S. Afr. J. Agric. Ext. Ndlovu & Zenda
Vol. 52 No. 2, 2024: 159-177
10.17159/2413-3221/2024/v52n2a16282 (License: CC BY 4.0)

The Impact of Climate Change on Food Security and Natural Resource Management in Smallholder Crop Farming Systems at Mthonjaneni Local Municipality, Kwazulu-Natal, South Africa

Ndlovu, N.[1] and Zenda, M.[2]

Corresponding Author: N. Ndlovu. Correspondence Email: ndlovunosipho331@gmail.com

ABSTRACT

This study assessed the impact of climate change on food security and natural resource management on crop farming systems. Forty-five respondents were interviewed using an open-ended, and structured questionnaire. The open-ended questions allowed respondents to share their thoughts and experiences in their own words, while the structured questions helped to ensure that all respondents were asked the same questions and that the data collected was consistent. The results of this study showed that smallholder farmers perceived an increase in hot days (51.1%), a decrease in rainfall (51.1%), and a decrease in flood occurrence (71.1%). In addition, 95.2% of the respondents indicated that climatic conditions have influenced their farming systems. Natural resource changes noticed by farmers because of climate change include reduced grazing feedlot for livestock farmers (85%), reduced herbaceous cover (80%), decline in volume of water (57.8%), and increased tree damage and land degradation (11.1%). Increased soil erosion (6.7%) and increased bush encroachment (2.2%) were some of the natural resource challenges facing smallholder farmers. Some signs of climate change experienced by farmers included increases in crop pests (71%) and crop disease (8,9%). The adaptation strategies applied included the following: use of water harvesting, use of little soil disturbance techniques, adjusted fertiliser use, application of different planting dates techniques, use of different crop varieties, use of drought tolerant seeds, applied crop

[1] Master's student at the University of Free State: Department of Sustainable Food Systems and Development, Faculty of Natural and Agricultural Sciences, University of the Free State, Republic of South Africa, ndlovunosipho331@gmail.com

[2] Research Associate the University of Free State: Department of Sustainable Food Systems and Development, Faculty of Natural and Agricultural Sciences, University of the Free State, Republic of South Africa, mashyit@yahoo.co.uk, Orcid 0000-0001-6069-8226

Vol. 52 No. 2, 2024: 159-177
10.17159/2413-3221/2024/v52n2a16282

diversification, use of techniques that shortened growth length, planting new trees and avoiding planting on sloppy areas, and applied soil conservation techniques. Agriculture extension advisors should address vulnerable systems, including agricultural water and natural resources. In addition, it is important for agriculture extension advisors to strengthen the link between climate change adaptation and key climate change policy processesto improve their effectiveness and ability to deal with the effects of climate change. This will help overcome shortcomings along the food value chain and ensure food security.

Keywords: Smallholder Farmers, Climate Change Impacts, Food Security, Natural Resources Management, Adaptation Strategies

1. INTRODUCTION

Based on current data trends, climate change will continue to affect global weather patterns, water resources, crop yields, and marine ecosystems (Partey, Zougmore, Ouedraogo, & Campbell, 2018). Climate change and rapid population growth put many people's food and livelihood security at risk, particularly in developing countries (Zougmore et al., 2018). Among the drastic changes affecting food production are rising temperatures, declining and more unpredictable rainfall, increased pest infestation, and diseases. Climate change is already threatening water access globally, resulting in more severe droughts and floods (Assan, Suvedi, Dlabisi & Allen, 2018).

South Africa has a rich natural resource base that drives rural economic growth (Carelsen, Ncube & Fanadzo, 2023). However, climate change severely impacts agricultural production, particularly among smallholder rural farmers who rely on nature for their livelihood (Mdiya et al., 2023). This study aimed to investigate the impact of climate change on food security and natural resources. In addition, it was based on the challenges faced by smallholder farmers due to climate change and the adaptive strategies that farmers could implement to cope with climate change.

The increases in temperature result in excessive water evaporation, leading to increased levels of atmospheric water vapour and frequent heavy and intense rainfall in the future (Islam & Kieu, 2020). The effects of flooding caused by heavy rain are connected to soil erosion or degradation of landslides. This affects farming practices, which are the most important

10.17159/2413-3221/2024/v52n2a16282

contributors to the food chain, because soil erosion decreases soil fertility and negatively affects agricultural crop yield (Zwane, 2019). Crop resilience to climate change will be critical for global food security in the coming decades. A decrease in crop productivity has already been observed because of climate change. Studies in Southern Africa predicted significant reductions in crop productivity because of future warming and shifts in precipitation patterns (Yamba et al., 2019). Scientists predict future negative changes in cereal crop yields because of climate change for Southern African countries without agricultural climate change adaptation strategies. Without adaptation, most countries' long-term mean crop yield is expected to fall (Senyolo, Long, & Omta, 2021).

Crops will not have enough available nutrients because flooding significantly imbalances the level of plant-available nutrients. Climate change is a sign that there is an imbalance in the natural world, and agriculture will be affected since it relies on or is very dependent on nature's water, soil, air, and weather. Akiyode et al. (2017) assert that the biggest challenge is that plants do not flower when it’s too humid. Pests thrive due to hot temperatures, and cold temperatures result in vegetables freezing.

Food security is a huge priority in Africa because many people are malnourished. Masipa (2017) agrees with Shisanya and Mafongoya (2017) that climate changes affect all the main pillars of food security: access, availability, utilisation, and stability. South Africa is regarded as one of the most food-secure countries, but it is found to be food insecure at a local level.

The accumulation of scientific evidence by Kang, Khan, and Ma (2009), Bazylevch and Kupalova (2014) and Zwane (2019) indicate that increasing greenhouse gas emissions will warm our planet. As a result, the impact of climate change on agriculture has received increased attention in the literature over the last decade. Crop yields in many countries are expected to be reduced as temperatures rise and precipitation patterns change. According to the Intergovernmental Panel on Climate Change (IPCC) (2011), most land areas will experience an increase in average temperature, more regular heat waves, stressed water resources, and desertification. The poorest countries and populations will bear the greatest burdens of climate change.

