nutrient Management in Mitigation. 2020 Vision for Food, Agriculture and Environment., international Food Policy research institute. Focus 16, Brief 7: 1-2

Food and Agriculture Organization of the United Nations (FAO) 2013. Climate smart Agriculture for development. Available at http://www.fao.org/climatechange/climatesmart/en/ accessed Feb 2013

Future Farming, 2008. Climate change: be part of the solution Focus on: nutrient management. Fact Sheet 21.

Glanzberg, J. 1994. Water harvesting traditions in the desert southwest. PDJ 20: 8-11.

Global Climate Adaptation Partnership (GCAP) and partners. (2011). The economics of climate change in the United Republic of Tanzania. Unpublished report, 139 pp.

Hanoi Communique, 2011. Hunger for Action. 2nd Global Conference on Agriculture, Food Security and Climate Change. 3-7 September 2012, Hanoi, Vietnam. Available at www.rijksoverheid.nl/...**hanoi**.../the-**hanoi**-communique.pdf visited March 2013

Hatibu, N. and Mahoo, H. 1999. Rainwater harvesting technologies for agricultural production: a case for Dodoma, Tanzania. Sokoine University of agriculture, Department of Agricultural Engineering and Land Planning

Havlin, J. L., Kissel, D. E., Maddux, L. D., Claassen, M. M. and Long J. H. 1990. Crop Rotation and Tillage Effects on Soil Organic Carbon and Nitrogen. Soil Science Society of America Journal 54: 448-452.

Headey, D. 2011. Deja Vu in the Horn of Africa. 2011 Global Food Policy Report. IFPRI, Washington DC, USA. 25-38

High Level Task Force (HLTF) on Global Food Security 2011. Food and nutrition security: comprehensive framework for action. Summary of the Updated Comprehensive Framework for Action

Hoffmann, U. 2011. Assuring food security in developing countries under the challenges of climate change: key trade and development issues of a fundamental transformation of agriculture. Re-thinking development in an age of scarcity and uncertainty new values, voices and alliances for increasing resilience. 19 to 22 September, University New York

Huggins, D.R. and Reganold, J.P. 2008. No till: The quiet revolution. Agriculture. Scientific American 71.

ICRAF (World Agroforestry Centre). 2011. Agroforestry options for Tanzania. Policy Brief.

IHDP, 2008. The Chagga Homegardens on Mount Kilimanjaro. Mountain Research Initiative (MRI) Global Change Research Network in African Mountains

IIRR and ACT 2005. International Institute of Rural Reconstruction and Africa Conservation Tillage Network.. Conservation agriculture: a manual for farmers and extension workers in Africa. Nairobi: IIRR

Ikerra, S.T., Semu, E. and Mrema, J.P. (2006). Combining Tithonia diversfolia and MPR for improvement of P availability and maize grain yields on a chromic acrisol in Morogoro, Tanzania. *Nutrient Cycling in Agroecosystems* 76:249-260

Jonsson, M. Assessing the climate change mitigation potential of the EADDMICCA pilot project with the Ex-Ante Carbon Balance Tool (EX-ACT). Mitigation potential of the MICCA Programme Pilot Project: Enhancing agricultural mitigation within the east Africa dairy development project (EADD) in Kenya. Mitigation of Climate Change in Agriculture (MICCA) Programme Background Report 6.

Kaliba, A.R.M., H. Verkuijl, W. Mwangi, A.J.T. Mwilawa, P. Anandajayasekeram, and A.J. Moshi. 1998. Adoption of Maize Production Technologies in Central Tanzania. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT), the United Republic of Tanzania, and the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR).

Kangalawe R., Mwakalila S., and Masolwa P. (2011). Climate Change Impacts, Local Knowledge and Coping Strategies in the Great Ruaha River Catchment Area, Tanzania. Natural Resources, Vol. 2 No. 4, 2011, pp. 212-223. doi: 10.4236/nr.2011.24027

Kangalawe, R.Y.M., Mung'ong'o, C.G., Yanda, P.Z., Mwakaje, A.G., Kalumanga, E. (2009). Climate change and variability impacts, vulnerability and adaptive capacity in Kasulu District, Tanzania. Chapter 2. In: Kangalawe, R.Y.M., Mung'ong'o, C.G. and Yanda, P.Z. (Eds.). People's Perceptions and Community Response to Climate Change and Variability: Selected Cases from Tanzania. Institute of Resource Assessment, University of Dar es Salaam.

