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Efficacy of Adaptation of Smallholder Maize Production to Climate Variability in Selected Countries of Kenya

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Abstract

Maize is a staple food for 96 percent of Kenyans. Smallholders supply up to 75 percent of maize produced in Kenya but are affected by unpredictable timing, duration, and distribution of rainfall, especially during the growing season. To enhance maize productivity adoption of robust adaptation measures is vital. The study aimed to evaluate the level of efficacy of adaptation of smallholder maize production to climate variability in Kitui and Laikipia counties. Data from 273 smallholder maize producers drawn from Kitui and Laikipia counties was analyzed. A questionnaire was administered to collect data on demographic, socio-economic characteristics, and adaptation choices. The level of efficacy of adaptation was derived based on the Multiple Criteria Evaluation. Results showed that the majority of smallholders in the study (47 percent) reported a low level of efficacy of adaptation most of whom were from Laikipia County (54 percent) as compared to Kitui County (44 percent). Overall, a very small proportion of smallholders reported a high level of efficacy of adaptation (7 percent). The study concluded that the level of efficacy of adaptation of smallholder maize production to climate variability in semi-arid areas was low. The County Governments through the department of agriculture and environment could establish guidelines for a robust combination of adaptation choices to ensure the suitability and enhancement of maize production.

Keywords: Adaptation, Multiple Criteria Evaluation, Efficacy of adaptation, criteria weighted score, index

1. Introduction

World over, there is heightened concern about the need to increase food production to feed the growing population owing to the magnitude of challenges relating to hunger and famine. To sustain the resolve to combat hunger, much focus is on support to agricultural practices that lead to increased agricultural output, protection of ecosystems that support agriculture, strengthening the capacity to adapt agriculture to climate change, improvement of the quality of soils, increased access to inputs and knowledge to enhance agriculture production among other ways in line with the Sustainable Development Goals (United Nations, 2015).

Despite being responsible for food security, agriculture is one of the sectors adversely affected by climate variability. Climate variability affects agriculture through increasing temperatures, rainfall variability, recurrent droughts, recurrent famine, pests, and diseases among others (Olsson et al., 2019). This is detrimental to maize production in Kenya, especially where 80 percent of the land area already constitutes Arid and Semi-Arid Lands receiving only between 200 and 700 millimeters (Republic of Netherlands, 2018).

In Kenya, maize production outstrips production in some years with worse divergence than others (Kirui, 2014). The stagnation in maize production has a direct negative impact on food security since the highest incidents of food insecurity are associated with maize shortage (Kabubo-Mariara and Kabara, 2015). Maize is the staple food for approximately 96 percent of Kenyans and about 75 percent of its production is by smallholders (Njagi et al., 2017). Furthermore, it accounts for about 40 percent of the crop area in Kenya (International Maize and Wheat Improvement Center, 2015). However, unpredictable timing, duration, and distribution of rainfall especially during the growing season affect maize production adversely. The contribution of smallholder maize production to food nutrition and security and household income makes adaptation vital for sustained production and improved household livelihoods. The major goal of adaptation is to increase the capacity of maize production systems to minimize or overcome the impacts of climatic shocks (Nhemachena and Hassan, 2007). Wrong selection or inappropriate application of adaptation choices could further exacerbate low maize yields leading to financial losses.

In the recent past, farmers particularly smallholders are encouraged to practice Climate Smart Agriculture to reinforce adaptation efforts (Food and Agriculture Organisation, 2013). This involves increasing agricultural productivity and incomes and combining adaptation to climate change and mitigation (Abegunde and Obi, 2022). Adaptation could be undertaken at farm level or macro level scales. Farm-level adaptation involves decision-making by smallholders to respond to season-to-season climate variability (Hassan and Nhemachena, 2008). Adaptation could be limited by the level of resource endowment and information both at micro and macro levels. Thus, although smallholders may be aware of the climatic changes, resource and information limitations may affect the level or results of adaptation (Schipper, 2020). It is important to evaluate the efficacy of adaptation practiced. Efficacy is the perceived judgment of the capability of adaptation choices to successfully produce desired results with respect to effectiveness, high yield, affordability, farmer implementability, and additional benefits.

Studies on adapting agriculture to climate change (Hassan and Nhemachena, 2008; Kabubo-Mariara, 2008; Kebede and Adane, 2011; Bryan et al., 2013; Mabe et al., 2014; Fadina and Barjolle, 2018; Ndamani and Watanabe, 2016; Ahmed, 2016 and Shikuku et al., 2017) explored numerous adaptation choices employed by farmers and the determinants of adaptation. However, no studies in Kenya estimated the efficacy of adaptation, particularly in reference to smallholder maize production. In addition, most of the studies had challenges analyzing the simultaneous application of multiple adaptation choices by farmers. Therefore, the main objective of this study was to evaluate the levels of efficacy of adaptation of smallholder maize production to climate variability in selected counties in Kenya to address the research gaps identified and add to existing knowledge.

2. Methods

2.1. Area of study

In this study, smallholders were considered individuals who farmed on 5 acres piece of land and below. Two areas were considered in the study: Kitui located in lowland areas and Laikipia County located in highland areas.

