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Nomcebo R Ubisi, Paramu L Mafongoya, Unathi Kolanisi, Obert Jiri*

Smallholder farmer's perceived effects of climate change on crop production and household livelihoods in rural Limpopo province, South Africa

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Abstract: This study investigated the perceived effects of climate change on crop production and household livelihoods of smallholder farmers in Mopani and Vhembe district, South Africa. Data was collected through a questionnaire administered to 150 smallholder farmers. The questionnaires were complemented by 8 focus group discussions and secondary data. Multinomial logit regression model was used to analyse the factors influencing smallholder farmers' choice of climate change adaptation strategies. The study findings revealed that subsistence farmers perceived prolonged droughts (56.4%) as the main shock stressing crop production. Droughts often lead to low crop yield and high crop failure (73.3%). In response to the prevailing climatic conditions different gender adopted different strategies, 41% of female farmers adapted by changing planting dates, while male farmers employed crop variety and diversification (35%) and mixed cropping (15%). The smallholder farmers were vulnerable with limited adaptive capacity to withstand climate change due to compromised social, human, physical, natural and financial assets. The results showed that smallholder farmers tend to adapt better when they have access to extension officers ($P<0.01$). Therefore, it is important for the government to strengthen the relationship between smallholder farmers and extension officers for better climate change adaptation.

Keywords: Smallholder farmers, climate change, adaptation, livelihoods, food security

***Corresponding author Obert Jiri,** Faculty of Agriculture, University of Zimbabwe, P. O. Box MP167, Mt Pleasant, Harare, Zimbabwe, E-mail: obertjiri@yahoo.co.uk
Nomcebo R Ubisi, Paramu L Mafongoya, Unathi Kolanisi, Obert Jiri, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa

1 Introduction

Climate change threatens various sectors of economic development including natural resources, agriculture and food security, forestry, tourism, manufacturing and health [1,2]. The effects of climate change are characterised by changes in rainfall variability, increasing number of seasons without enough rainfall and increased temperatures which lead to extensive droughts and heat stress lowering crop productivity [3,4,5] The African continent is already suffering from food insecurity and malnutrition, [1] highlighted that about 23 million people in 11 African countries are affected by acute food insecurities and facing malnutrition. Climate change in this continent exposes smallholder farmers to worse hunger scenarios [6].

Climate change and variability has negatively affected the well-being of most rural smallholder farmers through its adverse impacts. Smallholder farmers in rural areas have been experiencing low agricultural productivity, crop failure, human disease outbreak, pest and diseases, lack of water, shortages of agricultural-based food items at a household level and food insecurities [7]. These impacts have posed a huge threat to food security and livelihoods of most farmers around the world compromising the well-being of rural smallholder farmers, as most rural smallholder farmers depend on natural climatic sensitive resources such as agriculture for their livelihoods [8]. Therefore, climate change and variability has been seen as a threat to their agricultural production which is mostly rain-fed [9]. Climate change and variability is set to hit the agricultural sector the most severely and cause suffering, particularly for smallholder farmers [5,10,11].

Agriculture is the largest known sector to be greatly impacted by climate change and variability because of the size and sensitivity of the sector [12,13,14]. According to [13] the extent of damage by climate change to African agriculture will depend on future climatic scenarios, as well as the type and level of inputs used for agricultural

production. Studies have revealed that the African continent is most likely to be affected by climate change and variability with prolonged droughts, reduced rainfall and increased temperature [15]. [12] highlighted that the impacts will not be the same across the continent, the western, central and southern Africa areas are most likely to experience hotter and drier seasons. Climate change variation could bring both negative and positive effects as climate change is affecting the agricultural sectors of different countries in different ways. According to [14], the negative effects of climate change pose a great potential to result to extensive livelihood losses especially for smallholder farmers in all countries since they depend mainly on agriculture as their main source of livelihood [9]. [16] supports this argument by highlighting that there are frequent droughts that have been observed over the past decades reduce soil moisture and water resources for plants, consequently resulting in severe water stress. Reduced soil moisture hinders plant growth in non-irrigated agriculture.

