Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.13, No.3, 2023

Challenges Faced by Smallholder Farmers in the Implementation of Adaptation Strategies to Climate Variability in the Arid and Semi-Arid Areas in Kenya

Peter I. Emoit[1]* Niamh Gaynor[2]
1. PhD Student-Track, School of History and, Dublin City University, St. Patricks Campus, Drumcondra, Dublin 9, Ireland
2. School of law & Government, Dublin City University, Glasnevin, Dublin 9, Ireland
*E-mail of corresponding author: peter.emoit2@mail.dcu.ie

This research is financed by Augustinian Province, Ireland.

Abstract
Smallholder Farmers in Kenya have several challenges in implementing adaptation strategies due to the prevailing climate change and variability. It is unclear how various challenges have affected the farmers, especially in Evurore division, Embu County. Therefore, this paper examined the challenges smallholder farmers face in implementing adaptation strategies to climate variability in Kenya's arid and semi-arid areas. The study adopted a descriptive research design with a target population of 50,620 people from 13,008 households in the Evurore division. A sample of 169 respondents was selected scientifically from the target population using the Yamane Taro formula. The sample population was also comprised of 17 key officials purposively chosen for the study. The study relied on primary and secondary data obtained using semi-structured questionnaires and published metrological data. Data were analyzed using descriptive statistics such as mean and frequencies and regression analysis. The paper established that implementing the adaptation strategies has been minimal due to smallholder farmers' challenges, including a lack of training for smallholder farmers on climate-smart agriculture, conservation agriculture, soil conservation, and water conservation. These challenges negatively influenced the farmer's adaptation strategies. This study used a regression model to determine the relationship between the smallholder farmers' perception of climate change and the adaptation strategies used to adapt to climate change. The study results indicate a significant positive correlation between challenges (r = 0.068; p< 0.05). The paper recommended that the government, through agricultural extension officers, train farmers on the effective implementation of adaptive strategies in the region.

Keywords: Climate Variability, Arid and semi-arid areas, Smallholder Farmers and Adaptation Strategies to Climate variability
DOI: 10.7176/JEES/13-3-05
Publication date: April 30th 2023

1. Introduction

Overreliance on rain-fed agriculture and low adaptive capacity to climate change have made many African countries vulnerable to adverse climate changes. According to intergovernmental Panel on climate change climate change is happening and is caused by anthropogenic activities (IPCC, 2021). This has accelerated extreme weather events such as floods and droughts that adversely affect agricultural production, causing food insecurity and exacerbating the perennial famine in developing countries. The extreme events are now a matter of concern because of their frequency and impacts that affect close to 350 million people globally and in sub-Saharan Africa, notwithstanding Africa's 4% carbon emission into the atmosphere (IPCC, 2022; Aminga and Krampe, 2020).

In Africa, several countries have vast arid and semi-arid lands (ASALs). These countries in SSA are thus plagued by droughts and flash floods that result in the loss of human lives, the decimation of livestock and a gross reduction in farm produce (Filho et al., 2018; Ng'ang'a et al., 2016). Moreover, there has been an outbreak of community conflicts due to water scarcity precipitated by frequent droughts (UN Habitat, 2014; Filho et al., 2018). International organizations, developed states and non-governmental organizations have come up with concerted efforts to help the affected poor households (HHs) in developing countries adapt to the vagaries of climate change

Although there is growing progress in research on climate adaptation in Africa, more research on this issue indicates that adaptation to climate change is still limited and faces numerous challenges (Murieta et al., 2021). Besides, the Paris agreement's global goal (2015) on adaptation, which focuses on building adaptive capacity and resilience and minimizing smallholder farmers' vulnerability to climate change, has not reached its optimal stage (Helgeson and Ellis, 2015). Some of the notable impacts of climate change on smallholder farmers are ASALs, which include food shortage (87.29%), increased food prices (76.27%), and decreased availability of water (72.43%) (Kalele et al., 2021). The percentages of the affected population show that despite the various on-farm adaptation strategies used, the adaptation levels remain low (Kalele et al., 2021). This, therefore, calls for more research to determine the adaptation strategies suitable for ASALs that will cushion smallholder farmers and all

who live in the ASAL areas from the impacts of climate change.

Given the challenges of adaptation in Africa and Kenya, whose arid and semi-arid landmass is 84%, such regions are prone to drought, erratic rainfall, floods, and food insecurity (Karimi et al., 2019). One particular area experiencing such conditions is Evurore, located in lower Eastern, Mbeere North Sub-County, Embu County, Kenya. Climate change has thus altered the community's livelihoods in Evurore, who are predominantly smallholder farmers, hence the need to focus on this population. According to Mugi-Ngenga et al. (2015), climate variability affects crop production among the smallholder farmers in ASALs, who rely on rain-fed agriculture, which is affected by the droughts that have become frequent (Aryal, et al., 2021). Research shows that most African countries "are extremely vulnerable and exposed to climate hazards" (Amegavi et al., 2021).

