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Sustainability of Adaptation Strategies in Rainfed Agriculture to Climate Change and Variability in Nyang'oro Ward in Iringa District, Tanzania

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Abstract

This study assesses the sustainability of adaptation strategies in rainfed agriculture to the effects of climate change and variability (CC & V) in Nyang'oro ward in Iringa District, Tanzania. The study involved a total of 138 respondents, of which 120 were household heads; whereby 82 respondents were from Nyang'oro village, and 38 were from Chamndindi village. The study employed a cross-sectional survey research design using both quantitative and qualitative research approaches. Primary data were collected through questionnaires, in-depth interviews and focus group discussions; and secondary data were collected through documentary review. Descriptive statistics were used to analyse quantitative data with the SPSS software, version 27; while qualitative data were analysed through content analysis. The study found that strategies used to adapt to the effects of CC & V in rainfed agriculture varied in terms of sustainability, such that some were sustainable while others were not. Sustainable adaptation strategies were used by a few households. As a result, crop production remains vulnerable to the effects of CC & V. The study concludes that the vulnerability of rainfed agriculture to the effects of CC & V in the study area is caused by the household heads' selection of strategies as few individuals used sustainable adaptation strategies. The study recommends the government and other stakeholders to put more efforts on capacity building on the use of sustainable strategies in the adaptation to the effects of CC & V on rainfed agriculture by smallholder farmers to ensure optimum and sustainable crop production in a changing climate.

Keywords: *adaptation strategies, climate change and variability, rainfed agriculture, sustainability*

1. Introduction

Climate change and variability (CC & V) endanger all sectors of human life, but agriculture is characterized as the most sensitive to climatic stresses (Kumar et al., 2019). CC & V directly influences the intensity and productivity of rainfed agriculture to smallholder farmers (Tow et al., 2011). It affects rainfed agriculture through increased number of seasons without enough rainfall, poor distribution of rain during the rainy season, rainfall peak season ending earlier than normal, increasing crop pests and diseases, frequent droughts, and increasing temperatures (Phillipo et al., 2015).

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Crop production in rainfed agriculture in arid and semi-arid regions is highly exposed to the adverse effects of CC & V due to its complete reliance on the frequency, intensity and timing of rainfall (Bakhsh & Kamran, 2019). A study by Ahmed et al. (2019) revealed that variability in temperature alters the phenology of crops through high respiration rates, reduction in pollen germination, shorter grain filling period, lesser biomass production, and low yields in rainfed agriculture.

Despite significant strides in improving yields on rainfed agriculture in many developing countries, it is still vulnerable to CC & V effects (Wan et al., 2011). As projected by the World Food Programme (WFP, 2015) CC & V is expected to decrease yields from rainfed agriculture in Sub-Saharan Africa (SSA) in 2050 by 14% (rice), 22% (wheat) and 5% (maize). In this regard, assessment of the sustainability of adaptation strategies to CC & V effects in rainfed agriculture is crucial to help reduce the vulnerability of crop production to CC & V, and ensure optimum and sustainable crop production (Belay et al., 2017; Ahmed et al., 2019).

Most countries in the world depend primarily on rainfed agriculture for their grain food production (Bhattacharya, 2018). Globally, rainfed agriculture accounts for about 80% of the total physical agricultural land, and contributes about 60% to crop production (Mongi et al., 2010; Bhattacharya, 2019). About 93% of cultivated land in SSA is rainfed (FAO, 2012). In Tanzania, more than 80% of the population depends on climate-sensitive rainfed agriculture as a source of livelihood (Natai, 2016). However, rainfed agriculture is a fragile and risk-prone ecosystem in SSA due to high spatial and temporal variability in rainfall (Kotir, 2011). This is because rainfall is concentrated in a short rainy season (approximately between three to five months), with few intensive rainfall events that are unreliable in temporal distribution manifested by high rainfall variability causing recurrent floods, droughts, and dry spells (Lal & Stewart, 2016).

