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Climate variability and maize production among small-scale farmers in Gabiley, Somaliland

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Abstract

Climate change and variability make it challenging for developing countries to grow food, especially in places like Somaliland, where the agroecological systems are weak. Political instability and poverty exacerbate these problems. This study examined the perceived impacts of climate variability on maize production among small-scale farmers in the Gabiley District of Somaliland. A questionnaire was used to collect responses from 191 people. The non-parametric Mann-Kendall test and Sen's slope tests were used to look at the trend of Twenty Years of Data from 2004 to 2023. These tests showed that rainfall in the Gabiley region has been going down over the past twenty years. We also used linear trend analysis of regression to look at maize data from 2012 to 2024. The downward-sloping linear trendline shows that the maize yield has been going down over time. We used simple linear and multiple regression analyses to find out how climate change affects maize yields. The findings (R= .284a, R2 = 0.080, p = .001b). showed that changes in the climate as a whole had a statistically significant effect on maize production. This study examined three research questions: (1) What are the recent trends in climate variability in the Gabiley District? (2) What is the effect of climate variability on maize production for small-scale farmers? (3) What weather conditions have the most effect on maize yield? I posited that diminishing rainfall and heightened temperature variability adversely impact maize production. In conclusion, this study highlights that persistent drought is the principal climate-related factor adversely affecting maize production for small-scale farmers in the Gabiley District of Somaliland. The results give important information to people who want to see climate-smart agriculture adopted in the Gabiley District. Suggestions include using drought-resistant crop types, water-saving methods, crop diversification plans, policy support programs, and more research on how to adapt to climate change.

Keywords Climate variability, Temperature fluctuations, Recurrent drought, Small-scale farmers, Maize production

1 Introduction

Climate change and fluctuation have already affected global food crop output. Ray et al. [18]. According to research, agricultural productivity is under a lot of stress due to climate change [20]. Through altered agro-ecological conditions, climate change has an impact on agriculture and food production [10]. Hunger and malnutrition may result from the significant negative shocks to food production brought on by climate change, such as the expansion of catastrophe zones and the decrease in food production. As a result, these topics have risen to the top of international debates in many nations [12]. The largest output losses that maize producers have yet to experience are expected to occur more frequently with a just 1.5 °C increase in global temperatures [3]. Climate change is also making it harder to access water supplies and making heat waves and droughts more severe and extended. Because of this, crops have a harder time surviving in harsh environments brought on by water scarcity. Maize is normally tall and broad-leaved, and a severe drought during the seedling or growing stage causes leaf curling and limited growth [19].

Climate variability has a significant impact on rain-fed subsistence crop output. Rainfall variability and temperature fluctuations are the most essential climatic factors that affect crop production, development, and yield [16].

In Africa, where rain-fed agriculture is essential for farming and adaptive ability is limited, climate change exerts a greater influence [4]. Climate change was predicted to reduce maize potential and achievable yields by 2.1% and 8.0%, respectively, between 1961 and 2009 [8]. Due to the rise in stressors, including population growth, water shortages, land degradation, and food insecurity, developing nations, including those in Africa, are particularly vulnerable to climate change [6]. Because of its weak adaptive capability and reliance on rainfall for agriculture, Sub-Saharan Africa is the region most susceptible to the effects of climate change and variability [9].

Somaliland has seen significant climate occurrences as a result of climate change [7]. Recent years have seen an increase in land degradation, a decrease in crop and livestock productivity, an unusual recurrence of droughts, frequent floods, the emergence of invasive and exotic plant species, and other effects of climate change on Somaliland's agropastoral communities [2]. Climate change has wounded Somaliland, resulting in notable changes in precipitation patterns and a decrease in overall rainfall [5]. Vulnerable communities are disproportionately affected by the rising frequency of droughts and other climate-driven risks like flooding. The recent drought in 2021 has significantly affected livestock and impacted approximately 1.2 million individuals, as reported by the Somaliland government. An estimated 1.1 million animals required immediate veterinarian care and additional nutrition [14]. Due to the drought, many people in Somaliland perished from a lack of grazing and water. The climate-related issues Somaliland faces, such as food insecurity, the loss of livelihoods for pastoralists, and competition for resources, are common in many countries in the Horn of Africa (and more broadly throughout Sub-Saharan Africa), even though the precise dynamics and effects differ greatly depending on the context. The average annual rainfall in Somaliland is between 150 and 500 mm, far less than the global average, and is insufficient to meet the country's water and agricultural needs NADFOR, [13]. Abdulkadir Abdulkadir [1] highlights the nation's vulnerability to climate change in another report. It describes the calamities that have struck Somaliland between 1960 and 2017. Since 1960, Somaliland had gone through sixteen droughts by 2017. The most severe and pervasive of these were the droughts that occurred in 1973–1974, 1984, 1991, 2010–2011, and 2016–2017. Nevertheless, droughts continued to occur in 2017. The country has had further droughts in the years since, such as the extreme droughts in 2019 and 2022, which brought the region's susceptibility to climate change and variability even more to light.

