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Climate Change Adaptation: Role of Local Agricultural Innovations in Semi-Arid Tanzania

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Agriculture which supports the livelihoods of the majority is challenged by many stressors including climate change impacts. Impacts such as floods and droughts have left farmers with no reliable option rather than farm management and off-farm activities such as irrigation, use of improved seed varieties, crop and livelihood diversification. Nevertheless, contribution of such practices to improving livelihood among smallholder farmers is generally documented and concluded. This study was therefore carried out to determine effectiveness of local agricultural innovation system in enhancing livelihood of smallholder farmers in semi-arid Tanzania. The study was conducted in Sanjaranda and Gurungu villages, Manyoni District. Literature review and Participatory Rural Appraisal (PRA) methods including focus group discussions and household interviews; key informant interviews, and transect walks were employed to collect data. Results from the study indicate that, the surveyed communities were knowledgeable of climate change of their localities in the past 20 years. Changes in the climate included shifting of rainfall seasons, fewer and erratic

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rains and an increase in temperature. Meteorological data also supported a decreasing trend in rainfall and an increase in annual average temperature by 0.7ºC in the past 30 years. Responding to these changes, farmers developed a number of farming practices that included use of improved seed varieties, improved agronomic practices, in-situ rainwater harvesting and application of farm yard manure. These practices were also supported by public activities, civil society organisations and the private sector contributions to increase trends in crop yields in one way or another. This study argue that, strengthening local agricultural innovation system could enhance community livelihoods under changing environment.

Keywords: Agriculture; climate change; innovation system; Sanjaranda.

1. INTRODUCTION

Agriculture is the mainstay of nearly all nations and rural development [1]. The sector contributes to the majority of African's livelihoods particularly in SSA (Sub Saharan Africa), where 65 percent of employments and 32 percent of GDP are derived [2]. In Tanzania for instance; more than 75 percent of the population living in the rural setting is directly or indirectly depending on agriculture [3]. Despite the importance of this sector, climate and non-climatic stressors obstruct the development of the sector [4].

Climate change is reported to add stress to this sector [4,5,6]. It is predicted that, billions of people particularly those in developing countries including the East African countries would face changes in rainfall patterns causing severe water shortages, flooding in other areas, and temperature rise that would cause shifts in crop growing seasons [1].

A number of studies show that, climate change has reduced and will continue to reduce the length of the growing season as the result of reduced rainfall duration in terms of number of rain days [7,8,9,10]. Such impacts have the tendency of reducing yields of various crops in semi-arid Tanzania [11] and the likelihood of exacerbating food insecurity and the spread of disease vectors [12]. While semi-arid lands including central regions of Tanzania particularly Dodoma, Singida and Tabora are dry in nature; climate change impacts such as drought and floods are predicted to worsen agricultural production which to the largest extent is rain-fed dependent [13,9,10].

It is evident that, farmers have been adapting to external shock including environmental changes such as droughts and floods by diversifying their crops, irrigation and managing water resources [14]. However, uncertainties of climate change impacts pose a novel threat to farmers and to the majority of poor people in Africa who lack the capabilities to adapt to climate change [14,15,12]. Recent studies such as [16] show that, a number of agricultural innovations exist at local contexts and farmers have adopted them to enhance their capacity to adapt to climate change impacts. However, most of these studies do not demonstrate how these innovations have contributed to enhancing farmers' livelihoods especially in improving food production within these contexts. It is thus important to understand what is taking place at a community / local level in terms of application of such innovations and their contributions to enhancement of communities' livelihoods under the changing climate.

This study therefore aimed at understanding agriculture innovations and their contribution to climate change adaptation among smallholder farmers in Manyoni District. Specifically this study:

a) Examined farmers' perceptions of climate change in the study area.
b) Determined effectiveness of local agricultural innovations on agricultural production.

2. MATERIALS AND METHODS

2.1 Research Area

The study was conducted in Manyoni District. The District is a semi-arid land and has been experiencing food shortages as a result of drought [17,7]. The study involved two villages videlicet Sanjaranda and Gurungu, both found in Sanjaranda ward (Fig. 1).

2.1.1 Climate of the study area

The District experiences low rainfall and short rainy seasons which are often erratic with fairly widespread drought in one year out of four. Total rainfall ranges from 500 mm to 700 mm per annum with high geographical, seasonal and annual variation. There are two well defined seasons, the short rainy season during the months of December and March and fades away in May and this is followed by the long dry season to November. Temperature in the District ranges from about 20ºC in July to 30ºC during the month of October. There is also a well-defined difference between day and night temperatures. Maximum temperature during the day are very hot going up to 32ºC and chilly nights going down to 15ºC respectively [18].

2.2 Data Collection Methods

Both primary and secondary data were collected to address the study objectives. Primary data sources included focus group discussions (n=35), key informant interviews (n=13) including extension officers, elders and village government leaders; a household survey (n=94). A sample of 10% for households were randomly selected in both study villages [19]. The household sample was a representation of the sub-villages and also of gender consideration whereby women were 40 and men were 54. Transect walks and field observations (n=4) were also employed to more understand issues raised during focus group discussion and household survey. On the other hand, secondary data included review of books, journals, government and project reports, and internet sourced materials as well as the analysis of meteorological archive and crop yield data.

