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Drought Adaptation Strategies Among Smallholder Cereal Farmers In Makueni County, Kenya

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Abstract
Increasing frequency and severity of drought increase vulnerability of smallholder cereal farmers globally. Arid and Semi-Arid Lands cover 80% of Kenya and location around the equator are major factors in drought development in the country. Frequent droughts result in fluctuations in cereal yields hence food insecurity in Makueni County. This study evaluated community-based and indigenous knowledge drought adaptations practiced by smallholder cereal farmers in Makueni County, Kenya. This study adopted explanatory sequential mixed methods research design. Household surveys (N=225) and key informant interviews (N=16) were used. Descriptive techniques were used in data analysis. The study found that frequent droughts in Makueni County resulted in adoption of small farm sizes for production of maize, sorghum and finger millet. Majority of the farmers produced between 1 and 10 bags of cereals. Majority (50.2%) of the smallholder cereal farmers who adopted community-based adaptations and indigenous knowledge-based drought adaptations strategies recorded an in increase in cereal yields in Makueni County. Early planting (66.7%), timely weeding (61.4%), manure application (57.0%), improving land tillage (56.1%), seed spacing (55.3%) and planting drought-resilient seeds (44.7%) led to the high annual cereal yields ranging between 1 and 10 bags in Makueni County. The drought adaptation strategies are commendable for upscaling in agro-ecological zones with similar climatic conditions in order to improve food production in the country. Information and data generated by this study is expected to result in improvement in drought adaptation policy formulation and adaptive capacity of smallholder cereal farmers hence, improvement in food production and security.
Keywords: *Adaptation, Community-Based Adaptations, Drought, Indigenous Knowledge*

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I. Introduction

Increasing frequency and severity of droughts have been recorded in various parts of the world (Han *et al.*, 2022; Leeper *et al*., 2022; Wahl *et al*., 2022; Xue & Ullrich, 2022). Global drought trends have been uncertain with regional drought fluctuations, whereby 52 global mega-droughts were recorded from 1951 to 2016 (Spinoni *et al*., 2019). A high frequency and increasing severity of droughts were recorded in global drought hotspots such as Mid-West United States, a large area of South America, parts of the Eurasian belt that includes Eastern Europe to Eastern Asia and equatorial Africa (Reho *et al*., 2024). A high frequency of droughts is a key concern for governments and cereal farmers in the affected regions due to rapidly increasing population hence increasing demand for food.

Even though frequent droughts significantly affect cereal yields, Community-Based Adaptations (CBAs) influence production (Mundia *et al.*, 2019). Adoption of early maturing sorghum varieties resulted in improved yields in Nigeria (Yakubu *et al*., 2021). Cereal crop irrigation farming was undertaken as a drought adaptation strategy in Sudan where water from the Blue Nile and White Nile Rivers was used thereby improving yields (Kool *et al*., 2014). Further, increased adoption of CBAs (Mundia *et al.*, 2019) and Indigenous Knowledge (IK) in drought adaptation in sub-Saharan countries including Ethiopia (Wendmu *et al*., 2022), Sudan (Eltohami, 2016; Kool *et al*., 2014) and Tanzania (Madege *et al.*, 2017) resulted in improved cereal yields.

Over 10 severe droughts were recorded in East Africa since 1970s (Haile *et al.*, 2019). In addition, widespread drought episodes occurred in East Africa where the events were experienced in 2000, 2005/2006, 2007, 2008, 2011 and 2016 (Ayugi *et al*., 2022). Increasing frequency of droughts significantly influence yields of sorghum (*Sorghum bicolor* (L.) Moench), finger millet (*Eleusine coracana* (L.) Gaertn) and maize (*Zea* *mays* (L.) which were used as drought adaptation strategies in Arid and Semi-Arid Lands (ASALs) in Kenya. However, increasing drought events still significantly influenced cereal production and food security in ASALs in Kenya (Ondiko & Recha, 2022).