2.2. Data types and sources

A cross-sectional research design was used where data with respect to the long rain growing season of 2017 (March to August) was collected from smallholders to facilitate the assessment of the level of efficacy of adaptation of smallholder maize production to climate variability. A questionnaire was used to collect data on adaptation practised and socioeconomic variables. Respondents were selected using multistage sampling. Respondents from Kitui and Laikipia counties were clustered at the Ward level and then selected using simple random sampling.

2.3. Measurement of the levels of efficacy of adaptation of smallholder maize production to climate variability

The multiple criteria evaluation method was used in deriving levels of efficacy. The approach of evaluating adaptation choices based on various criteria was established by the Intergovernmental Panel on Climate Change (Carter et al., 1994). Some of the criteria used in evaluating adaptation by earlier studies include effectiveness, efficiency, flexibility, farmer implementability, and independent benefits (Thi and Chaovanapoonphol, 2014). The evaluation of efficacy in the present study was based on five criteria: effectiveness, high yield, farmer implementability, affordability, and additional benefits. In the context of this study, effectiveness measures the ability of the adaptation choice to reduce losses in smallholder maize production. According to Smith (1996), effectiveness was used to measure the ability of adaptation to reduce vulnerability to climate change (Thi and Chaovanapoonphol, 2014). High yield in the present study was used to measure the ability of adaptation choice to increase yield despite climate variability. Titus (1990) measured the ability of adaptation choice to perform well under different climate change settings with the criteria of flexibility (Thi and Chaovanapoonphol, 2014). Affordability was used to measure the extent to which smallholders could meet the cost of adapting. According to Dolan et al. (2001), economic efficiency could be used to assess whether the additional cost of farming occasioned by adaptation exceeded the economic benefits of adaptation.

Farmer implementability was used to measure the extent to which smallholders could implement selected adaptation choices considering their level of knowledge and skills. Thi and Chaovanapoonphol (2014) measured farmer implementability as the degree to which an adaptation choice was understandable, observable, and compatible with farm operations. Additional benefits criterion was used to measure the extent to which an adaptation choice had multiple benefits. Smith and Lenhart (1996) suggested that the benefits of adaptation irrespective of the adverse impacts of climate change could be evaluated based on independent benefits criteria (Dolan et al., 2001).

Smallholders selected their preferred adaptation choices from the following options: manure, fertilizer, agroforestry, changing planting dates, increasing land size, decreasing land size, irrigation, mulching, mixed cropping, and conservation agriculture. Thereafter, they evaluated the adaptation choices by assigning scores to the adaptation applied using a five-point scale (1- lowest score and 5 highest-score) with respect to effectiveness, high yield, affordability, farmer implementability, and additional benefit criteria.

Furthermore, extension officers evaluated the criteria for assessing the efficacy of adaptation by assigning scores to each criterion on a scale of 1 to 5 based on how best they perceived the criterion contributed to a reduction of the adverse impacts of climate variability (Dolan et al., 2001). The average criteria score corresponding to each criterion was divided by the total criteria score and weighted by 10 to derive the criteria weighted score (Cw) for each criterion as follows:

$$Cw = \frac{\sum_{i}^{n} ACs_i}{TCs_i} \times 10 \text{ ....1}$$

Where ACs_i is the average criteria score while TCs_i is the total criteria score.

Thereafter, the scores assigned by smallholders for the respective adaptation under each criterion was multiplied by the criteria weighted score to derive the weighted sum ($Wsum_{ij}$) as follows:

$$Wsum_{ij} = \sum_{i=1}^{n} S_j \times Cw \text{..................................2}$$

Where S_j is the score assigned by smallholder i for adaptation j, Cw is the criteria-weighted score (Thi and Chaovanapoonphol, 2014). A proportion of smallholders applied multiple adaptation alternatives at the same time. Therefore, the weighted sum with respect to all the adaptation choices employed by a smallholder was added up to create an index for efficacy. The index for efficacy of adaptation (Z_i) was expressed as follows:

$$Z_i = MWsum_i + FWsum_i + AGWsum_i + PWsum_i + INWsum_i + DWsum_i + IRWsum_i + MUWsum_i + MXWsum_i + CAWsum_i \text{ ....3}$$

Where $MWsum_i$ is the weighted sum for manure, $FWsum_i$ is the weighted sum for fertilizer, $AGWsum_i$ is the weighted sum for agroforestry, $PWsum_i$ is the weighted sum for changing planting dates, $INWsum_i$ is the weighted sum for increasing land size, $DWsum_i$ is the weighted sum for decreasing land size, $IRWsum_i$ is the weighted sum for irrigation, $MUWsum_i$ is the weighted sum for mulching, $MXWsum_i$ is the weighted sum for mixed cropping and $CAWsum_i$ is the weighted sum for conservation agriculture.