Filho et al. (2018) argue that less has been done in climate change adaptation to cushion the communities from climate change threats. These threats are coupled with a lack of resources, policies and good governance to implement adaptation approaches (Simon & Leck, 2015). Climate change adaptation at the community and regional level has received attention (Ashaolu, & Iroye, 2018). This notwithstanding, the biggest challenge bedeviling developing countries is the lack of climate data and impact models that support adaptation in rural areas (Ashaolu, & Iroye, 2018). Furthermore, studies show that developing countries have limited tools that examine, comprehend, and document the design to help cope with climate change risks and sustain agricultural productivity (Ojo et al., 2021).

Research has shown that one-third of the world's drought affects sub-Saharan African countries and those in the global South (IMF, 2020; IPCC, 2022). The latest IPCC (2022) report projected an increase in harshness and extreme events such as drought that will affect many people if adaptation to climate change efforts is not accelerated. Moreover, droughts affect food production and security in ASALs, where smallholder farmers' subsistence farming depends on rain. The situation is worse in Kenya, where 84% of the landmass is arid and semi-arid land (ASAL), and the average annual rainfall is 625mm (Ndiritu, 2020). Besides, an associated pestilence outbreak (Locusts) threatens many lives (IMF, 2020).

In Kenya, smallholder farmers' livelihoods in ASALs have been affected by the perennial droughts that have become a common phenomenon (Ochieng et al., 2016; GoK, 2013). The impacts of climate change in the ASAL areas have led to severe droughts that trigger famine (Speranza et al., 2007) and make most of the smallholder farmers in ASALs susceptible to food insecurity (Dougill et al., 2017). Apart from susceptibility to food insecurity, Ndiritu (2020) argues that the other impacts smallholder farmers face is "loss of rural livelihoods, reduced water availability that will plummet farm and pastoral production in the ASAL areas". This leads to rural-urban migration due to a decline in farm yields that forces the young demography to migrate to towns in search of jobs (Giovannucci et al., 2012). According to a study by Beddington et al., (2012), when the young people desert the rural areas, they leave behind women and the elderly in the villages, obliging them to take over roles that are not theirs, such as social protection. Thus they become vulnerable to the effects of climate change that limit the implementation of adaptation strategies and farm production.

2. Literature Review

The study reviewed several past studies on the challenges farmers face in implementation of adaptation strategies to climate variability

2.1 Challenges of Climate Change and Adaptation strategies in Arid and semi-arid areas

The temperatures in ASALs often range from 40°C-20°C, and the mean rainfall received is estimated to be 250mm-500mm per annum (Ayugi et al., 2016). The increase in the surface temperature is estimated to be 0.5 degrees Celsius in the past 50-100 years (IPCC, 2014). Therefore, most ASAL areas experience more dry spells and erratic rainfall exacerbated by climate change (Ndiritu, 2020).

Huynh et al., (2020) argues that every community has a body of knowledge that helps them use and manage land. They have mechanisms and strategies that help them adapt to challenging situations. Studies have shown that indigenous knowledge (IK) has not been integrated into climate adaptation strategies making it difficult for the local community to decide which suitable approach is good. Vinyeta and Lynn (2013) found that IK helps in the "detection of environmental changes, and formulation of adaptation strategies" to build resilience against the effects of climate change. More studies have shown that adaptation strategies that integrate IK and incorporate them with scientific knowledge boost people's capacity to adapt to the impacts of climate change (Kettle et al., 2014). However, when new knowledge is imparted to smallholder farmers who cannot adapt and implement it and is void of local knowledge, adaptation to climate change becomes difficult.

A study on adaptation barriers and strategies towards climate change in the Malaysian ASALs by Masud (2017). Established that farmers in the region were aware of climate change adaptation and thus were ready to address the challenges of climate change through effective adaptation strategies. The study established that social and economic factors such as lack of credit facilities, age of the household, farm experience, education levels, and limited access to agricultural extension services and markets had a significant effect on the adaptation of alternative

practices.

In study by Quandt et al., (2023) assessing opportunities and gaps in climate change adaptation through agroforestry established that improvement in agroforestry can improve coping mechanisms on risks and uncertainties brought by change in climate thus increasing the adaptive capacities. The study identified challenges such as limited awareness on the role of biophysical modeling and the influence of social economic factors on climate change. The study identified three major gaps that affect the implementation of adaptive strategies; this are lack of extensive research on the need for integrated biophysical – social economic effects on adaptive practices, uneven distribution and access of information on geographical climate patterns and inadequate funding to institutions responsible for studying the weather patterns

Jellason et al. (2021) found that the most significant challenges that smallholder farmers face are a lack of proper awareness of climate change, adaptation policies, and access to climate information and weather that smallholder farmers can utilize to cushion themselves from the effects of climate change. A study by Bryan et al. (2013) revealed that apart from the strategies employed, there is an inadequate adaptation strategy amongst farmers in managing the effects of climate change. This is attributed to a lack of access to and control of land and financial capital.