Numerous drought responses, policies and institutional frameworks have been put in place by the Government of Kenya (GoK). Also, GoK prioritized agriculture as a key economic pillar and developed Kenya Vision 2030 Plan (GoK, 2007), "Big Four Agenda" (GoK, 2017) and Food Security Act, 2014 (GoK, 2014). However, increased frequency and severity of droughts have been experienced from 1990 to 2020, with significant effects on rain-fed cereal production and yields in ASALs. Even though drought-tolerant (DT) cereal varieties, including: sorghum, finger millet and maize are suitable for varied agro-ecological zones (AEZs), including ASALs (SCAO, 2021), there was limited information on the extent to which DT cereal varieties, CBA and IK drought adaptation strategies have been adopted and their outcomes in ASALs such as Makueni County.

The GoK and the County Government of Makueni (CGoM) implemented the Kenya Cereal Enhancement Programme – Climate Resilient Agricultural Livelihood (KCEP-CRAL), which was effective from 2014 to 2022 in Makueni County through Ministry of Agriculture (MoA). The main objectives of KCEP-CRAL were to contribute towards increasing productivity and profitability of key cereal commodities - maize, sorghum, and millet, and associated pulses hence improving national food security and smallholder income generation. These efforts were geared towards supporting farmers in both medium- and high-potential cereal production areas in Kenya. Though, frequent droughts still remain a major challenge to cereal production in ASALs in Kenya (Nyangena, 2020; Ondiko & Karanja, 2021). Therefore, this study addressed the drought adaptation gaps by evaluating CBA and IK-based drought adaptation strategies practiced by smallholder cereal farmers in Makueni County, Kenya.

II. Materials And Methods

Study Area

This study was conducted in Makueni County which is located 200 kilometres Southeast of Nairobi city, Kenya. Makueni County is located between latitudes 1^0 35' and 3^0 00'S and between longitudes 37^0 10' and 38^0 30'E (Figure 1). The County is neighbouring Machakos County to the North, Kitui County to the Northeast and East, Kajiado County to the West and Southwest, and Taita Taveta County to the South. Makueni County has a surface area of 8,177 km^2 (KNBS, 2019). The County has six sub-Counties, namely: Mbooni, Kilome, Kaiti, Makueni, Kibwezi West and Kibwezi East (Amukono, 2016).

Makueni County is classified as AEZ V which is an ASAL in Southeastern Kenya. The region receives 300 millimetres (mm) to 400mm and 800mm to 1200 millimetres (mm) of rainfall per annum, mostly in the Southern lowlands and Northern highlands of the county respectively (Kitinya *et al.*, 2012). The county experiences two rainfall seasons in March-April-May (MAM) and October-November-December (OND) whereby frequent droughts are also experienced (Amukono, 2016; Gichure, 2017). Makueni County experiences high temperatures with a mean ranging between 23.0^0 Celsius (C) to 27.0^0C (Amukono, 2016). Further, the lowlands experience higher temperatures of up-to 35.8^0C (GoK, 2013). This study was done in the following sub-Counties: Kibwezi West, Kibwezi East, Kilome and Makueni due to the popularity of DT sorghum, finger millet and maize varieties which perform well in the ASAL region.

