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The Significance of the Diversification of Food Crops in Abating Impacts of Climate Variability: The Case of Rungwe District, Tanzania

Atupakisye S. Kalinga,[*] Richard Y.M. Kangalawe[**] & James G. Lyimo[§]

Abstract

It is widely recognised that insufficient and unreliable rainfall threatens the status of food security among farmers in developing countries due to their dependence on rain-fed agriculture. Consequently, the need to understand the importance of the diversification of food crops in abating the impacts of climate variability becomes imperative. This paper studies the diversification of food crops as one of the major adaptation strategies of the impacts of climate variability and its implication on food security. Data were collected through documentary review, household interviews, focus group discussions, key informant interviews, and field observation. Qualitative data were analysed using content analysis, while quantitative data were analysed by SPSS version 20 and Excel spreadsheet to summarize the results. The results show that the production of a variety of crops and the use of improved crop varieties were important aspects in the diversification of food crops that better cope with the impacts of climatic variability. The diversification of food crops has emerged to be one of the practices of climate smart agriculture (CSA), which helps farmers to adapt to the impacts of climate variability as it helps in reducing the risk of total crop failure. The study recommends that the government provide farmers with knowledge and skills about proper practices of CSA, and ensure improvement in extension services, which are important for accessing updated information related to impacts of climate variability, new technologies and associated adaptation strategies.

Keywords: *climate variability, adaptation, food crop diversification, food security*

1. Introduction

Climate change and variability have affected many economic sectors, including agriculture. Agricultural production is a risky activity, particularly where farmers rely heavily on rain that is becoming increasingly uncertain due to climate change (Martey et al., 2021). Temperature is projected to rise more than the global average which, when accompanied by unfavourable changes in precipitation, leads to stressed agricultural systems due to increased droughts, shorter growing seasons, increased incidence of pests and diseases, increased

[*]Mwalimu Nyerere Memorial Academy, Dar es Salaam, Tanzania: atusamka@yahoo.com (Corresponding author)
[**]Mwalimu Nyerere Memorial Academy, Dar es Salaam, Tanzania
[§]Institute of Resource Assessment, University of Dar es Salaam, Tanzania

floods, and decreased agricultural productivity (Ahenkan et al., 2020; Mensah et al., 2020). Climate change has created a threat to food security through its influence on rainfall, soil moisture and food production; and the situation is expected to worsen in the forthcoming years (Ochieng et al., 2016; Mavhura et al., 2021). Farmers' decisions on what crops to produce or incorporate into production is conditioned by changes in environmental and weather conditions (FAO, 2019). In Kenya, and other developing countries, farming activities and food security are directly influenced by climate change and variability because most of the population live in rural areas and rely on agriculture for their livelihoods. This becomes worse because many rural communities depend on rain-fed agriculture, and are highly vulnerable to climatic and environmental hazards such as droughts, floods and other weather events (Ochieng et al., 2016).

The modern portfolio theory (MPT), developed by Harry Markowitz, has a key element of diversification. The theory assumes that investors are risk-averse, and emphasises that most people should have multiple investments to maximise overall returns within an acceptable level of risks (Elton et al., 2014). The theory can be used to construct a portfolio of activities that maximise overall returns without bigger risks. This study applies this theory in the diversification of food crops that can minimise the risks and uncertainties related to the impacts of climate variability by spreading the effects of climate risk across different crops. Therefore, the diversification of food crops is an appropriate strategy for managing the risk of climate variability, which is the greatest challenge for many rural farmers (Wan et al., 2016).

Previous studies have discussed practices of crop diversification in dealing with climate change impacts. Impacts of climate change have stimulated the need for crop diversification where farmers grow different types of crops, instead of just one type, to improve food supply in changing climatic conditions (Mubanga et al., 2015). This is due to the recognition that climate change can have negative consequences for food production that results into food insecurity (Lakhran et al., 2017). In Morogoro region, Tanzania, some households have concentrated on the production of fast-growing crops rather than slow-growing ones to reduce risks related to climate change (Ponte & Brockington, 2021). Crop diversification was found to be important in ensuring food availability and nutrition, as it improves food productivity and income stability. This has been considered so because if one crop fails, farmers can depend on the other crop (MugendiNjeru, 2013). Therefore, crop diversification has been found to be among the most common adaptation measures in reducing risks and threats of the impacts of climate change and variability (Kissinger et al., 2013). Crop diversification enables smallholder farmers to survive the negative impacts of climate changes (World Bank, 2014; Manda et al., 2016), and consequently improves food productivity and livelihoods in general (Rosenstock et al., 2016).

Lakhran et al. (2017) contends that crop diversification is one of the practices of climate smart agriculture (CSA) that helps smallholder farmers adapt to climate change in reducing the risk of total crop failure and secure food supply opportunities, while at the same time providing with alternative means of income generation. CSA is an integrated approach and a preferred method by rural farmers dealing with detrimental consequences of environmental change, while improving agricultural productivity and environmental outcomes (World Bank, 2014). While various studies have indicated that climate change has been the main driver for crop diversification, other studies have reported that the market has also driven farmers into practices of crop diversification.