Drought and mean annual temperature rise are the most prevalent climate variables cited to pose high risks to SSA's rainfed crop production systems (Zougmoré et al., 2016). Natai (2016) reported that rainfall in Tanzania is not predictable in about 75% of the country; and only about 21% of the country can expect an annual rainfall of more than 750mm with a 90% probability. For example, about 565,000 Tanzanians whose livelihoods depended on rainfed agriculture in 2005 faced severe hunger resulting from drought (Fundisha, 2019). Furthermore, Mkonda and He (2017) predicted that increasing temperature and decreasing rainfall in Tanzania is estimated to reduce yields from rainfed agriculture by 3.6% for maize, 8.9% for sorghum, and 28.6% for rice by 2050. To minimize the harmful effects of CC & V on rainfed agriculture, various strategies like planting early maturing crop varieties, farming drought-resistant crops, crop diversification, agriculture diversification, and irrigation have been adopted (Masendeke & Shako, 2013). However, due to the lack of sustainability of these strategies used to adapt to the adverse effects of CC & V in rainfed agriculture, there has been an increased vulnerability of crop production in rainfed agriculture (Handmer, 2012).

According to CARE (2019), yields of most crops in Iringa district have declined in the last few decades. Some crops and production systems will be more affected in the future despite strategies used to adapt to the effects of CC & V on rainfed agriculture. Although adaptation efforts are increasing to reduce the vulnerability of CC & V in rainfed agriculture, it is expected to be insufficient in enabling communities to cope with climatic changes due to longer-term climate change and variability (Pereira, 2017). Besides, it is not empirically known whether smallholder farmers' choice of adaptation strategies in the district is influenced by the sustainability of the adaptation strategies.

Therefore, this present study intends to assess the sustainability of adaptation strategies in rainfed agriculture to CC & V effects in Iringa district to ensure sustainable crop production. It should be understood that though rainfed agriculture in Iringa district is also impacted by non-climatic factors—such as the lack of farm inputs, soil infertility, poor farming methods, poor marketing and cultural preferences—CC & V have an overriding influence because even the non-climatic factors are dependent on the climate (Haule, 2019).

2. Theoretical Framework

This paper was informed by the sustainability theory. Sustainability refers to the capacity to maintain some entity, outcome or process over time (Mensah, 2019). Central to the sustainability theory is to maintain or improve beneficial conditions, particularly with improved capacity to extend desirable conditions over the long-term (Harrington, 2016; Mensah, 2019). Indeed, sustainability explicitly emphasizes the maintenance of the desirable aspects of natural and/or social conditions and, where possible, improve such conditions (Harrington, 2016; Lankoski, 2016).

There are three pillars of sustainability: environmental sustainability, where ecological integrity is maintained, all of earth's environmental systems are kept in balance while natural resources within them are consumed by humans at a rate where they are able to replenish themselves; economic sustainability, where human communities across the globe are able to maintain their independence and have access to the resources that they require, financial and others, to meet their needs; and social sustainability, where universal human rights and basic necessities are attainable by all people, who have access to enough resources to keep their families and communities healthy and secure (Mensah, 2019). Sustainability involves maintaining the functionality of a system without compromising its capacity to do so in the future (Herrera, 2017). The pursuit of sustainability is oriented toward long-term treatment of natural resources, social systems and people in ways that are consistent with human well-being and dynamic system stability (Harrington, 2016; Brundtland et al., 2018).

The relevance of the sustainability theory in climate change adaptation strategies is that strategies should be able to improve the well-being of an affected community in the long-term (Agyei, 2016; Harrington, 2016). Socio-ecological systems in Iringa district are highly vulnerable to the effects of CC & V (Haule, 2021). Therefore, sustainable CC & V adaptation strategies in rainfed agriculture are anticipated to enhance local communities' resilience to the effects of CC & V, and improve human well-being by increasing crop yields, while maintaining socio-ecological system stability (Boström, 2012; Agyei, 2016). A study by Agyei (2016) in eastern Ghana established that the main qualities of sustainable adaptation strategies were low-cost strategy, economic equity, and flexibility to precipitation and temperature. However, it was found that smallholder farmers' choices of climate change adaptation strategies were based primarily on historical experiences, knowledge of strategies, and the availability of resources to implement a particular strategy.

