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Challenges and opportunities for extenuation and alteration in the farming production across the gradient of Rungwe District, Tanzania

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ABSTRACT

Enhancement of farmers' awareness is essential in determining and planning adaptation options in farming activities. It inverts a critical situation and concern among smallholder farmers where vulnerability is high due to low ability to adapt. The study employed a survey method to collect both qualitative and quantitative data using household survey, key informant, Focus group discussion and field observation. Then the data organized and analysed using content and trend analysis of qualitative data, while the quantitative data were analysed by using Microsoft Excel and SPSS software. The results indicate a problem in conveying opportunities in farming production across the zone and the need for understanding the challenges and opportunities as essential in formulating adaptation options and minimizing adverse effects on agricultural production. It revealed the need for strengthening the capacity of farmers and institutions for identifying and assessing the challenges within different farming system across agro-ecological zonesthrough educating farmers and other relevant stakeholders on improving livelihoods, productivity and agricultural production. Such knowledge and initiatives require an appropriate package of information and support to meet the challenges,

uncertainties and exploit opportunities in agricultural production. The study suggested the need for understanding the challenges, information and knowledge needed for an effective response to the changing climate. This would include the use of appropriate agricultural crop production practices, technologies and strategies to reduce risk and vulnerability in the farming communities. Such strategies may include modifying the cropping system or crop combination, an adjustment in the cropping calendar and farming practices.

Keyword: Farming, agroecological gradients, adaptation challenges and opportunities

1. INTRODUCTION

Developing feasible, innovative and improved technologies for adapting to future situations, and to enhance resilience adaptive capacity of vulnerable communities provides an important option. This requires substantial planning, extenuation strategies, alteration measures and improved knowledge to sustain land productivity and enhance production (Gwambene, 2011). Such improvements should include long-term and comprehensive (integrated) programmes that promote understanding of agricultural production, the interactions between social/political structure and functions as well as ecosystem attributes. Thus the need to unpack required farming production information and disseminating among smallholder farmers and other key stakeholders.

Across the gradients, different zones identified to characterise biophysical and edaphic characteristics. Such characteristics form different agro-ecological and resilience zones in which the farming activities and farmers can be categorized basin on their operate, types and composition of farm portfolio and landholding or annual revenue generated from farming activities (Salami, *et al.,* 2010). In the area with high population densities, smallholder farmers usually cultivate less than an acre, reducing the opportunity for diversification and commercialization. Within the setting and vicinity, the enduring smallholder farmers' challenge is low productivity stumbling from the lack of access to markets, high production cost, and low technology compounded by the food insecurity (Salami *et al.,* 2010; Kumar and Kumar, 2018). The climate is one of the key factors of agricultural production with significant impacts on production across the zone. It is reflected in the context of essential inputs (water, solar radiation, and temperature) that necessary to support plant and animal growth (Antle, 2009). Across the zones, weather and climate form an important factor in crop production as farmers rely on them to make decisions on what to produce (Gwambene and Liwenga, 2016). Other factors influencing the farmers' decisions on the production across the zones include transportation cost, access to labour, land availability, crop types and varieties, use of inputs, quality of products, market sources and land tenure. Besides, the farming practices/ technology, weeds, and a wide array of public policies increase vulnerability to the loss of crops across the agro-ecological gradients. Such factors are affected by individual attitudes towards risk and change, adaptive capacity, and external factors constraining or supporting adaptation and mitigation measures. The complexity of interacting factors over time induced a spatial organization of agriculture that tends to be economically efficient in the face of various constraints on the system.

The occurrence and distribution of rainfall, numbers of wet and dry days, minimum and maximum daily temperatures and the strength of the wind have changed (Paul *et al.,* 2009; Gwambene, 2011). These changes have had significant impacts on agricultural crop production across the gradients. For example, changes in patterns and distribution of rainfall and temperature and land use across the gradients have significantly altered the hydrology of crop-producing areas (Gwimbi and Mundoga, 2010). Moreover, fluctuation in rainfall and temperature has also triggered the emergence of new pests and diseases that wreak havoc on crops, and livestock growth and development (Orindi and Murray, 2005). As such, understanding the impacts of climate variability on agriculture is vital in formulating adaptation strategies and options to minimize the adverse effects and, hence, ensure sustainable livelihoods. This study addresses the challenges of adaptation and mitigation measures in farming production at the community level across the gradient to enhance surmountable community adaptation and mitigation strategies.

Deterring of the negative effects of climate variability and improving livelihood and food security have been the focal priorities for development agencies and policymakers (Hassan and Nhemachena, 2008; Wegner and Zwart, 2011; IFPRI, 2012). Such measures require substantial strategies to sustain adaptation measures in agricultural production in the perspective of climate variability. This needs to involve extension services that have the potential to facilitate adaptation strategy. Therefore, more effort is needed for extending these services to farmers especially, in poor communities. In line with such measures, appropriate and timely information on predicted changes are needed for empowering farmers to take appropriate steps in adjusting their farming practices. Such facilities will inform and provide farmers with opportunities to effectively adapt to changes and increase farm production.

