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ASSESSMENT OF AGRICULTURAL PRODUCTION VULNERABILITY IN THE CONTEXT OF CLIMATE VARIABILITY IN CENTRAL TANZANIA

Brown Gwambene

Department of Geography, Faculty of Social Sciences and Entrepreneurship, Marian University College, P.O. Box 47, Bagamoyo, Tanzania. E-mail: gwambene@gmail.com

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ABSTRACT

This study envisages assessing the dynamics and vulnerability of agricultural production to climate variability so as to increase resilience and creating opportunities for increasing agricultural production and environmental sustainability. The results indicated that more frequent and severe extreme climatic events especially, drought is the challenge of agricultural production and on ensuring food security in the area. Changes in temperature and rainfall (timing and quantity) potentially affect agriculture production. It was revealed that the yield potential and yields from rain-fed agriculture have been decreased and local food supplies are negatively affected due to the increased temperature and unpredictability of rainfall. About 80% of farmers are not sure on harvesting their crops as evidenced by the loss of harvest for three consecutive years due to unpredictable rainfall and an increase in temperature. It was further indicated that 90% of losses on crop produce were due to impacts associated with the unpredictability of rainfall and increases in pests and diseases. Addressing adverse effects of climate variability is among the critical challenges facing the rural communities because of their reliance on rain-fed subsistence agriculture which is one of the climate-sensitive livelihood activities. Such situation had posed a challenge in agricultural production, livelihoods and resources management. In addressing such challenges agricultural production was recommended to be improved through growing drought and pest/disease resistance crops, early maturing crops, adjustment of planting time, development of irrigation infrastructure where ever possible, subsidization of agricultural inputs and implements of rural social services as coping and adaptation strategies.

Keywords: Adaptation, Agriculture, Climate variability, Food security, Vulnerability and Central Tanzania

1.0 BACKGROUND

Climate change and variability are already being experienced in terms of gradual increases in temperature, increased variability in annual rainfall regimes and a greater prevalence of extreme events such as drought and floods (Gwimbi and Mundoga, 2010). Variability in temperature and rainfall distribution and patterns is a major threat to rural livelihoods and to food security in the developing world who depends on climate-sensitive activities (Kangalawe *et al.,* 2005; Orindi and Murray, 2005; Tizale, 2007; FAO, 2009). The seasonal shift and changes in precipitation patterns have a severe impact on the agricultural production and other livelihood activities (Pew, 2006; Majule, *et al.,* 2009). Year to year variability in climate already contributes to food shortages and poverty where exposure is high and adaptive capacity is low (Gwambene 2011). The decline in agricultural production in farming communities results in low harvests that lead to the need for communities to buy rather than using their own produced food. However, such a strategy only manages to make the communities vulnerable to rising food prices and increase production costs (IUCN, 2007; Gwambene, 2011).

More frequent and severe extreme climatic events are the challenge of agricultural production and ensuring food security around the globe. Climate change and variability potentially affect agriculture through changes in temperature, rainfall (timing and quantity), strong wind and the interaction of these elements (UNHCR, 2009; Gwambene, 2011). Huge impacts of climate variability have been observed on food security, water availability, human health and socioeconomic and infrastructure development (IUCN, 2007). The reliance of the majority of poor people upon assets derived from natural resources which are affected by climate variability and extreme

weather events, such as drought, floods and strong wind, increased the vulnerability to changes (IPCC, 2007; Majule *et al,* 2009). The situation is predicted to be worse in most of the poor rural community of the developing countries and will pose a challenge in agricultural production and adaptation measures due to their low adaptive capacity.

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC, 2007) showed that global average mean temperature and the frequency of hot extremes, drought, and precipitation will increase in response to increased concentrations of greenhouse gases in the atmosphere. The combination of long-term change average temperatures and greater extreme droughts and floods could have negative impacts on agricultural production (Anley *et al.,* 2007; Majule *et al.,* 2007; NAPA, 2007; FAO, 2009). According to IUCN 2007 report and NAPA 2007 document, there is an expected decrease in areas suitable for agriculture, the length of growing seasons and yield potential. In some areas, yields from rain-fed agriculture have been projected to deceased by up to 50% by 2020 (IUCN, 2007). Local food supplies are projected to be negatively affected by decreased food crop production in productive areas due to increased temperatures, and unpredictability of rainfall. The livelihood of more than 80% of the population of Tanzania relies directly on agricultural production are particularly vulnerable to such changes. The 2007 Tanzania's National Adaptation Program of Action (NAPA) estimates that projected temperature and rainfall changes could decrease the average annual food crop yield by 33%.

The semi-Arid agro-ecological zones of central Tanzania are greatly affected by various challenges ranging from climatic to none-climatic challenges. Such challenges have various implications in the livelihood systems as well as sustainable natural resource management in the areas. Agricultural production, food security and livelihood security are particularly vulnerable to climate variability and dynamic nature of the global economy. Such situation requires the development of interventions that consider the challenges and existing opportunities for enhancing resilience within the semiarid lands. It is the aim of this paper, therefore, discusses the challenges and potential opportunities resulting from the climate in agricultural production in the semi-arid area in central Tanzania. Address adverse impacts of climate variability are among the critical challenges facing the African continent because of most of her people rely on rain-fed subsistence agriculture which is one of the climate-sensitive economic activities.

2.0 METHODOLOGY

This study was conducted in 2009 and 2012 in two villages of the Dodoma region in the central zone of Tanzania as indicated in Table 1. One is located on more accessible location and the other in a remote area. The Central Zone comprises Dodoma and Singida administrative regions, which are part of the semi-arid zone. Rainfall in the area is erratic and the area experiences a single rainfall between Novembers and April; however, it experienced severe reductions in rainfall and uneven distribution. About 85% of the rain falls between January and March and it is generally, falls for short intervals with an average of 600 mm per annum (NAPA, 2007). The topography of the area is characterized by plains with scattered inselbergs, ridges and hills. Bushland, woodland, wooded grassland, and grassland characterize the vegetation of the area as in most of the semi-arid areas. The region's economy depends entirely on crop production and livestock (Agriculture) which, still characterized by low productivity. Changes in rainfall make the central part of the country to less favoured and unsustainable of agricultural production.

Table 1. The description of study villages

S/N	Village	District	Characteristic
1	Mpunguzi	Dodoma	The village is highly accessible to high population, experience frequent drought, involve in irrigation for horticultural production through water from the sand river. The main crop grown in the village includes horticulture, maize, sunflower, sorghum and groundnuts
2	Nagulo Bahi	Bahi	The village is located in remote areas, experience drought, involve in crops and livestock production. The main crop grown in the village includes rice, maize, sorghum and groundnuts.

A multidisciplinary approach was used to generate relevant data and information in the study area. To capture information on local perceptions, perspectives and experiences related to climate change and agricultural production in the respective areas, both primary and secondary data were collected, organized and analyzed. The methods involved the collection of bio-physical and socioeconomic data, including climate (temperature, rainfall and the wind) production trends, crop types, diseases and pests and soils types and management information. The qualitative data were collected through participatory research methods (including focus group discussions, historical timelines, key informant interviews and seasonal calendars) and quantitative approaches collected through household questionnaire surveys. These methods coupled with field observations to check and confirm some of the information. The field observation, assisted in soliciting biophysical information and proving information gathered.

In order to generate respective information a variety of methods were deployed in the analysis of different specific objectives. The qualitative data were analyzed by using content and trend analysis, while quantitative data were analyzed by SPSS and Microsoft Excel software. The data generated and presented in the form of descriptive Tables and Figures.

3.0 RESULTS AND DISCUSSION

3.1 General characteristic of local population

3.1.1 Local livelihood activities

Agricultural production is the main livelihood activity that absorbed a large number of labour powers in the study area. The finding indicated that most households depend on agricultural activities to sustain their livelihood. Basing on FGD and household survey, socioeconomic activities in the study area include the agriculture crop production, livestock keeping, small business activities and others are involved in casual labour and employments as indicated in Figure 1. Together with farming, some household members are involved in non-farm activities that include carpentry, bicycle repair, food vending, production of local brew and other small scale businesses such as running small shops, selling of crops, provision of transport services (by use of motorcycles and bicycles), and casual labour.

Figure 1 Major livelihood activities in study area

Crops are grown for both food and cash; the main food crops produced include maize, sunflower, rice, groundnuts, Bambara nuts, sweet potatoes, cassava, sorghum and vegetables (onions, tomatoes and spinach). Cash crops produced are sunflower and cotton. The cotton used to be grown extensively, but due to poor and dwindling prices as well as the lack of market, most farmers abandoned it while sunflower is a newly booming crop grown for cash. Livestock is kept by a few farmers especially, for cattle, sheep, pigs and donkeys. Most farmers keep the chicken lather than other animals. The livestock kept include cattle, goats, sheep, pigs, chicken, ducks and donkeys as draught animals.

3.1.2 Local perception on and climate variability

The climate is usually evaluated over a period of a year looking at the behaviors of the main parameters of climate/weather which are rainfall, sunshine, wind, temperature, humidity and cloud cover. Change in the occurrence and statistical of these parameters induces the perception of changes as it has an impact on livelihood activities in farming communities. Climate variability in the study villages was described by using weather elements including rainfall, temperature, humidity, winds, sunshine, drought, disease pathogens. The observed changes on main weather element in the past twenty years include changes in rainfall that in past used to start in November/ December through April/ May, the cold season was in June and July, dry season from July through October and the wind occurred in August and September. Now every aspect has changed, rainfall is unpredictable and has no specified pattern, it can start in January or February and stop in February or March; the dry season has extended, from May to December/ January. Likewise, the temperature and frequency of wind have increased and they have no specific season. Respondents were able to indicate different aspects of climate that have changed and the main aspects of change as indicated in Figure 2.

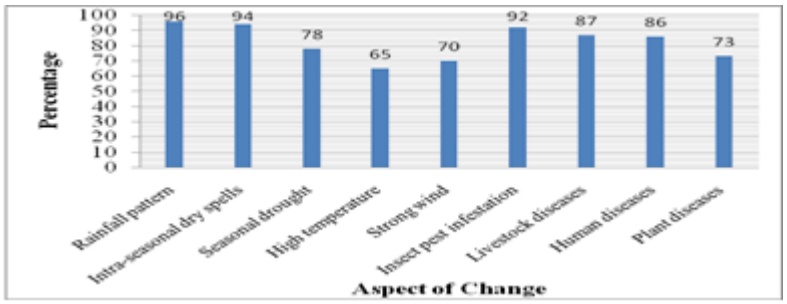

Figure 2. The main aspects of change reported by respondents

The changes and variability were explained by using bad and good years. Basing on climate aspects, a bad year described as the one with famine, more diseases, bad economic situation, shortage of rainfall, high temperature, low harvest and seeds dry out. Unlike good years was characterized as the one with enough food, reliable rainfall, good harvests, a decrease of diseases, availability of fish, plenty of grazing and water for livestock. A good year means a year with the adequate amount of well-distributed rainfall both in time and space which results in high yields. A bad year is the opposite of a good year, it is when receives less rainfall than usual, not well distributed in time and space, as a result production is impacted negatively. The results show the increase in the number of bad years that has adverse impacts on agricultural production and food security. For example, good year mentioned in the villages are 1998, 1999, 2000 and 2001 there were good condition and sufficient rainfall.

Farmers are observing changes and have a good understanding of them. The results indicate a high level of community's awareness of changes in their environment. This will be because such changes negatively affect their livelihood activities. The main aspects of climate perceived include changes in rainfall, which has decreased and has become erratic, variable in time, distribution and intensity. Other aspects of changes include increased in temperature, decrease in soil moisture and increase in occurrence and velocity of the wind.

The analysis shows that across study sites climate has been changing as indicated by different parameters. It

was interesting to have an explanation on why such changes have taken place in order to strengthen the knowledge base for adaptation in agriculture production. The perceived causes of the changes include deforestation and forest degradation that affects the climate system at a local level. It was reported that the frequency of drought has been increased due to decreased and unpredictable rainfall and an increase in temperature. Such changes were reported to affect crop farming such as rice, maize, sorghum, and groundnuts. Livestock also perceived to be affected by the occurrence of pest and diseases and changes on pasture and water. Fishing activity and other resources such as water and forest resources reported being affected by climate change.

To adapt to changing climate and variability farmers developed a coping and adaptation measures. Such measures include changing the more common used agricultural practices and other livelihood activities. The main observed changes in crop production are the introduction of new type of seeds, for example, *wahiwahi* and *shingo ya mwali* for rice, Macia for Sorghum, Seed 4, Sitaha and Kilima for maize, a record for sunflower and mwezi mmoja for groundnuts. In other side changes in livestock include the introduction of other animals such as pigs and decrease in the number of livestock, especially cattle. These changes were perceived to be the results of climate change and variability.

3.2 Vulnerability to climate variability and agricultural production dynamics

The results indicated that more frequent and severe extreme climatic events, especially drought are the challenge of agricultural production and on ensuring food security in the area. Changes in temperature and rainfall (timing and quantity) potentially affect agriculture production. It was revealed that the area suitable for agriculture, the length of growing season, yield potential and yields from rain-fed agriculture have been decreased and local food supplies are negatively affected due to the increased temperature and unpredictability of rainfall. Reduction of income from agriculture has been adversely affected most business activities such as food vending, shop keeping, carpentry and transportation. This is simply because businessmen cannot afford to buy merchandise and to offer the required services.

Rainfall and temperature are an important parameter in agricultural production (growth and development). There are an optimum rainfall and the temperature range for maximum yield for any crop. For example, warmer temperatures speed annual crops through their developmental phases and also increase their water requirements. If a crop variety is being grown in a climate near its temperature optimum, a temperature increase of several degrees could reduce photosynthesis and shorten the growing period. High temperature during flowering may lower growing number, size, and quality. Substantial temperature increases could have significantly negative impacts, limiting the potential benefits of increased CO_2 concentrations.

Climate Variability increased drought and warmer temperatures that exacerbated epidemics and prevalence of leaf fungal pathogens and overwintering population of pests. Insect pests are responsible for major impacts on yield quantity. In general, higher temperatures increase the rate of development with less time between generations. The increase in temperature in the dry area has increased survival and increased insect populations in the subsequent growing season. The most prevalent pests are stock borers, mites, and caterpillars while the prevalent diseases are maize strikes, tomato pledges, cassava mealybug, yellow mottle virus (rice) and fungus (groundnuts). During the post - harvest period, crop losses have been caused by grain borers and fungus.

3.2.1 Implication of climate variability on crop production

Major losses in crop production are associated with prolonged drought and attack from pests and diseases. It was revealed that recently increase pests and crop diseases has contributed significantly to a decrease in land productivity and crop production. Pest incidences result in a loss of more than half of the yields and the highest loss is on rice as indicated in Figure 3, probably due to drought indicating increasing dry spells. It was reported that the impacts of diseases associated with climate change significantly reduce maize, rice and groundnut yields.

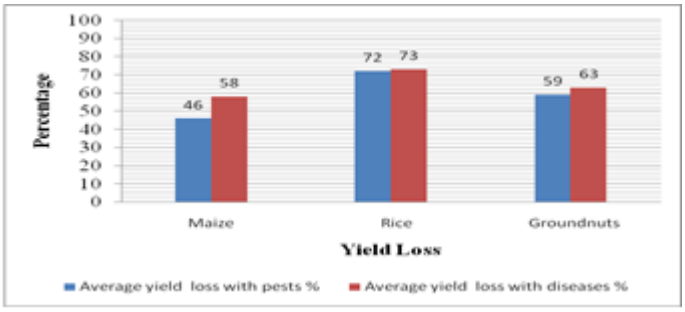

Figure 3: Extent contribution of climate-related pest and diseases on loss of crop yield

It was further indicated that 90% of losses on crop produce were due to impacts associated with the unpredictability of rainfall and increases in pests and diseases. About 80% of farmers are not sure on harvesting their crops as evidenced by the loss of harvest for three consecutive years due to unpredictable rainfall and an increase in temperature. The analysis revealed that intra-seasonal drought (49%) erratic rainfall (47%) and insect pests (44%) are occurring more frequently. As a result, farmers have continued to realize insecure harvest. Conversely, it was noted that strong wind (23%) and extreme cold (15) and flood (30) are not frequently occurring across the study area as shown in Figure 4. To minimize such loss a proper agronomic practices need to be instituted in order to strengthen the capacity to adapt and increase crop productivity.

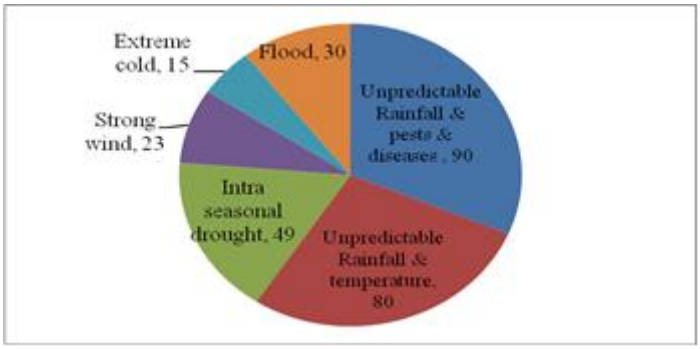

Figure 4 The factors that contribute to the crop losses

3.2.2 Implication of climate variability in livestock production

Effects of climate variability on livestock are based on a number of variables that includes factors such as the magnitude of temperature increase, drought and animal feed prices. Dairy cows are particularly sensitive to heat stress, with a temperature optimum for milk production. However, in the study area there are fewer dairy cows at the household level. The local cattle and poultry industries are affected, through direct effects on production and indirectly through changes in grain prices, pasture productivity, water access and availability, and costs of veterinary services.

One of the major reported reasons for reduced livestock production in the studied villages is the recurring of droughts that have caused significant loss of cattle since the last decade. Drought characterized by scarcity and unreliable rainfall has caused a scarcity of water and forage needed for livestock production, hence reducing the livestock numbers and quality of products significantly. Inadequate pasture and shortage of water for livestock together with increases in other livelihood activities, especially the expansion of crop farming and settlement in the areas reduced the grazing land for livestock. Factors such as disease and drought challenges have adverse effects on livestock production and productivity. It reduced the numbers of livestock and resulted in a loss in income of the livestock keepers.

In addition, the prolonged drought caused by variability of rainfall has resulted in the very poor quality of pasture and availability of water, which has also triggered the outbreak of livestock pests and diseases resulting in a

decrease in livestock population and production. Livestock diseases such as East Coast Fever (ECF) in cattle, Contagious Caprine Pleuropneumonia (CCPP) in goats and New Castle Disease in poultry have been reported to be a major hindrance in livestock production in the studied areas.

3.2.3 Implications of climate variability on food security

There have been incidences of food shortages in the area during the last 10 to 20 years. It was reported that due to the variability of rainfall which has resulted in a prolonged drought, agricultural output of food crops, especially maize, rice, groundnuts and beans has been adversely affected. In past 10 years, it was observed an increase in losses of crops in the field and after harvests that caused by drought and high temperature, crop pests and diseases.

Climate change poses a significant threat to the food security and livelihoods of people who depend on the small-scale production of crops, livestock, and forests (FAO, 2009). In central Tanzania, the health of animals and humans has been threatened by food shortage resulted from climate variability, especially the drought and the increase of temperature. The yield of most important and desirable agricultural crops has been reduced and resulted in additional increases in price, for example, crops such as maize and rice. Such situation increases the burden and vulnerability to the livelihood of the poor and jeopardizes poverty alleviation strategies.

Poor adoption of novel technologies, poor access to appropriate seeds, mechanization and the adoption of good agricultural practices increased challenges among farming communities. The situation of food insecurity has been worsening since the 1990s. During years of serious food shortage or famine, people do not have a wide range of types of food to eat. Most of the household eats once a day, reduce the amount of food and eat whatever available for them as a coping mechanism.

3.3 Local copping and adaptation measures in agricultural production

3.3.1 Adaptation in crop production

Adaptation requires the participation and sharing of knowledge among different stakeholders and up-scaling of successful innovations to a wide range of stakeholders. Such adaptation measures may include participatory learning of effective soil and water management practices as influenced by tillage, crop species and varieties, training among different communities with different innovations and up-scaling of successful innovations in a wide range of stakeholders.

Adaptation strategies could also include changes in tillage practices, selection of varieties with greater drought and disease tolerance, and development and implementation of improved Integrated Pest Management (IPM) programs. The extent of adaptation will depend mostly on the affordability of proposed strategies, the rate of climate variability and access to know-how or technology. Different coping and adaptation strategies in crop production based on communities' perceptions are shown in Figure 4 below.

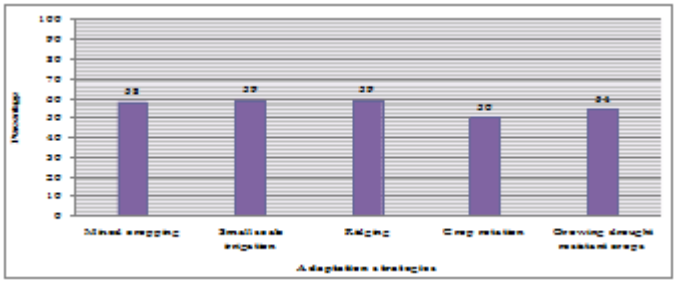

Figure 5 Local adaptation strategies based on communities' perceptions

3.3.2 Adaptation in livestock production

Different coping and adaptation strategies based on communities' perceptions include migrating with animals, keeping small ruminants and distribution of livestock as indicated in Figure 5.

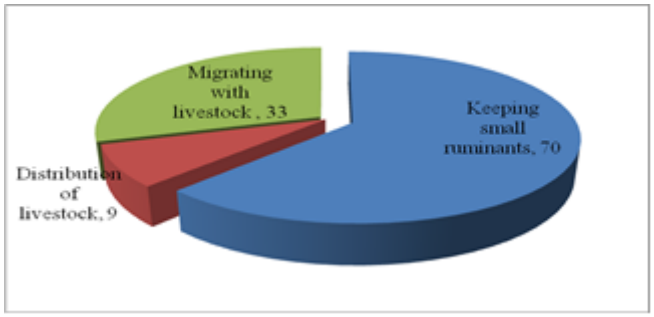

Figure 6 Viability copping and adaptation strategies in the livestock sector

3.4 Opportunities for improving resilience on agricultural production

Despite the potential challenges such as increased disease pressure and more frequent occurrence of extreme climate events, climate change may also bring opportunities for the introduction of new crops and increased yields. Irrigation farming also provides an opportunity for growing crops all-year round, even when there is a drought or failure of the rains. Opportunities for altering manure management, therefore, occur in dairy and poultry operations with confined livestock. However, due to high vulnerability to the impact of climate variability, most farmers failed to realize the potential opportunity that may be resulted from climate change and variability.

