Decadal Impacts of Climate Change on Rainfed Agriculture Community in Western Somaliland, Africa

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Abstract: The western region of Somaliland is prone to climate change and variability due to the widespread use of rainfed agriculture, which has been the practice historically since the colonization era; however, this mode of livelihood is losing its significance due to climate change. This research aims to examine the impact of climate elements' trends (rainfall and temperature) on rainfed agriculture communities and how these changes affect the rainfed agriculture community. The specific objectives of this study are to determine the major trends of precipitation and temperature over the past three decades, and to assess the level of awareness of climate change in communities' perception of environmental change in terms of rainfed agriculture. Hence, the study adopted a mixed-methodology approach to concluding the quantitative and qualitative aspects of the research. The main outcome of this study was that climate change has been an active challenge in western rainfed agriculture regions of Somaliland for the last three decades. Decadal precipitation and temperature trend analysis (1985–2015) indicated reduced rainfall both annual and seasonal, and an increase in annual temperature, both in terms of the maximum and minimum. The decrease in annual total rainfall from the Awdal and Waqooyi Galbeed regions was 2 mm/year and 1.5 mm/year, respectively, while in the long rainy season, the decrease of rainfall was 1.4 mm per season and 0.88 mm per season, respectively. In the case of maximum and minimum annual temperatures, both stations depict an increase in temperature. This increase in temperature was 0.043–0.045 °C for the Awdal region and 0.06–0.02 °C for the Waqooyi Galbeed. The qualitative phase of this study supported the quantitative observations, and respondents (≥45 years of age) reported decreasing annual rainfall, a declining long rainy season, and increasing maximum and minimum temperatures. Furthermore, participants mentioned an increase in the occurrence of drought, a reduction of rainfed agriculture productivity, the disappearance of indigenous plants and animals, and an increase of exotic plant species. In addition to that, respondents outlined current adaptation practices; however, these adaptation strategies are short-term, and farmers need more appropriate and practical adaptation practices in the future.

Keywords: Somaliland; rainfed agriculture; decadal; climate change; impact; Africa

1. Introduction

Climate change is already threatening the basics of human survival because it affects the existence of human life, such as the right to safe drinking water, health, housing, and most importantly, the right to access food [1], and in some regions, it triggers conflicts that claim the loss of property and human life [2]. Climate change undermines global sustainable development goals, particularly those aiming to eliminate poverty and reduce hunger, and reach a sustained global environment and economic conditions [3]. Climate change is projected to reduce agriculture productivity in continents such as Africa, where more than half of its population practises rainfed agriculture, by lessening the plantation period, increasing the occurrence of extreme weather events, degrading the existing water resources, and encouraging the proliferation of insects and pests [2,3].
is a huge concern about the impact of climate change on rainfed agriculture productivity, particularly in semi-arid regions of Africa [4–8]. Food insecurity is already a global issue, and every country is alarmed by the consequences of climate change on agriculture productivity [9]. Subsistence farming has been defined as crop production and its associated activities, which together act as a livelihood strategy where the main production is consumed directly, without using any form of irrigation and synthetic fertilizers, thus depending on climatic behavior [10]. Rainfed agriculture practices have been carried out in Somaliland since the colonization era, particularly in the western regions [2]. Before the collapse of the central government of Somalia in 1991, these regions were the sorghum and maize belt of the country [8]. Several studies in the literature, including those studies, reported that this mode of livelihood is losing its significance across Somaliland as a result of successive droughts, poor water management, a rise in the population, and rural migration. The instability and local adaptation practices are failing, as occurrences of extreme weather events become the new normal. However, the extent of the climate change impact across the western rainfed agriculture regions in Somaliland is not investigated thoroughly, and there exists a knowledge gap in the literature.

Climate change has been active in Somaliland over the past three decades, in the form of extreme climate events [11]. The synergistic effect of environmental degradation and extreme weather events attributed to human-induced climate change has resulted in a decrease in livestock production and a further increase in food insecurity in Somaliland [10,12]. Local communities are not fully aware of the consequences of climate change [13]. In Somaliland, climate change effects are in the form of extreme weather events; although droughts and floods are common in the country, the rate of occurrence and intensity has changed over the past decades [14,15]. In many areas, crops do not reach the stage of harvest due to the delaying and insufficient quantity of rainfall. Other factors that contribute to the loss of agricultural productivity are excessive erosion due to unsuitable crop practices and the increase of pests and weeds [16]. Still, other effects of climate change in Somalia include rapid deforestation, declining fauna and flora diversity, and species migration, particularly avifauna [11].