Climate change, combined with population growth, will significantly impact the availability and quality of water resources (Nhamo et al., 2019). Malhi, Kaur and Kaushik (2021) reported

10.17159/2413-3221/2024/v52n2a16282

that there would be no or little adaptation at the aggregate level. Farmers' climate change mitigation in South Africa has received little attention, especially at the farm level. Furthermore, the climate change impact literature is lacking in examining the factors influencing adaptation strategies. Nonetheless, agro-economic rationality suggests that addressing climate change requires mitigation strategies and that farmers adjust their production processes to eliminate negative effects.

The innovation system approach provides a broad framework for addressing climate change and ensuring food security. Stakeholder participation, linkages, and institutional contexts in the processes are all critical in agricultural innovations for climate change adaptation (Zougmore, 2018). This means that climate change poses challenges to agriculture that cannot be addressed in isolation, demanding concrete, innovative steps to reduce the vulnerability and the adaptive capacity of poor people with low incomes and to help them learn about adaptation strategies. These actions include adaptation, which refers to intentionally planned changes in a system to reduce, moderate, or capitalise on the expected negative effects of climate change (Senyolo et al., 2019). Adaptation is meant to assist farmers in achieving food security, income, and better livelihoods to avoid disastrous consequences for agriculture. This will include irrigation, adjustments of cropping systems, the timing of farming operations, and knowledge on how to alternate varieties of crops (Malhi, Kaur & Kaushik, 2021).

This study ought to bridge the gap between what is known and not known in the discourses on climate change, as the impact of climate on food security and natural resources has received little attention, particularly at the farm level. Furthermore, studies that focus on the impact of climate change on natural resources are lacking. Nonetheless, addressing climate change requires mitigation and adaptation strategies, and farmers need to adjust their production processes to lower any adverse effects. This study emphasises that adaptation is critical if farmers are to mitigate the potential negative effects of climate change.

2. METHODOLOGY

2.1. Study Area

The Mthonjaneni Local Municipality (Melmoth), located within the King Cetshwayo District (KCDM) in South Africa, has GPS coordinates of S 28º35’06.3’’ E 31º23’03.6’’ (Figure 1).

Mthonjaneni is located 44km away from Ulundi town, previously the capital city of KwaZulu-Natal (KZN) Province (Abegunde et al., 2019). It comprises exceptional biodiversity and people of different religious missions and cultures. This study was conducted in Mthonjaneni Local Municipality under King Cetshwayo District. Mthonjaneni Local Municipality has a high agricultural production potential determined by soil, climate, vegetation, and topography (Mthonjaneni SEA, 2007 and Municipality IDP, 2016-17 & 2020-21).

FIGURE 1: Study Area

2.2. Data Collection

Data was collected by the researcher using a questionnaire. The developed questionnaire helped to gather information from farmers by answering a set of closed questions. The questions in the questionnaire addressed the objectives of this study, mostly the one regarding adaptation and coping strategies to climate change variables. English was used as the language for asking and answering questions. For those who did not understand English, the researcher helped translate the questions into the language they understood. Since this research had quantitative data (numbers), the data was analysed using a Statistical Package for the Social Sciences (SPSS). The quantitative data collected on the farmers was analysed and interpreted according to how they answered the questions to help conclude this study.

A non-probability sampling method was applied to select 45 smallholder crop farmers residing in Melmoth, Mthonjaneni Municipality, under King Cetshwayo District, KZN. In this sampling procedure, not every member had an equal chance of being selected. The non-probability sampling method is used when the probability of farmers being included in the sample is not known, and only certain farmers may have a chance of being selected (Queiros, 2017). Non-

probability sampling was chosen because it is less time-consuming and less expensive than probability sampling.

3. RESULTS AND DISCUSSION

3.1. Demographic Information

3.1.1. The Gender of the Respondents

Table 1 illustrates the gender of the respondents. Of the total of forty-five respondents, a significant portion (*n* =23, 51.1%) were females, and twenty-four were males (*n* =22, 48.9). Even though there is not much difference in this case, generally, in Mthonjaneni, females are the ones who work in fields during the day while males are herding cattle, and some are working very far away (e.g. Johannesburg). Hence, many women are working very hard to ensure that the household is stable in terms of food security.

TABLE 1: Gender of the Respondents

GENDER	FREQUENCY	PERCENT	VALID PERCENTAGE
MALE	22	48,9	48,9%
FEMALE	23	51,1	51,1%
TOTAL	45	100	100%

3.1.2. The Age of the Respondents

Figure 2 shows that a significant portion (*n* =17, 39.5%) are farmers aged 60 years and older, followed by respondents aged between 34 and 40. The lowest percentage was obtained for the ages of 20 to 33. This indicates that youth in Mthonjaneni might not be involved in agriculture. This agrees with FAO (2014) and Zenda and Malan (2021), who reported that youth are not involved in agriculture. These results further elaborate that most of the world's food in developing countries is made by ageing farmers with little youth involvement. It continues to highlight the key challenges youth face: limited access to land, difficulties in accessing green jobs, inadequate access to financial services, market access barriers, and no involvement in policy dialogue.

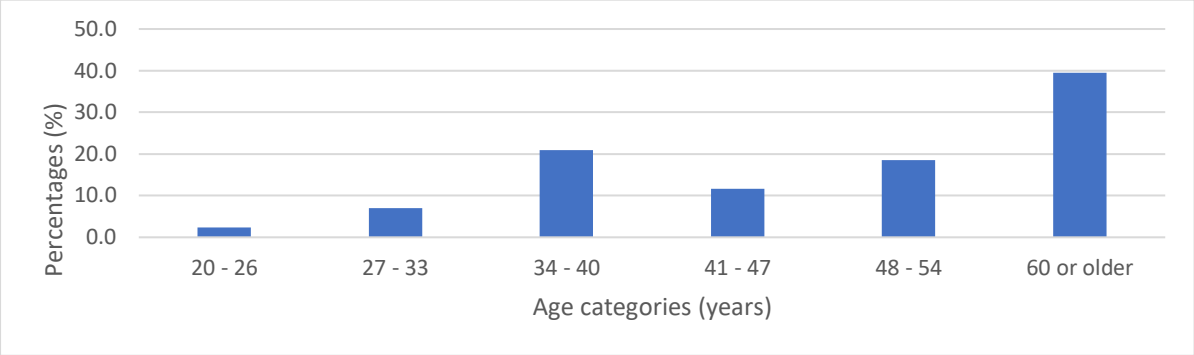

FIGURE 2: The Percentage of Respondents Who Participated in the Study by Age

3.1.3. Level of Education

The chart in Figure 3 illustrates the level of education of the respondents. The highest percentage were of respondents who had never been to school (37,8%), while 24,4% of the respondents were from those who matriculated. In addition, the respondents with tertiary qualifications and those who had attended school between grades 9 to 12 were 13,4% and 13,3%, respectively. Lastly, the lowest percentage was for those who attended grade R to grade 8 (11,1%). Since most of the Mthonjaneni farmers were older farmers in this study, the highest percentage of farmers were those aged between 60 years and older. The findings agree with the research conducted by Imana and Zenda (2023) in Kenya, which found that most respondents had never been to school.

