

Nature of climate change-induced risks in semi-arid northwestern Ghana: Gauged observations, perceptions of smallholder farmers, and perspectives for livelihood adaptation

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Abstract

Climate variability and impact have been an endemic challenge to smallholder farmers who largely depend on rainy weather for livelihoods in semi-arid north-western Ghana. Many households in semi-arid regions exhibit low levels of adaptive capacity due to ineffective adaptation strategies and poor coping strategies. This study examined (1) trends in gauged rainfall and temperature data spanning the period from 1984 to 2014 and (2) smallholder farmers' perceptions about yearly cyclical weather, and difficulties associated with climate change adaptations. The study adopted the participatory rural appraisal design using questionnaire, interviews and focus group discussions for collection of data for analysis. Estimated parameters partially supported that yearly temperatures are increasing, whereas annual rainfall is declining, although the latter is not significantly related to the former. Smallholder farmers' perceptions about changing weather conditions did not corroborate the observed declining annual rainfall trend. These farmers are faced with livelihood-affecting risks during either 'prolonged dry periods from October to May' or 'short annual rainy season from mid-May to September. Therefore, access to climate information and available climate adaptation strategies could improve farming activities and livelihoods of farmers in response to climate change.

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smallholder farmers' perception, climate change induced risks, semi-arid north-western Ghana, future directions

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Introduction

Semi-arid northern Ghana has largely been characterized by low rainfall, high temperatures and prolonged drought conditions (Abbam et al., 2018; Klutse et al., 2020; Limantol et al., 2016). From year to year, the weather remains increasingly unreliable as recent inconsistencies in the trends and/or variations in rainfall and temperatures have been threatening socio-economic activities, rain-fed crop production and livelihood in the semi-arid northernmost Ghana (Abbam et al., 2018; Limantol et al., 2016; Manzanas et al., 2014). Smallholder (or subsistent) farmers who are the majority of inhabitants in these zones of northern Ghana are the most affected (Abbam et al., 2018; Antwi et al., 2015; Asante et al., 2021; Limantol et al., 2016). Reliance on yearly rainfall cycle to produce crops often coincides with the rainy season when floods occur in communities as the overflow of water from streams and perennial rivers spread to cultivated portions of farmers' farmland (Antwi et al., 2015). Thus, erratic rainfall in north-western Ghana has seriously been affecting livelihood of smallholder farmers (Asante et al., 2021). Because of these challenges, smallholder farmers rely on their observations and knowledge about changing weather conditions in order to timely apply strategies for livelihoods (Antwi et al., 2015; Asante et al., 2021). As their experience and sensitivity were influenced each year, these smallholder farmers appear to perceive climate change better (Asante et al., 2021; Guodaar et al., 2021; Limantol et al., 2016). They always try to synchronize their rain-fed farming activities with the onset of rainfall (Limantol et al., 2016). To some extent, their perceptions seem to be helping in such a way that they produce crops for livelihood. As a result, these farmers have been perceiving temperatures and time-length of dry weather events to be increasing from year to year (Limantol et al., 2016). On the other hand, because smallholder farmers in northwestern Ghana are also affected by floods during rainy season each year, the majority of respondents could hypothetically perceive that annual rainfall was rather increasing.

Perceptions of farmers about weather events require studies, because their livelihoods were actually affected each year by drought, floods and climate

change-associated land degradation (e.g., topsoil erosion and declining soil productivity), among others (Antwi et al., 2015; Asante et al., 2021; Banuoku et al., 2017; Guodaar et al., 2021; Limantol et al., 2016; Tesfahunegn et al., 2021). Perceptions of smallholder farmers have increasingly been the only option they used to predict trends in weather conditions so that they can adapt or explore various livelihood strategies better against the risks associated with climate change and variability (Asante et al., 2021; Guodaar et al., 2021; Tesfahunegn et al., 2021). As suggested by Asante et al. (2021) and Guodaar et al. (2021), the need to examine knowledge gaps between currently used livelihood strategies and unexplored opportunities will require that studies compare perceptions of farmers with measured weather data.

In this study, weather elements (e.g., measured rainfall and temperatures) for the period from 1984 to 2014 were analyzed. After that, observed trends in weather conditions were tested against ranked smallholder farmers' perceptions, which were confirmed against the views of both focus group discussants and the key interviewed informants, who have lived and experienced impacts of climate change in the study area. Our efforts were to (i) assess perceptions of farmers about weather events, (ii) assess factors that influence livelihood strategies of farmers against harsh weather conditions in northwestern Ghana, and (iii) suggest perspectives for future directions in the study area. Therefore, our main objective is to provide ample information for future research that will improve livelihoods of smallholder farmers against 'climate change-induced' risks in semi-arid northwestern Ghana.

Materials and methods

The study area: location, size and population

This study was done in Nandom District whose map has been reported by Lente et al. (2022). The district is at (10°51'08.65" N, 2°45'37.91" W) in the north-western part of the Upper West Region of Ghana.

Nandom District shares a boundary with Lawra District in the south, Lambussie Karni District in the east, and the Republic of Burkina Faso in both north and west (Lente et al., 2022). The total surface area of the district is about 395 km² (Brinkhoff, 2023). At least 86% of the inhabitants in Nandom District live in rural areas (GSS, 2023). The population density of the district currently stands at 130 persons km⁻² (Brinkhoff, 2023; GSS, 2023). Thus, the district is more populated than others in the Upper West Region of Ghana (GSS, 2023).

Agro-ecological characteristics influenced by climate change in Nandom District

Soil surface usually appears bare, largely because indiscriminate bush burning burn several dying plant species of short grasses and shrubs, among others, on land surface during dry season. Hence, vegetative cover on land surface in the study area appears very poor in the wet season, thereby allowing powerful erosion by wind or runoff (*authors' personal observations*). However, there are a few fire-resistant plants, which includes baobab (*Adansonia digitata*), dawadawa (*Parkia biglobosa*) and shea (*Vitellaria paradoxa*), among others. The agro-ecological characteristics in Nandom District are similar to those of a semi-arid Sudan savannah zone or Guinea savannah areas in northern Ghana (Heve et al., 2016; Klutse et al., 2020; