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Mixed Cropping as a Response to Climate Change in Manyoni District, Tanzania

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Abstract

This article assesses the role of mixed cropping in response to climate change in Manyoni district, Tanzania. The study adopted a mixed research design where quantitative and qualitative research approaches were used. Simple random and purposive sampling were used to select respondents for the study. Household survey, in-depth interviews, focus group discussions, observation and document review methods were used to collect data. The household survey included 362 heads of households. Data on rainfall and temperature was collected from the Tanzania Meteorological Agency (TMA), while linear analysis was used to determine the trends of rainfall and temperature. The findings revealed that about 80.9% of the households engaged in farming perceived climate change through the decrease in rainfall, and 88.7% perceived it through the increase in temperature. The study found that mixed cropping is still a practical farming system in response to climate change due to various potentials associated with it, including: crop insurance, improvement of soil fertility, assurance of crop production, and minimization of pests and diseases that attack crops. The findings also revealed that not all farmers were practicing the mixed crop farming system due to various impediments, such as the impact of Western farming knowledge, and the lack of education and information about the usefulness of mixed cropping in response to climate change. The study concludes that mixed cropping as a traditional farming system is still viable, appropriate and a game-changer in dealing with climate change. Thus, it is recommended that collective strategies to promote mixed cropping as a traditional farming system be sustained to increase crop production.

Keywords: *mixed cropping, response, climate change, Manyoni District, Tanzania*

1. Introduction

It is reported that the agriculture sector contributes about 40% of the gross domestic product (GDP) of Sub-Saharan Africa (SSA), and employs 62% of the population (Niang et al., 2014; Ombogoh, et al., 2021). There is a significant contribution of agriculture on the livelihoods of smallholder farmers; however, the majority of them are heavily reliant on rain-fed agriculture, which continues to be a major challenge. The IPCC report stresses that rural agricultural communities in SSA are the most vulnerable to climate change as they derive their livelihoods mainly from nature-dependent and climate-sensitive sectors such as agriculture (IPCC, 2021).

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Climate change is one of the substantial global challenges in the twenty-first century (Bates et al., 2019). As stipulated in the IPCC Fifth Assessment Report, changes in rainfall and temperature are anticipated to cause an extensive impact on crop production (IPCC, 2020). The report forecasts that mean annual global surface temperature is expected to increase by 1–3.5^{0}C by the year 2100, and the global mean sea level is expected to rise by 15–95cm (Apata et al., 2018). The projected increase in global average surface temperature is expected to increase spatial and temporal variations in patterns of precipitation (Niang et al., 2014). These changes are expected to have far-reaching ramifications on the vulnerability and responses to climate change, especially in the Global South (Sawe, et al., 2018).

According to Falaki et al. (2019), Africa has become the most vulnerable continent to the impacts of climate change. This vulnerability of the African continent is further aggravated by the fact that climate is predictably becoming hotter (Lyimo & Kangalawe, 2015). Africa has been identified as a region that is profoundly affected by climate change. FAO and ECA (2018) testify that adverse climate conditions have led to a decline in Africa's agriculture, which is important for future youth employment; and this has threatened food security, which has negatively affected the health and livelihoods of people. The high vulnerability of Africa's agriculture to climate change is associated with, as mentioned earlier, heavy reliance on rain-fed systems. Authors like Nelson et al. (2019), as quoted in Ombogoh et al. (2021), project that climate change is anticipated to reduce crop production to between 10 and 35% by the year 2050 because of decreases in rainfall patterns, and increases in temperature and extreme events (Sawe et al., 2018). The effects of climatic changes are expected to be particularly severe in SSA where poverty rates make populations more vulnerable than in other parts of the world (Majule, 2019).

Devereux and Edward (2014) caution that East Africa is already among the most food-insecure parts of the world, and climate change continues to affect life in rural communities as the majority of the people are smallholder farmers who depend on rain-fed agriculture. In Tanzania, crop production is the leading economic activity, especially for smallholder farmers. Similarly, it has been frequently affected by climate change and variability.

Predictions in the Tanzania National Adaptation Programme of Action (NAPA) indicate that the mean daily temperature will rise by three to five degrees Centigrade throughout the country (URT, 2021). Annual rainfall is expected to decrease by 5% to 15% in areas that receive unimodal rainfall, and a decrease of 5% to 45% in areas that receive bimodal rainfall (URT, 2021). The primary food producers in Tanzania are smallholder farmers in rural areas, and these are the most vulnerable group to climate change and extreme climatic events. The impacts of climate change have mostly affected the livelihoods of poor communities because of their low adaptive capacity and high dependence on rain-fed agriculture (Majule, 2019).