The equal interval scale was used in classifying the index for efficacy into three levels (low, moderate, and high) as shown below (Thi and Chaovanapoonphol, 2014):

$$\text{Interval} = \frac{\text{Highest Value} - \text{Lowest Value}}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

3. Results and Discussion

3.1. Weighted scores for evaluation criteria and adaptation choices

The extension officers evaluated the following criteria and thereafter weighted them as per equation 1: effectiveness, high yield, affordability, farmer implementability, and additional benefits. The criteria weighted score is shown in table 1:

Table 1. Criteria weight

Criterion	Weight (Cw)
Effectiveness	**3.2**
High yield	**2.3**
Affordability	**1.8**
Farmer implementability	**1.5**
Additional benefit	**1.2**

Source: survey data

In addition, smallholders evaluated each of the following adaptation choices and assigned scores: manure, fertilizer, agroforestry, changing planting dates, increasing land size, decreasing land size, mulching, mixed cropping, and conservation agriculture. The scores assigned by smallholders with respect to each adaptation applied were multiplied by the criteria weighted score to obtain the weighted sum for each adaptation choice under each evaluation category. The summary results are presented in table 2.

Table 2. Weighted scores for the adaptation choices

Adaptation choices	Effectiveness	High yield	Affordability	Farmer implement ability	Additional benefit	Weighted sum	Ranking
Manure	10.9	9.55	7.51	4.73	4.74	37.42	4
Fertilizer	11.94	9.65	6.23	3.81	4.77	36.4	7
Agroforestry	10.2	8.76	6.83	4.13	4.55	34.47	9
Changing planting dates	11.59	9.42	7.58	4.14	4.76	37.49	3
Increasing land size	9.51	9.44	6.35	5.51	4.13	34.94	8
Decreasing land size	7.42	6.17	7.2	4.98	4.04	29.8	10
Irrigation	12.38	10.21	7.13	4.67	4.8	39.2	1
Mulching	10.63	8.84	7.26	5.03	4.8	36.56	6
Mixed cropping	11.2	9.05	7.48	4.49	4.72	36.94	5
Conservation Agriculture	12.04	9.8	7.66	3.78	4.85	38.12	2

Source: survey data

3.1.1. Effectiveness

From table 2, the two most effective adaptation choices in reducing maize production losses were: irrigation and conservation agriculture. Conservation agriculture improves water holding capacity and reduces evaporation hence facilitating the minimization of the adverse impacts of climate variability (Su et al. (2021)). Verma (2021) also notes that conservation agriculture contributes to the reduction of warming of the atmosphere by sequestering carbon dioxide thereby reducing the vulnerability to the impacts of global warming. Liu and Basso (2020) simulated long-term maize yields using a crop model and confirmed that conservation agriculture reduced yield loss considerably as compared to conventional tillage. On the other hand, irrigation was found to moderate canopy temperature thus enhancing adaptation from heat stress thus suggesting that irrigation was effective in reducing loss in maize production (Moradi et al., 2013). The results suggest that dedicating more land to maize production to the conservation of agriculture and irrigation could be key to minimizing maize losses caused by climate variability.

The least effective adaptation choices were decreasing land size and increasing land size. The results suggest that adjustment of farm size may not be effective in reducing losses in maize production. Increasing maize farm size is associated with the loss of land area covered with trees which leads to an increase in maize yield in the short run and a decrease in the long run (Epule and Bryant, 2015). This is because deforested areas escalate the adverse impact of climate change on maize production when such areas become vulnerable to soil erosion and compromise nutrient storage (Khodadadi et al., 2021).

3.1.2. High yield

From table 2, irrigation was also found to contribute the most to high yield followed by conservation agriculture. This finding is consistent with previous studies on irrigation. Moradi et al. (2013) established that irrigation contributed to increased maize yields as compared to baseline values. Olajire et al. (2020) also classified irrigation among adaptation choices that were efficient in improving yields. On the other hand, findings that conservation agriculture contributed to high yields are supported by Su et al. (2021) who established that conservation agriculture enhanced yields and attributed this to the presence of crop residues which facilitated enhanced soil organic matter, water retention capacity and reduction in soil water evaporation and surface runoff. Furthermore, Mutuku et al. (2021) found that conservation agriculture increased yields in low-fertility land. The results suggest that enhancement of irrigation and conservation agriculture could contribute to increased maize production thereby improving food security.

Decreasing land size and agroforestry were found to contribute the least to high yield. The result is supported by Abdulaleem et al. (2019) who established a positive relationship between farm size and maize yield. However, increased yield due to a reduction in farm size could occur if the land used was of high quality (Gollin, 2018). This implies that if low-quality land was reduced, yields would decline. Noack and Larsen (2019) also found that in Uganda yield decreased with an increase in farm size. The finding on agroforestry was not as expected. However, although agroforestry is instrumental in improving microclimate, carbon sequestration, soil fertility, and soil moisture, it may contribute to low maize yields since smaller crops may compete for light, water, and nutrients with the trees (Nyaga et al., 2019). In addition, agroforestry may inhibit the use of machinery during farming due to hindrances by the roots of the trees (Ibrahim et al., 2019). The findings on agroforestry suggest that the provision of technical guidance on agroforestry to smallholders could enhance its adoption and its ability to promote increased yields. For instance, identification of the right tree species to combine with maize production and the right tree species for the respective agroecological zones since results could be site-specific (Raskin and Osborn, 2019). The findings further suggest the need for proper farm planning to enhance positive results.