According to Kurdy´s-Kujawska (2021), a portfolio of crops enables farmers to adapt to changing climatic conditions because diversified crops minimise the risk of losses in production, while stabilising incomes. In West and Central Africa, for example, farmers preferred climate-smart cowpea so as to reduce the negative impacts of climate change (Alene et al., 2015). They adopted improved varieties and were willing to pay for early-maturing rather than for late-maturing seeds to reduce the risk of crop failure due to climate change (ibid.). Similarly, in Uganda and Rwanda, the adoption of improved bean varieties was to mitigate the adverse effects of climate change because they were shorter-season and drought-tolerant varieties observed to be central in guaranteeing food security throughout the year (Larochelle et al., 2015).

Crop diversification is considered to be an important strategy because it increases farmer's resilience, while improving their income stability. A study in Namibia indicated that exposure to the stresses of climatic change has influenced farmers' decisions to diversify their crops (Mulwa & Visser, 2020). With a diversity of crops, farmers are less exposed to damages in production and become less vulnerable to the negative impacts of climate change (Myeni & Moeletsi, 2020; Aribi & Sghaier, 2020). In India, risk-averse farmers were more likely to diversify their crops because they found crop diversification was safer as it increases the resilience of the entire agricultural production when there is unfavourable climatic conditions (Auffhammer & Carleton, 2018). Mango et al. (2018) have a similar view: that diversifying crops reduces the risks associated with low income from agricultural production, food insecurity and nutrition insecurity. Thus, the production of a portfolio of crops ensures that agricultural production is not completely destroyed during events of weather hazards.

While various scholars have argued that it is the influence of climate change that has led to crop diversification, others view crop diversification as resulting from market opportunities rather than climate change. A study in Morogoro, for example, pointed out that famers prefer the use of improved crop varieties because they mature faster than the traditional varieties (Ponte & Brockington, 2021). Improved crop varieties refer to high-yielding varieties (HYVs), which involve genetically modified organisms (GMOs). They are associated with products of genetic improvement, and result from conventional crop improvement within their species of origin (Walker, 2015). Farmers adopt improved crop varieties not only for consumption but also for sale in their localities, larger domestic markets in urban centres, as well as in regional and international markets (Labarta, 2015). For instance, a study by Walker (2015) indicates that in Sub-Saharan Africa (SSA), the adoption of improved bean varieties was influenced by market demand depending on diverse preferences among farmers, traders, processors and consumers for the various traits in bean varieties, e.g., colour, grain size and growth habit. Thus, market demands have also forced farmers to crop diversification to meet growing market demands and maximise benefits from agricultural production.

A study in Ethiopia showed that an increasing demand for various crops, especially in urban markets, promoted crop diversification in rural areas for income diversification (Mussemal et al., 2015). The authors further contend that crop diversification depends more on market information, accessibility to market and market infrastructures. According to them, smallholder farmers rarely depend on only one crop: they produce a combination of crops to meet market demands caused by growing populations in urban centres. This helps them reduce marketing risks; and ensures income stability and food security (ibid.).

Crop diversification is considered as a livelihood strategy for sustaining farmers' lives while adapting to the impacts of climate change and variability (Brown et al., 2019). Due to the important role that crop diversification plays in sustaining farmers' livelihoods, it is important that sustainable land management practices (LMPs) are adopted to mitigate the adverse impacts of climate change and avoid declining agricultural productivity (Boris et al., 2018). It is acknowledged that sustainable land management practices—such as crop rotation, intercropping, cover crops, relay cropping and fallowing—help to enhance the efficiency of carbon sequestration in agriculture, while improving food productivity. Also, crop rotation—particularly rotations with legumes and non-legumes—improves biomass production and soil carbon sequestration (Chhabra et al., 2018).

As mentioned earlier, various studies have established that market forces and impacts of climate change are among factors that have influenced farmer's decision to practice crop diversification. While market forces have encouraged farmers to diversify crops to meet increasing market demands for various crops (Kurdy´s-Kujawska, 2021; Larochelle et al., 2015; Alene et al., 2015), the impacts of climate change and variability have also compelled farmers to diversify their crops to reduce the risk related to changing environmental conditions (Mussemal et al., 2015; Walker, 2015; Labarta, 2015). This study focuses on the linkages between the diversification of food crops and impacts of climate variability. Despite a wide literature on crop diversification and impacts of climate change and variability (Myeni & Moeletsi, 2020; Aribi & Sghaier, 2020; Mulwa & Visser, 2020; Auffhammer & Carleton, 2018; Lakhran et al., 2017), most studies have left unanswered specific questions on the ways of diversifying the production of food crops in responding to the impacts of climate variability, and their implication on food security: the focus of this study. Also, adaptation to the impacts of climate change and variability differ from one location to another, depending on the knowledge and perceptions of the respective communities (Mavula et al., 2021). Consequently, the increasing risk of food security arising from negative impacts of climate change and variability requires more understanding on adaptation strategies to improve food production (Jiri & Mafongoya, 2018; Rojas-Downing et al., 2017). It is this need that led to this study, which examines the diversification of food crops as an adaptation strategy towards the adverse impacts of climate change and variability, using Rungwe district in Mbeya region, Tanzania, as the study case.