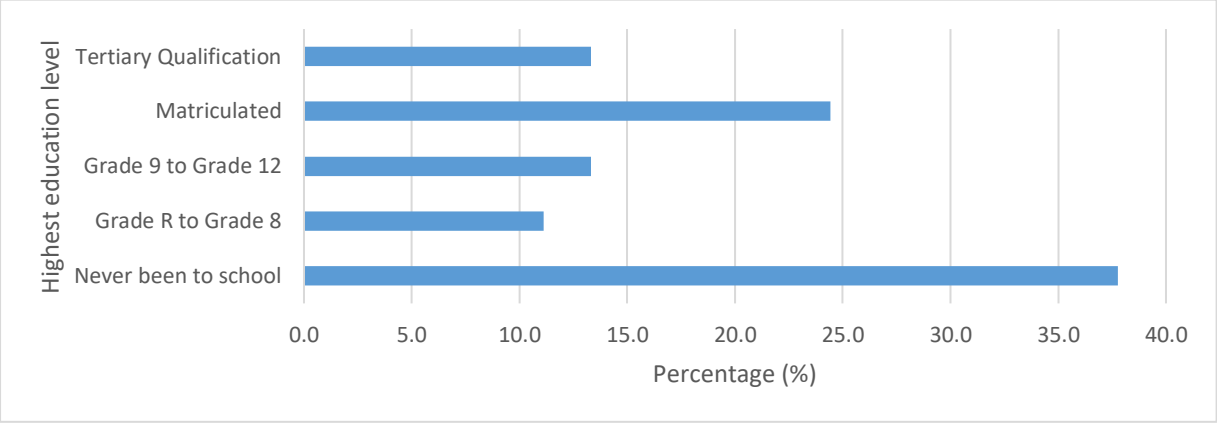

FIGURE 3: The Respondents' Education Level

3.1.4. Number of Years in Farming

Farming experience is paramount when practising crop farming due to the skills required to operate crop farming systems. When smallholder crop farmers are experienced, they can easily

adapt to new innovative ideas. The results in Figure 4 show the number of years each respondent had farmed in the study area. The highest percentage was found in respondents who had farmed for more than ten years but less than 20 years (*n*=24. 55,8%), followed by those who have farmed for more than five years but less than ten years (*n* =11. 25,6%). The respondents who had farmed for less than five years also followed (*n*=6. 14,0%), and the lowest percentages were found from those who had farmed for more than 20 years (*n*=2. 4,6%).

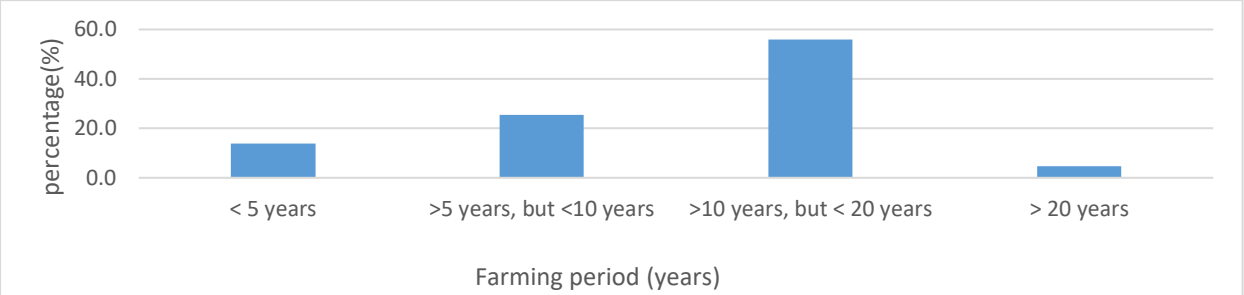

FIGURE 4: The Farming Period of the Respondents

3.2. Climate Change Information and Farmers' Perceptions

Figure 5 illustrates the respondents' perception of flood occurrence. The majority of the respondents (*n*=32. 71,1%) perceived a decrease in flood occurrence, with a small portion who did not know (*n*=7. 15,6%), and the remaining (*n*=6) did not answer this question. The frequency of floods has decreased over the last two years. This is because the area has experienced periods of dry spells. These results in Mthonjaneni agree with those of Assan et al. (2018) that climate change already threatens water access, resulting in more severe droughts. Developing countries remain susceptible and vulnerable to climate change, especially small-scale farmers relying mostly on rain-fed production systems (Abegunde et al., 2019). Cacho et al. (2020) agree with both Richardson et al. (2018) and Abegunde et al. (2019) that climate change is still going to be a huge threat to food security because smallholder farmers produce a large proportion of food produce, and smallholder or small-scale farmers are still going to experience a significant hit because of the reliance on rain-fed systems.