A study by Kimaro et al. (2018) that sought to assess climate change perception and adaptation strategies among pastoral communities in Northern Tanzania found that pastoralists perceive climate change as erratic and reduced amounts of rainfall, rise in temperature, and prolonged and frequent periods of drought. The study established that the popular adaptation strategies employed by the pastoralists were water harvesting through the building of underground cisterns and building dams. In addition, pastoralists moved their livestock to areas where there is water and grazing land, and range movement, that is, preserving grazing land through adopting sustainable range management practices such as rotational grazing. The study, however, established that the farmer lacked appropriate training on how to carry out these adaptation strategies effectively. Government restrictions on the movement of herds of cows also negatively affected the pastoralists' activities.

A study to examine climate change perceptions and adaptation strategies in Siaya sub county, Kenya by Wetende, (2018) established that most farmers were not aware of adaptation strategies. however, those who had limited awareness on adaptive strategies, viewed them from a narrow perspective of containing diseases as opposed to responding to climate change. This included spraying of crops, and preserving maize stoves as feeds for livestock in the dry season. The study recommends for creation of awareness on climate change and facilitation to access of relevant technology to enhance implementation of climate change adaptation practices.

Kamau et al. (2015) found that the local communities resort to charcoal burning, sand harvesting, hunting and rainwater harvesting as adaptation strategies. Additionally, a study carried out in the ASALs of Kitui and Yatta (Kenya) by Oremo (2013) found that most of the smallholder farmers' adaptation to climate change is constrained by lack of education, information and scientific and technological knowledge and training that is essential for the implementation of the new adaptation strategies.

2.2 Theoretical Framework

The paper was supported by the capability approach theory which was advanced by Amartya Sen in the 1980s. this theory was later advanced by Martha Nussbaum. This theory was developed on the premise that human beings have different capabilities or abilities to achieve different types of functioning, such as being healthy, educated, or having a sense of autonomy. These capabilities are influenced by various factors, including social, cultural, economic, and political circumstances. For example, a person's capability to achieve good health may be influenced by factors such as access to clean water, medical care, and a healthy environment.

According to Gasper, (2017) the theory emphasizes the importance of expanding people's capabilities and freedoms, so they can choose to pursue what they value most in life. This approach places value on individual diversity and the importance of ensuring that individuals have the necessary opportunities and resources to achieve their capabilities. In this sense, the Capability Approach is often seen as a way of promoting social justice and human development. Therefore, the capability theory focuses on people's ability to adapt to challenging situations like chance in climate and living conditions in the society

3. Materials and Methods

3.1 Study areas

The study was carried out in all the eight locations in Evurore division's in Mbeere North Sub-County, Embu County, Kenya. The area is situated in lower eastern Kenya and is part of the larger Mbeere. The location area of the study was selected because the community is agro-pastoralist and depends on farm and animal production for subsistence, thus small scale farmers in the region are vulnerable to climate change and variability. In addition, previous studies have established that farmers in the region are aware of climate variability, this there in need to explore challenge affecting effective adoption of adaptation practices.

3.2 Research design

The study used a descriptive research design using quantitative tools to obtain data on challenges faced by smallholder farmers in the implementation of adaptation strategies to climate variability. The regions covered by the study include Ishiara, Kamarandi, Ndurumori, Iriatune, Nguthi, Muringari, Kanyuambora and Kiang'ombe. Stratified sampling technique was used to ensure that respondents across the heterogeneous population groups, classified according to gender, such as female-headed and male-headed households, were selected.

3.3 Sample Size

The study targeted a population of 50,620 people in 13,008 households in the Evurore division. The sample size of the study was determined scientifically using Yamane'(1967) formulae,

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

n = size of the sample,
N = targeted population
e= error margin.
Therefore:

$n=N/(1+N[e]^2)$

$n=560/1+560\ (0.05)\ (0.05)\ =235$

Further stratified sampling and simple random sampling techniques were used to select the respondents.

3.4 Data Collection

The study relied on both primary data which was collected using semi structured questionnaires and secondary data that was obtained from peer-reviewed literature and policies on climate change adaptation from Kenya and other ASAL areas. These data consisted of the national adaptation and climate change strategic plans. Construct and Content validity of the research instruments were enhanced through consultation with subject experts and extensive review of past studies on climate variability and adaptation strategies. Quantitative data was analyzed descriptively using mean, frequency and inferentially using multiple regression analysis.

4. Results and Discussion

The section presents the findings of the study these includes demographic data, descriptive and inferential statistics

4.1 Demographic Data

From the 235 households selected for the study, 169 were successfully interviewed using a semi-structured questionnaire, with an overall response rate of 71.9%. According to Babbie (2011), a response rate of 60% is considered good, and a response rate of 70% is considered impressive for a study. The study established that 15.38% of the household heads were aged between 26 – 35 years, 27.81% were aged between 36 – 45 years, 24.26% of the household head were aged between 46 – 55 years, 20.12% were aged between 56 – 65 years, and 8.86% were aged between 66 – 75 years whereas 3.55% of the household head were aged above 76 years. The findings also showed that 18% of respondents were women, while 82% were men.

