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Full Length Research Paper

Enhancing capacities of individuals, institutions and organizations to adapt to climate change in agricultural sector using innovative approaches in Tanzania and Malawi.

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Smallholder agriculture underpins most rural livelihoods and national economy in Tanzania and Malawi. Agricultural production by small holders in such countries is frustrated by several factors including climate change and variability (CC&V). Non agriculture community livelihoods activities and ecosystems are also negatively affected, adding costs to adaptation. The overall objective of the paper is sharing research experience on how climate change adaptation within agriculture sector can be strengthened using innovation approaches. Findings are based on a four years action research project funded by DFID through IDRC in Tanzania and Malawi. A total of 16 villages, 8 each in Tanzania and Malawi were involved and a Participatory Action Research was used. In total 360 farmers were initially involved in the project. Findings showed thas CC&V is affecting farming communities, institutions and organizations differently. Communities could adapt better if relevant information on climate and required products reaches them on time. Behaviour changes of different boundary partners like farmers, extension workers, agricultural based NGOs, stockists, media, with policy support (at both national and local levels) positively reduced vulnerabilities to CC&V and as a result sorghum, maize, beans and sunflower crop yields improved. For local innovation systems to work better a collective mobilisation of resources and collaboration of different boundary partners is required in this context. Adaptation program should focus more in supporting action oriented research or programs if capacity to adapt need to be strengthened in agricultural sector using innovative approaches.

Key words: Boundary partners, Tanzania, innovation system, Malawi, sustainable, livelihood.

INTRODUCTION

In many sub-Saharan African (SSA) countries, poverty and food insecurity are linked to low agricultural productivity which accelerating climate change and variability (CC&V) threatens to make even worse (Devereux and Edwards, 2004; Slingo et al., 2005). It is estimated that about 75% of the population of sub-

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Saharan Africa lives in arid and semi-arid areas that cover about 75% of sub-Saharan Africa. These areas are characterized by low soil chemical fertility and low annual rainfall that is poorly distributed (Maitima et al., 2009; Mubaya et al., 2010; Mugabe, 2011). Under this situation agricultural productivity by small scale farmers is very low resulting both in food and income insecurity leading to poverty (Majule, 2010). Different studies conducted in different parts of Tanzania and Malawi showed that the livelihood of the communities in the two countries depends on agriculture which is also climatically challenged by droughts and floods in low and high potential areas respectively (Majule et al., 2008). Most farmers are aware of the adaptive strategies to put in place in their fields but they are limited in implementing them because of lack of information for example about the on set of the rain season (Mubaya, 2010; Mugabe et al., 2010), lack of information about appropriate seeds to plant and types of new crops to grow (Kangalawe et al. 2005) and also on how to appropriately manage soils and water under dry conditions.

In this context agricultural Innovation System (IS) is defined as *a* 'network of organizations, enterprises and individuals focused on bringing new products, new processes and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance' (Sunding and Zilberman, 2000). In this case adaptive capacity within the context of agricultural innovation systems in Tanzania and Malawi is considered to be the ability of farmers, institutions and organizations to respond successfully and make adjustments to the challenges associated with climate change and variability (CC&V) (Brooks and Adger, 2005; Mortimer and Manvel, 2006). There are several factors that determine adaptive capacities and among them are limited technology and low education levels, limited endowment of different natural resources, weak social relations as well as limited financial resources. Research institutes and other similar organizations in both Tanzania and Malawi have been able to generate different information and products that can be used by farming communities to strengthen adaptation to CC&V. Most of these have rarely reached communities to bring about effective positive change.

In Tanzania and Malawi, a key challenge for decision makers is to understand the context and strategies of farmers and other stakeholders in agriculture for adapting to CC&V, including increasingly variable climatic conditions. Diverse farming environments and complexities associated with the context of peoples' livelihoods varying over time and space suggest a need for localized innovation to enhance and sustain productivity (FAO, 1997). This is because attempts made singly by different individuals and organizations in addressing agricultural development challenges seems not to be effective because farming communities require a number of issues to be address at a time.

In light of the above definition, a four years action research project implemented in Tanzania and Malawi intended to foster processes for two-way communication and engaged amongst different agricultural institutions and organizations and for supporting their information, products and other needs in order to strengthen vulnerable farmers' and other stakeholders' capacities to adapt to climate change and variability. The research targeted farming communities in two countries each with two contrasting sites namely the less and more favored areas (agro-ecologically and socio-economically).

The overall objective of the paper is to share experience on how capacities of individuals, organizations and systems within the agricultural innovation systems in less favoured areas and more favoured areas of Tanzania and Malawi to adapt to the challenges and opportunities arising from CC & V could be enhanced using innovation approaches. Specifically the paper first presents findings on how different communities perceive climate in terms of impacts and vulnerability. Secondly the paper explains how different communities have been able to adapt to challenges associated with climate change. Thirdly the paper discusses major findings on how different selected adaptation options can bring improvement on crop production and finally some behaviour changes observed among institutions and organizations which participated in the learning process.

MATERIALS AND METHODS

Analytical framework and study areas

This study used a combination of sustainable livelihood approach, innovation systems and learning alliance in order to contribute towards capacity building within agricultural innovation systems to adapt to climate change in Tanzania and Malawi in specific case study villages presented in Tables 1 and 2. A detailed approach used in this study is found in Majule et al. (2008) and also on www.ccaa-agrictama.or.tz. Specific study areas in Tanzania and Malawi were selected based on the variations in biophysical and social economical potentials. In this case low potential areas had low rainfall (less that 1000 mm per year), soils are generally poor with low fertility, and have few social institutions and poor social infrastructure such as roads, irrigation structures for effective adaptation. On the other hand, high potential areas are those having high rainfall (more that 1000 mm per year) enough to support two crop growing seasons, soils are relatively fertile in particular vertisols and andosols, have many and strong local institutions, well established networks and also well established social infrastructures including roads and irrigation structures. Tables 1 and 2 present specific areas per country where this action research was implemented. Specific study

Table 1. A summary of key PAR stages followed in the implementation of the action research.

Methods	What?	When
Project inception workshop in Tanzania	Research team mobilization, initial engagement of stakeholders and planning research activities	Before research actions in mid 2007
Situational analysis (SA) in Tanzania and Malawi	Explored understanding of climate change issues at community level through focus group discussions in a total of 16 villages (8 in Tanzania and 8 in Malawi) using a checklist	After inception workshop in 2007
National Stakeholders Consultations	Consultations with policy makers, private sectors, NGO's, government institutions, marketing bodies, media and other agriculture stakeholders in both Tanzania and Malawi using a questionnaire	After SA in 2008
National Consultation Workshops	Explored roles of stakeholders on climate change (Policy, NGO's, Private sectors, Media, Local Governments etc)	These were conducted after situational analysis and stakeholders consultations in year 2
Planning and implementation of action research	Plan and take forwards agreed action research topics from implementation in learning villages	This was done in years 2, 3 and 4 of the project
Learning visits (Participatory Monitoring and evaluation)	To learn findings from different boundary partners involved in implementing action research in study villages	This done in years 1, 2 and 3 after the rain season ended
Learning Workshops	Share findings across zones within countries	Conducted after field learning visits To share findings after In 2010 seasons
National Consultation Group meetings	Deliberate of policy issues and advice the project team	After the annual planning meetings and after learning visits

sites in Tanzania are presented in Figures 1a and b for Malawi.

Data collection methods

Situational analysis and stakeholders consultation

Situation analyses to explore rural peoples' knowledge, perceptions and strategies in relation to CC&V within a broader livelihoods context was done by trans-disciplinary teams in eight less favoured and eight more favoured villages in both Malawi and Tanzania. These were followed by consultations with other AIS actors and the objectives were to: Identify key stakeholders, their roles and activities in relation to the agricultural innovation system (AIS) and CC&V; Understand their current perceptions and practices regarding CC&V and adaptation; Identify patterns of interaction, including relationships; Examine enabling environments (policies, infrastructure, informal institutions, incentives); Identify individuals and organizations to work with the project e.g. in the National Consultation Group and/or as part of the Learning Alliance. A total of 74 and 83 interviews were

Table 2. A summary of perceptions, vulnerability and associated impacts in two case study areas.

Country	United Republic of Tanzania		Republic of Malawi	
	Low potential areas	**High potential areas**	**Low potential areas**	**High potential areas**
Perceptions and changes	-Climate (temperature, rainfall, wind, whirl wind) -Temperature increasing over the last 30 years -Rainfall decreasing and becoming more unpredictable and variable -Disappearance of a second rainfall peak within a season -Rainfall coming late and ends soon	-Climate (temperature, rainfall, dew, wind, lightning) -High temperature starts early and increasing over the last 30 years -Cool period increased -Rainfall came late and unpredictable -Dew decreasing	-Climate (temperature, rainfall, wind, whirl wind) -Temperature increasing -Rainfall decreasing and becoming more unpredictable -Rainfall coming late and ends soon -Unpredictable floods	-Climate (sunshine, rainfall, dew, coldness) -High temperature starts early -Cool period extended -Rainfall came late, unpredictable -Dew decreasing
Impacts	-Declining crop yield -Traditional crops abandoned -Poor livestock production -Increasing livestock diseases such East Cost Fever (ECF)	-Decline soil fertility -Stunted crop growth -Destruction of mature crops in the field and stored ones due to shift of rainfall	-Increasing hunger periods -Increasing dependency on natural resources -loss of human property due to floods	-Landslides and soil erosion -Crops damaged -Animal loss due to floods -Increasing malaria
Vulnerability	-The poor in the community -Women, children, and elders are the most vulnerable -People with less education -Disabled and sick people -Crop growers and livestock keepers	-The poor are most vulnerable -Women, children, elders are the most vulnerable	-The poor vulnerable -Women, children, elders, sick people -Communities living in flood plains -Communities in areas with poor infrastructures -Areas with less social network -Communities living in flood plains	The poor are most vulnerable -Women, children, elders are the most vulnerable

held in Tanzania and Malawi respectively.

Participatory identification research and training needs

Village situation analyses and consultations with non farmer stakeholders identified information needed to strengthen adaptive capacity (e.g. rainfall patterns), products required (types of fertilizers, seeds etc), training needs (e.g. training on climate science) for the different key stakeholders/ boundary partners. A long list was analyzed by the project team, and a small number were identified that could be addressed by the project given the resources available. A short list was presented back to respective project villages for approval and after agreement with communities were then implemented through learning plots which was then monitored for three seasons.

Participatory monitoring and evaluation (PM&E)

The project developed and used an outcome mapping M&E framework. Key boundary partners (AIS actors) were identified and desired indicators of change