2. METHODOLOGY

2.1. Study area

The study conducted in three zones of the Rungwe district in Mbeya region, Southern Highlands of Tanzania that is lowland, midland and the highlands. The district was selected due to its agricultural potential within the vertical landscape gradient with diverse characteristics, which allow for the production of many crops. The area experiences diverse constraints and opportunities and for a long time, the district has been one of the areas considered as a food basket for the country. Bio-physical conditions that determine crop and animal production characterize agro-ecological zones that define a set of measurement and or properties. The farming system, social-cultural, political ecology and climatic conditions determine crop and animal production. For example, criteria used for Agro-ecological zones differentiations include climate (total annual amount, distribution, duration of rainfall, the incidence of drought and temperature), parent material (soil characteristics, nutrient supply, texture, structure, drainage, depth and slope), altitude, landscape, vegetation and biological conditions.

The highland zone covers about 10% of the total area of the district with an altitude ranging between 2000 – 2865 masl meters above the sea level. Generally, the highland zone is cold (5^0c - 18^0c) throughout the year with average rainfall ranging from 1500mm to 2700mm (Gwambene, 2012; Nyunza and Mwakaje, 2012). The area is suitable for agriculture. The main crops grown are round potatoes, maize, and pyrethrum (Tea Research Institute of Tanzania, 2004).The midland zone covers about 75% of the total land in the district. The zone occupies more of Pakati and Busokelo divisions (District Council) that lie between the highland and the lowland zone. This zone experiences moderate temperature (16^0c - 28^0c) with cold weather in June and July and receives an annual rainfall between 800 mm and 2200 mm. The soil is good for agriculture and livestock keeping. The main crops grown include Tea, Coffee, Cardamoms, Beans, Bananas, Maize, Groundnuts, etc. Ranges of the type of crops produced in this zone and are the most productive in the area. The main vegetation found in this zone includes erythrina, ficus, groveler, pines, Cyprus's, eucalyptus, etc. (Gwambene, 2012). Fruits such as pineapple, guava, avocado, mango, orange, citrus, pineapples and papaya are grown in the zone. The lowland zone lies in the southern part of the district between an altitude of 498 to 772 meters above sea level (*masl*) with an average rainfall ranging between 900 mm and 1200 mm per annum. It covers about 15% of the total land area of the district. The zone covers Ilima, Masukulu, and Kambasegela wards in Pakati division, Itete and Kisegese wards in Busokelo division (URT, 2010; Gwambene, 2012). Generally, the weather is warm (20^0c - 30^0 c) throughout the year compared to other zones. The area is suitable for growing paddy, maize, beans, cocoa, and cassava. Natural vegetation found in this zone includes miombo, bushes such as acacia, albiria and ficus (URT, 2010; Gwambene, 2012). The lowland zone experience drought and floods.

2.2. Data collection methods

An extensive review of relevant literature from previous studies on climate change and variability was used in the collection of secondary data. The review focused on adaptation and mitigation measures, agricultural production, community livelihood activities and socio-economic activities. Information on the challenge of adaptation and mitigation strategies, climate change and variability, were gathered from different sources, including meteorological agency, internet sources, library, environmental departments, agricultural and livestock departments and natural resources divisions. Furthermore, variables such as socio-economic, land tenure, resources management, agricultural production, food security and incomes in selected areas were collected.

Both quantitative and qualitative methods were used to collect primary data from the study areas that include key informant interviews, focus group discussion, household surveys and field observation. For effectiveness and triangulation of data collection, these methods were used to complement each other. Quantitative data were collected through a household survey using a structured questionnaire that was divided into themes with specific information to be collected. The focus group discussions (FGD), key informant interviews (KI) and field observation (FO) through which qualitative and quantitative information was collected formed a ground for discussion.

2.3. Data processing and analysis

The collected data from different sources and methods were organized, edited, coded, tabulated, compiled, processed and analysed using different techniques. Content and trend analysis used to analyse qualitative data from key informant interviews, focus group discussions and observations during and after data collection. Quantitative data from the household survey was organized and analysed by using the Statistical Package for Social Sciences (SPSS 20) and Microsoft Excel software. The results presented in descriptive form, Tables, and Figures.

3. RESULTS AND DISCUSSION

3.1. Adaptation measures in agricultural crop production

The study revealed that the effort of people responding differently to climatic events in their environment is based on their adaptive capacity and environmental resources available to them. Farmers have various strategies to sustain and maintain production, which is important for their livelihoods. Such strategies used to deal with current climate variability and extremes often produce benefits as well as form a basis for adapting to future anticipated change. Most of the adaptation measures have a positive effect on crop yields, significantly enabled farmers to cope with the adverse effects and provide the opportunity for increasing agricultural production and land productivity.

Adaptation is critical and of concern among smallholder farmers where the risk and vulnerability are high due to low adaptive capacity. It helps farmers to sustain livelihood and enhance food security and income in the face of changing climate and socio-economic conditions (Gwambene, 2018b). Farmers have reduced the potential impairment through developing tactical responses that guard them against losses of production and used for reducing income vulnerability. The adaptation strategies ranged from on-farm to off-farm activities including the use of different crop inputs and adoption of soil and water management practices (URT, 2010).

3.1.1. Existing adaptation measures

The current adaptation measures across the gradients include strategies to diversify livelihood and protect plants' sensitive growth stages against the adverse effects of extreme events (Kristjanson *et al.,* 2012; Nyanga, 2012; Gwambene, 2018). The diversification strategies serve as an important form of insurance to the impacts of climate variability. This strategy reduces risk by taking full advantage of the available resources and making efficient use of it. Diversification strategies in the study area involve growing a variety of crops on the same plot or different plots, thus reducing the risk of complete crop failure.The existing adaptation measures provide an opportunity for farmers to safeguard against losses due to fluctuating precipitation, increasing temperatures, pests and diseases. Table 1 presents the current adaptation measures used to cope with the impacts of climate variability in the study area.

Table 1 Measures taken to deal with the impacts of climate variability in agriculture

Measures to deal with climate variability impacts	Lowland (%)	Midlands (%)	Highland (%)	Total (%)
Irrigation farming	33.3	12.5	00.0	45.8
Tree planting	22.2	12.5	10.0	44.7
Depend on rainfall (season)	00.0	00.0	20.0	20.0
Contour farming and Trench making	00.0	00.0	20.0	20.0
Casual labour	00.0	00.0	20.0	20.0
Involve in business	11.1	08.3	00.0	19.4
Environmental management	00.0	08.3	10.0	18.3
Use of organic fertilizer	11.1	04.2	00.0	15.3
Cassava production	11.1	04.2	00.0	15.3
Planting through watering the seeds	00.0	12.5	00.0	12.5
Not cutting trees	00.0	12.5	00.0	12.5
Managing harvest	11.1	00.0	00.0	11.1
Food storage	00.0	00.0	10.0	10.0
Brick making	00.0	00.0	10.0	10.0
Water source management	00.0	08.3	00.0	08.3
Use of pesticides	00.0	04.2	00.0	04.2
Not planting eucalyptus within water sources	00.0	04.2	00.0	04.2
Garden farming	00.0	04.2	00.0	04.2
Pruning banana trees / reducing leaves	00.0	04.2	00.0	04.2

The perceived and used measures range from measures for improving and managing harvest to land/ environmental management. The pronounced measures include crop diversification, planting drought-tolerant crops and/or weather-resistant and

varying the planting and harvesting dates. Also, the strategies take in the use of water for irrigation, soil management techniques, growing early maturing crop varieties and diversifying from farming to non–farming activities. Also, it includes the use of different crop varieties, use of fertilizers and pesticides and practising soil and water management techniques. Other strategies used are practising small-scale irrigation use of agriculture extension services, growing different types of crops on different land units and water harvesting.

Diversification in the study area involves growing many crop varieties on the same plot or different plots, hence reducing the risk of complete crop failure since different crops are affected differently. The use of additional water for irrigation and water management and harvesting techniques also used to modify the growing season. However, due to a shortage of land for diversification, farmers in the midland zone use an intercropping method. For example, bananas are intercropped with tomatoes and other crops such as beans and maize, groundnuts with maize, round potato and maize.

3.1.2. Crop livestock integrations

In lowland and midland zones, agricultural crop production is well integrated with livestock production as most households keep stall-fed cattle using crop residues and pasture produced by households. The manure from cattle hutches is used in crop production, providing a mutual benefit whereby the crop residue used to feed livestock. Livestock keeping, especially dairy cattle are another important strategy commonly used in the midlands, especially for milk and farmyard manure in banana fields. It was revealed that most of the interviewed farmers in this area were involved in keeping livestock and used farmyard manure in their fields. Such results are in line with other studies (USAID, 1999; URT, 2010, Tilumanywa, 2013; URT, 2015; Gwambene, 2018b).

Livestock keeping is among the important activities being undertaken in Rungwe district and particularly in the midland and lowland zones. Livestock was reported to be a reliable source of income, especially in the midland zone where farming activities are characterized by small plot size. The major livestock types being kept in the study area are cattle, sheep, goats, chicken and pigs. It was noted that the major population of livestock kept is local breeds in low land, with significant populations of improved breeds, while in the midland area improved breeds of cattle are dominant as shown in Table 2.

Table 2 Types and numbers of livestock owned by sample households in the study area

Livestock, owned	Number per Hh	Lowland %	Midland %	Highland %
The local breed of Cattle	01-02	30.4	01.7	00.0
	03-05	23.2	00.0	00.0
	06-10	01.8	00.0	03.2
Improved breed of Cattle	01-02	08.9	05.0	03.2
	03-05	00.0	16.7	00.0
Goats local breed	01-02	05.4	01.7	00.0
	03-05	05.4	00.0	00.0
	06-10	01.8	00.0	00.0
Pigs	01-02	08.9	03.3	09.7
	03-05	05.4	03.3	03.2
Chicken	01-05	35.7	50.0	51.6
	06-10	35.7	26.7	22.7
	11-15	00.0	06.6	03.2
	15+	05.4	01.7	03.2
Ducks	01-05	05.4	01.7	00.0

The importance of livestock production is growing in the area, account for about 35 % of the household income in the middle and lowland areas of the study area. It serves diversified functions such as income-generating, improving diet, providing draught power, optimal utilization of land that is not suited for cultivation, as an asset, and insurance during difficult times. Interaction between crop and livestock is increasing in the study area that often benefits agricultural crop production through enhanced availability of manure, draught power for cultivation and transportation of harvest and agricultural inputs. On the other hand, livestock production benefits from crop residues that constitute an important fodder resource.

Farmers in lowland and midland zones keep improved cattle as an adaptation strategy to land shortage (improved cattle need smaller size area and have a high quantity of output), land exhaustion and as a coping mechanism to climate variability. As one aged farmer in the midland zone said:

'In the past, we used to produce more crops in a small land area and keep many local breeds of cattle. But now the situation has changed; land productivity has decreased due to climate change, environmental degradation and land exhaustion, also there is no more grazing area for local cattle. Thus currently, we depend on dairy cattle as an alternative for food and cash. We use farmyard manure for banana production. Those who have no cattle their fields are infertile and produce small quantities of crops with low quality'.

The results indicated that livestock forms an important part in adaptation to climate variability. It is used as food and source of income at the household level. The cattle are also used as a source of draught power, particularly in the lowland zone that favoured by physical factors, used as bride price, and means of savings and also commonly used for supplying manure that helps to maintain soil fertility. Other studies also reported similar results (Orindi and Murray, 2005; Gwambene and Majule, 2010, Tilumanywa, 2013). The nature of the soil (volcanic soil) and terrain (steep and gentle slopes) in the highland zone limits the use of draught animal for cultivation. These adaptation measures provide an opportunity for farmers in all zones to withstand climate variability impacts and improve production, household income and food security.

3.1.3. The potential and effective adaptation measures

The potential and effective adaptation strategies to reduce vulnerability to the impact of climate variability and related factors were explicated during FGDs, Key informant interviews and household interviews. Table 3presents the suggested alternative measures to improve and adjust agricultural production and improve land productivity. These alterations include changing planting dates, increasing irrigation to boost agricultural crop production in selected areas, promoting the use of drip irrigation for specific areas, promoting local knowledge and reducing reliance on maize as a staple food by growing other early maturing and weather tolerant crops. For example, cassava and sweet potatoes in lowland and midland zones and peas in the highland zone are grown as weather tolerant crops. Other adaptation practices include the use of crop rotation, pest management and better use of weather information in the production process.

Table 3 Proposed effective adaptation strategies expressed in percentage of respondents

Effective adaptation strategies	Lowland	Midland	Highland	Overall
Reduction of prices of agricultural inputs	10.1	35.4	57.5	34.3
Improve agricultural production knowledge	31.7	43.0	17.5	30.8
Improve markets for produces	31.9	06.3	00.0	12.7
Improve extension services	02.9	10.1	05.0	06.0
The government should provide food relief	04.3	02.5	010	05.6
Education on climate variability	10.1	01.3	00.0	03.8
Improve capital and implements	04.3	01.3	02.5	02.7
Water source management	04.3	03.8	00.0	02.7
Not cutting trees and tree planting	02.8	02.5	02.5	02.6
Involve in cassava production	04.3	01.3	00.0	01.9
Produce for business	00.0	01.3	02.5	01.3
Improve access to land	00.0	02.5	00.0	00.8

The results postulated that most respondents perceived reduction of prices of agricultural inputs and improvement of access to agricultural loans (34.33%) as the most viable adaptation measure to increase agricultural production and food security. It was followed by an improvement of the crop market (38%), improved knowledge on the use of fertilizer (30%), and improved extension services (18%). Other strategies are the improvement of agricultural production knowledge (16%), education on climate variability (11%) and provision of relief food (7%) to poor farmers. Besides, measures such as improvement of round potato production, water source management, not cutting trees and tree planting, involvement in cassava production, improved maize seeds, producing for peddling, improvement in irrigation farming and improving access to land were among the important adaptation measures. Other adaptation measures include involvement in gardening, growing early maturing crops, livestock keeping, natural tree conservation, reduce counterfeit pesticides, improving input subsidies, encouraging group work (group formation) and diversification of crops. These measures are important at the individual and community levels.

The potential adaptation also includes adjustment of the cropping calendar by taking into consideration and synchronising with the period expected to have more reliable rainfall. For effective measures consideration of water requirements for crops at different stages of growth and development is important. Modification of the cropping system or crop combination is another potential adaptation that including crop rotation and deciding on what crops to be planted by considering the seasonal climate forecasts for the growing season. Planting of crops that have a short growth period is the most efficient means to fight drought and is the most effective strategy for crops under moisture constraint. Such a strategy allows the growing of succeeding crops at the period once rainfall and residual moisture are available for the plant. Besides, stress-resistant, early-maturing or short-duration varieties of crops which are more resistant to drought, frost or flooding and promoting other alternative food crops are among the potential adaptation strategies. These calls for the development of clear plans and awareness creation on effects and adaptation measure to climate variability. Such strategies need to sustain agricultural production and environmental management that in turn increase productivity and boost food security through irrigation, strengthen early warning system, tag on improved agronomic practices and promoting improved crop production.

For successful adaptation, it is important to consider the decision on crop varieties and understanding the crops that require less water that can utilize available soil moisture to provide a reasonable yield. Planting early maturing crops may be the most efficient means to escape from the effect of drought, and the most effective adaptation measure for crops under moisture constraint. Based on the FGDs and key informant interviews it was suggested that improvement and efficient water use and management are important measures especially in adapting to drought. In the areas vulnerable to extreme weather conditions, such as drought, flooding, and waterlogging will require promotion of organic agriculture practice that acknowledged increasing soil organic matter content by most of the respondents during key informant and FGD, and hence higher water holding capacity that makes crops more resistant to drought. Organic agriculture reduces the vulnerability in agricultural production by increasing land/ soil productivity through enhancing biological diversity and soil nutrient. Use of organic manure maintains long-term soil fertility, increase soil biological activity and make use of recycled wastes of plant and animal to return nutrients to the land, hence improve soil productivity (Muller, 2009). The use of organic manure is among the important adaptation measures that promote the healthy use of soil and water and also minimize pollution from agricultural practice (Tizale, 2007; Muller, 2009). Therefore promotes the practice that diversifies sources of income and provides a viable alternative for resource-poor farmers and improves biodiversity is among the best adaptation option in addressing the impact of climate variability and increasing food security across the gradients.