On the highest education level attained by the household heads, the study revealed that 56.2% of respondents had attained primary education, 29% had secondary education, 11.2% had college or university education, and those that did not go to school, 3.6%. In addition, the findings on marital status of the household revealed that most household heads were married and living together with their families, representing 83.4%, 8.3% were widowed, and 4.7% of the household were divorced. The results found that most households had 4 to 5 members representing 21.3%. While 16% of the respondents had a household size of 6 members, and 13.6% of the respondents had a household size of 3 members. This shows that most respondents had an average household size of 4 to 5.

On the primary source of household income, the result showed that 28.4% of the respondent practiced crop farming as their primary source of income, and 9.5% practised crop farming and livestock farming. Further, the results indicated that 3% of the respondents practiced crop, livestock farming and formal employment as their primary source of income. Additionally, 12.4% practiced crop farming and menial jobs (Vibarua), 7.7% practiced formal employment, and 16.6% practiced menial jobs as their primary source of income

On the household land ownership status, the study found that 28.4% of the respondents bought their land, 1.8% had either bought or inherited from the family, 2.4% communally owned the land, and 64.5% had inherited the land from the family or worked on the family land. Further, the results revealed that 1.8% had leased the land, and 1.2% had leased family land or inherited it.

4.2 Descriptive Statistics

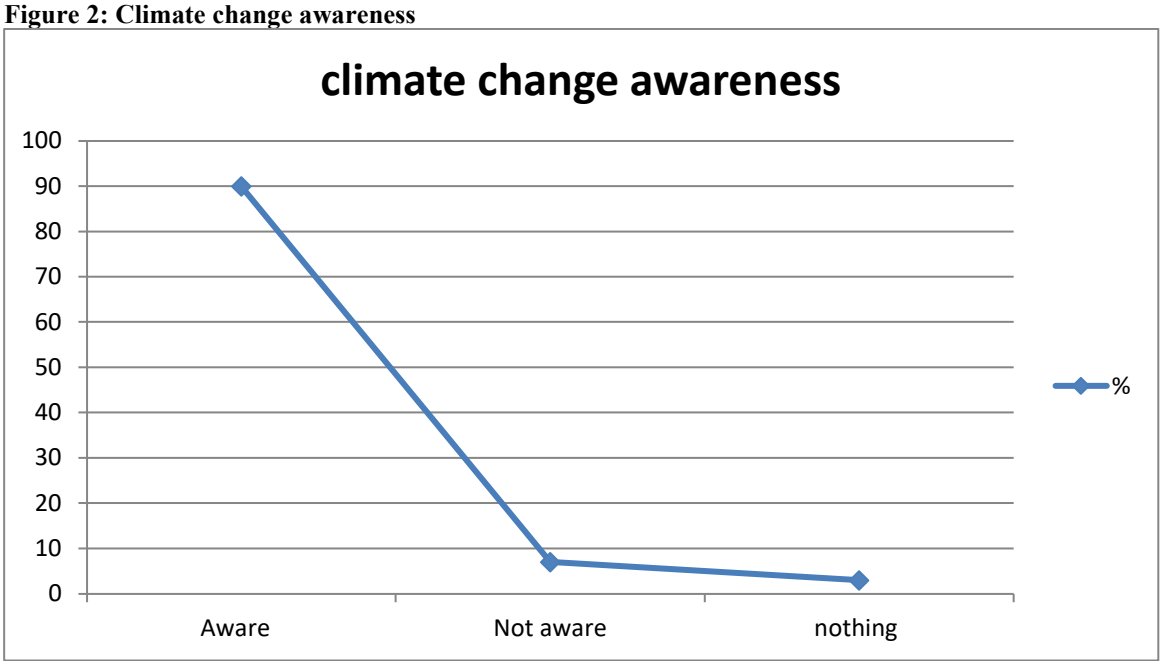
This study aimed to determine the adaptive strategies used by smallholder farmers in ASAL of Evurore division of Mbeere North, Kenya. This study employed a qualitative research design based on interviews with participants

in the agricultural sector, livestock, community leaders, project leaders and local authorities' cooperative. It included 17 respondents from eight locations and community members with their experience to maximize the results and significance of this study. The interviews were based on eight thematic areas (questions) as per the responses coded as per the thematic areas.

4.3 Awareness of Climate Change and Variability

The findings revealed that 90% of the respondents were aware of climate change and variability, 7% indicated that they were unaware, and 3% did not bother about climate change. Even though the findings show that a significant 90% were aware of climate change.