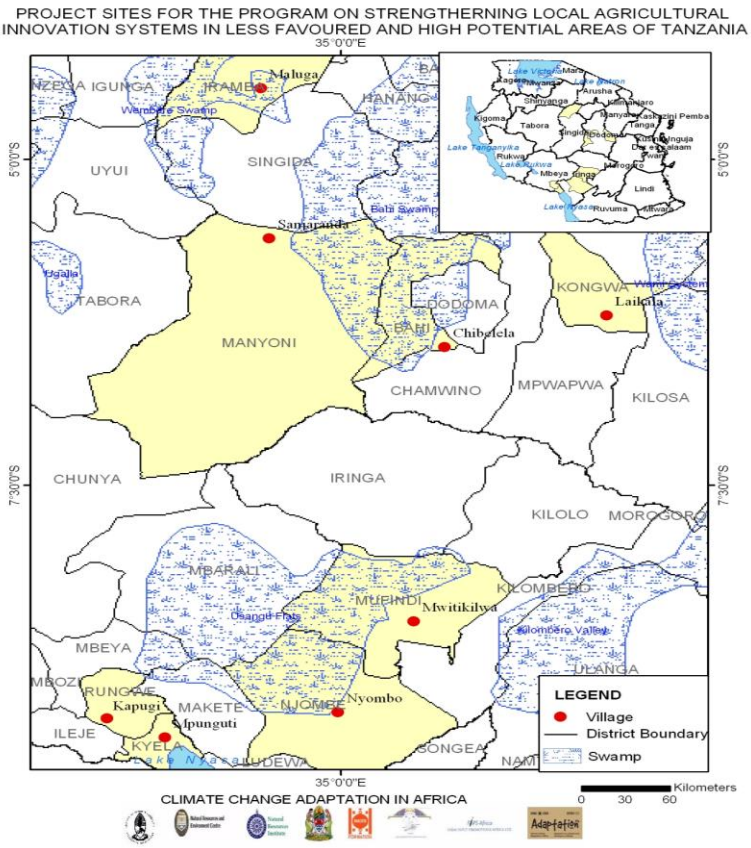


Figure 1a. Study areas in Tanzania.

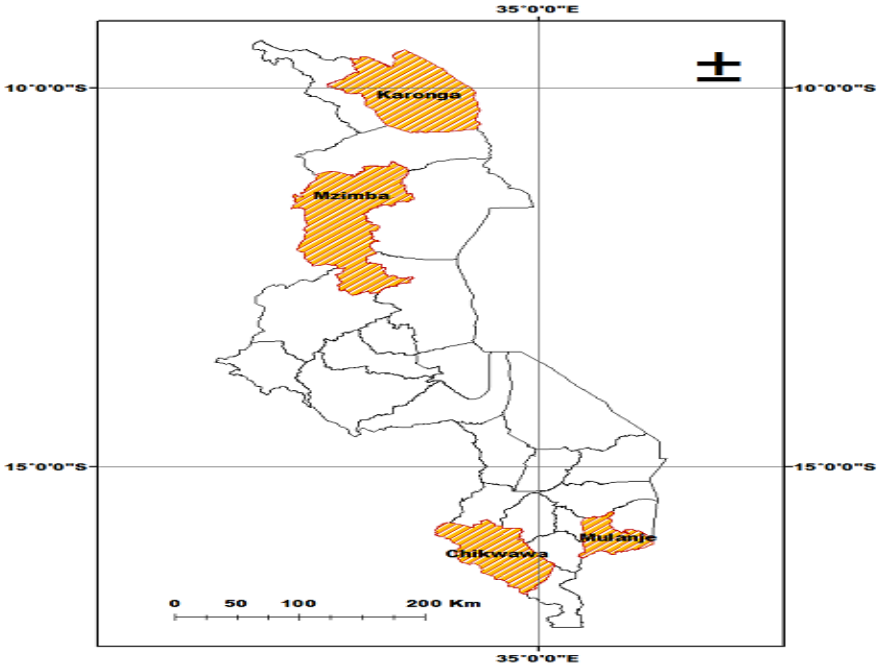


Figure 1b. Study areas in Malawi.

Table 3. A summary of different identified adaptation options for associated impacts in study areas.

Country	United Republic of Tanzania		Republic of Malawi	
	Low potential areas	**High potential areas**	**Low potential areas**	**High potential areas**
Existing adaptations	-Use drought resistant crops (eg sunflower) -Small scale irrigation of crops -Increasing non farm income-generating activities -Use of appropriate crop varieties (early maturing) -Introduction of new crops	-Increasing wetland farming -Improved social networks -Use of improved seed varieties -Use of artificial fertilizers -Strong networking among different formal and informal institutions	-Increased sunflower, cassava cultivation -Traditional irrigation of crops in dimba -Improved agronomic practices -Increasing non - farm income-generating activities	-Increasing dimba farming -Strong social networks -Well established institutions -Communication well established - Strong networking among different formal and informal institutions

identified. Updating of progress against outcome mapping progress makers by boundary partners was done during learning workshop in Morogoro Tanzania in 2010, and learning visits. National Consultation Groups were formed in Tanzania and Malawi to facilitate learning between the project and national decision makers.

In executing this study a Participatory Action Research (PAR) approach was used and the different stages used are summarized in Table 1.

RESULTS AND DISCUSION

This section first presents findings on how different communities perceive climate in terms of impacts and vulnerability. Secondly the paper explains how different communities have been able to adapt to challenges associated with climate change. Thirdly the paper discusses major findings on how different selected adaptation options can bring improvement on crop production and finally some behaviour changes observed among institutions and organizations which participated in the learning process.

Local perception on climate change, vulnerability and impacts

The understanding by local communities about climate, climate change and variability, indicators of change, impacts and vulnerability was clearly evident (Table 4). Across countries and sites, communities perceived climate elements to be temperature, rain, sun heat, wind as well as dew. These elements used by communities to explain changes over time have also been reported by Majule et al. (2008). This conformed to findings reported for other parts of Tanzania (Lema and Majule, 2008; Mongi et al., 2009; Kalanda et al., 2011). A summary of climate issues in both Tanzania and Malawi are summarized in Table 2.

Adaptation to climate change

Adaptation to CC&V is the adjustment of a system to moderate the impacts of climate change, to take advantage of new opportunities or to cope with the consequences (IPCC, 2001). Adaptation strategies by rural communities in Tanzania and Malawi (Table 3) involve the action that people take in response to, or in anticipation of projected or actual CC.

Less favoured areas

These areas in both Tanzania and Malawi receive less than 1000 mm of rain per annum and normally have a single rain season. Due to harsh environment these areas are the most vulnerable to CC and adaptation strategies identified are very weak (Table 3). In Tanzania the emerging of rather more crops tolerant to drought and introduction of drought tolerant crops in particular sunflower and sorghum seem to be good options for farmers in the area. Sunflower is used directly as source of oil which is used directly or sold for income to meet other needs at house hold level. Sorghum, in particular short term varieties, seem to adapt well but market for the crop still needs to be developed. The findings are in broad agreement with those reported by Lema (2009) and Mongi et al. (2010) for the same case study area. Small scale irrigation in particular using ground water or river beds was also reported to be potential for developing irrigated crops and vegetables. This was also reported by Nyamudeza (1998) and Majule and Mwalyosi (2005) under similar conditions. Methods for extracting and managing such water need to be strengthened and

Table 4. Sorghum grain yield (kg/ha) as influenced by in-situ rainwater harvesting techniques and fertilizers application at Laikala village, Dodoma Region, Tanzania.

Tillage methods	Farmyard (Tons/ha)			MPR	Mean
	0	2.5	5		
Slash and burn (Traditional tillage)	1000	1000	1650	1660	1328
Ripping (Magoye ripper)	2085	3750	4580	2500	3229
Deep ploughing (Spring hoe-jembe)	1660	2080	3750	3750	2810
Shallow plough (Ox-plough)	1250	833	1500	1000	1146
Tie Ridging (Ox- ridger)	2080	2917	2080	2000	2269
Mean	1615	2116	2712	2182	

Source: Farmer learning plots.

in this case irrigation service providers need to be brought on board. In Malawi the same methods existed but support from large scale irrigation schemes such as Ilovo Sugar Company is necessary. Other adaptation strategies are listed in Table 3.

High potential areas

In these agro ecosystems CC impacts were not as severe as in less potential areas due to a number of adaptation options. High rainfall and the nature of landforms namely wetland areas, flood plains and valley bottom (*Vinyungu and Dimbas*) enable communities to cultivate both crops and vegetable in dry and wet seasons. This practice is not sustainable in ecosystem management as it compromises other ecosystem needs (Majule and Mwalyosi, 2005).

Findings also revealed that diversification in turn seeks to build up income streams that have different risk attributes, transform the opportunity set and its risks. Depending on the impact of livelihood activities on household assets, a distinction can also be made between accumulative, adaptive, coping and survival activities. Ellis (2000) also reported that accumulative and adaptive activities augment or transform the asset base while coping and survival activities draw down the assets to maintain the level of consumption.

Performance of different crops in learning plots

Crop performance based on tillage and fertilizer management

The analysis indicated that sorghum grain yield at Laikala village (Dodoma Region in Tanzania) ranged from 1000 $kgha^{-1}$ under Slash and burn without fertilizer to 4580 $kgha^{-1}$ under ripping with 5 tons/ha of Farm Yard Manure (FYM) (Table 4). Rainwater harvesting using ripping tillage method in combination with 5 tons of FYM increased sorghum grain yields remarkably by 358%. The preliminary findings suggest that the use of farmyard manure compared to Minjingu Phosphate Rock (MPR) in the first year of cultivation is important in the semi-arid agro-ecological areas where soil moisture supply is the most limiting factor. The positive impacts of using FYM could be attributed at least in part, to the increased soil water retention due to influence of organic manure on soil physical properties. Similar observations on responses being reported were found by Sakala (1998) and Majule (1999) after incubating soils with different rates of FYM.

Conversely, further analysis indicated that sorghum grain yield obtained from plots to which fertilizer were not applied at Laikala village varied between 1000 $kgha^{-1}$ for Slash and burn and 2085 $kgha^{-1}$ for ripping tillage method. The configurations of seedbed using tillage implements alone had positive effects on sorghum performance compared to traditional tillage of slash and burn. The percentage increase in sorghum grain yield varied from 25% using ox- plough tillage implement to 108.5% using Magoye ripper tillage implements without any fertilizer (Table 5). Results with FYM and MRP coupled with improved tillage practices are in broad agreement with findings by Mahoo et al. (2007) and Majule and Shishira (2008).

Major changes observed to different boundary partners

Changes in agronomic practices

Through the project implementation strategy and the approach that was used that is sustainable livelihood framework, learning alliance and innovation system in all 16 project sites in Tanzania and Malawi it was possible to establish changes among different Boundary Partners (BP) involved in this action research. The changes are assessed based on the outcome challenges developed for each of the boundary partners during monitoring and evaluation trainings (Plates 1 and 2).

Table 5. Major changes observed from project BP in both Tanzania and Malawi.

Project Boundary Partners	United Republic of Tanzania	Republic of Malawi
Farming communities	-Increased knowledge on climate -Planting well adaptable crops (sunflower, sorghum, banana, wheat and beans) -Planting new tree crops eg avocardo -Using deep tillage equipments -Establishing more adaptation groups -Capacitated to produce quality declared seeds -Using irrigation pumps to grow vegetables	-Increased knowledge on climate -Planting well adaptable crops (maize, rice, pineapples, cassava, -Planting new tree crops eg avocardo, oranges and citrus -Increased participation of local communities in research -Established more farms with box ridges to harvest water -Getting supplement water for irrigation from sugar can plantation diverted from Shire river -Accessing irrigation equipment – such as pumps (Mphampha)
Extension staff	-Transferring knowledge in form of package to other villages -Documenting and disseminating successfully strategies using flip cameras -Increased their responsibility to work with farmers -Include adaptation activities into DADPs	-Transferring knowledge to other villagers and nearby villages -Documenting and disseminating successfully strategies using flip cameras -Increased knowledge in laying out adaptation plots through country partnership
NGO's	-Packing seeds and fertilizers according to farmers demand -Supplying inputs and tools suitable to farmers -Training farmers on agronomic practices	-Packing seeds and fertilizers according to farmers demand -Supplying inputs and tools suitable to farmers -Participating in training farmers
Policy level	-Increased knowledge on CC issues -Supporting farmer groups in terms of tillage tools such as power tillers -Mainstreaming climate change issues in planning process particularly in DADPs -Support tree planting initiatives by groups - Supported replication of promising adaptations to other non project areas	-Promoting climate change issues at local and national levels -Raising awareness on climate change impacts -Advice Visiting project activities on site -Facilitate dialogue with some private sector dealing with commercial farming to support vulnerable communities on irrigation -Supported replication of promising adaptations to other non project areas
Media group	-Publishing climate change adaptation news -Broadcasting climate change news -Visiting project sites and associated activities	-Publishing climate change adaptation news -Broadcasting climate change news -Visiting project sites and associated activities