Kaumbutho Pascal, Kienzle Josef, eds. 2007. Conservation agriculture as practised in Kenya: two case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations

Kavia, F.Y., Mushongi, C.C. and. Sonda, G.B. 2007. Factors affecting adoption of cassava varieties: a case of Cassava Mosaic Disease tolerant varieties in Lake Zone Regions - Tanzania African Crop Science Conference Proceedings 8: 1875-1878

Khan, Z., Amudavi, D. And Pickett, J. 2008. Push-Pull Technology Transforms Small Farms in Kenya. PAN North America Magazine, pp 20-22.

Kitalyi, A., Nyadzi, G., Lutkamu, M., Swai, R., Gama, B. 2011. New climate, new agriculture: how Agroforestry contributes to meeting the challenges of Agricultural development in Tanzania. Tanzanian Journal of Agricultural Sciences, 10 (1): 1 – 7.

Kizughuto TM, Shelukindo HB. 2003. The challenges facing the catchment approach in the East African highlands, the case of the Usambara mountains experiences and way forward. SECAP discussion paper. Soil Erosion and Agro-forestry program (SECAP), Lushoto District, Tanzania

Logsdon, S.D. and D.L. Karlen 2004. Bulk density as a soil quality indicator during conversion to no-tillage. Soil Till. Res. 78: 143–149

Mariki, W.L., Marietha, Z.O., Kassam. A., Kienzle, J., Friedrich, T., 2011. Conservation Agriculture (CA) in Tanzania: the case of Mwangaza B CA Farmer Field School (FFS), Rhotia Village, Karatu District, Arusha, Tanzania. World Congress of Conservation Agriculture .[Online] Available at: http://aciar.gov.au/files/node/13993/conservation_agriculture_ca_in_tanzania_the_cas_21062.pdf [Accessed Feb 2013].

Masangano, C.M. and C. A. Miles. 2004. Factors Influencing Farmers' Adoption of Kalima Bean (Phaseolus vulgaris L.) Variety in Malawi. Journal of Sustainable Agriculture 24, 2

Massawe, J.B.H. and Amuri, N. 2012. Soil fertility and agronomic practices evaluation for improved rice production in lowland rice producing areas of Kilombero and Wami valleys, Morogoro, Tanzania. A consultancy service for NAFAKA project, USAID Feed the Future, Tanzania.

Mati, B. 2007. 100 ways of managing water for smallholder agriculture in Eastern and Southern Africa. A Compendium of Technologies and Practices. SWMnet Working Paper 13. 52pp

McCarthy, N., Lippe, L. And Branca, G. 2011. Climate-smart agriculture: Smallholder adoption and implications for climate change adaptation and mitigation. Mitigation of climate change in Agriculture Series 4. FAO

Mendoza, T. C. and Samson, R. 1999. Strategies to avoid crop residue burning in the Phillipines context. A paper presented in the International Conference on "Frostbite and Sun burns" Canadian International Initiatives towards Mitigating Climate change, hosted by International program (IP) of the Canadian Environmental Network (CEN) and Salvadoran Center for Appropriate Technology (CESTA), 24th April to May 2 1999, Canada

Mkoga, Z.J., Tumbo, S.D., Kihup, N. and Semoka J. 2010. Extrapolating effects of conservation tillage on yield, soil moisture and dry spell mitigation using simulation modeling. Physics and Chemistry of the Earth 35: 686–698

Mongi, H., Majule, A. E., and Lyimo, J.G. 2010. Vulnerability and adaptation of rain fed agriculture.

Monyo ES, Ngereza J, Mgonja MA, Rohrbach DD, Saadan HM, and Ngowi P. 2004. Adoption of improved sorghum and pearl millet technologies in Tanzania. PO Box 776, Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics. 28 pp

More, A (2009). Climate Change and Rural Livelihoods in Tanzania: A case study of Ibuti and Majawanga. MSc Thesis, University Of Copenhagen, Faculty of Life Sciences.

Mowo, J.G., B.H. Janssen, O. Oenema, L. German, J.P. Mrema and R.S. Shemdoe (in press), Agriculture, Ecosystems and Environment.

Munguambe, I. N. 2007. Rainwater Harvesting Technologies for Small Scale Rainfed Agriculture in Arid and Semi-arid Areas. Integrated Water Resource Management for Improved Livelihood-CICIAR Challenge Program on Water and Food . Water Net.