3.1.3. Affordability

Table 2 shows that conservation agriculture and changing planting dates had the highest weighted score on affordability. Conservation agriculture was found to significantly reduce the cost of farming since ploughing is not required and it preserves crop cover permanently (Verma, 2021). On the other hand, smallholders' practice of changing planting dates mostly depends on indigenous knowledge (Nyakaisiki et al., 2019). Therefore, it does not require any financial outlay. Waongo et al. (2015) observed that changing planting dates was a low-cost climate change adaptation strategy. Although affordable, smallholders may be challenged in determining when to commence planting. Mugiyo et al. (2021) found that there was no consistency in the dates reported by farmers as the early planting date. The findings suggest that accurate identification of appropriate planting time could facilitate the practice of changing planting dates. Mugiyo et al. (2021) therefore recommended the establishment of a crop calendar to facilitate the selection of planting time with respect to specific crop varieties.

The least affordable adaptation choices were fertilizer and increasing land size. Fagariba et al. (2018) found that fertilizer was less affordable to the majority of farmers even though they acknowledged that it boosted yields. It was therefore ranked low among other adaptation choices such as changing planting dates, agroforestry, manure, irrigation, and growing drought-resistant crops. Other studies (Wushuai et al., 2021; Elise et al., 2020) found that fertilizer costs could be prohibitive leading to low application, especially with an increase in land size. Ndamani and Wanatabe (2016) also established that adaptation to climate change was higher in small farm sizes than in large farms due to cost. In China, the increase in subsidies made fertilizer affordable leading to increased agricultural productivity (Ren et al., 2019). The results suggest that reduction of the cost of farm inputs such as fertilizer could render an increase in land size more affordable to smallholders.

3.1.4. Farmer implementability

Table 2 also shows that increasing land size and mulching had the highest weighted scores for farmer implementability. The results are plausible because the most commonly used mulches are largely available locally from the farms. Some of the materials used include crop residues such as ground nut cover, wheat and paddy straws, dry leaves, grass, bark, sawdust, and compost (Telkar et al., 2017). Mulch is applied artificially or naturally on the surface of the land and therefore is not knowledge-intensive (Ranjan et al., 2017).

Conservation agriculture and fertilizer had the lowest farmer implementability. According to Tadesse (2016), few farmers adopt conservation agriculture due to technical constraints. Conservation agriculture also requires specialized equipment, particularly for seeding and planting hence farmers may require training to use them appropriately (Verma, 2021). There could be uncertainties relating to the management of pests, especially for farmers accustomed to conventional tillage (Fanadzo et al., 2018). Smallholders may also need knowledge of sustainable weed management strategies (Lee and Thierfelder, 2017). The findings suggest that although conservation agriculture was found affordable, effective, and contributing to high yield, its adoption is hampered by technological challenges. On the other hand, knowledge of the right time, type, and quantity of fertilizer and the condition of the soil are necessary. Cairns et al. (2021) noted low adoption of fertilizer use among women. In addition, Mideksa et al. (2021) found that the majority of the farmers applied fertilizer below the recommended quantities. However, education was found to improve the intensity of fertilizer usage attributed to the ability of farmers to understand and interpret information (Mideksa et al., 2021). The results suggest that education and capacity building of farmers could enhance proper adoption of conservation agriculture and fertilizer.

3.1.5. Additional benefits

From table 2, conservation agriculture had the most additional benefits followed by irrigation and mulching. Conservation agriculture saves time, reduces production and environmental costs, increases yield, and improves soil quality (Jat et al., 2021). Irrigation also promotes an increase in farm income besides lessening the adverse impacts of climate change (Osewe et al., 2020; Da Cunha et al., 2015). Mulching on the other hand helps to moderate soil temperature, conserves soil moisture, and suppresses diseases and pests (Ranjan et al., 2017). Decreasing the land size and increasing land size were found to have the least additional benefits. Adjustment of land size could be affected by other factors such as the inability of farmers to apply adequate input to boost production in the case of increasing land size (Zhang et al., 2021). The results suggest that a combination of adjustment of land size and other adaptation choices could contribute to the realization of additional benefits.

Overall, conservation agriculture emerged as the most robust adaptation alternative based on the outlined criteria. This result suggests that enhancing smallholders' capacity to adopt conservation agriculture could boost maize production.

3.2. Distribution of smallholders based on the levels of efficacy of adaptation

Results showed that the lowest index of efficacy was 12.4 while the highest was 260.4. The difference between the highest and lowest index of efficacy was divided by three to establish the interval scale as 82.6. The interval scale was established in line with Thi and Chaovanapoonphol (2014). Based on the interval scale, the levels of efficacy were defined as follows: low level of efficacy of adaptation (12.4 to 95); moderate level of efficacy of adaptation (95.1 to 177.7), and high level of efficacy of adaptation (177.8 to 260.4). Table 3 shows the levels of efficacy of adaptation for Kitui and Laikipia counties.

Table 3. Distribution of smallholders as per the levels of efficacy of adaptation

Levels of efficacy	Laikipia County		Kitui County		Combined	
	Frequency	%	Frequency	%	Frequency	%
Low	45	54	84	44	129	47
Moderate	32	39	93	49	125	46
High	6	7	13	7	19	7

Source: survey data

Table 3 shows that most of the smallholders reported a low level of efficacy of adaptation (47 percent) while very few (7 percent) reported a high level of efficacy of adaptation. Majority of the smallholders who reported a low level of efficacy of adaptation were from Laikipia County (54 percent) while most of those who reported a moderate level of efficacy of adaptation were from Kitui County (49 percent). However, an equal proportion of smallholders (7 percent) reported a high level of efficacy of adaptation in both counties.