Figure 2: Climate change awareness



Source: Field Data (2022)

4.4 Challenges Faced in Implementation of Adaptation Strategies

In assessing the challenges faced in implementation of adaptation strategies, the findings showed that deforestation was the main challenge at 30.9%, global warming at 17.7%, and soil erosion at 17.0%. The drought, which affects most ASALs, trailed at 13.3 %, and pollution was 10%. The other challenges were lack of irrigation water sources, inadequate rainfall and sand harvesting, sunshine, and water pollution, lack of food, high temperatures and infertile soils. Quandt (2021) and Wetende et al. (2018) from past studies equally established that the major challenge that most smallholder farmers have is lack of access to information on climate change and therefore they were not aware of climate change and adaptation policies that support adaptation strategies. The findings also showed that most organizations had their programmes integrated with climate change awareness and sensitization campaigns. "The public is informed on climate change issues through the public *barazas (Meetings)*, especially public holidays", said one of the Extension officers working at the ministry of agriculture.

Further the study found that deforestation was the main challenge to the effective implementation of climate change adaptation strategies, followed by soil erosion. This confirms the findings of the study by Kamau et al. (2015) that in ASALs, people resort to charcoal burning for survival, and in the process, they cut down trees and accelerate soil erosion due to sand harvesting. Surprisingly, drought, which other studies had indicated and found to be a perennial problem affecting the livelihoods of the people in ASAL areas (Ochieng et al., 2016; GoK, 2013), did not come out as a significant challenge. The findings suggest that the challenges to effective implementation of adaptation strategies result from deforestation, global warming, soil erosion and drought, leading to susceptibility to food insecurity and famine (Speranza et al., 2007, Dougill et al., 2017, Ndiritu, 2020).

The key officials' interviews revealed that most smallholder farmers could not implement the adaptation strategies they were trained on because they lacked knowledge, finance and government commitment. Moreover, this study's findings align with those of Oremo (2013) and Kamau et al. (2015), that adaptation strategies require financial support.

Table 11: Challenges of climate change and adaptation strategies

Challenge	Frequency	%
Pollution	29	10%
Soil erosion	50	17.7%
Global warming	48	17.0%
Deforestation	87	30.9%
Drought	32	11.3%
Lack of irrigation water source	8	2.8%
Inadequate rainfall	6	2.1%
Sand harvesting	5	1.8%
Sunshine	4	1.4%
Water pollution	4	1.4%
Lack of food	3	1.1%
Hot Temperatures	2	0.7%
Infertile soil	2	0.7%
Natural calamities	1	0.4%
Fowl armyworms	1	0.4%

Source: Field Data (2023)

4.5 Adaptation Strategies

The findings in Table 12 revealed that 20.3% of the respondents practised water conservation methods, 24.2% of the respondents practised tree planting, 14.1% of the respondents reduced the number of livestock, and 11.7% practised irrigation farming, while 10.9% practised mixed farming. Other coping strategies to adapt to the effects of climate change include training, planting drought-tolerant crops, and climate-smart agriculture and soil conservation methods.

These findings reflect what the smallholder farmers had been trained on by the key officials working in various government sectors and other organizations. The challenges to implementing adaptation strategies, as found by other studies (Busayo and Kalumba, 2021, Orimoloye et al., 2021, Kalele et al., Oremo, 2013, and IPCC, 2014), are lack of technical capacity, illiteracy, information and on-going training that enhances the capacity of smallholder farmers to adapt. One of the key officials confirmed this when she said, “We have trained the farmers on conservation agriculture, rainwater harvesting and drought-tolerant crops. The challenge is that most farmers are poor and cannot implement what they learned from the training”. Despite all this, there was a strong consensus amongst the key officials that training smallholder farmers in conservation agriculture, climate-smart agriculture, soil conservation and drought-tolerant crops could not lead to effective adaptation strategies.

In earlier studies, Kamau et al. (2015) found that smallholder farmers’ adaptation strategies were limited to what will sustain them, such as charcoal burning, sand harvesting, hunting and rainwater harvesting. When asked about the adaptation strategies they employ to adapt to the extreme effects of climate change. Additionally, the findings of other studies (Huynh et al., 2020, Hosen et al.,2020; Kettle et al., 2014, Vinyeta and Lynn, 2013) revealed that adaptation strategies fail because the IK and adaptation strategies are not integrated with the scientific and technological knowledge. This could explain why the training smallholder farmers received bore minimal results.

Table 2 Adaptation Strategies

Measure	Frequency	Percent
Water conservation methods	26	20.3
Planting trees	31	24.2
Irrigation Measures	15	11.7
Trainings	6	4.7
Drought-tolerant crops	4	3.1
Reducing the number of livestock	18	14.1
Climate-smart agriculture	4	3.1
Mixed farming	14	10.9
Soil conservation methods	10	7.8

Source: Field Data (2023)

4.6 Inferential statistics

The study used correlation analysis to establish the relationship between the variables under study.

4.7 Correlation Results

The study results indicate that there was significant positive correlation between challenges ($r = 0.068$; $p < 0.05$).

These findings reveal that challenges are positively related to climate change, indicating that an improvement in one or all of these variables would lead to adopting adaptation strategies. This confirms the findings of the WHO (2011) studies that young people leave the village to look for jobs in towns and cities.