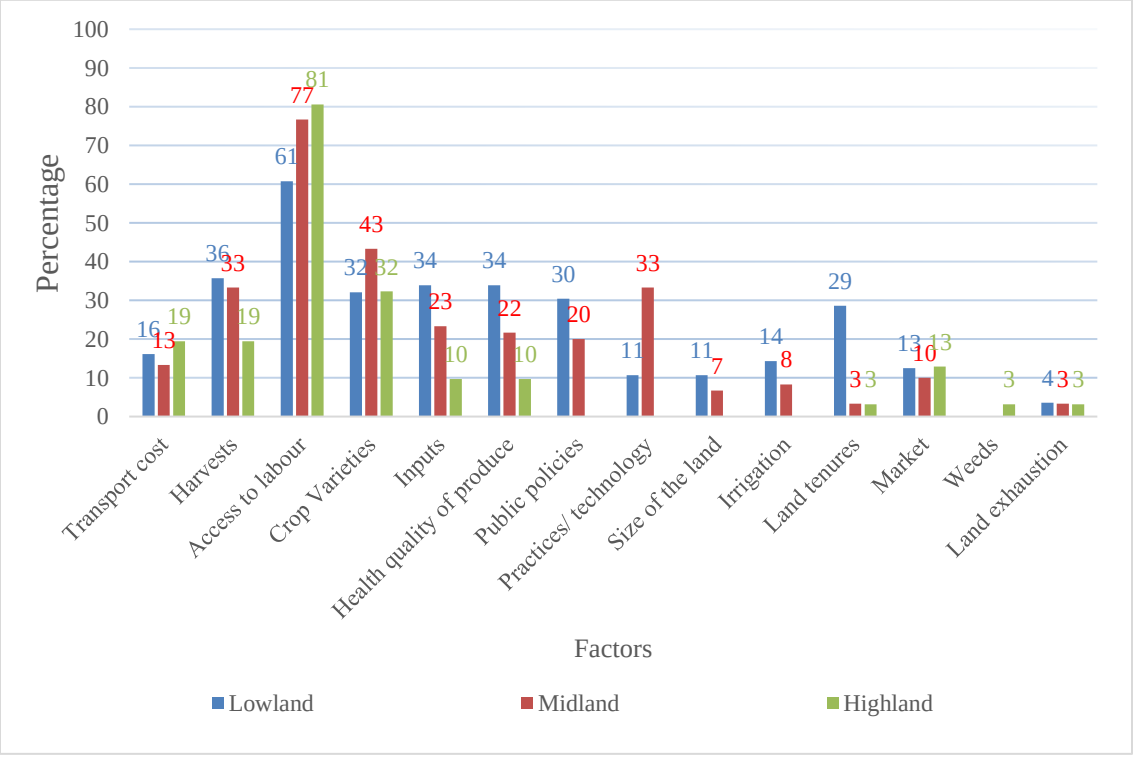

Figure 1 Factors affecting agricultural crop production decisions

3.2. Factors influencing adaptation measures and choice of crops to produce

The reported factors that affect agricultural crop production decisions in all study zones include transportation cost, access to labour, crop varieties and use of inputs, land exhaustion, quality of produce, market sources and land tenures. Policies and political issues also influence decisions on what and how to produce. Based on the household survey, the perceived factors that affect the decision of farmers to produce or adopt new crops are shown in Figure 1. Practices/ technology, weeds, size of land and irrigation were reported to influence the decision on what to produce in all zones. The results matched with Burton *et al.* (2010) who argued that farmers make decisions on what to produce based in part on site-specific climate conditions and many other non-climatic factors. Such factors include a wide array of public policies, transport costs, access to inputs and labour and other social services. These factors exaggerated through individual attitudes toward risk and change, external constraining, the ability to adapt and support adaptation strategies.