Quantitative data from structured questionnaire were coded and analysed using IBM SPSS (Statistical Package for the Social Sciences) version 20 spreadsheet data; through which descriptive statistics were run to give frequencies and then cross tabulation was undertaken. Similarly, multiple questions were analysed to give frequencies and percentages. Cross-tabulation was also undertaken to compare different variables considered under the study in two villages. Qualitative data were summarised and analysed through content analysis. On the other hand, temperature and precipitation data from Manyoni and Dodoma Airport meteorological stations were analysed through Microsoft Office Excel, 2007 to illustrate patterns of change in the form of graphs. Maize, sunflower yields from Sanjaranda Agricultural and Livestock Office were analysed through Microsoft Office Excel, 2007 to show the trend. On the basis of household, an independent sample t-test was conducted at a significance level of 0.05 was to detect if crop yield of the two villages increased equally with time and innovations employed.

3. RESULTS AND DISCUSSION

3.1 Socio-economic Profile of the Respondents in the Study Area

3.1.1 Education profile

Table 1 shows that 78.1% of respondents in Sanjaranda and 100% of Gurungu villages had attained their primary education, whereas 15.6% and 0.0% of respondents in Sanjaranda and Gurungu respectively had attained their secondary education. Generally, the majority of the respondents (85%) had attained primary education. This could probably be resulting from increased awareness on the importance of education in the study villages. Interview with key informants revealed that, the presence of the Sanjaranda Bible College (SBC) influenced education awareness in the study villages, since it had been operating in the ward supporting both education, and training services prior independence (1961).

Educational attainment (both formal and informal) has an influence on the level of adaptation to climate change. It builds on human capital that enables people to pursue different livelihood strategies and achieve their livelihood objective. Education, training and awareness can influence people's behaviour and habits in accordance with current and projected climate conditions. Such activities do not directly reduce people's vulnerability, but train them to adapt to the current climate, to consider future climate change in their decision making and to be prepared for extreme events [20]. Also, key informants indicated that, farmers that are trained in good agriculture practices are better off in innovations (improved way/new way of doing things) as contrasted to those who have not been exposed to any training. Therefore educated / trained people are likely to be advantageous to adapt to climate change impacts as opposed to those that are not equipped with any training. Therefore, the more knowledgeable the society becomes, the higher the chances to adapt to climate change and variability.

3.1.2 Economic activities profile

Fig. 2 reveals that, the majority of the respondents in the study villages are either pure crop farmers or agro-pastoralists that is livestock

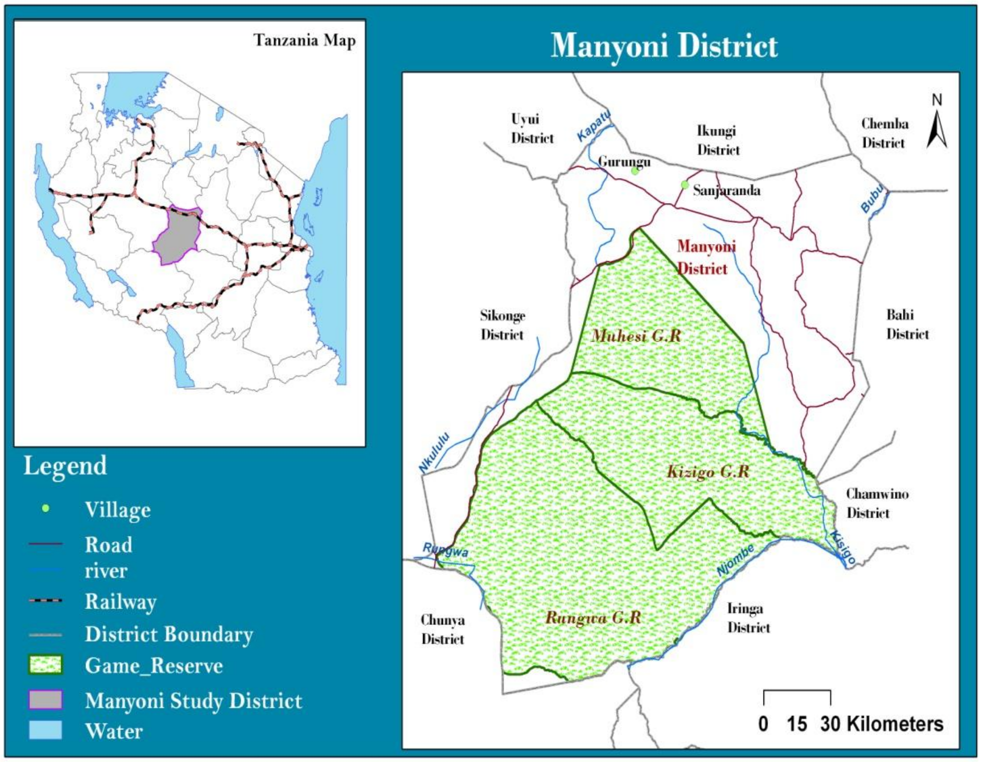

Fig. 1. Map of Manyoni District, showing the location of study area

keepers obtaining more than 25% but less than 50% of agriculture income from livestock keeping in areas with an annual rainfall between 400 and 600mm and length of growing period of 75 to 90 days where cropping millets and sorghum is possible [21]. Findings from the two villages for example showed that, 64.1 and 43.3% of respondents in Sanjaranda and Gurungu villages respectively were agro-pastoralists whereby 34.4 and 53.3% were pure crop farmers in the former and the latter villages respectively. Crops grown in the villages included sunflower, maize, sorghum, millets, groundnuts as well as vegetables. On the other hand livestock kept included cattle, goats, sheep and chicken.