4.8 Regression Coefficient Results

Regression is a mathematical approach to finding an underlying relationship or difference between two or more observations. In addition, the regression models used in this study provide insight into the drivers of smallholder farmers' ability to adapt to climate change. Regression analysis was performed with the independent variables being challenges, and adaptation strategies were the dependent variables

Table 3: Regression Coefficient Results

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Model					
(Constant)	650.466	570.116		1.141	.256
Challenges	.007	.020	0.034	0.372	0.007

Dependent variable: Adaptation Strategies

Source: Study Data (2023)

The results shown in Table 15 show that the climate change adaptation strategies would be 650.5 if challenges of adaptation strategies were held constant. The results further showed that the climate change adaptation strategies increased by 0.007units for every unit increase in challenges. The climate change adaptation strategies in Evurore division, Kenya. As a result, the study established the following regression model:

$Y = 650.466 + 0.007X_1$

Where Y = climate change adaptation strategies

β_0 = Constant Term

β_1 = Beta Coefficients

X_1 = Challenges

5. Conclusion and Recommendation

This study attempted to understand the challenges farmers faced as they adapted to climate change by analyzing the potential risks of climate change impacts, assessing their adaptive capacity, and exploring the effectiveness of adaptation strategies. The results indicated that climatic challenges significantly affected adaptation strategies. Additionally, the perception of the residents in regards to climate change had a significant effect on the adaptation strategies. The study found that subjective factors such as perception, knowledge, attitudes and behaviour determine the smallholder farmers' implementation of adaptation strategies.

Deforestation, followed by soil erosion, was determined to be a significant obstacle to successfully implementing adaptation strategies. The findings reveal that there appears to be an overall trend among smallholders toward more drought-tolerant crops. This can be explained by their practice of tree planting, water conservation, and irrigation as part of their coping strategies for drought.

The findings from this study indicate that smallholder farmers' implementation of adaptation strategies in ASALs is constrained by the high costs associated with farm inputs. The study recommends for creation of awareness on climate change and facilitation to access of relevant technology to enhance implementation of climate change adaptation practices in.Evurore region.

REFERENCES

Alexander, K., Hettiarachchi, S., Ou, Y., & Sharma, A. (2019). Can integrated green spaces and storage facilities absorb the increased risk of flooding due to climate change in developed urban environments. *Journal of Hydrology*, *579*, 124201.

Amegavi, G. B., Langnel, Z., Ofori, J. J. Y., & Ofori, D. R. (2021). The impact of adaptation on climate vulnerability: Is readiness relevant? *Sustainable Cities and Society*, *75*, 103325.

Aminga, V. M., & Krampe, F. (2020). *Climate-related Security Risks and the African Union. SIPRI*. accessed 2021-08-30. Available at: https://www. sipri. org/publications/2020/sipri-policy-briefs/climate-related-security-risks-andafrican-union.

Aryal, J. P., Sapkota, T. B., Krupnik, T. J., Rahut, D. B., Jat, M. L., & Stirling, C. M. (2021). Factors affecting farmers' use of organic and inorganic fertilizers in South Asia. *Environmental Science and Pollution Research*, *28*(37), 51480-51496.

Ashaolu, E. D., & Iroye, K. A. (2018). Rainfall and potential evapotranspiration patterns and their effects on climatic water balance in the Western Lithoral Hydrological Zone of Nigeria. *Ruhuna Journal of Science*, *9*(2), 92-116.

Ayugi, B. O., Wen, W., & Chepkemoi, D. (2016). Analysis of spatial and temporal patterns of rainfall variations over Kenya. *Studies*, *6*(11).

Ayugi, B., Tan, G., Gnitou, G. T., Ojara, M., & Ongoma, V. (2020). Historical evaluations and simulations of precipitation over East Africa from Rossby centre regional climate model. *Atmospheric Research*, *232*, 104705.

Beddington, J. R., Asaduzzaman, M., Bremauntz, F. A., Clark, M. E., Guillou, M., Jahn, M. M., ... & Wakhungu, J. (2012). Achieving food security in the face of climate change: final report from the Commission on Sustainable Agriculture and Climate Change. *Achieving food security in the face of climate change: final report from the Commission on Sustainable Agriculture and Climate Change, CGIAR Secretariat Publications (2012)*.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., & Herrero, M. (2013). Adapting agriculture to climate change in Kenya: Household strategies and determinants. *Journal of environmental management*, *114*, 26-35.

Busayo, E. T., & Kalumba, A. M. (2021). Recommendations for linking climate change adaptation and disaster risk reduction in urban coastal zones: Lessons from East London, South Africa. *Ocean & Coastal Management*, *203*, 105454.

CIDP, "Embu county integrated development plan," Tech. Rep., CIDP, Vacoas-Phoenix, Mauritius,2019, https://www.embu.go.ke/wp-content/uploads/2019/09/APPROVED-CIDP-2018-2022.pdfCounty report.

Dougill, A. J., Dixon, J. L., Stringer, L. C., & Cull, T. (2017). Identifying climate services needs for national planning: insights from Malawi. *Climate Policy*, *17*(2), 189-202.