This study addresses the gap by producing an evaluation of the impact of climate variability on maize production in the Gabiley District of Somaliland. The study provides three significant insights. First, it provides localized evidence regarding the impacts of rainfall variability, temperature fluctuations, and rainfall distribution patterns on maize yields, aspects that have been examined primarily at continental or national scales. Second, it gives policymakers useful information that can help the government make smallholder farmers' climate adaptation planning, early warning systems, and resilience-building strategies stronger. Third, the study enhances scholarly comprehension of the climate-agriculture relationship in semi-arid regions by examining the climatic stressors that most significantly influence yield outcomes, thereby providing a pragmatic basis for enhancing food security in Somaliland.

The study is based on the idea that changes in temperature, rainfall patterns, and drought frequency have a direct effect on crop growth, yield stability, and farmers' decisions about how to adapt, especially in systems that rely on rain. In areas like Gabiley, where farming depends almost entirely on natural rainfall, changes in the weather can make farming less efficient and make farmers more vulnerable. Using this conceptual framework allows for a systematic analysis of the interactions between climatic stressors and local production systems, as well as their influence on maize yield trends over time.

2 Materials and methods

2.1 Study site description

Gabiley is situated 58 km west of Hargeisa, the capital of Somaliland. total population of 420,430. It has been considered to be the fastest-growing population district in Somaliland due to its fertile land. It is situated at an elevation of 491 m above sea level. Its coordinates are 10.1814 and 45.5628 or 10°10'53" N and 45°33'46" E. The Gulf of Aden borders it on the north, the Awdal area borders it on the west, the Hargeisa district borders it on the east, and the Somali area of Ethiopia borders it on the south. The communities of the district are farmers who rely on small-scale farming as a source of livelihood. The majority of Somaliland's food production is found in this region, making up to 85% of Somaliland's food sources (Fig.1).

Gabiley lies within a semi-arid region, which is characterized by rainfall variability and recurrent droughts. Its location makes it vulnerable to climate variability, which affects maize production. Mapping the study area helps to contextualize the climatic challenges affecting crop yield.

2.2 Research design and sampling method

This study used a non-experimental explanatory design, since the analysis examines the relationship between climate variability (independent variable) and maize production (dependent variable). The Mann–Kendall trend analysis uses secondary climate data over multiple years, which is longitudinal in nature. The study also used a cross-sectional survey. A cross-sectional survey design was used in this study, which enabled

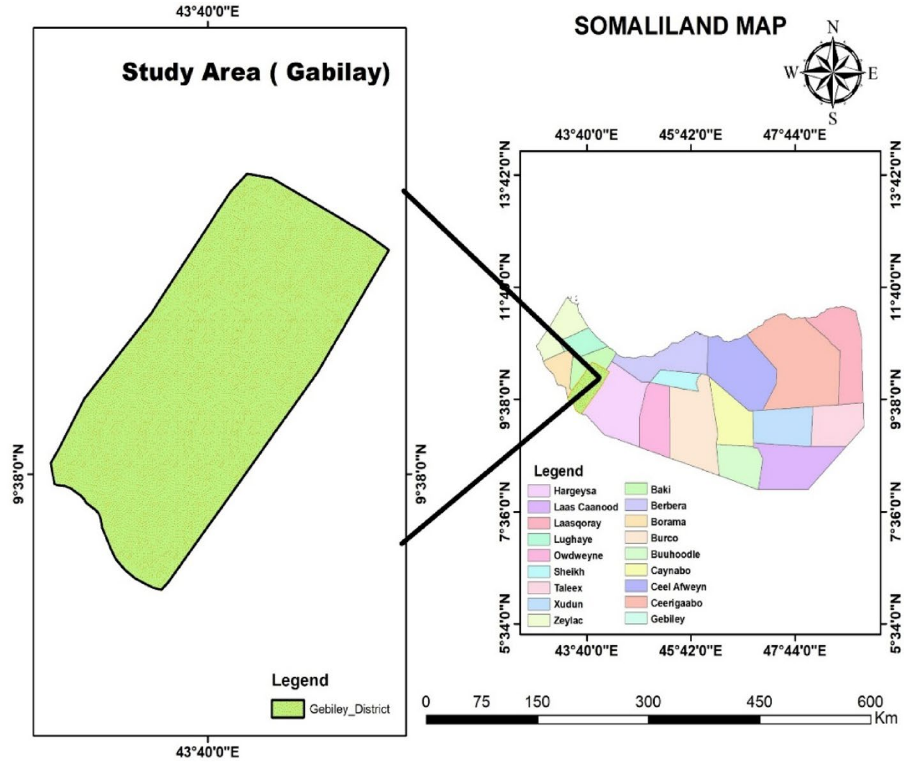

Fig. 1 Location of the study area in the Gabiley District, Somaliland

the researcher to collect data from a large sample in a short time. According to the Ministry of Agriculture and Development in Somaliland, approximately 3500 farmers have been registered in the Gabiley region. The sample size is then calculated using Yamane's Formula to produce:

- a 7% margin of error, which is the highest acceptable error.
- 95% level of confidence, which is the level at which research is certain.
- 0.5 level of significance for the 191 farmers who took part in the study.