On the other hand, formal employment and casual labour accounted for 0.0% in Gurungu village and 6.2% in Sanjaranda village; whereas petty business which was more pronounced in Sanjaranda (a growing township) was also reported to contribute to community livelihoods.
Other economic activities such as beekeeping as represented by 3.1% for Sanjaranda and 3.3% for Gurungu village were also noted in the study area. During focus group discussion it was further revealed that, community members that were engaged in more than one income generating activities (IGAs) such as petty business were somewhat less vulnerable to climate change impacts since their livelihoods were beyond farming; a sector that is climate sensitive.

3.2 Farmers' Perception of Climate Change

Majority farmers were found to be aware of climate change basing on their experience on increasingly changes in the rainfall seasons as well as increasing temperature. As illustrated in Table 2, about 95 and 97% of respondents in Sanjaranda and Gurungu respectively perceived rainfall to be more erratic / unpredictable. Likewise, farmers observed early onset in rainfall and early cessation. Under normal circumstances, rainfall onset would bein October to early June.

Early rainfall onset and early cessation had implications on longer drought periods as revealed by 61.9 and 86.7% of respondents in Sanjaranda and Gurungu respectively.

On the other hand, temperature was reported to have increased in the past 20 years as responded by 90.5% and 86.3% of farmers in Sanjaranda and Gurungu respectively. Few respondents however indicated that, temperatures were decreasing while others reported that they were on average (Table 3). Similar findings on temperature increase were reported by [22] from four semi-arid regions in four African countries; Botswana, Ethiopia, Ghana and Malawi, as well as in [17,7].

3.3 Analysis of Rainfall and Temperature in the Study Area

3.3.1 Analysis of rainfall trend

Fig. 3 elucidates a decreasing trend in rainfall over the past 30 years especially from 1982 which was recorded as the highest peak at 971.6 mm. Since then, rainfall has been decreasing over time with lowest peaks less than 500 mm in 1987, 1991, 1993, 1996, 2003, 2005 and 2012 associated with droughts.

Related to that, long term record of mean monthly rainfall over the past 30 years indicated that, monthly rainfall season commenced on October and built up in December and March; and faded away in May. The analysis also marked two rainfall peaks in December and March. However, the former peak on average was found to be higher than the latter peak; that is 605.4 mm and 489.5 mm respectively. Likewise, the analysis demonstrated variability and irregularity in the amount within a single peak. For example, rainfall amount in the first peak between 1989 and 1999 recorded 98.5 mm whereas between 2007 and 2013 read 193.0 mm. Similarly, a temporal anomaly in the pattern of rainfall peaks was observed in the study area. For instance, first rainfall peaks of 1981-1990 and 2001-2010 started in December as usual whereas of 1991-2000 and shifted to January February respectively (Fig. 4).

The study also realised that, between the two rainfall seasonal peaks, (December and March) peaks; an inter-seasonal dry period was a common phenomenon in January and February (Fig. 4). This was reported to interfere stages of plant growth and therefore retarded crop production in semi-areas of Tanzania. Similar observations are found in [9,10].

Generally, rainfall unpredictability in terms of onset and cessation in Central Tanzania are supported by [23,17,7,24] studies conducted in Dodoma and Singida regions respectively.

3.3.2 Analysis of temperature trend

Generally, the National Adaptation Plan of Action (NAPA) show that, an average annual temperature will increase by 3.5ºC throughout the country while the annual temperature will increase by 4ºC in Central and Western Tanzania [6]. However, this study found that, there has been an increase in average annual temperature by 0.7ºC between 1970 and 2012 (Fig. 5). Also, both maximum and minimum temperatures increased by 0.3ºC and 1.0ºC. Similarly, about 96% of respondents in the study area claimed that temperature has been increasing over the past 20 years. Such findings comply with studies conducted in central Tanzania [17,7,24].

Each plant particularly grain crops have their optimal temperature requirement for their growth. It is already evident that, increase in temperature can have negative impacts on phenology especially in low Latitudes [25,26]. Increase in local temperatures could have detrimental effects on plant growth stages such of reproduction in grains, and thereby reducing grain filling that results into poor yields and quality [27,28]. Crop water balances may also be affected through changes in precipitation as well as increased evapotranspiration [27].

3.4 Effectiveness of Different Agriculture Innovations in Supporting Agricultural Production

Generally, this study revealed that, a number of agriculture innovations existed in the study villages. These innovations adopted by farmers were also opted as adaptation strategies to climate change (Table 4). Among others, such innovations included:

Table 1. Education profile of heads of households in the study villages

Education level	Sanjaranda		Gurungu	
	Frequency	Percentage	Frequency	Percentage
No Education	03	04.7	00	0.0
Primary education	50	78.1	30	100.0
Secondary education	10	15.6	00	0.0
Others	01	01.6	00	0.0
Total	**64**	**100.0**	**30**	**100.0**

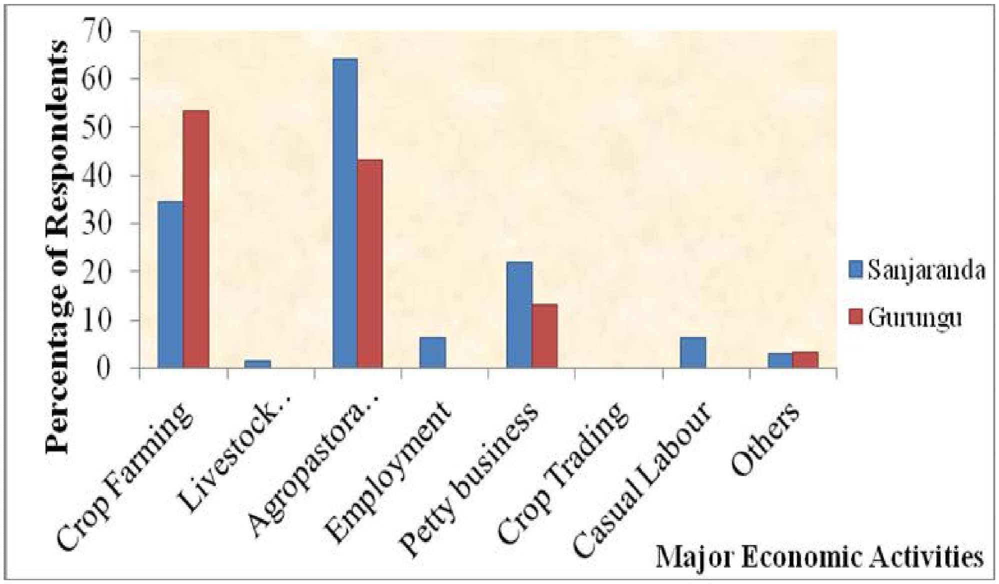

Fig. 2. Major economic activities pursued by respondents in the study villages

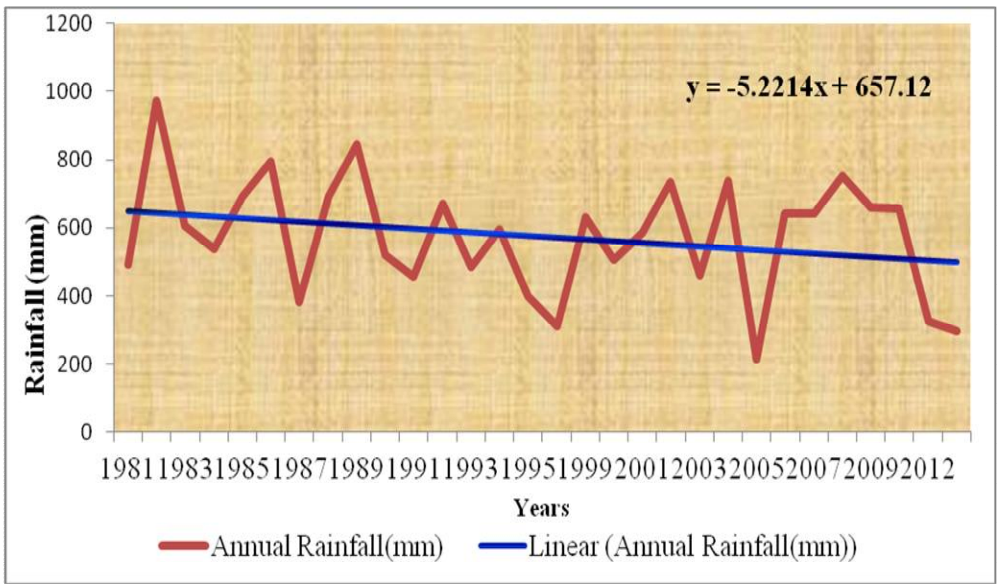

Fig. 3. Annual rainfall trend in the study area

3.4.1 Improved crop varieties

About 81.2 and 76.7% of respondents in Sanjaranda and Gurungu respectively used improved seed varieties of maize, sunflower and sorghum (Table 5). However, farmers in the former village were far better than the latter village because of increased awareness and accessibility to extension services. The study also found that, the Ward Agriculture and Livestock Office; and two Quality Declared Seeds (QDS) groups operated in Sanjaranda village. This to some extend was reported to be of great influence to farmers in Sanjaranda. Likewise, implementation of agriculture related projects such as District Agriculture Development Plans (DADPs), Climate Change Adaptation in Africa (CCAA) and International Aid Services (IAS) climate change project through Sanjaranda Bible College / Rural Training Centre (SBC/RTC) facilitated a number of Farmers' Field Schools (FFSs) commonly known as *shamba darasa*. Through FFSs it was reported that, farmers were trained on how to use of improved seed varieties.

For example, during FGD it was noted that, FFSs under CCAA programme were provided with seed varieties such *as record* for sunflower, *kilima* for maize and *macia* for sorghum. These varieties were reported to be early maturing and high yielding compared to traditional varieties used by farmers in the past years; although few farmers still use the recycled seeds.

3.4.2 Application of Farm yard manure (FYM)

This study found that, more than 50% of farmers (53.3 and 56.7% in Sanjaranda and Gurungu villages respectively), incorporated FYM into soils whereas 3.1% and 0.0% applied industrial fertilisers (Table 4). The rest of the farmers applied not any kind of either fertiliser because some could not afford, especially those with no livestock while others claimed that their farms were fertile. These findings were also observed [Urassa N and Swai E, unpublished report]that, 56% of farmers in Sanjaranda ward applied FYM to replenish soil nutrients as well as sustaining soil moisture in their farms while 43% of the respondents applied not because of the earlier mentioned reasons as well as inadequate knowledge on the importance and how to use fertilisers.

3.4.3 *In-situ* rainwater harvesting (RWH)

In-situ rainwater harvesting occurs where rainwater is conserved on the same area where it falls as opposed to rainwater harvesting system where rainwater is transferred into a catchment [IUCN-TCO, 2011, unpublished report]. About 42.2 and 30% of farmers in Sanjaranda and Gurungu respectively reported to practice insitu RWH with the use farm implements especially ox-plough during farm preparation. Deep ox-tillage was reported to enhance water penetration and absorption of plant nutrients hence improved crop yield, unlike hand hoe tillage which is prone to water run-off and soil

Table 2. Proportion (%) of farmers' perception of long term changes in precipitation

Perception on precipitation	Village	
	Sanjaranda	Gurungu
Erratic rains	95.2	96.7
Early rainfall onset	65.1	83.3
Late rainfall onset	00.0	00.0
Early rainfall cessation	66.7	86.7
Late rainfall cessation	01.6	00.0
Drought	61.7	86.7

Note: Proportion (%) is based on multiple responses

Table 3. Perception of long term changes in temperature in the study village

Temperature trend	Village	
	Sanjaranda	Gurungu
Increasing	90.5	86.3
Decreasing	1.6	3.4
Average	7.9	10.3
Total	**100.0**	**100.0**

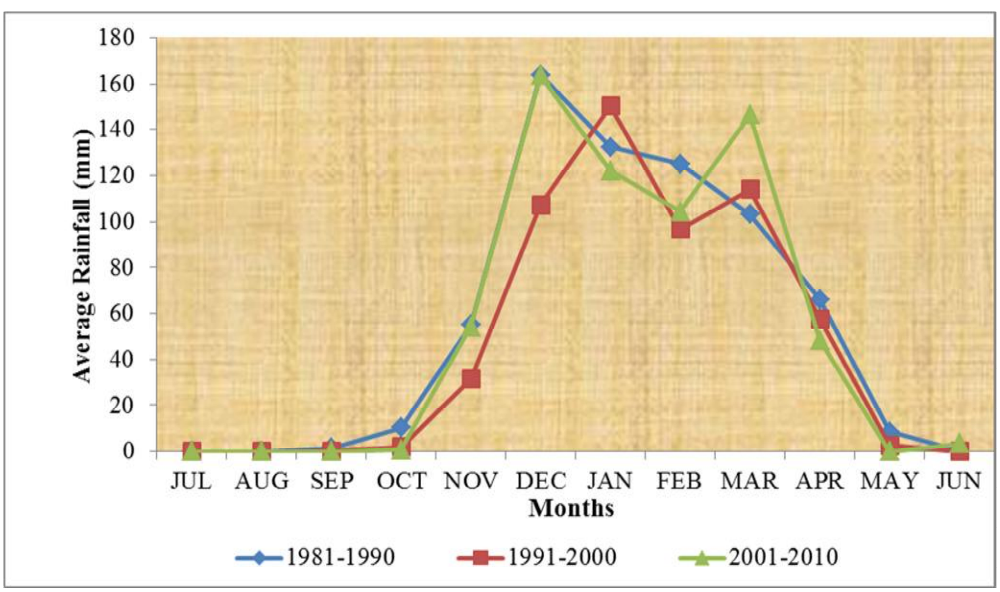

Fig. 4. Variation in monthly rainfall pattern and distribution in the study area

nutrient loss. However, [Urassa N and Swai Eunpublished results] show that, ox-plough tillage was practiced by 83% of farmers in Sanjaranda ward as a whole whereas hand hoe was practiced by 15% of farmers and tractors by 2%.

3.4.4 Improved agronomic practices

Exposure to extension services and involvement of farmers into different networks such as FFSs in the study villages were revealed to have changed traditional farming practices into productive way. These included proper spacing contrary to seed broadcasting in the past, thinning, and soil nutrient management, especially the use of FYM. 65.4 and 47.4% (Table 4) of respondents in Sanjaranda and Gurungu villages respectively proved to have changed their agronomic practices. However the former village is found to be more practical than the latter village because of accessibility to extension services, moreover involvement of many farmers in FFSs facilitated such practices into their own farms.

3.5 Yield Trends of Selected Crops in the Study Area

Figs. 6, 7 and 8 present analysis of maize, sunflower and sorghum yield trends. Crop yield data at a village level were obtained from Ward Agricultural Extension Office archive; and were from 2005/6 to 2011/12 farming seasons.

3.5.1 Maize yield trend in between 2005 and 2012

Maize yield indicated an upward increase with minor variations due to seasonal rainfall variability in the study villages (Fig. 6). Such an increase at a village level was reported by the Field Agricultural Officer (FAO) to be result the use of improved crop varieties (Table 5). Maize yields in Sanjaranda were generally found to be higher than Gurungu. Such increase was noted from 2008/2009.

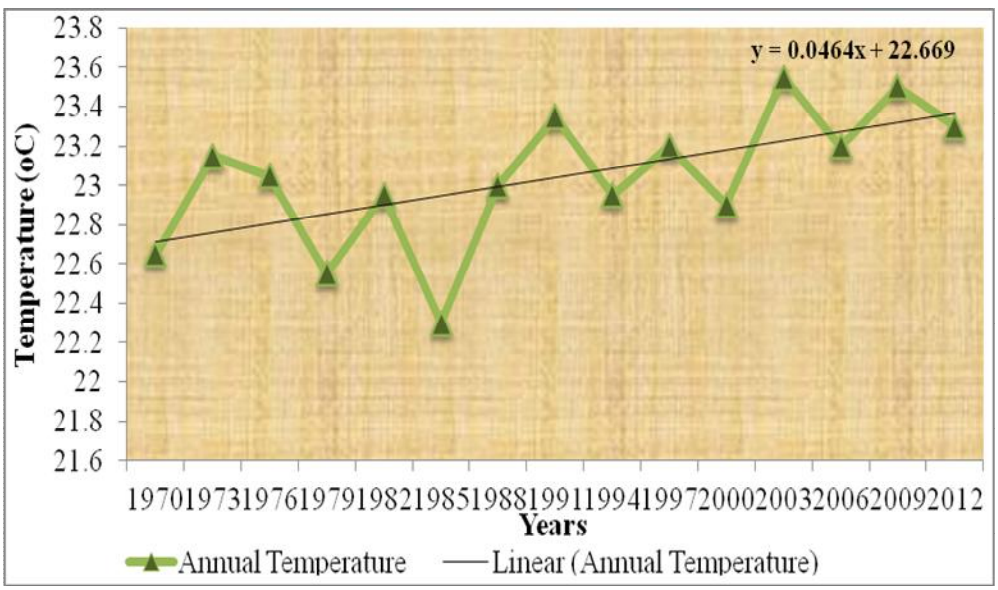

Fig. 5. Average annual temperature in the study area

Table 4. Proportion (%) of agriculture innovations adopted by farmers

Agriculture Innovations	Villages	
	Sanjaranda	Gurungu
Improved crop varieties	81.2	76.7
Improved agronomic practices (proper spacing thinning, adjustment in planting dates)	65.4	47.4
Application of farm yard manure (FYM)	53.3	56.7
In-situ rainwater harvesting	42.2	30.0
Application of industrial fertiliser	03.1	00.0

Note: Proportion is based on multiple responses

Table 5. Crop varieties adopted by farmers (%) in the study villages

Crop varieties	Village	
	Sanjaranda	Gurungu
Maize (*Seed-Co*)	42.2	40.0
Maize (*Kilima*)	14.1	00.0
Maize (*DK*)	15.6	10.0
Maize (*Panar*)	03.1	00.0
Maize (*Hybrid*)	03.1	20.0
Sunflower (*Zebra / Pundamilia*)	25.0	40.0
Sunflower (*Record*)	25.0	10.0
Sunflower (*Kenya fedha*)	12.5	03.3
Millet	04.7	00.0
Sorghum (*Pato & Macia*)	03.1	06.7

Note: Proportion is based on multiple responses

An independent t-test at household level between the two villages was tested to see if maize yields increased equally between 2004-2006, 2007-2009, 2010-2012 farming season. The t-test results were t (69)=2.09, *P*=0.04; t (77)=1.84, *P*=0.07 and t (81)=2.25, *P*=0.0 2 respectively. This revealed, maize yields between the villages differed significantly whereby in Sanjaranda were higher than Gurungu except for 2007-2009 season where production was almost equal.

3.5.2 Sunflower yield trend in between 2005 and 2012

Similarly, Fig. 7 shows that, the average yield of sunflower in both villages increased between 2005/6 and 2009/10 season in both villages. In Sanjaranda although the yield doubled particularly from 2007/8 where projects such as CCAA and SBC were implemented in the village. Similarly, in between 2010-2012, sunflower yield increased in Gurungu. This was also reported to have been attributed to the use of improved seed varieties and because sunflower is drought resistant. Moreover, operation of SBC project in the village also contributed significantly. Findings by [29,8] in Sanjaranda particularly indicated that, sunflower yield increased between 2 and 3 folds following the adoption of high yielding varieties such as *record*.

At a village level, yields were also reported to have increased in Sanjaranda and Gurungu villages as well. However, a t-test conducted at household level amid the two villages between 2004 and 2006, 2007 and 2009, 2010 and 2012 were t (41)=0.15, *P*=0.88, t (66)=1.97, *P*=0.5 and t (69)=4.69, *P*=0.00. This revealed mean production of sunflower was almost equal in the two villages except for 2010-2012 where is Sanjaranda mean yield were 6 bags/acre and 5 bags/acre in Gurungu.

3.5.3 Sorghum yield trend in between 2005 and 2012

On the other hand, sorghum yield (Fig. 8) for both villages increased with time. The study however noted that, sorghum yield in Gurungu in 2010/2011 and 2011/12 was higher than Sanjaranda. This was attributed by an increasing awareness on the application improved agronomic practices such as the use of improved crop varieties specifically *pato* and *macia*. Also, sorghum was reported to be drought tolerant. Awareness on the use of such improved seed varieties was facilitated by SBC/IAS climate change project in Gurungu, likewise, learning from neighbouring villages such as Sanjaranda. An independent t-test at household level, however between 2007-2009, 2010-2012 were t (9) =-1.36, *P*=0.2, and t (11)=0.31, *P*=0.88 indicated that, yields between the two villages were the equal.

3.6 Behaviour Changes of Farmers in Strengthening Their Adaptive Capacity to Climate Change Adaptation

Increasing climate change impacts require farmers to adjust/alter existing practices, resources and behaviour mindsets or in some cases to adopt new ones to respond to these changes [11,30]. Experimentation, innovation and adoption as part of the learning process are essential in ensuring the system's ability to cope with and respond to changing circumstances [11]. Throughout this study it was learned that, farmers in the study area had adjusted their behaviour practices related to farm management. These include application of improved agronomic practices described in Table 4, use of improved crop varieties (Table 5) as well as incorporation of weather information particularly local weather information in planning agriculture activities.

3.7 Local Agricultural Innovations and Main Actors in the Study Villages

This study also found that, innovations in the study villages were facilitated by a number of actors that is individuals or organisations in the public or private domain; either working as a network or individually.

3.7.1 The role of public service providers in agricultural innovations in the study area

Public sector and departments were identified as key players in local agricultural innovations in the study villages (Table 6). They included village/ward extension offices, District Agricultural and Livestock Officers (DALDOs), research institutes such as Hombolo Agriculture Research Institute (ARI) in Sanjaranda), village government and the Singida Region-Agriculture and Cooperative. These actors were reported to have played a central role of connecting farmers with other actors in the network. Their services ranged from advisory service, inputs provision, as well as information sharing. However field experience in the study villages revealed that, there was a limited number of extension workers who also served a double role of crop and livestock officers. Therefore, the central role by the public units is not a guarantee for quality services and innovation to farmers [31].