El-Beltagy, A., & Madkour, M. (2012). Impact of climate change on arid lands agriculture. *Agriculture & Food Security*, *1*, 1-12.

FAO. 2020. The State of Agricultural Commodity Markets 2019–2020. Trade and food security: Achieving a better balance between national priorities and the collective good. Food and Agriculture Organization of the United Nations, Rome. Accessed April 19, 2020. http://www.fao.org/publications/soco/the-state-of-agricultural-commodity-markets-2019-20/e

Filho, W., Balogun, A. L., Ayal, D. Y., Bethurem, E. M., Murambadoro, M., Mambo, J., ... & Mugabe, P. (2018). Strengthening climate change adaptation capacity in Africa-case studies from six major African cities and policy implications. *Environmental Science & Policy*, *86*, 29-37.

Gasper, D. (2017). What is the capability approach? Its core, rationale, partners and dangers. In *Development ethics* (pp. 217-241). Routledge.

Gebeyehu, A. K., Snelder, D., Sonneveld, B., & Abbink, J. (2021). How do agro-pastoralists cope with climate change? The case of the Nyangatom in the Lower Omo Valley of Ethiopia. *Journal of arid environments*, *189*, 104485.

Giovannucci, E. L. Kantor, E. D., Rehm, C. D., Haas, J. S., & Chan, A. T (2015). Trends in prescription drug use among adults in the United States from 1999-2012. *Jama*, *314*(17), 1818-1830.

Gravetter, F. J., Wallnau, L. B., Forzano, L. A. B., & Witnauer, J. E. (2020). *Essentials of statistics for the behavioral sciences*. Cengage Learning.

Habitat, U. N. (2014). A new strategy of sustainable neighborhood planning: Five principles. *Nairobi, Kenya: United Nations Human Settlements Programme*.

Habitat, U. N. (2014). Urban patterns for a green economy leveraging density. *Nairobi: UNON Publishing Services*.

Hansen, J., Sato, M., & Ruedy, R. (2012). Perception of climate change. *Proceedings of the National Academy of Sciences*, *109*(37), E2415-E2423.

Helgeson, J., & Ellis, J. (2015). *The role of the 2015 agreement in enhancing adaptation to climate change* (No. 2015/1). OECD Publishing.

Hidalgo, M., Bartolino, V., Coll, M., Hunsicker, M. E., Travers-Trolet, M., & Browman, H. I. (2022). 'Adaptation science'is needed to inform the sustainable management of the world's oceans in the face of climate change. *ICES Journal of Marine Science*, *79*(2), 457-462.

Hosen, N., Nakamura, H., & Hamzah, A. (2020). Adaptation to climate change: Does traditional ecological knowledge hold the key. *Sustainability*, *12*(2), 676.

Huynh, C., Le, Q. N. P., Nguyen, M. T. H., Tran, P. T., Nguyen, T. Q., Pham, T. G., ... & Trinh, H. N. (2020). Indigenous knowledge in relation to climate change: adaptation practices used by the Xo Dang people of central Vietnam. *Heliyon*, *6*(12), e05656.

IPCC (2021). Summary for policymakers. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, *(Cambridge University Press), pp. 1–41*

IPCC (2022). Synthesis report summary for policymakers. *An Assessment of the Intergovernmental Panel on Climate Change*.

Jackson, C. R., Meister, R., & Prudhomme, C. (2011). Modelling the effects of climate change and its uncertainty on UK Chalk groundwater resources from an ensemble of global climate model projections. *Journal of*