The findings indicate that although Laikipia County is located in the highlands and perceived to have agroecological zones with better potential for maize production than Kitui County, the level of efficacy of adaptation was low for most of the smallholders than in Kitui County. This suggests that there is a possibility that smallholders in areas perceived to have a better potential for maize production might not be practicing intensive adaptation despite the knowledge that climate was changing (Adeagbo et al., 2021). The results are also supported by Mutunga et al. (2017) who found that smallholders in drier areas adopted more than those who resided in wetter areas. This further brings to question the optimality of adaptation, especially where multiple adaptation choices are practiced. For instance, a combination of organic and inorganic fertilizers was found to enhance soil fertility and consequently maize productivity (Roba, 2018). However, the proportion to be applied when they are used in combination to achieve optimal results may not be obvious to smallholders. These results suggest that capacity building on multiple applications of adaptation choices could facilitate the enhancement of the level of efficacy of adaptation to smallholder maize production (Bedeke et al., 2019).

The scope of the present study was to assess smallholder maize production and the results of the analysis may not be generalized for large-scale maize production. In addition, the areas of study were mainly semi-arid and results may not be generalized for high-potential areas. Further research could be undertaken on determinants of levels of efficacy of adaptation. In addition, a study on maladaptation in smallholder maize production could explain low levels of efficacy despite adaptation by smallholder maize producers.

Conclusion

In Kenya, maize is the staple food for approximately 96 percent of Kenyans hence its adequate production is synonymous with food security. Smallholders supply up to 75 percent of maize produced in Kenya but are affected by unpredictable timing, duration, and distribution of rainfall, especially during the growing season. Further, they experience increasing temperatures, increasing weeds infestation increasing incidents of pests and diseases among other issues. Smallholders recognize that the climate is changing and the majority of them are adapting to climate variability based on imitation, knowledge, and resources at their disposal. However, the outcome is not always as expected. Although the majority of smallholders could be practicing single or multiple adaptations, inappropriate application or wrong selection of adaptation choices coupled with limited knowledge by smallholders on the capability of adaptation choices in producing the desired results could further contribute to low maize yields and consequently financial losses hence the need to evaluate the levels of efficacy of adaptation.

This study takes a departure from previous empirical studies as it undertakes a comparison of two semi-arid areas; one in the highlands and the other in the lowlands. In addition, this study focused on smallholder maize producers and not maize farmers in general, and examined the levels of efficacy of adaptation noting that previous studies in Kenya had mostly assessed adaptation and determinants of adaptation.

The objective of the study was to evaluate the level of efficacy of adaptation of smallholder maize production to climate variability. Primary data on demographic, and socio-economic characteristics was collected directly from smallholder maize producers. A total of 273 smallholder maize producers were sampled through multistage sampling. The respondents were drawn from the Ward level from Kitui South, Rural, Central, and Mwingi Central sub-counties of Kitui County and Laikipia North and East sub-counties of Laikipia County.

The level of efficacy of adaptation of smallholder maize production to climate variability was evaluated based on Multiple Criteria Evaluation. The results showed that on aggregate most of the smallholders reported a low level of efficacy of adaptation while very few reported a high level of efficacy of adaptation. This implies that although the majority of smallholders in the overall sample adapted maize production to climate variability, they did not achieve desired results. Majority of the smallholders who reported a low level of efficacy of adaptation were from Laikipia County while the majority of those who reported a moderate level of efficacy of adaptation was from Kitui County. Evaluation of individual adaptation choices showed that the two most effective adaptation choices in reducing maize production losses and also contributing to high yields were: irrigation and conservation agriculture while the least effective adaptation choices were decreasing land size and increasing land size. Decreasing land size was also found to contribute the least to high yield followed by agroforestry. The results also showed that the most affordable adaptation choices were conservation agriculture and changing planting dates while the least affordable adaptation choices were fertilizer and increasing land size. However, increasing land size had the highest farmer implementability followed by mulching while conservation agriculture and fertilizer had the lowest farmer implementability. The adaptation choices perceived to have the most additional benefits were conservation agriculture, irrigation, and mulching while decreasing land size and increasing land size were found to have the least additional benefits.

The study concludes that the level of efficacy of adaptation for smallholder maize production in semi-arid areas was low. The study also concludes that most of the smallholders in areas perceived to have better potential in maize production such as Laikipia County have low levels of efficacy of adaptation in comparison to smallholders in areas with lower maize production potential such as Kitui County.

This study provides evidence that smallholder maize production in semi-arid areas yields a low level of efficacy of adaptation, especially in areas that are considered less vulnerable. Increasing the levels of efficacy of adaptation calls for appropriate selection of the type and combination of adaptation practices by smallholders. The County Governments through the department of agriculture and environment could establish guidelines for a robust combination of adaptation choices. Smallholders may therefore require support from the department in charge of crop production through capacity-building programmes such as; field practical training on effective ways to implement conservation agriculture and irrigation to enhance adoption. The capacity building should also be backed up by policies and incentives such as affordable pricing for the requisite tools and equipment to encourage adaptation choices providing high levels of efficacy. The County Government in areas perceived to have a better potential for maize production should sensitize smallholders on the need to augment adaptation to cultivate a positive attitude towards adaptation.

