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Intra-gendered perceptions and adoption of climate-smart agriculture: Evidence from smallholder farmers in the Upper East Region of Ghana

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ABSTRACT

Climate-smart agriculture (CSA) remains a key strategy for sustaining agricultural systems and achieving food security and nutrition. Despite this, uncertainty remains on how intra-gendered dynamics influence its adoption in dryland farming systems. This study implements both quantitative and qualitative approaches including household surveys, key informant interviews, and focus group discussions to explore how intra-gender dynamics shape the perceptions and adoption of climate-smart agriculture in three selected communities (Katanga, Dakio, and Zonno) in the Bolgatanga East District of the Upper East Region of Ghana. Specifically, the study answers the following research questions: (i) What is the degree of change in rainfall and temperature in the Bolgatanga East District? (ii) How does gender shape the perception of smallholder farmers on climate variability in the study communities? (iii) Which CSA interventions are employed by smallholder farming households in the study communities? (iv) Which socio-demographic factors influence intra-gendered perceptions and adoption of CSA in the study communities? Binary logistic regression was used to identify the factors influencing male and female farmers' perceptions and adoption of climate-smart agriculture. Rainfall and temperature trends from 2010 to 2020 were analyzed using the Mann-Kendall trend test. We found that over the past ten years, smallholder farmers in the district have seen rising temperatures and erratic rainfall patterns. Less educated female smallholder farmers adopted CSA interventions relative to more educated female farmers. Married male smallholder farmers employed CSA interventions on their farms compared to single and divorced male farmers. The adoption of CSA was higher for female farmers with inherited farmland than for those with rented land. Our results indicate that the source of income and farming experience influence male smallholder farmers' adoption of crop rotation and their decision to diversify crops on their farms. The farmland tenure system, farming experience, and income source of female farmers influence their choice to change planting dates. The study recommends the integration of intra-gendered dynamics in policy reforms to reduce the vulnerability of smallholder farmers with different socioeconomic characteristics to climate variability in Ghana.

1. Introduction

Ghana's smallholder farmers are already experiencing the impacts of climate change, including unpredictable rainfall, rising temperatures, frequent droughts, pests, and disease outbreaks (Diko et al., 2021). Food security is adversely affected, and this has a negative impact on achieving Sustainable Development Goals (SDGs) 1 and 2. Overreliance on rainfall for agriculture by smallholder farmers in the country exacerbates the effects of a changing climate on their livelihoods (Makate et al., 2019). In Ghana, temperatures rise across different agroecological zones, whereas rainfall decreases and becomes more erratic (Asante & Amuakwa-Mensah, 2015). Floods and droughts associated with climate change and potentially affecting food production are anticipated to become more pronounced, particularly among the most vulnerable smallholder farmers (Antwi-Agyei et al., 2021b).

A significant adaptation measure to ensure global and household food security is the adoption of climate-smart agriculture (CSA). The Food and Agricultural Organization (FAO) defines CSA as agriculture that sustainably enhances productivity, improves resilience (adaptation), reduces greenhouse gas (GHG) emissions (mitigation) to the greatest extent possible, and contributes to national food and nutrition security and development goals (FAO, 2013). Therefore, this context is embraced globally as an approach to transforming and protecting the agricultural sector. In fact, the Government of Ghana (GoG) through the Ministry of Food and Agriculture (MoFA) designed the Ghana Agriculture Sector Investment Programme (GASIP) which focused on CSA

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adoption to enhance climate change resilience among smallholder farmers and resource-poor rural people (MoFA, 2016). There is an emerging literature on CSA interventions across sub-Saharan Africa. For example, Abegunde et al. (2019) found that CSA interventions, such as using organic manure, crop rotation, and crop diversification, enhance the average monthly farm revenue in the Mthonjaneni Municipality of South Africa. Adopting CSA reduces food insecurity by 44% and enhances dietary diversity by 22% for a typical adopting family. As Zougmoré et al. (2016) reported, across West Africa CSA interventions, including conservation agriculture, alternating wetting, and drying for rice production, and agroforestry, help to establish sustainable cropping systems. The motivations and barriers to adopting CSA by smallholder farmers in the transitional and savannah agroecological zones of Ghana have been explored by Antwi-Agyei et al. (2021a). Others, such as Akrofi-Atitianti et al. (2018), investigated the determinants of CSA practice among cocoa production systems in Ghana. Despite this, research on intra-gendered differences in the awareness and adoption of climate-smart agriculture in dryland agricultural systems has been largely ignored. This hampers gender-specific climate change policies and plans that address the different socioeconomic contexts in which CSA adoption occurs. Therefore, there is a need to explore the awareness and adoption of climate-smart agriculture from an intra-gendered perspective to offer policymakers the opportunity to incorporate intra-gender dynamics in the development of climate change policies and interventions to reduce smallholder farmers' vulnerability to the variable climate.

This study aimed to explore how intra-gendered dynamics influence smallholder farmers' perceptions and adoption of climate-smart agriculture using empirical data from Bolgatanga East District in Ghana's Upper East Region by posing these questions: (i) What is the degree of change in rainfall and temperature in the Bolgatanga East District? (ii) How does gender shape the perception of smallholder farmers on climate variability in the study communities? (iii) Which CSA interventions are employed by smallholder farming households in the study communities? (iv) Which socio-demographic factors influence intra-gendered perceptions and adoption of CSA in the district?

2. Gender and climate change adaptation in Ghana

The Upper West, Northern, and Upper East regions of Ghana are the most deeply agrarian regions where much labor is invested in agriculture with fewer returns, highly insecure agricultural livelihoods, and prevalent malnutrition (Ghana Statistical Service, 2014). In semi-arid Ghana, women are more involved in all agricultural activities than men (Ahmed et al., 2016). Female-led agricultural production is increasingly becoming more market-oriented than its male counterpart in Ghana because women immediately send cultivated crops to the market after harvest (GSS, 2014). This proportional growth of crops by gender reflects gendered patterns in agriculture and options for climate change adaptation. For instance, of the three million people actively involved in agricultural production in the country, about 43.43% and 56.56% respectively females and males are employed in the sector (FAO, 2015).

Many smallholder farmers in sub-Saharan Africa employ different coping and adaptation strategies to minimize their vulnerability to the impacts of climate change (Stanturf et al., 2011). Smallholder farmers use coping strategies to deal with the dangers of food insecurity and income loss caused by climatic and non-climatic stressors (Assan et al., 2018). Assan et al. (2020) found a gendered pattern in the coping measures adopted by households in Lawra District of the Upper West Region of Ghana. Female-headed households borrow money from friends and relatives (45%), sell wild fruits and vegetables (29%), make groundnut paste and local soap for sale, and migrate to major cities to offset the negative effects of climate stress. During the dry season, female heads engage in these activities because of their inability to raise capital to undertake livelihood options, such as soap-making and beekeeping. To cope with the effects of climatic shocks, their male counterparts engage in activities such as selling cattle, relocating in search of work, and relying on harvested crops (16%) (Assan et al., 2018). Households reduce their daily intake and skip animal proteins when coping methods for food and income decrease, leading to malnutrition, particularly among mothers and small children (Assan et al., 2020).