DADPs: Refers to district agriculture development plans.

There were significant changes in the way farmers managed their farms. For example before the project most communities did not follow properly agronomic practices such as planting on line, use of appropriate



A B C

Plates 1. Shows different communities predicating in action research activities in Malawi.



A B C

Plate 2. Shows different communities predicating in action research activities Tanzania.

seeds and also keeping records on different farm management operations. All these took place during the project and more farmers are continuing learning on that.

Changes in Behaviour of different boundary partners

The project adopted the outcome mapping approaches for implementation of the Participatory monitoring and evaluation process. In this case outcome challenges for each of the boundary partners listed in Table 5 were developed by the partners themselves.

Overall changes in crop productivity after the

Before the projects farmers in most case studies were for example not planting on line, rarely using FYM or used without following recommended rates, they were not using climate information and local varieties of crops were used (Majule et al., 2008) and this was the main reason for low yields. Most of the project intervention targeted to address those issues and changes were being observed during monitoring and evaluation process. Although it was not intended to observe direct increase in crop yields for different crops within that short period of time, we noted that a combination of different approaches in implementing the project resulted into a significant changes on different crop yields within a period of four years in most project sites in both countries and sites particularly in less favoured areas. The evidence is presented in Figures 2 and 3 for Tanzania sites and is purely based on responses from individuals who participated in FDG with researchers during participatory monitoring and evaluation.

Following improved cropping practices including use of manure, supplementing crops with irrigation water particularly in Mphampa and Mpasu villages in Malawi maize crop yield of SC 403 variety increased significantly (Figure 4). Figure 5 shows that introduction of appropriate agronomic practices have been able to increase groundnut yields in study villages in Malawi. Increase is highest with Nsinjiro variety indicating that this is less vulnerable to climate change stress in the study village.

The number of farmers participating in the project or those adopting the practices was reported also to increase in both Tanzania and Malawi case study villages. Strengthening farmers' ability to manage maize in the face of climate change and variability and high land pressure in most of these villages has made a contribution to food security and poverty reduction. This has being achieved through increasing use of resources

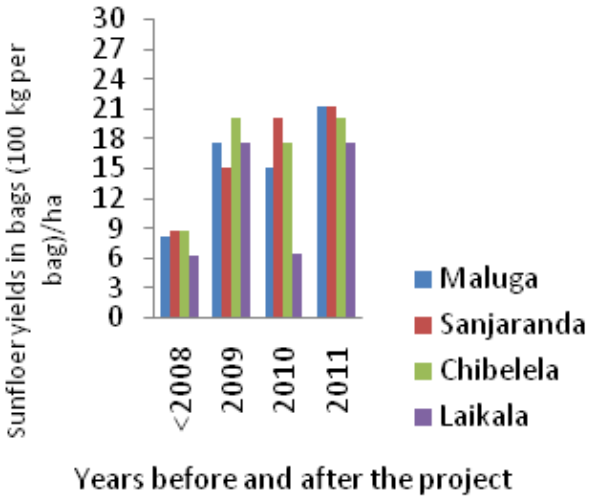


Figure 2. Pattern of sunflower yields in Tanzania.