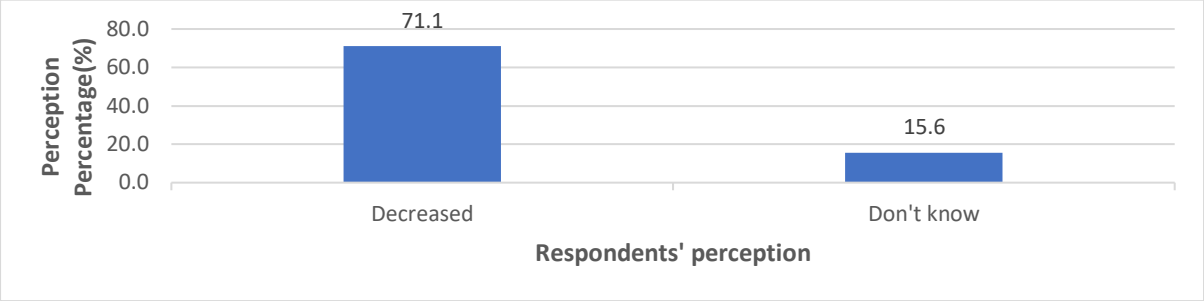

FIGURE 1: The Perception of Respondents in Relation to the Frequency of Floods

Figure 6 illustrates the respondents' perception of whether climatic conditions have influenced their farming systems. In this study, the definition of the farming system was refined to focus on the specific ways in which weather and climatic conditions influence various aspects of the farming systems, such as crops, soil and water management. A significant percentage (95,2%) of the respondents indicated that climatic conditions have influenced their farming systems, while 4,8% are unaffected by climatic conditions. Smallholder or small-scale farming systems are ranked as the main economic activity in rural areas, especially in Mthonjaneni. Their dependency on seasonal rainfall as their main source of water for crops and the use of traditional farming methods may result in crop failure. Climate change has resulted in more negative effects on water resources, food security, and human health. These adverse effects are highly observed in reducing the yield of maize, rice, wheat, and forests. Soil and crop water balance have been measured with crop growth models with the help of parameters of different climate models. It was also found that in South Africa, climate variability is one of the significant factors that affect year-to-year production (Zwane, 2019). As a result of the challenges caused by climate change, there is a great need to build resilience and increase capacity to adapt (Harvey et al., 2018) since climate change decreases the yield of many crops. These results indicate that climatic conditions are a severe issue that needs to be addressed.

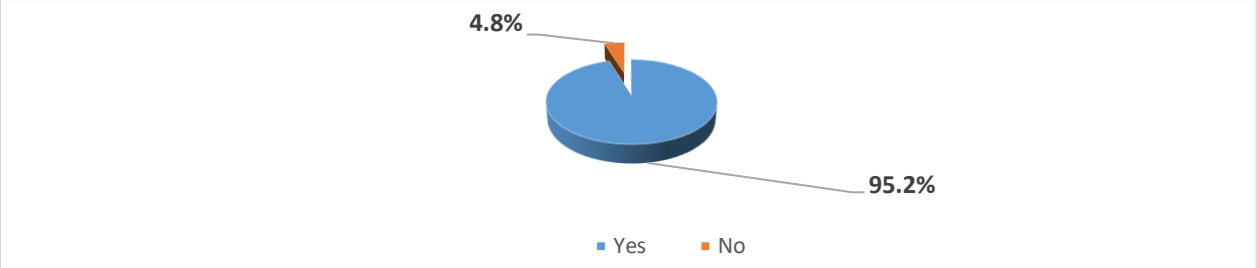

FIGURE 6: The Respondents' Perception of Climatic Conditions Influence Their Farming Systems

3.2.1. Perception of the Respondents on Temperature and Rainfall Change Over Ten Years

This section illustrates the respondents' perceptions of temperature and rainfall over the past ten years.

Figure 7 shows the respondents' temperature perception over the past ten years. The results indicate that 51,1% experienced hot days over the past ten years. In Southern Africa, increases in temperature affect the agricultural sector and the ability of the region to achieve adequate access to food. Efforts to overcome this stress are slowed down by increasing temperatures. This is why it is essential to build resilience, implement adaptive strategies and build sustainable food production systems capable of mitigating climate change impacts (Nhamo et al., 2019).

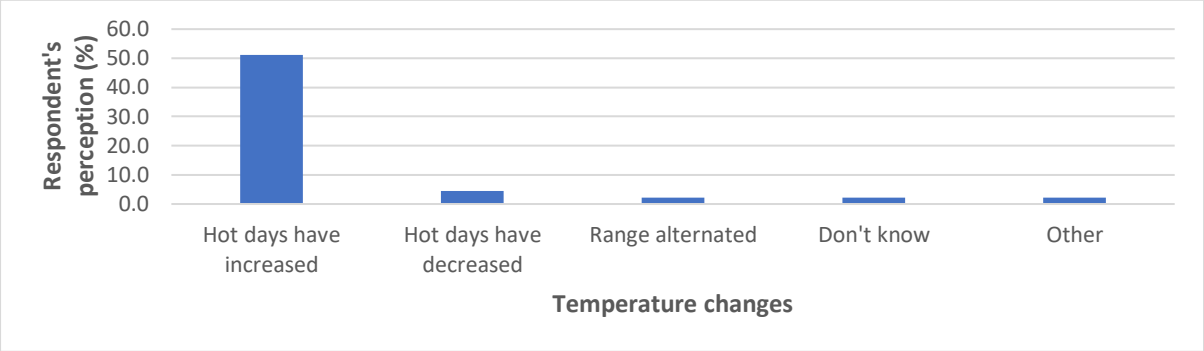

FIGURE 7: Respondents' Perception of Temperature Change Over The Last Decade

Figure 8 depicts the respondents' perception of rainfall over the past ten years. The results revealed that 51,1% of the respondents experienced decreased rainfall. Among the drastic changes affecting food production is unpredictable rainfall. Climate change threatens global water access, resulting in more severe droughts and floods (Assan et al., 2018). A decrease in rainfall will result in negative effects on smallholder crop-producing farmers. Agricultural yields will decline as a result of a reduction of rainfall.