Hydrology, *399*(1-2), 12-28.
Jellason, N. P., Conway, J. S., & Baines, R. N. (2021). Understanding impacts and barriers to adoption of climate-smart agriculture (CSA) practices in North-Western Nigerian drylands. *The Journal of Agricultural Education and Extension*, *27*(1), 55-72.
Kalele, D. N., Ogara, W. O., Oludhe, C., & Onono, J. O. (2021). Climate change impacts and relevance of smallholder farmers' response in arid and semi-arid lands in Kenya. *Scientific African*, *12*, e00814.
Kamau, S. W., Kuria, D., & Gachari, M. K. (2015). Crop-land suitability analysis using GIS and Remote Sensing in Nyandarua County, Kenya. *Journal of Environment and Earth Science*, *5*(6), 121-131.
Kangalawe, R. Y., & Lyimo, J. G. (2013). Climate Change, Adaptive Strategies and Rural Livelihoods in Semiarid Tanzania. *Natural Resources*, *4*(3), 266-278.
Karanja Ng'ang'a, S., Bulte, E. H., Giller, K. E., McIntire, J. M., & Rufino, M. C. (2016). Migration and self-protection against climate change: a case study of Samburu County, Kenya. *World Development*, *84*, 55-68.
Karimi, M. S., Fazelpour, F., Rosen, M. A., & Shams, M. (2019). Comparative study of solar-powered underfloor heating system performance in distinctive climates. *Renewable energy*, *130*, 524-535.
Kettle, N. P., Dow, K., Tuler, S., Webler, T., Whitehead, J., & Miller, K. M. (2014). Integrating scientific and local knowledge to inform risk-based management approaches for climate adaptation. *Climate Risk Management*, *4*, 17-31.
Kimaro, E. G., Mor, S. M., & Toribio, J. A. L. (2018). Climate change perception and impacts on cattle production in pastoral communities of northern Tanzania. *Pastoralism*, *8*, 1-16.
Masud, M. M., Azam, M. N., Mohiuddin, M., Banna, H., Akhtar, R., Alam, A. F., & Begum, H. (2017). Adaptation barriers and strategies towards climate change: Challenges in the agricultural sector. *Journal of cleaner production*, *156*, 698-706.
Mavhura, E., Manatsa, D., & Mushore, T. (2015). Adaptation to drought in arid and semi-arid environments: Case of the Zambezi Valley, Zimbabwe. *Jàmbá: Journal of Disaster Risk Studies*, *7*(1), 1-7.
Mugenda, O. M., & Mugenda, A. G. (2003). Research methods: Quantitative and. *Qualitative. Approaches. Nairobi*.
Mugi-Ngenga, E. W., Mucheru-Muna, M. W., Mugwe, J. N., Ngetich, F. K., Mairura, F. S., & Mugendi, D. N. (2016). Household's socio-economic factors influencing the level of adaptation to climate variability in the dry zones of Eastern Kenya. *Journal of Rural Studies*, *43*, 49-60.
Murieta, E. S., Galarraga, I., & Olazabal, M. (2021). How well do climate adaptation policies align with risk-based approaches? An assessment framework for cities. *Cities*, *109*, 103018.
Ndiritu, S. W. (2020). Beef value chain analysis and climate change adaptation and investment options in the semi-arid lands of northern Kenya. *Journal of Arid Environments*, *181*, 104216.
Njeru, P. N., Maina, I., Lekasi, J. K., Kimani, S. K., Esilaba, A. O., Mugwe, J., & Mucheru-Muna, M. (2016). Climate smart agriculture adaptation strategies for rain-fed agriculture in drought-prone areas of Central Kenya. *International Journal of Agricultural Resources, Governance and Ecology*, *12*(2), 113-124.
Ochieng, J., Kirimi, L., & Mathenge, M. (2016). Effects of climate variability and change on agricultural production: The case of small scale farmers in Kenya. *NJAS-Wageningen journal of life sciences*, *77*, 71-78.
Ojo, T. O., & Baiyegunhi, L. J. S. (2021). Climate change perception and its impact on net farm income of smallholder rice farmers in South-West, Nigeria. *Journal of Cleaner Production*, *310*, 127373.
Oremo, F. O. (2013). *Small-scale farmers' perceptions and adaptation measures to climate change in Kitui County, Kenya* (Doctoral dissertation, University of Nairobi,).
Orimoloye, I. R., Belle, J. A., Olusola, A. O., Busayo, E. T., & Ololade, O. O. (2021). Spatial assessment of drought disasters, vulnerability, severity and water shortages: a potential drought disaster mitigation strategy. *Natural Hazards*, *105*, 2735-2754.
Quandt, A., Neufeldt, H., & Gorman, K. (2023). Climate change adaptation through agroforestry: opportunities and gaps. *Current Opinion in Environmental Sustainability*, *60*, 101244.
Rajamani, L. (2016). Ambition and differentiation in the 2015 Paris Agreement: Interpretative possibilities and underlying politics. *International & Comparative Law Quarterly*, *65*(2), 493-514.
Simon, D., & Leck, H. (2015). Understanding climate adaptation and transformation challenges in African cities. *Current Opinion in Environmental Sustainability*, *13*, 109-116.
Speranza, C. (2010). Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni district, Kenya. *The European Journal of Development Research*, *22*, 623-642.
Stavi, I., Paschalidou, A., Kyriazopoulos, A. P., Halbac-Cotoara-Zamfir, R., Siad, S. M., Suska-Malawska, M., ... & Ficko, A. (2021). Multidimensional food security nexus in drylands under the slow onset effects of climate change. *Land*, *10*(12), 1350.
Torhan, S., Grady, C. A., Ajibade, I., Galappaththi, E. K., Hernandez, R. R., Musah-Surugu, J. I., ... & Global Adaptation Mapping Team. (2022). Tradeoffs and synergies across global climate change adaptations in the

food-energy-water nexus. *Earth's Future*, *10*(4), e2021EF002201.

Vinyeta, K., & Lynn, K. (2013). Exploring the role of traditional ecological knowledge in climate change initiatives. Portland, OR: US Department of Agriculture, Forest Service. *Pacific Northwest Research Station*.

Wetende, E., Olago, D., & Ogara, W. (2018). Perceptions of climate change variability and adaptation strategies on smallholder dairy farming systems: Insights from Siaya Sub-County of Western Kenya. *Environmental development*, *27*, 14-25.

Yamane, T. (1967). Sampling Formula. *E-Book www albookez com*.