Several studies have been conducted in Somaliland regarding the impact of climate change, but those studies were based on respondents’ insights and covered a small portion of the country [17–19]. This study attempts to expand the knowledge of climate change across the western regions of Somaliland which form the food basket of this unrecognized nation, by combining thirty years of meteorological data to identify trends in precipitation and temperature, and the perceptual insights of the farmers. Rainfed agriculture practices have been exercised in Somaliland since the colonization era, particularly in the western regions [20–24]. Before the collapse of the central government of Somalia in 1991, those regions were the sorghum and maize belt of the country [25,26]. Several studies in the literature, including those studies conducted by FAO [27], reported that this mode of livelihood is losing its significance across Somaliland. However, the extent of the climate change impact across the western rainfed agriculture regions in Somaliland is lacking in the literature. In this study, the authors focused on the trends of climate variables such as rainfall and temperature over the last three decades, and how the rainfed agriculture communities in Somaliland are facing these challenges. This study is important in that it will help to expand and understand the problem of climate change in Somaliland, particularly the western regions of Awdal and Waqooyi Galbeed.

This study will seek to answer how climate variables such as precipitation and temperature have changed over the past decades, and how the rainfed agriculture community perceives those trends. The climate of Eastern Africa in general, and Somaliland in particular, is well known for its variable nature and erratic conditions [28–31]. This study will help expand and understand the problem of climate change in Somaliland particularly, in the rainfed agriculture regions of Awdal and Waqooyi Galbeed. This study is unique in the perspective that the researchers focused on the trends of climate variables such as rainfall and temperature over the last three decades, and how the rainfed agriculture communities
in Somaliland are facing these challenges. The objectives of this study is to determine the major trends of precipitation and temperature over the past three decades, to identify the level of awareness of climate change, to assess communities’ perception of environmental change, and to evaluate how these trends are impacting the rainfed agriculture community.

2. Materials and Methods

This investigation adopted a concurrent triangulation design in a mixed-methodology approach. This refers to a research design that requires the gathering of quantitative data, and then analyzing and examining qualitative data [32,33]. This approach used the strength of quantitative data to trace decadal trends of precipitation and temperature in western regions of Somaliland. The qualitative phase of the study aided in understanding the impacts of climate change on the rainfed agriculture community, and validating the quantitative findings. The household survey was carried out using a structural questionnaire applying both quantitative and qualitative techniques. Household surveys assisted in mapping the community’s level of awareness of climate change, and assessing communities’ perception of environmental change. Sometimes, a single method is not enough because of the complex nature of the problem; hence, a mixed-method approach is far more effective [34]. Merging the quantitative and qualitative phases of the results will assist in complementing each other and overcoming the weaknesses of one method [34]. Therefore, the combination of both will yield a result that is reliable and conclusive. The study will utilize the advantages of the mixed-method design in a way that the quantitative method will assist in examining the issue at the group level, while the qualitative aspect (e.g., focus group discussion and the key informant interview) will assist in probing the issue at the individual level [35].

2.1. Data Control and Method of Analysis

Total daily precipitation and temperature were obtained from the weather stations and processed using Excel and PivotTable. The missing daily data were filled in using the arithmetic averaging method. Minitab software (Minitab-19.1.1.0 version) was employed for the trend analysis of the long rainy season (MAMJ) and total annual precipitation trend analysis of annual maximum and minimum temperatures. Minitab trend analysis for time-series data can use various models of analysis, such as quadratic, S-curve (Pearl-Reed logistic), exponential, and linear $Y_t = y + \beta 0 + \beta 1 t + et$. In this study, mean absolute percentage error (MAPE), mean absolute deviation (MAD), and mean squared deviation (MSD) were used to adapt the best model; the model which has the least values from these measurements was employed. In this study, we adopted a linear trend model, as qualitative data was collected through focus group discussions, key informant interviews, and questionnaires from the same regions where historical climate data were obtained. Purposive sampling techniques were used to select farmers from four villages. Furthermore, these villages were selected because this area is well known for its rainfed agriculture practices and contributed to the country’s food security, and drought is prominent in these villages. The age of the selected respondents was important because the period under investigation is 30 years; hence, participants whose age was between 40–60 years were interviewed.

2.2. Study Area

Figure 1 shows the location of the study area in Africa, the western regions of Awdal and Waqooyi Galbeed. Somaliland receives two types of rainfall. The first one or the main one starts at the beginning of April and, in some areas, late March, and ends in June. In addition, a short rainy season, known locally as Dayr or Karan, starts in early October and lasts until late December. Each of these seasons is followed by dry periods [36]. The short rainy season is particularly important for crop production, as it occurs at the time of the plant production stage, particularly for the sorghum, and replenishes the water table. A failure or lack of the short rainy season results in prolonged droughts and low yield productivity in the study area [37]. The last decade’s failure of short rainy
seasons results in successive droughts, such as droughts in the years 2007, 2011, and 2017 [38]. The total annual rainfall in the coastal regions of Somaliland is 100 mm, but the rainfall increases in the southwestern regions, reaching 400 mm level. The climate of Somaliland is classified as dry and semi-dry [37]. The rainfall in Somaliland is a result of the movement of the Intertropical Convergence Zone that moves from north to south and produces two rainy seasons in Somaliland. The soil of the study area has been classified as vertisols, leptosols, and regosols with low water holding capacity and nutrient contents. The forest in the western area of Somaliland is dominated by drought-tolerant species such as *A. tortilis, A. bussei,* and *A. senegal,* most of which grow along the banks of streams [37]. In the past decade, vegetation in this area has been cleared due to increased farming, coupled with the production of charcoal, which resulted in extensive deforestation. Similarly, in the past decades, the appearance of invasive species such as *Prosopis juliflora* (Garawa) and *Parthium hysterophorus* (Kalliginoole) caused serious environmental and ecosystem degradation in the region.