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

$$\frac{3500}{1 + 3500(0,07^2)} = 191$$

where N is the total population, e is the sampling error between 1% and 20%, and n is the number of the sample size.

Gabiley was purposively selected because it is one of the major maize-producing areas in Somaliland, is highly exposed to recurrent drought and rainfall variability, and has a high concentration of small-scale farmers who depend on rainfed agriculture.

This study used Stratified sampling. Stratified sampling is where the population is divided into strata (or subgroups), and a sample is taken from each subgroup. Its goal is to guarantee that each stratum is fairly represented. Using stratified sampling, the size of each stratum in the sample was determined. Districts = $\frac{\mathbf{Sub-grouppopulation}}{\mathbf{Totalpopulation}} \times \mathbf{samplesiz}\mathrm{e}$. For instance, $\frac{750}{3000} \times 191 = 48$. The sample size for all four sub-districts (Wajaale, Kalabayr, Alley badey, and Galooley) that grow maize in the Gabiley region was determined in the same way. 48 respondents were chosen from each of the four districts. The researcher identified subgroups and then selected responses randomly from each district to form a sample. Simple random sampling is the most widely used probability sampling method because it is easy to implement and analyze.

2.3 Data sources and collection methods

Both primary and secondary data are used in the data collection process. Primary data were obtained by using a structured questionnaire, and secondary data were obtained from Climatic data (especially rainfall) at annual time steps from 2004 to 2024, covering 20 years, were obtained from FAO SWALIM and the Ministry of Agriculture and Development in Somaliland. On the other hand, the annual maize yield data (2012 to 2024), estimated area harvested, production, and yield of major crops in Somaliland were obtained from the Ministry of Agriculture and Development.

3 Data analysis

3.1 Trend analysis of rainfall data using the Mann-Kendall Test

The non-parametric Mann-Kendall test is often used to find monotonic patterns in environmental, climatic, or hydrological data. The Mann–Kendall (MK) test was used to determine the trends in rainfall. It is a non-parametric test, which has no criterion conditions on the data to be normally distributed. Recent studies on climate variability, precipitation extremes, and hydrological time series have shown this. The study used rainfall data from 2004 to 2023 and maize yield data from 2012 to 2024. Rainfall data from 2004 to 2023 and maize data yield from 2012 to 2024 were used. The Mann-Kendall (MK) and Sen's slope tests were employed since they are two of the most popular and well-known non-parametric trend detection methods. These tests are mainly used for data that are not normally distributed (as is the case for most hydro-meteorological time series data).

$$= S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\left(x_j - x_i\right)$$

where n is the total length of the data, xi and xj are two generic sequential data values, and the function sing (xi-xj) assumes the following values

$$sign(x_i - x_j) = \begin{cases} 1,\ if(x_i - x_j)\ >\ 0 \\ 0, if(x_i - x_j) = 0 \\ -1, if(x_i - x_j) < 0 \end{cases}$$

3.2 Sens slope tests of rainfall data

A set of linear slopes can be computed using the formula below or Sen's slope test.

$$= Q_{ij} = \frac{x_j - x_i}{j - i}$$

where xj and xk are data values at time j and k (j > k), respectively. Sen's estimate of slope is represented by values of Qi.

3.3 Linear trend analysis of maize yield data

The trend in maize yield data from of 12 years (2012–2024) in the Gabiley region was analyzed using Linear Trend analysis.

3.4 Regression analysis between climate variables and maize production

This study employed regression analysis in contrast with a recent study and findings about the effect of climate variability on maize production [4]. The study has shown that an increase in the total average annual temperature by 1°C will decrease the annual maize yield by 0.031 metric tons per hectare. Thus, there is a negative relationship between the total average annual temperature and the annual maize yield. The study used Simple linear regression and multiple Linear regression (MLR). The predictor variables (recurrent drought, temperature, and rainfall) were correlated with the response variable (maize yield). Each predictor is correlated with maize yield using simple linear regression, and after that, all three predictor variables are used in multiple linear regression to establish a cause-and-effect relationship to predict the combined effect of several independent variables on maize yield.

3.5 Methodological framework

The methodology employed in this study is summarized in Fig. 2.

