Climate change impacts and adaptation by arable farmers in Mmanoko village, Kweneng District, Botswana.

Abstract

Climate change is one of the major environmental challenges facing the world today. It is widely believed that it will have significant adverse impacts on rainfed agriculture that is practiced mostly by small-scale famers in developing countries. Worldwide, farmers have continued to adapt to the effects of clmate as adaptation is considered one of most viable options to the adverse impacts of climate change and variability. This cross-sectional survey was carried out in Mmanoko village in the Kweneng District, Botswana. The aim of the study was to determine and evaluate climate change adaptation strategies in response to impacts of climate change on arable farming in Mmanoko village. A Multi-Criteria Evaluation (MCE) method was also used to evaluate, score, prioritize adaptation strategies using a predetermined set of four criteria (effectiveness, flexibility, institutional compatibility and equity). Most farmers reported to have observed a decrease in the rainfall amounts, increase in the mean temperatures, delayed onset and early cessation of rains over the past 10 years. The most commonly used adaptation measures included crop diversification (mixed cropping, crop rotation, intercropping), shifting of planting dates; the use of drought-tolerant and early maturing crops. The results of the MCE method revealed that farmers preferred adaptation strategies that are effective, flexible, compatible with existing legilsation as well as easily accessible to all regardless of their socio-economic status. Crop diversification (intercropping, mixed cropping and crop rotation) was the most highly rated adaptation practice in terms of effectiveness, flexibility, compatibility and equity

Keywords: Climate Change; Impact; Adaptation; Arable Farming; Livelihood; Mmanoko village; Kweneng District; Botswana.

1. Introduction

Climate change and its impacts remain critical issues in the interaction of society and the local environment, particularly in Africa where millions of people have been severely affected (Kotiri 2010; Adger, 1996). The changes in the state of the climate can be identified by changes in the mean and variability of its properties (IPCC, 2007) and/or change in weather patterns of any area over a long period of time. This can be observed by realizing very significant changes in the earth's temperature, rainfall and wind patterns including other measures of the change in climate that can happen over several years.

According to the IPCC (2014), the surface temperature is projected to rise in the 21st century and heat waves are very likely to be experienced more frequently. It is also reported that extreme rainfall events will become more intense and frequent in many regions. While many sectors of the economy are prone to the effects of climate change (Smith et al., 1996; Sango, 2013; Shiferaw, 2014), there is general agreement that climate change will have an adverse impact on agriculture, and prarticulalrly rainfed-agriculture (Adaptation at Scale in Semi-Arid Regions -ASSAR, 2018; Sango, 2013; Shiferaw, 2014; Ubisi et al., 2017; IPCC, 2014; Mogomotsi et al., 2020). Sango (2013) argues that climate change impacts are unequally distributed whereby low-income populations in developing countries are more highly affected than in the developed countries. Moseley (2016) observes that various countries and groups of people within a country are impacted differently. According to Ubisi et al. (2017), the African continent, especially Sub-Saharan Africa, is most likely to be disproportionately affected by climate as a significant proportion (80%) of its population is dependent on agriculture as a source of food and income (FAO, 2016; Kgosikoma et al., 2018). The vulnerability of the African continent to climate change and variability is exacerbated by several factors, including farming that is often practiced in higher risk areas such as flood plains, hillsides and deserts, as well as its greater reliance on the sensitive and vulnerable moisture (Randolph & Agrawal, 2017; Randolph & Agrawal, 2017; Moseley, 2016). The effects of climate change and variability on agriculture have mostly presented themselves as crop failure, yield declines, and reduction in the quality of the produce (Sissoko et al., 2011; Zurovec & Vedeld, 2019), consequently affecting food security.

In Botswana, the manifestations of climate change across the country include a temperature rise of above 1.5^0C, which is anticipated to increase the incidence of drought and its severity that has implications for the agriculture sector (ASSAR, 2018). Evidence shows that half of Botswana's population residing in rural areas depends on arable farming for income and food (Ministry of Agriculture, 2002; Government of Botswana, 2016; Seleka & Mmopelwa, 2018). Botswana has also been cited as one of the countries that will experience the most significant extreme changes in temperatures and rainfall under global warming above preindustrial levels (ASSAR, 2018). Indeed, Botswana's recently developed climate change policy recognizes climate variability and change as a major threat to the sustainability of key climate dependent sectors of the economy such as agriculture (Ministry of Environment & Tourism, 2021).

Small-holder farmers, government and non-governmental organizations in Botswana have responded to climate change and impacts throught various adaptation strategies which are viewed as a viable and deliberate options to reduce the anticipated adverse effects of climate change (Lema & Majule 2009; Amjath et al., 2019; Regmi & Pandit, 2016; Rashid et al., 2014; Smit & Pilifosova, 2001). Adaptation may be defined as any action taken to alleviate or moderate the anticipated negative impacts of climate change including taking advantage of new opportunities (Ford et al., 2010) provided they are adopted and implemented (Skinner et al., 2001). It includes both government policy responses and decision-making industries as well as producers at farm level (Smit & Skinner, 2002; Aryal, et al., 2020; Mnguni, 2016). Adaptation may be anticipatory, reactive; private or public, autonomous (spontaneous) or planned (Rashid et al., 2014; Smit & Skinner, 2002). Various factors such as assets, access to appropriate technology, institutional framewoks and farm practices, influence adaptation to clmate change (Aryal et al., 2020; Regmi & Pandit, 2016).

