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Changes in Rainfall and Temperature and Its Impact on Crop Production in Moyamba District, Southern Sierra Leone

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Abstract

Rainfall and temperature are the important variables that are often used to trace climate variability and change. A Perception study and analysis of climatic data were conducted to assess the changes in rainfall and temperature and their impact on crop production in Moyamba district, Sierra Leone. For the perception study, 400 farmers were randomly selected from Farmer-Based Organizations (FBOs) in 4 chiefdoms and 30 Agricultural Extension Workers (AWEs) in the Moyamba district were purposely selected as respondents. Descriptive statistics and Kendall's test of concordance was used to analyze the data collected from the farmers and AEWs. Data for the analysis of variability and trends of rainfall and temperature from 1991 to 2020 were obtained from the Sierra Leone Meteorological Agency and Njala University and grouped into monthly, seasonal and annual time series. Regression analyses were used to determine the statistical values and trend lines for the seasonal and annual time series data. The Mann-Kendall test and Sen's Slope Estimator were used to analyze the significance and magnitude of the trends respectively. The results of both studies show evidence of climate change in the Moyamba district. A substantial number of farmers and AEWs perceived a decrease in the annual rainfall amount, length of the rainy season, a late start and end of the rainy season, an increase in the temperature during the day and night, and a shortened harmattan period over the last 30 years. Analysis of the meteorological data shows evidence of variability in the seasonal and annual distribution of rainfall and temperature, a decreasing and non-significant trend in the rainy season and annual rainfall and an increasing and significant trend in seasonal and annual temperature from 1991 to

2020. However, the observed changes in rainfall and temperature by the farmers and AEWs partially agree with the results of the analyzed meteorological data. The majority of the farmers perceived that; adverse weather conditions have negatively affected crop production in the district. Droughts, high temperatures, and irregular rainfall are the three major adverse weather events that farmers perceived to have contributed to a substantial loss in the yields of the major crops cultivated in the district. In response to the negative effects of adverse weather events, a substantial number of farmers take no action due to their lack of knowledge, technical or financial capacity to implement climate-sensitive agricultural (CSA) practices. Even though few farmers are practicing some CSA practices on their farms, there is an urgent need to build the capacity of farmers and AEWs to adapt to and mitigate the negative impacts of climate change. The most priority support needed by farmers is the provision of climate-resilient crop varieties whilst the AEWs need training on CSA practices.

Keywords

Climate Change, Rainfall, Temperature, Farmer's Perception, Crop Productivity, Sierra Leone

1. Introduction

Climate change is among the major challenges that need urgent attention in the 21st century. Agriculture is among the largest sectors emitting greenhouse gas (GHGs) in the atmosphere [1]. Rainfall and temperature are the two most important variables in the field of climate sciences and hydrology which are frequently used to trace the extent and magnitude of climate change and variability [2], hence changes in their pattern can affect human health, ecosystems, plants, and animals [3]. Precipitation is a vital part of the hydrologic cycle and changes in its pattern would directly influence the water resources of a given area, thus altering the spatial and temporal distribution of runoff, soil moisture, and groundwater reserve [4]. According to [5], examining the trends of rainfall and temperature is important to understand climate variability and change because both are highly variable spatially and temporarily at different local, regional, and global scales. The local climate in Sierra Leone is tropical with two distinct seasons. The rainy season runs from May to October with an average temperature of 22˚C - 25˚C whilst the dry season is from November to April with temperatures reaching 25˚C - 27˚C, accompanied by dry, cool winds from the Sahara Desert. The rainy season is largely controlled by the movement of the tropical rain belt, Inter-Tropical Convergence Zone (ITCZ), which oscillates between the northern and southern tropics over the course of a year [6].

In Sierra Leone, agricultural production and productivity are dependent on rainfed agriculture. Agriculture is central to food security and rainfall trends and variability are the frequently mentioned factors contributing to food insecurity [7]. Since 1960, there has been evidence of increasing temperature, decreased and unpredictable rainfall, and substantial climatic hazards such as floods, strong winds, and thunderstorms in Sierra Leone [8]. The decreased and unpredictable rainfall has often resulted in seasonal droughts [9] causing the poor establishment of seedlings and wilting of crops at the start and end of the rainy season respectively thus contributing to low crop yields in the country. The increasing temperature has contributed to the insurgence of new pests and diseases in the country [10]. These have threatened the fragile agricultural system [8] posing serious challenges in the struggle to achieve sustainable food production. Other studies have shown that climate change will affect all four dimensions of food security, namely food availability, access to food, stability of food supplies, and food utilization [8]. For farmers to adapt effectively to climate change, they must have correct perceptions about the state of the climate and possible future trends. In practice, farmers take decisions in the context of their environment, and differences may exist between perceived and real environments [9].

In the Moyamba district, farming calendars are closely associated with the timing of the local rainfall, therefore improved forecasts of the onset and termination of the rainy season would be of great benefit to smallholder farmers. Regarding this, trend analysis of climatic variables has received a great deal of consideration from scholars recently. The characterization of the intra-and inter-annual trend of meteorological variables in the context of a changing climate is vital for assessing climate-induced changes that have already occurred and this will be further helpful to make predictions for better preparedness to develop feasible adaptation and mitigation strategies in agriculture [11]. In addition, there is a need to assess the perception and knowledge of farmers and agricultural extension workers on climate change and how it affects crop productivity in the Moyamba district. Several studies on farmers' perception of climate change and its impact on crop production and analysis of rainfall and temperature time series data at different periods of records have been conducted throughout the world [12] [13]. Few trend analysis studies on rainfall have been conducted in Sierra Leone [9] [14]. Studies to detect changes in the variability and trends of rainfall and temperature in the last climatological period (1991 to 2020) alongside the perception and knowledge of farmers and agricultural extension workers deserve urgent attention in light of the impact of climate change on crop production in Moyamba district. Therefore, this study was designed to assess the changes in rainfall and temperature and their impact on crop production in the Moyamba district. The specific objectives were to:

1) Assess the perception of farmers and agricultural extension workers versus meteorological data on changes in rainfall and temperature patterns in the Moyamba district.

2) Assess the perception of farmers on the impact of climate change on crop production and their strategies and needs for climate change adaptation and mitigation in the Moyamba district.

2. Materials and Methods

2.1. Description of the Study Area

The studies were conducted in the Moyamba District. Moyamba district is located in the Southern Province and borders the Atlantic Ocean in the west, Port Loko district and Tonkolili district to the north, Bo district to the east, and Bonthe district to the south. The district is the largest in the Southern Province by geographical area and comprise of fourteen chiefdoms (**Figure 1**).

Agriculture remains the mainstay of the district residents and the largest sector of the economy in the district, providing livelihoods for over 71% of the population. Crops grown in the district include oil palm, cereals (maize, rice, sorghum, and millet) starch food crops (yam, cassava, sweet potato, and cocoa yam), and grain legumes (groundnut and cowpea). In addition, cashew, pepper, ginger, pineapple, and sugarcane are popular farm products in the district. Despite the abundance of land and water resources, the majority of the farmers have smallholdings of 0.5 to 2 hectares, operating as basic subsistence food production units.