4 Results

4.1 Socio-demographic characteristics of the respondents

The researcher studied the farmers' socio-demographic characteristics. Some of these are gender, age, level of education, and marital status. These variables are well-established in the literature as principal factors influencing farmers' awareness, perceptions, and adaptive responses to climate variability [17]. They also influence access to information, decision-making capacity, vulnerability levels, and overall resilience. Including

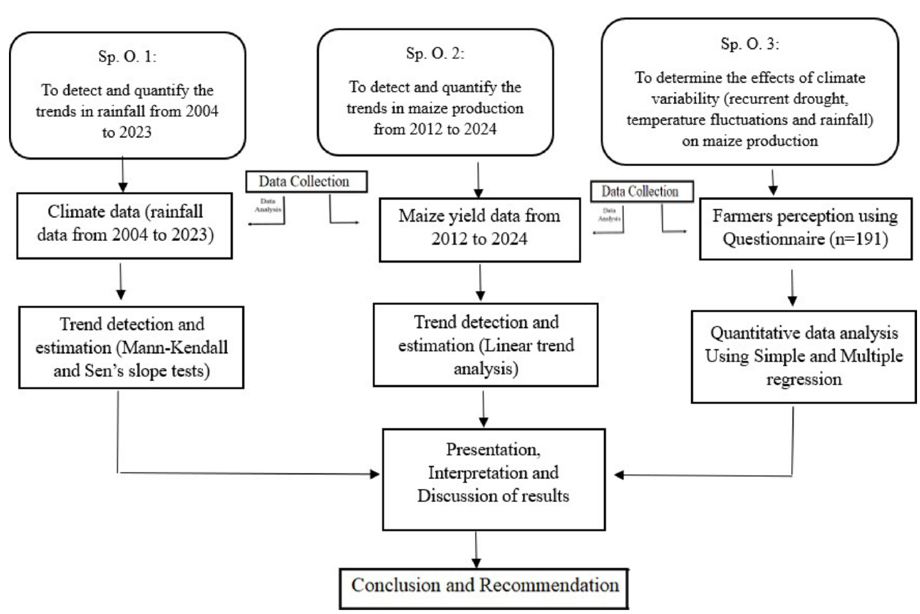

Fig. 2 Methodological framework

Table 1 Socio-demographic characteristics of the respondents

Variables	Frequency	Percent
Gender		
Male	110	57.6
Female	81	42.4
Age		
17–23	31	16.2
24–29	76	39.8
30–34	68	35.6
34–39	13	6.8
40–44	3	1.6
Education		
Primary	71	37.2
Secondary	23	12
University	17	8.9
Others	45	23.6
None	35	18.3
Marital status		
Single	68	35.6
Married	115	60.2
Divorced	8	4.2

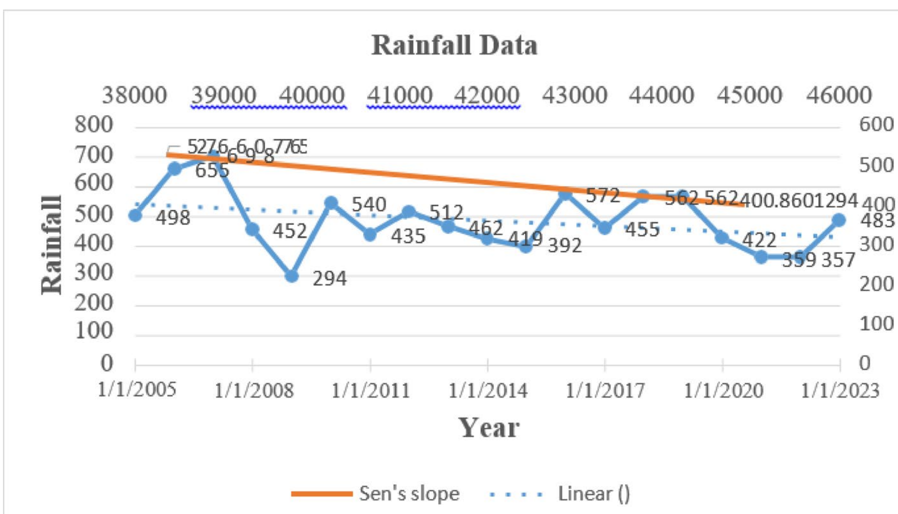

Fig. 3 Total annual rainfall trend in the Gabiley District from 2004 to 2024 [11]

Table 2 Summary of MK and Sen's slope estimation for total rainfall in Gabiley (2004–2023)

Time series	Kendall's tau	Significance	Q
2004-2023	-0.235	0.172	-0.019

Kendell s tau = denotes strength and trend direction; Significance = denotes the presence or absence of statistical significance; Q = denotes trend magnitude

these characteristics helps interpret variations in climate perceptions and yield outcomes among respondents.