It is worth noting that the sustainability theory is criticized for being defined differently by different interest groups; being applied to many different desires and thus its meaning is not always clear; what is sustainability in one area may not be so in another area; and, lastly, cultural differences can significantly influence community efforts to move along a path towards sustainability (Harrington, 2016). Despite these criticisms, however, the theory was chosen to inform this study because it adds some useful ideas to the assessment of sustainability of adaptation strategies in rainfed agriculture. This means that local-level studies aimed at examining the sustainability of adaptation strategies in rainfed agriculture to the effects of CC & V are encouraged since an adaptation strategy that is sustainable in one area may not necessarily be so in another area. Hence, this paper uses the case of smallholder famers from Nyang'oro ward of Iringa district to examine the sustainability of adaptation strategies in rainfed agriculture to the effects of CC & V.

3. Context and Methods

3.1 Description of the Study Area

This study was conducted in Nyang'oro ward in Iringa district, Tanzania (Figure 1). The district is located between latitudes 7° 00' and 8° 30' south of the Equator; and between longitudes 34° 00' and 37° 00' east of the Greenwich meridian (URT, 2013). The district was selected because communities in the study area use various strategies to adapt to CC & V on rainfed agriculture, even though despite the use of these strategies, rainfed agriculture is still vulnerable to the effects of CC & V. The district is characterized by semi-arid climatic conditions, with an annual rainfall below 600mm and temperature ranging from 20ºC to 25ºC; and rainfed agriculture is most common (Kihupi, 2016).

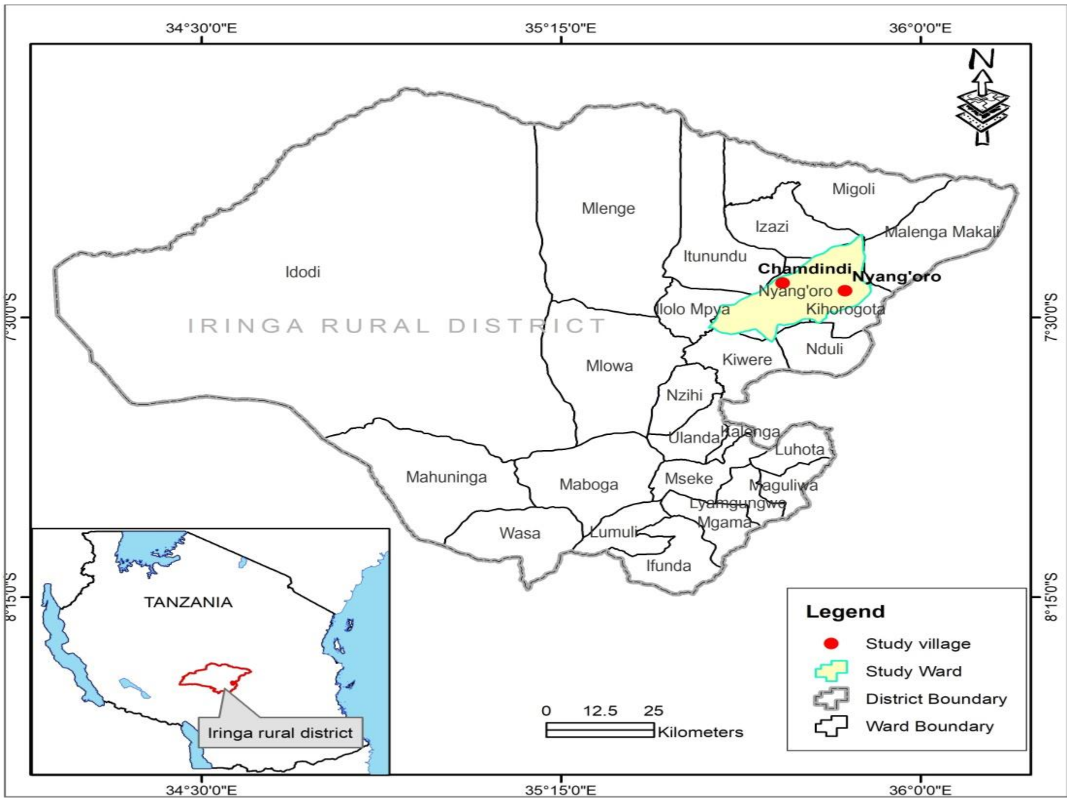

Figure 1: ***Location of the Study Area***
Source*:* Field data, 2021 (URT) (2020).