Over time, smallholder farmers all over the world have been responding to the impacts of climate change differently depending on their adaptation capacity and the levels of vulnerability (Sawe, 2018). Some of the farm-level adaptation strategies used by smallholder farmers include growing of drought-tolerant crops, changing the farming calendar, and employing crop rotation and mixed cropping to replace monocropping (Mngodo, 2013). Mixed cropping has been practised by smallholder farmers as one of the old farming systems, and it is considered the most appropriate farming system in response to climate change compared to other traditional farming systems such as crop rotation and monocropping (Wambugu & Muthamia, 2016).

Mixed cropping is defined as the "… amplification of cropping in time and space leading to growing two or more crops on the same field in a year" (Andrews & Kassam, 2015; Joshi, 2017; Degla et al., 2021). Mixed cropping represents a within-field diversification strategy that is based on ecological intensification. It aims to maximize productivity per land area using only few external inputs (Zinyengere et al., 2021). As stated earlier, mixed cropping is not a new form of agricultural technology, rather it is an ancient means of intensive farming. It has been practised in many parts of the world as a way to maximize land productivity in a small area by improving the intensity of land and labour use for better profit and stabilization of farm income (Joshi, 2007). This cropping pattern of planting two or more crops on the same field is more common in semi-arid regions that have less rainfall, higher temperatures, and shorter crop growing seasons (Rezitis, 2016). In general, the use of multi-cropping systems is more prevalent in developing countries. The history of mixed cropping is old; however, the concept has received very little attention from agricultural scientists despite its usefulness in crop production in the context of climate change (Andrews & Kassam, 2015).

Recently, some interest has been generated on the mixed cropping system as one of the viable and potential climate change adaptation strategies compared to monoculture (Degla et al., 2021). Apart from climate change, the other factor limiting production of crops under monoculture is energy, especially the oil crisis. The oil crisis is of prime concern affecting the livelihoods of poor and marginal communities of Asia, Africa and Latin America (Rezitis, 2016). As oil prices continue to increase, the cost of production of agricultural commodities also increase. As a result, there has been an increase in the cost of fertilizers, pesticides, fuel, farm equipment and irrigation facilities; most of which are almost out of reach of small farmers of the third world (Popp et al., 2014). The ultimate impact of these factors could exert pressure on food and nutritional insecurity of already vulnerable groups of the population -- such as children, pregnant/lactating women and elders -- who are in dire need of food for growth, maintenance and production. Hence, there is the need to consider other farming alternatives that might allow people to substitute innovative biological or agronomic practices and varieties for these high-cost inputs and the alarming climate change.

Literature suggests that multiple cropping offers one of the most important and promising alternatives compared to other traditional farming systems such as crop rotation and monocropping. For instance, Hoshikawa (2020) reports that the mixed crop system has been adopted by marginalized smallholder farmers in Ethiopia as it maximizes water-use efficiency and minimizes soil erosion, which are serious drawbacks to monocropping. Kotschi et al. (2022) add that the monocropping system of farming has been a challenge to African smallholder farmers as it requires high levels of external inputs, and it is also labour-intensive. Therefore, basing on the evidence from literature, it is considered that the mixed cropping system is one of the best farming systems to restore farmers' hope and their desire for household food security. However, there is a shortage of information from literature on the efficacy of the mixed cropping system in responding to climate change. Therefore, this study was conducted to uncover this knowledge gap: it explores the importance of the mixed cropping system to smallholder farmers as the best farming practice in responding to climate change, and the challenges that have faced its adoption.

2. Theoretical Literature Review

This study was guided by the climate change vulnerability and adaptability assessment model, which was developed by Fussel and Klein (2006) to explain the impacts of climate change on crop production and farming systems adopted by smallholder farmers in response to the impacts of climate change. The model states that changes in climatic variables (rainfall and temperature) affect crop farming differently, depending on the direction and magnitude of the changes. The model highlights some adverse impacts of climate change, including an increase in the frequency and intensity of droughts and floods, crop failure, reduction in water resources, pasture deterioration and an increase in crop pests and diseases.

Moreover, the model states that when climate change occurs, smallholder farmers respond to these impacts by adopting different adaptation measures depending on a household's adaptive capacity. These measures are undertaken by smallholder farmers to reduce their vulnerability to climate change. Therefore, the climate change vulnerability and adaptability assessment model was used in this study to explore the usefulness of the mixed cropping system as one of the basic farming systems performed by smallholder farmers in responding to climate change in Manyoni district.

3. Context and Methods

3.1 Study Area

The study was carried out between February and March 2017, in Singida Region, located in the semi-arid zone of central Tanzania. Manyoni district was selected to represent districts that have often experienced climate change and frequent food insecurity (URT, 2021). Four villages (Lusilile, Udimaa, Makanda and Magasai), as shown in Figure 1, were selected purposively for the study. These villages were selected because most of the smallholder farmers there were engaged in mixed cropping, so the area was believed to be a suitable site for appropriate data collection. Manyoni district is one of the six districts of Singida region in central Tanzania. The district lies between 6°7°S and 34°35°E, covering an area of 28,620km², that is just about three-thirds (58%) of the entire area of Singida region (URT, 2021).