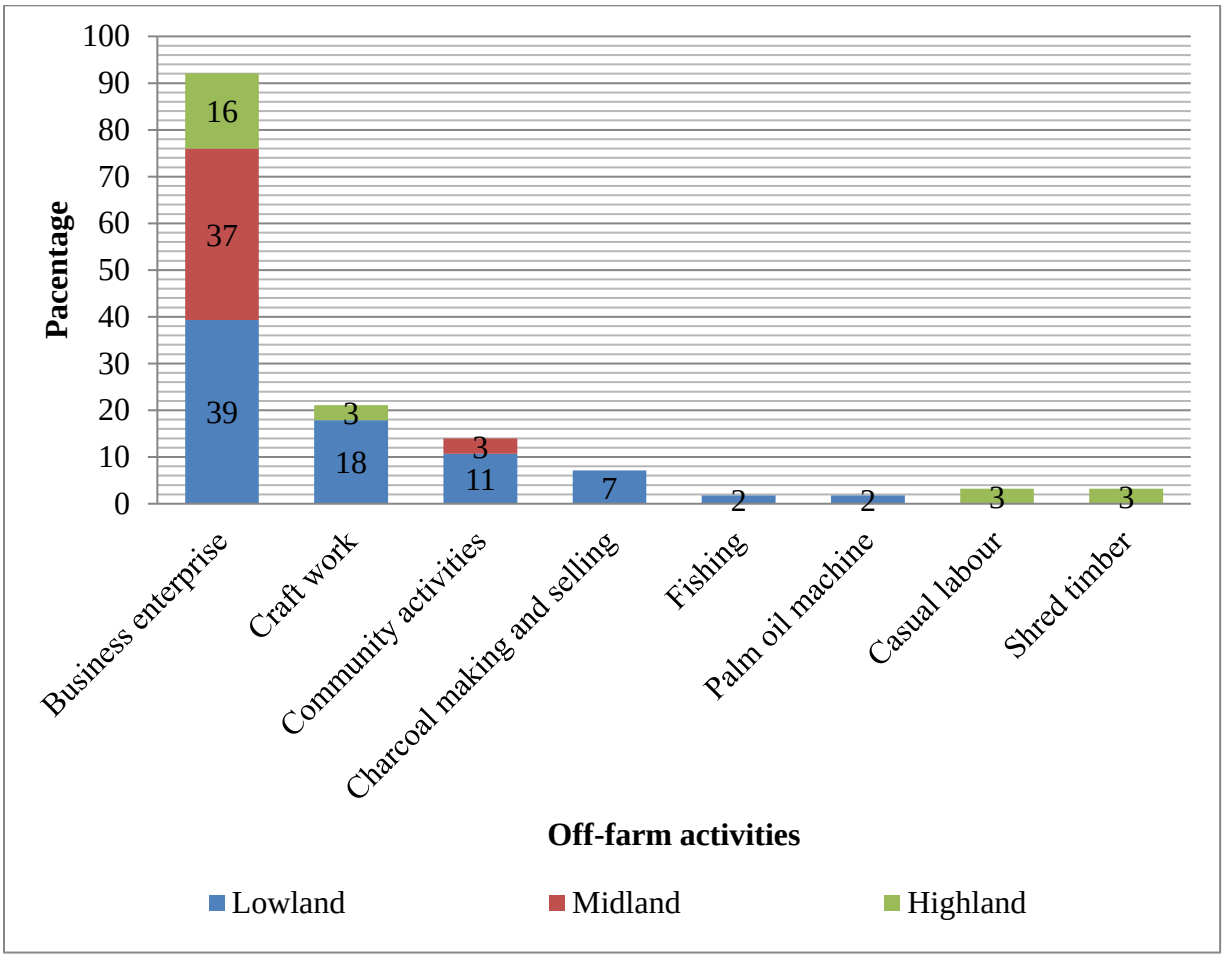

Figure 2 Household's off-farm income-generating activities

Field observation and key informant interview revealed that land condition and climatic factors, especially, fluctuating rainfall affect the decision on what and when to produce. For example, in the past smallholder farmers were more concerned with increasing production, but currently, their focus is more on reducing risk resulting from climate variability. It was revealed that well-off households can produce more and can afford to rent fields in another area and manage their farm.

Understanding the factors influencing farmers' production decision provides an opportunity in understanding and planning for adaptation measures and improvement of production at a local level. The choice of suitable adaptation measure at the household level depends on factor endowments that include access to land, the size of land owned/used and capital resources at the disposal of households. Better access to farm and inputs such as improved implements and inputs were found to promote the use of improved agronomic practices and increase household adaptability capacity. For example, in the highland zone, the use of fertilizer is in the improved farming practices especially, on round potatoes. The sizes of household, land and capital resources at a farm level were also considered to be a production determinant (Hassan and Nhemachena, 2008), Tilumanywa, 2013).

The small size of land characterizes the farming activities across the gradients that limit further expansion of farming activities. In these lands mixed livestock and cropping activities are practised. As in other parts of the region, larger farm sizes are associated with rain-fed farming systems, while smaller size land is within irrigated agriculture (Gwambene and Majule, 2010; Tilumanywa, 2013). It was revealed that land shortage is experienced in both rain-fed and irrigation farming systems, although in irrigated farming the problem is more acute. The results indicate that many farmers own small land size, for example, 36% in the lowland, and in the midlands, 43% own 0.25 to 1 acres, 25% in lowland, 44% in the midlands and 38% in highland owned 1.25 to 3 acres and by across the gradients farmers own not more than ten acres. In the midland zone that influences agricultural production and adaptation to climate variability since farmers have less land for mechanization and crop diversification. This situation has forced most farmers to involve in off-farm activities to supplement agricultural production. Off-farm activities increase adaptability capacity and household income, especially during crop failure. The mentioned and described activities indicated in Figure 2.

The results indicate that most farmers involved in the business in all zones (lowland 39%, Midlands 37% and highland 16%), craftworks mainly in lowland (18%) and highland by 3%. Charcoal making and sell were reported in lowland (7%) mainly, while casual labour and shredding timber (3%) was mostly practised in highland areas. The casual labour in highland was attributed to round potato production, which demands high labour, especially during the harvesting period. Also, timber production has increased in the highland area because tree planting has gained momentum as a cash crop, for the area replacing pyrethrum production. Based on the FGDs and key informant interviews few households or individuals are involved in firewood selling.

Asset ownership and livelihood characteristics as reported during FGDs and key informant interview have influenced in the choice of adaptation strategies in all zones. The study results indicated that farmers with fewer assets and fewer alternatives focused on subsistence and put more efforts on improving their situation. The well-equipped farmers, endowed with agricultural assets involve participating in cash-crop production and market activities. Asset and livelihood characteristics affect long-term increments in agricultural production and total household income. Assets such as land, physical and financial capital, network and house ownership were perceived to influence the agricultural crop production and adaptation strategies in all zones.

3.3. Policy issues and anticipated future situation

Policy awareness and strategies among interviewed farmers were low. In most cases, farmers used by-law, which is sometimes conflicting with other national policies. The study revealed that even where the by-laws were known the political will has a greater impact on its implementation. Besides, it was apparent that there is a lack of enforcement of by-laws and the implementation of the policy. Based on FGDs in all zones, there were no clear agricultural policies to guide farming practices. Lack of enforcement and clear policy to guide farming practices resulted in low productivity and increased household vulnerability to climate variability. Tanzania national policies related to climate change include; the National Land policy (1997). National Environmental Policy (1997); Agriculture Policy, (2013); Livestock policy (2006); National Water Policy, (2002); National Forestry Policy, (1998); National Health Policy, (1990). The strategies include the National Climate Change Strategy and Action Plan and the National Strategy for Growth and Reduction of Poverty (2011-2015).