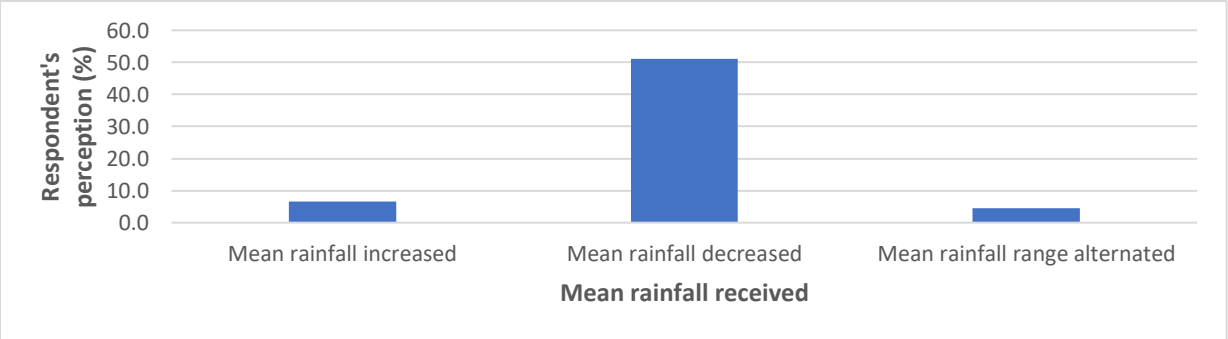

FIGURE 8: The Perception of Rainfall Changes Over The Last Decade

3.3. Natural Resource Changes Noticed by Farmers as a Result of Climate Change

Figure 9 below depicts the changes respondents (smallholder farmers) noticed due to climate change. In this regard, respondents were allowed to mention more than one change that they had experienced. They could mention all the changes that they had been observing without limitations. A significant percentage (91,1%) observed reduced grazing feedlot for livestock (85%), reduced herbaceous cover (80%), decline in the volume of water (57,8%), increased tree damage and land degradation (11,1%), increased soil erosion (6,7%) and increased bush encroachment (2,2%). Most farmers in Mthonjaneni do not apply regenerative agricultural practices. They only exploit natural resources without restoring degraded areas.

Additionally, farmers do not apply conservation methods and plant trees to stabilise the greenhouse gas and emissions from natural resource pollution. Arora (2019) agrees with this claim, which states that anthropogenic activities cause a loss of about 15 billion tons of fertile soil every year and increase greenhouse gas and emissions. The imbalance in the carbon cycle due to deforestation can be corrected by planting new trees. Forests absorb or decrease the amount of released carbon dioxide. Climate change results in the degradation of natural resources, such as desertification and nutrient-deficient soils.

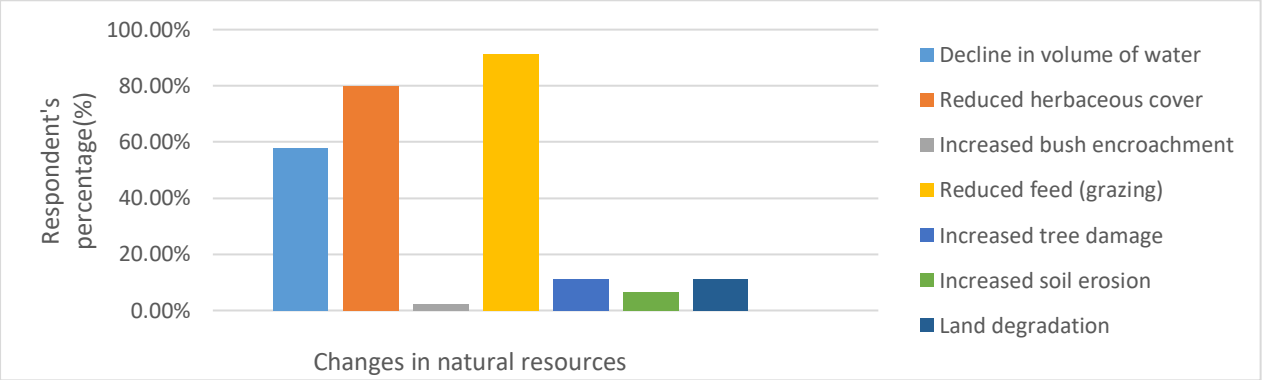

FIGURE 9: Changes that Farmers Notice as a Result of Climate Change

3.4. Farmers' Perception of Crop Event Uncertainties

Figure 10 illustrates the farmers' perceptions of climate change-related events' frequency and severity. The results of the study indicate the following: crop pest abundance 71% out of 100% of respondents, crop disease abundance 8,9% out of 100% of respondents, weed abundance and frequency of drought occurrences 0% out of 100% of respondents, respectively. Each

respondent answered all questions with a yes or no answer. Extreme weather events, including high temperatures and irregular rainfall distribution, are already causing crop failure in areas without access to proper irrigation. The agriculture extension advisors should encourage farmers to supplement water shortages during dry spells. Increased temperatures result in increased pests, diseases, and weeds infestation, which could affect both crops and livestock (Cole et al., 2018). Carbon dioxide may also stimulate growth in plants; however, research also proves that it decreases the nutritional value of food crops because the concentration of carbon dioxide in the atmosphere decreases the amount of essential minerals such as proteins in plant species such as cereals (Nhamo et al., 2019). Among the drastic changes affecting food production are rising temperatures, declining and more unpredictable rainfall, more constant extreme weather, increased pest infestation, and diseases. Climate change threatens global water access, resulting in more severe droughts and floods (Assan et al., 2018).

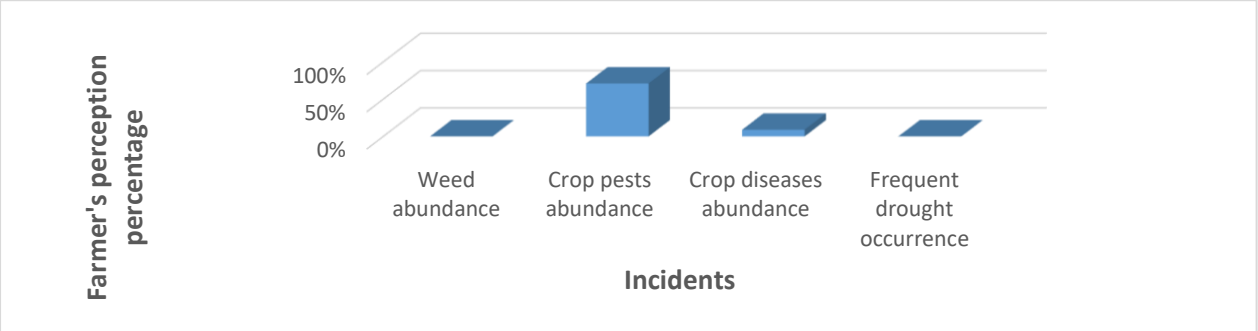

FIGURE 10: Farmers' Perceptions of the Incidents Resulting from Climate Change Impacts

3.5. Adaptation Strategies Employed to Cope with Climate Change

According to Mpandeli et al. (2018), adaption strategies are proactive interventions encompassing long-term planned policies and investment decisions. This involves the use of different strategies that will address the impact of climate change in the long term. Many farming communities remain vulnerable to climate change. Respondents were allowed to pick more than one technique they applied to cope with climate change. Figure 11 illustrates adaptation strategies used by the respondents to cope with climate change variability. The adaptation strategies applied include the following: use of water harvesting (84,4%), use of little soil disturbance techniques (46,7%), adjusted fertiliser use (40%), application of different planting dates techniques (37.8%), use of various varieties (20%), use of drought tolerant seeds (17,8%), applied crop diversification (15,6%), use of a technique that shortens growth length

(6,7%), planting new trees and avoiding planting on slopes (6,7%), applied soil conservation techniques (4,4%), moved to different site and use of contour ploughing (0%).

According to the study by Karki et al. (2019) conducted in Nepal, due to the dependency on rain-fed systems, farming communities were forced to change planting dates, and some were forced to plant late because of the untimely rainfall. The farmers adjusted the time for sowing and harvesting because of the dependency on rainfall and planting according to the rainfall calendar and timing. Some farmers were forced by climate change to adopt technologies that included the use of chemicals such as insecticides and pesticides because of the increase in pest infestation. Farmers end up spending much on production (pesticides and seeds). Again, the results of Karki et al. (2019) demonstrated that farming communities have started using drip irrigation, water harvesting, and adopting measures such as agroforestry. These strategies include zero tillage and mulching to conserve moisture and avoid soil disturbance. Some Mthonjaneni farmers have started to employ some of these adaptation strategies.

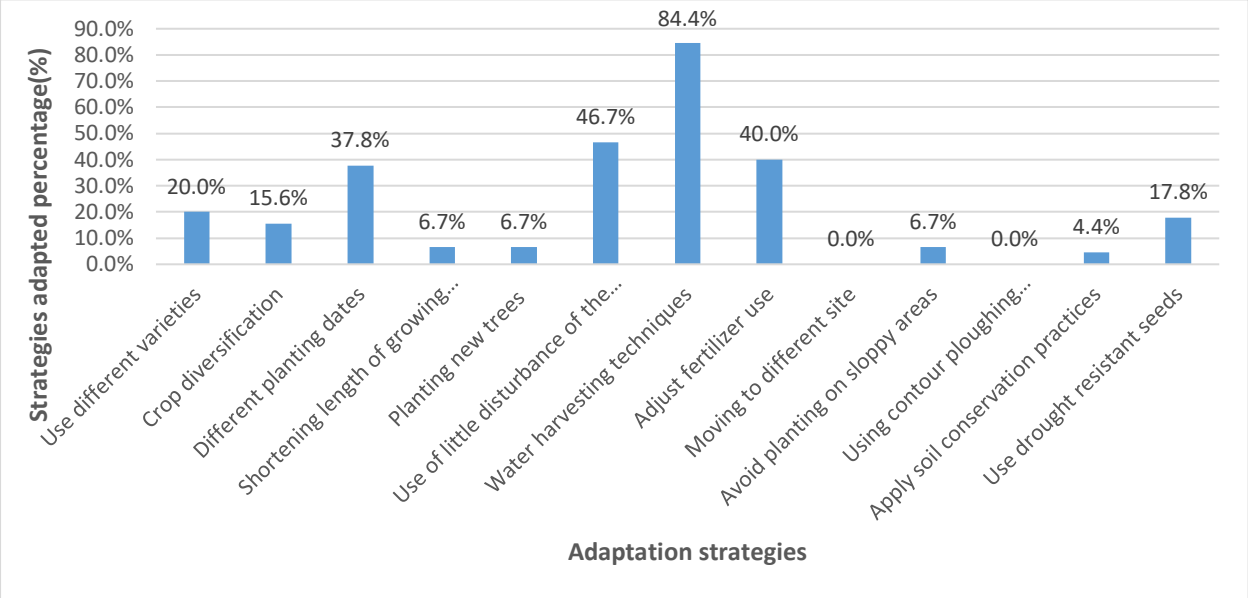

FIGURE 11: Strategies Adopted by Farmers to Cope with Climate Change

Climate change is best seen as an extraordinary confluence of well-known risks rather than as a brand-new hazard in eradicating poverty and promoting shared prosperity. The study by Jalal et al. (2021), which was conducted in Bangladesh, examined how household vulnerability and income diversity are affected by climate change. The findings show that, over time, sources of income have changed.

In the current study, 44% of the respondents indicated that they did not have a problem accessing food, while 55.6% indicated that they had been struggling to access food in the past two years. These results suggest that the issue of access to food is a challenge that needs to be addressed as soon as possible. These results agree with the claims and results of Hall et al. (2017) and Assan et al. (2018), which stipulate that one in every four people in Africa lacks enough food to live an active and healthy life. Hall et al. (2017) suggest that changes in temperature and rainfall patterns affect crop yields, water availability, pests and diseases, and livestock health, all of which will directly impact food security. Mthonjaneni is already facing similar challenges of crop yield decline, resulting in food insecurity. Zougmoree et al. (2019) predicted a high potential for hunger across Africa from now to 2050; however, these predictions can be avoided if adaptation responses can be implemented.