Table 1 presents demographic data, likely from a survey on the perceived and measured effects of climate variability on maize production. The sample is predominantly male (57.6%) compared to female (42.4%). This shows that more men are involved in maize production or decision-making regarding climate variability. Most respondents

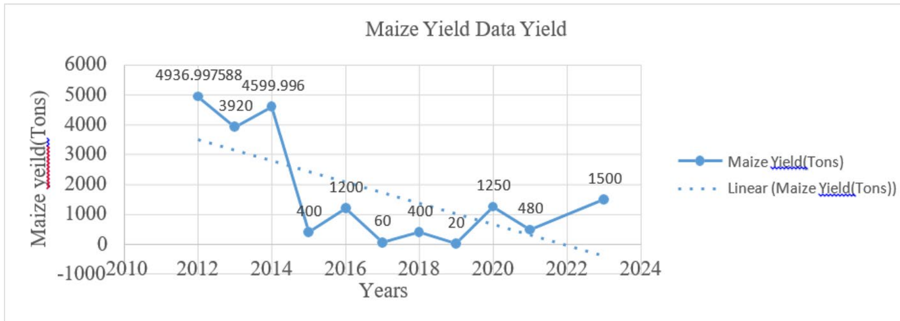

Fig. 4 Annual maize yield trends in the Gabiley District from 2012 to 2024 [11]

fall within the 24–34 age range (75.4%), suggesting that young to middle-aged individuals are more engaged in maize farming. The 40–44 age group is the least represented (1.6%), possibly due to a shift away from farming or reduced involvement in climate-related decision-making.The majority of respondents have a primary (37.2%) education. Only 8.9% have a university education, and another 23.6% fall into the "Others" category (possibly vocational or informal education). This suggests that climate variability perceptions and adaptation strategies may be influenced by lower formal education levels, which could affect scientific understanding and decision-making. The majority are married (60.2%), followed by single individuals (35.6%), and a small proportion are divorced (4.2%). This could reflect the role of family structures in farming decisions, where married individuals may have more responsibilities and be more risk-averse in adapting to climate variability.

4.2 Trend analysis of rainfall

The figure illustrates year-to-year fluctuations in rainfall along with the Sen's slope estimate and linear trendline. Both trend indicators show a gradual decreasing pattern in annual rainfall over the 20 years, confirming a long-term decline in precipitation. This downward trend highlights increasing rainfall variability and recurrent dry conditions, providing essential context for understanding the climate-related challenges affecting maize production in the study area.

The starting rainfall value in the trend (Sen's slope) is approximately 527.66 mm. The projected value towards the end of the time series is around 400.86 mm, confirming a decline. The graph indicates a declining trend in annual rainfall over time. The consistent downward slope in both Sen's slope and linear regression suggests a long-term decrease.

The Sen's slope (Q) test indicated that the total annual rainfall in Gabiley decreased at a rate of 7 mm per annum. The Sen's slope (Q) represents the rate of change in annual rainfall over time. From the graph, the Sen's slope is calculated as:

$$\mathrm{Q} = 527.66 - 400.86$$

Since the x-axis represents time in years, the decrease per annum is:

$$\mathrm{Q} = \frac{527.66 - 400.86}{19 years} = 7\mathrm{mm/year}$$

Negative value (−0.235) indicates a decreasing trend in total annual rainfall over the study period. And it suggests a weak to moderate negative correlation. *p* 0.172 represents the p-value or statistical significance of the trend. A typical threshold for significance is 0.05 (5%), meaning that a value greater than this suggests the trend is not statistically significant. Here, 0.172 (> 0.05) implies that the observed decrease in rainfall could be due to random variations rather than a consistent long-term trend. Sen's Slope (Q = −0.019 mm/year) measures the rate of change in rainfall per year. A value of −0.019 mm/year indicates that rainfall is decreasing at a very slow rate. The small magnitude suggests that, while the rainfall is declining, the rate of decline is not significant in practical terms.

4.3 Trend analysis of maize yield

Maize yield data from 12 years were analyzed using Linear Trend analysis. For the trend detection and quantification in this study, trend analyses were conducted for the variable of maize yield data in metric tons for the period of 2012 to 2024.

This graph represents the maize yield (in tons) over the years from 2012 to 2024. The maize yield has shown a declining trend over time, as indicated by the downward-sloping linear trendline.

The initial yield in 2012 was quite high at around 4937 tons, but it has significantly decreased over the years.

4.4 Relationship between climate variables and maize yield using regression analysis

Data for this study were analyzed using simple linear regression and multiple linear regression. The main purpose of a regression is to predict a variable from unknown to known. The association between maize production and climate variability was ascertained using simple linear regression.

4.4.1 Measurement of variables

The variables used in the regression analysis were measured as follows:

- Maize Production (MP): Farmers' self-reported maize output measured in Kilograms per hectare as a continuous variable.
- Recurrent Drought (RD): Measured using Likert-scale perception scores indicating drought frequency and severity.
- Temperature Fluctuation (TF): Measured using Likert-scale responses reflecting unusual temperature changes.
- Rainfall Variability (RV): Measured using Likert-scale responses assessing irregularity in rainfall timing and distribution.