The present study has addressed the research gap and contributed to knowledge by evaluating the efficacy of adaptation. Evaluation of adaptation practises could shed more light on why there was insufficient maize production despite adaptation by the majority of the smallholders. The study also explored an alternative approach that could be used in analyzing multiple adaptations to address the challenges faced by most empirical studies undertaking an assessment of adaptation. In addition, the study provided a methodology that can be used in ranking adaptation practises to facilitate policy decisions.

References:

1. Abdulaleem, M.A., Oluwatusin, F.M., & Ojo, O. (2019). Efficiency of Maize Production among Smallholder Farmers in Southwest, Nigeria. *Asian Journal of Agricultural Extension, Economics & Sociology*.
2. Abegunde, V.O. and Obi, A. (2022). The Role and Perspective of Climate Smart Agriculture in Africa: A Scientific Review. *Sustainability 2022*, 14, 2317. https://doi.org/10.3390/ su14042317.

3. Adeagbo, O.A., Ojo, T.O., & Adetoro, A.A. (2021). Understanding the Determinants of Climate Change Adaptation Strategies Among Smallholder Maize Farmers in South-West, Nigeria. *Heliyon, 7*.
4. Ahmed, M.H. (2016). Climate change adaptation strategies of maize producers of the Central Rift Valley of Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 117, 175-186.
5. Bedeke, S., Vanhove, W., Wordofa, M., Natarajan, K., & Van Damme, P. (2018). Perception of and response to climate change by maize-dependent smallholders. *Climate Research*.
6. Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestre, S. & Herrero, M., (2013). Adapting Agriculture to Climate Change in Kenya: Household Strategies & Determinants. *Journal of Environmental Management* 114: 26-35.
7. Cairns, J.E., Chamberlin, J., Rutsaert, P., Voss, R.C., Ndhlela, T. & Magorokosho C. (2021). Challenges for Sustainable Maize Production of Smallholder Farmers in Sub-Saharan Africa. *Journal of Cereal Science*, Volume 101, 2021.
8. Carter, T.R., Harasawa, H. and Nishioka, S. (1994). Intergovernmental Panel on Climate Change Technical Guidelines for Assessing Climate Change Impacts and Adaptations, Department of Geography, University College London.
9. Da Cunha, D., Coelho, A., & Féres, J. (2015). Irrigation as an Adaptive Strategy to Climate Change: An Economic Perspective on Brazilian Agriculture. Environment and Development Economics, 20(1), 57-79. doi:10.1017/S1355770X14000102.
10. Dolan, A. H., Smit, B., Skinner, M. W., Bradshaw, B. and Bryant, C. R. (2001). Adaptation to Climate Change in Agriculture: Evaluation of Options. *Occasional Paper* No. 26.
11. Elise, S., Mvodo, M. & Ivette, M. E. (2020). Assessing the Impacts of Variable Input Costs on Maize Production in Cameroon. *Agricultural Sciences*, 2020, 11, 1095-1108 https://www.scirp.org/journal/as ISSN Online: 2156-8561 ISSN Print: 2156-8553 DOI: 10.4236/as.2020.1111071.
12. Epule, T. E. & Bryant, C. (2015). Maize Production Responsiveness to Land Use Change and Climate Trends in Cameroon. *Sustainability* 7(1):384-397. 10.3390/su7010384.
13. Fadina, A.M., & Barjolle, D. (2018). Farmers' Adaptation Strategies to Climate Change and their Implications in the Zou Department of South Benin. *Environments*.

14. Fagariba, C.J., Song, S., & Baoro, S.K. (2018). Climate Change Adaptation Strategies and Constraints in Northern Ghana: Evidence of Farmers in Sissala West District. *Sustainability*, 10, 1484.
15. Fanadzo, M., Dalicuba, M. & Dube, E. (2018). Application of Conservation Agriculture Principles for the Management of Field Crops Pests. In book: Sustainable Agriculture
16. Food and Agriculture Organization. (2013). Climate-Smart Agriculture. Food and Agriculture Organization of the United Nations: Rome, Italy, 2013.
17. Gollin, D. (2018). Farm Size and Productivity: Lessons from Recent Literature. IFAD Research Series No. 34 ISBN: 978-92-9072-868-9. SSRN: https://ssrn.com/abstract=3321659.
18. Hassan, R. and Nhemachena, C. (2008). Determinants of Climate Change Strategies of African Farmers: Multinomial Choice Analysis. *African Journal of Agricultural and Resource Economics* Vol. 2 No. 1. ISSN 1993-3738.
19. Ibrahim, A.O., Adeji, A.S. & Meduna, P.N. (2019). Constraints Facing Agroforestry Practices Among Farmers in New Bussa, Nigeria. *Journal of Research in Forestry, Wildlife & Environment* Volume 11(3).
20. International Maize and Wheat Improvement Centre. (2015). DT Maize. Drought Tolerant Maize for Africa. A Quarterly Bulletin of the Drought Tolerant Maize for Africa Project Volume 4 no. 3.
21. Jat, H.S., Datta, A., Choudhary, M., Sharma, P.C., & Jat M.L. (2021). Conservation Agriculture: Factors and Drivers of Adoption and Scalable Innovative Practices in Indo-Gangetic Plains of India – a review. *Int. J. Agric. Sustain.*, 19 (2021), pp. 40-55.
22. Kabubo-Mariara, J. and Kabara, M. (2015). Climate Change and Food Security in Kenya. Environment for Development Discussion Paper Series.
23. Kabubo-Mariara, J.K. (2008). Global Warming Crop Selection and Adaptation Options in Kenyan Agriculture. Climate Change Research Progress ISBN: 978-1-60021-998-6, Nova Science Publishers, pp 269-289.
24. Kebede D & Adane H. (2011). Climate Change Adaptations and Induced Livelihoods. Drylands Coordination Group Report No. 64.
25. Khodadadi, M., Alewell, C., Mirzaei, M., & Ehssan-Malahat, E., Asadzadeh, F., Strauss, P. & Meusburger, K. (2021). Deforestation Effects on Soil Erosion Rates and Soil Physicochemical Properties in Iran: A Case Study of Using Fallout Radionuclides in a Chernobyl Contaminated Area. 10.5194/soil-2021-2.