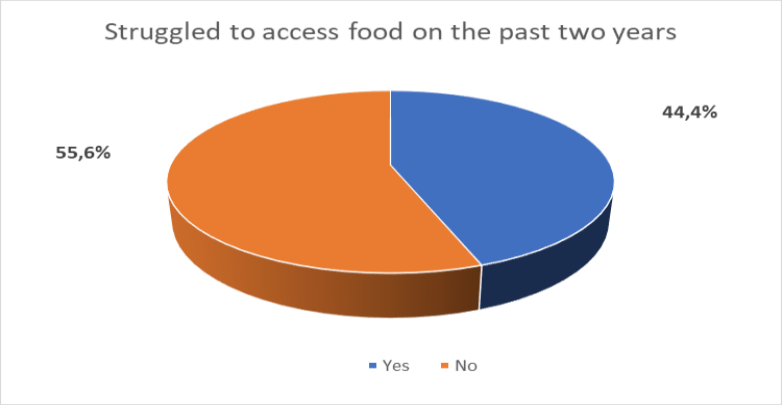

FIGURE 12: The Percentage of the Respondents Who Sometimes Struggle to Access Food

3.6. Household Coping Strategies

Figure 4.14 illustrates the household coping strategies of the respondents over the last 10-20 years. The household coping strategies include the following: relying on less expensive food (19%), limiting portion size at mealtimes (18%), reducing the number of meals per day and borrowing food from family and friends (16%), harvesting immature crops (2%) skipping a day without eating and diverting seeds for consumption both sitting at 1%. In the study, the researchers focused on food security in terms of food availability, which is defined as the physical presence of food within the household. This includes food produced by the household and food purchased or received from outside sources. The researchers also considered food accessibility, which refers to the ability of household members to obtain sufficient food in terms of quantity, quality and variety. Food security is fundamental in all parts of the world, especially in developing regions. This is because many people rely on agriculture as their

10.17159/2413-3221/2024/v52n2a16282

primary source of livelihood. These results indicate that food insecurity is a serious issue that needs to be addressed by the Department of Agriculture Extension.

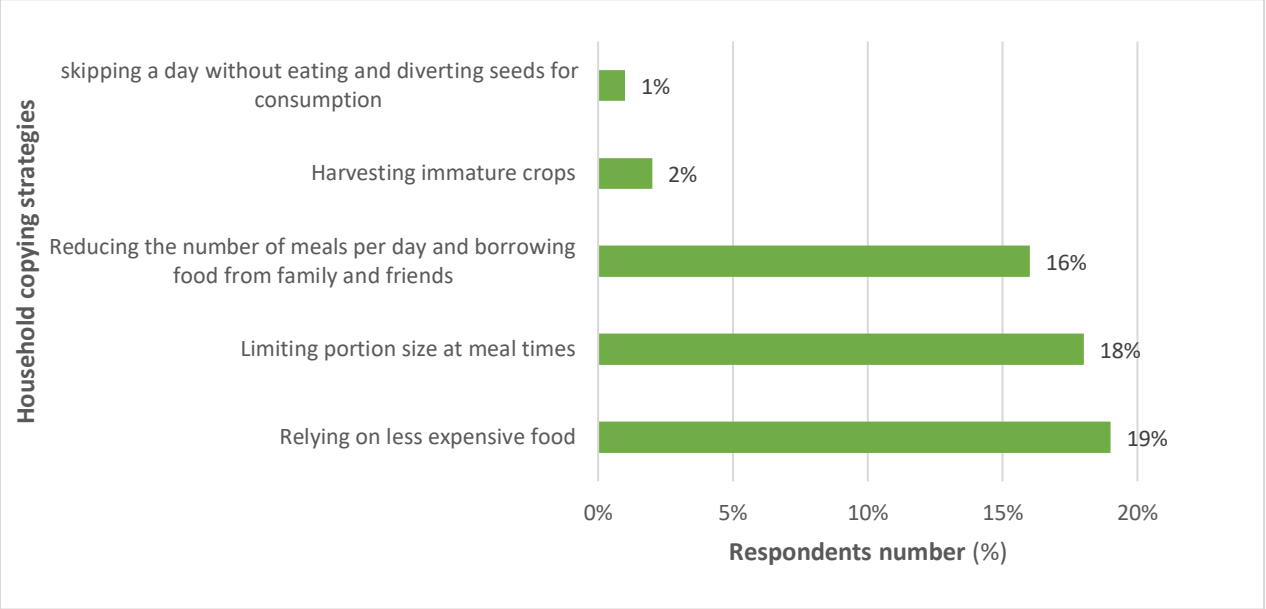

FIGURE 13: The Number of Respondents Using Various Household Coping Strategies

4. CONCLUSIONS AND RECOMMENDATIONS

This study sought to investigate the impact of climate change on food security and natural resources on smallholder crop farming systems. In this current study, the researchers focused on food security in terms of food availability, which is defined as the physical presence of food within the household. This includes food produced by the household and food purchased or received from outside sources. The researchers also considered food accessibility, which refers to the ability of household members to obtain sufficient food in terms of quantity, quality and variety. It was found in this study that smallholder farmers perceived increased hot days, decrease in rainfall, increased number of hot days and increased food insecurity. For smallholder farmers' livelihoods to remain viable under variable climatic changes based on these results, the agricultural extension advisors in the study area should address the following:

1. Extension advisers should educate Mthonjaneni farmers on natural resource management techniques and adaptation strategies to cope with the adverse effects of climate change.

10.17159/2413-3221/2024/v52n2a16282

2. Integrated natural resource management, also known as the collective action of governance, is one of the most important tools that should be added to the toolboxes of natural resource managers.
3. A small percentage of farmers only used the regenerative agriculture practices, including planting new trees, avoiding planting on slopes, and applying soil conservation techniques. Therefore, these practices should be introduced in a study area under the Department of Agriculture and various stakeholders.
4. It is important for agriculture extension advisors to strengthen the link between climate change adaptation and key climate change policy processes to improve their ability to deal with the effects of climate change. This will help overcome shortcomings along the food value chain and ensure food security.

REFERENCES

ABEGUNDE V.O., SIBANDA M. & OBI A., 2019. The dynamics of climate change adaptation in sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers. *Climate.,* 132(l7): 1-23.

AKIYODE O., TUMUSHABE., A., KATONGOLE, H. & ONU, P., 2017. Climate change, food security, and environmental security. *Int. J. Sci. World.*, 5(2): 172-176.

ARORA, N.K., 2019. Impact of climate change on agriculture production and its sustainable solutions. *Environ. Sustain.,* 10(2): 95-96.

ASSAN, E., SUVEDI, M., DLABISI, L.S. & ALLEN, A., 2018. Coping with and adapting to climate change: A gender perspective from smallholder farming in Ghana. *Environments.,* 5(86): 1-9.

BAZYLEYCH, V. & KOPALOVA, G., 2016. Climate change: The major threat of the 21st century. *Bulletin of Taras Shevchenko National University* of KynI, 159(6): 6-11.