Smallholder farmers, particularly rural or communal farmers, are vulnerable to the effects of climate change due to their marginal location, low levels of technology, limited access to climate information and lack of other essential farming resources resulting in increased vulnerability and food insecurity [17]. According to the Intergovernmental Panel on Climate Change, vulnerability is a function of exposure to climate change and variability, sensitivity to climate shocks and stresses, and adaptive capacity [18]. Therefore, it is important for smallholder farmers to be aware of the effects of climate change and variable weather patterns, so that they can employ coping and adaptation measures such as planting different varieties of the same crop, mixed cropping and water conservation practices [14,19]. Coping and adaptation methods used by farmers are measures that are relatively inexpensive such as changing planting dates and diversifying crops, while those that are costly or require more capital such as irrigation systems were used by very few smallholder farmers [14,20,21]. However, [22] emphasised that these adaptation measures can only be achieved through smallholder farmers themselves taking adaptive initiatives or by governments implementing policies.

The impact of climate change will bring substantial losses especially to smallholder farmers whose main source of livelihood derives from agriculture. Such impacts can be significantly reduced through adaptation of appropriate strategies. Given the high dependence on rain-fed agriculture and prevailing drought conditions in semi-arid regions such as Limpopo [23], the area may be quite vulnerable to the current and future climatic changes. [24] revealed that there are well-established concerns of climate change in South Africa, however, there is little information on the negative effects of climate variability on the well-being of smallholder farmers. This study, therefore, aimed to investigate the effects of climate change on the well-being of smallholder farmers in rural Limpopo province, South Africa.

2 Materials and Methods

2.1 Description of the study area

The study was carried out in Limpopo province, South Africa, within two district municipalities namely Mopani (23.3167^0 S, 30.7167^0 E) and Vhembe (22.9333^0 S, 30.4667^0 E) (Figure 1). The Mopani District is situated in the North-eastern part of the Limpopo Province covering an area of about 25 344, 13 km^2 in the province, with farming as the second largest employer in the district. However, this district is characterized by low rainfall (between 400mm to 900mm per year), resulting in limited water resources causing severe water shortages and regular drought conditions particularly in the lower-lying areas of the district. Vhembe district is located in a semi-arid area that is frequently affected by dry spells, often growing into severe drought. The district is the most northern district of Limpopo province with a rainfall pattern ranging between 246mm to 681mm per annum. Vhembe district covers an area of about 25 592 km^2 which is predominantly rural, with a population size of about 1, 294,722 people. As reported by the [23] the two district municipalities were the most vulnerable to climate change experiencing extreme climatic risk as well as high climate variability in the province.

2.2 Data Collection

Both quantitative and qualitative methods were used to collect data in the study. The quantitative research method was used to compare responses across the respondents. On the other hand, the qualitative research method was used to seek understanding of the farmer's perspective or situation by regarding the respondents as experts of their situation. This methodology was found appropriate for this study because the study aimed to investigate experiences of farmers with regards to the impacts of climate change and variability on smallholder farmer's livelihoods and food security.

A representative population of 150 smallholder farmers in Mopani and Vhembe participated in this study.

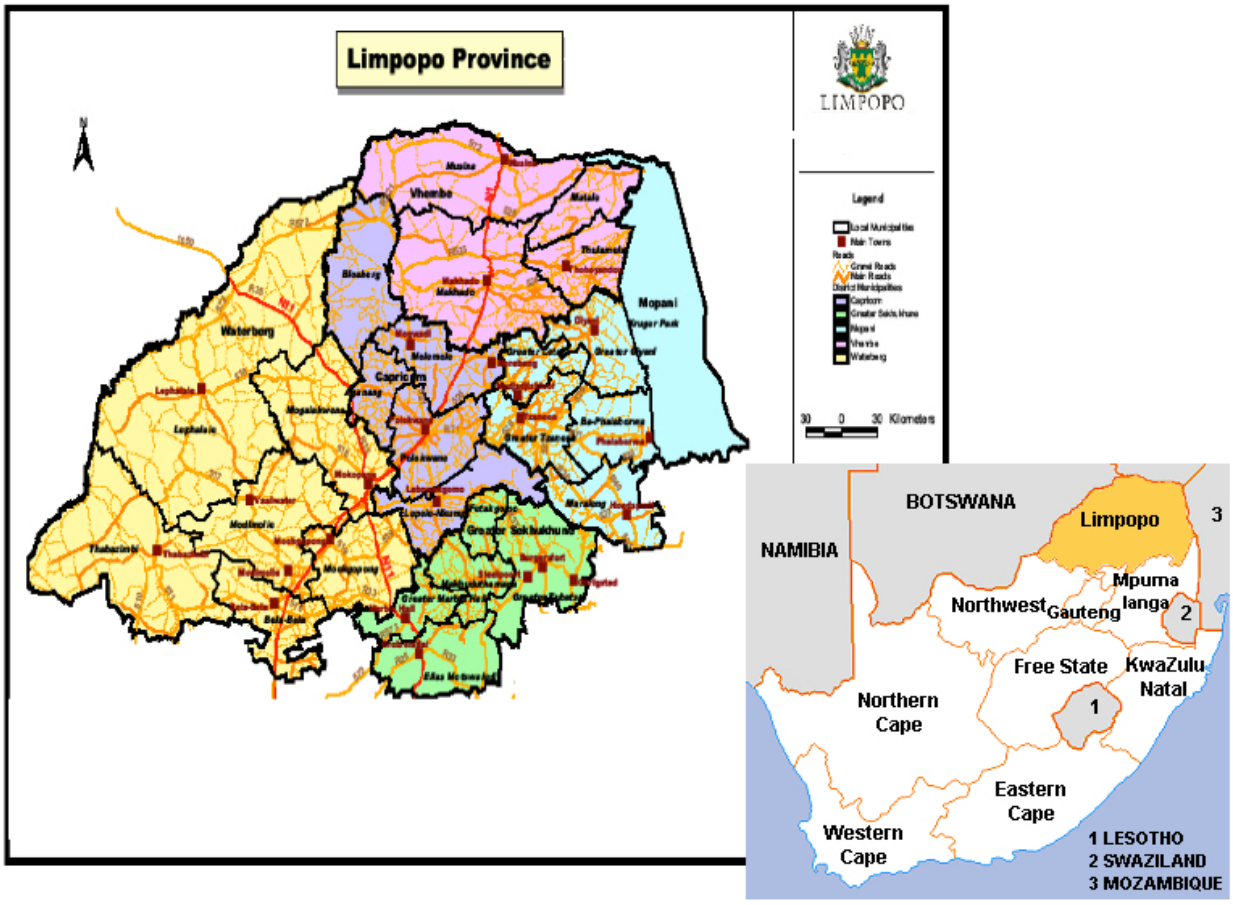

Figure 1.

The local extension officer of each local municipality provided a list of households and the smallholder farmers were randomly selected from each local municipality. The extension worker selected every fifth household in their area for administering the questionnaire. Focus group discussions participants were also selected to be representative of the youths, women, elderly and cheer leaders in both communities.

2.3 Data analysis

A Statistical Package for Social Sciences (SPSS) version 23.0, Microsoft excel 2010 statistical package and STATA version 8 were used for questionnaire data analysis. Focus group discussions and secondary data were analyzed through content analysis by identifying themes, concept, patterns and trends. Multinomial logit regression model was used to analyse the factors influencing the choice of climate change adaptation strategies by smallholder farmers. The estimation of the multinomial logit regression model was made analyzing several variables while normalizing one variable (reference or base category). This model specification was used by several researchers to model climate change adaptation practices of smallholder farmers in Africa [10,22]. In this study, the category "not adapting" to climate change variability was used as the reference category. A brief description of the explanatory variables used in the multinomial logit model is provided in Table 1.

2.4 Empirical model

Multinomial logit regression model (MNL) was used to analyse the factors influencing smallholder farmers' choice of climate change adaptation strategies. MNL model for choice of adaptation strategies specifies the relationship between the probability of choosing an adaptation option and the set of explanatory variables [25]. It was established that the sampled smallholder farmers were following three adaptation strategies namely: crop and variety diversification, changing dates of planting

Table 1: Variables used in the multinomial logit model to explain participation status