26. Kirui, L. K. (2014). Maize Supply Response to Climate Variability and Prices in Kenya. The Kenya Institute for Public Policy Research and Analysis. *Discussion Paper* No. 174 of 2014.
27. Lee, N. & Thierfelder, C. (2017). Weed Control Under Conservation Agriculture in Dryland Smallholder Farming Systems of Southern Africa. A review. *Agron. Sustain*. Dev. 37, 48 (2017). https://doi.org/10.1007/s13593-017-0453-7.
28. Liu, L., & Basso, B. (2020). Impacts of Climate Variability and Adaptation Strategies on Crop Yields and Soil Organic Carbon in The US Midwest. PLoS ONE, 15.
29. Mabe, F.N., Sienso, G. and Donkoh, S. (2014). Determinants of Choice of Climate Change Adaptation Strategies in Northern Ghana. *Research in Applied Economics*; Vol 6, No. 4. ISSN 1948-5433.
30. Mideksa, D.I., Moti, J. & Fikadu, M. (2021). Determinants and Profitability of Inorganic Fertilizer Use in Smallholder Maize Production in Ethiopia. *Cogent Food & Agriculture*, 7:1, 1911046, DOI: 10.1080/23311932.2021.1911046.
31. Moradi, R., Koocheki, A., Nassiri Mahallati M & Mansoori, H. (2013). Adaptation Strategies for Maize Cultivation Under Climate Change in Iran: Irrigation and Planting Date Management. *Mitig Adapt Strateg Glob Change* 18: 265−284.
32. Mugiyo, H., Mhizha, T., Chimonyo, V., & Mabhaudhi, T. (2021). Investigation of the Optimum Planting Dates for Maize Varieties Using A Hybrid Approach: A case of Hwedza, Zimbabwe. *Heliyon*, 7(2), e06109. https://doi.org/10.1016/j.heliyon.2021.e06109.
33. Mutuku, E.A., Vanlauwe, B., Roobroeck, D., Boeckx, P., & Cornelis, W. (2021). Physico-Chemical Soil Attributes Under Conservation Agriculture and Integrated Soil Fertility Management. *Nutrient Cycling in Agroecosystems*, 1-16.
34. Mutunga, E.J., Ndung'e, C.K. & Muendo, P. (2017). Smallholder Farmers Perceptions and Adaptations to Climate Variability in Kitui County. *Journal of Earth Science and Climate Change*. 8:389 doi 10.4172/2157-7617.1000389.
35. Ndamani, F. & Watanabe, T. (2016). Determinants of Farmers' Adaptation to Climate Change: A Micro Level Analysis in Ghana. *Scientia Agricola*. 73. 201-208. 10.1590/0103-9016-2015-0163.
36. Nhemachena, C. and Hassan, R. (2007) Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. IFPRI *Discussion Paper* No. 00714. International Food Policy Research Institute, Washington DC.