Developing countries and those living in poverty are disproportionately affected by climate change, which exacerbates existing disparities in access to food, clean water, and general well-being (Aguilar & Castaeda, 2008). Women have more health and life expectancy risks than males and are more vulnerable to floods, droughts, severe rain, and water scarcity (World Health Organization [WHO], 2014). The changing climate is an extra burden, pushing people into chronic poverty by severely hindering their access to livelihoods (Olsson et al., 2014). The scarcity of essential resources such as firewood and water heightens the burden on rural women. Women are more vulnerable not because they are naturally weaker but because they face different conditions of vulnerability than men (Aguilar & Castaeda, 2008). For example, rural women, particularly in northern Ghana, are burdened with family upkeep, feeding their children, and assuming most household responsibilities. In the northern regions of Ghana, if a child is hungry, he or she goes to the mother and not to the father. Mothers spend most of their time with their children, while fathers hardly stay at home. Fathers hardly remove chop-money; hence, women must work to provide food for their children. Aguilar and Castaeda (2008) also found the representation of women in the climate change adaptation and mitigation decision-making processes to be low. These indicate that people who are more socially and economically marginalized are the most vulnerable to the effects of the changing climate.

Gender inclusion in the adoption of climate-smart agriculture is essential. Studies, such as Ahmed et al. (2016), posited that understanding gender-differentiated vulnerability, risk exposure, coping capacity, and women's ability to recover from climatic shocks requires knowledge of unequal power relations and levels of resource availability. For example, Antwi-Agyei et al. (2017) found that gender roles can influence vulnerability to climatic variability and the adoption of adaptation practices. Remteng et al. (2021) also noted how addressing gender issues may have positive effects on climate mitigation and adaptation as well as sustainable development, particularly in the management of water resources and agriculture. Therefore, it is imperative to appreciate how intra-gender roles influence the perceptions and adoption of climate-smart agriculture to reduce the threats of climate variability in dryland farming systems.

3. Study design and methods

3.1. Description of the study area

One of the smallest administrative regions in Ghana is the Upper East region. The region has a total land area of 8842 km^2s (Ghana Statistical Service [GSS], 2014). Bolgatanga East District (Fig. 1) was chosen for this study from among the region's 15 districts based on its vulnerability to climate variability (Baffour-Ata et al., 2021). Created with the Legislative Instrument (LI) 2350, the Bolgatanga East District has Zuarungu as its capital. It is bordered to the north by the Bongo District, south and east by Talensi and Nabdam District, and Bolgatanga Municipality to the west and has a total land area of 70.80 km^2s (GSS, 2014).

The climate of the region is characterized by a rainy season from May/June to September/October, with a mean annual rainfall of 800–1100 mm. Long dry spells with dusty harmattan winds continue during the dry season, which lasts from November until mid-February (Ghana Statistical Service, 2014). Savannah woodlands make up the district's native vegetation, which is distinguished by its sparsely spaced, drought-resistant trees and grasses. Agriculture is the sole livelihood option for smallholder farmers amid the permeating effects of the changing climate on agriculture in the region. The district exclusively depends on rain-fed subsistence farming, with over 92.2% engaged in agriculture

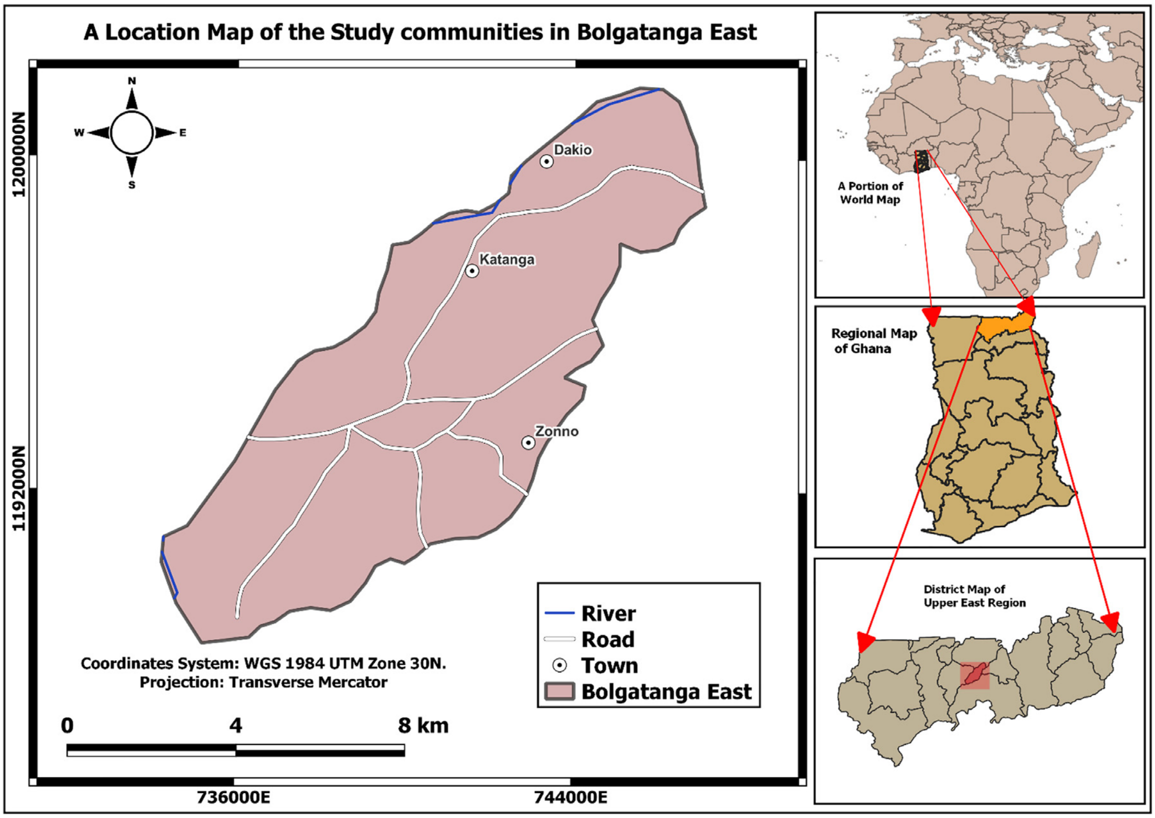

Fig. 1. Location map of the study communities.