Consequently, this paper responds to the following questions: (i) In what ways is the diversification of food crops carried out in Rungwe district as a result of the impacts of climate variability, and how do they influence food security; and (ii) what are the land-use management practices that were applied to reduce adverse impacts of climate variability? The paper adds to the body of knowledge on how the diversification of food crops can contribute towards reducing the adversity of the impacts of climate change and variability, and improve household food security.

The remaining part of this paper is organised as follows. Section 2 covers a description of the study area and the methodologies used in the study. Section 3 presents the results and discussion about the relationship between the diversification of food crops and impacts of climate variability, and their implication on food security. It also discusses the implication of the diversification of food crops and land-use management strategies on adapting and mitigating the impacts of climate change and variability. Section 4 draws the conclusion and makes recommendations.

2. Context and Methods

In this paper, data used are based on a study conducted in six villages, namely: Kikota, Ilolo, Idweli, Ntokela, Masukulu and Ijigha in Rungwe district, Mbeya region, Tanzania (Figure 1). The Rungwe district was selected because it is one of the districts where households depend on rain-fed agricultural practices that are influenced by impacts of climate variability.

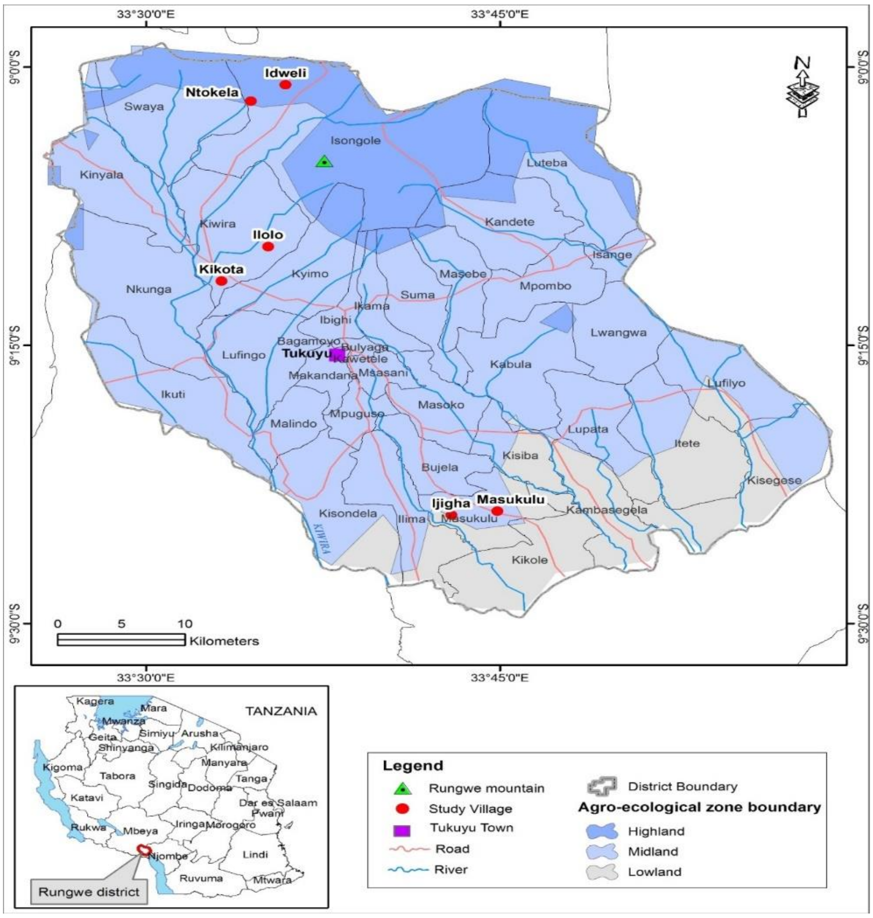

Figure 1: Map of Rungwe District Showing Administrative Boundaries and the Study villages

Source: GIS Unit, Institute of Resource Assessment, University of Dar es Salaam, 2016

The study employed a stratified random sampling design. Stratification was carried out whereby the ecological gradients of the district were placed into strata, and purposive sampling was used to obtain six sample villages where a diversification of food crops had emerged as an adaptation strategy to the impacts of climate variability. With the help of district officials, purposive sampling was used to obtain the six villages, i.e., two villages from each ecological gradient. Ntokela and Idweli villages were selected from the highland zone, Kikota and Ilolo from the midland zone, while Masukulu and Ijigha villages were selected from the lowland zone. Boyd et al. (1981) recommended a sampling intensity of 5% of the total number of households in a study site, and that a sample size should entail a reasonable proportion of units in the sampling frame, but not less than 30 units.