3.5 Potential adaptation strategies and recommended measures

Among the suggested and recommended adaptation measures include changing planting or harvest dates which are effective and low-cost options. Changing varieties are another low-cost option, although some varieties can be more expensive or require investments in new planting equipment. Such varieties include those grow well under stressed soil moisture and are resistant to diseases and pests. Proper agronomic practices such as increased use of irrigation, fertilizer, herbicide, and pesticide may be necessary to achieve maximum benefits from increased climate variability. Such practices will need investments in new irrigation or drainage systems or other capital items such as infrastructure and marketing mechanisms.

Another, suggested measures include optimize manure management, crop rotations by using legumes, rotation crop-pasture, green manures, mixed cropping systems that combine annual and perennial crops (e.g., Agroforestry) and promotion of land use that enhance soil organic matter. This will need farmers to be educated on the use of improved and proper seeds and involve in economic diversification to improve production and their livelihood. Rain water harvesting techniques should be improved for controlling runoff and use during summer/ dry period for livestock and horticulture agriculture production. This should include the development of the technology for underground water harvesting, including borrowing experience from other countries.

In the livestock sector, a proper education on livestock production such as the optimal number of cattle a farmer should keep in consideration the capacity of the land was recommended. Adaptation strategies in livestock sector should include growing elephant grasses, Water harvesting for livestock and separation of grazing land with other land use.

Development and dissemination of management practices that best adapt to seasonal climate variability should be the main focus of the adaptation strategies. Such adaptation measures associated with seasonal climate variability have to focus primarily on techniques such as shifting planting dates, changing crop varieties, and local practices. Adaptation strategies also might require farmers to use management practices and technologies that are beyond those existing today. Research must play a proactive role to generate necessary responses and technologies that farmers will need to handle such future challenges. Provision of education is imperative in the process involved in establishing adaptation strategies to reduce risks associated with climate variability in an efficient and effective way.

Improvement of coordination between farmers, extensions/ expertise, researchers and the government in addressing problems are an important adaptation option in agricultural production. This will increase adaptation

knowledge and resilience to farmers. In additional to the coordination improvement of access and use of weather information was recommended.

4.0 CONCLUSIONS

Climate change significantly affects agricultural production and different forms of livelihoods in semi-arid and is bound to have the biggest effect on the livelihood of smallholder farmers. The reliance on rain-fed subsistence agriculture, which is one of the climate-sensitive livelihood activities and compounded with low adaptive capacity increased vulnerability to the changing climate. Such situation had posed a challenge in agricultural production, livelihood sustainability and in resources management. More frequent and severe extreme climatic events especially, drought is among the challenge of agricultural production and on ensuring food security in the semi-arid area. Farmers are not sure on harvesting their crops as evidenced by the loss of harvest for three consecutive years due to unpredictable rainfall and an increase in temperature. 90% of losses on crop produce were due to impacts associated with the unpredictability of rainfall and increases in pests and diseases.

Addressing adverse effects of climate variability is among the critical challenges facing the rural communities in central Tanzania because of their reliance on rain-fed subsistence agriculture which is one of the climate-sensitive livelihood activities. This will need improvement of agricultural production through growing drought and pest/disease resistance crops, early maturing crops, adjustment of planting time, development of irrigation infrastructure where ever possible, subsidization of agricultural inputs and implements and rural social services. Social services include finance, infrastructure, equipment and human power. In enhancing the sustainability of coping and adaptation strategies there is a need of paramount improvement of coordination and capacitating research, extension services, meteorological services and another private sector in agriculture. Coordination between farmers, extensions/ expertise and the government in addressing problems should be improved. Such improvement should include the provisional of more training on how to adapt and cope with climate change on agriculture and on the utilization of opportunity arising from climate change and variability.

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