Table 1
Selection of the study respondents.

Community	Smallholder farmers		Total
	Males	Females	
Katanga	38	32	70
Dakio	37	33	70
Zonno	32	38	70
Total	107	103	210

(GSS, 2014). Cultural systems impose certain restrictions on women in the district (Apusigah, 2004).

3.2. Data collection

Three communities, namely Dakio, Katanga, and Zonno, were purposively selected based on the advice of agriculture extension agents (AEAs) and their participation in the Ghana Agriculture Sector Improvement Programme (GASIP). This study employed a mixed-method approach involving household surveys, key informant interviews, and focus group discussions (FGDs) to collate information on how male and female smallholder farmers perceive climate variability from 2010 to 2020 in the Bolgatanga East District and the climate-smart agricultural interventions that smallholder farmers use to address the threats of climate variability as well as factors that influence such adaptation options. A mixed-method approach allows the research questions to be studied from different perspectives. In addition, this approach helps combine subjective insights from qualitative research with generalized quantitative data (Regnault et al., 2018). The study utilized quantitative data taken from the Ghana Meteorological Agency (GMet) as well as qualitative data taken in February 2022 from 107 male and 103 female-headed households in three communities in the district (see Table 1). In all, two hundred and ten (210) farming households were selected for the study by simple random sampling technique. This was obtained from the total household population of 131, 550 (GSS, 2014) using Yamen's (1967) formula: $n = [\frac{N}{(1+N(e^2)}]$, where n denotes the unknown sample size, N= total population of the district, "e" which is the margin of error. In this study, the allowable error was set as 5%. A cross-sectional research design was employed in the study to investigate a variety of qualitative and quantitative data. De Boer et al. (2016) reported that using a cross-sectional design helps to estimate the exposures and outcomes of study participants at the same time. The use of a cross-sectional design helps to evaluate the beliefs, attitudes, and behaviors of a population (Xiang et al., 2016). A one-day preliminary survey was carried out together with the agricultural extension agents in each of the study communities to introduce the research to the study communities in their local language (Gurene). The household survey questionnaire and the focus group discussion guide were randomly pre-tested in each of the study communities during the preliminary survey. In all, seventy (70) participants each from Katanga, Dakio, and Zonno were used in the study. To generate gender-specific responses, two separate focus group discussions comprising 10 male and 10 female farmers were set up in each community. Participants in the focus group discussions demonstrated a comprehensive understanding of climate variability and CSA interventions during the household surveys. In addition, 3 key informant interviews were conducted in each community with the community leaders who share appreciable knowledge of climate variability, to elicit more comprehensive responses. Responses from both the focus group discussions and key informant interviews were recorded using mobile phones. The recorded voices were played several times and transcribed with the help of the agricultural extension agents who were proficient in the local language (Gurene).

3.3. Data analysis

The district's historical trends in rainfall amounts, intensities, and minimum and maximum temperatures were determined using a time series analysis. Sen's slope estimator was used to estimate the magnitude of the trend, and the Mann-Kendall trend test was used to analyze trends (Baffour-Ata et al., 2021). The Mann-Kendall test hypothesizes an insignificant trend in the time series. Baffour-Ata et al. (2021) employed the Mann-Kendall test to examine the trend of rainfall and temperature due to its non-parametric nature and lower susceptibility to outliers. According to Connor et al. (2014), the Mann-Kendall trend test calculation is given by

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} rij \quad (1)$$

Where rij = sign (xj – xi) = +1 if xj – xi > 0 = 0 if xj – xi = 0 = -1 if xj – xi < 0

An extremely high positive S value denotes an upward trend, whereas an extremely low negative value denotes a downward trend. The district variance in rainfall and temperature was calculated using the coefficient of variation (CV). In earlier studies, such as those by Jamal et al. (2021) and Baffour-Ata et al. (2021), the method for estimating CV is highlighted.

Data from household surveys were coded for analysis using IBM Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistics, including frequency and percentages, were used to quantify the data obtained from the household surveys. The chi-square test was used to assess the relationship between variables. A 95% significance level (α) was used.

The chi-square statistics is computed as:

$$x_c^2 = \sum \frac{\left(O_i - E_i\right)^2}{E_i} \quad (2)$$

Where: C = degree of freedom

Oi = observed value

Ei = expected value

Factors that influence smallholder farmers' perceptions of variability in the climate, as well as the adoption of climate-smart agricultural interventions, were analyzed in a binary logistic regression model framework (Fosu-Mensah et al., 2012). The binary logistic regression model has been used by Ali et al., 2021 to explore factors influencing how farmers cope and adapt to climate change.

The binary logistic model for 'k' independent variables (X_1, X_2, X_3, …, X_k) is given in Eq. (3):

$$\text{Logit P(X)} = \alpha + \sum_{i=1}^{k} \beta_i x_i \quad (3)$$

Exp (β_i) = odds ratio for a person having characteristics i versus not having.

β_i = regression coefficient

α = constant.

The two dependent variables used in the model analysis were perception of climate variability and adoption of CSA, while the independent variables were socio-demographic characteristics such as age, farmland tenure system, household size, access to climate information, and access to extension services. Fosu-Mensah et al. (2012) have shown that these factors may influence climate change perception and the demand for adopting a climate adaptation strategy. Thematic analysis was used to analyze the qualitative data from the focus group discussions and key informant interviews (Maguire & Delahunt, 2017). This study employed thematic analysis because of the wide variety of research questions. Thematic analysis reduces data in a flexible manner compared with other data analysis methods (Castleberry & Nolen, 2018). Relevant quotations from key informants and focus group discussants were used to emphasize the discourse.

4. Results

4.1. Sociodemographic characteristics of the study respondents

Among the 210 smallholder farmers interviewed, 107 (51%) were males and 103 (49%) were females (Table 2). Most study respondents

Table 2
Sociodemographic characteristics of the study respondents.

Variable	Gender		All	X^2	*p*-value
	Male (*n* = 107)	Female (*n* = 103)	(*N* = 210)		
Age (years)				11.559	0.009
30 and below	6 (5.61)	12 (11.65)	18 (8.57)		
31 – 40	11 (10.28)	22 (21.36)	33 (15.71)		
41 – 50	22 (20.56)	26 (25.24)	48 (22.86)		
Above 50	68 (63.55)	43 (41.75)	111 (52.86)		
Educational level				4.980	0.173
No formal education	79 (73.83)	64 (62.14)	143 (68.10)		
Basic	15 (14.02)	27 (26.21)	42 (20.00)		
Secondary	10 (9.35)	9 (8.74)	19 (9.05)		
Tertiary	3 (2.80)	3 (2.91)	6 (2.8)		
Marital status				1.945	0.378
Single	8 (7.5)	4 (3.9)	12 (5.7)		
Married	95 (88.8)	97 (94.2)	192 (91.4)		
Divorced	4 (3.7)	2 (1.9)	6 (2.9)		
Household size				1.561	0.458
1–5	24 (22.43)	27 (24.29)	51 (24.29)		
6–10	50 (46.73)	102 (48.57)	102 (48.57)		
11–15	33 (30.84)	57 (27.14)	57 (27.14)		
Income source				6.697	0.035
Farming	83 (77.57)	69 (66.99)	152 (72.38)		
Non-farming	24 (22.43)	34 (33.01)	58 (27.61)		
Farming experience (years)				10.865	0.004
Below 10 years	7 (6.54)	15 (14.56)	22 (10.48)		
10–20 years	17 (15.89)	30 (29.13)	47 (22.38)		
Above 20 years	83 (77.57)	58 (56.31)	141 (67.14)		
Farmland tenure system				3.323	0.190
Rented	4 (3.74)	9 (8.74)	13 (6.19)		
Inherited	98 (91.58)	92 (89.32)	190 (90.48)		
Purchased	5 (4.67)	2 (1.94)	7 (3.33)		

Values in parenthesis are in percentage relative to the sub-total of males (107) and females (103) denoted by "n" and the sample population (210) denoted by "N. X^2 denotes Pearson's Chi-square.

Table 3
Gender and perceptions of climate variability.

Variables	Reduced		Increased		X^2	p-value
	Male ($n = 107$)	Female ($n = 103$)	Male ($n = 107$)	Female ($n = 103$)		
Rainfall onset	74 (69.2)	71(68.9)	33 (30.8)	32 (31.1)	0.001	0.972
Rainfall intensity	61 (57.0)	61 (59.2)	46 (43.0)	42 (40.8)	0.106	0.745
Rainfall amount	56 (52.3)	54 (52.4)	51 (47.7)	49 (47.6)	0.000	0.989
Temperature	8 (7.5)	6 (5.8)	99 (92.5)	97 (94.2)	0.230	0.632
Dry spell	51 (47.7)	40 (38.8)	56 (52.3)	63 (61.2)	1.666	0.197
Heatwave	13 (12.1)	13 (12.1)	94 (87.9)	90 (87.4)	0.011	0.917
Windstorm	17 (15.9)	18 (17.5)	90 (84.1)	85 (82.5)	0.095	0.758

Percentages and respondent counts are shown as numbers within and outside parentheses. X^2 demotes Pearson's Chi-square.

(n = 111; 53%) were over 50 years old. In addition, most respondents (n = 143; 68%) had no formal education. The majority of households (n = 152; 72%) were dependent on crop farming. Approximately 141 of the study respondents (67%) had over 20 years of farming experience.

4.2. Gender and perceptions of climate variability in the study district

Smallholder farmers' perceptions of climate variability are presented in Table 3. The results showed that there was no significant difference ($p > 0.05$) in the experiences of climatic variability among smallholder farmers in the study communities. Both male and female smallholder farmers reported changes in rainfall onset, intensity, and volume, as well as temperature, dry spells, heat waves, and windstorms. The majority (69%) of the respondents perceived a reduction in rainfall onset compared to ten years ago. Both male (52.3%) and female (52.4%) farmers indicated that the rainfall amount was poor. Regarding temperature, 93% of male and 94% of female farmers perceived increasing temperatures in the study communities over the last ten years. Discussions in the focus groups emphasized variability in the climate (Appendix 2A and Appendix 2B). For example, some farmers reported the following.

"These days, the rainfall amount has reduced. It rains once and stops after ploughing. We prepare the lands to start planting and the rains do not come as expected." (Female FGD, Zonno, February 2022).

Another group reinforced this, stating that "Compared to the past, temperatures are high nowadays. The high temperature causes our maize to dry and fall off the plant. Even the seeds we sow do not germinate because of high temperatures." (Male-FGD, Katanga, February 2022).

4.3. The degree of change in rainfall and temperature in the Bolgatanga East District

According to the findings, there was a 21.9% variability in the Bolgatanga East District rainfall pattern between 2010 and 2020. The year 2019 recorded the highest annual rainfall (1363.4 mm), whereas 2014 recorded the lowest (617.3 mm) (Fig. 2A). The trend line indicates that rainfall in the district has decreased, even though it was not statistically significant ($p = 0.640$). Furthermore, the district's temperature varied by around 1.4% during the study period, with the greatest annual temperature of 36.2 °C recorded in 2020. (Fig. 2B). The temperature in the district increased from 2010 to 2020, as indicated by a p-value of 0.219.

4.4. Intra-gendered perceptions and adoption of climate-smart agricultural interventions

Appendix 1A, 1B, 1C and 1D, male and female farmers' decisions about which climate-smart agricultural intervention to employ to lessen the effects of climatic variability are highlighted. The results indicate that less educated female farmers are more likely to adopt climate-smart agriculture interventions than are relatively more educated female farmers. Similarly, the results showed that more educated male farmers do not use climate-smart agriculture compared to less educated farmers. Additionally, our analysis revealed that married female smallholder farmers use climate-smart agriculture on their farms more than single and divorced female farmers. In addition, married male farmers in the study communities employ CSA interventions such as crop rotation (78%), crop diversification (63%), and stone bunding (81%), as compared to single and divorced male farmers. Moreover, the results indicated that female farmers with inherited farmlands have a higher chance of adopting climate-smart agriculture interventions than female farmers with rented farmland. Similarly, the adoption of CSA interventions was higher among male farmers with inherited farmland than those with rented land. The analysis further showed that female farmers whose livelihoods primarily depend on crop farming employ climate-smart agriculture compared to female farmers with non-farming livelihood options. Similar findings were recorded for male smallholder farmers who depend on farming as their main source of income compared to those who rely on non-farming livelihoods (see Appendix 1D). For instance, some farmers reported these during key informant interviews.

"It is not every farmland that is fertile. It is difficult to farm millet and maize differently because we do not have enough farmland. We, therefore, grow them all together so that we can get enough to feed our families." (A married female key informant interviewee, Zonno, February 2022).

"The rains do not come always. When it rains once, we do stone budding to conserve water for the rice to grow. Sometimes too, the floods carry manure away from the crops and we do stone bunding to prevent it. I have to do this to obtain rice for the market. If not, I cannot pay my children's school fees." (A married male key informant interviewee, Dakio, February 2022).

4.5. Factors influencing male and female smallholder farmers' perceptions and adoption of climate-smart agriculture

The results revealed that the source of income ($p = 0.030$) of male smallholder farmers influences their perceptions and adoption of crop rotation (Table 4). However, their female counterparts highlighted that household size ($p = 0.020$), income source ($p = 0.015$), and farming experience ($p = 0.021$) influence their adoption of crop rotation. The farming experience ($p = 0.007$) and household size ($p = 0.049$) of male smallholder farmers influence their decision to diversify crops on their farmland. However, the source of income ($p = 0.018$) of female farmers determines their decision to diversify crops on their farmlands. The results showed that the farmland tenure system ($p = 0.062$) and farming experience ($p = 0.027$) are the key factors influencing female smallholder farmers' choice to change planting dates. The results highlight that both male and female smallholder farmers store seeds for emergencies. However, farming experience and income sources influence how male smallholder farmers perceive and adopt this practice. However, their female counterparts indicated that their adoption was largely influenced by the farmland tenure system available to them ($p = 0.062$).

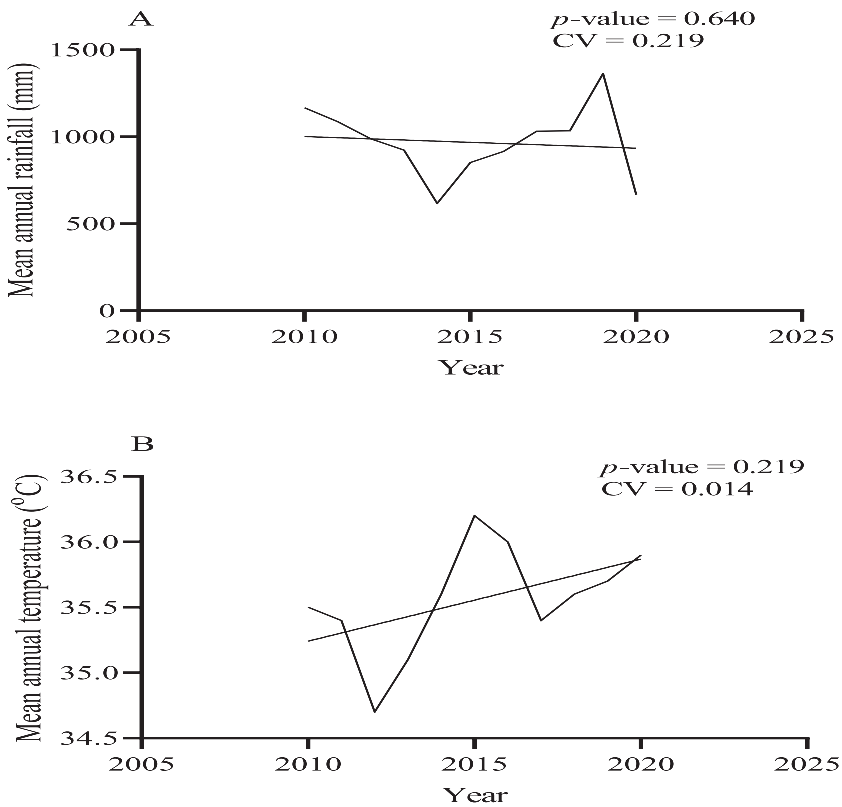

Fig. 2. Mean annual rainfall (A) and temperature (B) trend for the study district.

Table 4
Binary logistic regression of factors influencing smallholder farmers' perceptions and adoption of climate-smart agriculture.

Socio-demographics	Male smallholder farmer					
	Crop rotation	Crop diversification	Mulching	Timely harvesting	Seed banking	Changing planting date
Income source	-0.997 (0.030) *	-5.503 (0.179)	1.248 (0.010) *	1.738 (0.233)	1.141 (0.030) *	15.023 (0.998)
Household size	0.281 (0.545)	0.699 (0.049) *	0.136 (0.654)	-0.373 (0.635)	-0.163 (0.0612)	-0.290 (0.604)
Farming experience	-1.270 (0.182)	1.686 (0.007) *	0.667 (0.245)	2.220 (0.034) *	1.208 (0.049) *	-7.826 (0.999)
-2 Log likelihood (R^2)	69.822[a] (0.160)	112.241[a] (0.240)	130.261[a] (0.146)	31.963[a] (0.241)	118.664[a] (0.149)	43.866[a] (0.184)
	Female smallholder farmer					
Income source	-0.913 (0.015) *	-0.829 (0.018) *	0.482 (0.179)	-0.515 (0.404)	0.745 (0.179)	0.274 (0.697)
Household size	1.072 (0.020) *	-0.244 (0.544)	0.384 (0.240)	0.085 (0.906)	-0.754 (0.056)	-1.227 (0.136)
Farming experience	1.050 (0.021) *	0.707 (0.134)	0.498 (0.235)	-1.412 (0.232)	-1.006 (0.130)	2.228 (0.027) *
Farmland tenure system	0.347 (0.642)	1.188 (0.118)	1.182 (0.111)	-0.534 (0.842)	2.095 (0.045) *	-3.656 (0.062)
-2 Log likelihood (R^2)	49.242[a] (0.156)	94.387[a] (0.261)	123.195[a] (0.129)	37.126[a] (0.086)	90.938[a] (0.190)	35.420[a] (0.362)

p-values and standardized beta coefficients (β) are denoted by numbers within and outside parentheses.*(p-value is significant at the 95% confidence interval).

5. Discussion

5.1. The degree of change in rainfall and temperature in the Bolgatanga East District

The trends in temperature and rainfall were consistent with what smallholder farmers reported. The analysis revealed variations in rainfall patterns and increasing temperatures in the study district (Appendix 2A and Appendix 2B). The trend analysis supports several studies, including that by Baffour-Ata et al. (2021) and Antwi-Agyei et al. (2014) who reported that temperature has been increasing with variable rainfall in the northern regions of Ghana. Adu-Boahen et al. (2019) reported that prolonged high temperatures coupled with erratic rainfall characterized the climatic trends in the region. This indicates that smallholder farmers in the region experience extreme drought and dry spell conditions that affect their agricultural livelihoods (Stanturf et al., 2011). This trend is expected to continue because temperature levels are projected to increase with decreasing rainfall in all agroecological zones of Ghana (Environmental Protection Agency [EPA], 2021). The downward trend of rainfall in the district could accelerate drought, which would hinder dry-season farming as dugouts and rivers dry up. Drought reduces crop yield by reducing soil moisture and water availability for crop growth. As agriculture in Ghana is rainfall-dependent, crop farming could reduce drastically in the district.

5.2. Gender and perceived climate variability in the Bolgatanga East District

How smallholder farmers perceive climate variability in Bolgatanga East District mirrored the climatic data trends received from the Ghana Meteorological Agency (GMet). Both male and female smallholder farmers affirmed that temperatures were increasing, and the district received little rain. Owing to their shared understanding of climate variation, male and female smallholder farmers are better equipped to understand how crop cultivation is impacted by climate variability. Action-

Aid Ghana and other non-governmental organizations are increasing women's access to agricultural opportunities in Ghana's northern regions. Through these initiatives, gender inequalities that hinder the productivity of Ghanaian women in agriculture are reduced. These findings are consistent with those of Assan et al. (2020), who reported that men and women share similar views on rainfall and temperature changes. Additionally, the results agree with those of Jamal et al. (2021) found that smallholder farmers in the central region of Ghana have perceived increased temperatures over the past 15 years. The high temperatures and variable rainfall perceived by smallholder farmers in the study communities are factors causing water stress in the area.

5.3. Intra-gendered adoption of climate-smart agriculture in the Bolgatanga East District

The study showed that the adoption of climate-smart agricultural interventions was higher among less educated female farmers than among relatively more educated ones. This finding could be attributed to the fact that less educated female farmers solely depend on crop farming as their main source of income because they do not have the academic qualifications required by employers in off-farm jobs. As climate variability materializes, they utilize crop rotation, mulching, changing planting dates, and crop diversification, to reduce climatic threats to their livelihood. Non-educated farmers in the study communities indicated that they actively participate in extension service training organized by agricultural extension agents in the communities to learn about climate change adaptation options. However, the findings showed that the adoption of climate-smart agriculture was very low among female farmers with relatively high educational levels. This is because educated female farmers have access to off-farm income, which allows them to secure additional financial resources. They consider crop farming as a secondary source of income. Similarly, the results showed that relatively more educated male farmers do not use climate-smart agriculture as compared to less educated farmers. These findings contradict the nearly universal belief that access to education promotes climate change adaptation and enhances adaptive capacity (Antwi-Agyei et al., 2012; Walker et al., 2022).

The study also showed that married female farmers employ climate-smart agricultural interventions on their farms more than single and divorced female farmers do. Married female farmers in the study diversify crops on their farmland because they have more mouths to feed. Crop diversification, intercropping, and planting early maturing varieties of crops help them increase food production to sustain their households (Wrigley-Asante et al., 2019). The minimal adoption of CSA among single and divorced female farmers in the study communities is because single and divorced female farmers have less consumption per capita than their married counterparts, and hence, they are less affected by crop failure. In addition, they are likely to be less financially capable, leading to low adaptive capacity and the adoption of climate-smart agriculture interventions, such as emergency seed banking and fertilizer application. The results indicated that married male farmers employ climate-smart agriculture interventions, such as the rearing of animals, including poultry and livestock, to increase their household income as compared to single and divorced male farmers. It has long been customary for married Ghanaian men to protect and provide for their families (Sarfo et al., 2021). By virtue of this social norm, married men in the study communities employ different climate-smart agriculture to secure income and food for their household than single and divorced male farmers.

Further, the results showed that female farmers who had inherited farmland were more likely to adopt climate-smart agricultural interventions than those who had rented farmland; female farmers with rented lands operate within a timescale, so they cannot store seeds for the next growing season. However, female farmers with inherited farmlands participate in high-value crop production and diversify their crops to generate family income. As indicated by Feliciano, (2019), they are less dependent on men and have strong bargaining power in the household. A higher proportion of male smallholder farmers with inherited farmland tenure systems have adopted climate-smart agriculture than those with rented land. Male farmers with inherited farmland could decide to rotate crops on their land and translate processes of surface runoff by employing stone bunding and planting cover crops such as cowpea, pigeon pea, and groundnut to maintain soil fertility for agricultural productivity. The analysis showed that female farmers whose livelihoods primarily depend on crop farming in the study communities employ climate-smart agricultural interventions. They use a suite of climate-smart agriculture interventions to moderate the risks from climate variability. This finding supports those of Aryal et al. (2018) and Zougmoré et al. (2018) who highlighted that climate-smart agriculture increases productivity and helps farmers adapt their farming systems to the predicted effects of the changing climate. Female farmers who have choices for non-farming livelihoods are not likely to employ CSA interventions because they engage in off-farm livelihoods including selling cattle, working as food sellers, and depending on family and friends. Off-farm livelihood activities, as indicated by Antwi-Agyei et al. (2014), help smallholder farmers spread the risk of crop failure. Similar findings were recorded for male farmers whose source of income is on crop farming as compared to male farmers with non-crop farming livelihoods.

5.4. Determinants of intra-gendered adoption of climate-smart agriculture

Over 82% of both male and female farmers used crop rotation, although this was higher for males than females. The source of income was the main factor influencing the adoption of crop rotation among male farmers. Crop rotation involves planting different crops sequentially on the same plot. In most Ghanaian farming communities, the practice is of interest to farmers because it helps maintain soil fertility, reduce soil erosion, and increase crop productivity. Shah et al. (2021) explained that increased crop rotation systems increase farm revenue therefore farmers integrate different crops in the same area to raise their income. Similarly, Haque (2022) reported that an increase in farmers' income increases the probability of switching crops by 6.8%. For female farmers, household size, income sources, and farming experience influenced their adoption of crop rotation. Female farmers with a stable source of income and financing can purchase seeds of different crops. These results are consistent with Tufa et al. (2022), highlighting that women prefer producing diverse crops because of their social role as food crop producers. The results of the analysis show that household size has an impact on how smallholder farmers, both male and female, diversify their crops. The results presented are similar to those of Sichoongwe et al. (2014) who reported that smallholder farmers with large household sizes diversify their crops to increase food production levels.

As adaptation strategies, female farmers reported that they change planting dates because of their farming experience and access to a secured land tenure system. Experienced farmers are able to recognize the variability in climate and adjust their cropping calendars according to these changes. Families that have access to secured land make investments in agroforestry systems to increase their food security (Oyawole et al., 2020; Antwi-Agyei et al., 2021c). The results highlight that both male and female smallholder farmers store seeds for emergencies. Women have traditional roles as seed custodians, and as Howard-Borjas and Cuijpers (2002) indicated, they are responsible for tasks related to seed management, including the selection, storage, and preservation of seeds.

5.5. Linking intra-gendered adoption of climate-smart agriculture and development in Ghana

Considerable efforts to put development and the adoption of climate-smart agriculture in harmony have been met at the international level. In sub-Saharan Africa, agriculture and food systems are mostly included in national development plans (Zougmoré et al., 2018). For instance, a significant CSA alternative has been implemented in Malawi using a mix of basin tillage conservation agriculture, drought-tolerant maize cultivars, and pigeon pea intercropping (Mutenje et al., 2019). Similar actions to enhance the integration of climate-smart agriculture into policy development have taken shape at the national level. For example, in 2015, the Government of Ghana created the National Climate-Smart Agriculture and Food Security Action Plan (see Essegbey et al., 2015). In 2018, Ghana issued an Investment Framework for Resource Mobilization into Climate-smart Agriculture. Ghana's Ministry of Food and Agriculture in collaboration with the World Bank unveiled the Climate-Smart Agricultural Investment Plan (CSAIP) for Ghana in 2020 (Diko et al., 2021). The Ministry of Food and Agriculture in Ghana and other development organizations including the Consortium of International Agricultural Research Centers (CGIAR), the World Bank, and the Food and Agricultural Organization (FAO) are working to promote the adoption of climate-smart agriculture in the country.

Efforts to link climate-smart agriculture and development are perhaps most visibly articulated via national policies and frameworks. There is a growing recognition that climate variability has gender-differentiated impacts (Mensah et al., 2022; Aguilar, 2021; Lawson et al., 2020; Friedman et al., 2019). Therefore, the local-level integration of intra-gendered perceptions and adoption of climate-smart agriculture can be particularly valuable and should be encouraged through flexible policies to promote resilient agricultural systems for sustainable development in Ghana. For a truly effective, symbiotic approach to reducing the vulnerability of smallholder farmers with different socioeconomic characteristics to climate variability in Ghana, we will need a radical transformation in how we think about intra-gendered dynamics in society.

6. Conclusion

The responsibilities of male and female smallholder farmers affect how vulnerable they are to climate variability and how they choose to respond. Therefore, a study on the perceptions and adoption of climate-smart agriculture using a gender lens remains significant, especially in dryland farming systems. This paper explored rainfall and temperature changes, the perception of male and female smallholder farmers on climate variability, intra-gendered adoption of climate-smart agriculture interventions, and factors that influence such adoption in the Bolgatanga East District of the Upper East Region of Ghana. Trend analysis revealed an irregular rainfall pattern and an increase in temperature in the study communities. Both male and female smallholder farmers indicated that rainfall was poor, and temperatures increased compared with their childhood. The study also indicated that less-educated female smallholder farmers adopt climate-smart interventions than relatively more-educated female farmers. In addition, married male smallholder farmers employ CSA interventions on their farms more than single and divorced male smallholder farmers do. Also, the findings showed that it is more likely for female farmers with inherited farmland to adopt climate-smart agriculture than their male counterparts who have rented farmland. The source of income, farming experience, and household size influenced male smallholder farmers' adoption of crop rotation and the decision to diversify crops on their farms. The farmland tenure system, farming experience, and income source of female farmers influence their choice to change planting dates. This study recommends the integration of intra-gendered dynamics in policy reforms to reduce the vulnerability of smallholder farmers with different socioeconomic characteristics to climate variability in Ghana.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Appendix 1A
Intra-gendered adoption of climate-smart agricultural interventions.

CSA Interventions	Educational Level							
	Males (n = 107)				Females (n = 103)			
	N	B	S	T	N	B	S	T
Crop rotation	70 (65)	12 (11)	9 (8)	3 (3)	47 (46)	21 (20)	7 (8)	3 (3)
Crop diversification	58 (54)	7 (7)	6 (6)	3 (3)	47 (46)	22 (21)	6 (6)	3 (3)
Changing planting date	72 (67)	15 (14)	10 (9)	3 (3)	58 (56)	26 (25)	9 (9)	3 (3)
Appropriate use of fertilizer	72 (67)	13 (12)	10 (9)	3 (3)	59 (57)	24 (23)	7 (7)	3 (3)
Using traditional agroecological knowledge	70 (65)	15 (14)	10 (9)	3 (3)	60 (58)	24 (23)	9 (9)	3 (3)
Cover cropping	74 (69)	15 (14)	7 (7)	2 (2)	58 (56)	26 (25)	9 (9)	2 (2)
Mixed farming	77 (72)	15 (14)	10 (9)	3 (3)	64 (62)	25 (24)	9 (9)	3 (3)
Intercropping	73 (68)	14 (13)	9 (8)	3 (3)	63 (61)	26 (25)	9 (9)	3 (3)
Stone budding	71 (66)	13 (12)	9 (8)	2 (2)	60 (58)	25 (24)	6 (9)	3 (3)
Crop residue mulching	47 (44)	12 (11)	4 (4)	5 (5)	42 (41)	18 (17)	5 (5)	2 (2)
Timely harvesting of produce and storage	76 (71)	14 (13)	9 (8)	3 (3)	61 (59)	26 (25)	8 (8)	3 (3)
Emergency seed banking	54 (50)	11 (10)	8 (7)	2 (2)	50 (49)	23 (22)	7 (7)	2 (2)
Planting early maturing varieties of crops	78 (73)	15 (14)	10 (9)	3 (3)	60 (58)	26 (25)	9 (9)	3 (3)
Using climate information	59 (55)	11 (10)	9 (8)	3 (3)	49 (48)	23 (22)	7 (7)	3 (3)

Values in parenthesis are in percentage (%) relative to the sub-total of males (107) and females (103). *N*= no formal education *B*= basic education *S*= secondary education *T*= tertiary education.

Appendix 1B

CSA Interventions	Marital Status					
	Males (*n* = 107)			Females (*n* = 103)		
	Single	Married	Divorced	Single	Married	Divorced
Crop rotation	7 (7)	83 (78)	4 (4)	3 (3)	74 (72)	1 (1)
Crop diversification	5 (5)	67 (63)	2 (2)	2 (2)	75 (73)	1 (1)
Changing planting date	8 (7)	88 (82)	4 (4)	4 (4)	90 (87)	2 (2)
Appropriate use of fertilizer	7 (7)	87 (81)	4 (4)	4 (4)	87 (84)	2 (2)
Using traditional agroecological knowledge	8 (7)	87 (81)	3 (3)	4 (4)	90 (87)	2 (2)
Cover cropping	6 (6)	88 (82)	4 (4)	4 (4)	90 (87)	1 (1)
Mixed farming	8 (7)	93 (87)	4 (4)	4 (4)	95 (92)	2 (2)
Intercropping	8 (7)	87 (81)	4 (4)	4 (4)	95 (92)	2 (2)
Stone budding	6 (6)	87 (81)	2 (2)	3 (3)	90 (87)	1 (1)
Crop residue mulching	5 (5)	60 (56)	1 (1)	2 (2)	64 (62)	1 (1)
Timely harvesting of produce and storage	7 (7)	91 (85)	4 (4)	4 (4)	92 (89)	2 (2)
Emergency seed banking	6 (6)	67 (63)	2 (2)	3 (3)	77 (75)	2 (2)
Planting early maturing varieties of crops	8 (7)	94 (88)	4 (4)	4 (4)	92 (89)	2 (2)
Using climate information	7 (7)	72 (67)	3 (3)	3 (3)	78 (76)	1 (1)

Values in parenthesis are in percentage (%) relative to the sub-total of males (107) and females (103).