37. Njagi, T., Mathenge, M., Mukundi, E. and Carter, M. (2017). Maize Technology Bundles of Food Security in Kenya. Innovation Lab for Assets and Market Access Policy Brief. Feed the Future.
38. Noack, F. and Larsen, A. (2019) The Contrasting Effects of Farm Size on Farm Incomes and Food Production. *Environmental Research Letters*, 14. Article ID: 084024. https://doi.org/10.1088/1748-9326/ab2dbf.
39. Nyaga, J., Muthuri, C.W., Barrios, E., Oborn, I., Sinclair, F.L. (2019). Enhancing Maize Productivity in Agroforestry Systems Through Managing Competition: Lessons from Smallholders' Farms, Rift Valley, Kenya. *Agroforestry Systems* 93, 715–730 (2019). https://doi.org/10.1007/s10457-017-0169-3.
40. Nyakaisiki, K., Mugume, I., Ngailo, T. and Nakabugo, R. (2019). The Use of Indigenous Knowledge in Predicting Changes in Seasonal Rainfall by Smallholder Farmers of Ruteete Subcounty, Kabarole District. *Journal of Geoscience and Environment Protection*, 7, 13-22. doi: 10.4236/gep.2019.71002.
41. Olajire, M.A., Matthew, O.J., Omotara, O.A., & Aderanti, A. (2019). Assessment of Indigenous Climate Change Adaptation Strategies and Its Impacts on Food Crop Yields in Osun State, Southwestern Nigeria. *Agricultural Research*, 9, 222-231.
42. Olsson, L., H. Barbosa, S. Bhadwal, A. Cowie, K. Delusca, D. Flores-Renteria, K. Hermans, E. Jobbagy, W. Kurz, D. Li, D.J. Sonwa, L. Stringer. (2019). Land Degradation. In: Climate Change and Land. IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, And Greenhouse Gas Fluxes In Terrestrial Ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.
43. Osewe, M., Liu, A. & Njagi, Timothy. (2020). Farmer-Led Irrigation and Its Impacts on Smallholder Farmers' Crop Income: Evidence from Southern Tanzania. *International Journal of Environmental Research and Public Health*. 17. 1512. 10.3390/ijerph17051512.
44. Ranjan, P., Patle, G.T., Prem, M., & Solanke, K.R. (2017). Organic Mulching- A Water Saving Technique to Increase the Production of Fruits and Vegetables. *Current Agriculture Research Journal*, 5, 371-380.
45. Raskin, B. and Osborn, S. (2019). Agroforestry Handbook. Agroforestry for the UK July 2019.

46. Republic of Netherlands. (2018). Climate Change Profile: Kenya. Ministry of Foreign Affairs, Netherlands. www.govenment.nl/foreign-policy-evaluations.
47. Republic of South Africa. (2012). A framework for the development of smallholder farmers through cooperative development. Department of Agriculture, Forestry and Fisheries.
48. Roba, T. (2018). Review on: The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility. Open Access Library Journal 5, 1-11. doi: 10.4236/oalib.1104618.
49. Schipper, E. L. F. (2020). Maladaptation: When Adaptation to Climate Change Goes Very Wrong. *One Earth*, 3(4), 409–414.
50. Shikuku, K. M., Winowiecki, L., Twyman, J., Eitzinger, A., Perez, J. G., Mwongera, C., Läderach, P. (2017). Smallholder Farmers' Attitudes and Determinants of Adaptation to Climate Risks in East Africa. *Climate Risk Management* Volume 16.
51. Shongwe, P. (2014). Factors Influencing the Choice of Climate Change Adaptation Strategies by Households: A Case of Mpolonjeni Area Development Programme (ADP) in Swaziland. *Journal of Agricultural Studies* Volume 2 No. 1.
52. Su, Y., Gabrielle, B., Beillouin, D. et al. (2021). High probability of yield gain through conservation agriculture in dry regions for major staple crops. Sci Rep 11, 3344. https://doi.org/10.1038/s41598-021-82375-1.
53. Tadesse, Addis. (2016). Adaptation and Constraints of Conservation Agriculture. *Journal of Biology, Agriculture and Healthcare* Vol. 6 No. 1 of 2016. www.iiste.org.
54. Telkar, S. G., Singh, A. K. and Kumar, J. (2017). Effect of Population Proportion of Component Crops on Growth, Yield and Nutrient Uptake of Component Crops in Maize+Soybean Intercropping. *International Journal of Bio-resource and Stress Management* 2017, 8(6):779-783. Doi: https://doi.org/10.23910/ijbsm/2017.8.6.3c0363 .
55. Thi, T.P. and Chaovanapoonphol, Y. (2014). An Evaluation of Adaptation Options to Climate Pressure on Highland Robusta Coffee Production, Daklak Province, Vietnam. *World Journal of Agricultural Research*, Volume 2 No.:205-215.
56. United Nations Economic Commission for Africa. (2015). Cereal Crops: Rice, Maize, Millet, Sorghum, Wheat. An Action Plan for African Agricultural Transformation. Feeding Africa 21-23 October 2015.

57. United Nations. (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution 70/1 Adopted by the General Assembly on 25 September 2015.
58. Verma, H. (2021). Conservation Agriculture (CA) practices to improve Soil Fertility. In book: Sustainable Soil Fertility Management (pp.101- 127). Publisher: NOVA Science Publishers, New York, U.S.A.
59. Waongo, M., Laux, P., Kunstmann, H. (2015). Adaptation to Climate Change: The Impacts of Optimized Planting Dates on Attainable Maize Yields Under Rainfed Conditions in Burkina Faso. *Agricultural and Forest Meteorology*, Volume 205,2015, Pages 23-39, ISSN 0168-1923, https://doi.org/10.1016/j.agrformet.2015.02.006
60. Wushuai, Z., Chunrong, Q., Kimberly, M., Carlson, X., Ge, X., Wang, X., Chen. (2021). Increasing Farm Size to Improve Energy Use Efficiency and Sustainability in Maize Production. *Food and Energy Security*. Volume10, Issue1 February 2021.
61. Zhang, W., Qian, C., Carlson, K.M., Ge, X., Wang, X. & Chen, X. (2021). Increasing Farm Size to Improve Energy Use Efficiency and Sustainability in Maize Production. *Food and Energy Security*. Issue 1 February 2021.