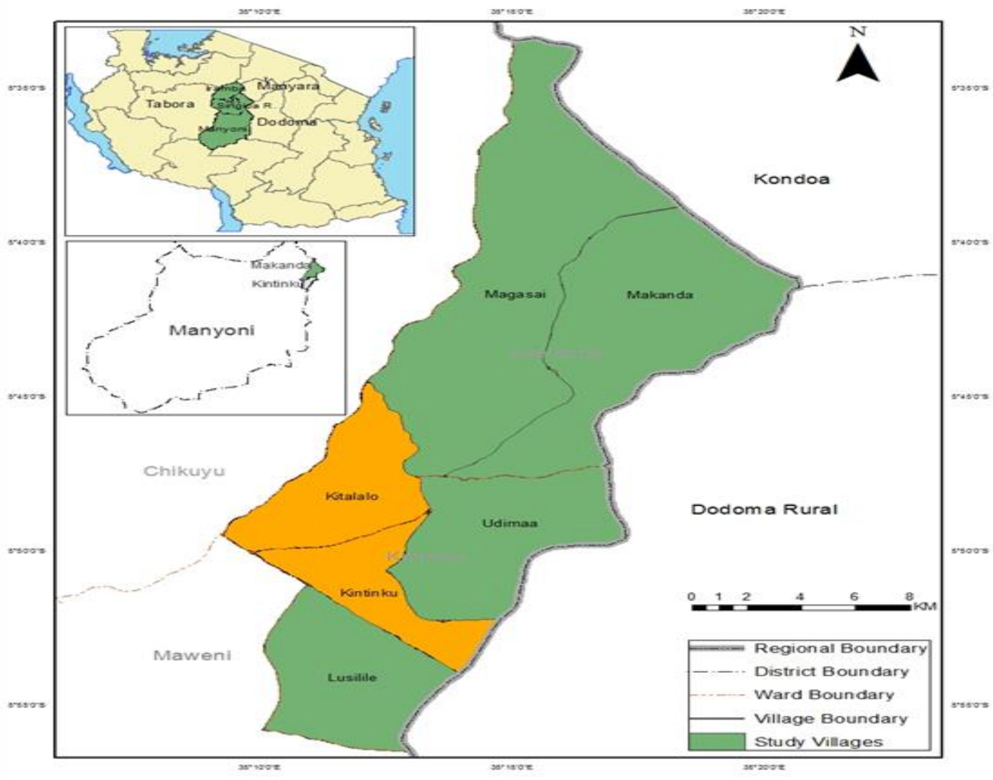

Figure 1: Location of the Study Area
Source: Cartographic Unit, Department of Geography - UDSM, 2017

The Manyoni District experiences low rainfall and short rainy seasons, which are often erratic with fairly widespread droughts in one year out of four. Total rainfall ranges from 500mm to 700mm per annum; with high geographical, seasonal and annual variations (Benedict & Majule, 2015). The district forms part of the semi-arid central zone of Tanzania, experiencing low rainfall and short rainy seasons, which are often erratic with fairly widespread drought (Manyoni District Profile, 2014). The temperatures in the district range from about 20ºC in July to 30ºC in October. Temperatures are almost constant throughout the year, with mean daily temperatures ranging from 20 to 30ºC. August, September and October are the warmest months due to relatively small differences in elevation (Lyimo & Kangalawe, 2017).

3.2 Sampling and Data Collection Methods

The article adopted a mixed research design of both quantitative and qualitative methods. A sample of 362 heads of household were selected for the study, and these were involved in a household survey. This was because, in most cases, they were the decision-makers at the household level; and were believed to be more knowledgeable about the study theme. The estimation of the sample size was done by the following formula, as proposed by Yamane (1967), at 95% confidence level, and p = 0.05 as illustrated below:

$$n = \frac{N}{1 + N(e)^2}$$

Where:

n = sample size
N= population size for households in the sampled villages
e = the level of precision measured by a probability scale of 5%.

Therefore, $n = \frac{3854}{1 + 3854(0.05^2)}$

n = 362

The study used both primary and secondary data sources. Secondary data was collected from reading different published and unpublished literature, obtained from different sources of information. The sources comprised of papers published online by scientific and reputable journals, books, and unpublished documents from local government offices. Also, visits were made to the main library of the University of Dar es Salaam and the Ministry of Agriculture. Moreover, meteorological data was obtained from the Tanzania Meteorological Agency (TMA) in Dar es Salaam. Primary data was collected through a household survey, in-depth interviews, focus group discussions (FDGs), and field observation.