Therefore, this study adopted a sampling intensity of 5% of household size, but where 5% was below 30 respondents, more were added to make a minimum of 30 units. A total of 253 respondents participated in the study.

Moreover, the study employed a cross-sectional design that enables to collect data from different individuals within a given period of time. The study utilised both quantitative and qualitative approaches as this improve the validity of data (Almalki, 2016). Information was collected from multiple sources to reduce the chances of bias, while improving the research validity (Denzin & Lincoln, 2018). The methods of data collection comprised of documentary review, household interviews, focus group discussions (FGDs), key informant interviews (KIIs) and field observation. Documentary review involved reviewing government reports, journals and websites. Household interviews were conducted through a structured questionnaire, where specific information could be obtained -- for example, on food crops produced, impacts of climate variability, adaptation strategies, and the land-use management practices applied. In-depth interviews were conducted with ward and village executive officers, village chairpersons, agricultural extension officers, representatives of elders and of community-based organisations (CBOs). One FGD was conducted in every study village, which involved local rulers, and leaders of various associations like traders, drivers and tea growers. FDGs and KIIs were important in gaining additional information on the role of the diversification of food crops, the reasons for adopting improved crops against traditional ones, changes that occurred as a result of climate change and variability, and the constraints faced in adaptability. Field observation was useful in gaining additional information and confirming information provided by the other techniques.

With respect to data analysis, quantitative data were analysed using the SPSS, version 20; and Excel spreadsheet. Cross-tabulation was conducted between variables to acquire a basic summary of different variables such as frequencies and percentages. On the other hand, content analysis was used to analyse qualitative data; while trend analysis was used to determine climate variability from 2006 to 2017. The findings are presented in various ways, including tables, graphs and maps.

3. Results and Discussion

3.1 Diversification of Food Crops and Climate Variability

The impacts of climate variability has created threats on agricultural production that has forced rural farmers to adapt to changes to minimise and resist their impacts. Due to prolonged drought periods and unreliable rainfall, farmers responded through producing a variety of crops rather than relying on only one crop, along with growing improved crops as an adaptation mechanism towards the impacts of climate change and variability.

It was observed through FGDs that, with increasing climate variability, the traditional crop varieties fail to supply sufficient food for households because they take a long duration to mature; while improved crop varieties mature only in a short period of time. For example, traditional maize varieties mature in six months, while improved maize varieties only take three months to mature. Thus, insufficient amounts of rainfall compelled farmers to diversify from traditional into improved crop varieties. The improved varieties were preferred more because they could cope with short rain seasons than the traditional varieties. For instance, the majority of respondents (92.1%) indicated to have shifted from the old varieties into improved varieties of maize, followed by beans (51.8%), round potatoes (43.8%) and banana (40.7%) (Table 1). Improved maize varieties included *Uyole 96, Uyole 84, njano* and *Uyole 98.*

Table 1: Percentages of respondents practising improved crop varieties

Crops	Kikota n=48	Ilolo n=40	Idweli n=30	Ntokela n=75	Masukulu n=30	Ijigha n=30	Total n=253
Maize	95.8	90	93.3	97.3	76.7	73.3	92.1
Beans	58.3	52.5	66.7	73.3	16.7	6.7	51.8
Banana	95.8	72.5	0	0	53.3	40	40.7
Round Potato	22.9	10	86.7	93.3	0	0	43.8
Paddy	0	0	0	0	13.3	6.7	18.6
Avocado	25	32.5	3.3	4	6.7	13.3	13.8

Note: The total does not add up to 100 due to multiple answers from the same respondents
Source: Field Survey, 2016

As indicated in Table 1, the diversification into improved varieties of round potatoes has mainly been practiced in Ntokela (93.3%) and Idweli (86.7%), where farmers use improved varieties of round potatoes such as *arika, tigo, obama, CAP and kiding'a.* In Kikota and Ilolo villages farmers have used improved banana varieties such as *Phia, yangambi, Grandenaine, Williums* and *Chinese Cavendish*. Discussions with KIIs revealed that improved banana varieties were adopted to reduce the risk of the impacts of climate variability because they have a high ability to survive with short rains than the traditional ones. Some traditional banana varieties such as *kisukari* and *mwamnyila* were easily affected by pests like banana weevils and nematodes, as well as diseases like wilting and fungal diseases that were facilitated by climate variability. Therefore, farmers adopted improved varieties that are less susceptible to disease and attack by pests to improve food security.

Discussions with KIIs and FGDs indicated that agricultural extension officers and the Uyole Agricultural Institute have played a great role in providing information on new agricultural technologies, which has enabled farmers to have access to improved seeds in the district. In Kikota village, one of the FGDs participants ascertained:

"Improved maize seeds have been very useful because even with short rains they are able to grow and give high yield. Despite the impacts of climate variability [that result] in fluctuating growing seasons, the harvesting season has not changed (February/March) because the improved maize seeds mature within three months, and hence compensates for the delayed period of rainfall."