While policy makers have developed adaptation strategies and practices to cope with the changing environment, these have mostly been a one-size fits all top-down approaches that pay-limited attention to local farmers' experiences. Furthermore, a wide range of adaptation practices in rainfed arable agriculture does not translate to being equally applied or accepted in various and dynamic agro-environments (Rashid et al., 2014). Understanding existing and potential adaptation options is critical not only in the farmers against adverse climatic conditions, but also in the improvement of food security. This study is aimed at determing and evaluating climate change adaptation strategies against impacts of climate change on arable farming in Mmanoko village.

2. MATERIAL AND METHODS

2.1 Description and justification of the selection of the tudy area

The study was carried out in Mmanoko village in the Kweneng district in Botswana, situated 40 km northweast the city of Gaborone, and lies between 24°28`27``S Latitude and 25˚40`34``E Longitude at an altitude of 1,086m (Figure 1). The selection of Manoko village as a study site was based on three reasons. Firstly, the village has experienced rainfall variability over a long period of time that has affected rain-fed agriculture which is one of the main livelihoods in the area. Secondly, the village is characterised by diverse arable farming and adaptation practices. Thirdly, the proximity of the village to the city of Gaborone city and Molepolole village, has offered farmers easy access to agricultural technologies and information that could have contributed to the diverse farming and adaptation practices.

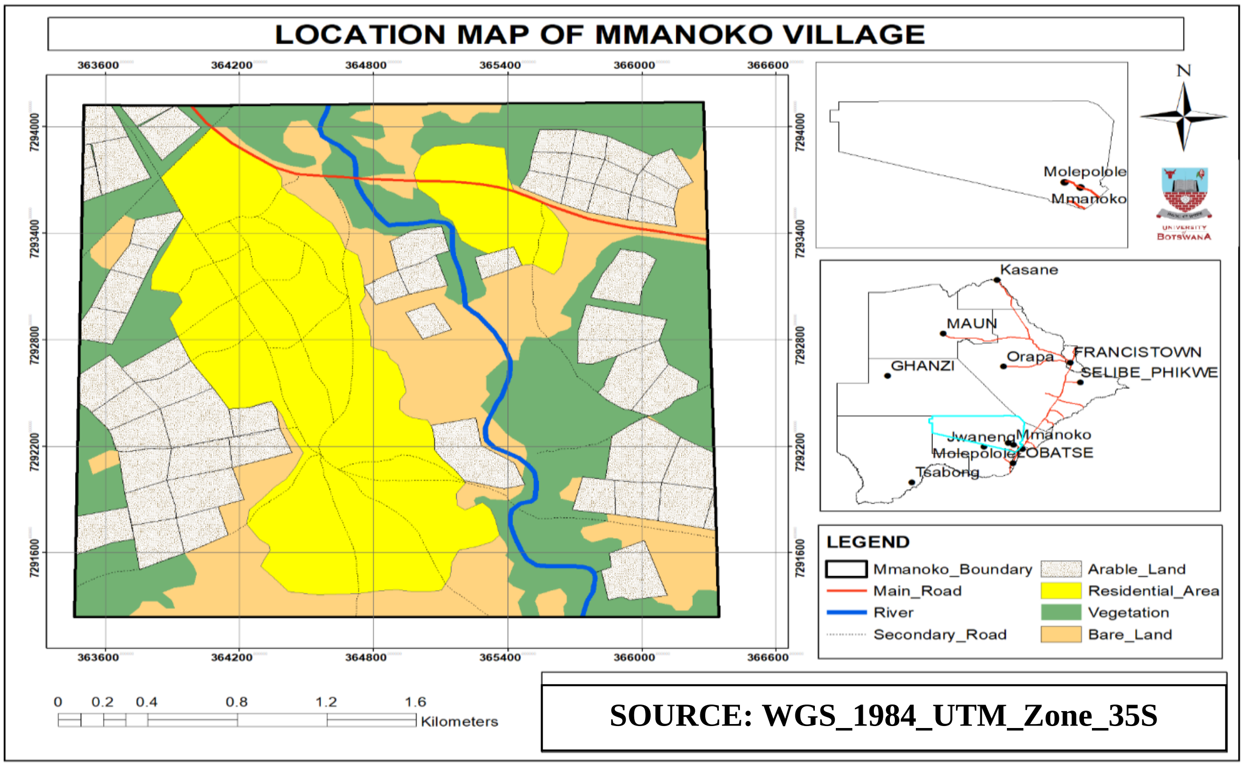

Figure 1. Location of Mmanoko village

The population of Mmanoko village is estimated at 1846, comprising 870 males and 976 females (Statistics Botswana, 2022). The village has 203 households with an average household size of 4.6 persons. The literacy rate, unemployment rate and poverty rate have been estimated at 82.5%, 6.1% and 0.291, respectively (Statistics Botswana, 2015). Mannoko village has also experienced moderate to severe food insecurity levels, estimated at a rate of 53.29% nationally in 2021/22 (Statistics Botswana, 2023).

The main economic activity in the village is arable farming, however, due to its proximity to the capital city, there are opportunities for private business, economic diversification as well as accessibility to farming information and technology. Other livelihoods sources include diversity income generating activities and temporary employment in the poverty alleviation programme.

The climate of the area is semi-arid with low rainfall, ranging between 300 and 500 mm, as well as hot summers and cool winters (Kgosikoma et al., 2018). The Koppen-Geiger Climate Classification System classifies the climate as hot semi arid climate (BSh). The average monthly temperature ranges between 12.9°C and 30.8°C. According to Government of Botswana (2016), common dry spells occur during the cropping seasons, a situation that accounts for periodic failure of crops across the region. The annual average temperatures in the study area are substantially high during the year and have been gradually increasing since 2009 recording average extremes of up to 30°C. Figures 2 and 3 show annual average rainfall (1971-2018) and annual average temperatures (1989-2020) for the study area.

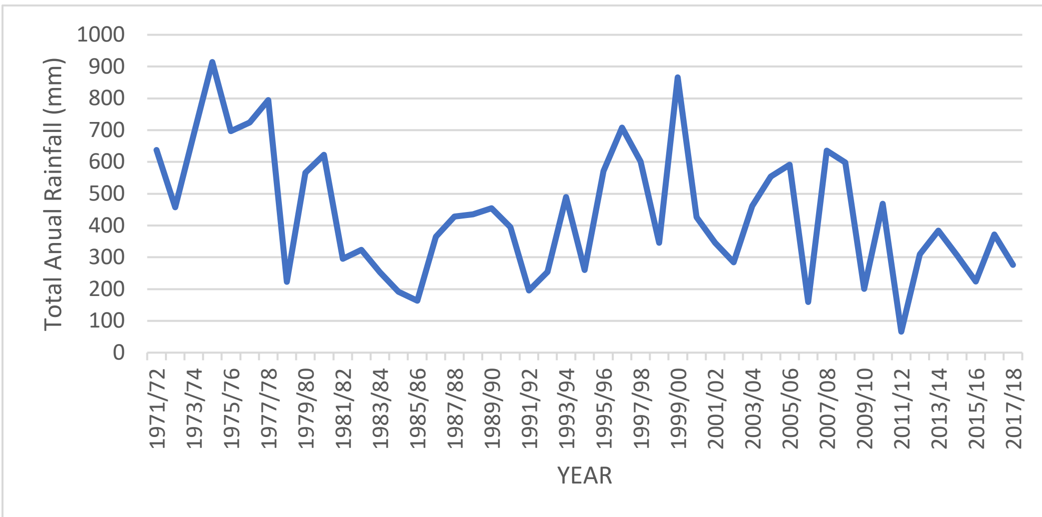

Figure 2. Annual average rainfall (1971-2018) for the the study area

Source: Department of Meteorological Services

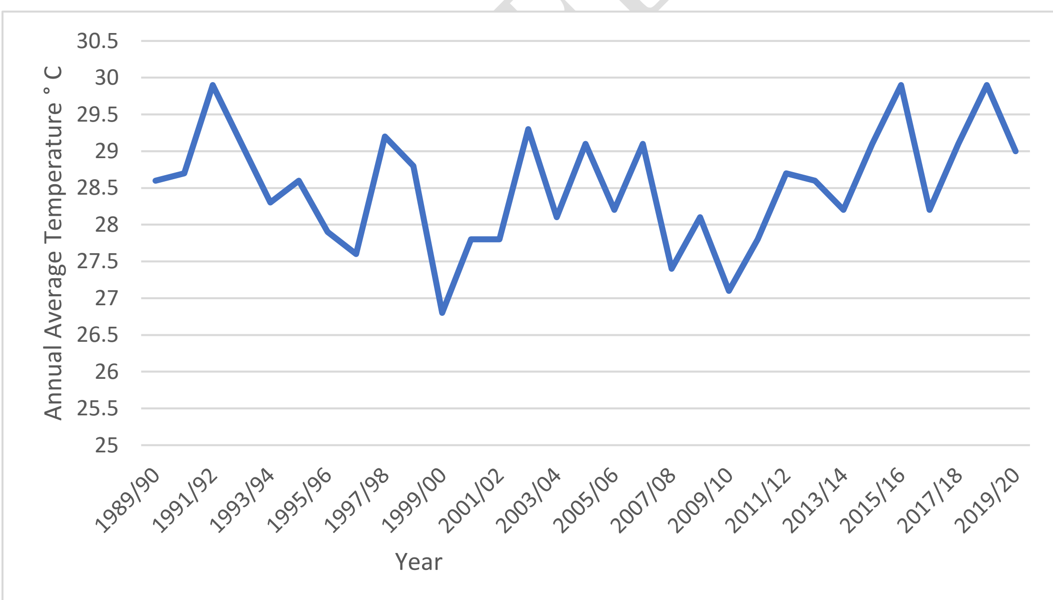

Figure 3. Annual average temperatures (1989-2020) for the study area

Source: Department of Meteorological Services

The study area is chracterised by clay, loamy, tropical and more fertile soils (Ijagbemi, 2006) that have a greater capacity to retain water. Thus, in terms of soils, the area has a relatively high potential for arable farming. Notwithstanding, the area has experienced variability in agricultural production from year to year, which is determined largely by the amount of precipitation received.

2.2 Significance of the Study

The study's significance lies in the fact that since agriculture is a major economic activity for many people, an understanding of adaptation strategies by policy makers will contribute to more support from government in terms of devising ways of reducing the impacts of climate change. Such support could include enhancing climate resilience and adaptive capacity of arable farmers. Secodly, the study wil contribute to the implementation of the newly developed climate change policy in which agriculture and food security have been identified as priority areas. Thridly, this study is in line with the United Nations (UN) SDG 2 (achieving food security and promoting sustainable agriculture) and SDG 13 (taking action on climate change) attainment of which Botswana and other UN members are committed.

2.3 Research Design

A cross-sectional mixed methods approach was used in the study. The mixed methods approach allows both quantitative and qualitative techniques and methods of data collection to be used to study the research problem in depth (Ford et al., 2010; Bell, 2014; Petty et al., 2012). Both qualitative and quantitative approaches have their own strengths and limitations (Palinkas, 2015), therefore integrating them has complementarity effect. The use of Mmanoko village as a case study enables an indepth understanding of the area in terms exploring, explaining and describing issues in the real-life context in which they exist an indepth study (Crowe et al., 2011). The case study approach therefore helped the researchers to get in-depth knowledge on the farmers' actual adaptation practices, challenges and opportunities.

2.4 Sampling

Simple random sampling was used to select arable farmers that participated in the face-to-face survey. To select a sample of arable farmers, the Yamane formula was used: $n = N/1+N (e)^2$, where:

N = the total population of arable farmers
n = sample size
e = sampling error (0.027)
With the help of the Agriculture Extension Officer in the study area, a list of all arable farmers in the village was obtained. The sampling frame comprised 108 arable farmers. Applying the Yamane formula led to a sample size (n) of 100 farmers.

For the Focussed Group Discusstion (FGD) and Key Informant interviews (KII), purposive sampling was used. Purposive sampling involves choosing individuals that are not only knowledgeable or experienced with the issue of interest, but also can articulate issues effectively. Twenty (20) arable farmers were selected from the 108 farmers to participate in the FGD. These were devided into the two (2) groups, each comprising 10 farmers. The first group was used for an indepth understanding of types and forms of adaptation strategies used by the farmers to reduce the impacts of climate. The group comprised five (5) females and five (5) males with the age range of 35 – 80 years. The second group, which included two (2) technical officers, was used to evaluate the adaptation strategies using Multi Criteria Evaluation (MCE) process, which is a set criterion involving effectiveness, flexibility, compartibilty, equity. The group comprised five (5) females and five (5) males with the age range of 35-80 years.

Five (5) Key informants comprising a representative of Department of Metereological Services, Department of Crop Production, Agriculture Extension Office, Village Develoment Committee (VDC) and the Mmanoko Extension Farmers Committee, were also purposively selected.

2.5 Data collection

A semi-structured questionnaire was used to collect primary data from arable farmers, while interview guides were used for the Key informant and FGD. Respondents were informed that their responses would not be linked to their identities and that they had the the right to withdraw from the study at any stage of the interview, for whatever reasons. The semi-structured questionnaire was administered face-to-face in the local language (Setswana). Data was collected on several aspects including farmers' demographic variables, socio-economic profile, perceptions and opinions on climate change and awareness, effect of climate variability and change on crop production and their livelihoods and strategies used in response to impacts of climate change. Issues covered in FGD included farmers perception of climate change and variability, adaptation strategies to climate change and variability, barriers to adaptation and suggestion and solutions to the challenges faced.

The main activity of the second FGD was to evaluate and prioritized existing adaptation practices using the Multi Criteria Evaluation methods developed (MCE) by Dolan et al. (2001). The MCE framework was used to assess adaptation practices based on their effectiveness, flexibility, compatibility, and equity. According to Dolan et al. (2001), *effectiveness* is an evaluation of whether the adaptation measure is effective in meeting the set and or targeted objective; *flexibility* describes whether the adaptation strategy will be flexible in meeting policy objectives applied under a wide range of uncertainty and future climatic scenarios; *compatibility* is the degree to which an adaptation strategy can easily be integrated within the existing legislative frameworks; *equity* descrbes whether the adaptation practice can be easily and equally accessed by all members of the society regardless of their socio-economic status, knowledge..

2.6 Data Analysis

Data collected from the farmers survey was analysed using descriptive statistics and was presented in frequency tables. crosstabulations and charts. Chi-square analysis was performed to determine if there was any association between categorical variables. Qualitative data was analysed through content analysis. Content analysis is an approach for making deduction by rigorously and objectively measuring attributes of text (Robson, 2002). The summative content analysis technique was used to interpret data extracted from document analysis, open-ended questions from survey questionnaire, FGD discussions as well as interviews to draw the context and meanings. The researchers reviewed the written notes, listened to consented recorded interviews, and the facilitated focus group discussions to discover the experiences and meanings from them. Data was coded, and the categories and subcategories were generated using qualitative analysis in Microsoft Word. Audio tapped data was transferred from the recording device into Microsoft Word; patterns and relationship were identified. The data was then organised into appropriate themes that were derived from the research objectives and questions to draw appropriate meanings and conclusions.

Multi Criteria Evaluation method (MCE) was used to systematically assess and score adaptation strategies to climate change and variability against criterion of effectiveness, flexibility, compatibility and equity. The evaluation process under the MCE involves the following steps:

Step 1: Assigning weights to each criterion

Each criterion (effectiveness, flexibility, campatibility and equity) was assigned a weight to reflect its importance to the farmer in terms of reducing the vulnerability of the farmer to climate chage impacts. A weighting scheme of 1-10 was used to assign the weights to each of the selected criterion, with 1 being the least important, 5 neutral, and 10 being the most important.

Step 2: Assigning scores for adaptation strategies

Each adaptation strategy was then evaluated by assignining a rating scale of 1-5, where 1 represents a very ineffective, 3 a neutral (neither effective nor ineffective) and 5, a very effective. Table 1 shows the rating scales used for scorig each adaptation strategy.

Table 1. Criteria scale

Criterion/Rating	**1**	**2**	**3**	**4**	**5**
Effectiveness	Very ineffective	Ineffective	Neutral	Moderately effective	Very effective
Flexibility	Very inflexible	Inflexible	Neutral	Moderately flexible	Very flexible
Compatibility	Very incompatible	Incompatible	Neutral	Moderately compatible	Very compatible
Equitability	Very inequitable	Inequitable	Neutral	Moderately equitable	Very equitable

Source: Dolan et al. (2001)

Step 3: Calculating the weighted score for the adaptation strategies

The weighted score for each adaptation strategy was calculated from: Rating scale for the adaptation strategy * Weight assigned assigned to the respective criterion. The weighted scores for the respective adaptation strategies were then summed up.

Step 4: Constructin a performance matrix to rank and prioritize adaptation strategies

The final step was to construct a performance matrix where the adaptation strategies were ranked. Thus, an adaptation strategy with the highest weighted score was the most preferred by farmers.

3. RESULTS AND DISCUSSIONS

3.1 Demographic and socio-economic profile of the respondents

The sample of farmers comprised equal proportions of males and females (Table 2). In farming communities, especially in the African setting, it is often the case that farming is mostly pursued by male-headed households mainly due to differences in resource endowments. This may also explain why male-headed households have better adaptive capacity than female headed households. Similar finding in differences in gender participation in farming has been reported by Omari (2010) in other parts of Botswana, Mngumi (2016) in Tanzania, and Belete (2013) in Ethiopia.

Most of the respondents (44.9%) were above the age of 60 years which could imply that these farmers were more experienced because of their long-term exposure to the harsh and variable climate conditions. A chi-square test showed a statistically significant association between the number of years in farming (experience) and age of the respondent [$X^{2:}$ 6, 98) = 32.6, P = 0.0001]. Most of the arable farmers (57%) have practiced farming for at least 10 years, albeit at subsistence level. The second largest group of arable farmers were in the age range of 46-60 years (33.7%), followed by those aged between 36-45 years (15.3%) and less than 35 years (6.1%).

Considering the age of the respondents, these results seem to suggest that the younger people in Mmanoko village do not actively participate in arable farming. The lack of or low participation in farming by young people has also been observed in other studies (e.g. Kgosikoma et al., 2018; Nhemachena & Hassan, 2007; FAO, 2014) and has been attributed to factors such as lack of land and financial resources. In terms of education, most (43%) of the farmers in Mmanoko village do not have any formal education (44%), while 31% had secondary education. The sources of livelihoods include drought relief program (Ipelegeng) (43%) informal employment (35%) and Old Age Government Pension Scheme (35%).

Table 2. Demographic and socio-economic characteristics of arable farmers in Mmanoko village

Variable	Frequency (n = 98)	%Respondents
Gender		
Female	49	50
Male	49	50
Age Group		
≤35	6	6
36-45	15	15
46-60	33	34
>60	44	45
Education Level		
None	43	44
Primary	18	18
Secondary	30	31
Tertiary	**7**	7
Income Source		
Formal employment	16	16
Informal employment	34	35
Pensioner	4	4
Old Age Scheme	34	35
Ipelegeng	42	43
Years in Farming		
≤5	12	12
5-10	30	31
>10	56	57
Size of Field (Ha)		
≤ 6	62	63
6-10	27	28
>10	9	9

3.2 Changes in rainfall and temperatures in the study area

When asked if they have observed any changes in the mean temperatures and rainfall patterns in Mmanoko village over the past 10 years, all the arable farmers indicated to have observed some changes during their farming experience (Figure 4). Most farmers farmers observed a decrease in the rainfall amounts and an increase in the mean temperatures over the past 10 years. Scientific data on rainfall and temperature from the Department of Meteorological Services also confirmed that the study area experienced consistent downward trend in rainfall since the 1970s and increasing mean maximum temperatures from 1989 to 2020.

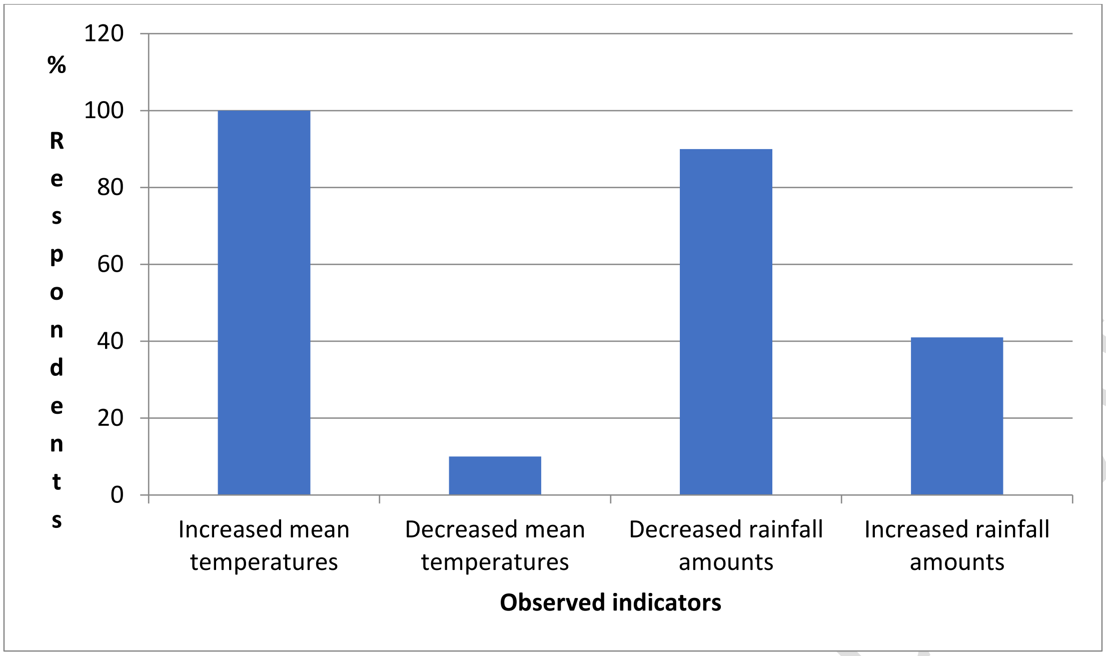

Figure 4. Number of arable farmers observing changes in mean rainfall and temperatures in Mmanoko village.

The farmers also indicated that they have observed delayed starting or onset of the rains (99%), early cessation of rainfall season (62%), decreased number of rainy days (76%) and increase in frequency of droughts (90%), all of which threaten arable farming as a livelihood (Table 3). Farmers aged 60 years and above indicated to have observed increased drought frequency, delayed onset rains, increased temperatures and decreased rainy days. The reports by farmers are consistent with the findings of other studies which have also found that older farmers have much more experience regarding the past and present climatic conditions (e.g. Belete, 2013; Bosekeng et al., 2020; Chalchisa, 2016). Existing research in Botswana (e.g. Kgosikoma et al., 2018), also shows that the area has experienced increase in the frequency of droughts with a number of years receiving total annual rainfall of 300mm or lower. However, Agrawal and Perrin (2007) posit that the experience and knowledge of farmers on climate change and variability does not necessarily translate into adaptation

Table 3. Percentage number of arable farmers making observations on indicators of climate change and variability in Mmanoko village

Observed Indicators	**Age Group (n = 98)**				
	≤35	**36-45**	**46-60**	**>60**	**Total**
Increased mean temperatures	6	15	34	45	100
Decreased mean temperature	1	1	3	5	10
Delayed on-set of rains	6	14	34	45	99
Early rainfall cessation	3	6	11	42	62
Increased rainfall amounts	4	3	12	21	40
Decreased rainfall amounts	2	13	22	45	82
Increased rainy days	0	3	11	20	34

Decreased rainy days	4	9	18	45	76
Increased drought frequency	4	12	29	45	90
Decreased drought frequency	1	1	3	0	5
Frequent heat waves	6	6	22	35	69
Increased floods	0	3	8	3	14
Decreased floods	2	0.0	2	4	8

During the first focus group discussion, one of the participants reported that;

"We have indeed experienced climate change in Mmanoko village, rainfall season is no longer predictable, it varies from season to season. We used to know that people plough in November but of late if you plough during that time, in the month of December, the heat will be so extreme that it destroys all that you have planted"

The FGD also confirmed the delay in onset of rains and therefore a shift in the ploughing and growing seasons as well as increased drought frequency. The focus group also revealed that in recent years, the area has been receiving heavy rains accompanied by huge hailstones destroying plants in the fields. The Agriculture Extension Officer also confirmed the varying rainfall amounts, increased mean temperatures and delayed onset of rains which have shifted from October to as late as mid-November. The officer also indicated that,

"The planting season in Mmanoko village begins at the end of November because the onset of rains is experienced in mid-November, and by mid-December the rainfall amount reduces, the whole of January it doesn't rain until towards the end of the month, which is also the end of the ploughing season".

The chairperson of the Village Development Committee also had this to say:

"Rain comes late, after the cropping season it rains again, yet the season is over, it's very unpredictable for instance, the recent rains were heavy with too much hail stones which destroyed people's watermelons and beans"

The FGD also observed that winter sets in too early with very cold temperatures. On the issue of floods, members of the focus group reported that they have never experienced floods as such but extreme and excessive heavy rainfalls than normal, a situation which has also been reported by the Government of Botswana (2020).

The observation made by farmers during the social survey, focus group and key informants are consistent with the findings or sentments of IPCC (2014) that the surface temperatures are projected to rise in the 21st century and very likely that the heat waves will be more frequent and of longer duration, and that extreme rainfall events will become more intense and frequent in many regions.

3.3 Impacts of Climate change and variability on arable farming in Mmanoko village

Decreasing rainfall trend in the area has had a significant impact on arable farming in Mmanoko village. The impacts of associated with climate change and variability are presented in Table 4. Increase in weeds, pests and diseases, decrease in crop yields, and change in planting seasons are the most common reported impacts. affecting many arable farmers depend on rainfed agriculture. Most od these impacts are similar to the impacts reorted by Statistics Botswana (2019) which include increase in pests, weeds and plant diseases, changes in cropping and harvesting seasons, shortened growth period, increase in the frequency of crop failure, and reduced crop yields.

Table 4. Perceive impacts of climate change and variability on arable farmers.

Reported main impacts	**Gender (n = 98)**

	Male %	Female %	Total
Increase in weeds pests & crop diseases	48	50	98
Change in cropping and harvesting seasons	49	45	94
Reduced crop yields	44	47	91
Plant rot	47	40	87
Poor plant growth	40	46	86
Increased frequency of crop failure	49	35	84
Soil erosion	32	27	59
Destruction of farm infrastructure	30	10	40

3.4 Currently used adaptation strategies in Mmanoko village

All the farmers reported that they have adapted to the effects of climate change and variability. The most common adaptation measures are: crop diversification (mixed cropping, crop rotation, intercropping), shifting of planting dates; the use of drought tolerant and early maturing crops (Figure 5). Farmers explained that the high adoption of certain practices such as crop diversification, shifting of planting dates, and use of drought tolerant and early maturing crops is due increased enrolment of farmers in some of the government support programmes. One such program is the Integrated Support Program for Arable Agriculture Development (ISPAAD) that aimed at increasing grain productivity and production through access to farm inputs and credit.