CARELSEN, C., NCUBE, B. & FANADZO, M., 2023. Support services to smallholder farmers during the 2015-2018 drought in the Overberg and West Coast Districts, South Africa. *S. Afr. J. Agric. Ext.,* 51(2): 128-149.

CACHO, O.J., MOSS, J., THORNTON, P.K., HERRERO, M., HENDERSON, B., BODIRSKY, B., HUMPERNODER, F., POPP, A. & LIPPER, L., 2020. The value of climate-resilient seeds for smallholder adaptation in sub-Saharan Africa. *Clim. Change.*, 162(1): 1213-1229.

COLE, M.B., AUGUSTIN, M.A., ROBERTSON, M.J. & MANNERS, J.M., 2018. The science of food security. *Sci Food.*, 14(2): 1-8.

HALL, C., DAWSON, T.P., MACDIAMID., J.I., MATTHEWS, R.B. & SMITH, P., 2017. The impact of population growth and climate change on food security in Africa: Looking ahead to 2050. *Int. J. Agric. Sustain.*, 2(152): 124-135.

HARVEY, C.A., RODRIGUEZ, M.S., RODRIGUEZ, R.M., VIGUERA, B., GAUDARRAMA, A.C., VIGNOLA, R. & ALPIZAR, F., 2018. Climate change impacts and adaptation among smallholder farmers in Central America. *Agric. Food Sec.*, 57(7): 1-20.

IMANA, C. & ZENDA, M., 2023. Impact of climate change on sustainable pastoral livelihoods in Loima Sub-County, Turkana County, Kenya. *S. Afr. J. Agric. Ext.*, *51*(1): 13-33.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE [IPCC]., 2011. *Special report on renewable energy sources and climate change mitigation, Summary for policymakers*. Abu Dhabi, United Arab Emirates, 5-8 May.

ISLAM, S.M. & KIEU, E., 2020. Tackling regional climate change impacts and food security issues. A critical analysis across ASEAN, PIF, and SAARC. *Sustainability.*, 883(12): 1-2.

KARKI, S., BURTON, P. & MACKEY, B., 2020. Climate change adaptation by subsistence and smallholder farmers: Insights from three agro-ecological regions of Nepal. *Cogent Soc. Sci.*, 1(6): 1-23.

KANG, Y., KHAN, S. & MA, X., 2009. Climate change impacts on crop yield, crop water productivity and food security – A review. *Prog. Nat. Sci.*, 19(12): 1665-1674.

MALHI, G.S., KAUR, M. & KAUSHIK, P., 2021. Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability.*, 13(1318): 1-21.

MASIPA, T.S., 2017. The impact of climate change on food security in South Africa: Current realities and challenges. *J. Disaster Risk Studies.*, 9(1): 2-7.

MDIYA, L., ALIBER, M., NGARAVA, S., BONTSA, N. & ZHOU, L., 2023. Impact of Extension Services on the use of climate change coping strategies for smallholder ruminant livestock farmers in Raymond Local Municipality, Eastern Cape Province, South Africa. *S. Afr. J. Agric. Ext., 51*(2): 150-166.

MPANDELI, S., NAIDOO, D., MABHAUDHI, T., NHEMACHENA, C., NHANO, L., LIPHADZI, S., HLAHLA, S. & MODI, A.T., 2018. Climate change adaptation through water-energy-food nexus in Southern Africa. *Int. J. Environ. Res. Public Health.,* 15(2306): 1-9.

MTHONJANENI MUNICIPALITY INTEGRATED DEVELOPMENT PLAN PUBLICATION, 2016-2018. KwaZulu-Natal, South Africa.

MTHONJANENI MUNICIPALITY INTEGRATED DEVELOPMENT PLAN PUBLICATION: A review, 2021-2022. KwaZulu-Natal, South Africa.

NHAMO, L., MATCHAYA, G., MABHAUDHI, T., NHLENGETHWA, S., NHEMHACHENA, C. & MPANDELI, S., 2018. Cereal production trends under climate change. Impacts and adaption in Southern Africa. *Agriculture.*, 9(30): 1-16.

PARTEY, S.T., ZOUGMORE, R.B., OUEDRAOGO, M. & CAMPBELL, B.M., 2018. Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learned. *J. Clean. Prod.*, 187: 285-295.

QUEIROS, A., FARIA, D. & ALMEIDA, F., 2017. Strengths and limitations of qualitative and quantitative research methods. *Eur. J. Educ. Studies.*, 3(9): 3-86.

RICHARDSON, K.J., LEWIS, K.H., KRISHNAMURTHY, P.K., KENT, C., WILTSHIRE, A.J. & HANLON, H.M., 2018. Food security outcomes under a changing climate:

Impacts of mitigation and adaptation on vulnerability to food insecurity. *Clim. Change.*, 147(10): 327-341.

SENYOLO, M.P., LONG, T.B. & OMTA, O., 2021. Enhancing the adoption of climate change smart technologies using public-private partnerships: A lesson from WEMA case South Africa. *IFAMA.*, 24(5): 755-776.

SHISANYA, S. & MAFONGOYA, P., 2016. Adaptation to climate change and the impact on household food security among rural farmers in UMzinyathi District of KZN. *Internal Society Plant Pathol.*, 2(10): 56-57.

YAMBA, S., APPIAH, D.O. & SIAW, L.P., 2019. Smallholder farmers' perceptions and adaptive response to climate variability and climate change in Southern Africa in southern rural Ghana. *Cogent Soc. Sci.*, 5(1): 1-23.

ZENDA, M. & MALAN, P., 2021. The sustainability of small-scale sheep farming systems in the Northern Cape (Hantam Karoo), South Africa. *S. Afr. J. Agric. Ext.*, 49(1): 105-121.

ZOUGMORE, R.B., PARTEY, S.T., OUEDAONGO, M., TOURQUEBIAU, E. & CAMPBEL, B.M., 2018. Facing climate variability in sub-Saharan Africa: Analysis of climate-smart agriculture opportunities to manage climate-related risks. *Cah. Agric.*, 27(34): 1-9.

ZWANE, E.M., 2019. Impact of climate change on primary agriculture, water sources, and food security in Western Cape, South Africa. *J. Disaster Risk Studies.*, 1(562): 2-20.