Appendix 1C

CSA Interventions	Farmland Tenure System					
	Males (*n* = 107)			Females (*n* = 103)		
	Rented	Inherited	Purchased	Rented	Inherited	Purchased
Crop rotation	3 (3)	86 (80)	5 (5)	4 (4)	73 (71)	1 (1)
Crop diversification	3 (3)	67 (63)	4 (4)	3 (3)	74 (72)	1 (1)
Changing planting date	4 (4)	91 (85)	5 (5)	9 (9)	86 (83)	1 (1)
Appropriate use of fertilizer	3 (3)	90 (84)	5 (5)	9 (9)	82 (80)	2 (2)
Using traditional agroecological knowledge	4 (4)	89 (83)	5 (5)	9 (9)	85 (83)	2 (2)
Cover cropping	1 (1)	93 (87)	4 (4)	8 (8)	85 (83)	2 (2)
Mixed farming	4 (4)	96 (90)	5 (5)	8 (8)	91 (88)	2 (2)
Intercropping	4 (4)	90 (84)	5 (5)	9 (9)	90 (87)	2 (2)
Stone budding	2 (2)	89 (83)	4 (4)	6 (6)	86 (83)	2 (2)
Crop residue mulching	2 (2)	61 (57)	3 (3)	2 (2)	64 (62)	1 (1)
Timely harvesting of produce and storage	3 (3)	94 (88)	5 (5)	9 (9)	87 (84)	2 (2)
Emergency seed banking	2 (2)	69 (64)	4 (4)	6 (6)	74 (72)	2 (2)
Planting early maturing varieties of crops	4 (4)	97 (91)	5 (5)	8 (8)	89 (86)	1 (1)
Using climate information	3 (3)	74 (69)	5 (5)	7 (7)	73 (71)	2 (2)

Values in parenthesis are in percentage (%) relative to the sub-total of males (107) and females (103).

Appendix 1D

CSA Interventions	Income Source			
	Males (*n* = 107)		Females (*n* = 103)	
	Farming	Non-farming	Farming	Non-farming
Crop rotation	77 (72)	17 (16)	57 (55)	21 (20)
Crop diversification	61 (57)	13 (12)	59 (57)	19 (18)
Changing planting date	76 (71)	24 (22)	65 (63)	31 (30)
Appropriate use of fertilizer	74 (69)	24 (22)	62 (60)	31 (30)
Using traditional agroecological knowledge	74 (69)	24 (22)	63 (61)	33 (32)
Cover cropping	77 (72)	21 (20)	66 (64)	29 (28)
Mixed farming	81 (76)	24 (22)	68 (66)	33 (32)
Intercropping	77 (72)	22 (21)	67 (65)	34 (33)
Stone budding	73 (68)	22 (21)	63 (61)	31 (30)
Crop residue mulching	47 (44)	19 (18)	43 (42)	24 (23)
Timely harvesting of produce and storage	79 (74)	23 (21)	66 (64)	32 (31)
Emergency seed banking	55 (51)	20 (19)	52 (50)	30 (29)
Planting early maturing varieties of crops	82 (77)	24 (22)	65 (63)	33 (32)
Using climate information	60 (56)	21 (20)	51 (50)	31 (30)

Values in parenthesis are in percentage (%) relative to the sub-total of males (107) and females (103).

Appendix 2A
Annual temperature data for the study district.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean (°C)
2010	37.5	40.1	40.4	40.1	36.5	32.9	31.3	30	30.9	33	37.2	36.6	35.5
2011	35.1	37.3	40.1	39.3	36.6	34.1	32.3	30.5	32.2	34.6	37.9	35.3	35.4
2012	35.1	37.9	39.9	38.6	34.1	33.2	31.1	30.6	31.3	33.5	36.5	35	34.7
2013	35.4	38.4	39.4	37.3	35	34.5	32	30.4	31	34.5	37.8	35.8	35.1
2014	36.7	37.8	39.3	37.9	35.8	34.6	33.9	31.8	30.9	35.6	37.4	36.1	35.7
2015	35.5	39.3	39.9	40.8	39.2	34.8	33	31.3	32.5	34.7	38.6	35.4	36.3
2016	35.8	33.8	37.1	37.8	36.5	33.8	35.8	36.2	36.5	34.7	37.7	35.9	36.0
2017	35.9	38.3	41.3	37.7	36.4	32	31.6	30	31.5	35.3	37.3	35.1	35.2
2018	35	38	39.8	39.5	36.5	33.3	30.3	34.2	31.5	34	37.6	35.6	35.4
2019	36.3	38.4	40.3	39	37.2	34	31.3	30.4	31.6	32.6	37.5	37.5	35.5
2020	35.7	38	41.3	40.1	37.4	33.7	31.1	32.7	31.6	33.7	37.8	35.7	35.7

Appendix 2B
Annual rainfall data for the study district.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Mean (mm)
2010	0	22	2.3	77	154	145.6	157	305.5	170.3	133.6	0	0	1167.3
2011	0	0	1.2	52.6	194.4	147.8	120.4	414.1	142.3	13.9	0	0	1086.7
2012	0	0.9	0	99.9	154.4	79.3	241.9	128.8	235.1	47.7	0	0	988
2013	0	0	12.1	159.4	130.2	38.7	133.4	268.3	82	98.6	0	0	922.7
2014	4.2	0	19.6	43.7	50.7	71.6	112.2	69.1	193.5	23.2	29.5	0	617.3
2015	0	3.2	0	26.3	61.3	85	103.6	283.7	239.8	49.4	0	0	852.3
2016	0	0	10.5	30.9	97.1	112.2	354.9	148.9	150.5	10	0	0	915
2017	0	0	3.6	29.1	179.1	177.8	260.6	259	81.2	32.6	8.9	0	1031.9
2018	0	19.8	18.5	21.8	117.1	94.2	284.5	305.6	117.5	55.8	0	0	1034.8
2019	0	0	23.6	104.3	119.1	90.5	202.6	293.9	261.2	268.2	0	0	1363.4
2020	0	0	0	20.2	121.2	149.8	151.3	71.6	98.6	54.3	0	0	667

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