With the impacts of climate variability, improved maize varieties were considered important because they take only three months to mature, while the traditional maize varieties take a long duration of six months to mature, and are associated with high risks of crop failure due to pests and diseases, which can ultimately lead to food insecurity. Improved varieties are also associated with the use of farm inputs like chemical fertilisers, insecticides and herbicides, which also improves food productivity.

The results show that the majority of households produced multiple crops than a single crop to avoid/reduce the adverse impacts of climate change on food production. For instance, it was observed that all households (100%) produced maize, and 73.1% produced beans with other crops such as bananas (58.5%), vegetables (50.6%) and round potatoes (41.5%) (Table 2). Discussions with the KIIs and FGDs indicated that food crops like maize, beans, bananas, sweet potatoes, yams, cassava and round potatoes; vegetables like tomatoes, cabbages and carrots; as well as fruit trees like avocadoes and mangoes: all are used for both sale and consumption (Tables 2).

Table 2: Percentages of Respondents who Produced Food Crops

Crops	Kikota (n=48)	Ilolo (n=40)	Idweli (n=30)	Ntokela (n=75)	Masukulu (n=30)	Ijigha (n=30)	Total (n=253)
Maize	100	100	100	100	100	100	100
Beans	64.6	60.0	53.3	72.0	100	100	73.1
Banana	100	100	00.0	00.0	100	100	58.5
Vegetables	50.0	57.5	43.3	44.0	53.3	63.3	50.6
Round potatoes	00.0	00.0	100	100	00.0	00.0	41.5
Ground nuts	37.5	25.0	00.0	00.0	60	63.3	25.7
Sweet potatoes	16.7	24.0	06.7	09.3	56.7	60.0	24.5
Yams	27.0	30.0	00.0	00.0	50.0	43.3	20.9
Paddy	00.0	00.0	00.0	00.0	90.0	83.3	20.6
Cassava	22.9	25.0	00.0	00.0	30.0	43.3	17.0

Note: The total does not add up to 100 due to multiple answers from the same respondents
Source: Field Survey, 2016

As can be observed in Table 2, maize and beans were observed to have high response throughout all the study villages because they were the main food and cash crops for the majority of the households in the study area. As said earlier, the cultivation of a variety of crops helps to lessen the negative impacts of climate variability. This is because production loss is reduced with diversified food crops as the impacts of climate variability vary from one crop to another; and may have strong impact on specific crops than others. During FGDs, one of the participants claimed:

> *"Diversifying food crops is like putting eggs into different baskets rather than putting all of them in one basket so that when eggs in one basket are damaged you have others in another basket; therefore, you remain stable with the remaining basket."*

This indicates that producing a diversity of food crops is essential in maintaining food security for households because when one crop fail due to climate variability, one has food from other crops.

These results conforms to the modern portfolio theory which argues that a diversity of investments maximises the overall returns without a bigger risk. In this study, farmers have diversified their crops while implementing the practices of modern portfolio theory that considers potential risks and their implication on food production. They have reduced the risk of crop failure through producing a number of crops and adopting improved crop varieties that improve and sustain food security. Therefore, the diversification of food crops is a form of insurance where small farmers diversify their crops to minimise losses resulting from production risks under changing weather conditions (Dasmani et al., 2020; Belay et al., 2017).

Through discussions in FGDs and KIIs, the study found that households responded towards climate variability by changing the growing seasons of maize. For instance, before 2011 the growing seasons for beans and maize in Kikota and Ilolo was May and July/August, respectively; but from 2011 onwards the growing seasons for maize changed to October/November because the amount of rainfall for July/August became insufficient for maize growing when compared to that of October/November; while for May the amount of rain remained unchanged and was still sufficient to allow the growing of beans. Therefore, from 2011 to 2017 farmers shifted the maize-growing season from July/August to October/November, which had sufficient amount of rainfall for the crop (Figure 2).

As indicated in Figure 2, there was a peak of rainfall in April and May that promotes the growing of beans, but discourage maize-growing in the July/ August period. This encouraged the adoption of improved maize varieties that could be grown in October/November, and be harvested in February/ March. Traditional maize varieties takes six months to mature, therefore fail to comply with the short rain season, hence fail to ensure food supply in the conditions of climate change and variability.