2.2. Data Collection Procedure and Analysis

2.2.1. Field Survey on Farmers' and AEWs' Perception and Knowledge of Climate Change and Its Impact on Crop Production

The study was conducted in the Kori, Bagruwa, Fakunya, and Kaiyamba chiefdoms in Moyamba District (**Figure 1**). Kori and Bagruwa are the chiefdoms implementing a 20-month (March 2021 to November 2022) project titled

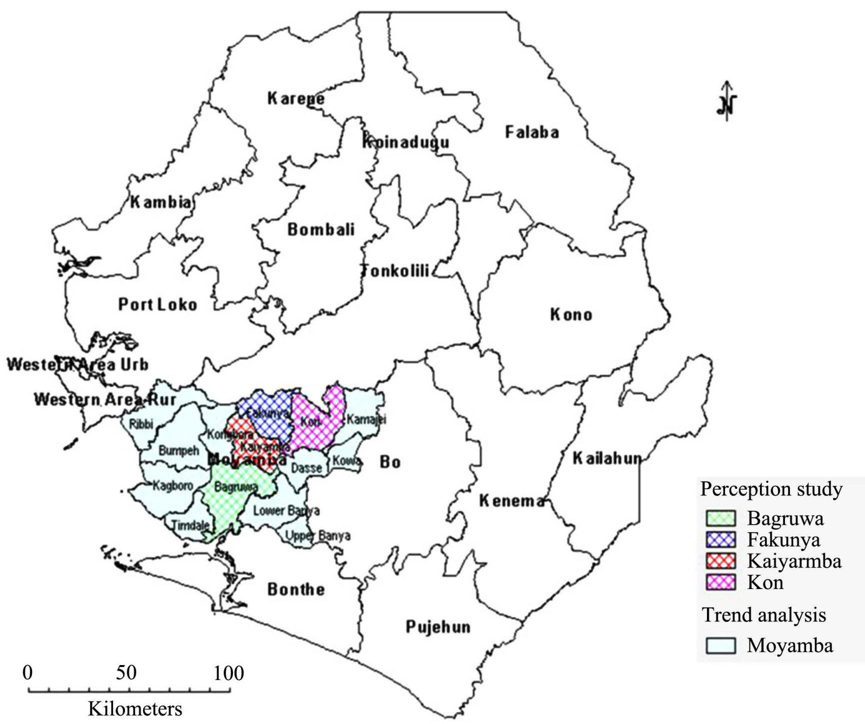

Figure 1. Map of Sierra Leone showing the study areas.

"Sustainable Land Management for Climate Change Adaptation and Mitigation". The project is implemented by Action against Hunger in partnership with the Sierra Leone Agricultural Research Institute. Fakunya, and Kaiyamba chiefdoms are adjacent to these chiefdoms.

Population, sampling procedure, and sample size

The target populations for the study were AEWs of the Ministry of Agriculture in the Moyamba district and farmers from FBOs in Kori Bagruwa, Kayamba, and Fakunya chiefdoms. A total of thirty (30) of AEWs were purposively selected for personal interviews. Multi-stage random sampling was used to select FBOs in the first stage and farmers for the personal interviews in the second stage. Cochran's formula for the infinite population [15] was used to determine the sample size of 400 farmers at a response rate of 96% (100 respondents per chiefdom).

$$n = \frac{Z^2 * (p)(q)}{d^2} \tag{1}$$

where: n is the sample size, Z is the value for the selected alpha level, (1.96 at 95 percent confidence level). p is the estimated proportion of an attribute that is present in the population (0.5). q is $1 - p$ (0.5). (p) (q) was the estimate of variance. d is the acceptable margin of error for the proportion being estimated (0.05).

Data collection.

Desk reviews were used to collect secondary data. Computer-Assisted Personal Interview (CAPI) was used to collect primary data from the sampled farmers and AEWs using a structured questionnaire. Digital forms of the questionnaire were prepared in CSPro 7.5 and were uploaded on the CSEntry app on android tablets for data collection.

Data analysis

Statistical Package for Social Sciences (SPSS) software was used to analyze the data. Descriptive statistics (frequencies and means) were used to analyze the quantitative variables collected from the personal interviews. Kendall's test of concordance was used to determine the degree of agreement of the farmers and MAF AEWs in ranking their needs for climate change adaptation and mitigation. Microsoft Excel 2019 was used to prepare the tables and figures after analysis.

2.2.2. Analysis of Trends in the Monthly, Seasonal and Annual Rainfall and Temperature Patterns

Acquisition of rainfall and temperature data

For a variety of reasons, reliable long-term rainfall and temperature records of gauged data for Moyamba district for the climatology period of 1991 to 2020 are unavailable. Data on meteorological variables (rainfall and temperature) for the analysis of variability and trends of rainfall and temperature were obtained from the Sierra Leone Meteorological Agency (satellite data from AgriMet station) and Njala University (biased corrected historical rainfall and temperature time-series data which was generated from the Soil & Water Assessment Tool Climate Change Model) [16]. Quality control of the available time-series data was done to identify errors in data sets that may introduce non-climatic shifts in climate time series which have the potential to affect the quality of data and the results of the climatic trends. Correlation analysis was performed on the time series to check for a statistically significant correlation between the annual time series data before selecting the data source for combination.

Data analysis

The rainfall and mean temperature data were grouped into monthly, seasonal, and annual time series before analysis. The seasonal time series data were grouped into two seasons, namely the dry season (November to April) and the rainy season (May to October).

Linear relationship between year and climatic variables

Regression analysis was used to determine the linear relationship between year and climatic variables (rainfall and temperature). Microsoft Excel 21 was used to determine the statistical values and trend lines of the linear regression analysis. The regression equation is one of the simplest methods to determine the relationship of time series data. The slope of regression describes the trend whether positive or negative. In this study, the dependent variables were rainfall and temperature and the independent variable was the year. Linear regression requires the assumption of normal distribution. In this case, the null hypothesis is that the slope of the line is zero or there is no trend in the data. The equation of the linear regression line was calculated as follows:

$$y = a + bx \tag{2}$$

where x is the independent variable and it is plotted along the x-axis, y is the dependent variable and it is plotted along the y-axis, b is the slope line and a is the intercept (value of y when $x = 0$).

Significance and magnitude of the trend

The Mann-Kendall test was used to determine the significance and magnitude of the rainfall and temperature trends for the different time series using the Data Analysis Tool of Real Statistic (XRealStats). A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and nonparametric procedures. The Mann-Kendall test is a non-parametric approach that has been widely used for the detection of trends in different fields of research including hydrology and climatology [17]. Each data value is compared to all subsequent data values. The initial value, S, is assumed to be 0 (no trend). If a data value from a later period is higher than a data value from an earlier period, S is incremented by 1. If the data value from a later period is lower than a data value from an earlier period, S is decremented by 1. The net result of all such increments and decrements yields the final value of S. The Mann-Kendall statistic (S) was calculated as follows:

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\operatorname{sgn}\left(x_j-x_i\right) \tag{3}$$

where n is the number of data points, x_j and x_i are the data value in time series i and j ($j > i$), respectively and $\operatorname{sgn}(x_j - x_i)$ is the sign function and is calculated as:

$$\operatorname{sgn}\left(x_j-x_i\right)=\begin{cases}+1, & \text{if } \operatorname{sgn}\left(x_j-x_i\right)>0\\ 0, & \text{if } \operatorname{sgn}\left(x_j-x_i\right)=0\\ -1, & \text{if } \operatorname{sgn}\left(x_j-x_i\right)<0\end{cases} \tag{4}$$

A very positive value of S is an indicator of an increasing trend, and a negative value indicates a decreasing trend.