![Map of Somaliland](image)

**Figure 1.** Map showing the location of the study areas, the western regions of Awdal and Waqooyi Galbeed.

### 2.3. Climate Data and Analysis

Daily average precipitation data were collected from two main stations in Somaliland, in Borama and Hargeisa from 1985–2019. The study period of both of the climate parameters (temperature and precipitation) was 30 years. Stations were selected based on their data availability and the proximity of the area under investigation. The total annual rainfall of
the long rainy season (March, April-May-June) for the last three decades was analyzed to detect periods of low rainfall, and decadal trends were also analyzed. Similarly, the maximum and minimum annual temperatures of both stations were analyzed to identify trends in temperature. All series of the data (1984–2015) was complete and no filling in the gaps was required. Descriptive statistics were employed to analyze the mean, average, maximum, minimum, standard deviation, kurtosis, skewness, and coefficient variance of both precipitation and temperature. The coefficient of variation is used to describe the degree of variability of rainfall [39]. Skewness and kurtosis were used to describe the distribution of rainfall [40,41]. Minitab software was employed for the trend analysis of the long rainy season (MAMJ) and annual precipitation, and similarly, for the trend analysis of annual maximum and minimum temperatures [42,43]. Figure 2 shows the overall design of the study used to carry out the research.

Figure 2. Flow diagram showing the design of the study.

Qualitative data was collected through focus group discussions, key informant interviews, and questionnaires from the same regions where historical climate data were obtained. Purposive sampling techniques were used to select farmers from four villages, two villages for each region. Furthermore, these villages were selected because these areas are well known for their rainfed agriculture practices and their contribution to the country’s food security. A total of 160 questionnaires were distributed to the farmers, with
40 questionnaires for each village. Eight focus group discussions were conducted, two for each village, consisting of 5 to 6 people in each group. Further, twelve key informant interviews were also undertaken, three for each district. A statistical package for social science (SPSS) was employed to analyze the questionnaire. Interviews were conducted in the local languages first and then translated into the English language verbatim. The interview transcript was analyzed using a thematic approach. Both the variables of interest and the common or repeated themes were recorded using the coding approach. This approach involves pointing out meaningful units to code, and identifying the themes into sub-themes, thereby moving the analysis to a higher interpretive level [34]. Sub-themes were merged into the variables of interest, and one or several code units also emerged. Out of twelve key informant interviews, only six were subjected to analysis because respondents outlined similar issues.

3. Results and Discussion

3.1. Quantitative Data Analysis

Data on total daily precipitation and average daily temperature were obtained from two weather stations in Somaliland (Borama and Hargeisa, Table 1 from the period 1985–2015). The stations were selected based on proximity and the availability of the data. Total monthly and annual precipitation data were obtained from daily data, and monthly and annual maximum and minimum temperatures were obtained from daily temperature data using Excel PivotTable. Total daily precipitation and temperatures were obtained from the stations. The missing daily data were filled in using the arithmetic averaging method. Descriptive statistics were employed to analyze the mean, average, maximum, and minimum, standard deviation, kurtosis, skewness, and coefficient variance, of both precipitation and temperature. Data from both stations were organized, analyzed, and presented separately. The study period of both of the climate parameters (temperature and precipitation) is 30 years. The descriptive statistics of the average monthly and annual precipitation of the stations of interest are given below.

The results from the Borama station showed a coefficient of variation ranging from 68 to 210%, while that of annual rainfall was 52%. The highest annual rainfall was 452 mm, recorded in 1997, while the lowest annual rainfall was 76 mm and was recorded in 2000. The results of the Hargeisa station revealed a coefficient of variation between 79% and 290%, and the annual coefficient variation of rainfall was 53%. The maximum and minimum rainfalls ever recorded were 461 mm in 1977 and 58 mm in 2001 in Hargeisa.