3.2 Sample Size and Sampling Procedures

The study used purposive and random sampling techniques in selecting participants and the study area. Iringa district was purposively chosen because over 90% of agricultural activities in the area depend on rainfall. The local community has been adapting to the effects of CC & V by using different strategies (Kihupi, 2016). Nyang'oro ward and the two villages (Nyang'oro and Chamndindi villages) were randomly selected due to their similarities in household activities and environmental characteristics. Household heads were selected randomly using a list of household heads from the respective village executive officers (VEOs). Purposive sampling was employed to select key informants deemed to possess crucial information for the study.

A total of 120 household heads (82 from Nyang'oro and 38 from Chamndindi villages), aged 30 years and above, were selected for questionnaires to collect quantitative data. Household heads aged at least 30 and above years were selected as they had stayed in the study area for a long time, and as such could possess enough experience of CC & V, and information based on adaptation strategies. Also, household heads were selected because they are the decision-makers in their families. Four (4) key informants consisting of 2 village executive officers (VEOs), 1 agricultural extension officer (AEO), 1 ward executive officer (WEO), and 14 FGD participants (7 from each village), also participated in this study.

3.3 Sources of Data and Data Collection Methods

Primary data were collected through a structured interview, in-depth interviews and focus group discussions (FGDs). Questionnaires with open- and closed-ended questions were administered to 120 household heads. Open-ended questions were used to collect qualitative data based on respondents' experiences on CC & V, as well as adaptation strategies. Closed-ended questions were used to collect quantitative data to ensure uniformity on answers, and simplify data analysis. In-depth interviews were used to collect data from key informants to determine official support during the study. Two FGDs were conducted to collect narrative information from 14 participants who were selected from the two villages. Documentary reviews from government reports and scholarly works were also used to collect both qualitative and quantitative secondary data.

3.4 Data Analysis

Qualitative data were analysed through a content analysis technique whereby themes and subthemes were derived. Quantitative data were analysed through descriptive statistics with the help of the Statistical Product and Service Solutions (SPSS) software, version 27.

4. Results and Discussion

4.1 Socio-economic and Demographic Characteristics of Respondents

Characteristics of Respondents

Local communities' vulnerability to the effects of CC & V and their choice of sustainable adaptation strategies are greatly influenced by their socio-economic and demographic characteristics. This study, therefore, examined the key socio-economic and demographic characteristics of the respondents as shown in Table 1.

An examination of the respondents' gender, age structure, education levels and employment status were important in this study because the sustainability of the strategies used to adapt to the effects of CC & V on rainfed agriculture always depend on experience and knowledge. Results in Table 1 indicate that the respondents differed in terms of age and levels of education. Respondents aged 40-49 years were many compared to other age categories. The study further found that most of the respondents (64.2%) had primary education. Variation in ages among respondents implies that respondents had different levels of experience on the effects, strategies used to adapt to, and the sustainability of the strategies used to adapt to the effects of CC & V on rainfed agriculture in the study area.

Table 1: Selected Characteristics of Respondents (N=120)

Characteristics of Household Heads	Description of variables	Frequency	Percent
Gender of respondents	Male	72	60
	Female	48	40
Total		**120**	**100**
Age category	30–39	21	17.5
	40–49	36	30
	50–59	30	25.3
	60–69	19	15.8
	70+	14	11.7
Total		**120**	**100**
Level of education	No school	40	33.3
	Primary school	77	64.2
	Secondary school	3	2.5
Total		**120**	**100**
Employment status of respondents	Unemployed	117	97.5
	Employed	3	2.5
Total		**120**	**100**

Source: Field data, 2021

Furthermore, Table 1 shows that the majority of respondents had primary education (64.2%), and few had attained secondary education (2.5%). Education level and age of respondents influence the selection and sustainable use of the strategies used to adapt to the effects of CC & V in the study area. Mkonda and He (2017) assert that farmers' perception of CC & V varies with areas, age, education and sex; indicating that farmer's perceptions are crucial when choosing adaptation strategies.

4.2 Strategies Used to Adapt to the Effects of CC & V on Rainfed Agriculture

The study examined the strategies used by the respondents to adapt to the effects of CC & V in rainfed agriculture (Figure 2).