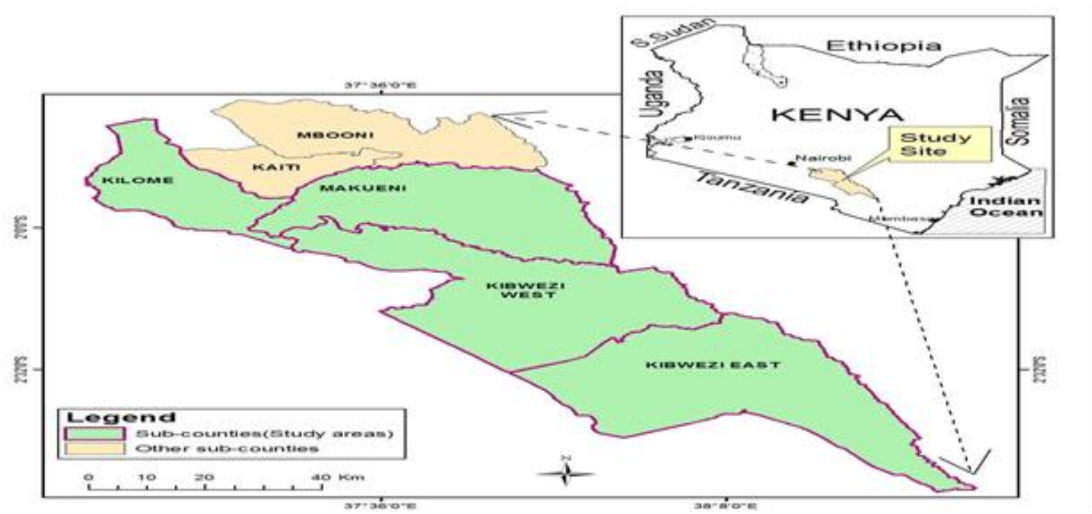

Figure 1: Map of the Study Area Showing the Study Sites.
Source: Independent Electoral and Boundaries Commission (IEBC) (2013)

Data Collection

Household Survey

Data on drought adaptation strategies was collected using semi-structured questionnaires which were administered to 225 smallholder cereal farming households in Makueni County. Household survey was conducted on smallholder cereal farming households in Kibwezi East, Kibwezi West, Kilome and Makueni sub-Counties. The units of analysis were smallholder cereal farmers. Systematic random sampling was used for the selection of smallholder cereal farmers that had practiced cereal farming in the study area. After defining the population, the sample size was established using systematic random sampling. Systematic random sampling spreads the sample evenly over the population and provides an equal chance (probability) of selecting any of the units in the target population hence avoiding sampling bias (Sharma, 2017). Sharma reported that the technique is precise in the unit selection and increases the distribution and representation of respondents thereby increasing the validity of the collected data. The technique was also chosen for the study due to the availability of a list of cereal farmers in the Ministry of Agriculture (MoA) in the study area[6]. The selected smallholder cereal farmers were administered with questionnaires for the collection of drought adaptation data.

Key Informants

Key informant interview guides were administered to 16 key informants whose selection was based on their administrative position, age, knowledge and experience of drought adaptations in a geographical area. Key informants consisted of Sub-County Agriculture Officers (SCAO), chiefs, village elders and officials of Non-Governmental Organizations (NGO) in the sub-Counties. Key informants were used to provide informed responses (Karanja, 2018). The responses were focused on CBA and IK drought adaptations in Makueni County.

III. Results And Discussion

Drought Adaptation Strategies and their Outcomes in Makueni County.

This study found that CBA and IK drought adaptations were popular strategies in Makueni County. Majority (50.2%) of the smallholder cereal farmers who adopted CBA and IK adaptations to drought recorded an increase in cereal yields while 11.1% of the farmers recorded reduction in yields (Table 1). However, 38.7% of the cereal farmers reported no change in cereal yields in the study area. The high percentage of farmers who practice CBA and IK cereal production techniques with positive results is an indication of the significant role of CBA and IK techniques in managing food security in the study area.

The results of this study are in concurrence with those of a study done in Indonesia (Qomariah *et al.*, 2021), which established that a number of communities in the country adopted CBA which is a community-led process in resolving the challenges of the community based on priority needs. Further, adoption of CBA to droughts in Africa were suitable due to the application of local knowledge, location specific solutions, prioritization of the challenges of the community, significant environmental benefits and customary or communal representation which bore significant success in the implementation of the projects in the community (Mfitumukiza *et al.*, 2020).

Table 1: CBA and IK Drought Adaptations

outcome of CBA and IK drought adaptations that you practiced	No. of Respondents	Respondents %
Increased yields	106	50.2
No change	82	38.7
Reduction in yields	24	11.1
Total	**212**	**100.0**

Table 2 shows that timely weeding (61.4%), improving land tillage (56.1%), seed spacing (55.3%) and timely application of organic manure (54.4%) were the most popular drought adaptations which resulted in sorghum yields ranging from 1 to 10 90 kilogramme (kg) bags in Makueni County. Embracing the mentioned drought adaptation strategies by all sorghum farmers in Makueni County will result in improvement in yields hence improvement in management of food insecurity in the county.

The results of this study corroborate those of a study conducted in Nigeria (Onyeneke *et al.*, 2019) which revealed that ecological pest management, traditional and conservation land tillage practices and organic carbon improvement result in improvement in cereal yields. Sorghum seed spacing between 30 and 45 centimetres (cm) was recommended in order to improve cereal production in Southern Africa[9]. Improvement in land tillage practices resulted in improvement in cereal yields in ASALs in East Africa (Madege *et al.*, 2017). Improving spacing between cereal crops also resulted in improved cereal yields in ASALs (WFP, 2018).