The coefficient of variation is used to describe the degree of variability of rainfall (high percentage), and the data indicated a high inter-annual variability of rainfall in the region. A coefficient of variation (CV) of less than 20% indicated moderate variability, and CV > 30% showed a very high variability of rainfall. The CV values > 40% and 70% depicted an extremely high inter-annual variability of precipitation [39]. Based on this observation, the meteorological data of precipitation shows that all months, for both the Borama and Hargeisa stations, had more than 40% of the coefficient of variation (CV), depicting extreme temporal variability of rainfall over the observed stations. The coefficient variation of the long rainy season (April, May, and June) at Borama station was 95%, 123%, and 144%, respectively, while that of Hargeisa station was 79%, 107%, and 169%, respectively. This highlights the extremely high variability of precipitation over the long rainy season. Similarly, statistical analysis of all the periods under investigation shows a homogeneous character in the context of rainfall variations in both stations, so it can be concluded that high rainfall variability is a common precipitation characteristic in the study area. The highest coefficient of variation was found in February (220%), followed by October and November (209% and 207%, respectively). The lowest coefficient of variation was observed in August (68%) at the Borama station, while at Hargeisa, the highest CV was in February, November, and June at 290%, 194%, and 169%, respectively, and the lowest coefficient of variation of rainfall was found in April at 69%. Hence, it is concluded that the stations under investigation recorded similar rainfall characteristics, although they
differed in some of the periods. Variability of rainfall is a common feature in east African precipitation [44]. To test the normal distribution of rainfall in the observed stations, we employed skewness and kurtosis. Negative skewness indicates the observed data are skewed left, while the positive highlights that the data are skewed right [40,41].

Table 1. Statistical summary of total monthly rainfall at the Borama and Hargeisa weather stations between 1985 and 2015.

<table>
<thead>
<tr>
<th>Period</th>
<th>WEATHER STATION</th>
<th>MEAN</th>
<th>MAX</th>
<th>MIN</th>
<th>SD</th>
<th>KRT</th>
<th>SKW</th>
<th>CV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>Borama station 1985–2015</td>
<td>9.08</td>
<td>42</td>
<td>0.18</td>
<td>11.3</td>
<td>2.38</td>
<td>1.8</td>
<td>124</td>
</tr>
<tr>
<td>Feb</td>
<td>8.06</td>
<td>85</td>
<td>0.11</td>
<td>16.9</td>
<td>14.6</td>
<td>3.66</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>23.9</td>
<td>108</td>
<td>0.18</td>
<td>29.6</td>
<td>1.27</td>
<td>1.5</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>Apr</td>
<td>36.9</td>
<td>181</td>
<td>0.21</td>
<td>35.1</td>
<td>9.2</td>
<td>2.6</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>16.1</td>
<td>92</td>
<td>0.06</td>
<td>19.7</td>
<td>9.2</td>
<td>2.6</td>
<td>123</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>5.4</td>
<td>26.2</td>
<td>0.01</td>
<td>7.9</td>
<td>1.5</td>
<td>1.6</td>
<td>144</td>
<td></td>
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<tr>
<td>Jul</td>
<td>22.2</td>
<td>84</td>
<td>0.64</td>
<td>20.4</td>
<td>2.2</td>
<td>1.5</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>18.3</td>
<td>49</td>
<td>4.64</td>
<td>12.4</td>
<td>1.11</td>
<td>1.3</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Sep</td>
<td>8.88</td>
<td>87</td>
<td>0.98</td>
<td>33.2</td>
<td>28.1</td>
<td>5.1</td>
<td>168</td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>15.89</td>
<td>181</td>
<td>0.11</td>
<td>30.5</td>
<td>21.9</td>
<td>4.4</td>
<td>209</td>
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</tr>
<tr>
<td>Nov</td>
<td>14.7</td>
<td>122</td>
<td>0</td>
<td>10.2</td>
<td>6.3</td>
<td>2.5</td>
<td>207</td>
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<tr>
<td>Dec</td>
<td>5.9</td>
<td>40</td>
<td>0</td>
<td>11.1</td>
<td>5.9</td>
<td>2.6</td>
<td>174</td>
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<tr>
<td>Annual</td>
<td>185</td>
<td>452</td>
<td>76</td>
<td>98</td>
<td>1.07</td>
<td>1.3</td>
<td>53</td>
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<table>
<thead>
<tr>
<th>Period</th>
<th>HARGEISA STATION 1985–2015</th>
<th>MEAN</th>
<th>MAX</th>
<th>MIN</th>
<th>SD</th>
<th>KRT</th>
<th>SKW</th>
<th>CV%</th>
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<tr>
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<td>12.6</td>
<td>24.8</td>
<td>4.81</td>
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<td>21.7</td>
<td>4.04</td>
<td>2.08</td>
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<td>29.1</td>
<td>-0.2</td>
<td>0.8</td>
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<td>May</td>
<td>32</td>
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<td>10.2</td>
<td>2.6</td>
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<td>11.1</td>
<td>9.5</td>
<td>2.9</td>
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<tr>
<td>Jul</td>
<td>11.2</td>
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<td>9.9</td>
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<td>1.2</td>
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<td>29.7</td>
<td>2.1</td>
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<td>2.6</td>
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<tr>
<td>Annual</td>
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<td>461</td>
<td>59</td>
<td>89</td>
<td>3.2</td>
<td>1.5</td>
<td>53</td>
<td></td>
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</tbody>
</table>

SD: Standard deviation, MAX: Maximum, MIN: Minimum, CV: coefficient of variation, KRT: Kurtosis, SKW.