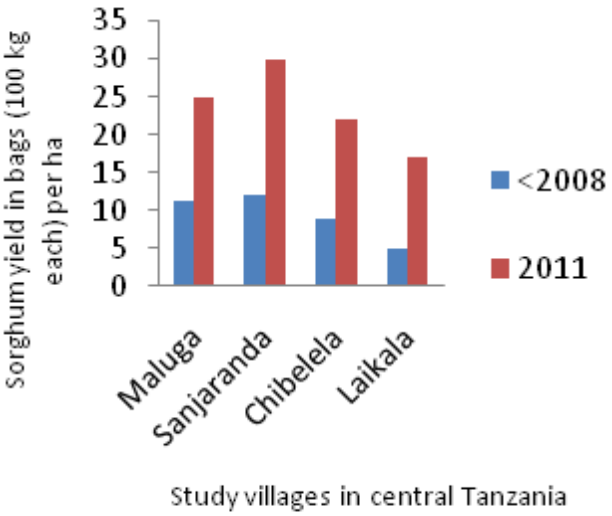


Figure 3. Pattern of sorghum yields (Tanzania).

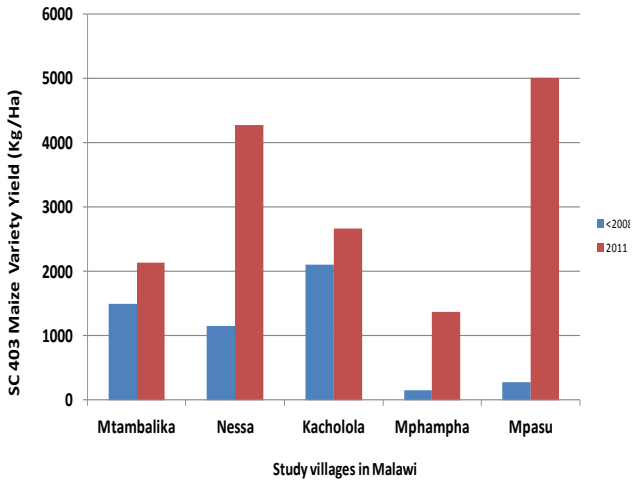


Figure 4. Maize yield in Kg/ha in Malawi study villages.

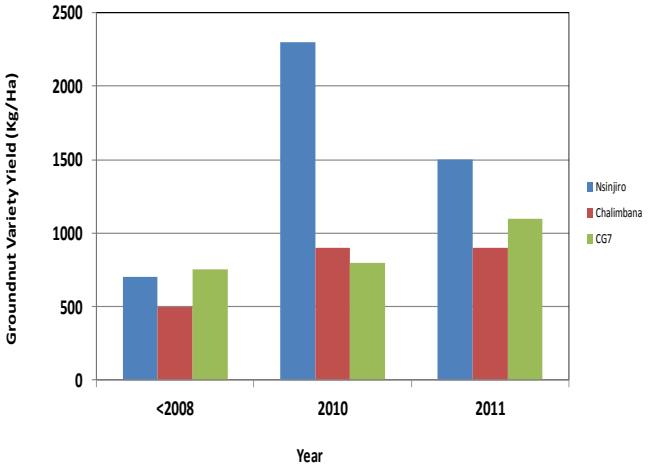


Figure 5. Increase in groundnuts yields in Malawi study villages.

such as hybrid maize seed, manure and water. Scaling up approaches to strengthening adaptive capacity will need to take into account access to such resources at scale.

CONCLUSIONS

Agriculture remains to be a key sector in terms of supporting community livelihoods in rural areas of Tanzania and Malawi. However climate change is negatively affecting a sector differently in different agro ecological zones within both countries. To strengthen the capacity of communities and other stakeholders within agricultural sector, innovative approaches are required through participation of different actors such as extension, media, NGO's, private sector and others with a strong political support. Behaviour change within different actors is needed for example farming community needs to move away from traditional tillage practices, needs to grow more adaptable crops and follow appropriate agronomic practices. Planning at community level needs to be supported by local authorities and policies in terms of finance and technologies. However more training on climate issues is needed for various actors and innovation systems need to be strengthened.

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