Table 2: **Cross-Tabulation of Agronomic Drought Adaptations and Sorghum Yields (N=212)**

Agronomic Drought Adaptation Techniques	Practicing (%)				Total Practicing (%)	Not Practicing (%)
	1 – 10 bags	11 – 20 bags	21 – 30 bags	>31 bags		
Improving land tillage/ cultivation practices	56.1	2.6	2.6	0	61.3	38.7
Improving seed spacing	55.3	4.4	1.8	0.9	62.4	37.6
Practicing timely weeding	61.4	5.3	2.6	0.9	70.2	29.8
Timely application of organic manure	54.4	2.6	2.6	2.6	62.2	37.8
Practicing mono-cropping	47.4	3.5	2.6	0	53.5	46.5
Practicing inter-cropping with legumes	32.5	2.6	2.6	0.9	38.6	61.4
Practicing inter-cropping with finger millet or maize	28.9	3.5	2.6	0.9	35.9	64.1
Practicing agroforestry	26.3	2.6	0.9	1.8	31.6	68.4

Table 3 shows that planting cereal seeds early (66.7%), application of farm manure (57.0%) and planting drought-resilient cereal seeds (44.7%) led to the highest sorghum produce between 1 and 10 bags in Makueni County. Planting seeds early (1.8%), planting short period seeds (1.8%), increasing farm size (1.8%) and using IK-based weed and pest control strategies (1.8%) resulted in above 31 bags of sorghum in Makueni County.

The results of this study agree with those of a study conducted in Nigeria (Onyeneke *et al.*, 2019) which found that planting cereal seeds early, adoption of new cereal varieties, ecological pest management, traditional and conservation land tillage practices and organic carbon improvement result in improvement in cereal yields.

Table 3: Cross-Tabulation of Drought Adaptations and Sorghum Yields (N=212)

Farm Management Drought Adaptations	Practicing (%)				Total Practicing (%)	Not Practicing (%)
	1 – 10 bags	11 – 20 bags	21 – 30 bags	>31 bags		
IK drought prediction and monitoring	36.0	2.6	0	0.9	57.5	42.5
Rain water harvesting and supplementary irrigation	30.7	3.5	2.6	0.0	36.8	63.2
Planting seeds early	66.7	4.4	2.6	1.8	75.7	24.5
Planting seeds late	17.5	0.9	0.9	0.9	20.2	79.8
Planting drought resilient seeds	44.7	1.8	1.8	0.9	49.2	50.8
Planting improved seeds	32.5	4.4	2.6	0.0	39.5	60.5
Planting short period seeds	34.2	4.4	0.9	1.8	41.3	58.7
Use farm manure	57.0	4.4	2.6	0.9	64.9	35.1
Increasing farm size	26.3	1.8	2.6	1.8	32.5	67.5
Decreasing farm size	24.6	1.8	0.0	0.9	27.3	72.7
IK bio-control of weeds/ pests	40.4	3.5	2.6	1.8	48.3	51.7
Farm mechanization	17.5	2.6	1.8	0.0	21.9	78.1
IK seed preservation techniques	40.4	2.6	1.8	0.9	45.7	54.3

The results of this study also corroborate those of studies conducted in Ghana and ASALs in East Africa (Dumba *et al.*, 2021; Julia, 2015; Madege *et al.*, 2017; Radeny *et al.*, 2019) respectively, which found that adopting early maturing and drought-resilient cereal varieties resulted in improvement in cereal yields. In addition, application of farm manure resulted in improvement in cereal yields (Rurinda *et al.*, 2020).

Table 4 shows that majority of the farmers practiced the following agronomic drought adaptations: timely weeding (54.4%), improving seed spacing (50.0%), mono-cropping (49.1%), land tillage and timely application of manure (47.4%) which resulted in production of finger millet ranging from 1 to 10 bags in Makueni County.