4.4.2 Model specification

The functional form of the model is expressed as:

$$\mathrm{MP} = \mathrm{f}(\mathrm{RD}, \ \mathrm{TF}, \ \mathrm{RV})$$

The statistical model used is:

$$\mathrm{MP} = \beta 0 + \beta 1\mathrm{RD} + \beta 2\mathrm{TF} + \beta 3\mathrm{RV} + \varepsilon$$

Table 3 Summary of the Regression analysis of the effect of recurrent drought on maize production

Model	B	R	R^2	R^2adj.	Std. ε	F	t	Sig.
Constant	1.277				.543		2.351	.020
Recurrent drought	.048	.147	.022	.016	.024	4.157	2.039	.043

Dependent variable: maize production

Table 4 Summary of the Regression analysis of temperature fluctuation on maize production

Model	B	R	R^2	R^2adj.	Std. ε	F	t	Sig.
Constant	3.859				.596		6.475	.000
Temperature Fluctuation	-.036	.179	.032	.027	.014	6.255	2.501	.013

Dependent variable: maize production

4.4.3 Simple linear regression of recurrent drought and maize production

The research used a straightforward regression model of Y = a + bX, where b is the constant term with Y and X, and a is the regression coefficient.

Climate variability is represented by X, and maize production by Y.

Simple linear regression, which is shown in Table 3, was used to examine how farmers in Gabiley District viewed the impact of recurring drought on maize production.

In Table 3 it shows that the simple linear regression between the recurrent drought and maize production was (R =.147, R^2 = 0.016, R^2 adj = 0.022, p =.043). The low R2 value (R^2 = 0.016) indicates that recurrent drought alone cannot account for the fluctuations in maize yield in the Gabiley District. The connection is insignificant, but it suggests that yield outcomes are likely influenced by both climatic and non-climatic factors. Socio-economic circumstances, farm-level management practices, soil quality, and technology accessibility may hold greater significance in future research.

The significance value of p =.043 of this objective is lower than p =.05, thereby rejecting the null hypothesis of no significant effect of recurrent drought on maize production. Therefore, there is a substantial impact of recurrent drought on maize production among small-scale farmers in Gabiley District, Somaliland.

The Simple Linear Regression model of this objective was:

$$\mathrm{MP} = 1.277 \; + .048\mathrm{RD} \tag{1}$$

where MP = Maize production and RD = Recurrent drought.

4.4.4 Temperature fluctuation and maize production

The perceived effect of temperature fluctuation on maize production among farmers in Gabiley District, Somaliland, was analyzed using Simple linear regression, represented in Table 4.

Table 4 shows us that the perceived effect of temperature fluctuation on maize production among small-scale farmers in the Gabiley district, Somaliland. The study shows that temperature fluctuation has a significant effect on maize production in the Gabiley district (R^2=0.032, R^2 adj. =0.027, p =.013). This indicates that the R value of 0.179 shows that there is a weak positive association between temperature fluctuation and maize production among production among farmers in Gabiley District, Somaliland. Its significance value of p 0.013 is lower than the accepted significance value *(p* =.05), and for the sake, there is a significant effect of temperature fluctuation on maize production among small-scale farmers in Gabiley district, Somaliland. Therefore, the null hypothesis of no significant effect of temperature fluctuation on maize production was rejected. Thus, temperature fluctuations have a significant effect on maize production.

The Simple Linear Regression model of this objective was:

$$\mathrm{MP} = 3.859 \ - .036\mathrm{TF} \tag{2}$$

where MP = Maize production and TF = Temperature fluctuation.

4.4.5 Rainfall variability and maize production

The perceived effect of the rainfall variability on maize production among farmers in Gabiley District, Somaliland, was analyzed using Simple linear regression, represented in Table 5.

Table 5 shows us that the perceived effect of rainfall variability on maize production among small-scale farmers in the Gabiley district, Somaliland. The study shows that rainfall variability has a significant effect on maize production in Gabiley district (R^2=0.020, R^2 adj. = 0.015, p =.049). This indicates that the R value of 0.142 shows that there is a weak positive association between rainfall variability and maize production among production among farmers in Gabiley District, Somaliland. Its significance value of p 0.049 is lower than the accepted significance value (p = 0.05) and for the sake, there is a significant perceived effect of rainfall variability on maize production among small-scale farmers in Gabiley district, Somaliland. Therefore, the null hypothesis of no significant effect of rainfall variability on maize production was rejected. Thus, rainfall variability has a significant perceived effect on maize production.

The Simple Linear Regression model of this objective was:

$$\mathrm{MP} \ = \ 3.575 \ - \ .032\mathrm{RV} \tag{3}$$

where MP = Maize production and RV = Rainfall variability.

4.4.6 Multiple linear regression model – test of three variables

A multiple linear regression model was used to determine the significance of climate variability on the maize production of small-scale farmers. This led to the adoption of a set of indicators to achieve the desired objectives.