Based on the analysis of all the periods under investigation, a positive skewness implies that rainfall distribution in this region is flat (evenly distributed). Kurtosis is the measure of light and sharpness of the peak. Positive kurtosis depicts a peaked distribution, while negative kurtosis shows a flat distribution [40,41]. The analysis showed a range of kurtosis between 1.7 and 21.99 at the Borama weather station, and showed a positive kurtosis, meaning that the precipitation has a high frequency and is not equally distributed, while at the Hargeisa station, it ranged from 0.2 to 24. In this station, all months have a positive kurtosis except April, indicating that rainfall is not equally distributed. Overall, in Somalia and Somaliland, the beginning and the end of rainfall is the biggest challenge that farmers face in terms of water availability [12]. Several studies have identified similar patterns in rainfall across East African countries, particularly in Ethiopia and Kenya [45,46]. This is generally attributed to the warmer sea surface temperature in the Indian Ocean and the Pacific Ocean [47].

3.2. Trend Analysis

Statistical software was employed for the trend analysis of the long rainy season (MAMJ) and total annual precipitation, and similarly, for the trend analysis of annual maximum and minimum temperatures. The trend can also be defined as a long-term fluctuation over time-series data [48]. Trend analysis is a technique that matches the general
trend model to time-series data and provides projections for the future [42]. Minitab trend analysis for time-series data can take various models of analysis, such as quadratic, S-curve (Pearl–Reed logistic), exponential, and linear. In this study, mean absolute percentage error (MAPE), mean absolute deviation (MAD), and mean squared deviation (MSD) were used to adapt the best model. In this study, the research adopted a linear trend model:

\[ Y_t = y_t + \beta_0 + \beta_1 t + e_t. \]

where \( Y_t \) is the climate variable (precipitation or temperature), \( \beta_0 \) is the independent variable, \( \beta_1 \) is the average change of climate parameter from one period to the next, \( 't' \) is the time, and \( 'e' \) is the random error. In this case, a linear regression equation was adapted as \( y = a + bx \), where \( x \) represents years and \( y \) climate variables (precipitation and temperature), \( b \) is the slope of the line, and \( a \) is the intercept. Many studies throughout Africa and other parts of the world employed Minitab software to identify trends in temperature and precipitation, including those that were conducted in Jordan and Egypt [42,43].

3.3. Precipitation Trend Analysis

The trends of the annual (Figure 3a,b) and long rainy seasons (Figure 4a,b) were analyzed using a linear trend model, as it is a major and important rainfall in Somaliland and accounts for 75% of total annual rainfall [48]. The results of the trend analysis of both stations were given in Figures 2 and 3. The trend analysis of the long rainy season depicts a negative trend at both the Borama and Hargeisa stations, showing a decrease in rainfall at the Borama station of 1.4 mm per season, while that of Hargeisa was 0.88 mm per season. Many studies in the literature identified similar patterns in rainfall across East African countries, particularly those conducted in Ethiopia and Kenya [45,46].

![Trend Analysis Plot for Total annual rainfall At Borama 1985-2015](image)

![Trend Analysis Plot for total annual rainfall at hargeisa 1985-2015](image)

Figure 3. Annual rainfall trends at Borama (a) and Hargeisa (b) stations.
Furthermore, at the Borama station, the highest rainfall during the long rainfall season was 189 mm which was recorded in 1989, while the lowest rainfall was observed to be 3 mm and was recorded in 1999. Rainfall data indicated erratic conditions during the periods of 1995–2005, with peaks of high and low rainfall patterns. Likewise, the Hargeisa station recorded the wettest season at 211 mm of rain in 1987, while the driest season was recorded in 1999 at 19 mm of rain. The periods of low rainfall were observed to be from 1998 to 2004, with peaks of high and low amounts of rainfall. Based on the results of both descriptive statistics and trend analysis, it is concluded that both annual and seasonal rainfall variability is high in the study area. The peaks of high and low rainfall patterns are often described as droughts and floods. This is attributed to warmer sea surface temperatures in the Indian Ocean and the Pacific Ocean [49]. The results are in a line with those in the literature, which observed a decrease in the long rainy season in East Africa [49,50].