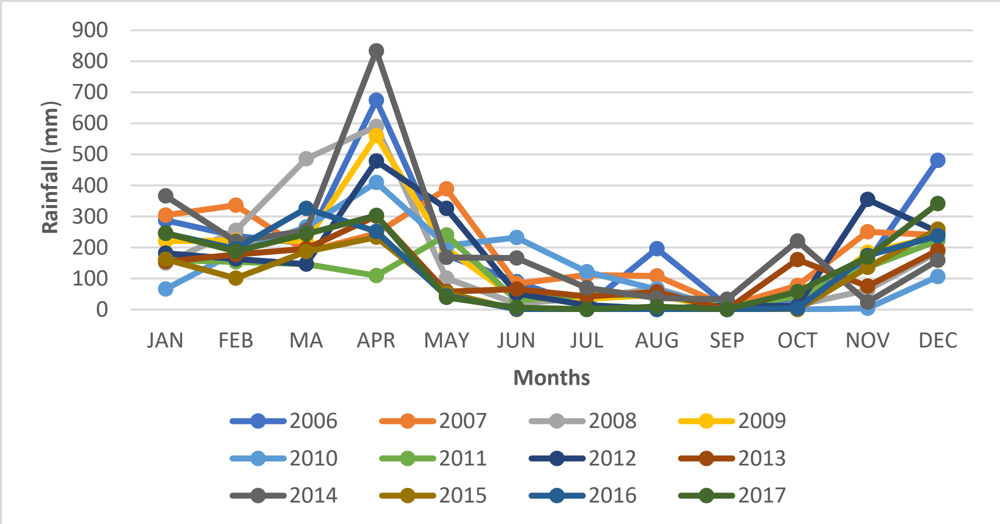

Figure 2: Climate Data on Annual Rainfall (mm) from 2006 to 2017
Source: Tanzania Meteorological Agency, 2016

Despite the change in the growing season for maize, the harvesting period has not changed: it has remained to be February/March. This is due to the adoption of improved maize varieties that mature for three months only. This implies that farmers have adapted to climate variability through changing their growing season depending on the changing patterns of rainfall, and adopted improved crop varieties that conform with the changing patterns of rainfall; thus becoming resilient to the shocks and stresses of climate variability.

Various studies indicate that crop diversification is useful in lessening the impacts of climate change and variability. For instance, a study in Tunisia highlighted that, with the diversity of food crops, farmers are less exposed to the impacts of climate change; and have become resistant to changing environmental conditions (Aribi & Sghaier, 2020). Similarly, a study in Sub-Saharan Africa by Walker (2015) reported that the diversification into improved crop varieties has reduced the risks of unfavourable weather conditions. These findings also concur with Mango et al. (2018), whose study in Central Malawi found that diversifying crops reduces the risks associated with low agricultural production, food insecurity and nutrition insecurity. This is because when there are adverse climatic conditions, crops diversification increases the resilience of the entire agricultural production (Auffhammer & Carleton, 2018). These observations equally agree with findings in Ethiopia, which reported that farming households have produced a portfolio of crops to reduce the risk of production damage by changes in climatic conditions (Mussemal et al., 2015). Furthermore, Chhabra et al. (2018) emphasizes that a combination of crops through crop integration has provided an immediate solution to threats on food security, and ensured adequate replenishment to declining environmental securities. Also, farmers prefer the use of improved varieties than indigenous seeds because the former guarantee food availability due to their ability to mature within a short period of time (Alene et al., 2015). This indicates that changes in climatic conditions has been associated with opportunities of new technologies to be accommodated in farming activities, while ensuring food supply for households.

3.2 Diversification of Food Crops and Food Security

As seen above, the impacts of climate variability have compelled farmers to diversify their crops and use improved crop varieties to reduce the risk of crop failure. Through FGDs and KIIs it was observed that improved crop varieties and the combination of crops have led to improved food availability and food access in the study area. This is because producing a number of crops reduces the risk of crop failure, while improved crop varieties are relatively more resistant to drought condition, a situation that has enabled farmers to overcome various risks related to adverse impacts of climate variability. When asked about the number of meals consumed per day, about 71% of respondents indicated that they consumed three meals per day; while 18.8% consumed two meals, with others (10.2%) consuming more than three meals per day. This has been possible due to high involvement in the production of various food crops and improved crops that have enabled constant food supply in the area. The food crops produced are used to feed household members; and are also for sale to obtain income to meet other requirements such as clothes, education, medical treatment; and the purchase of foodstuffs not produced by households, agricultural inputs, as well as other household facilities.

Through FGDs and KIIs it was emphasised that the diversity of food crops reduces the risk of food insecurity because when one crop fails due to climate variability, other crops may survive because the impact of climate change is different to different crops. If, and when the harvest of some food crops like maize, round potatoes and yams are affected by climate variability, other crops like cassava, sweet potatoes, beans and vegetables can be available for households; and can also be sold to obtain income to purchase the missing food types. Despite that maize flour was the staple food in the study villages, cassava and banana have provided an alternative flour; and have helped reduce the risk of food shortages. This indicates that the diversification of food crops is a critical option for farmers because it reduces their vulnerability to food insecurity, and enhances their resilience to stresses and shocks caused by climate variability.

The adoption of improved crops was a solution to unfavourable impacts of climate variability such as increased droughts and shorter rain seasons. For instance, improved varieties of crops like maize and round potatoes use only three months to mature, hence can be grown and harvested two or three times a year per field, which results into increased number of months with food at the household level; and therefore reduces the possibility of food insecurity. Also, improved crop varieties can thrive within the available shorter growing season because they are fast-maturing species. This implies that improved crop varieties enhance and sustain households' food security due to their high ability of maturing faster than indigenous ones.