The Multiple Regression Model for the study was:

$$\mathrm{Y} = \mathrm{f}\,(\mathrm{X})$$

$$\mathrm{Y} = \mathrm{f}(\mathrm{X1}, \mathrm{X2}, \mathrm{X3};$$

$$Y = a + a1X1 + a2X2 + a3X3$$

where;

Table 5 Summary of the Regression analysis of the effect of rainfall variability on maize production

Model	B	*R*	R2	R^2 adj.	Std. ε	F	t	Sig.
Constant	3.575				0.609		5.868	0.000
Rainfall variability	−0.032	0.142	0.020	0.015	0.016	3.912	−1.978	0.049

Dependent variable: maize production

Table 6 Multiple regression model of recurrent drought, Temperature fluctuation, Rainfall variability, and Maize production

Model	B	*R*	R2	R^2adj.	Std. ε	F	t	Sig.
Constant	3.167				0.789		4.012	0.000
Recurrent drought	0.071				0.024		2.957	0.004
Temperature fluctuation, Rainfall variability	−0.041				0.016		−2.559	0.011
	−0.019				0.018		−1.103	0.271
Model		.284[a]	0.080	0.066	0.86128	5.456		0.001

[a] Dependent variable: maize production

Y: Dependent Variable: Maize production, X1: IV1: Recurrent drought, X2: IV2: Temperature fluctuation, X3: IV3: Rainfall variability, Constant = a, a1, a2, and a3 are parameters for the variables X1, X2 and X3 respectively.

The statistical model to be used in the regression is:

$$\mathrm{Y} \ = \mathrm{a} + \mathrm{a1X1} + \ \mathrm{a2X2} + \ \mathrm{a3X3} + \varepsilon$$

I (i = 0, 1, 2, 3) are parameters,

0 is the intercept (constant)

ε represents the random errors.

Table 6 was summarized in the results of the multiple regression model.

Table 6 shows R, which is the correlation between the observed and predicted values of the dependent variable to be 0.284, while R-squared, which is the proportion of variation in the dependent variable, is 0.080. The adjusted R-squared is 0.066, showing a relationship between the observed and predicted values of the dependent variable. The regression model's explanatory power was relatively weak (R2 = 0.08) despite the fact that maize yield had a statistically significant relationship with climate variability. Only 8% of the variation in maize production is due to climate factors, and the remaining variation is likely due only to other socio-economic and institutional factors. Significant variables that can impact yield outcomes include irrigation access, improved seed and fertilizer use, soil fertility control, extension programs, input costs, and policy support. Although not part of the current model, these factors have a significant impact on the production performance of farmers in the Gabiley District.

The model illustrates that maize production is manipulated by the sum of the combined outcome of recurrent drought, temperature fluctuation, and rainfall variability, as confirmed by the R^2. The regression analysis has pointed out that the climate variability explains 6% variation in the maize production of the farmers.

The subsequent empirical model was generated using the beta coefficients:

$$\mathrm{MP} = 3.167 + .071\mathrm{RD} - .041\mathrm{TF} - .019\mathrm{RV}$$

where MP = Maize production, RD = Recurrent Drought, TF = Temperature Fluctuation, and RV= Rainfall variability.

More so, the model in Table 6 illustrates that a unit change in recurrent drought causes a 7.1% variation in maize production. While recurrent drought and temperature fluctuation demonstrated an insignificant variation in the maize production, recurrent drought exhibited a positive and significant variation in the maize production in the Gabiley district. Therefore, this study suggested that recurrent drought is the factor that is responsible for the poor maize production in small-scale farmers in the Gabiley district in Somaliland. More so, the model in Table 6 reveals that for every unit change in temperature fluctuation causes a 4.1% change in the maize production in small-scale farmers in Gabiley district, and it is significant (p =.011). This suggests that temperature fluctuation is also a significant predictor of maize production.

The model also reveals that a unit change in rainfall variability causes a 1.9% change in maize production in small-scale farmers in Gabiley district in Somaliland, though it is not significant (p =.271). This implies that rainfall variability is not an important factor to explain maize production in small-scale farmers in the Gabiley district in Somaliland.

4.4.7 Interpretation of model fitness

The F-statistic confirms that the overall regression model is significant. Although the explanatory power is modest, the results demonstrate that climate variability significantly influences maize production. Remaining unexplained variation may be due to factors such as soil fertility, irrigation access, seed varieties, and farmer management practices.

5 Discussions

The findings of this study provide important insights into how climate variability affects maize production in the Gabiley District of Somaliland. The detected decline in rainfall over the 20 years, and also the downward trend in maize yields over the last 12 years, suggest that climate affects maize production. This aligns with other studies in Somaliland showing that climate change, exhibited primarily through decreasing rainfall, increased drought, and adverse impacts on agricultural productivity [17].

The regression analysis also highlights which variable is the most influential in maize yield reduction. Recurrent drought and temperature fluctuations impact maize production, with drought showing a positive relationship. The analysis also highlights that the variables together can strengthen the effect of yield reduction. These align with research in Sub-Saharan Africa stating that the general relationship between rainfall, temperature, and maize yield was such that maize yield increased with increasing rainfall of the right amount and distribution pattern and declined with increasing temperature [4], p.13. The study also emphasizes that climate variability and/or change have adverse consequences on maize production.