The procedure used for the trend analysis of the long rainy season was also applied to the trend analysis of total annual rainfall. The trend model which has the least values of MAPE, MAD, and MSD was employed in this study. The linear trend model was adopted because the model had the least value of MAPE, MAD, and MSD as compared to other time-series trend models. Figures 3 and 4 present the annual trend results and future projections.

Both of the stations of interest showed a negative trend as the total rainfall decreased by 2 mm per year in the past three decades at Borama, while at the Hargeisa station, the decrease of rainfall was 1.5 mm per year. The observed and projected trend results are similar to previous studies that have been conducted in parts of Somalia and East Africa [48,50]. However, results depict high inter-decadal variability of rainfall, with periods...
of low rainfall from 1999–2010 in Borama, while Hargeisa experienced a similar pattern during 1998–2008. Similar patterns were observed during the rainfall trend analysis from 1998 to 2004, with peaks of high and low amounts of rainfall. Therefore, it is concluded that the decades between 1990 and 2020 were the driest among the periods under investigation.

3.4. Temperature Trend Analysis

Minitab software was employed for the trend analysis of maximum and minimum annual temperatures in the Borama and Hargeisa stations for the period from 1985 to 2015, and the forecast of maximum annual temperature was projected until 2050 (Figures 5 and 6). The linear trend model was adapted because it has the least values of MAPE, MAD, and MSD (Table 2), while the other trend analysis models showed higher values of these measurements. Therefore, the linear trend model was found to be the best fit.

![Figure 5. Trend analysis in maximum and minimum annual temperature in Borama.](image)

![Figure 6. Trend analysis in maximum and minimum annual temperature in Hargeisa.](image)

| Table 2. Accuracy measures for the model selection of temperature analysis. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| Name            | Linear          | Quadratic       | Exponential     | S-Curve         |
| MAP             | 0.84            | 0.95            | 0.98            | 0.99            |
| MAD             | 0.26            | 0.30            | 0.34            | 0.40            |
| MSD             | 0.11            | 0.32            | 0.16            | 0.50            |
Both maximum and minimum annual temperatures in the Borama station from the studied period (1985–2015) depicted an increasing trend of temperature (Figure 6), and the increase in maximum and minimum annual temperature was observed to be 0.043 to 0.045 °C per year, respectively, while that of the Hargeisa station from the period under study depicted upward trends of temperature, and an increase in maximum and minimum annual temperatures of 0.06 and 0.02 °C per year, respectively.

Based on the maximum temperature analysis in the Borama station, the hottest year recorded was 2010 at 32.8 °C, and the minimum temperature recorded was 19.4 °C in the year 1991. Similarly, maximum temperature analysis shows that the period between 1997 and 2010 was the hottest in the region.

On the basis of the maximum temperature analysis at the Hargeisa station, the hottest year recorded was 2015 at 30.1 °C, while in the minimum temperature analysis, the hottest year was 2006 at 18.4 °C. The temperature analysis indicated a steady increase in temperatures during the period 1994–2010, making it the hottest decade in the region. The increasing trend of maximum annual temperature in Hargeisa (0.06 °C) is higher than that of Borama (0.04 °C), while the minimum annual trend analysis in the Borama station shows 0.04 °C, and Hargeisa 0.02 °C. It is important to note that both the trends of temperature in Borama and Hargeisa are less than that of the global average temperature of 0.8 to 1 °C over the past hundred years [50–52].

3.5. Qualitative Analysis

Qualitative data was collected through focus group discussions, key informant interviews, and questionnaires from the same regions where historical climate data were obtained (Figure 7). Purposive sampling techniques were used to select farmers from four villages, two villages for each region. Furthermore, these villages were selected because the areas are known for rainfed agriculture practices and contributed significantly to the country’s food security. The questionnaire aided in collecting demographic characteristics, and farmers’ perceptions about the changes in climate and the environment. Interviews aided in probing the magnitude of the impact and recording possible adaptation measures available to the farmers facing climate change. Both the focus group discussions and the key informant interviews were conducted after receiving permission from the participating adults (≥45 years of age), following general ethics and standard procedures.

Figure 7. Age and gender of respondents.

3.6. Demographic Profile

Of a total of 160 participants, 58% of them were males, while 41.9% were females, as the majority of farm owners were males. The temporal scale of the study was thirty years; hence, participants whose ages were between 45 and 60 years of both genders were preferred, since their experience and knowledge were vital to this study. In addition,
respondents’ ages are important, as age affects the decision to adopt new technology in agriculture practices.

About 35.65% of participants described changes in rainfall patterns, 23.8% of the participants mentioned increasing drought, 18.15% of them pointed out a reduction of rainfall, and only 9% of participants mentioned an increase in flood occurrence (Figure 8). Based on the comments, the main climate challenge faced by the rainfed agriculture communities in the western Somaliland regions include the timing of precipitation, increasing drought occurrence, reduction of rainfall, increasing temperature, and incidence of floods. Likewise, meteorological analysis of precipitation and temperature in these regions revealed similar patterns, and the model used in this study was adopted to analyze precipitation and temperature, in relation to the changes that climate brought and how this affects local conditions and the environment. Respondents mentioned the decline of indigenous trees that previously covered the local areas and the emergence of new tree species, which they described as having lesser values. Respondents identified the names of various trees that declined during their lifetime. The new and invasive species that dominate the area include Prosopis juliflora (Garanwaa) and Parthium hysterophorus (Kalidinole).

![Figure 8. Stakeholders’ perception of climate change.](image)

These trees have been seen in the area for over 15 to 20 years, based on the opinions of the respondents; however, the precise timing of the introduced species is not agreed upon. The magnitude of the social and economic impact of these trees is beyond the scope of this study. Furthermore, respondents outlined that Prosopis juliflora has a tolerance for water scarcity, which seems to be the possible reason that this tree dominates rapidly in the area. A community member reported:

“Fifty years ago when they used to travel in the forest along with their herds to search water and pasture for their animals. They did not need to cook food as they relied only on the milk of their livestock and eat edible crops that were abundant at that time. But now if you travel to the area they used to travel to in the past, you will starve to death as edible crops vanished. Also, it seems that the wild animals migrated from the area during the civil wars.”
3.7. Integration of Quantitative and Qualitative Findings

In contrast, this study depicts how changes in rainfall and temperature in the western Somaliland regions have changed in the last three decades (1985–2015) and how these trends affect the rainfed agriculture communities. Only four of the quantitative findings were consistent with the experience and perceptions of the rainfed agriculture community. Spatial variability of rainfall was the only quantitative finding in which qualitative findings were not supported. This could be because agricultural communities did not move from their areas; hence, they cannot tell how the rain in their area is different from other areas.

3.8. Decreasing Rainfall

In the case of annual rain and the short rainy season, participants reported that in the past twelve months of the year, each month has a distinctive climate character. For instance, March to June was the rainy period, and July to September was relatively hot, although scattered rainfall was received in Salaxlay village, which is south of the capital city Hargeisa. Furthermore, this time of the year used to receive a local rain known as “Somalia”, which no longer exists. October, November, and early December marked the short rainy season. Respondents mentioned that the short rainy events have increased in the past ten years. Furthermore, 30–40 years ago, the number of wet days and months was higher and the whole year seemed to be winter. A respondent reported:

“In the past, the rain was more predictable and reliable but in the last thirty years the predictability and the reliability of precipitation become difficult, and the traditional knowledge which we engage to forecast rainfall is no longer reliable. The rain becomes “ila-meeyayo” meaning “uncertain” as a result we changed the growing pattern of crops. In the past, we cultivated two times a year both in GU and DAYR but now we cultivate only once a year”.

3.9. Decreases the Long Rainy Season

Farmers in the study area outlined that the long rainy season is reducing, both in amount and frequency. They also perceived a decline in rainy days and an increase in dry days. The participants also reported that in the past, long rainfall (March, April, May, and June) was more predictable and sufficient in amount for growing crops, but in recent decades, the length of this season is reduced. Therefore, instead of getting rain for four months, they only received one or two months of rain, which may be two consecutive months or separate months. A respondent reported:

“In the past, the length of the rainy season was 120 days and sometimes 150 days but now we only receive rain for 90 days, and in some times it’s even less than 40 days”.

3.10. Temporal Rainfall Variability

With respect to rainfall variability both annual and seasonal, respondents identified many changes. They described that the rainfall is not like what it used to be in the past, and the normal seasons of the rain, which are the long rainy season, locally known as “GU”, and the short rainy season, locally known as “DAYR”, are no longer reliable. They added that, when it does rain, it is heavy and lasts for only a short period. This is a problem for land cultivation, as these kinds of rains resulted in soil erosion and the destruction of the new seeds. They also perceived that rain direction changes. Concerning the long rainy season, farmers mentioned that they receive rain when they least expected it. They did not grow crops because traditional knowledge of rain forecasts is no longer a viable option, which puts the farmers in a risky situation.

3.11. Increased Maximum and Minimum Temperatures

In relation to changes in temperature, respondents who observed an increase in temperature in the area in the late 1970s reported that they perceived the increase in temperature in several ways, and described that, in the past, it was easy to travel in the
morning from village to village, and sometimes, they used to travel 50–60 km, but in the recent decades, as temperature increases, it has become difficult to travel. Our discussion with Jarahoroto village inhabitants revealed that, 50–40 years ago, the whole year was cold from October to January, but in the last forty years, the number of cold days has become rare, while hot days and months have become more common. In the study area, the increase in temperature affects genders differently. Females and males have different roles in the context of Somali culture. Females generally are responsible for fetching water for household consumption, and transporting milk and other agricultural goods to the nearest cities, while males do the work of cultivating and harvesting the crops. In the last decades, it has become difficult for women to travel, and transport and bring back goods needed from the cities, because of the rising temperatures.