A household survey was used to collect quantitative data from heads of household using a semi-structured questionnaire, which had both open-ended and close-ended questions. Heads of household in each village were requested to provide information to the researcher by filling in the questionnaires. This method was used to collect information on demographic characteristics of smallholder farmers, farmers' perceptions on climate change, and the potentials of mixed cropping as a response to climate change. In-depth interview with key informants was used to collect qualitative data. The key informants comprised 17 people who were knowledgeable about the study theme. These included the District Agricultural Officer, ward executive officers, ward agricultural officers, village executive officers and village elders from the four study villages. This method was used to collect information on perceptions of climate change, types of crops grown under mixed cropping, and the potentials of the mixed cropping system as a response to climate change. The information was recorded using a tape recorder and a notebook.

Moreover, focus group discussions (FGDs) were also used to collect qualitative data. The focus groups consisted of 9 participants per group. A checklist with guiding questions was used as a tool for the FGDs. One group was formed in each village comprising of smallholder farmers: of both men and women, youths and elders. Furthermore, physical observation was done in the field to capture and verify issues raised during FGDs and in-depth interviews, such as types of crops grown under mixed cropping and challenges resulting from the adoption of mixed cropping. Generally, in-depth interviews and FGDs were conducted to complement quantitative information from the household survey.

3.3 Data Analysis and Presentation

Qualitative data from key informants, interviews and FGDs were analysed through content analysis and presented through descriptive statements and direct quotations. Quantitative data collected from the household survey was coded, processed and analysed using the Statistical Package for Social Sciences (SPSS IBM, version 23). Analysis of variance (ANOVA) was used to determine statistical differences in the use of the mixed cropping system between the study villages. Climatic data for rainfall and temperature was analysed using Microsoft Excel to generate graphs showing patterns of temperature and rainfall as components of climate change. Moreover, simple regression analysis was done to determine the trend of rainfall and temperature. Results for quantitative data were presented by using figures and tables.

4. Results and Discussion

4.1 Socio-economic Characteristics of Respondents

The findings in Table 1 indicate that the majority of the respondents (74.4%) involved in the study were males; while 25.6% were females. This is attributed to Tanzania's tradition whereby males are the heads of household. About 43.9% of the respondents were aged between 30 and 39, 21.1% were aged between 40 and 49, those aged 50 to 59 were 16.3%, and 14.9% were aged 60 and above. Furthermore, 70.8% of the respondents were married, (10.7%) were single, (5.2%) were separated, and (6.1%) were widowed. Additionally, 24% of the respondents had not attained formal education, while the majority (65%) had attained primary education. Those who had attained secondary education were 8%, while the rest (3%) had attained a diploma and above. With regard to household size, the study revealed that households with between 1 and 3 members were 23.2%, 42.3% had between 4 and 6 members, 22.1% had between 7 and 9 members, and 12.4% had above 10 household members. Crop farming was the leading socio-economic activity (76.8%), followed by livestock keeping (19.6%); while others were small businesses (2.2%). Of the respondents interviewed, 1.4% were in formal employment.

Table 1: Socio-economic Characteristics of Participants

					Total
Gender	Male	Female			
	74.4%	25.6%			100
Age	30-39	40-49	50-59	60+	100
	43.9%	21.5%	16.3%	14.9%	
Marital status	Married	Single	Separated	Windowed	100
	78.0%	10.7%	5.2%	6.1%	
Education level	None	Primary	Secondary	Diploma and above	100
	24.0%	65.0%	8.0%	3.0%	
Household size	1-3	4 – 6	7 – 7	10+	100
	23.2%	42.3	22.1	12.4	
Socio-economic	Farming	Livestock	Employed	Small business	**100**
Activities	76.8%	19.6%	1.4%	2.2	

Source: Field data, 2017

4.2 Farmers' Perception of Climate Change

The findings show that about 98% of the respondents were aware that climate (rainfall and temperature) has been changing, except for only 2% who had a different opinion (Table 2). This implies that the majority of the respondents were aware of the concept of climate change, which provided an avenue to understand and participate in this study. These findings agree with those of Deressa et al. (2015), in Ethiopia, who found that about 88% of THE farmers were aware of the concept of climate change. Furthermore, studies conducted by Lyimo and Kangalawe (2017) in Shinyanga rural district admitted that local farmers were aware that the climate is changing, as manifested through changes in rainfall and temperature patterns.

As mentioned earlier, most smallholder famers perceived climate change through rainfall and temperature. With reference to change in rainfall, the findings indicate that about 99.2% of the respondents acknowledged that rainfall had changed, while 0.8% claimed that they had not noticed any changes in rainfall (Table 2). Those who had not noticed any changes were newcomers; therefore they were unaware of the changes that had occurred in the study area.

Table 2: Farmers' Perceptions on Changes in Rainfall

Farmers' perception	**Study Villages**								**Total (N=362)**	**Total %**
	Lusilile		***Udimaa***		***Makanda***		***Magasai***			
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*		
Decreasing	85	78	63	88.7	80	79.2	65	80.2	293	81
Fluctuating	24	22	8	11.3	20	19.8	14	17.3	66	18.2
No changes	0.0	0.0	0.0	0.0	1	1.0	2	2.5	3	0.8
Total	**109**	**100**	**71**	**100**	**101**	**100**	**81**	**100**	**362**	**100**

Source: Field data, 2017

The farmers' general concern about decreased amounts of rainfall is supported by long-term rainfall data from the Manyoni Meteorological Station, collected by the Tanzania Meteorological Agency (TMA), and covering the period between 1986 and 2016 (Figure 2). The analysis was done using a simple regression model. The results indicate a significant decrease in the trend of rainfall as shown by y = -2.9551x + 623.13mm. The decrease in the trend is explained by 3.4% of the variance observed in Manyoni district (R^2 = 0.034).

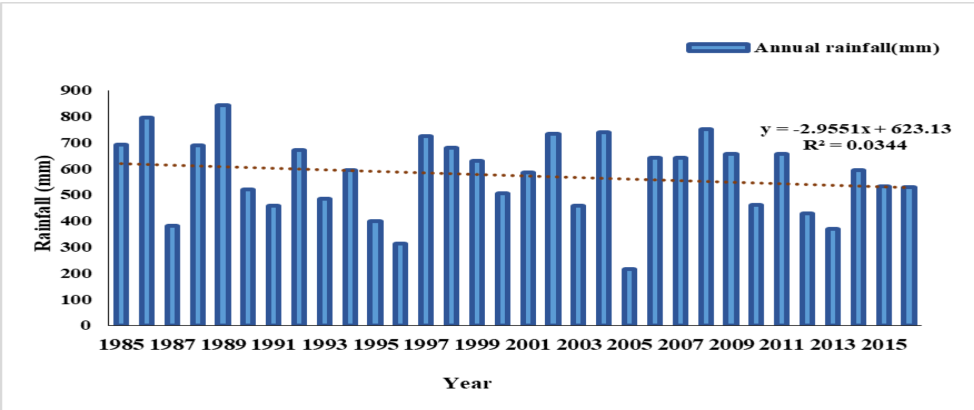

Figure 2: Average Annual Rainfall Trends in Manyoni District

Source: TMA, 2017

Temperature was also perceived to have changed. The results show that about 88.7% of the farmers asserted that temperature had increased, 10.5% asserted that temperature had been fluctuating, while 0.8% had not noticed any changes. These were probably new farmers whose experience with changes in temperature was inadequate (Figure 3). During in-depth interviews with key informants and FGDs, it was reported that there had been an increase in temperature compared to thirty years earlier, and this was associated with the recurrent droughts and frequent food shortages.

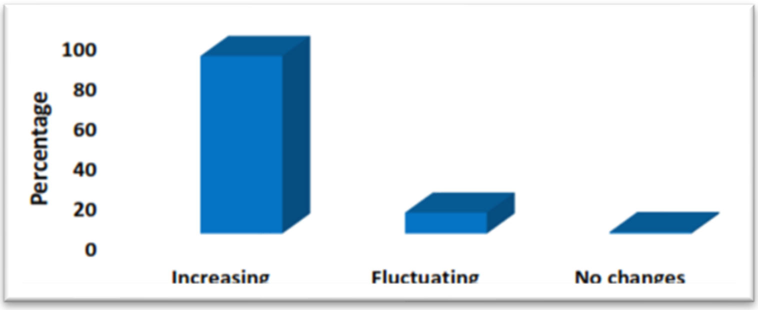

Figure 3: Farmers' Perceptions of Changes in Temperature

Source: Field data, 2017

An analysis of temperature patterns and trends was necessary to determine whether the observed trend was statistically significant. Moreover, an analysis of the meteorological data was done to check the consistency between farmers' perceptions and trends in meteorological observations in Manyoni district. The annual mean maximum temperature and annual mean minimum temperature were analysed using the Microsoft Excel software. The results are shown in Figures 4 and 5.

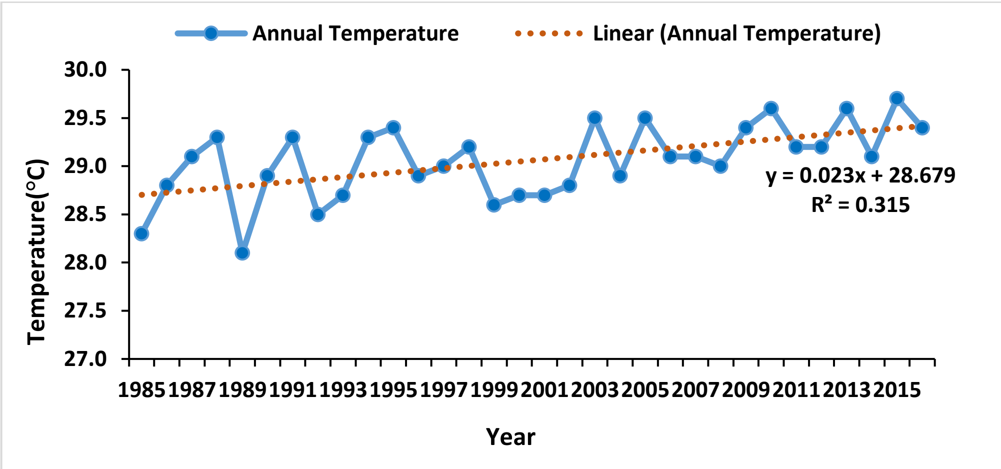

Figure 4: Annual mean Maximum Temperature, Manyoni District

Source: TMA, 2017

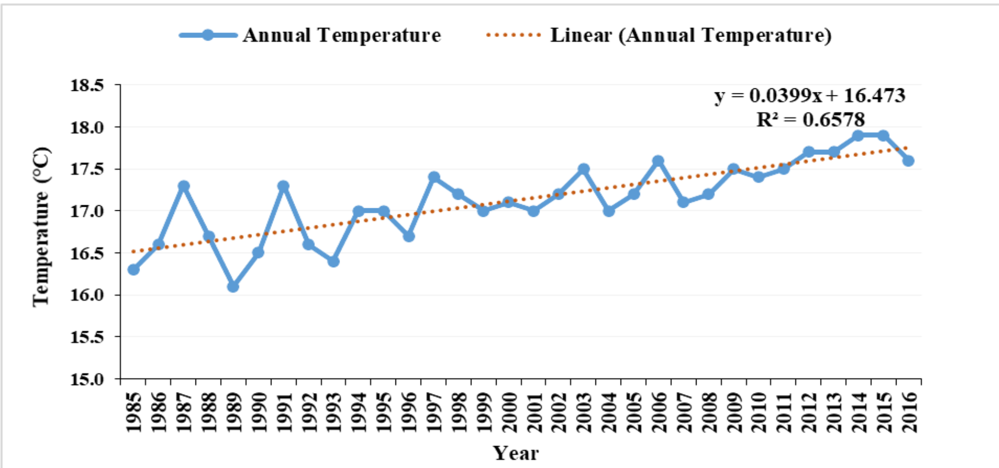

Figure 5: Mean Annual Minimum Temperature, Manyoni District

Source: TMA, 2017

The trends in Figures 4 and 5 suggest an increase in annual mean temperature. The annual mean minimum temperature showed a great increase ($y = 0.0399x + 16.473$), compared to the annual mean maximum temperature ($y = 0.023x + 28.679$). This is explained by 66% of the observed variance in the annual mean minimum temperature ($R^2 = 0.657$) than the observed 32% of the maximum temperature ($R^2 = 0.315$) in the study period from 1985 up to 2016. The data indicates that for a period of 32 years—from 1985 to 2016—the mean minimum temperature in Manyoni district had increased by 1.3°C; while the mean maximum temperature had increased by 1.1° C. The analysis of temperature data indicated that annual mean minimum temperature had increased at a higher rate than the annual mean maximum temperature. This implies that temperature in the district is increasing, thus affecting crop production. Therefore, this provided a platform to assess the level of vulnerability between farmers engaged in mixed cropping, and those practising other farming systems such as monocropping and crop rotation. The results are similar to those of Sivakumah et al. (2017) in India, who noted that both minimum and maximum temperatures had been increasing at different levels. The same results were obtained by Kangalawe and Lyimo (2015) in Tanzania, as well as Malik et al. (2012) in Pakistan.

4.3 Rate of Farmers Practicing Mixed Cropping

Data indicates that above three-quarters (76%) of the smallholder farmers were practising mixed cropping as a strategy to respond to the impacts of climate change, while about a quarter (24%) admitted that they were not practising mixed cropping (Table 3). During FGDs and interviews with key informants, it was intimated that farmers had been using mixed cropping as a way of spreading the risks caused by climate change. When asked about the types of crops they grew, the majority of the smallholder farmers acknowledged that they cultivated cereal crops and leguminous crops on the same field. Lantican (2016) defines cereal crops as agronomic crops belonging to the grass family *gramineae,* which are used as staples. The major cereal crops noted in Manyoni district are millet, maize, and sorghum. Preliminary data showed that these cereal crops are principally intercropped with leguminous crops. Legumes, on the other hand, are cover plants grown principally for pulses, livestock silage, and green manure. The major legume crops in the district include groundnuts, cowpeas, and beans.

Table 3: Farmers' Responses on the Practice of Mixed Cropping

Response	Percentage
I practice mixed cropping	76%
I don't practice mixed cropping	24%
Total	**100%**

Source: Field data, 2017

4.4 Mixed Cropping as a Response to Climate Change

As stated earlier, the aim of this study was to analyse the role of mixed cropping in response to the impacts of climate change. The findings discovered that there were potentials of a mixed cropping system in the context of climate change; as clarified in the sub-sections that follow.

4.4.1 Mixed Cropping Insures Crop Yield Amid Climate Change

Crop yield insurance in unfavourable climatic conditions was considered to be a major potential of mixed cropping in response to the impact of climate change, as reported by 34.8% of household heads (Table 4). The majority of households who acknowledged this role pointed out that planting many crops on a single piece of land increases the possibility of reducing crop loss; that is, in case one crop fails to mature due to extreme climatic conditions, another crop that is more tolerant will mature, and hence guarantee food availability to households and the community in general. The findings of this study are supported by various scholars who conducted studies in different countries, for example, Tambo and Abdoulaye (2015) in Nigeria, Hess (2014) in Bolivia, and Stringer et al. (2013) in Malawi. Their findings showed that mixed cropping increases the possibility of crop harvests in a changing climate. Similarly, Beets (2014) reported that crop insurance in anomalous climatic conditions is the great potential of the mixed cropping system, because of the different adaptive capacities it has in response to climate change. Sawe et al. (2018) attested to the fact that crop insurance is a major opportunity of intercropping in that, if environmental factors change, some of the intercrops do well, while others do poorly.

Table 4: Potentials of Mixed Cropping in Response to Climate Change

Potentials	**Study Villages**				**Total**
	Lusilile % *(n = 109)*	***Udimaa*** % *(n = 71)*	***Makanda*** % *(n = 101)*	***Magasai*** % *(n= 81)*	
Mixed cropping insures crop yield	38.6	37.4	31.0	34.6	34.8
Offers a variety of crop production	15.0	29.3	20.5	25.0	21.4
Increases soil fertility	19.9	14.0	18.2	13.7	16.9
Gives higher production per unit area	21.4	16.0	23.9	22.6	22.0
Minimized crop pests and diseases	5.6	3.3	6.4	4.1	4.9
Total	**100**	**100**	**100**	**100**	**100**

Source: Field data, 2017

4.4.2 Mixed Cropping Improves Soil Fertility

The results in Table 4 show that about 16.9% of the household heads acknowledged that practising mixed cropping increases soil fertility. This is because mixed cropping involves the cultivation of two or more crops of different characteristics at the same time in the same farm. FGDs were convinced that combining legumes and cereals improves soil fertility because of the nature and characteristics of leguminous crops in promoting soil fertility. The common crops intercropped in the study area were legumes and cereals. Legumes included beans, cowpeas, and groundnuts; while cereals included maize and millet. Furthermore, during an interview with the district agriculture and extension officers, they confirmed that intercropping controls soil erosion by preventing rain drops from hitting the bare soil. For instance, when maize and cowpeas are intercropped, cowpeas act as the best cover crop and reduces soil erosion. Also, it was reported that taller crops act as wind barriers for shorter crops.

These findings are in line with those of Synnevag et al. (2015) and Boko et al. (2016), who were of the opinion that legumes are an important source of soil fertility as they supply nutrients to the soil, which in turn supports cereal crops. This is likely because legumes have the ability to fix atmospheric nitrogen (N) when combined with cereals in the mixed cropping system. Therefore, by fixing atmospheric nitrogen, legumes offer the most effective way of improving the productivity of poor soils in a mixed cropping system. Moreover, Beets (2014) reports that intercropping is a popular farming system used by smallholder farmers in SSA because of its nutritional complementary advantage. Ruthernberg (2017) adds that mixing genotypes may stabilize yields, and thus contribute to food security.

4.4.3 Mixed Cropping Offers Production of Different Crop Varieties

Table 4 illustrates how mixed cropping supports the production of different crop varieties, as reported by 21.4% of household heads. This is because the same piece of land is used for the cultivation of more than one crop variety at the same time. Therefore, smallholder farmers are assured of getting more crop varieties, and therefore are able to reduce household food insecurity. Moreover, the majority of respondents were engaged in mixed cropping because it is less labour- and cost-intensive. Moreover, it was noted that the majority of smallholder farmers in the study area are poor, and they cannot afford to cultivate large areas; therefore, they practice mixed crop farming. These observations correspond with Peyton's (2015) findings, who reported that mixed cropping has been practised by smallholder farmers in South Africa because it offers a variety of crop production that promotes household food security in the face of looming climate change.