Discussion through FGDs and KIIs revealed that some households were involved in the production of improved varieties of avocadoes, which were brought by a settler from Zimbabwe who hired the Rungwe Mission area for the production of the crop. The variety is known as *hass* (Photo 1).

Photo 1: Improved Variety of Avocadoes as Observed in Ilolo Village

Like other improved crop varieties, the new variety of avocadoes takes a short time to produce fruits -- normally three years -- while the traditional ones take about ten years. Also, the crop is in great demand not only in local markets, but also in external markets because they take two to four weeks to ripen, which allows its transportation over great distances.

The findings on the role of the diversification of food crops on enhancing farmers' resilience has also been reported by various scholars. For instance, Myeni and Moeletsi (2020) reported that, in South Africa, crop diversification helps in reducing climate variability risks and increases farmer's resilience with stabilised incomes. Also the findings on improved varieties are in agreement with Ponte and Brockington (2021), whose study in Morogoro found that farmers diversified into the cultivation of fast-maturing crops like tomatoes, cabbages and beans to reduce the adverse impacts of climate change in the area. Similarly, Jayne, (2018) suggested that new varieties that have the ability to mature earlier than the traditional ones are essential to match with the changing climate and the growing food demand. Equally, Barrett et al. (2017) emphasised that improved crop varieties helps to improve rural economy, while transforming agricultural activities into a more productive sector. All these finding are in line with a study by Snyder et al. (2021), which indicated that rural farmers in Arusha and Manyara regions have adopted new agricultural practices of improved seeds; and have shifted from traditional into improved maize seeds as a response towards the impacts of climate change and variability. Furthermore, Manda et al. (2016) established that improved varieties were considered as climate-smart agriculture (CSA) practices that can make households resist the deleterious impacts of climate change and variability in smallholder agricultural systems. Being one of the climate smart-agricultural (CSA) practices, it implies that the diversification of food crops is a useful adaptation strategy because it reduce farmers' vulnerability to the vagaries of weather, while sustaining their resilience to the stresses and shocks of the impacts of climate variability.

3.3 Land-use management Practices and Adaptation to Climate Variability

The application of proper land-use management strategies are significant in mitigating the impacts of climate variability. Land-use management practices such as mixed cropping, agroforestry, the use of inputs like fertilisers, herbicides and insecticides, crop rotation, mulching and crop residues management are more or less important in mitigating the impacts of climate variability and improving land productivity.

Mixed cropping has emerged to be one of the dominant land-use management practices (LMPs) in improving food security, land productivity and reduces the incidence of pests and diseases caused by climate variability. The study results show that 75.9% of the respondents practised mixed cropping. With mixed cropping, after the harvest of one crop, another crop remains; and this protects the soil from erosive agents. It was revealed through KIIs and FGDs that it is only the mixed cropping of maize and beans that has been practiced in all the study villages, while a combination of other crops varied from one village to another. For instance, the intercropping of coffee and bananas was dominant in Kikota and Ilolo villages, while cocoa and bananas were dominant in Masukulu and Ijigha villages. Also in Kikota and Ilolo villages, vegetables like tomatoes, green pepper, okra and egg plants were intercropped with bananas, while in Masukulu and Ijigha villages sunflower could be intercropped with maize and groundnuts on the same piece of land.

The findings on the role of mixed cropping in mitigating climate change and variability was also reported by Chhabra et al. (2018), who suggested that mixed cropping is an effective technique to optimise plant production, balance the input and output of soil nutrients, suppress weeds and insects, control plant disease and resist extreme climatic events. Also, the use of mixed cropping and crop rotations improves the soil organic carbon (SOC) content, and enhances aggregation. Similarly, a study in Oyo State, Nigeria, by Alawode et al. (2020) reported that about 72.5% of farmers practised mixed cropping to protect themselves against potential risk of the impacts of climate change.

Some respondents acknowledged that they have practised tree planting (15%) and agroforestry (48%). Agroforestry occurs when trees are deliberately integrated with crops on the same plot, e.g., cocoa and banana in Masukulu, and avocadoes and beans in Kikota and Ilolo. This was observed through FGDs and confirmed by field observations. Agroforestry helps to protect the soil and crops from erosion and extreme storm events because high rainfall intensity can cause landslides and flooding. Also, trees are essential in maintaining moisture in an area, as well as reducing emission in the atmosphere.

Other scholars have reported on the role of agroforestry on livelihoods and on the environment. A study by Kangalawe et al. (2014) emphasised that in Kilimanjaro tree planting was an important source of cash income for households and for controlling soil erosion, as well as retaining water in the area. Similarly, Chhabra et al. (2018) observed that agroforestry is one of the best options that increases resilience to farmers because it reduces pressure on forests by increasing tree cover; and mitigates climate change effects because the amount of carbon stored in the soil system depends on agricultural management systems and practices. Similar findings were reported by Eririogu et al. (2019): that cassava-based farmers in Imo State, Nigeria, adapted agroforestry to ensure food security throughout the year. Further, a similar observation reported that agroforestry protect crops from extreme climatic events, such as strong winds, protects crops from lower precipitation as they maintain moisture in a place (Sileshi et al., 2012). Furthermore, a study by Lin (2011) indicated that agroforestry protects crops from extreme storm events, like hurricanes and tropical storms, in which high rainfall intensity and winds could cause premature seed- and fruit-drop from crop plants.