“A female respondent, describing the increase in temperature, mentioned that, in the past, it was easy to go to the nearest village in the morning, but in the last decades, as the sun is too hot and there is little water available on the surface wells, it has become difficult for them to travel; therefore, nowadays, they use transportation, or they travel with male family members at night.”

3.12. Comparison Analysis

Decadal precipitation and temperature trend analysis (1985–2015) indicated reduced rainfall both annual and seasonal, and an increase in annual temperature, both in terms of the maximum and minimum. The decrease in annual total rainfall from both the Awdal and Waqooyi Galbeed regions was 2 mm/year and 1.5 mm/year, respectively, while in the long rainy season, the decrease of rainfall was 1.4 mm per season and 0.88 mm per season, respectively. This is in line with the previous studies conducted in some parts of Somalia and the Horn of Africa. Those studies highlighted reduced precipitation from 1982 to 2015, and its association with drought. Some seasons showed above-normal rainfall, which results in a catastrophic flood [53]; however, other studies indicated an increase in rainfall during October and December and a decline from June to August by 2050 in East Africa. The meteorological data of precipitation shows that all months, for both the Borama and Hargeisa stations, had more than 40% of the coefficient of variation (CV), depicting extreme temporal variability of rainfall. Several studies have identified similar patterns in rainfall across East African countries, particularly in Ethiopia and Kenya [45,46]. This is generally attributed to the warmer sea surface temperature in the Indian Ocean and the Pacific Ocean [47].

In the case of maximum and minimum annual temperatures, both stations depict an increase in temperature. This increase in temperature was 0.043–0.045 °C for the Awdal region and 0.06–0.02 °C for the Waqooyi Galbeed. This is in agreement with other studies that have been conducted in the region, which highlighted that Africa has already experienced a 0.7 °C increase in temperature over the last century, and general circulation models indicate an increase of 0.2 °C to more than 0.5 °C each decade [54]. Similarly, respondents mentioned an increase in the number of hot days and dry days in the year, in the other studies conducted in Somalia that rely on people’s perceptions, that identify a similar pattern [55].

4. Conclusions

It can be concluded that rainfall and temperature have changed in the western Somaliland regions in the last three decades (1985–2015). The decrease in seasonal rainfall at both weather stations (Borama and Hargeisa) in Somaliland was 1.44 mm and 0.8 mm per season, and the decline in annual rainfall was 2 mm and 1.5 mm per annum, respectively. The coefficient of variation of the long rainy season (April, May, and June) the at Borama station was 95%, 123%, and 144%, respectively, while that of the Hargeisa station was 79%, 107%, and 169%, respectively, depicting extremely high variability of precipitation over the long rainy season for both stations. Qualitative data supported the meteorological findings. Respondents described that rainfall is not like what it used to be in the past,
and the normal seasons of the rain, which are a long rainy season, locally known as GU, and a short rainy season locally known as ‘Dayr’, are decreasing both in amount and in frequency. With regard to the long rainy season which is under investigation in this study, because it accounts for 70% of total rainfall received in the area, participants perceived a decline in the rainy days and an increase in the dry days. The meteorological observations indicated an upward trend of maximum and minimum annual temperatures at both stations. The increase in maximum and minimum annual temperature in the Borama station was observed to be 0.043 °C and 0.045 °C per annum, while at the Hargeisa station, it was 0.06 °C and 0.02 °C per annum, respectively. It is important to mention that the increase in temperature is less than the global temperature trends. Similarly, the period 1994–2010 was the hottest period in the study area. This increase in temperature affects genders differently, as females and males have different roles in the context of Somali culture, where females are generally responsible for fetching water for household consumption and transporting milk and other agricultural goods to the nearest cities, making them more exposed to daytime temperatures. With regard to climate change impacts, household respondents reported that crop production such as sorghum, maize, beans, and millet was reduced in the last 30–40 years, as a result of rainfall pattern changes, drought occurrences, increasing temperature, decreased soil moisture, and increasing insects. In relation to the current adaptation practices in the rainfed agriculture community, farmers plant crops that are more tolerant to drought and high temperatures. People are moving away from the agriculture sector to other sectors which are more financially rewarding, such as charcoal production, or migrating to cities to find a job. The Ministry of Environment and Climate Change in Somaliland, together with other ministries such as the Ministry of Agriculture and Livestock, put in place a five-year National Climate Adaptation Plan. Although this plan was approved by Parliament, it is still in the implementation phase. In conclusion, climate change impacts will be felt more at the household level since they are the first ones to experience the consequences of crops failure, heatwaves, and unpredictable rainfall both annual and seasonal, and this will be due to the increasing frequency and severity of droughts, and increasing insects and pest species.

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