Independent variable	Description
Age	Continuous variable for farmers age
Gender	Dichotomous; 1 if individual is male and 0 otherwise
Marital status	Dichotomous; 1 if individual is married and 0 otherwise
Education	Continuous The level of household head's formal education
Farming	Dichotomous; 1 if farming is the main source of income and 0 otherwise
Years of Experience	Continuous variable for household head's age
Land Fertility	Dichotomous; 1 if land is fertile, and 0 otherwise
Extension Availability	Dichotomous; 1 if extension services are available to farmers, 0 otherwise
Climate awareness	Dichotomous;1 if smallholder farmers were aware of climate change, 0 otherwise
Reliability	Dichotomous;1 if they rely on farmer to farmer for climate information and 0 otherwise
Rainfed	Dichotomous;1 if smallholder farmers rely on rain fed irrigation, and 0 otherwise
Training	Dichotomous;1 if access to extension services, and 0 if no extension services
Hectares	Dichotomous;1 for hectares greater than 1 and less than 2.5ha, and 0 otherwise

and mixed cropping. There were also those who were not practicing any adaptation strategies. The MNL model was specified as follows:

The dependent variable was the participation status (1 = not adapting; 2 = crop and variety diversification; 3 = mixed cropping; 4 = change planting dates).

Letting P_j (j = 1,2,3) be the probabilities of a smallholder farmers being in each adaptation strategy and assuming that j =1 is the reference category, the multinomial logit model showing the relative probabilities of being in the three participation categories as a linear function of X_{ki} for the i^{th} household, according to [26], is estimated as:

$$\ln (P_j/P_1) = \log (P_j/P_1) = \beta_{0j} + \beta_{1j}X_{1i} + \ldots \beta_{kj}X_{ki} + u_{ji}$$

For j = 2, 3 and i = 1, 2...n farmers where:
ln = the natural logarithm (or $\log_e$)
P_1 = the probability of the smallholder farmers being in the reference category (Not adapting);
P_2 = the probability that the smallholder farmers diversifying crop varieties
P_3= the probability that the smallholder farmers are adapting mixed cropping
P_4 = the probability that the farmers change planting dates
β_{kj} are the MNL coefficients to be estimated and,
X_{ki} is the k^{th} explanatory variable explaining the i^{th} farmers

3 Results

3.1 Vulnerability of smallholder farmers to non-climatic and climate change shocks

Smallholder farmers in this study were affected by both climatic shocks and non-climatic shocks. The smallholder agricultural sector was mainly dominated by elderly women (64%) of which 40% were between the ages 60 to 69 years and 60% of these women had no formal education. Ninety four percent of the households were headed by men and 44% of the men had no formal education. Most of the farmers had income of $100 or less per month mainly from farming and pensions (Table 2).

According to the respondents the climate change had a negative effect on their household food security status due to crop losses experienced over the years. Female farmers (54%) were found to be more vulnerable as they reported to have experienced very severe losses of agricultural based food over the past 10 years whereas the losses for male farmers were moderately severe (46%) (Table 3).

Table 4 revealed the different farmers with different experience of climatic shocks over the past ten years. Prolonged droughts were observed to have increased as well as very hot seasons. About 7.4% of the subsistence

Table 2: Smallholder farmers' sources of income in Limpopo province, South Africa

		Gender (%)	
		Male	**Female**
Total household income per month ($)	Below 50	19	16
	51 - 100	52	64
	101- 200	20	11
	Above 200	9	9
Source of income	Pension	31	43
	Farming	57	44
	Part-time job	6	2
	Remittances	0	1
	Social grant	6	10
Total % for the different Gender		36	64

Table 3: Perceived crop production losses and coping strategies by smallholder farmers in Limpopo

		Gender (%)	
		Male	**Female**
How severe has the crop loss been over the past 10 years?	Very Severe	52	54
	Moderately severe	46	38
	Not severe	2	7
How did you cope with these shortages?	Eat less food	37	26
	Change diet	22	35
	Borrowed money	19	18
	Received food from relatives	13	11
	Sent older children away to work	9	9
Total % for the different males and females in the study		36	64

Table 4: Climatic shocks observed by smallholder farmers

Type of Farmers	Floods	Prolonged droughts	Very hot seasons	Haven't observed any changes
Subsistence farmers	7.4%	56.4%	29.8%	6.4%
Farming for selling and consumption	0%	44%	56%	0%
Food producers	3.2%	41.9%	54.8%	0%

farmers observed increase in floods, but a few farmers stated not to have observed any climatic changes.

Different gender adopted different adaptation strategies better (Table 5). Male smallholder farmers adapted by employing crop variety and diversification better than female farmers. Female smallholder farmers employed the changing dates of planting strategy better than male farmers, which involved delaying the common planting season. Male farmers preferred mixed cropping better than female farmers and they seemed to adapt better than female farmers in this study area.

Multinomial logistic regression analysis was estimated to determine the factors influencing a smallholder farmers' choice of adaptation strategies to cope with the impacts of climate change (Table 6). The results indicated that farming as a source of income for smallholder farmers has a negative impact on improving crop varieties and diversification for farmers. Being aware of the changing climate has a positive significant impact on the adaptation of changing planting dates ($P<0.05$)

Table 5: Awareness and adaptation strategies to climate change of smallholder farmers in Limpopo

		Gender (%)	
		Male	**Female**
Have you ever heard about climate change?	Yes	56	35
	No	44	65
Level of Education	No Formal education	44	60
	Primary	22	24
	Secondary	28	15
	Tertiary	6	1
What adaptation measures have you used to deal with the changes in temperatures?	Crop and variety diversification	35	21
	Changing dates of planting	39	41
	Mixed cropping	15	10
	None	11	28

Table 6: Multinomial logistic regression estimates for the choice of adaptation strategies

Adaptation	**Crop and variety**			**Changing planting dates**			**Mixed cropping**		
	Coef.	**Std. Err.**	**P>z**	**Coef.**	**Std. Err.**	**P>z**	**Coef.**	**Std. Err.**	**P>z**
Age	-0.21	0.35	0.55	0.28	0.36	0.43	0.61	0.44	0.16
Gender	-0.83	0.78	0.29	-0.46	0.79	0.56	0.07	1.00	0.95
Marital status	-0.26	0.63	0.68	-0.38	0.65	0.57	-0.53	0.82	0.52
Education	0.56	0.44	0.20	0.63	0.44	0.15	0.37	0.56	0.51
Farming	-1.45*	0.81	0.07	-0.51	0.85	0.55	-1.10	0.94	0.24
Long	-0.24	0.33	0.47	0.12	0.32	0.70	-0.66	0.42	0.12
Fertile	0.46	0.61	0.45	0.37	0.61	0.55	0.66	0.76	0.39
Extension	0.66	1.01	0.52	0.89	0.96	0.36	-0.14	1.50	0.92
Climate awareness	1.99**	0.75	0.01	2.51***	0.76	0.00	1.61*	0.96	0.09
Reliable	0.33*	0.19	0.09	0.27	0.20	0.17	0.05	0.24	0.83
Rainfed	-0.17	0.78	0.83	-1.03	0.72	0.15	-1.28	0.92	0.16
Training	-0.17	1.05	0.87	16.94	1499.71	0.99	-0.46	1.22	0.71
Hectares	0.77	0.60	0.20	-0.42	0.53	0.43	1.25*	0.72	0.08
_cons	-0.69	2.51	0.78	-17.04	1499.71	0.99	-2.80	3.07	0.36

*** = values statistically significant at 0.01 probability level, ** = values statistically significant at 0.05 probability level, * = values statistically significant at 0.10 probability level

Base category: not adapting

Number of observations: 150

and mixed cropping (P<0.05) because farmers are always updated on what is happening around.

Table 7 shows that the adaptation capacity of the smallholder farmers on human capital was affected by the low level of education within the farmers, since a majority of the smallholder farmers had no formal education (54.7%) and the active group was mostly old people between the age of 60-69 years, so it was hard for the farmers to search or read about climate change as only 8.7% had access to the internet (social networks) and

only 30% had access to social groups, this shows how the social capital is affected in the area. Another limitation to the physical capital was lack of access to physical infrastructure, as only 3.3% had access to irrigation schemes. Limited access to climate interventions (20.7%) and support services (6.7%) was also seen as a negative factor that hindered the farmers' adaptive capacity as well as lack of drought tolerant crops. About 23.4% of farmers had access to water from rivers and dams, these findings reveal that if there is no rain then these farmers do not have access to water for irrigation. The financial capital for the smallholder farmers was very unstable as only 0.7% of the farmers had access to insurances to help them recover in case of disasters, meaning that if a disaster happens 99.3% of the farmers would lose all the crops and did not have money to recover as only 3.3% have part-time jobs with the rest mainly depending on farming for income (Table 7).

The respondents also highlighted that the climate change effects had a negative effect on the socio-economic aspects of the smallholder agricultural production and on their emotional status (Table 8).

Table 7: Livelihood assets and adaptation capacity of smallholder farmers' in Limpopo

Livelihood assets	Description of sensitivity and vulnerability of the smallholder farmers
Human	65% of female smallholder farmers have never heard of the concept climate change 56% of men revealed to have known about climate change. 76% were in good health to enable labour 54.7 %have no formal education
Social (clubs)	8.7 % only had access to social networks 30% only had access to social groups and these were mainly women
Physical	3.3% of farmers who have access on Irrigation infrastructure, 10.7% Access to drought tolerant seed 20.7% Access to interventions 6.7% Access to support services
Natural	23.4% access to rivers and dams 42% only had productive land and these were mainly the farmers who were producing for the market
Financial	0.7% access to Insurance 3.3% Access to diversified income sources (part-time jobs)

Table 8: Negative effects of climate change on smallholder farmer's well-being

Theme	Concepts	Quotes
Socio-economic effect on agricultural production	Declining crop yields	*"Our production yield have dropped, so we experience food insecurities"*
	Increased water scarcity	*"there is no rain, hence no water, no crops"*
	Increased new pest &disease invasions	*"We keep on losing our crops due to new pests in our fields such as aphid attacks"*
Emotional Effect	Loss of Hope	*"We keep on losing our crops"*
	Fearful	*"If these prolonged droughts persist and there's no rain, we are afraid we will die of hunger and food insecurity"*
	Helpless	*"The issue of climate change is beyond our control, there's nothing we can do"*
Food and nutrition security status	Food availability and access compromised	*" We have not planted because there are no rains"* *" Last year we did not plant we were waiting for rains, and we suffered"*

4 Discussion

4.1 Vulnerability of smallholder farmers to non-climatic and climate change shocks

The gendered trends in this study concur with previously reported active involvement of women in smallholder agriculture activities as they bear the primary role of providing food for the family [27]. The findings also confirmed that the smallholder agriculture is dominated by older women. These are women who are the custodians of farming knowledge, therefore, if agricultural development and climate change interventions as support systems are to be designed, the dominance of the older women generation and their knowledge should be considered for future engagement of women in farming. On the other hand, as shown by [28], the dominance of older women in farming could indicate limited physical abilities (prone to illnesses), less adaptability and reluctance to move away from the 'norms'. Therefore, labour saving technologies need to be prioritized in smallholder farming communities.

[28] stated that the low education level trends are a hindering factor in accessing relevant information from various media sources. Furthermore, limited education of both men and women poses a constraint to job opportunities thus weakening household economic status and it even threatens future development interventions.

Cash income for the smallholder farmers was obtained from selling farm produce (Table 2). [29] concluded that smallholder farmers use agricultural production as the cornerstone of their livelihoods. They practice other activities, in addition to farming, such as wage labour, making crafts or petty trading for income generation. These findings are also similar to what was revealed by [30] that in most rural areas farmers used a variety of livelihood strategies such as wages, salaries, social grants and pension remittances.

4.2 Household food security and coping strategies

To deal with impacts of climate change and variable weather, the smallholder farmers have different coping and adaptation strategies. Eating less food was the most practiced strategy among male farmers (37%) so to make sure there was enough for the rest of the family and for female farmers they coped by changing their diet (35%). These results show a negative effect on the food security status of the smallholder farmers, because food was neither always available nor accessible, therefore, could not utilize their preferred meals and there was also a lack of stability (Table 3). Therefore, the four pillars (availability, accessibility, utilization and stability) of food security were compromised among these farmers negatively affecting livelihoods [31]. While not all vulnerability is attributable to climate change and variability, climate change has definitely exacerbated the already existing vulnerabilities in the Province. Climate vulnerability has exposed them to increased food insecurity and poverty, and consequently to limited and compromised livelihood options since farming is their main source of income. Identified factors such as the age, health status, level of education and gender seemed to be the major factors that exacerbated the smallholder farmers' vulnerability to climate change, exposing them to food insecurity and reducing the viability of livelihoods.

4.3 Smallholder farmers climatic shocks observations

Smallholder farmers in the study areas were exposed to a number of shocks and stresses that affects their livelihoods. The farmers highlighted that they have been experiencing prolonged droughts, heat waves, increased dry seasons and reduced rainfall seasons which led to frequent livestock deaths, human disease outbreaks, crop failure, reduced yield and food insecurities over the past 10 years (Table 4). This was also highlighted by the key informants of the local municipalities. The subsistence farmers (Table 4) perceived prolonged droughts (56.4%) as the main shock stressing their production whilst other farmers were of the opinion very hot seasons were the significant shock (56% and 54.6%). These results are supported by [32] who observed that smallholder farmers perceived droughts and increased temperatures to be the major problems brought about by climate change in southeastern Zimbabwe.

4.4 Awareness and adaptation strategies to climate change of smallholder farmers in Limpopo

These findings revealed that most of female smallholder farmers (Table 5) are not adapting very well to climate variability, because a high proportion were not aware of it, hence it was difficult for them to employ adaption strategies. Lack of support services to disseminate climate information and high level of illiteracy (60%)

among smallholder farmers might be other hindering factors for them, since they would be unable to read and understand (e.g. weather forecast) and keep up with what is happening around them. Poor adaptation strategies put the well-being of the smallholder farmers at risk, because they find it difficult to cope. Therefore, farmers need support systems that will disseminate information about climate change and keep them updated in order for them to respond to the climatic threats [33]. These results also show that the climate change is perceived differently by men and women, and they adapt differently to its effects. Therefore, climate change interventions and support systems should take special attention of the gender dynamics [34].

4.5 Determinants of farmers' choice of adaptation strategies to climate change

Multinomial logistic regression analysis indicated that farming as a source of income for smallholder farmers has a negative impact on improving crop varieties and diversification for farmers. Similar conclusions were made by [35] that being a smallholder farmer with little surplus income hinders the expansion of some climate change adaptation strategies. This means that it is not easy for smallholder farmers to employ adaptation strategies based on their income from farming, because income alone without awareness will not assist them to adapt better. The adaptation options for smallholder farmers are also determined by the farmers' awareness of climate change. The study findings highlight that being aware of climatic change variability has a positive significant impact towards adapting to crop variety and diversification. Smallholder farmers who are aware of climate change have a high probability of employing combination of adaptation strategies. Indeed, it is an important precondition for farmers to take up adaptation measures [36]. The findings (Table 6) further reveal that access to extension services for climate change information increases the likelihood of smallholder farmers adapting to new crop variety and diversify their enterprises. This is because access to extension service assists farmers through educational trainings; help them improve their farming methods and techniques through the provision of up-to-date information [37]. The study findings are similar to [38] found in Ethiopia, that having access to extension services increases the probability of using improved crop variety and soil and water conservation techniques. Extension officers are most likely to influence decision of farmers to use other type of adaptation strategy to cope up with adverse impacts of climate change. Access to land size greater than 1 ha and less than 2ha has a positive and significant impact on the likelihood of using mixed cropping strategy by 0.08%.

4.6 Livelihood assets and adaptation capacity of smallholder farmers' in Limpopo

Table 7 reveal that the adaptation capacity of the smallholder farmers on human capital was affected by the low level of education. The active group was mostly old people between the age of 60-69 years, so it was hard for the farmers to search or read about climate change as only few had access to the social media platforms. The study findings reveal that the adaptive capacity of the smallholder farmers is determined by the five livelihood assets, therefore, lack of assets make it hard for farmers to easily adapt to the climatic variability and change. This agrees with [39] who also concluded that most households use adaptation strategies linked to livelihood diversification to adapt to the increased climate variability seen in recent decades. Most households now engage in multiple non-arable farming livelihood activities in an attempt to avoid destitution because of crop failure linked to climate variability (particularly drought).

4.7 Negative effects of climate change on smallholder farmer's well-being

During focused group discussions, the farmers confirmed that this climate variation was getting worse each year: *"We have not received any rain since beginning of January this year"* and the dry spells were reported to be worsening compromising their well-being. As mentioned by the smallholder farmers the climate change over the past few years has resulted in prolonged droughts, reduced rainfall and very high temperatures which resulted in low crop yields. The smallholder farmers stated that lack of water for irrigation was another major challenge so the negative changes in rainfall patterns affected their livelihoods, because they end up delaying their planting seasons in anticipating for rainfall until it is too late in the season to plant. These findings support the [23] that Limpopo province has been experiencing extreme droughts, heat waves and reduced rainfall. These negative climatic effects compromise the well-being of the farmers as they experience food shortages. Due to the erratic temperature changes and unpredictable rainfall the respondents have observed new pest and disease

invasions. The farmers highlighted the "aphid attacks" of cabbage as one of the troublesome pests. The farmers have also noticed these invasions in summer during hot seasons. Similar results were highlighted by [5] that smallholder farmers' production systems are directly threatened by the increasing temperatures that cause heat stress on plants, reducing water availability, lowering overall productivity and introducing new pests and diseases. According to the report by the [1] the invasion of crops by pests and diseases were caused by the rising temperatures and changes in precipitation patterns. Therefore, the increasing temperatures result in great loss of smallholder farmers' crop production. As some farmers highlighted during the FGDs even their indigenous ways of controlling pests seemed to be less effective, subsequently the new invasions infer some economic demands and unfortunately their knowledge seems to be limited on how to manage and control the pests (aphid attacks).

The negative effects of climate change have been seen to also affect the farmers emotionally (Table 8). The prolonged droughts resulted in some of the farmers losing hope since they lost almost everything the previous year and it was still hard for them to recover from the loss. The farmers highlighted that they were aware of their vulnerability status towards climate as they are highly exposed to the negative impact of climate change mainly rainfall shortages (drought). The farmers also stated that they are now more confused and living in fear, as they are not sure whether to continue farming or not, since there is less rain due to prolonged droughts. These farmers greatest fear is that the agricultural sector is the driver of their well-being, so they are bothered as unfavourable weather threatens their food security status and limits their livelihood options. The smallholder farmers highlighted that there is willingness to progress and to adopt strategies that will mitigate the climatic stresses and threats. However, they feel like the situation is beyond their control, thus feeling helpless since their indigenous knowledge which is cost-effective and most accessible seems to be outdated. More so, there is limited or inadequate support systems provided to face the climatic risks.

5 Conclusions and recommendations

The study findings revealed that climate change has a negative effect on smallholder farmers' livelihoods. Farmers have experienced extreme weather events such as droughts and reduced rainfall, yielding a negative effect in their crop production since there were lot of crop failures events due to prolonged droughts. The smallholder farmers worked around this situation by employing some coping strategies such as, eating less food a day, changing diet, borrowing money and some received food parcels from their relatives. Despite these diversified livelihood strategies, the smallholder farmers still remained vulnerable to poverty and food insecurity because their livelihoods are dependent of rainfed agriculture. This situation indicates the sensitivity of smallholder farmers to climate change and variability as agriculture is their main source of income and their livelihood option is farming. Different gender among the smallholder farmers employed different adaptation strategies such as crop variety and diversification, mixed cropping which was mainly adopted by male famers and changing planting dates employed mainly by female farmers as a way of mitigating the climatic risks. Explanatory variables that were significant in influencing choice of smallholder farmers when adapting to climate change were, farming as the main source of income for sustaining their livelihoods, climate change awareness, reliance on extension officers as a source for climate change information who are unfortunately lacking climate change knowledge and are supposed to provide support systems and interventions. Therefore, the government needs to ensure that the identified adaptation strategies are promoted and supported to help mitigate the climatic risks, and the interaction between smallholder farmers and extension officers should be strengthened. There is also a need to train extension officers on climate change and adaptation strategies, as well as other conservation agricultural practices so they could also disseminate correct and accurate information to the farmers, for better adaptation and improve well-being of farmers. Climate change and variability should be mainstreamed into food and nutrition security related policies, plans and programmes, and the engagement of youths to overcome "the energy crisis" and literacy problem to access climate change information should also be encouraged.

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