Murage, A. W.; Amudavi,D.M.; Obare. G.; Chianu, J.; and Khan, Z.R. 2010. Determining smallholder farmers' preferences for Push-Pull technology dissemination pathways in western Kenya. Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010

Mwandosya, M.J., Nyenzi, B.S., and Luhanga, M.L., (1998). The Assessment of Vulnerability and Adaptation to Climate Change Impacts in Tanzania. Dar es Salaam, Tanzania: Centre for Energy, Environment, Science and Technology (CEEST)

NAPA, 2007. National Adaptation Programme of Action (NAPA). Vice president's Office. Division of Environment, January 2007

Ndamugoba, D., 2006. *Conservation Agriculture for Sustainable Agriculture And Rural Development Farmer Field Schools Program in Bukoba Kagera, Tanzania.* Nakuru, s.n.

Neufeldt H, Kristjanson P, Thorlakson T, Gassner A, Norton-Griffiths M, Place F, Langford K, 2011. ICRAF Policy Brief 12: Making climate-smart agriculture work for the poor. Nairobi, Kenya. World Agroforestry Centre (ICRAF).

Nyadzi G.I. 2004. Nutrients and water dynamics in rotational woodlots: a case study in Western Tanzania. Wageningen University and Research Centre, Wageningen, The Netherlands, 192 p.

Nzabi, A. F. M. N. K. a. E. M., undated. Effect of cover crops and conservation tillage in improving maize yield in semi-arid areas of South-West Kenya. s.l., s.n., pp. 422-447.

Onyango, R.M.A., Mwangi, T. J.,. Kiiya, W.W. Kamidi, M.K. And Wanyonyi, M.W. 2000. Evaluation of Organic And Inorganic Fertilisers for Small Holder Maize Production in North Rift Kenya. Available at: http://www.kari.org/fileadmin/publications/legume_project/Legume2Conf_2000/1.pdf Accessed April 2013.

Owen, J., LeBranc, S and Fillmore, S. 2007. Short term effects of mechanical weeding on soil and tissue N in snap beans Results from a long-term organic vs. conventional rotations experiment Available at: http://www.organicagcentre.ca/Docs/Guelph2007/OwenJ%20Guelph%20organic%202007.pdf. Accessed March 2013.

Paavola, J., 2006. Justice in Adaptation to Climate Change in Tanzania. In 'Fairness in Adaptation to Climate Change' pages 201-222, edited by W. Neil Adger, Jouni Paavola, Saleemul Huq and M.J. Mace, 2006. The MIT Press: Cambridge, Massachusetts,

Pye-Smith C. 2011, Farming's Climate-Smart Future. Placing agriculture at the heart of climate change policy. CTA.

Rathgeber, E.M. 2011. Rural Women's Access to Science and Technology in the Context of Natural Resource Management. UN Women In cooperation with FAO, IFAD and WFP Expert Group Meeting Enabling rural women's economic empowerment: institutions, opportunities and participation, 20-23 September 2011, Accra, Ghana . Available at:

http://www.un.org/womenwatch/daw/csw/csw56/egm/Rathgeber-EP-6-EGM-RW-Oct-2011.pdf. Accessed March 2013.

RDS, 2001. Rural Development Strategy for Tanzania: Final Draft: Main Report. http://www.tzonline.org/pdf/ruraldevelopmentstrategy1.pdf

Reddy, B.V.s., Kumar, A.A. and Reddy, P.S. 2013.Genetic improvement of sorghum in the semi-arid tropics Available at http://oar.icrisat.org/4396/1/Genetic_improvement_of_sorghum_in_the_semi-arid_tropics.pdf. Accessed March 2013

Reiter, M. 2009. Conservation tillage trends in virginia agricultural production. Available at: http://www.ag.auburn.edu/auxiliary/nsdl/scasc/Proceedings/2009/Reiter_a.pdf. Accessed March 2013

Semoka, J.M.R., Msuya-Bengesi, C.P. and Amuri, N. 2010. Mradi wa Kukuza matumizi ya mbolea ya Minjingu Fosfati Pamoja na matumizi Sahihi ya mbole ambalimbali Katika Kilimo. Sokoine University of Agriculture, Alliance for a Green Revolution in Africa, Ministry Of Agriculture

Semoka, J.M.R., Shekifu, C.Y. and Mende, D. (1996). Nutrient constraints in selected rice growing areas of Morogoro region. In: *Meeting Framers Needs through Agricultural Research*. *Proceedings of the First Faculty of Agriculture AnnuaL Research Confrence.* (Edited by Matee, A.Z.; Sibuga. K.P.; Semoka, J.M.R. and Tsunoda, M.) 28-th Aug 1995. Sokoine University of Agriculture, Morogoro, pp 200-216