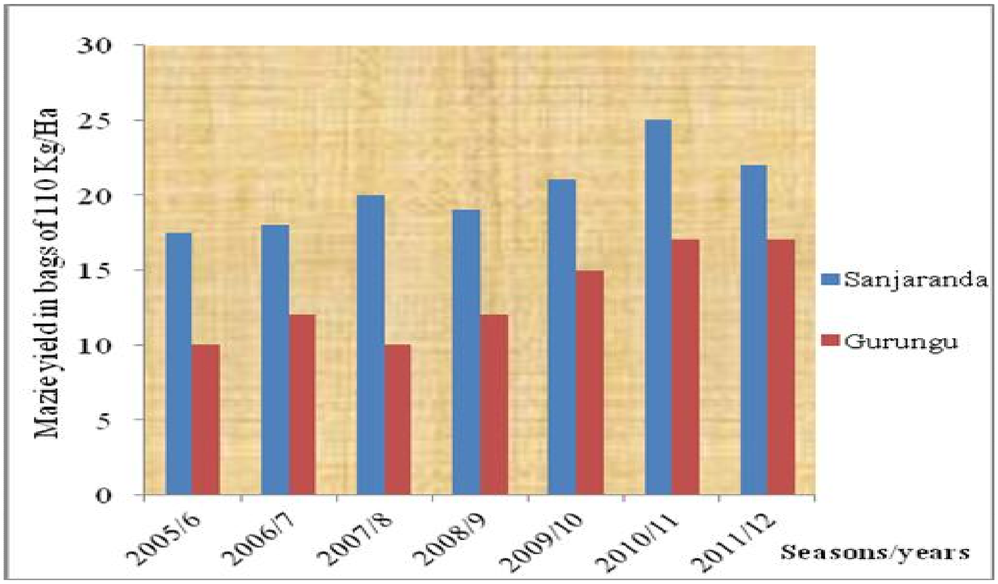

Fig. 6. Yield trend of maize in study villages

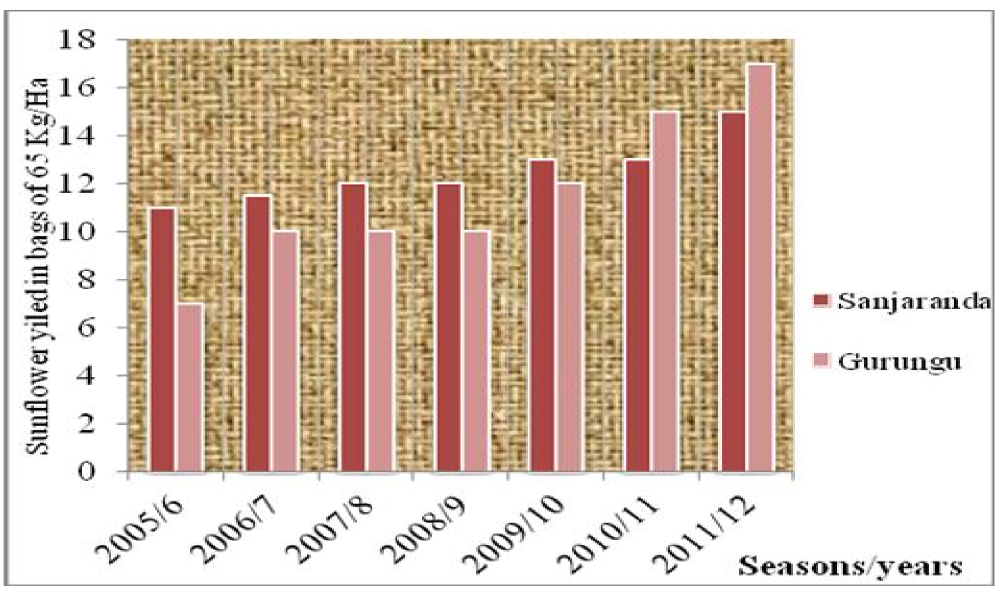

Fig. 7. Yield of sunflower in the study villages

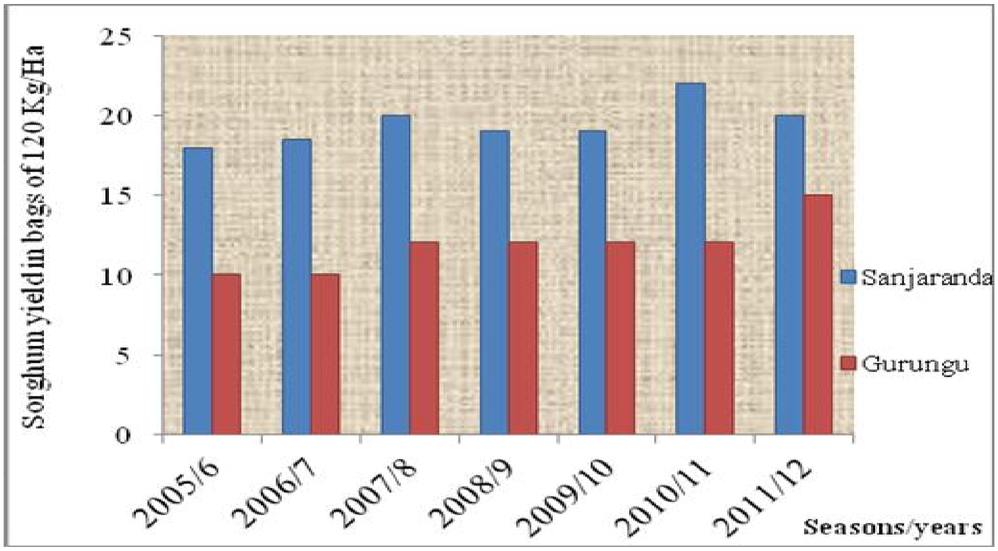

Fig. 8. Yield (average) of Sorghum in the study village

3.7.2 The role of private sector actors in LAIS

Despite of the key role of agriculture services being linked to public institutions, private actors such as stockist in Sanjaranda village played a big role in innovations through selling inputs such improved seed varieties and fertilisers.

Table 6. Key actors in agricultural innovations in the study area

Actors	Description
Public organisations	DALDO/DADPs, Singida Region Agriculture and Cooperative, IRA,ARI-Hombolo, extension offices, Village government
Private organisations	Stockists
Civil society organisations	SBC/AIS, Farmers Field Schools

3.7.3 The role of the civil society organisations in agricultural innovations in the study area

Civil Society organisations (CSOs) were also found to have a relatively close relationship with public organisations in the provision of social services in the study area. In both villages, SBC under Pentecost Church that had been operating in the ward over more than 40 years was reported to support not only farming innovations; but also provision of social services such as education and spiritual services in both villages. Learning from CCAA programme, the study was informed that; SBC/RTC was able to secure funds from IAS to support replication of agricultural innovations in Sanjaranda ward in 2012. Through these funds a, programme known as '*Empowering 210 small scale farmers at Sanjaranda ward 2010-2012,* more FFSs were formed and replication of and innovations benefited many farmers in the ward.

Of similar importance, FFSs were also considered by farmers to be influential in adoption of farming innovations in the study area. This study learned that, about 6 FFSs were found in Sanjaranda and two in Gurungu villages with support from DADPs, SBC/IAS and CCAA.

Generally, CSOs can thus be a good source of finance; training and practical learning to support agriculture innovations since they work directly with local communities particularly smallholder farmers.

4. CONCLUSION

This study concluded that, most respondents in the stud area were farmers; and have been experiencing changes in rainfall amount and pattern and increasing temperature in the past 20 years. In line with these changes, farmers at the local context have been able to adopt new adaptation strategies such as the use of improved seed varieties and application of farm yard manure. Among other factors, such innovations contributed to an improvement in crop yield. Therefore, collective efforts involving different actors are needed to enhance adaptive capacity of smallholder farmers who in most cases have inadequate information on appropriate farming practices relevant to climate change adaptation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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