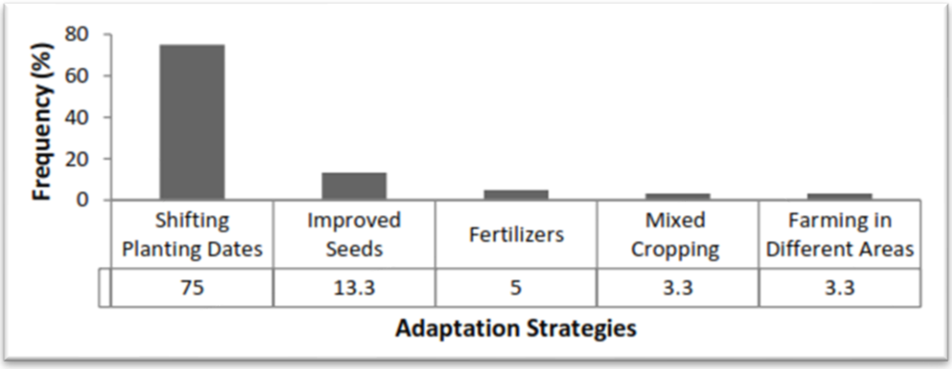

Figure 2: Adaptation Strategies to the Effects of CC & V
Source: Field data, 2021

The results in Figure 1 indicate that shifting planting dates (75%), use of improved seeds (13.3%), use of fertilizer (5%), mixed cropping (3.3%), and farming in different areas (3.3%) were the common adaptation strategies used to adapt to the effects of CC & V in rainfed agriculture. The results suggest that shifting planting dates was the most used strategy. The results relate to those of Mburu et al. (2015), who found that in Yatta district, Kenya, the main adaptation strategies of farmers included planting short-season varieties and changing planting dates.

4.3 Crop Production Trend for Five Years after Using Strategies to Adapt to the Effects of CC & V

For adaptation strategies to help local communities enhance their resilience to the effects of climate change and variability, they ought to be effective and sustainable. The study examined the trend of crop production of the households over the past five years, and the results are presented in Table 2.

Table 2: Crop Production Trends for Five Years (2015-2020)

Sustainability	Responses on Sustainability (%)					Total %
	Nyang'oro (N=82)		*Chamndindi (N=38)*		*Freq*	
	Freq	*(%)*	*Freq*	*(%)*		
Increasing	14	17.1	8	21.1	**22**	**18.3**
Decreasing	21	25.6	10	26.3	**31**	**25.8**
Fluctuating	36	43.9	14	36.8	**50**	**41.7**
No change	11	13.4	6	15.8	**17**	**14.2**
Total	**82**	**68.3**	**38**	**31.7**	**120**	**100**

Source: Field data, 2021

The results in Table 2 show that the majority of the respondents (41.7%) said that in the five years of using their strategies, yields fluctuated despite the strategies they used to adapt to the effects of CC & V. The results are supported by URT (2015): that there have been fluctuations of food crop production in Iringa.

4.4 Sustainability of Adaptation Strategies to the Effects of CC & V in Rainfed Agriculture

The study examined the sustainability of the strategies used by the respondents to adapt to the effects of CC & V as shown in Table 3. In examining the sustainability of the strategies used to adapt to the effects of CC & V, the study used the status of crops produced among smallholders within five years of using a specified strategy.

The results in Table 3 indicate that strategies used to adapt to the effects of CC & V on crop production in rainfed agriculture are not sustainable as the majority of respondents said yields obtained after using the strategies for five years were fluctuating.

Table 3: Sustainability of the Strategies Used to Adapt to the Effects of CC & V in Rainfed Agriculture