The results of this study corroborate those of a study conducted in Malawi (FAO, 2018) which revealed that pest and weed control results in control of diseases therefore improvement in cereal yields. Improving land tillage and spacing for seeds improved cereal yields in ASALs (WFP, 2018). Therefore, wide spacing was recommended for sorghum seeds in drylands to improve yields.

Table 4: Cross-Tabulation of Drought Adaptations and Finger Millet Yields (N=212)

Agronomic Drought Adaptation Techniques	Practicing (%)				Total Practicing (%)	Not Practicing (%)
	1 – 10 bags	11 – 20 bags	21 – 30 bags	>31 bags		
Improving land tillage/ cultivation practices	47.4	5.3	1.8	0	54.5	45.5
Improving seed spacing	50.0	4.4	0.9	0	55.3	44.7
Practicing timely weeding	54.4	6.1	0.9	0.9	62.3	37.7
Practicing timely organic manure application	47.4	4.4	0.9	0.9	53.6	46.4
Practicing mono-cropping	49.1	6.1	0.9	0	56.1	43.9
Practicing intercropping with legumes	26.3	4.4	0.9	0.9	32.5	67.5
Practicing intercropping with sorghum or maize	25.4	4.4	0.9	0	30.7	69.3
Practicing agroforestry	22.8	5.3	0.9	0.9	29.9	70.1

Table 5 shows that majority of the smallholder farmers adopted the following drought adaptation strategies: planting seeds early (59.6%), application of farm manure (46.5%) and planting drought-resilient seeds (39.5%) which resulted in production of finger millet ranging from1 to 10 bags.

The results of this study agree with those of a study conducted in South Asia (Ayugi *et al.*, 2022) which established that farmers in India, Nepal and Bangladesh adopted use of organic fertilizer in cereal production hence improvement in yields in the regions. The results of this study agree with those of studies conducted in ASALs in Pakistan (Khan *et al*., 2022), Western Nepal (Adhikari, 2018) and West Africa (Ogundeji & Okolie, 2021) respectively, which found that rain water harvesting and supplementary irrigation, adoption of early maturing cereal seeds and early drought warning improved drought-resilience and cereal yields. Use of farm manure also resulted in improvement in cereal yields in Africa (Rurinda *et al*., 2020).

Table 5: Cross-Tabulation of Drought Adaptations and Finger Millet Yields (N=212)

Drought Adaptation Techniques	Practicing (%)				Total Practicing (%)	Not Practicing (%)
	1 – 10 bags	11 – 20 bags	21 – 30 bags	>31 bags		
IK drought prediction and monitoring	30.7	2.6	0	0.9	34.2	65.8
Rain water harvesting and supplementary irrigation	28.9	6.1	1.8	0.9	37.7	62.3
Planting seeds early	59.6	5.3	1.8	0.9	67.6	32.4
Planting seeds late	15.8	2.6	0.9	0.9	20.2	79.8
Planting drought resilient seeds	39.5	3.5	0.9	0	43.9	56.1
Planting improved seeds	30.7	4.4	0.9	0	36	64
Planting short period seeds	30.7	4.4	0	0.9	36	64
Use farm manure	46.5	7.9	1.8	0.9	57.1	42.9
Increasing farm size	21.1	3.5	0.9	0.9	26.4	73.6
Decreasing farm size	19.3	2.6	0	0	21.9	78.1
IK bio-control of weeds/ pests	36.8	6.1	1.8	0.9	45.6	54.4
Farm mechanization	21.9	4.4	0.9	0	27.2	72.8
IK seed preservation techniques	36.8	4.4	0.9	0	42.1	57.9

Table 6 shows that planting maize seeds early (48.5%), application of farm manure (39.2%), planting drought-resilient seeds (35.3%) and planting early maturing cereal seeds (30.4%) resulted in maize yields ranging between 1 and 10 bags in Makueni County. The results also indicated that application of farm manure (5.4%), planting seeds early (4.9), supplementary irrigation (3.9%) and IK-based bio-control of weeds (3.9%) resulted in production above 31 bags of cereals.