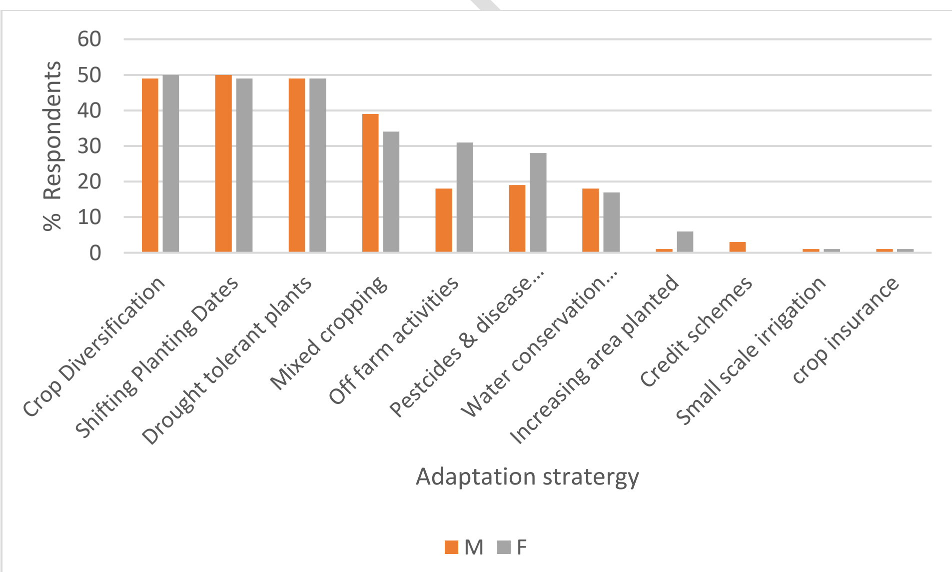

Figure 5. Adaptation strategies used by gender of arable farmers

Many of the adaptation measures reported in this study are similar to those practiced in small-scale crop farming in other parts of Africa. For instance in southwest Nigeria farmers mostly practice applied tillage methods such as ridging and terracing (Oyelere et al., 2020). In four selected communities in the Lawra district of Ghana, farmers ranked the use of improved crop varieties as the most important adaptation measures (Ndamani and Watanake, 2015). In Vhembe district, Limpopo Province of South Africa, farmers plant drought resistant crop varieties, shift from long season crops to short season crops, adjust their planting dates and use native crops based on indigenous indicators to forecast the weather (Zongho et al., 2023).

According to Juan et al. (2013), majority of small-scale crop farmers in Africa are quite aware of the changing climate and have generally implemented various adaptation measures such as crop diversification, planting different crop varieties, changing planting and harvesting dates and swictching to non-off farm activities. In this study the adoption rates for some of themse practices are higher than for others. For example, some farmers cited a lack of fundsas a constraining factor in using crop insurance. The FGD also revealed that some adaptation practices are not compatible with existing laws and policies. For istance irrigation farming may require farmers to have water rights, the application for which is a long process. The GD also revealed that farmers lacked skills, knowledge, and expertise in implementing some of adaptation strategies. In other parts of the African continent, such as in Ghana, Ndamani and Watanake (2015) reported high cost of farm inputs, limited access to weather information, and lack of water resources as the main critical limitations in adaptation. In the north-west region of Cameroon, lack of access to credit, household income and access to information were reported as factors limiting adaptive capacity (Awazi et al., 2021), while in Chengdu, China, unpredictable weather, limited farm size, scare water resources, high cost of farm inputs and insufficient information on weather information were the main limitations in adaptation (Picson & He, 2021).

3.5 Evaluation and prioritization of adaptation options for arable farming against climate change impacts

The results show that farmers rated the criterion (effectiveness, flexibility, campatibility and equity) equally important as they assigned the same and maximum weight of 10. Table 5 shows the results of the evaluation of the different adaptation strategies.

Table 5. Arable Farmers evaluation of adaptation options against evaluation criteria

Adaptation Option/Criterion	Effectiveness (10) [(a)]		Flexibility (10)		Compatibility (10)		Equity (10)		Totals	
	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Use of drought tolerant and early maturing varieties	5	50	3	30	5	50	5	50	18	180
Crop diversification	5	50	5	50	5	50	5	50	20	200
Shifting of planting dates	5	50	3	30	4	40	3	30	15	150
integrated farming	5	50	5	50	5	50	4	40	19	190
Use of fertilizers	3	30	5	50	5	50	1	10	14	140
Pest and weed management strategies	5	50	4	40	1	10	2	20	12	120
Water and soil conservation strategies (rainwater harvesting?)	5	50	2	20	1	10	1	10	9	90
Post-harvest storage	4	40	4	40	5	50	3	30	16	160
Cultivation more land	5	50	3	30	1	10	1	10	10	100
Small scale irrigation farming	5	50	5	50	2	20	1	10	13	130
Income diversification (increasing off farm activities)	3	30	1	10	4	40	1	10	9	90
Crop insurance	5	50	2	20	3	30	1	10	11	110
Credit scheme	5	50	1	10	4	40	2	20	12	120
Change of land use	1	10	1	10	2	20	1	10	5	50
Temporary relocation	1	10	1	10	1	10	1	10	4	40

NB: (a) () is the criterion weight assigned.