Since the sample size was large ($N > 10$), the test was conducted using a normal distribution, with the mean and the variance calculated as follows:

$$E\left[S\right]=0 \tag{5}$$

$$\operatorname{var}\left(S\right)=\frac{N\left(N-1\right)\left(2N+5\right)-\sum_{k=1}^{n}t_k\left(t_k-1\right)\left(2t_k+5\right)}{18} \tag{6}$$

where N is the number of tied (zero difference between compared values) groups, t_k is the number of data points in the kth tied group.

The standard normal deviate (Z-statistics) was then computed according to the formula [18] as follows:

$$Z=\begin{cases}\dfrac{S-1}{\sqrt{\operatorname{var}\left(S\right)}} & \text{if } S>0\\ 0 & \text{if } S=0\\ \dfrac{S-1}{\sqrt{\operatorname{var}\left(S\right)}} & \text{if } S<0\end{cases} \tag{7}$$

The presence of a statistical trend was evaluated using the Z value. A positive and negative value of the Z statistics indicates an upward and downward trend respectively. The Z statistic has a normal distribution to test for either upward or downward trend at the α level of significance (usually 5% with $Z_{0.025} = 1.96$), a Z value that is greater than 1.96 indicates a significant trend in the time series data. The probability value (p-value) from the two-tailed test using the Z value also can be used to test the significant trend. When the p-value is greater than α (0.05), it shows that there is no trend in the time series data.

Sen's slope estimator (β) was used to predict the magnitude of the trend. It is a non-parametric and robust estimate for quantifying monotonic trends in hydrologic time series [19]. A positive value of β connotes an "upward trend"; and a negative value for a "downward trend" [19]. The Sen's slope estimator was calculated as follows:

$$\beta=median\left(\frac{x_i-x_j}{j-i}\right) \tag{8}$$

where β is the slope between data points x_i and x_j, x_i is the data measurement at the time i, x_j is the data measurement at time j; and j is the time after time i.

3. Results and Discussion

3.1. Farmers' and AEWs' Perception and Knowledge versus Climatic Data on Changes in Rainfall and Temperature Patterns in the Moyamba District

3.1.1. Socioeconomic Characteristics of Farmers and AEWs

Table 1 presents the results of the socio-economic characteristics of the farmers interviewed. The results show that 67.8% of the farmers interviewed were males whilst 32.2% were females. The majority of the farmers (53.8%) did not attend any formal schooling. The low level of education indicates that the farmers interviewed may not likely have access to diversified information sources from print and electronic media that enable them to have a better perception of climate change and its impact on crop production. Similar results of low educational levels have been reported in previous perception studies with farmers in Nigeria [20]. The average age of respondents was 49 years indicating that the farmers interviewed have wealth of experience in the changes that occurred in climatic variables and their impacts on crop production during the last 30 years. Parallel studies have also reported that the respondents interviewed are middle-aged and old farmers [21]. The average household size of the farmers was 8 with more females than males except in the Bagruwa chiefdom. Ninety-two percent (92%) of the farmers depend on agriculture-related activities as their main source of household income. Sixty-five percent (65%) of the farmers owned the land they cultivated indicating access to land for farming is not a major challenge among farmers in the study area. Moreover, 85%, 77%, and 56% of farmers cultivate rice, cassava, and groundnut as their major crops.

Table 2 presents the results of the socioeconomic characteristics of the agricultural extension workers (AEWs) of the Ministry of Agriculture in the Moyamba district. The results show that 83.3% of the MAF Extension Workers interviewed were males whilst 16.6% were females. The educational level of the MAF Extension Worker was low. 70% of them had a certificate in Agriculture whilst 30% had diplomas and degrees in Agriculture related disciplines. 66.7% of them claimed they visit farmers at least once a week to provide them with extension service support. 40.4% of the MAF Extension Workers provided training as extension support, 31.0% of them provided agricultural inputs and 28.6% of them provided extension messages as support to farmers. For effective service delivery, the main challenge faced by 58.7% of the MAF extension Workers was lack of mobility, whilst 23.9% of them were challenged by lack of incentives and 17.4% by poor road network.

3.1.2. Changes in Rainfall in Moyamba District: Perception of Farmers and AEWs versus Climatic Data

Perception of farmers and AEWS of MAF on changes in rainfall

The results of the perception of farmers and AEWs showed that 92.8% of farmers and 100.0% of AEWs interviewed professed changes in rainfall in the Moyamba district over the last 30 years. Figure 2 presents the perception of

Table 1. Socioeconomic characteristics of the farmers interviewed.

Profile of the farmers	Chiefdoms				Pooled (n = 400)
	Fakunya (n = 100)	Kori (n = 100)	Bagruwa (n = 100)	Kaiyamba (n = 100)	
Gender					
Male (%)	74.0	68.0	64.0	65.0	67.8
Female (%)	26.0	32.0	36.0	35.0	32.2
Total	100.0	100.0	100.0	100.0	100.0
Age (average)	50.0	47.0	48.0	50.0	49.0
Educational Level					
None (%)	45.0	45.0	68.0	57.0	53.8
Primary (%)	27.0	26.0	16.0	18.0	21.8
Secondary (%)	20.0	28.0	13.0	21.0	20.4
Technical/ Vocational (%)	2.0	0.0	2.0	0.0	1.0
University (%)	6.0	1.0	1.0	4.0	3.0
Total	100.0	100.0	100.0	100.0	100.0
Household size (Average)					
Males	4.3	3.3	4.3	3.4	3.8
Females	4.9	3.9	4.2	3.8	4.2
Total	9.2	7.2	8.5	7.2	8.0
Major source of income (%)					
Remittances	1.0	3.0	1.0	1.0	1.5
Non-agricultural activities	10.0	11.0	3.0	2.0	6.5
Agricultural activities	89.0	86.0	96.0	97.0	92.0
Total	100.0	100.0	100.0	100.0	100.0
Access to land (%)					
Owned	73.0	79.0	50.0	58.0	65.0
Gift	4.0	5.0	3.0	1.0	3.2
Rent	23.0	16.0	45.0	41.0	31.3
Lease	0.0	0.0	2.0	0.0	0.5
Total	100.0	100.0	100.0	100.0	100.0
Crops cultivated (%)					
Cassava	32.1	23.5	32.6	29.2	29.7
Rice	32.9	32.3	31.9	34.2	32.9
Groundnut	25.0	24.9	20.4	16.5	21.4
Pineapple	0.4	7.8	0.0	0.4	1.8

Continued

Pepper	3.6	4.1	6.0	11.3	6.5
Potato	2.8	1.8	1.8	1.1	1.8
Yam	1.6	2.3	1.8	3.9	2.4
Cowpea	0.8	1.4	5.3	3.5	2.9
Pigeon Pea	0.8	1.8	0.4	0.0	0.7
Total	100.0	100.0	100.0	100.0	100.0

Table 2. Socio-economic characteristics of AEWs of the ministry of agriculture.

Profile of Extension Workers	Frequency	Percent
Gender		
Male	25	83.3
Female	5	16.6
Total	30	100.0
Educational Qualification		
Certificate	21	70.0
Ordinary diploma	3	10.0
Higher Diploma	4	13.3
Master's degree	2	6.7
Total	30	100.0
Frequency of extension visits		
Once a Week	20	66.7
Once Every Month	5	16.7
Twice Every Month	5	16.7
Total	30	100.0
Type of support provided		
Extension messages	12	28.6
Agricultural inputs	13	31.0
Training	17	40.4
Total	42	100.0
Major challenges		
Lack of mobility	27	58.7
Poor road network	8	17.4
Lack of incentives	11	23.9
Total	46	100.0

Continued

Received training on climate change		
Yes	27	90.0
No	3	10.0
Total	30	100.0
If yes, who provided the training		
Don't Remember	3	10.0
NGO	9	30.0
Government Agricultural Extension	2	6.7
Research Institute	13	43.3
Educational Institutions	3	10.0
Total	30	100.0

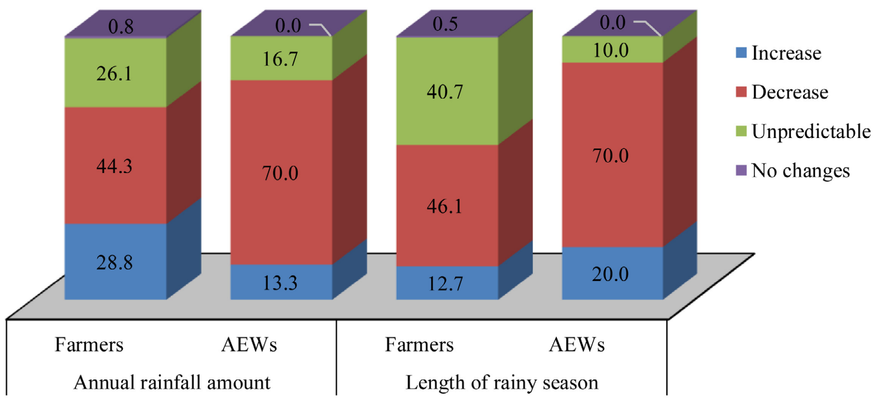

Figure 2. Percentage of respondents who observed changes in the annual rainfall amount and length of the rainy season.

farmers and AEWS on the annual rainfall amount and length of the rainy season. Among the farmers who perceived changes in rainfall, 44.3% of them perceived a decrease in the annual rainfall amount, 28.8% perceived an increase, 26.1% perceived an unpredictable rainfall whilst 0.8% observed no change in the annual rainfall amount. Considering the length of the rainy season, 46.1% of the farmers perceived a decrease in the length of the rainy season, 40.7% perceived unpredictable, 12.7% perceived an increase, and 0.5% perceived no change in the length of the rainy season. In contrast, the majority (70.0%) of the AEWs interviewed perceived a decrease in the annual rainfall amount and a decrease in the length of the rainy season during the last 30 years.

Figure 3 presents the results of the perception of farmers and AEWs at the start and end of the rainy season. The results show that 43.9% of the farmers perceived a late, 29.9% perceived an unpredictable, 25.6% perceived an early, and 0.5% perceived no changes in rainfall at the start of the rainy season, whilst 46.6% perceived a late, 39.4% perceived an unpredictable, 13.5% perceived an

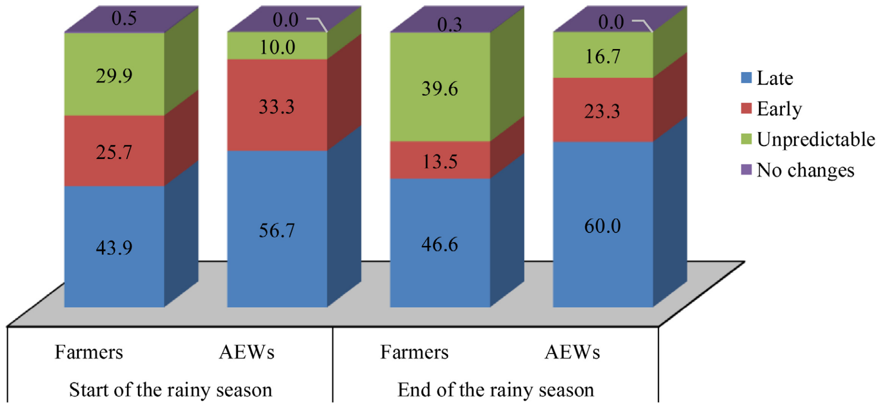

Figure 3. Percentage of respondents who observed changes in the rainfall events at the start and end of the rainy season.

early, and 0.3% perceived no changes in rainfall at the end of the rainy season. In contrast with the perception of farmers on changes in rainfall, the majority 56.7% of the AEWs perceived a late start (56.7%) and an early end (60.0%) of the rainy season.

Rainfall distribution trends from 1991 to 2020 in Moyamba district

Linear relationship between year and rainfall

Figure 4 presents the results of the linear relationship between year and rainfall distribution in the Moyamba district from 1991 to 2020. The results show variability in rainfall distribution and decreasing trend lines for the rainy season and annual rainfall from 1991 to 2020 in the Moyamba district. The R-squared (R^2) statistic of the regression models accounts for 0.27%, 2.29%, and 1.94% of the variation in the dry season, rainy season, and annual rainfall distribution respectively. The low R^2 values indicate a very weak relationship between rainfall and year meaning the regression model accounts for less of the variance in the rainfall distribution and that the data points of the rainfall distribution are widely dispersed around the regression line.

Significance and magnitude of the trend

Table 3 presents the results of the Mann-Kendall test for the monthly, seasonal and annual time series for rainfall in the Moyamba district from 1991 to 2020. At a 95% confidence limit, the results showed positive values of the MK-Stat and Z-stat for the months of June, October, and November and the dry season time series which indicates an upward trend in the rainfall. In contrast, the values of the MK-Stat and Z-stat for the other months, rainy season, and annual time series were negative which indicates a downward trend in rainfall for the remaining months, the rainy season, and seasonal and annual time series. However, the upward and downward trends in rainfall for the monthly, seasonal and annual time series were not significant ($p > 0.05$). The results of the Sen's slope estimator showed that the magnitude of the rainfall trend in May which is the usual month for the start of the rainy season decreased by 29.87% indicating the occurrence of few and intermittent rainfall events which may cause seasonal droughts at the start of the planting season in May. Consequently, the planting

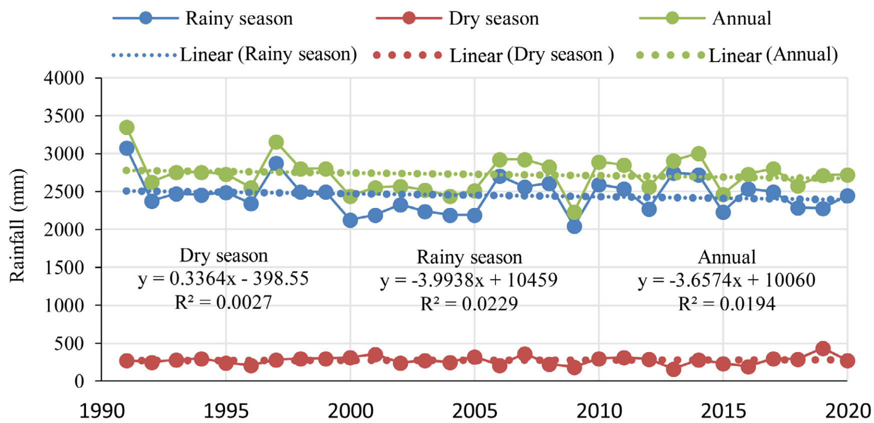

Figure 4. Linear relationship between year and rainfall for the seasonal and annual rainfall distribution in the Moyamba district from 1991 to 2020.

Table 3. Significance and magnitude of rainfall trend for the monthly, seasonal, and annual time series in the Moyamba district from 1991 to 2020.

Period	Mann-Kendall Test				Sen's Slope Estimator		
	MK-stat	z-stat	p-value	Trend	Slope	Lower	Upper
Monthly							
January	−4	−0.0536	0.9572	no	0.0000	−0.1270	0.1613
February	−42	−0.7319	0.4642	no	−0.0685	−0.4763	0.1218
March	−81	−1.4273	0.1535	no	−0.4765	−1.3370	0.1402
April	−60	−1.0528	0.2924	no	−1.0023	−2.6406	0.6910
May	−24	−0.4106	0.6814	no	−0.2987	−2.8548	1.6302
June	48	0.8390	0.4015	no	1.0505	−1.6616	3.5510
July	−3	−0.0357	0.9715	no	−0.0442	−5.0038	4.4783
August	−16	−0.2678	0.7889	no	−0.6002	−7.4218	4.1165
September	−22	−0.3747	0.7079	no	−0.4714	−2.8660	1.7495
October	36	0.6245	0.5323	no	0.6759	−1.2951	2.7586
November	94	1.6602	0.0969	no	0.8911	−0.0672	2.9083
December	−10	−0.1606	0.8724	no	−0.0126	−0.4881	0.4084
Seasonal							
Rainy	−17	−0.2855	0.7753	no	−2.1274	−15.3925	7.1414
Dry	9	0.1427	0.8865	no	0.1245	−2.2904	2.4377
Annual	−17	−0.2855	0.7753	no	−1.2853	−14.8620	8.0543

Note: Negative and positive MK-Test, z-test and Sen's slope figures denote a decreasing and increasing trend respectively. A Z-stat figure of less than 1.96 and p-values greater than 0.05 indicate a non-significant trend at a 95% confidence limit.

time for crops that are susceptible to drought spells at the early vegetative growth stage has gradually been shifted to June to ensure the good establishment of crops in the field [9]. In Sierra Leone, the planting period in the first cropping season is May-June. The amount and frequency of rainfall during this period are critical for farmers, especially if they want to plant early at the start of the rainy season. Due to the erratic rainfall during this period, farmers are faced with the risk of a dry period which may cause poor germination and dying of seedlings. Therefore, farmers need to plant at different dates as a coping strategy to adapt to the erratic pattern of rainfall [22]. The magnitude of the rainfall trend for the months of October which marks the end of the rainy season and November which marks the start of the dry season increased by 67.59% and 89.11% respectively. The result shows that the occurrence and intensity of rainfall events during these months were relatively high and may cause a reduction in the quality of the harvest for crops that require relatively drier periods at maturity. Thus, the start and end of the rainy season have gradually shifted to June and November. These results are in agreement with the findings of the perception of farmers and AEWs who considerably observed a late and unpredictable start of the rainy season and a late and unpredictable end of the rainy season. Even though the length of the rainy season has not changed which contradicts the perception of most of the farmers and AEWs, the magnitude of the rainfall trend for the rainy season decreased by 212.74% indicating lower intensity and rainfall events which could be attributed to the decrease in rainfall trends for the months of May, July, August, and September. If the identified trends continue and amplify, then cultivating twice in the rainy season a 90 days crop might become risky due to possible reduced rainfall and dry spells in the mentioned months. Consequently, only crops with maturity periods which are lesser than 3 months can be cultivated twice during the rainy season to avoid seasonal droughts. The magnitude of the annual rainfall trend decreased by 128.53% indicating the occurrence of seasonal drought spells during the cropping season and drier years in the coming years. This result agrees with the findings of the perception of farmers and AEWs which shows a considerable number of farmers and AEWs observed a decrease in the rainfall amounts during the rainy season. Previous studies in Sierra Leone have shown a decline in early seasonal rainfall and total rainfall amount in the country [9].

3.1.3. Changes in Temperature in Moyamba District: Perception of Farmers and AEWs versus Climatic Data

Perception of farmers and AEWs on changes in temperature

The results of the study show that 94.0% and 100.0% of the farmers and AEWs interviewed respectively perceived changes in the local temperature in the Moyamba district over the last 30 years. **Figure 5** presents the results of the perception of farmers and AEWs on the changes in the local temperature during the day and night. Among those who perceived changes in the local temperature 49.7% of them perceived an increase, 30.3% perceived a decrease, 19.4% perceived an unpredictable change, and 0.5% can't tell if there is a change in the

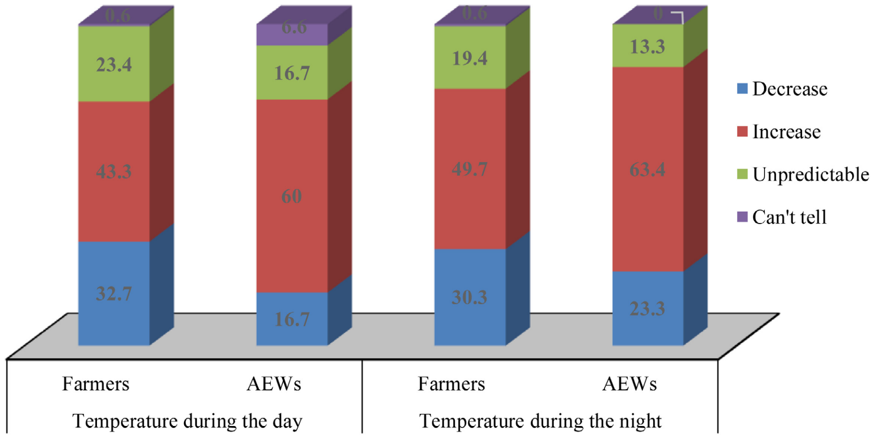

Figure 5. Percentage of respondents who observed changes in local temperature during the day and night.

local temperature during the night. Considering the local temperature during the day, 43.3% of the farmers perceived an increase, 32.7% perceived a decrease, 23.4% perceived an unpredictable, and 0.5% of them can't tell whether the local temperature has changed during the day. In contrast, the majority of AEWs perceived an increase in the local temperature during the day (60.0%) and night (63.3%). In confirmation, increasing temperatures since 1960 in Sierra Leone have been reported in the UNDP Climate Change Country Profile for Sierra Leone [8].

Figure 6 presents the results of the perception of farmers and AEWs on changes in the harmattan period during the last 30 years. The results show that 57.4% of the farmers observed a shortened, 31.6% observed a milder, 8.2%, observed no changes, 1.3% observed a prolonged, 1.1% observed a harsher, and 0.3% can't tell the changes in the harmattan period. Similarly, 53.3% of the AEWs observed a shortened harmattan period whilst 20.0% observed a prolonged one, 16.7% observed a milder and 10.0% can't tell whether the harmattan period has changed.

Temperature trends from 1991 to 2020 in Moyamba district

Linear relationship between year and temperature

Figure 7 presents the results of the linear relationship between year and temperature distribution in the Moyamba district from 1991 to 2020. The results show a long-term fluctuation in the seasonal and annual distribution of mean temperature. The R-squared (R^2) statistic shows that the regression model accounted for 11.9%, 20.03%, and 16.79% of the variation in the dry season, rainy season, and annual mean temperature distribution respectively. The low R^2 values indicate a weak relationship between the mean temperature and year meaning the regression model accounts for less of the variance in the mean temperature and the data points of the mean temperature are widely dispersed around the regression line. The linear trend lines showed an upward trend in the rainy season, dry season, and annual mean temperature distribution. Temperature increase in Sierra Leone could be associated with the decreasing annual rainfall

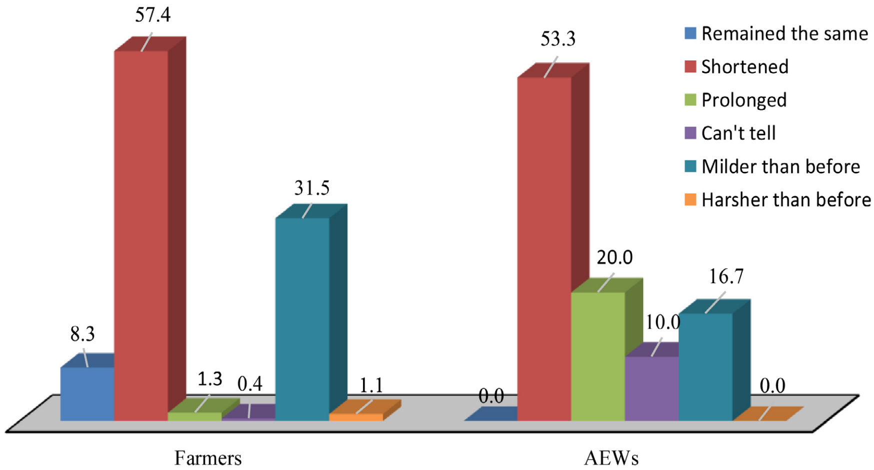

Figure 6. Percentage of respondents who observed changes during the harmattan period.

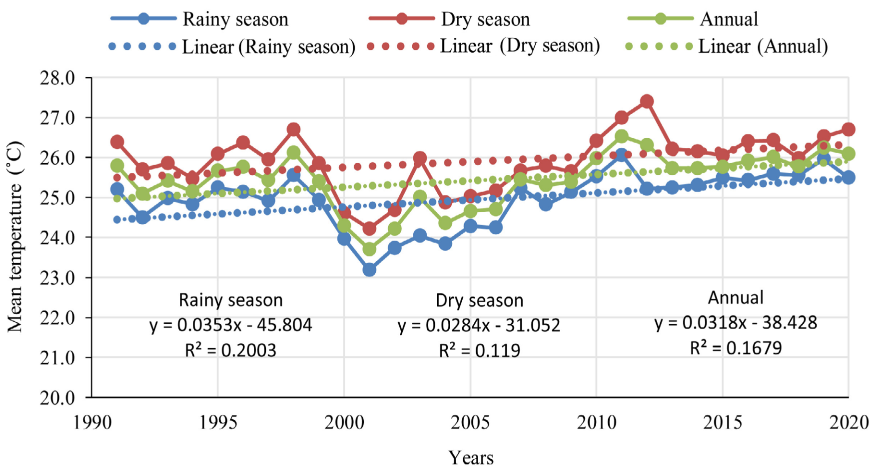

Figure 7. Linear relationship between year and rainfall for the seasonal and annual mean temperature in the Moyamba district from 1991 to 2020.

phenomenon which is related to the variation in precipitation concentration intensity due to the interaction between the laden northeast and south-eastern winds [13]. High temperatures in recent times have also been reported to cause the insurgence of new insect pests and a high incidence of existing insect pests which are severely reducing crop yields to insect damage [10].

Significance and magnitude of the trend

Table 4 presents the results of the Mann-Kendall test for the monthly, seasonal and annual time series for temperature in the Moyamba district from 1991 to 2020. At a 95% confidence limit, the results showed positive values of the MK-Stat and Z-stat for the monthly, seasonal, and annual temperature time series which indicates an upward trend in the mean temperature. However, the trend for the mean temperature was only significant ($p < 0.05$) for the months of May, July, August, September, October, and November, the rainy and dry season, and the annual time series, The result of an upward trend in the mean temperature is in agreement with the findings of the perception of farmers and

Table 4. Significance and magnitude of mean temperature trend for the monthly, seasonal, and annual time series in the Moyamba district from 1991 to 2020.

Period	Mann Kendall Stat				Sen's Slope estimator		
	MK-stat	z-stat	p-value	Trend	Slope	Lower	Upper
Monthly							
January	45	0.7850	0.4325	no	0.0163	−0.0147	0.0566
February	75	1.3202	0.1868	no	0.0160	−0.0150	0.0447
March	57	0.9991	0.3177	no	0.0346	−0.0329	0.1238
April	101	1.7841	0.0744	no	0.0382	−0.0061	0.1352
May	121	2.1409	0.0323	yes	0.0509	0.0031	0.1088
June	107	1.8911	0.0586	no	0.0262	−0.0014	0.0663
July	143	2.5334	0.0113	yes	0.0272	0.0043	0.0601
August	167	2.9616	0.0031	yes	0.0293	0.0091	0.0639
September	181	3.2114	0.0013	yes	0.0296	0.0129	0.0541
October	201	3.5682	0.0004	yes	0.0358	0.0162	0.0599
November	157	2.7832	0.0054	yes	0.0289	0.0072	0.0507
December	81	1.4273	0.1535	no	0.0359	−0.0111	0.0686
Seasonal							
Rainy season	173	3.0687	0.0022	yes	0.0357	0.0135	0.0659
Dry season	131	2.3193	0.0204	yes	0.0296	0.0024	0.0736
Annual	151	2.6762	0.0074	yes	0.0318	0.0096	0.0662

Note: Negative and positive MK-Test, z-test and Sen's slope figures denote a decreasing and increasing trend respectively. A Z-stat figure of less than 1.96 and p-values greater than 0.05 indicate a non-significant trend at a 95% confidence limit.

AEWs on the changes in the local temperature in Moyamba district as a considerable number of the farmers and AEWs observed an increase in the local temperature during the night and day. The results of Sen's slope estimator showed that the trend of the rainy season, dry season, and annual mean temperature increased by 3.57%, 2.96%, and 3.18% respectively. The significant and upward trends of the seasonal and annual temperature in the country are a cause for concern as we will be expecting hotter years in the future which may be conducive to the insurgence of new pests and an increase in the incidence of pests that may considerably reduce crop yields [10]. Regarding the harmattan period, the trend of mean temperature during the harmattan months of November, December, January, and February also increased by 2.89%, 3.59%, 1.63%, and 1.60% respectively indicating a milder harmattan period. This result is in agreement with the perception of a substantial number of farmers and AEWs who observed a milder harmattan period in the district.

3.2. Perception of Farmers on the Impact of Climate Change on Crop Production and Their Strategies and Needs for Climate Change Adaptation and Mitigation

3.2.1. Climate Change Impact on Crop Production

Table 5 presents the results of the negative effects of extreme weather events on crop production in the Moyamba district. The results show that 84.8% of the farmers interviewed revealed that, adverse weather events have affected the major crops they cultivate. Among the crops mentioned by the farmers, rice (37.6%), followed by cassava (19.5%), and groundnut (24.2%) were the three main crops seriously affected by adverse weather events. Sweet potato (1.4%), maize (5.6%), yam (1.5%), pepper (7.4%), cowpea (1.4%), and pineapple (0.7%) were less affected by the negative effect of adverse weather conditions.

Figure 8 presents the results of the perception of farmers on the adverse weather events that affect crop production in the Moyamba district. The results show that 48.1% of their crops were affected by drought, 24.5% by high temperature, 12.2% by irregular rainfall, 9.0% by flooding, 3.9% by erosion, 1.1% by storms/strong winds, and 1.1% by low temperatures. The results of previous studies have shown that increased temperature, and uneven and off-season rainfall leading to drought occurrences are the key negative impact of climate change on crop production [23].

Table 5. Perception of the negative effect of extreme weather events on crop production in the Moyamba district.

Negative effects of extreme weather events on crop production	Frequency	Percent
Extreme weather events affected HH crop production		
Yes	339	84.8
No	61	15.2
Total	400	100.0
Type of crops affected by extreme weather events		
Rice	270	37.9
Cassava	140	19.6
Groundnut	174	24.4
Sweet Potato	10	1.4
Maize	40	5.6
Yam	11	1.5
Pepper	53	7.4
Cowpea	10	1.4
Pineapple	5	0.7
Total	713	100.0

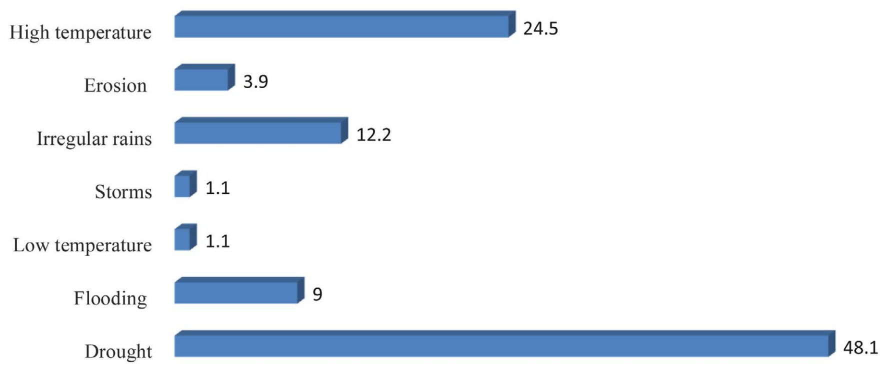

Figure 8. Extreme weather events that caused a reduction in crop yields (%).

Figure 9 presents the results of the estimated yield loss caused by extreme weather events in the Moyamba district. The magnitude of yield loss was estimated under three categories (above 60%, 40% - 60%, and below 40%). The results show that the great majority (73.5%) of the interviewed farmers are estimated to have been experiencing more than 40% of yield loss due to extreme weather events. The high yield loss due to adverse weather events may have negative consequences on household food production in the district.

3.2.2. Farmer's Coping Strategies in Response to Adverse Weather Events

Figure 10 presents the results of the coping strategies of farmers in response to adverse weather events. The results show that among the 339 farmers who experience adverse weather events, 41.9% of them do not take any action whilst 33.0% of the farmers change their crop production activities, 15.3% shift from on-farm to off-farm work, 3.5% use savings or borrow money, 3.5% reduce expenses at home and 2.7% sold household assets to get money in response to the negative effects of adverse weather events. Farmer's strategy in response to adverse weather events has been reported in previous studies [23]. Among the farmers who changed their crop production practices, 67.0% of them incurred an additional expenditure of SLL 879,640 (€73.32) ranging from SLL 250,000 (€20.84) to SLL 2,000,000 (€166.70).

3.2.3. Farmers' Knowledge and Use of Climate-Sensitive Agricultural Practices

Figure 11 presents the results of the farmer's knowledge and use of climate-sensitive agricultural practices in the Moyamba district. The results show that a greater majority (77.5%) of the farmers interviewed know CSA practices whilst 22.5% do not know CSA practices. Among the farmers who know CSA practices, 34.8% of them are currently using CSA practices on their farms whilst 65.2% of them are not using CSA practices on their farms which can be attributed to their lack of technical and or financial capability to implement the CSA on their farms.

Figure 12 presents the results of the type of CSA practices currently used by farmers in the Moyamba district. Among the farmers currently using CSA practices

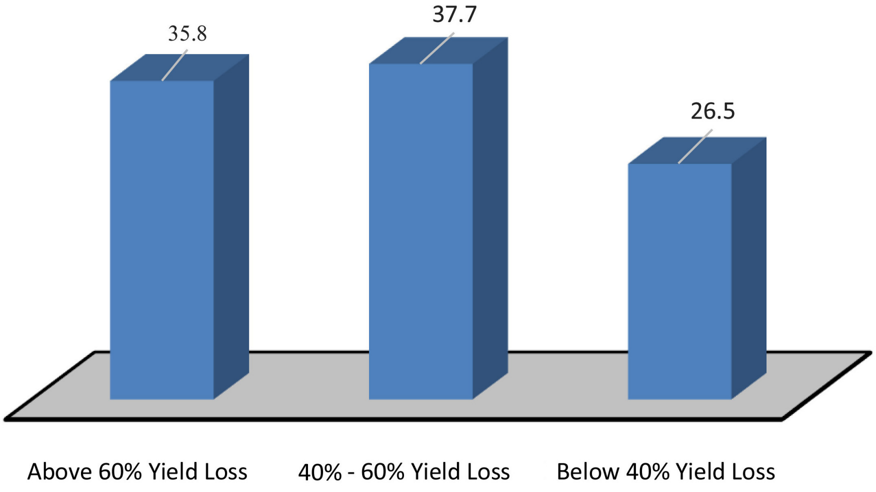

Figure 9. Percent estimation of reduction in crops yields caused by extreme weather events.

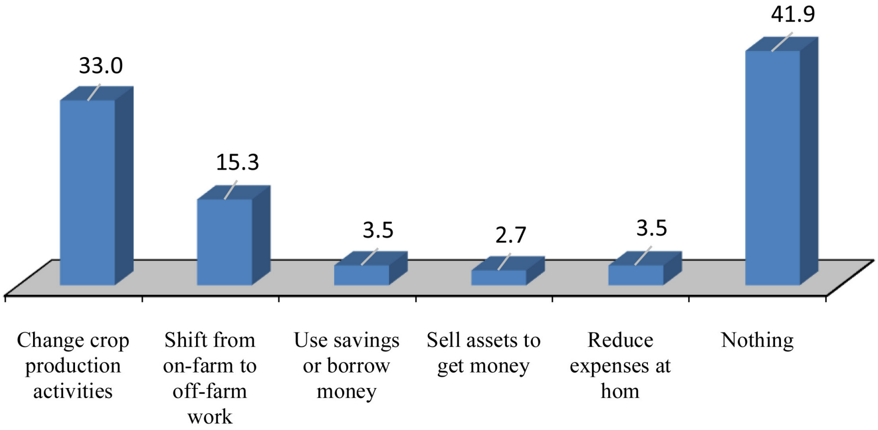

Figure 10. Percentage of the coping strategies of farmers in response to extreme weather events.

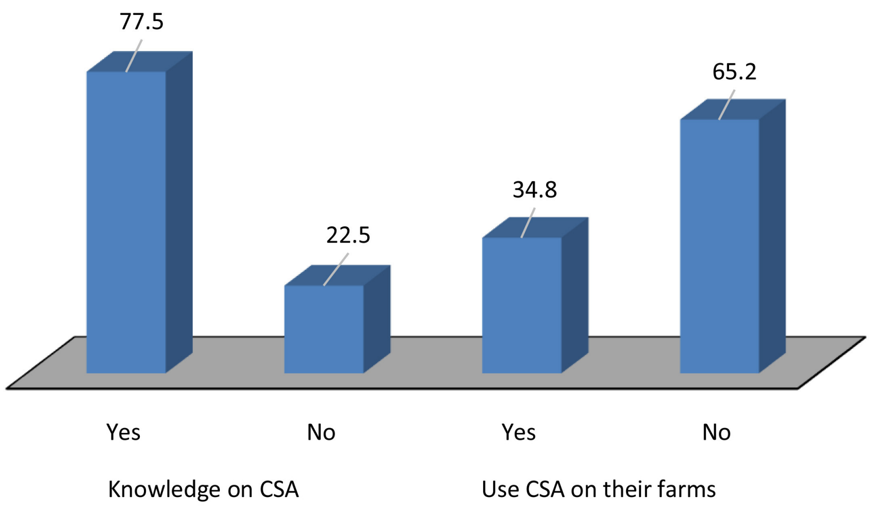

Figure 11. Percentage of farmers who have the knowledge and use climate-sensitive agriculture on their farms.

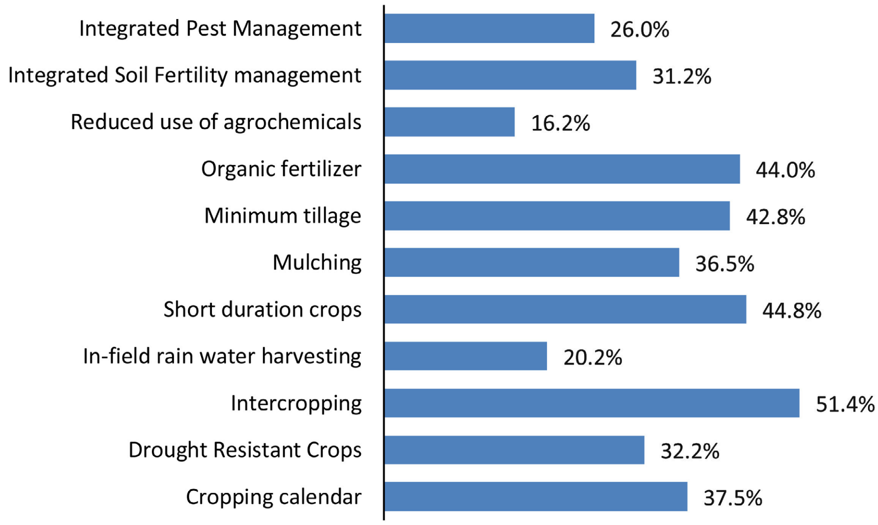

Figure 12. Type of CSA practices currently used by farmers in the Moyamba district.

on their farms, the majority of them (51.4%) are practicing intercropping. Results from previous studies have shown that farmers practice intercropping as a climate change adaptation strategy to increase production and land use efficiency [24] and crop diversification [25]. Besides intercropping, 44.8% of farmers are also currently planting short-duration crops, 44.0% of them use organic fertilizer, 42.8% of them practice minimum tillage, and 37.5% of them adapt their cropping calendar to prevailing weather conditions. Results from previous research studies have shown that farmers need to plant at different dates as a coping strategy to adapt to the erratic pattern of rainfall, and in cases where their crops repeatedly failed, they need to replant their fields many times depending on the commonly forecast weather indicators [26] and the use of weed residues to replenish soil fertility through minimum soil tillage practices and reduces surface runoff and erosion [27]. In addition, 32.2% of the farmers are using/planting drought-resistant crops, 20.2% practicing in-field rainwater harvesting, 36.5% are practicing mulching, 16.2% are practicing reduced rates of the application of agrochemicals, 26.0% practice integrated pest management (IPM) and 31.2% practice integrated soil fertility management.

3.2.4. Ranking of Capacity Building Needs of Farmers and AEWs of MAF for Climate Change Adaptation and Mitigation

Table 6 presents the results of the Kendall test of concordance in ranking the capacity-building needs of farmers and AEWs for climate change adaptation and mitigation in the Moyamba district. The results show that Kendall's concordance (Kendall's W) indicates a weak degree of agreement among the farmers (0.144) and AEWs of MAF Extension Workers (0.245) in the ranking of their capacity-building needs for climate change adaptation and mitigation at 1% probability level in the study area meaning the ranking of the capacity building needs among the farmers and the AEWs of MAF was however inconsistent. Access to climate-resilient crop varieties was ranked 1st, training on CSA practices was

Table 6. Kendall test of concordance in the ranking of the capacity-building needs of farmers and AEWs for climate change adaptation and mitigation in the Moyamba district.

Adaptation and mitigation needs	Farmers		AEWs	
	Mean Rank	Ranks	Mean Rank	Ranks
Climate-resilient crop varieties	1.76	1	1.90	2
Training on CSA Practices	1.81	2	1.57	1
Access to Meteorological Information	2.44	3	2.53	3
Kendall's W	0.144		0.245	
Chi-Square	115.395		14.712	
Asymp. Sig.	<0.0001		0.0001	

ranked 2nd and access to meteorological Information was ranked 3rd by the farmers whilst training on CSA practices was ranked 1st, access to climate-resilient crop varieties was ranked 2nd, and access to meteorological information was ranked 3rd by the AEWs of MAF. Previous studies have identified numerous ways in which governments, agricultural research centers, and other institutions could help smallholder farmers adapt to climate change, among these needs are the provision of climate-resilient crop varieties and training on CSA [28]. However, the climate change adaptation and mitigation needs of farmers differ when compared to the MAF Extension Workers. For instance, training on CSA was ranked 1st by the MAF Extension Workers whilst climate-resilient crop varieties were ranked 1st by the farmers. This result shows that farmers give more importance to inputs that are tangible for addressing the challenges posed by climate change whilst AEWs of MAF give more importance to training on CSA practices which are intangible. Therefore, project support to farmers and AEWs of MAF should be demand-driven and the strategies for addressing the challenges posed by climate change should be tailored according to their needs. Given the fact that both farmers and AEWs ranked 3rd the access to meteorological information, means that this option/solution is given lower consideration in the ranking of their priority needs. This may be attributed to their lack of knowledge in understanding the implications of meteorological information on their agricultural production and livelihoods.

4. Conclusion

Both studies show evidence of climate change in the Moyamba district from 1991 to 2020 even though the observed changes in rainfall and temperature by the farmers and AEWs partially agree with the results of the analyzed meteorological data. Both studies show that the rainy season starts late and ends late and the annual rainfall amount is decreasing. On the contrary, the results of the analyzed meteorological data show that the length of the rainy season has not changed whilst the farmers and AEWs perceived a shorter rainy season period.

Both studies show that the local temperature has increased during the last 30 years. Changes in rainfall and temperature as perceived by farmers have resulted in adverse weather events. Droughts, high temperatures, and irregular rainfall as the three major extreme weather events that farmers perceived to have contributed to a substantial loss in the yields of the major crop crops cultivated on smallholder farms in the district. The increase in temperature contributes to the high incidence of pests and diseases. A substantial number of farmers take no action in response to the negative effects caused by climate change due to their lack of knowledge, technical or financial capacity to implement climate-smart crop production (CSA) practices. Even though few farmers are practicing some CSA practices (intercropping, short duration crops, organic fertilizer, minimum tillage, and adapting their cropping calendar) on their farms in response to the negative effects of extreme weather events, there is an urgent need to build the capacity of farmers and AEWs to improve crop production and adapt to and mitigate the negative impacts of climate change. The most priority need of farmers is to support them with climate-resilient crop varieties *i.e.* short duration and drought resistant varieties of the major crops (rice, cassava and groundnut) cultivated in the district, whilst the AEWs need training on CSA practices for the dissemination of appropriate extension messages for climate change adaptation and mitigation on smallholder farms.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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