Households Characteristics	Variable	Production trend per acre for five years (%)																			
		Shifting planting dates				*Improved seeds*				*Fertilizer use*				*Mixed cropping*				*Farming in different areas*			
		In	***De***	***Fl***	***No***	***In***	***De***	***Fl***	***No***	***In***	***De***	***Fl***	***No***	***In***	***De***	***Fl***	***No***	***In***	***De***	***Fl***	***No***
Village	Nyang'oro (n=82)	4	0	43	27	7	0	5	0	1	0	4	0	2	0	0	2	1	0	2	1
	Chamndindi (n=38)	3	8	37	32	5	0	2	8	3	0	0	3	0	0	0	0	0	0	0	0
Education	No (n=40)	0	5	38	33	5	0	10	3	0	0	5	0	0	0	0	3	0	0	3	3
	P/r (n=77)	5	4	42	27	11	0	1	0	1	0	1	0	1	0	0	1	1	0	1	0
	Sec (n=3)	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Age	30-39 (n=21)	10	0	57	19	5	5	5	0	0	0	0	0	5	0	0	0	5	0	5	0
	40-49(n=36)	3	6	28	44	7	0	0	1	0	0	6	3	3	0	0	3	0	0	0	0
	50-59 (n=28)	4	4	50	25	4	0	4	7	4	0	4	0	0	0	0	0	0	0	0	4
	60-69 (n=21)	5	0	62	19	10	0	5	5	0	0	0	0	0	0	5	5	0	0	5	0
	70+ (n=14)	0	0	71	21	10	0	14	4	0	0	0	0	0	0	0	0	0	0	0	0
Total Average (N=120)		**3.4**	**2.7**	**43**	**24.7**	**6.4**	**0.5**	**4.6**	**2.8**	**0.9**	**0**	**2**	**0.6**	**1.2**	**0**	**0.5**	**1.4**	**0.7**	**0**	**1.6**	**0.8**

Note: In = increase, De = decrease, Fl = fluctuation, No = no changes observed
Source: Field data, 2021

The results in Table 3 show that perceptions on the sustainability of adaptation strategies used to adapt to the effects of CC & V differ according to the characteristics of the respondents. The table indicates that the majority of respondents (51.7%) said yields were fluctuating, and only 12.6% said yields were increasing. However, the study found that improved seeds and fertilizers were sustainable as the majority of the respondents using them said yields were increasing. Also, a participant in an FGD in Chamndindi village explained that despite using adaptation strategies, yields were still low, and sometimes they did not harvest anything as validated by the following quotation:

> *"Everybody performs what he or she believes will work…sometimes what you do fails, but since that is what you have been doing for long, you will continue to do the same."*

The quote above implies that although some of the strategies used to adapt to CC & V effects are not sustainable, still smallholder farmers use them. The findings relate with those of Belay et al. (2017), who reported that smallholder farmers could switch to more adopted crop varieties, but they may have lower productivity. Also, Kumar et al. (2019) said that the sustainability of any strategy used to adapt to the effects of CC & V should increase crop productivity.

4.4.1 Sustainability of Shifting of Planting Dates

The study found that shifting planting dates as an adaptation strategy to the effects of CC & V on crop production in rainfed agriculture was not sustainable. The results in Table 3 show that 43% of the respondents who shifted planting dates to adapt to the effects of CC & V on rainfed agriculture for five years said yields obtained were fluctuating. Village-wise, the study found that the majority of the respondents in Nyang'oro (43%) and Chamndindi (37%) said that yields were fluctuating. The results imply that shifting planting dates was not sustainable in both villages.

Educational-wise, the study found that yields were fluctuating as the majority of respondents in all levels of education (38% with no formal education, 42% with primary education, and 2% with secondary education) said yields were fluctuating. The results imply that despite the variation of the respondents' level of education, shifting planting dates was found to be unsustainable.

Age-wise, the majority of respondents with 30–39 years (57%), 50–59 years (50%), 60–69 years (62%), and 70 years and above (71%) said yields were fluctuating. On the other hand, no changes were observed for the majority (44%) of respondents with 40–49 years. This implies that the number of years in farming and experience that household heads have in farming activities had not helped respondents ensure optimum and sustainable crop production on rainfed agriculture through shifting planting dates. Unpredictable rainfall and prolonged dry spells have been accredited with the lack of sustainability of shifting planting dates in rainfed agriculture. The planting dates have shifted from October and mid-November to mid-December and mid-January. An FGD in Chamndindi revealed that despite shifting planting dates to adapt to the effects of CC & V, no changes in yields were observed as testified by one of the FGD participants:

> *"For different years, I have been adjusting planting dates, but always I harvest 1 to 3 bags of maize in an acre."*