According to the results, crop diversification (intercropping, mixed cropping and crop rotation) was the only adaptation strategy assigned the highest score of 5 in terms of effectiveness, flexibility, compatibility and equity, while temporary relocation was scored very low (1) for each of the four criteria. Adaptation strategies such as irrigated farming, though viewed as effective and flexible, may only be accessed (equity) by arable farmers who are highly resourced because these practices require development of some instructure.

During the focused group discussions farmers indicated that some adaptation strategies, such as the use of drought tolerant and early maturing plants, are not compatible with the prevailing environmental conditions. Farmes also noted that practices such as water and soil conservation strategies, cutivating more land and shifting planting dates, are not compatible with existing laws. For instance, cultivating more land was scored low (1) for compatibility with existing laws, and (1) for equity due to the long process involved in obtaining and in accessing land rights). Shifting planting dates was rated highly effective (5) but scored low for flexibility (3) and equity (3) as they are dependent on the stipulated guidelines for the Government programmess such as the ISPAAD. According to Regmi & Pandit (2016), farmers are more likely to consider the adaptation strategies to be compatible where there are conducive and available supporting structures in place. Overall, the evaluation of various adaptation strategies by farmers is consistent with findings reported earlier that existing laws may enhance or inhibit effective adaptations (McCathy et al., 2001; Regmi & Pandit, 2016)

The rankings of the preferred adaptation strategies, based on the weighted sum, are shown in Table 6. Thus, the highest ranked adaptation strategy is the is regarded as the most effective in reducing the vulnerability of the farmers to the imacts of climate change and variability in Mmanoko village.

Table 6. Total weighted scores and ranks for the different adaptation options.

Adaptation option	**Total Weighted score**	**Priority Rank**
Crop diversification	200	1
Integrated farming	190	2
Drought tolerant and early mature varieties	180	3
Post-harvest storage	160	4
Shifting planting dates	150	5
Use of fertilizers	140	6
Small scale irrigation	130	7
Credit scheme	120	8
Pest & weed control techniques	120	8
Crop insurance	110	9
Ploughing more land	100	10
Increase off-farm activities	90	11
Water and soil conservation strategies	90	11
Change of land use	50	12
Temporary relocation	40	13

The implication of prioritizing or ranking adaptation strategies is that having a variety of available adaptation strategies does not necessarily translate into them being adopted and implemented by all farmers. The prioritization of locally suitable adaptation strategies ensures that they are accepted or embraced by stakeholders in addressing their needs in their locality. In addition, priotization helps to determine or assess if there is any relationship between scientifically recommended adaptation strategies in crop production and those that are utilized or preferred at the local level. This is particularly so as adaptation requirements are highly different, dynamic and location specific (Regmi & Pandit, 2016).

The evaluative framework used in this study and the results thereof provide planners and decision makers with direction on which proposed adaptation strategies they should pursue when planning for arable farmers in Mmanoko village, as also reported by Dolan et al. (2001) and Van Ierland et al. (2013). Thus, it provides information or feedwork on what works and what doesn't, and what adjustments should be made for adaptation practices to work. For instance, the Government of Botswana, in its National Agriculture Plan (NAP) of 2014 and the National Adaptation Plan Framework (NAPF) of 2020, advocates for integration of adaptation to climate change at all levels but does not indicate which adaptation strategies would be promoted or implemented in each location such as Mmanoko village. It is therefore critical that adaptation strategies are assessed based on their appropriateness and suitability for the specified location before they are adopted or implemented

5. CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that arable farmers in Mmanoko village are currently feeling the brunt of climate change and variability effects on their livelihoods. The main impact is reduced crop yields owing to poor plant growth and rot, proliferation of weeds, pests and crop diseases, soil erosion and loss of soil nutrients. Arable farmers attributed these impacts to increasing temperatures and rainfall variability.

Farmers adaptation strategies to climate change and variability include crop diversification, changing planting dates, mixed cropping, use of drought tolerant and early maturing crops, use of fertilizers, and engaging in off-farm activities such as drought relief program and miniature jobs. The adoption rates of strategies such as crop insurance, use credit schemes, small-scale irrigation and the cultivation of more land, were low due to challenges such as lack of capital and technology.

The Multi Criteria Evaluation resulted in the following order of preferred climate adaptation measures: crop diversification, mixed cropping, use of drought tolerant and early maturing varieties, post-harvest storage and shifting planting dates. These adaptation strategies were considered to be effective, flexible, compatible and equitable. It is therefore crucial for policy and decision makers to use an integrative and inclusive approach in assessing and prioritizing the proposed adaptation strategies before implementating them.

Based on these findings, the Department of Crop Production should develop and implement robust extension support services for arable farmers particularly on the management and control of new crop pests, diseases and weeds as well as expertise to implement climate smart agricultural practices and technologies.

Both the departments of Crop Production and Meteorological Services should jointly increase farmers' education, awareness programs and information dissemination on climate change and possible adaptation options. The Department of Meteorological Services, in particular, should increase efforts in research and the provision of relavant forecasted climate related information to the Department of Crop Production and farmers for effective adaptation. Furthermore, these departments should put in place local level frameworks and institutions that support investments in crop production adaptation to climate change as well as facilitating engagements between arable farmers and private sector to increase farmers adaptive capacity. To support this initiative, the government should build partnership with the private sector to solicit financial and investment support to enable farmers to adapt accordingly.

Farmers should be involved in the selection and implementation of adaptations measures as they have wealth of knowledge and experience of the local environment. Their participation would be particularly important in the review of climate change related policies such as the National Adaptation Plan Framework. Furthermore, there should be deliberate effort to support research in the development of local specific climate adaptation measures such as new crop varieties and seeds that are drought and heat resistant.

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