The results in this study concur with those of a study conducted in Nigeria (Yakubu *et al.*, 2021) which established that adoption of early maturing sorghum varieties resulted in improved yields. Planting early maturing cereal seeds and varying planting dates resulted in improved cereal yields in Ghana (Dumba *et al.*, 2021). Further, irrigation farming improved cereal yields in Sudan (Kool *et al.*, 2014). In addition, adoption of IK drought adaptations such as integrating weed and pest bio-control with cereal production resulted in improvement in yields in Tanzania (Radeny *et al*, 2019).

Table 6: **Cross-Tabulation of Drought Adaptations and Maize Yields (N=212)**

Drought Adaptation Techniques	Practicing (%)				Total Practicing (%)	Not Practicing (%)
	1 – 10 bags	11 – 20 bags	21 – 30 bags	>31 bags		
IK drought prediction and monitoring	21.6	4.4	2.5	2.5	31	69
Rain water harvesting and supplementary irrigation	26	8.8	4.4	3.9	43.1	56.9
Planting seeds early	48.5	12.3	3.4	4.9	69.1	30.9
Planting seeds late	10.8	3.4	1	1.5	16.7	83.3
Planting drought resilient seeds	35.3	10.8	2	3.4	51.5	48.5
Planting improved seeds	24	7.4	3.9	2.5	37.8	62.2
Planting short period seeds	30.4	7.8	2.5	3.4	44.1	55.9
Use farm manure	39.2	10.3	3.4	5.4	58.3	41.7
Increasing farm size	15.7	4.4	2.9	2	25	75
Decreasing farm size	15.2	3.4	1	2.5	22.1	77.9
IK bio-control of weeds/ pests	25.5	10.8	2.5	3.9	42.7	57.3
Farm mechanization	12.7	5.4	2.9	1	22	78
IK seed preservation techniques	26	7.4	2.5	3.4	39.3	60.7

Table 7 shows that practicing timely weeding (41.7%) and improving seed spacing (40.7%) resulted in cereal production between 1 and 10 bags of maize in Makueni County. On the other hand, timely weeding (5.9%) and improving seed spacing (4.9%) resulted in production above 31 bags of maize in Makueni County. Agronomic drought adaptation strategies mentioned above can be used to improve maize production when adopted by most of the farmers in Makueni County.

The results of this study corroborate those of a study conducted in ASALs in Nigeria and East Africa respectively (FAO, 2018); WFP, 2018), which established that wide seed spacing improved cereal yields in poorly drained soils in drylands.

Table 7: **Cross-Tabulation of Drought Adaptations and Maize Yields (N=212)**

Agronomic Drought Adaptation Techniques	Practicing (%)				Total Practicing (%)	Not Practicing (%)
	1 – 10 bags	11 – 20 bags	21 – 30 bags	>31 bags		
Improving land tillage/ cultivation practices	38.7	7.8	2.9	3.4	52.8	47.2
Improving seed spacing	40.7	11.3	4.4	4.9	61.3	38.7
Practicing timely weeding	41.7	14.2	3.9	5.9	65.7	34.3
Timely application of organic manure	38.7	9.8	2.9	3.4	54.8	45.2
Practicing mono-cropping	28.9	8.8	2.5	2.5	42.7	57.3
Inter-cropping with legumes	28.9	5.9	2.9	1.5	39.2	60.8
Practicing inter-cropping with sorghum or finger millet	17.6	4.9	2	2	26.5	73.5
Practicing agroforestry	16.2	6.4	1.5	3.4	27.5	72.5

IV. Conclusion And Recommendations

Popular CBA and IK drought adaptation strategies in Makueni County included adoption of DT sorghum, finger millet and maize varieties which resulted in improvement in cereal yields. IK-based drought prediction and monitoring, supplementary irrigation, early planting of seeds and late planting of cereal seeds were also popular drought adaptation strategies among smallholder cereal farmers in Makueni County. Cereal farmers also adopted application of farm manure and bio-control of weeds, improved seeds, planting early maturing seeds and planting drought resistant cereal seeds. Agro-forestry, improving seed spacing, timely weeding, intercropping cereals with pulses and irrigation farming were also practiced in Makueni County. This study recommends that GoK and CGoM should work in partnership with other stakeholders in agricultural sector to improve agroforestry, afforestation, reforestation and soil and water management practices. These efforts will improve adaptation and resilience to droughts hence improvement in food production and security in Makueni County.

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