Interestingly, climate variables have a weak positive association with maize production. This can be described as maize farmers in the Gabiley district cultivating on a seasonal basis. Also, they employ unpredictability management practices such as adjusting planting dates; for example, they prepare and cultivate their land at the onset of the rainy seasons, such as spring and autumn rains. Other farmers fertilize the soil using organic manure. However, when all climatic variables were combined in the multiple regression model, the researcher found that the lone effect of rainfall variability has no significant perceived effect on maize production, but the integration of all the variables (recurrent drought, temperature fluctuation, and rainfall variability) will have a significant perceived effect on maize production. This finding ties with the findings of [15], which shows the Relationship between Climate Variables and Maize Yield Using multiple regression. The study shows that climate variables show an inverse proportional relationship with maize yield.

Overall, the regression model indicates that non-climatic factors such as soil fertility, access to inputs, and farm management practices may also contribute to maize yield production. These findings underline the importance of using adaptation strategies.

6 Conclusions and recommendations

This paper builds on studies on climate change and implications of its variability on Maize crop in the Gabiley region, Somaliland, by analyzing the effect of climate variability on maize production in the Gabiley District of Somaliland and shows that the rainfall variability, temperature fluctuations, and recurrent droughts reduce maize yields. The research tried to confirm farmers' perceptions of climate variability with the real variations based on rainfall (climate data) recorded from 2004 to 2023. And also maize yield data recorded from 2012 to 2024. Analysis using the Mann-Kendall trend test and Sen's Slope estimator showed a downward trend in annual rainfall for over 20 years, and a decrease of approximately 7 mm per year. This paper has confirmed that rainfall is less predictable, shorter in duration, and reduced in amount, whilst temperature has become warmer in recent years. Maize yield data also showed a declining trend over the past 12 years. Regression results further demonstrated that climate variables together have a combined effect on the production. These findings indicate that climate variability is not only a future challenge but an active limitation on agricultural productivity and food security in all. Overall, the study concludes that strengthening adaptive capacity and improving climate resilience are essential for sustaining maize production in the region.

To this end, it is urgent to encourage the development of climate information and early warning systems. This can be done by expanding and modernizing local meteorological stations. It can also be an improved data-sharing system between the Ministry of Agriculture and Non-governmental institutions. Furthermore, the government should improve water catchment and drought resilience through the construction of water catchment dams and reservoirs to store runoff during rainy seasons. farmers can also be given a polythene sheet to store rainwater. The Ministry of Agriculture should also train farmers about Climate Smart Agriculture, including mulching, conservation of tillage, and organic farming. They can also be encouraged to practice crop rotation, intercropping, and agroforestry practices. These CSAs can help farmers improve their maize and crop production. Finally, the government and NGO's can provide subsidies to the farmers. These subsidies include improved seeds, fertilizers, and irrigation equipment. They can also expand access to Micro-credits and insurance to help farmers mitigate climate risks.

Abbreviations

FAO	Food and Agriculture Organization
IPCC	Intergovernmental Panel on Climate Change
MOAD	Ministry of Agriculture and Development
CSA	Climate Smart Agriculture
NADFOR	National Disaster Preparedness and Food Reserve Authority
SWALIM	Somalia Land and Water Information

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Author contributions

Saed Mohamoud Muhumed is the Corresponding Author. Email: saed.muhumed@uoh.edu.soAuthor Contributions: S.M., have made contributions in the acquisition of the data, data collection, data coding and entry, data analysis, visualization, interpretation of the result. writing—original draft, reviewed and edited the manuscript.Mohamed Abdullahi Omar is

the co-author.Email: Mksala10@gmail.comAuthor Contributions: The added author was directly involved in organizing, supervising, and collecting primary field data, which formed a critical component of the research analysis.

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Data availability
The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study did not require ethical approval according to the guidelines of the University of Hargeisa, as the research involved non-invasive surveys with adult participants. However, informed consent was obtained, and measures were taken to ensure participant anonymity and confidentiality. This study was conducted in accordance with the ethical standards of the University of Hargeisa. Ethical approval was obtained from the Research Ethics Committee. Informed consent was obtained from all participants before their involvement in the study. The authors declare that all ethical guidelines were followed in the conduct of this research. No conflict of interest or ethical concerns arose in the study. Non-invasive interviews with farmers, as well as ethical review and approval, were obtained. However, all participants gave their verbal informed consent after being fully informed of the study's objectives, and their confidentiality and anonymity were rigorously protected.

Consent for publication
Participants consented to the publication of the study's results in scholarly and scientific journals. To safeguard the participants' identities, all data presented in this paper has been anonymized. Photographs, sensitive information, or personally identifiable information have not been revealed. Consent for publication was specifically acquired when participant quotes were used directly.

Competing interests
The authors declare no competing interests.

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