Appropriate public policy, strategies, investment and collective actions are important in supporting the coping and adaptation strategies for local farmers. Through such strategies can support the adoption of the measures to reduce the negative effects of the anticipated changes (Hassan and Nhemachena, 2008). Sound and well-planned enabling environment (institution, policy and strategies) will have great benefits to vulnerable rural communities. Generally, policy and strategies have a wide range of opportunities in prospect for improving agricultural productivity and efficiency and environmental quality by using all available appropriate technologies. The strategies for climate change adaptation and mitigation in agriculture are well articulated in the National Climate Change Strategy and Action Plan as indicated in Table 4. The policies and strategies are well planned and many farming problems were identified, but the main challenge is an implementation at the local level where the communities differ in perception, demands and obstacles they face.

The strategies would benefit farmers at the local level if they have been well presented to this target group. However, these good strategies are not well understood by most interviewed district and ward extension officers. Some of them are not aware of these important documents that can be used to guide adaptation and mitigation practices in their fields of work. In this situation, there is a need to enhance cooperation among relevant stakeholders and to find proper ways and techniques to ensure the dissemination of information and knowledge to key stakeholders as well as at the community level.

Appropriate adjustments in agricultural policies and strategies are equally important in mitigation of the adverse effects of climatic changes and variability. This requires a better understanding of the impact and probable nature to develop appropriate and attainable strategies across the gradients. For example, in the midland zone, the use of improved technology for increasing productivity and production in small areas is a feasible option rather than implementing mechanization to cultivate a larger area. In

the lowland and midlands zones, there is a need to promote the use of improved water-harvesting technologies, drought-tolerant crop and fodder varieties. Besides, increasing investments in new and existing irrigation systems is important for improving resilience, productivity, agricultural production and reducing food shortages over time. For effectiveness, it is imperative to take into account risks associated with climate variability and change. It should be noted that inclusion of climatic risks in the design phase and during the implementation of development initiatives is important for reducing vulnerability and enhancing sustainability.

Table 4 Strategies for climate change adaptation and mitigation in agriculture

	Goal	Strategic objectives	Strategic interventions
Adaptation	To enhance the resilience of the agriculture sector to climate change and variability for sustainable livelihood.	• To identify suitable crops for new agro-ecological zones. • To promote appropriate agricultural practices that increase resilience to climate change. • To promote the use of appropriate technologies in production, processing, storage and distribution	• Appraising crop suitability (cropping pattern) across the Agro-ecological zones • Promoting appropriate irrigation systems • Promoting early maturing and climate tolerant crops • Enhancing agro-infrastructural (input, output, marketing, storage) systems • Enhancing appropriate indigenous knowledge practices • Identifying and developing crop insurance strategy.
Mitigation	To promote and enhance the contribution of the agriculture sector to national sustainable development through the sustainable agricultural production system	• To minimize emissions from farm inputs. • To enhance carbon sequestration in agriculture sector.	• Promoting the adoption of high yielding technologies. • Promoting and enhance agroforestry systems. • Enhancing the management of agricultural wastes. • Promoting minimum tillage and efficient use of inputs. • Promoting best agronomy practices in paddy cultivation.

4 CONCUSSIONS AND RECOMMENDATION

Across the gradients, adaptation is critical and of concern among smallholder farmers where vulnerability is high due to low ability to adapt. The more pronounced measures include the use of different crop varieties, varying planting and harvesting dates, irrigation, increasing the use of water and soil management techniques and shortening the length of growing seasons. Diversification and changing from farming to non–farming activities are among the important strategies across the gradients. The capacity to adapt to the changing climate is the main challenge in the small farmer's household, with land shortage and exhaustion under the variable climate that increases vulnerability in crop production.

Enhancement of farmers' awareness is essential in determining and planning adaptation and mitigation options in farming activities across the gradients. This requires breeding and mingling improved technologies, viable adaptation options and mainstream adaptation in planning, policy and development activities at different levels. However, only a few farmers accessed such information with low reliability that limits the use and adoption of new technologies. Thus, developing effective mechanisms for information generation and sharing is among the important adaptation options across the gradients. Moreover, the tactical responses to climate variability and changes are important in reducing the potential damage among smallholder farmers and guard against losses due to climate variability and changes.

Across and within the gradients, farmer-to-farmer becoming a common and effective source of information in crop production activities where extension services are inefficient and weak. Farmer-to-farmer interaction revealed important sources of information not only exchanging ideas but also the adoption of technologies especially, for best practices/ technology and farmers deemed it acceptable. Multiple scale actions that involvement of all actors are needed to promote agricultural production opportunities and adaptation measures with more effort in turning knowledge into practice. These need to extend and improve agricultural production

extension services, ensuring the provision of support to the poorest farmers, given that this group is the most vulnerable to climate variability and least equipped to make the changes needed to sustain their livelihoods in the face of climate-related threats.

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