The results imply that, despite household heads adjusting to planting dates to adapt to the effects of CC & V to ensure optimum and sustainable crop production in rainfed agriculture, yields obtained were low and fluctuating. This means that shifting planting dates as an adaptation strategy to the effects of CC & V in rainfed agriculture was not sustainable in Chamndindi village. However, it was found during an FGD in Nyang'oro that shifting planting dates is sustainable when improved seeds are used, as revealed by one participant:

> *"On my side, I have been getting a lot of yields since I started adjusting dates of planting my crops by looking at the trend and information of rainfall, but in addition to that, I use improved seeds."*

The quote above implies that shifting planting dates can be sustainable only when improved seeds are used. The sustainability of shifting planting dates might be reduced in cases of unpredictable rainfall that makes it difficult to predict which date is suitable for planting. The findings concur with those of Jalota et al. (2012), who observed that, under the changing climate in central Indian Punjab, shifting planting date results in the least reduction in crop yields, and is considered as a practical adaptation measure to sustain yields in the future.

4.4.2 Sustainability of the Use of Improved Seeds

The results in Table 3 indicate that the use of improved seeds as an adaptation strategy to the effects of CC & V on rainfed agriculture in the study area is sustainable as the majority of respondents said crop yields were increasing. Village-wise, most respondents in both villages (8% in Chamndindi, and 7% in Nyang'oro) said yields were increasing. This implies that shifting planting dates was sustainable in both villages. Educational-wise, the majority (10%) of the respondents with no formal education said yields were fluctuating, but those with primary education (8%) said yields were increasing. No respondents with secondary education commended the production trends after using improved seeds. The level of education had no implications for improved seeds' sustainability as respondents with formal education (primary education) said that yields were decreasing. Those with secondary education did not comment on the production trends of crops after using improved seeds.

Results from FGDs also revealed that improved seeds result in higher yields than the use of the local seeds, as testified by one participant in Chamndindi:

> *"My friend, sometimes it seems like a wizardry. Near my farm, there is a friend's farm; he always harvests four times what I harvest every year only because he uses improved seeds."*

The above quote implies that smallholder farmers who used improved seeds get higher yields than those who did not. Improved seeds are a sustainable strategy to adapt to the effects of climate change and variability because they are resistant to diseases and droughts. Meughoyi (2018) and Kumar et al. (2019) had the same findings: that the use of improved seeds increases crop yields in a changing climate because they are resilient to both biotic and abiotic stresses.

4.4.3 Sustainability of Mixed Cropping
Mixed cropping is one of the strategies found to be unsustainable. The results in Table 3 indicate that the majority of respondents (1.4%) who mixed crops for five years said they had not seen any change in crop yields. Village-wise, while most respondents (2%) in Nyang'oro said yields were increasing, no respondent commented on the production trend after mixing crops for five years in Chamndindi.

Based on the ages of the respondents, the study found that there is a variation in the respondents' perception of the sustainability of mixed cropping as an adaptation strategy to the effects of climate change and variability. The results in Table 3 show that the majority of respondents aged 30–39 years (5%) said yields were increasing. In contrast, those aged 40–49 (3%) said no changes were observed after mixing crops to adapt to the effects of CC & V on rainfed agriculture for five years; while those aged 60–69 years (5%) said yields were fluctuating. Prolonged dry spells, especially in February, affects crop growth and productivity in the study area despite the variation in the ability of crops to resist droughts.

Results from an in-depth interview with the WAEO revealed that smallholder farmers have been mixing crops—especially maize, groundnuts and sunflower—but what they harvest at the end of the farming season is still low. Sometimes they do not get anything, especially in years with extreme climatic events like droughts. Furthermore, in-depth interviews with VEOs revealed that improved seeds and fertilizers in a mixed cropping result in higher yields. Therefore, improved seeds and fertilizers should be employed for mixed cropping to be sustainable. These findings disagree with those of Jamie (2020), who reported that mixed cropping ensures increased and stable yields, and better control of pests and diseases.