Sharma, N., T. Damhang, E. Gilgan-Hunt, D. Grey, V. Okaru and D. Rothberg (1996), African Water Resources: Challenges and Opportunities for Sustainable Development, World Bank Technical Paper No.33, African Technical Department Series, The World Bank, Washington DC, USA

Shetto, R. and Owenya, O. M. 2007. Conservation agriculture as practised in Tanzania: three case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations

Six, J., Paustian, K. And Combrink, C. 2000. Soil structure and soil organic matter: I. Distribution and aggregate size classes and aggregate associated carbon. Soil Science Society of American Journal 64; 681-689

Smith, R., Panciera, M. and Probst, A. 2010. Using a Grazing Stick for Pasture Management. A collaborative publication of Berea College and the University of Kentucky Cooperative Extension Service , University Of Kentucky College Of Agriculture, Lexington, KY, 40546 AGR-191.

Sungula, K. 2001. Chololo planting pits. in: Farmers' Initiatives in Land Husbandry: Promising technologies for the drier areas of East Africa (K. Mutunga, W. Critchley, P. Lameck, A. Lwakuba and C. Mburu). Technical Report No. 27.RELMA, UNDP, Vrije Universiteit, WOCAT

SUSTAINET EA 2010. Technical Manual for farmers and Field Extension Service Providers: Conservation Agriculture. Sustainable Agriculture Information Initiative, Nairobi.

SUSTAINET, undated. Sustainable Agriculture A pathway out of poverty for East Africa Rural Poor. Part 2. An example from Kenya and Tanzania. GTZ. Available at: http://www.sustainet.org/download/sustainet_publication_eafrica_part2.pdf visited April 2013

Tenge, A.J.M. 2005 Participatory appraisal for farm-level soil and water conservation planning in West Usambara highlands, Tanzania. Tropical Resource Management Papers, No. 63.

Tenge, A.J.M., J. de Graaff and J.P. Hella. 2004. Social and economic factors for adoption of soil and water conservation in west Usambara highlands, Tanzania Land Degradation and Development 15: 99-114

Tumbo, S., Mutabazi, K., Kimambo, A. and Rwehumbiza, F. 2011.Costing and planning of adaptation to climate change in animal agriculture in Tanzania. International Institute for Environment and Development (IIED), London, UK.

Tumbo, S., Mutabazi, K.D., Kahimba, F.C., Mbungu, W.B. 2012. Adoption and Outscaling of Conservation Agriculture in Tanzania. AgWater Solutions Project Case Study. IWMI. 31pp

Tumergamire, S., Kapinga, R., Zhang, D., Crissman, C. And Agili, S. 2004. Opprotunities for promoting orange-freshed sweet potatoes as a mechanism for combat vitamin A deficiency in Sub Sahara Africa. African Crop Science Journal12: 241 - 252

URT (2007). National Adaptation Programme of Action (NAPA). Vice President's Office. Division of Environment, January 2007

URT (2013). Nationa Climate Cgange Strategy. Vice President's Office. Division of Environment

Valenzuela, H. a. J. S., 2002. *Cowpea,* s.l.: Sustainable Agriculture Green Manure Crops SA-GM-6.

Verkler, T.L., K.R. Brye, E.E. Gbur, J.H. Popp, and N. Amuri (2008). Residue management and water delivery effects on season-long surface soil water dynamics in soybean. Soil Sci. 173: 444-455

Wageningen Statement, 2011. Climate-Smart Agriculture - Science for Action. 24-26 October 2011 - Ede / Wageningen - The Netherlands

Watkis P., Downing T., Dyszynski J., Pye S et al (2011). The economics of climate change in the United Republic of Tanzania. Report to Development Partners Group and UK Department for International Development Published January, 2011. http://economics-ot-cc-tanzania.org/Levira 2009

WHaTeR 2012. Water Harvesting Technologies Revisited. WP4 Environmental Sustainability

Yeo, A. 1998. Predicting the interaction between the effects of salinity and climate change on crop plants. Scientia Horticulturae 78: 159–174

Zagst, L. 2012. Socio-economic Survey CARE-MICCA Pilot Project in the United Republic of Tanzania. Mitigation of Climate Change in Agriculture (MICCA) Programme Background Report 3. FAO.