4.4.4 Mixed Cropping Offers High Crop Yields

It was discovered during the study that mixed cropping played a big role in ensuring the production of high crop yields, as opined by 22.0% of the respondents (Table 4). These findings correspond with findings from a study in Nigeria by Ndakidemi (2016), who testified that the major benefit of mixed cropping is the ability to produce greater yields by ensuring efficient use of resources that would otherwise not be utilized through monocropping. Gebru (2015) informed that different canopies of constituent crops that occur as a result of intercropping various plants help to maintain moistness within the soil, which is an important factor for plant growth, and promotes crop production in the context of climate change. Moreover, Vico and Berghuijs (2021) note that mixed cropping has been proposed as the best way for reducing some of the negative consequences of intensive agriculture, while maintaining or enhancing crop yields. Under mixed cropping, yields are increased, and crops are more stable in the face of variable climatic conditions, offering an avenue of climate change adaptation (Sawe et al., 2018).

4.4.5 Mixed Cropping Minimizes Damage by Crop Pests and Diseases

From the study, about 4.9% of household heads concurred with the fact that mixed cropping has a greater potential of minimizing crop pests and diseases than monocropping (Table 4). An in-depth interview with the Ward Agricultural Officer revealed that mixed cropping enriches the presence of predators and parasites, which are essential in preventing pests. Such predators normally attack plants at different levels and intensities. Focus group participants also testified that combining maize with cowpeas or groundnuts helps reduce the rate of bacterial wilt (*pseudomonas solanacearum*) attack on crops. Furthermore, it was noted that mixed cropping could influence the delay of the onset of diseases by minimizing the spread of disease-carrying spores and modifying environmental conditions to create less favourable conditions for the production and spread of pathogens. A similar observation was made by Fininsa (2014) who conducted a study in Ghana, and reported that mixed cropping had significantly reduced the frequency of crops being attacked by bacteriological diseases compared with the monocropping farming system. Similarly, Olufemi et al. (2019) established that intercropping maize with groundnuts or soybeans considerably decreases termite outbreak and subsequent loss of maize yield because it increases the nesting of predatory ants in maize fields.

4.5 Analysis of Variance on the Potentials of Mixed Cropping

A two-way analysis of variance was conducted to explore the impact of using the mixed cropping farming method in different villages, i.e., Lusilile, Udimaa, Makanda and Magasai, as adaptation to climate change. The results in Table 5 suggest that there was a significant difference at the $p < 0.05$ level in the main effects for different opportunities offered by mixed cropping farming system [F (5, 362) =3.241, $p = 0.005$], with the effect size of 0.104 (partial eta squared). This implies that mixed cropping was considered to have a significant potential as a response to climate change across the study villages.

Table 5: Analysis of Variance on the Potential of Mixed Cropping

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	564.742[a]	17	33.220	2.777	0.000	0.220
Intercept	4790.903	1	4790.903	400.553	0.000	0.706
Village	83.030	3	27.677	2.314	0.078	0.040
Potentials of mixed cropping	232.559	6	38.760	3.241	0.005	0.104
Village* potentials of mixed cropping	71.965	8	8.996	.752	0.652	0.035
Error	1997.441	167	11.961			
Total	**30637.000**	185				
Corrected Total	**2562.184**	184				

Note: [a.] R^2 = .220 (Adjusted R^2 = .141

Source: Field data, 2017

4.6 Challenges for the Adoption of Mixed Cropping

The study noted that despite the various opportunities brought about by mixed cropping in response to the impacts of climate change and variability, not all farmers used this farming system. This is due to the fact that farmers have different understanding and perceptions of the mixed cropping system, which discourage their decisions to use the system. Challenges that seemed to impede smallholder farmers from practising mixed cropping were the effects of modern agricultural practices and knowledge spread by extension services, especially on the adoption of new hybrid seeds and use of inputs that favour monocropping. These findings concur with those of Olufemi et al. (2019): that the introduction of modern farming techniques and the use of genetically modified seeds have unexpectedly affected traditional farming methods that seem to be environmentally friendly. Moreover, the lack of appropriate information and education about the potentials of mixed crop farming in response to the impacts of climate change was noted as another challenge. Vico and Berghuijs (2021) are also convinced that access to information on climate change adaptation influences smallholder farmers' decisions to respond to climate change.

5. Conclusion and Recommendations

The study has argued that climate change is really a global challenge affecting smallholder farmers in Manyoni district. Mixed cropping has been one of the practical climate change adaptation strategies due to various potentials associated with it. Therefore, this traditional farming system is still viable, appropriate and a game-changer in responding to climate change. However, it has been noted that not all farmers use this system in the study area due to various factors, including the impact of modernized agricultural practices and the spread of western farming knowledge from extension officers and the mass media. Another factor is the lack of education and awareness among farmers on the usefulness of the mixed crop system as an adaptation method to climate change.

Therefore, it is recommended that the government should promote traditional farming systems because they are still feasible and suitable in responding to climate change. Education should be provided to smallholder farmers on the usefulness of mixed cropping as a response to the impact of climate change, especially for those who neglected it. This should be accompanied with the establishment of more mixed cropping demonstration farms to give farmers hands-on experiences.

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