4.4.4 Sustainability of the Use of Fertilizers
The use of fertilizers to adapt to the effects of CC & V on rainfed agriculture was found to be a sustainable strategy. The majority (2%) of the respondents who used fertilizers for five years said that yields increased. The use of fertilizers improves soil fertility that has been depleted by prolonged droughts, high temperatures and heavy rains; hence improving crop productivity on rainfed agriculture. Village-wise, the study found that while most respondents (4%) in Nyang'oro village said yields were increasing, the majority of the respondents in Chamndindi village (3%) said no changes were observed after using fertilizers. This implies that fertilizers are more sustainable in Nyang'oro village than in Chamndindi village.

The results in Table 3 also show that no respondent aged 30–39 years commented on the production trend after using fertilizers. However, the majority (6%) of the respondents aged 40–49 and (4%) aged 60–69 years said yields were fluctuating, while no respondents aged 50–59, and 70 and above years, commented on the production trend of crops after using fertilizers for five years. The results imply that the use of fertilizers is one of the sustainable strategies used to adapt to the effects of CC & V on rainfed agriculture in the study area. One participant in the FGD held in Chamndindi village presented this testimony:

> *"Nowadays, we are using fertilizers because of these improved seeds; if you don't use fertilizers, you will always have lower yields. Those who use fertilizers always harvest higher yields than those who don't."*

The above quote implies that those who use fertilizers to adapt to the effects of CC & V have been harvesting much more than those who use local seeds. This means that fertilizers are sustainable strategies to climate change and variability: fertilizers hasten seed germination, crop growth, and improve fruits development. Farmers in the study area therefore should be encouraged to use industrial fertilizers to adapt to CC & V as it ensures optimum and sustainable crop production in rainfed agriculture. The findings of this study concur with those of Kumar et al. (2019), who reported that fertilizer use improves soil fertility, which helps to increase yield in soils that are affected by climate change and variability.

4.4.5 Sustainability of Farming in Different Areas

The study found that farming in different areas as a strategy used to adapt to the effects of CC & V on rainfed agriculture is not sustainable. The results in Table 3 reveal that most respondents (1.6%) said yields were fluctuating, which was caused by instabilities in rainfall and dry spells, especially in February. Village-wise, the study found that respondents from Chamndindi were not aware of farming in different areas as a sustainable adaptation strategy. The findings in Table 2 also show that the majority (2%) of the respondents in Nyang'oro said yields were fluctuating, while no respondent commented on its sustainability in Chamndindi. Education-wise, 3% of the respondents with no formal education said no change was observed after farming in different areas. Based on sex, female respondents (2%) said yields fluctuated even after farming in different areas for five years.

Age-wise, the majority (5%) of respondents aged 60–69 said yields were fluctuating, while most respondents (4%) aged 50–59 years said there was no change in yields observed before and after farming in different areas. Based on the size of farms, the majority (2%) of the respondents with 3–4ha said yields were fluctuating. Findings from FGDs revealed that smallholder farmers, who had established farms in Umasaini, Kibaoni and Kitope to increase yields from rainfed agriculture, had not seen any substantial increase in yields over the past five years; indicating unsustainability. Furthermore, an in-depth interview with the

WAEO found that household heads who farmed in different areas to adapt to the effects of CC & V for the five years obtained high yields. This implies that farming in different areas is more sustainable when improved seeds are used than traditional ones. This finding differs from Lana et al. (2017), who reported that farming in different areas takes the advantage of better soils and reduces the risk of total crop failure, which is associated with small-scale spatial distribution of precipitation.

5. Conclusion and Recommendations

Strategies used to adapt to the effects of CC & V in rainfed agriculture in the study area varied in terms of sustainability. The sustainable adaptation strategies included the use of improved seeds, farming in different areas, and the use of fertilizers. Furthermore, the study found that few respondents used sustainable adaptation strategies. This has caused crop production in the study area to be vulnerable to the effects of CC & V. Therefore, the vulnerability of crop production to the effects of CC & V in the study area is not caused by the sustainability of adaptation strategies, but the selection and mix of particular strategies. To ensure sustainable and optimum crop production on rainfed agriculture, the government and other agricultural stakeholders should support smallholder farmers by providing timely farm inputs and knowledge on sustainable adaptation strategies. The lack of knowledge and awareness on a particular strategy may reduce its sustainability in adapting to CC & V effects. Therefore, knowledge is an important factor in accessing relevant information about new improved agricultural technologies and strategies to increase agricultural productivity.

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