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Climate Change Perceptions by Smallholder Coffee Farmers in the Northern and Southern Highlands of Tanzania

Suzana G. Mbwambo [1,*], Sixbert K. Mourice [2] and Akwilin J. P. Tarimo [2]

[1] Tanzania Coffee Research Institute (TaCRI), Moshi P.O. Box 3004, Tanzania
[2] Department of Crop Science and Horticulture, Sokoine University of Agriculture, Morogoro P.O. Box 3005, Tanzania; sixbert.mourice@sua.ac.tz (S.K.M.); akwilin@sua.ac.tz (A.J.P.T.)
* Correspondence: suzana.mbwambo@tacri.org

Abstract: Smallholder farmers are among the most vulnerable groups to climate change. Efforts to enhance farmers' adaptation to climate change are hindered by lack of information on how they are experiencing and responding to climate change. Therefore, this paper examines smallholder farmers' perceptions of climate change, factors influencing their perceptions, and the impacts and adaptation strategies adopted over the past three to four decades. A list of farmers was obtained from the Agricultural Marketing Cooperative Society (AMCOS) and filtered on the basis of age and farming experience. In order to explore factors influencing household perceptions of climate change, a structured questionnaire was administered to the randomly selected household heads. Data on rainfall and temperature were acquired from Lyamungo and Burka Coffee estate (Northern Highlands zone) and Mbimba and Mbinga (Southern Highlands zone) offices of the Tanzania Meteorological Agency (TMA) with the exception of data from Burka Coffee estate, which were acquired from a private operator. Descriptive statistics and logistic regression models were used to analyze the data. Farmers' perceptions were consistent with meteorological data both pointing to significant decline in rainfall and increase in temperature since 1979. Factors such as level of education, farming experience, and access to climate information influenced farmers' perception on climate change aspects. Based on these results, it is recommended to enhance timely and accurate weather information delivery along with developing institutions responsible for education and extension services provision. The focus of education or training should be on attenuating the impacts of climate change through relevant adaptation measures in each coffee-growing region.

Keywords: *Coffea arabica*; climate change; farmers' perceptions; Tanzania

Citation: Mbwambo, S.G.; Mourice, S.K.; Tarimo, A.J.P. Climate Change Perceptions by Smallholder Coffee Farmers in the Northern and Southern Highlands of Tanzania. *Climate* **2021**, *9*, 90. https://doi.org/10.3390/cli9060090

Academic Editor: Anouschka Hof

Received: 24 March 2021
Accepted: 22 April 2021
Published: 2 June 2021

1. Introduction

There is substantial evidence that the mean and extremes of climate variables have been changing in recent decades and that rising atmospheric greenhouse gas concentrations could cause such trends to intensify in the near future [1]. According to [1] the case in Africa will be more pronounced than the global average, suggesting warming in all seasons. Studies have reported high variability in rainfall and associated adverse effects of rainfall changes in East Africa [2]. A study on climate change in Tanzania by [3] reported a consistent rise in night-time temperatures (Tmin) (0.31 °C/decade) for over fifty years in the Northern Highlands zone of Tanzania.

As temperature increases, its impact on agricultural crops is expected to be remarkably felt with consequences for millions of smallholder farmers, including an increasing burden of agricultural diseases and insect pests. Cash crops such as coffee will be the most affected by climate change [4]. As already pointed out by [3] a 1 °C rise in mean minimum (night-time) temperature will cause an annual yield loss of approximately 137 kg of coffee ha^{-1} in northern Tanzania.

Coffee is one of Tanzania's largest export crops [5], contributing 24% to the annual agricultural foreign exchange earnings and significant tax revenue. The crop contributes about 4% to gross domestic product (GDP), generating an average of US$100 million annually [5]. The coffee sub-sector also supports the livelihoods of over 450,000 farm families in 15 regions directly, and over 2.4 million people employed in its value chain indirectly [6]. The average smallholder coffee productivity ranges between 250 and 300 kg/ha, which is very low compared to the potential yield of over 1000 kg/ha. We hypothesize that climate change may be behind the decline of coffee yields in Tanzania, thus putting coffee production and the livelihoods of coffee farmers at risk [6]. This is because decrease in rainfall, especially the long rain season and increase in temperature negatively affects the expansion stage, during which rainfall is required to sustain berry development [3]. Furthermore, drought and increase in temperature results in fruit abortions, increased bean defects, reduced berry growth, and acceleration of ripening, leading to a reduction in coffee yield and quality [3]. Despite the prevailing trend of decreasing productivity, coffee still makes a significant contribution to smallholder livelihoods that produce 95% of coffee in Tanzania [6].

Therefore, a better understanding of climate change and variability by smallholder farmers is necessary for designing adaptation strategies and policies to deal with the impacts of climate change on the Tanzanian coffee sub-sector, where 95% of the produced coffee is grown by smallholder farmers. The understanding largely targets the smallholder farmers who are highly vulnerable to climate change because most depend on rain-fed agriculture, cultivating in marginal areas, and lack access to technical or financial support that could help them invest in more climate-resilient agriculture. Different climatic studies show that sub-Saharan Africa is among the worst impacted region by the climate change and thus, a better understanding of how farmers view climate issues is an imperative step toward improving resilience [7,8]. Therefore, it can be premised that perceived personal experiences could affect climate change belief and the corresponding adaptation measures taken. It is evident that in areas where farmers lack awareness and knowledge about climate change, their vulnerability has been increasing, causing poor yields, food shortage, and poverty [9].

Different studies indicate that smallholder farmers have been responding to climate change impacts through a range of interventions, including agronomic practices such as planting shade trees, pruning, planting drought-tolerant varieties, and application of organic fertilizers [4,10]. Some researchers have analyzed how farmer's perceived climate change in Tanzania. [10], investigated whether or not smallholder farmers in Tanzania perceived climate change across four regions: Iringa, Dodoma, Morogoro, and Tanga. Other studies by [9,11] compared smallholders' perception of climate change with meteorological data across different agro-ecological zones. These studies suggest that farmers have already perceived change in climate conditions. However, these studies were mainly done in arid and semiarid regions of Tanzania where coffee is not the main crop, and when done in Northern and Southern Highland zones, coffee was not taken into account. A study by [12] explored the perceived impacts of climate variability on coffee and banana farming in the highlands of Moshi rural District. The only drawback from this study was that it did not analyze factors influencing perception of climate change. Different scholars have indicated that the adoption of a particular adaptation method by individual households is influenced by several factors; e.g., in Ethiopia, [13] and Uganda, [14] found that farmers' education, access to extension services and credits, climate information, social capital, and agro-ecological settings had a great influence on farmers' choice of adaptation strategies to climate change. In Tanzania, [9] indicates that farmers' knowledge on climate change is a good base for undertaking effective adaptations. However, farmers' perceptions of climate change are contextual and location-specific as societies differ in culture, education, demographics, resource endowments, and biophysical and institutional characteristics. This heterogeneity influences the way they perceive changes in their local climate and the way they respond to the change [15]. Therefore, adaptation strategies of the farmers are linked with their perception of climate change and its impacts [16].

Therefore, the current study contributes to the rapidly advancing climate change and farmers' perception literature by providing practical evidence of the climate trends according to farmers' perceptions and factors affecting perception in the two major Arabica coffee-growing areas of Tanzania. The results will also be used as one step toward the formulation of climate change adaptation strategies specific for coffee in Tanzania and beyond. The research explores the possibility of increasing coffee production sustainably through improved agronomic practices for adaptation to climate change in the Northern and Southern Highlands of Tanzania by assessing farmer's perceptions and determining which factors influence their perceptions.

2. Materials and Methods

2.1. Description of the Study Area

The study area was purposively selected based on the level of Arabica coffee production. It comprised of two major Arabica coffee growing zones: the Northern Highland zone (Kilimanjaro and Arusha regions) and Southern Highland zone (Songwe and Ruvuma regions) (Figure 1). In these zones, Arabica coffee production is exclusively rain-fed. The Northern Highlands zone is characterized by a bimodal rainfall pattern, while the Southern Highland zone experiences a uni-modal rainfall pattern. The bimodal rainfall is characterized by a long rainfall season (March–May) and short rainfall season (October–December), whereas the uni-modal type receives rainfall for seven months (November–May) (Figure 2).

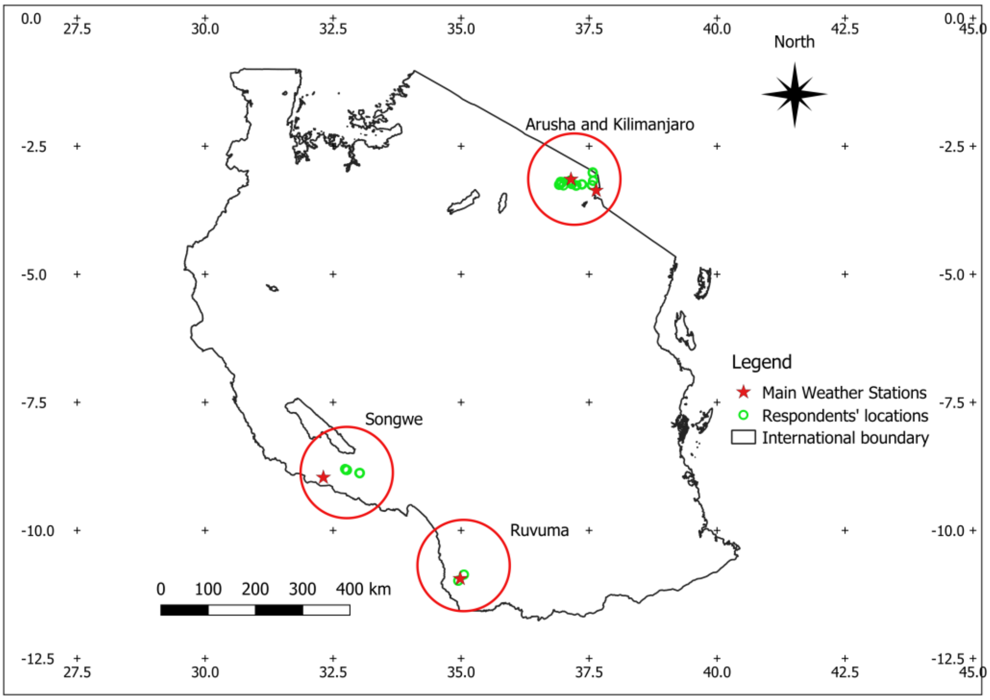
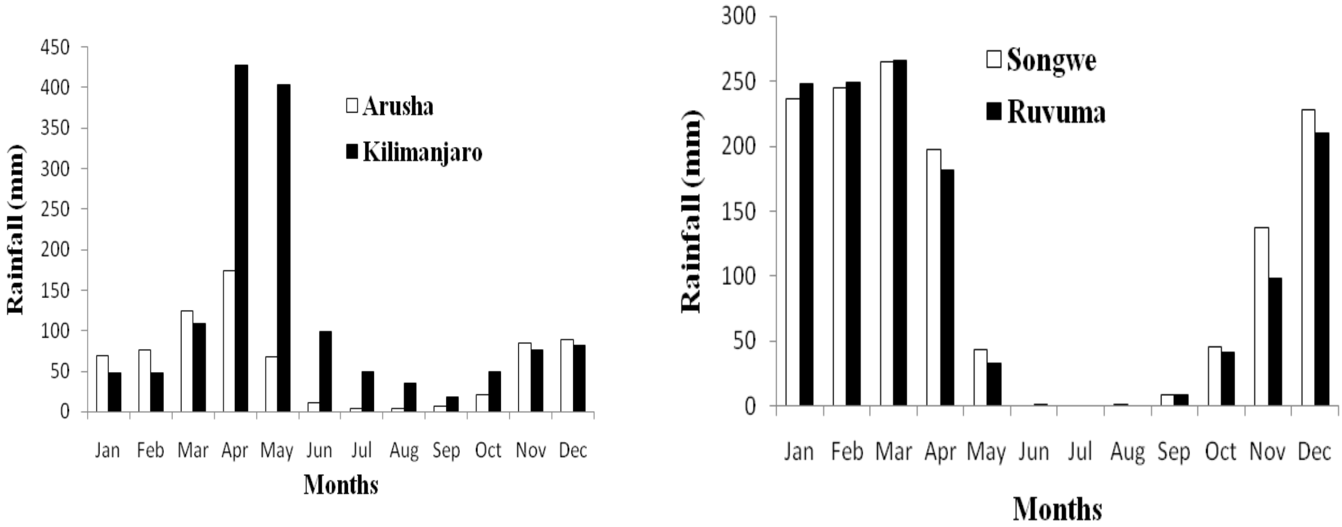


Figure 1. Map of Tanzania indicating study locations (red circle).

Within the Arabica coffee-growing regions, wards and villages were also purposively selected based on coffee production level (according to production data maintained by the local Agricultural Marketing Cooperative Societies (AMCOS)). This approach enabled the selection of villages that were fully involved in coffee production. A total of 14 villages from 7 districts and 14 wards were involved in this study (Table 1).



(**a**) (**b**)

Figure 2. Monthly mean rainfall: (**a**) Northern Highlands zone, (**b**) Southern Highlands zone.

Table 1. Selected villages and sample size.

Zone	District	Survey Date	Selected Wards	Selected Village	Households (N)	Sample Size (n)
Northern (Kilimanjaro)	Hai	20 January 2020	Masama kati	Isuki	35	14
		21 January 2020	Machame Narumu	Usari	33	13
	Rombo	22 January 2020	Ushiri Ikuini	Ushiri	43	17
		23 January 2020	Nanjara	Kibaoni	33	13
	Siha	24 January 2020	Karansi	Kandashi	34	13
		27 January 2020	Kashashi	Kirisha	40	16
	Moshi dc	28 January 2020	Mwika Kaskazini	Kinyamvuo	47	19
		29 January 2020	Uru Kaskazini	Njari	55	22
Northern (Arusha)	Arumeru	6 February 2020	Leguruki	Nkoasenga	47	19
		7 February 2020	Maruvango	Shishton	38	15
Southern (Songwe)	Mbozi	4 March 2020	Itumpi	Ikonya	53	21
Southern (Ruvuma)		5 March 2020	Bara	Itumpi	48	19
	Mbinga	9 March 2020	Luwaita	Luwaita	41	16
		10 March 2020	Utiri	Utiri	64	25
		Total			611	242

2.2. Sample Size and Procedure

Lists of smallholder coffee growers were obtained from AMCOSs and filtered on the basis of age (40–60 years), experience in growing coffee (more than 10 years) and minimum number of coffee trees (450). The sample size was calculated using [17] formula for calculating sample size from a population and a total of 242 households were obtained

$$\mathrm{n} = \frac{N}{1 + N\,(e^2)} = \frac{611}{1 + 611\,(0.05^2)} = 241.741 \approx 242 \quad (1)$$

where, n = sample size, N = population size (list of selected coffee growing households) = 611, and e = level of precision (95% confidence interval, level of precision will be 5%).

The respective sample for each village was allocated using proportionate sampling procedure [18]. Simple random sampling technique was also adopted to randomly select household heads from the various villages [19] such that each farmer had an equal opportunity of being selected for the study.

2.3. Data Collection

The survey used Open Data Kit (ODK) software installed on smart phone hand set and Samsung Galaxy Note 7 Tablet. This technology facilitated reduction in data-entry errors and spedup data management and cleaning. The survey was designed to measure farmers' perceptions on climate change using a structured questionnaire. Before launching the survey, the questionnaire was pretested. Data collected from the survey included internal factors (demographic variables, farming systems, farmers' perception of climate change, and time aware of climate change) and external factors (extension services and sources of weather information). In order to collect data on farmers' perceptions of climate change, farmers were asked whether they had observed any long-term changes in temperature and rainfall over the last 10–30 years. Secondary data on rainfall and temperature were acquired from Lyamungo and Burka Coffee estate (Northern Highland zone) and Mbimba and Mbinga (Southern Highlands zone). Data from Lyamungo, Mbimba and Mbinga were acquired from the offices of the Tanzania Meteorological Agency (TMA), while data from Burka Coffee estate were acquired from a private operator.

2.4. Data Analysis

Descriptive and inferential statistics namely frequencies, percentiles, Chi-square contingency test, and t-test were performed in STATA 13.0 (StataCorp LP, College Station, TX, USA) and SPSS 21.0 (IBM-SPSS Inc., Chicago, IL, USA) software. A binary logistic regression model also was used to assess farmers' perception of climate change as influenced by family, farm, and external variables and to determine factors affecting households' decision to adapt to climate change. According to [20], the dependent variable (i.e., perceived climate change, Y = 1 or not perceived climate change, Y = 0) was taken as a combination of an increase in temperature being accompanied by a decrease in rainfall. Following the assumption of standard logistic probability distribution, similar to the previous studies, including [18,21], a binary logistic model was applied, mainly to identify factors affecting farmers' perception of climate variability and change over agro-ecological zones (AEZs). This model uses Maximum Likelihood Estimation (MLE) procedure to ensure that the probabilities are bound between 0 and 1. The binary logistic model was regressed on a set of explanatory variables hypothesized based on literature and data availability that were considered to affect farmers' perception of climate change (Table 2).

Table 2. Variables hypothesized to affect farmers' perception of climate change.

Variable	Description	Value	Expected Sign
Household head	Sex of the head of the farm household	1 = male; 0 = female	+/−
Education level	Level of education attained by the head of the household	(1 = No formal edu., 2 = Primary edu., 3 = ODL educ., 4 = ADL edu., 5 = College, 6 = University)	+
Farming experience	Number of years of farming experience for the household head	Years	+
Crop failure experience	If household has experienced crop failure due to water shortage	1 = yes, 0 = no	+
Farm size	Size of the household farm	ha	
Extension	If household has access to extension services	1 = yes, 0 = no	+
Climate information	Access to weather condition	1 = yes, 0 = no	+
Time aware of climate change	The time in years that the head of the household was aware of climate change	Awareness about climate change (past two years, past five years, past seven years and more)	+/−

Missing values in the rainfall and temperature data set were determined according to the "3/5" rule (21). Taking into account this rule, the missing values in the temperature data set ranged between 5 and 19%, while that of rainfall ranged between 1 and 5%. The obtained missing values were estimated using the multiple imputation method due to its characteristics to account for uncertainty about the imputed values [22]. Rainfall Anomaly Index (RAI) analysis was used for the analysis of annual rainfall variability [8]. The statistical anomalies approach [18] was used to analyze the temperature for the 40-year period from 1979 to 2018, focusing on temperature patterns. Average values for temperature and rainfall for the 40-year period (climatological normal) served as the basis for the assessment for the stipulated period. Rainfall Anomaly Index (RAI) positive and negative values were calculated using Equations (2) and (3).

$$RAI = +3\left(\frac{RF - MRF}{MH10 - MRF}\right) \tag{2}$$

$$RAI = -3\left(\frac{RF - MRF}{ML10 - MRF}\right) \tag{3}$$

where RAI is the Rainfall Anomaly Index; RF is the rainfall for the year in question; MRF is the mean actual rainfall for the total length of the period; and MH10 and ML10 are the mean of the 10 highest and lowest (respectively) values of rainfall (RF) of the period.

Using these variables, the empirical specification of the binary logistic model was described as,

$$\begin{gathered} Ln(P/(1-P)) = \beta_o + \beta_1\text{household head} + \beta_2\text{edu1} + \beta_3\text{edu2} + \beta_4\text{edu3} + \beta_5\text{edu4} + \beta_6\text{edu5} + \beta_7\text{farming} \\ \text{experience} + \beta_8\text{crop\_failure} + \beta_9\text{farmsize} + \beta_{10}\text{extension services} + \beta_{11}\text{climate information} + \beta_{12}\text{1 year climate change} \\ \text{awareness} + \beta_{13}\text{2 years climate change awareness} + \beta_{14}\text{ 5 years climate change awareness} \\ + \beta_{15}\text{ more than 7 years climate change awareness} + \varepsilon_i \end{gathered} \tag{4}$$

where

β_i = coefficients of the independent variables, ε_i = disturbance term

- Dependent variable in the perception of climate change equation: The natural log of the probability of perceiving climate change (P) due to the influence of variables hypothesized in Table 2 divided by the probability of not perceiving (1-P).
- Dependent variable in the adoption of adaptation practices equation: The natural log of the probability of adopting adaptation practices (P) due to the influence of variables hypothesized in Table 2 divided by the probability of adopting adaptation practices without the influence of the variables hypothesized in Table 2 (1-P).

3. Results

3.1. Characteristics of the Households

Among the 242 sampled households, 90% were headed by men and 10% were headed by women. Respondents from Northern Highlands zone were of the age group between 41 and 70 years, while those of the Southern Highlands zone was dominated by those between 41 and 60 years (Appendix A, Table A1).

Chi-square results indicate that variations in farmer's age across the districts were significant, $\chi^2(26, N = 242) = 30.98$, $p < 0.05$. The land-holding size also significantly varied across the districts $\chi^2(26, N = 242) = 22$, $p < 0.01$. The majority of the respondents from the Northern Highlands zone had a farm size between 0.5 and 1ha, while those from the Southern Highlands zone had farm sizes between 1 and 2 ha. The study also showed significant variations ($p < 0.05$) of the respondent's education level between the districts, $\chi^2(36, N = 242) = 62.13$, $p < 0.05$. On the other hand, respondents had farming experience between 20 and 39 years with significant variations $\chi^2(36, N = 242) = 26.5$, $p < 0.05$ among the districts.

Results also indicate significant variations between male and female respondents in terms of time aware of climate change ($p < 0.1$) and sex of the household head ($p < 0.01$) (Table 3). There were also lack of significant variations ($p > 0.05$) in terms of education level, access to climate information and extension services between male and female respondents.

Table 3. Characteristics of male and female respondents in the Southern Highlands zone (%).

	Male	Female	χ^2	df	*p*-Value
	n = 60	n = 21			
Time aware of climate change					
One year aware of climate change	10	4.76			
Two years aware of climate change	11.67	33.33			
Five years aware of climate change	41.67	19.05	10.307	5	0.067
Seven years aware of climate change	1.67	9.52			
Ten years aware of climate change	21.67	14.29			
Household head					
Head of the household	100	24	56.967	1	0.000
Not head of the household	0	76			

Note. df = degree of freedom, χ^2 = Chi-square test, n = number of households, $p \leq 0.1$, $p \leq 0.05$, $p \leq 0.01$ show there was significant difference.

Similarly, in the Northern Highlands zone, the Chi-square test indicated a lack of significant variations ($p > 0.05$) in terms of education level and access to extension services between male and female respondents. However, significant variations between male and female respondents were observed in the time aware of climate change ($p < 0.05$), sex of the household head ($p < 0.01$), and access to climate information ($p < 0.1$)(Table 4). Most of the respondents (89%) were aware of climate change, while 11% did not know what climate change is. Among the subset of 89%, 146 (91%) of the respondents were from the Northern Highlands and 69 (85%) from the Southern Highlands.

Table 4. Characteristics of male and female respondents in the Northern Highlands zone (%).

	Male	Female			
	n = 127	n = 34	χ^2	df	*p*-Value
Access to climate information					
Farmers with access to climate information	78.74	64.71	2.878	1	0.090
Time aware of climate change					
One year aware of climate change	24.41	26.47			
Two years aware of climate change	23.62	23.53			
Five years aware of climate change	26.77	11.76	12.707	5	0.026
Seven years aware of climate change	7.09	2.94			
Ten years aware of climate change	12.60	11.76			
Household head					
Head of the household	100	53			
Not the head of the household	0	47	66.359	1	0.000

Note. df = degree of freedom, χ^2 = Chi-square test, n = number of households, $p \leq 0.1$, $p \leq 0.05$, $p \leq 0.01$ show there was significant difference.

Significant variations between time aware of climate change, sex of the household head, access to climate information and the perceptions of temperature increase and rainfall decrease were also observed in the Southern (Table 5) and Northern (Table 6) Highlands zones. Furthermore, out of 242 respondents, 79% had access to climate information mostly through media such as TV, radio, and mobile phones. On the other hand, there were significant differences (t = 1.9367, $p < 0.01$) among farming households with access to climate information in the Northern Highlands zone (76%) as compared to those in the Southern Highlands zone (86%). Among the 242 respondents, 163(67%) farmers perceived climate change by a way of change in intensity of the climate variables (increase in temperature and decrease in rainfall). There was also significant difference (t = 7.636, $p < 0.01$) between respondents with positive perceptions of climate change (increase in temperature and decrease in rainfall) and those with negative perceptions of climate change. However, there was no significant difference (t = 1.0316, $p > 0.05$) between farmers with positive perceptions of climate change in the Northern (70%) and those from the Southern Highlands zone (63%).

Table 5. Farmers' perceptions of increase in temperature and decrease in rainfall as influenced by time aware of climate changes, sex of the household head, and access to climate information in the Southern Highlands zone (%).

	Temperature Increase				Rainfall Decrease			
	n = 61	**χ^2**	**df**	***p*-Value**	**n = 55**	**χ^2**	**df**	***p*-Value**
Time aware of climate changes								
Past 1 year	10	86.213	10	0.000	11	89.214	10	0.000
Past 2 years	18				15			
Past 5 years	46				44			
Past 7 years	5				4			
Past 10 years	21				27			
Sex of the household head								
Male	80	13.255	2	0.001	87	19.148	2	0.000
Female	20				13			
Access to climate information								
Respondents with access	90	4.726	2	0.094	87	6.224	2	0.045
Respondents without access	10				13			

Note: df = degree of freedom, χ^2 = Chi-square test, n = number of households, $p \leq 0.05$, $p \leq 0.01$ shows there was significance.

Table 6. Farmers' perceptions of increase in temperature and decrease in rainfall as influenced by time aware of climate changes, sex of the household head, and access to climate information in the Northern Highlands zone (%).

	Temperature Increase				Rainfall Decrease			
	n = 133	**χ^2**	**df**	***p*-Value**	**n = 119**	**χ^2**	**df**	***p*-Value**
Time aware of climate change								
Past 1 year	30	92.237	10	0.000	34	70.745	10	0.000
Past 2 years	26				28			
Past 5 years	29				26			
Past 7 years	5				3			
Past 10 years	11				9			
Sex of the household head								
Male	94	13.967	2	0.001	92	10.116	2	0.006
Female	6				8			
Access to climate information								
Respondents with access	84	37.077	2	0.000	85	27.489	2	0.000
Respondents without access	6				15			

Note: df = degree of freedom, χ^2 = Chi-square test, n = number of households, $p \leq 0.05$, $p \leq 0.01$ shows there was significance.

3.2. *Comparing Smallholder Farmers' Perception with Meteorological Data*

Farmers' perceptions were compared with the results of the historical trends from meteorological data. Figure 3 shows farmers' perceptions of changing in rainfall amount categorized based on their respective districts. Many famers (above 70%) felt declining rainfall in their areas, with the exception of farming households from Mbinga districts where only 62% had a similar feeling of rainfall decline. Looking at the meteorological data from two districts one from Northern Highlands zone (Hai) and another from the Southern Highlands zone (Mbozi), we find that approximately half of the years within the study period experienced below average annual rainfall.

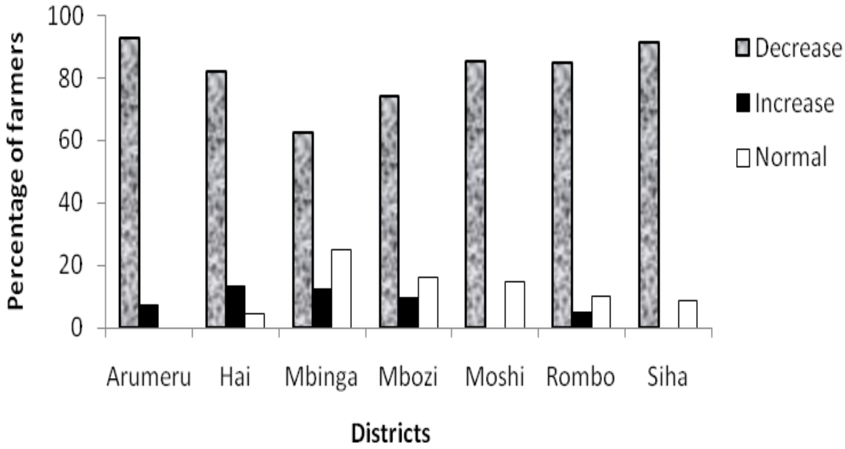


Figure 3. Farmers' perceptions of rainfall.

The average rainfall amount for Lyamungo was 1447.79 mm, while the highest average annual rainfall was 2194 mm recorded in 2006 and the lowest was 670 mm recorded in 1989. For the case of Mbimba, the average rainfall amount was 1342.79 mm, the highest average annual rainfall was 1693 mm recorded in 1994, while the lowest was 630 mm recorded in 1981. Figure 4a,b reveal that there is persistent high variability in annual rainfall based on a 5-year moving average. The 5-year moving average trend lines are not consistent throughout the 40-year period. The RAI for Lyamungo indicates that in the first and second decades, only five years respectively recorded an average rainfall above the average for the entire period. In the third decade and fourth decades, only 4 and 3 years respectively recorded an average rainfall above the average of the 40-year period. On the other hand, the RAI for Mbimba reveal that in the first and second decades, six years recorded an average rainfall above the average for the entire period. In the third decade and fourth decades, only 3 and 2 years respectively recorded above-average rainfall of the 40-year period. Hence, the fourth decade (2009–2018) was the driest of all four decades in both sites.

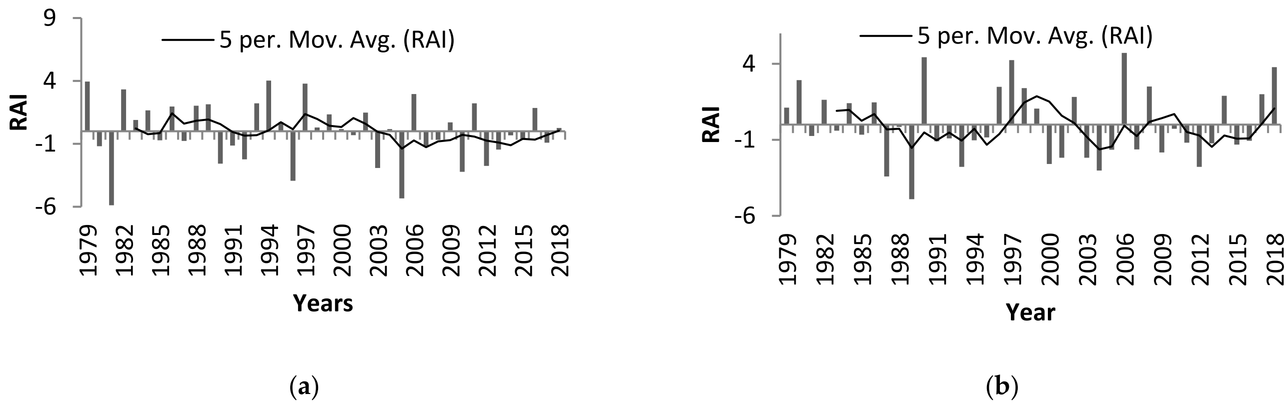


Figure 4. Rainfall Anomaly Index and 5-year moving average analysis for (**a**) Lyamungo-Northern Highlands zone and (**b**) Mbozi district-Southern Highlands zone from 1979 to 2018 (Source: Author's construct using data from TMA).

The majority of coffee farmers (more than 70%) from both the Northern and Southern Highlands felt an increase in temperature with the exception of Mbinga district, where only 67.7% of farmers perceived an increase in temperature (Figure 5). In the study period, the mean temperature for Lyamungo and Mbimba were 19.85 °C and 18.76 °C, respectively. Temperature values for the 40-year period were erratic, as indicated in Figure 6a,b. The highest average temperature for the four decades at Lyamungo was 20.47 °C, which was recorded in 2012, while the lowest for the period was 18.45 °C in 1979. At Mbimba, the highest average annual temperature was 20.5 °C recorded in 2010, while the lowest was 17.45 °C recorded in 2001. The yearly averages at Lyamungo (Hai district) from 2003 to 2018 were all above the average, while at Mbimba (Mbozi district), they were above from 2005 to 2018 for the 40-year period under study. Hence, the mean temperatures at Lyamungo (Northern Highlands zone) and Mbimba (Southern Highlands zone) have been increasing during the study period.

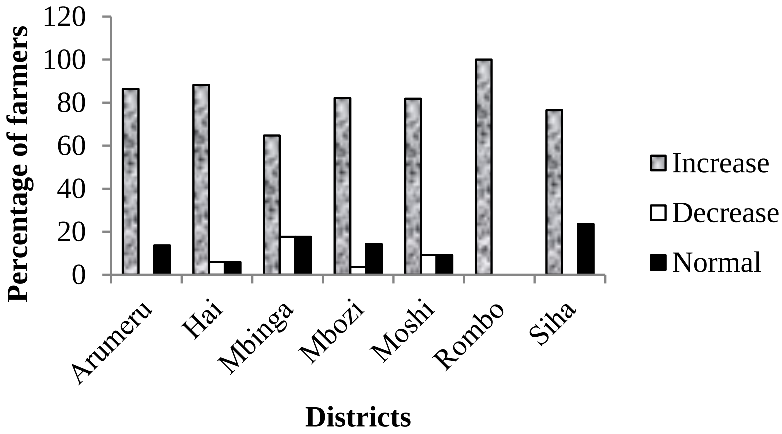
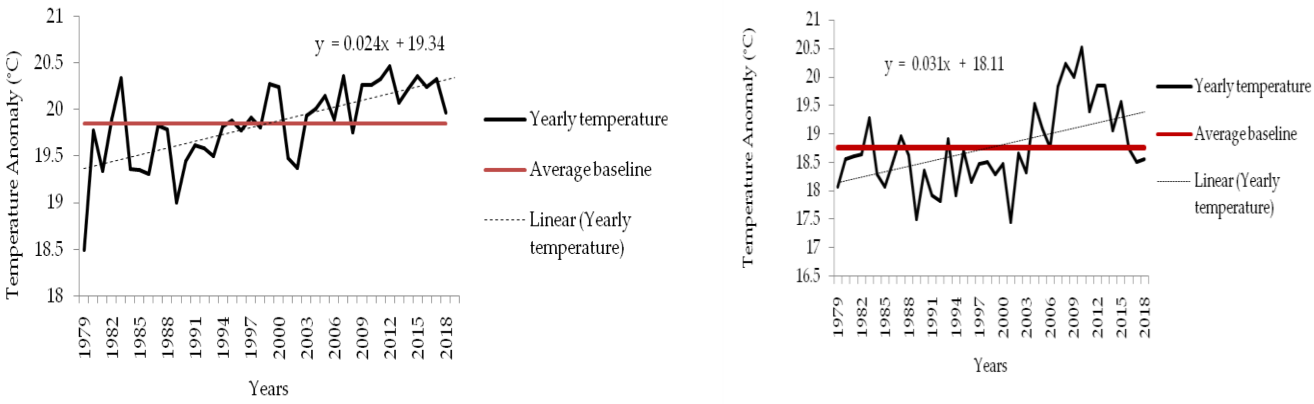


Figure 5. Farmers' perceptions of temperature.



(**a**) (**b**)

Figure 6. (**a**) Mean annual temperature anomalies for Lyamungo (Northern Highlands zone) from 1979 to 2018, (**b**) Mean annual temperature anomalies for Mbimba (Southern Highlands zone) from 1979 to 2018 (source: author's construct using data from TMA).

3.3. Perceived Impacts of Climate Change on Coffee Farming

Farming households noted climate change impact in terms of reduction of coffee yield (89%), increased crop insect pest (79%), increase crop diseases (63%), late coffee flowering (63%), and crop failure due to water shortage (59%). Variations in climate change impacts across the two zones were significant ($p < 0.05$) except for reduction in coffee yield ($p > 0.05$) (Table 7).

Table 7. Climate change impacts in coffee farming.

	Northern Highlands Zone	Southern Highlands Zone	χ^2	df	*p*-Value
Late coffee flowering	57	74	9.98	2	0.007
Reduced coffee yield	89	88	0.174	1	0.677
Crop failure	64	49	4.747	1	0.029
Coffee pest increase	82	73	5.85	2	0.054
Coffee disease increase	57	75	7.82	2	0.02

Note. df = degree of freedom, χ^2 = Chi-square test, $p \leq 0.05$, $p \leq 0.01$ shows there was a significant difference.

Another climate change impact pointed out by coffee farming households was prolonged harvesting period, which significantly varied, $\chi^2(9, N = 242) = 49.85$, $p < 0.01$ across the two zones (Figure 7).

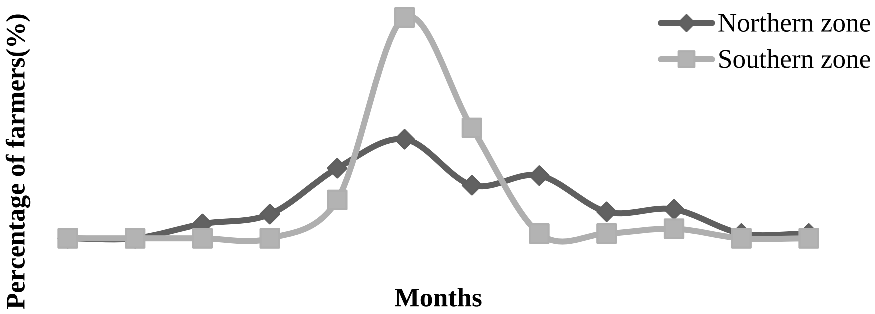


Figure 7. Coffee harvesting duration in the two zones.

On the other hand, there were significant positive associations ($p < 0.05$) among the increase in temperature, decrease in rainfall, and most of the climate change impacts mentioned by respondents (Table 8). There was also a significant negative association ($p < 0.05$) between increases in coffee insect pest and diseases with reduction in rainfall. However, a lack of significant association ($p > 0.05$) between late coffee flowering and increase in temperature was also observed. Reduction in yield as a result of climate change was reported to be significantly higher among male households than the female households.

Table 8. The association between climate change impacts and indicators of climate change.

	Decrease in Rainfall	Increase in Temperature
Reduced rainfall	1	
Increase temperature	0.5421 (0.000)	1
Late flowering	0.1790 (0.005)	0.1059 (0.100)
Reduced yield	0.3917 (0.000)	0.3175 (0.000)
Crop failure	0.3400 (0.000)	0.1763 (0.006)
Insect pest increase	−0.1084 (0.092)	0.8230 (0.014)
Disease increase	−0.5060 (0.042)	0.2060 (0.008)

Note: $p \leq 0.1$, $p \leq 0.05$, $p \leq 0.01$ indicate there was significance, p-value in parentheses.

Table 9 below indicates the results of the logistic regression model of farmers' perceptions of climate change. Male-led households positively perceived climate change ($p < 0.01$) more than female-headed households. Positive perception of climate change was significantly influenced by farmers who were trained up to standard seven ($p < 0.05$), and form four ($p < 0.1$). Furthermore, farmers with more farming experience were also more likely to have positive perceptions of climate change than farmers with low farming experience ($p < 0.1$). On the other hand, farmers who have experienced crop failure due to water shortage are more likely to have positive perceptions of climate change than farmers without such experience ($p < 0.01$). Farmers' access to climate information also increases the probability of perceiving climate change positively ($p < 0.01$). A positive perception of climate change was also significantly influenced by farmers who heard about climate change two years ago and five years ago ($p < 0.01$).

3.4. Farmers' Responses to Climate Change

Soil and water conservation practices comprised the use of terraces, cut-off drains, and mulching. The results indicated that 67 (28%) households used terraces in their coffee fields. This includes 49% from the Northern Highlands zone and 46% from the Southern Highlands zone. On the other hand, 31% of the respondents were using cut-off drains, which include 30% from the Northern Highlands zone and 37% from the Southern Highlands zone. Households that applied mulch in their coffee fields constituted 89%. Irrigation practice was the least adopted practice in the study area; only 31 (13%) households out of 242 were irrigating their coffee fields. This involved 27(17%) households from the Northern Highlands zone and 4 (5%) from the Southern Highlands zone. Dominant planted trees are *Grevillea robusta*, *Persea americana*, Albizia spp., and *Cordia africana*. The results also indicated that 41% of the farming households had started planting coffee varieties, which are tolerant to Coffee Berry Disease (CBD) and Coffee Leaf Rust Disease (CLR). However, still, of the majority of the farmers, 119 (73%) who perceived climate change still planted old coffee varieties, which are susceptible to CBD and CLR diseases.

Table 9. Factors influencing farmer's perceptions of climate change.

Explanatory Variables	Odds Ratio	Std. Error	z	*p*-Value	[95% Conf. Interval]	
					Lower	Upper
Household head	10.72	5.488	4.63	0.000	3.932	29.238
Farming experience	1.030	0.016	1.85	0.065	1.998	2.062
Primary education	3.169	1.423	2.57	0.01	1.314	7.642
Ordinary secondary education	3.373	2.270	1.81	0.071	0.902	12.615
Time aware of climate change (2 years)	3.279	1.393	2.8	0.005	1.426	7.538
Time aware of climate change (5 years)	3.778	1.624	3.09	0.002	1.627	8.774
Access to climate information	4.915	1.870	4.18	0.000	2.332	10.360
Crop failure	4.664	1.628	4.41	0.000	2.353	9.244
_cons	0.011	0.010	−5.07	0.000	0.002	0.063
Log likelihood					−110.186	
Number of observation					242	
Likelihood ratio test for zero slopes chi^2 (8)					85.34	
Probability > chi^2					0.000	
Pseudo R^2					0.2791	

Note: $p \leq 0.1$, $p \leq 0.05$, $p \leq 0.01$ shows there was significance.

From the surveyed soil nutrients sources, organic manure was the most widely applied nutrient source. About 55% of the farming households who perceived climate change used organic fertilizer, while 56% of those who did not perceive climate change were also using organic fertilizer. There was also significant differences ($p < 0.05$) in terms of most of the agronomic practices between the Northern and Southern Highlands zones with the exception of cut-off drains, which were not significantly different between the two zones ($p > 0.05$) (Table 10).

Table 10. Adoption of adaptation practices in the coffee-growing zones.

Adaptation Practice	Northern Highlands Zone	Southern Highlands Zone	t-Statistic	*p*-Value
	Mean Adopters (%)	Mean Adopters (%)		
Soil fertility management	94 (0.02)	80 (0.04)	3.267	0.001
Terraces	19 (0.03)	46 (0.06)	−4.610	0.000
Cut-off drains	28 (0.04)	37 (0.05)	−1.443	0.150
Mulching	94 (0.02)	70 (0.05)	4.49	0.000
Shade trees	96 (0.02)	70 (0.05)	5.920	0.000
Irrigation	17 (0.03)	5 (0.02)	2.63	0.009
Disease-resistant varieties	49 (0.50)	31 (0.46)	2.729	0.007

Note: $p \leq 0.1$, $p \leq 0.05$, $p \leq 0.01$ indicate that the means are significant different; standard deviation in parentheses.

3.5. Factors Influencing Household Decisions to Adapt to Climate Change

Household decisions to adapt to climate change were significantly influenced by the gender of the household head, farm size, education level, farming experience, access to climate information, access to extension services, and time aware of climate change in different ways (Table 11). The probability of male-headed household to plant disease-tolerant varieties was higher than that of a female-headed household (β = 0.981, $p < 0.05$). Farming experience negatively influenced the adoption of disease-tolerant varieties ($\beta = p < 0.05$). There is a positive relationship between farmers with larger farm size and the adoption of disease-tolerant varieties (β = 0.233, $p < 0.05$) and carrying out soil and water conservation methods through the use of terraces (β = 0.303, $p < 0.01$), unlike for farmers possessing small farm sizes. However, larger farm sizes decreased the probability of using mulches ($\beta = -0.208$, $p < 0.05$).

From Table 11 above, access to extension services significantly enhanced the adoption of planting shading trees (β = 1.054, $p < 0.05$), using cut-off drains (β = 0.698, $p < 0.05$), soil fertility management (β = 0.868, $p < 0.05$), and terraces (β = 0.759, $p < 0.05$) rather than those who use these practices without access to extension services. Access to climate information significantly influenced the use of terraces (β = 0.772, $p < 0.1$) and cut-off drains (β = 1.054, $p < 0.05$). The adoption of irrigation practice was significantly influenced by farmers who were trained up to form four (β = 2.669, $p < 0.05$), form six

(β = 3.728, $p < 0.05$), and university (β = 3.07, $p < 0.1$). Recent climate change awareness significantly (β = $p < 0.05$) influenced the use irrigation practices and intensification of routine activities (pruning insect pest control and disease control).

Table 11. Factors influencing the decision to adapt to climate change.

Adaptation Practices	Factors Influencing Adaptation Practices	B	Std. Error	Wald	df	p-Value	Exp(B)
Terraces	Farm size	0.304	0.106	8.253	1	0.004	1.355
	Extension services	0.759	0.361	4.429	1	0.035	2.136
	Access to climate information	0.772	0.460	2.814	1	0.093	2.164
	1 year time aware of climate change	−2.261	0.625	13.088	1	0.000	0.104
	2 year time aware of climate change	−1.188	0.469	6.406	1	0.011	0.305
	3 year time aware of climate change	−0.949	0.407	5.420	1	0.020	0.387
Manure	Extension services	0.860	0.474	3.292	1	0.070	2.363
Mulching	Farm size	−0.208	0.125	2.791	1	0.095	0.812
	Extension services	0.868	0.443	3.844	1	0.029	2.381
	Experience in crop failure	1.083	0.496	4.780	1	0.029	2.955
Cut-off drains	Extension services	0.698	0.323	4.686	1	0.030	2.010
	Farm experience	1.051	0.442	5.665	1	0.017	2.862
	1 year time aware of climate change	−1.197	0.487	6.035	1	0.014	0.302
Disease tolerant varieties	Farm size	0.233	0.094	6.126	1	0.013	1.263
	Farm experience	−0.041	0.20	4.185	1	0.041	0.960
	Extension services	0.567	0.296	3.670	1	0.055	1.762
	Gender of the household head	0.981	0.428	5.26	1	0.022	2.667
Irrigation	2 year time aware of climate change	1.220	0.610	3.998	1	0.046	3.386
	Experience in crop failure	1.205	0.525	5.272	1	0.022	0.300
	Ordinary secondary education	2.669	1.255	4.525	1	0.033	14.432
	Advanced secondary education	3.728	1.960	3.619	1	0.057	41.590
	University	3.070	1,856	2.734	1	0.098	21.533
Planting shade trees	Extension services	1.054	0.481	4.795	1	0.029	2.870
	Farmers' age	−0.068	0.034	4.141	1	0.042	0.934
Intensification of routine activities (pruning, pest and disease control)	1 year time aware of climate change	2.279	0.981	6.381	1	0.012	11.929
	2 year time aware of climate change	1.991	0.734	7.358	1	0.007	7.324
	5 year time aware of climate change	2.677	0.928	8.332	1	0.004	14.548
	7 year time aware of climate change	1.932	1.168	2.738	1	0.098	6.906

Note: $p \leq 0.1$, $p \leq 0.05$, $p \leq 0.01$ shows there was significance.

4. Discussion

4.1. Perceptions and Impacts of Climate Change in the Northern and Southern Highlands of Tanzania

The majority of farmers from the two major Arabica coffee growing zones in Tanzania were aware of climate change and had positive perceptions of climate change (increase in temperature and decrease in rainfall). These findings are in agreement with other studies conducted in Tanzania by [9,23]. The average annual linear trend for the four decades vividly shows that temperature at Lyamungo (Northern Highlands zone) and Mbimba (Southern Highlands zone) has been increasing. The meteorological data on rainfall also reveal that rainfall amount had decreased just as the respondents perceived. The consistency of farmers' perceptions with meteorological data in terms of temperature increase and rainfall decrease have also been reported by [9,22].

The findings revealed also that there was an association between reduction in coffee yield, crop failure, and increases in coffee insect pests and diseases with climate change indicators (increase in temperature and decrease in rainfall). According to [24], environmental conditions have a definite impact on the densities of insect pests such as Coffee Berry Borers (CBB) and black coffee twig borer (BCTB). [25], found that CBB positively correlated with temperature and coffee tree density. However, less rainfall in general may mean less bacterial blight, CBD, and CLR, since these diseases thrive in humid conditions. Another climate change impact reported by farmers was a prolonged harvesting period. According to [26], unpredictable rains caused coffee to flower at various times throughout the year, leading to the continuous harvesting of small quantities of coffee. This is because coffee plants require well-distributed annual rainfall and a dry period not exceeding five months. Coffee flowers in response to rainfall occurrence following a period of moisture stress.

The study also indicates that female farming households felt the impact of climate change just the same as male counterparts, with exceptions in the reduction in yield, which was felt more by male households. From the discussion with farmers during the interview, it was revealed that female engage themselves more with routine activities in the field, such as weeding, pruning, and harvesting, but the ones who take the produce to the market are the males. Therefore, this could be the reason why male households noted that there is reduction in yield as compared to female households. From this observation, both male and female are affected by climate change, although in different ways.

4.2. Farmers' Response to Climate Change

Some coffee farmers have adapted agronomic practices relevant to climate change. Response actions include planting shade trees, the use of disease-tolerant varieties, soil fertility management, soil and water conservation practices, and irrigation practices. These farming practices and techniques have also been proposed for adapting coffee farming to climate change by [4]. The findings reveal more adoption of soil fertility management, including mulching, the use of shade trees, irrigation, and the use of disease-tolerant varieties in the Northern Highlands zone as compared with the Southern Highlands zone. Terracing practice was the only agronomic practice highly used in the Southern Highlands zone as compared with the Northern Highlands zone.

Response actions such as planting shade trees reduce the amount of heat reaching the coffee crop and ensure that the loss of soil moisture through direct evaporation and transpiration is minimized [14]. On the other hand, planting disease-tolerant coffee varieties avoids diseases such as CBD and CLR, which could be aggravated by changes in temperature and rainfall. According to [27], inorganic fertilizers are most effective at high water levels, while manure performs better than inorganic fertilizers under low water levels, partly due to the former's ability to increase soil water retention.

4.3. Factors Influencing Households' Perceptions of Climate Changeand Household Decisions to Adapt to Climate Change

4.3.1. Gender of the Household

According to different scholars, males move from one place to the other in such a way that they can meet people and mass media to share experiences and ideas about contemporary climate trends [18,28]. On the other hand, [19] reported female-led household as having a higher probability of perceiving climate change than male-led households. Other studies reported a lack of significant variation between male and female-headed households on the perception of climate change [13,20,29]. Therefore, gender is not always positively associated with perception of climate change; rather, it is a mixed factor depending on the environmental issues studied [19]. However, this study suggests that both male and female households have been affected by climate change, although in different ways. Therefore, it is important to conduct research using both male and female participants, because the conclusions that we reach with one group might not be representative of what the other group experiences.

Male households have a high probability of planting disease-tolerant varieties rather than female-headed ones. Probably, this is due to the fact that men are wealthier than women and so they can afford to buy diseases-tolerant varieties. From the discussion with farming households from both zones, it appeared that coffee has traditionally been considered a "man's" crop and is still perceived as such by many people. So, it is easier for male-headed household to even uproot the old coffee varieties and replant the new tolerant varieties than it is for female-headed households. This is in agreement with the findings of [23].

4.3.2. Education Level

Overall, the results showed that educated farmers had a higher probability of perceiving climate change than illiterate farmers. In addition, the findings revealed that the majority of the households who engaged themselves in farming activities had attained a primary education level and only few had studied up to university level. These findings are in contrast with the findings from [18], who reported farmers with post primary education to have a higher probability of perceiving climate change than those with primary education. According to [18], 61% of the farmers who perceived climate change (increase in temperature and decrease in rainfall) had attained post primary education compared with 33% who had primary education. In this study, 71% of the respondents with positive perceptions of climate change had attained a primary education level, and only 29% of the respondents had attained post primary education. Level of education significantly influenced the use of irrigation practices. This is in agreement with other studies on factors influencing the adoption of adaptation practices by the household [10,14], which indicated that farmers with education were fully aware of adaptive options to choose from. However, in this study, the influence of the level of education on the decisions to adopt adaption practices was very low, which may be due to the fact that the majority of farmers had attained primary education, which maybe was not enough to influence the choice of adaptation practices. According to [30], it is not just education that is needed but a high-quality education (which is interdisciplinary and holistically fosters critical thinking and problem solving). Therefore, it is important for the institution that provides education to support not only the provision of curriculum content but also learning, which involves knowledge and skills as well as development of the individual and communities' capacity to deal with climate uncertainty.

4.3.3. Farming Experience

Farming experience influences farming households to have positive perceptions of climate change. This is because experienced farmers have better skills in farming techniques and management and hence are able to detect any changes in climatic conditions resulting from variability in climate. The fact that education and farming experience had a greater association with positive perception of climate change implies the capability of such farmers to better access information than to those with less experience and low education [28]. It was also found out that farmers with many years of farming experience were reluctant to plant disease-tolerant varieties. Thus, experienced farmers have a reduced likelihood of using disease-tolerant varieties. These findings are in contrast with those of [18], which indicated that experienced farmers have greater skills in farming techniques and management and are more able to detect any change in climatic conditions or change in crop production level resulting from variability in climate compared with inexperienced ones. During the interview, the experienced and aged farmers reported that it is not easy for them to replace the old coffee varieties with the new varieties, as they depend on them to run their life, and the new varieties will take up to three years to give them the crop. Therefore, it is important that proper education on how these farmers can adopt new technology such as planting new coffee varieties is given to each group of farmers from each region. This is because some of these farmers may lack proper information about the new technology. According to [31], farmers can replace their coffee trees by rows and so they can still get some yield from the old trees while waiting for the new ones to produce.

4.3.4. Crop Failure Due to Water Shortage

It was observed that farmers who have experienced more crop failure due to water shortage are more likely to have positive perceptions of climate change than farmers without such experience. According to [18], a rise in temperature in areas where farm production has already been hampered due to water shortage is likely to make farmers aware of adverse climate conditions.

4.3.5. Access to Climate Information

Farmers' access to climate information increases the probability of having positive perceptions of climate change. Other studies have also reported that farmers with better access to climate change information were more likely to perceive climate change [19,30]. This relationship arises because farmers' access to information on climate change broadens their information base and hence their probability to perceive climate change [18]. These findings also show that the majority of the respondents who were aware of climate change accessed climate information through various media such as TV, radio, and mobile phones. Thus, economically secure farmers are also more likely to perceive climate change positively than those who are economically insecure [28]. According to [8], developing countries need more tangible and accessible climate information in order to improve farmer's resilience through the impacts of climate change. In this study, access to climate information positively influenced the use of terraces and cut-off drains. Farmers who access climate information are more likely to be aware that climatic conditions are changing. According to [19], farmers' access to climate information increases the possibility of farmers to perceive climate change and take remedial actions against climate change. This is probably why farmers who had access to climate information opted to use terraces and cut-off drains as remedial action toward climate change.

4.3.6. Time Aware of Climate Change

Farmers who heard about climate change in most recent years are more likely to perceive climate change than those who heard about it a long time ago. This is in agreement with [15], who noticed that some famers place more weight on recent information. The time in which farmers obtained information about climate change significantly influenced the likelihood of using terraces, cut-off drains, irrigation, and intensification of routine activities (pruning, pest and disease control).

4.3.7. Farm Size

Perception of climate change in terms of increase in temperature and decrease in rainfall was not influenced by the size of the farm ($p > 0.05$). However, farmers possessing larger farm sizes had a higher probability of cultivating disease-tolerant varieties and carrying out soil and water conservation activities through use of terraces and planting shade trees than farmers cultivating in small farm sizes. According to [32], farmers with larger coffee fields are more likely to adapt climate change adaptation practices because they have more capital and resources. Coffee farmers with larger farm sizes are able to adopt tolerant coffee varieties, as they can still keep their old varieties while establishing new varieties in other fields and gradually replant the whole area with tolerant varieties. Due to the fact that a coffee plant is perennial, taking up to three years for famers to start harvesting, it is difficult to uproot all old trees and replant new ones. In additions, farm size negatively influences the use of mulches. This could be due to the fact that the management of large farms requires more capital and resources; hence becoming difficult for smallholder farmers to obtain enough mulching materials for the bigger farms.

4.3.8. Access to Extension Services

Access to extension services influenced farmers to plant shade trees in coffee fields as well as use cut-off drains, soil fertility management, and terraces than farmers growing coffee without access to such services. Farmers with access to extension services are more likely to perceive changing climatic conditions [18] and to have knowledge of the various management practices that they can use to adapt to such changing conditions [32]. However, in this study, access to extension services had no significant influence on the perceptions of climate change. Despite the great role of extension agents in disseminating knowledge and skills of how farmers should adapt to climate change, the majority of farmers reported not receiving any services from extension agents. Therefore, it is important for the policy makers to develop institutions that will enhance the access of extension services to farmers.

5. Conclusions

The results demonstrated that coffee farmers from the Northern and Southern Highland of Tanzania have experienced changes in climate (increase in temperature and decrease in rainfall). Moreover, climate change has already impacted coffee production in terms of reduction in yield, increase in coffee insect pests and diseases, late flowering, prolonged harvesting, and total crop failure in more adverse conditions. Climate change will continue to affect farmers' livelihood unless adaptation measures are taken. Recent awareness of climate change, access to climate change information, education level and the sex of the household head, and farming experience are factors affecting farmers' climate change perceptions. Smallholder farmers have been responding to unpredictable weather patterns in different ways with their level of response being influenced by the gender of the household head, education level, farming experience, farm size, access to extension services, and time aware of climate change information. Based on these results, it is recommended to enhance access to timely and accurate weather information together with developing institutions that enhances access to education and extension services. Each group of farmers with different levels of education should also be trained or advised in a different way. The focus of education or training should be on attenuating the impacts of climate change through relevant adaptation measures in each coffee-growing region. The findings of this study are also applicable to other areas growing coffee under similar conditions.

Author Contributions: Conceptualization, S.G.M., S.K.M. and A.J.P.T.; methodology and software, S.G.M.; validation, S.K.M.; formal analysis, visualization, and writing—original draft preparation, S.G.M.; project supervision, S.K.M. and A.J.P.T.; review and editing, S.K.M. and A.J.P.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research and APC were funded by Tanzania Coffee Research Institute (TaCRI).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data on rainfall and temperature were acquired from Lyamungo and Burka Coffee estate (Northern Highlands zone) and Mbimba and Mbinga (Southern Highlands zone) offices of the Tanzania Meteorological Agency (TMA) with the exception of data from Burka Coffee estate, which were acquired from a private operator.

Acknowledgments: The authors wish to acknowledge the generous financial support from coffee farmers in Tanzania and the Ministry of Agriculture to the Tanzania Coffee Research Institute which facilitated the Institute to fund this study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Demographic characteristics of farmers from two major coffee-growing zones (%).

	NorthernHighlands Zone					Southern Highlands Zone	
	Arumeru	Hai	Moshi	Rombo	Siha	Mbinga	Mbozi
	(n = 34)	(n = 27)	(n = 41)	(n = 30)	(n = 29)	(n = 41)	(n = 40)
Age (years)							
41–50	44	15	24	13	34	39	45
51–60	32	33	12	37	28	49	42.5
61–70	15	41	29	23	21	5	12.5
70–80	9	7	24	20	7	7	0
>80	0	4	10	7	10	0	0
Farm size (ha)							
<0.5	59	24	53	41	29	15	18
0.5–1	26	38	41	29	44	47	29
1.2–1.4	3	6	15	18	6	18	38
1.5–2	6	12	9	0	3	15	32
>2	6	0	3	0	3	26	0
Education level							
No formal education	18	4	7	13	14	2	0
STD 1-VII	62	59	73	60	76	78	77.5
Form I-IV	0	26	12	7	7	7	20
Form V-VI	6	4	0	0	0	0	0
College	9	4	2	0	0	0	0
University	0	0	2	3	0	0	0
Farming experience (Years)							
10–19	21	15	10	13	21	12	18
20–29	32	30	22	33	34	44	43
30–39	29	11	32	20	21	37	25
40–49	12	33	24	20	17	0	15
>50	6	11	12	13	7	7	0
Sex of the respondent							
Male	88	78	73	77	79	71	78
Female	12	22	24	23	21	29	22

n = Number of households.

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