The results show that farmers applied various farm inputs like fertilisers, herbicides and insecticides so as to improve land productivity and food production. About 64% of the respondents used herbicide such as Roundup and Gramoxone for controlling weeds, which resulted into reduced tillage. This is useful in mitigating the impacts of climate variability because it promotes minimum tillage that also reduces exposure of carbon into the atmosphere, while enhancing carbon storage within the soil. It was observed through KIIs that in addition to killing weeds, herbicides add fertility to the soil because they facilitate the decaying and decomposing of organic matter.

The findings on the practices of minimum tillage was also reported by other scholars. For instance, a study by Fasinmirin and ReichertIn (2011) indicated that farmers used minimum tillage to ensure long-term sustainability of agricultural systems. Similarly, Chhabra et al. (2018) emphasised that conservation tillage, when associated with crop residue mulch and cover crops, lead to improved soil organic carbon (SOC) pool. The benefits of conservation tillage are due to increase in SOC content and decrease in CO_2 emissions caused by ploughing. Also, Heyi and Mberengwa (2012) pointed out that weed management by herbicides enhance soil organic matter through reduced or zero tillage. Moreover, Eririogu et al. (2019) show that, in Nigeria, cassava was grown successfully under no-till to give it optimum growth, while conserving the soil's physical properties.

Also, it was revealed through FGDs and KIIs that farmers applied mulching and crop residue management to improve soil fertility. In periods of climate variability, these practices help to limit nutrient leaching from high intensity of rainfall. Also mulching and crop residues are important in preserving moisture in the field and limit loss of water through evaporation, thereby reducing the risks of crop failure due to unfavourable weather conditions.

Similar observation about mulching and crop residues was reported by Chhabra et al. (2018), who insisted that the severity of extreme weather events can be reduced by applying mulching and maintaining crop residue on the soil surface. Mulching and crop residue cover are important in reducing CO_2 emissions. Similarly, a study in Zimbabwe by Makate et al. (2016) suggests that sustainable land management practices -- such as mulching, crop residue management, intercropping and conservation tillage -- improves land productivity and helps to mitigate the deleterious consequences of climate change and variability among smallholder farmers (Makate et al., 2016). Sustainable cropping systems are essential in addressing the challenges of climate change, while improving land productivity (Rosenstock et al., 2016); and reduces greenhouse gas (GHG) emissions by enhancing the carbon sink (Lipper et al., 2014). Diversified cropping systems tend to be stable and resilient because they are associated with reduced weed and insect pressures, and increased soil fertility with increased yield per unit area (Lin 2011). Along with the diversification of food crops, the application of land-use management strategies have been useful in improving both land productivity and food security for households while adapting to the impacts of climate change and variability.

4. Conclusion and Recommendations

4.1 Conclusion

This paper examined the relationship between the diversification of food crops and the impacts of climate change and variability. The aim was to explore the diversification of food crops as an adaptation strategy towards the impacts of climate change and variability, and its implications on food security. Considering the discussion in this paper, it shows that the production of a variety of crops and the use of improved crop varieties were important aspects of the diversification of food crops that better cope with the impacts of climatic variability in Rungwe District. The diversification of food crops emerged as one of the practices of climate smart agriculture (CSA), which helps farmers to adapt to the impacts of climate variability through reducing the risks of total crop failure, and securing food supply opportunities to improve food security. For example, despite the change in the maize growing season, the harvesting period has not changed due to the adoption of improved maize varieties that mature earlier, and cope with the changing patterns of rainfall.

Also, the study revealed that various land-use management practices -- such as mixed cropping, agroforestry, the use of inputs like fertilisers, herbicides and insecticides, crop rotation, mulching and crop residues management -- were practiced in the study villages. These practices were found to be important not only in improving food security, but also in mitigating the adverse impacts of climate variability. This implies that the application of proper land-use management practices is useful in achieving multiple goals of improving the status of land productivity, enhancing food security, and mitigating the problem of climate variability in general.

4.2 Recommendations

Based on the findings presented in this paper, the following recommendations are made:

1. The government should provide farmers with knowledge and skills about proper practices of climate-smart agriculture (CSA) that results into improved food security, while enhancing farmers' resilience in the conditions of climate variability. Improved farmers' access to farm inputs -- particularly improved seeds, fertilisers and herbicides -- is essential in promoting food productivity and resilient agricultural production.
2. The government and private sectors should be encouraged to create appropriate initiatives and programs of support services to improve farmers' knowledge on diversifying food crops, which will enhance balanced diets and improved nutritional outcomes of households.

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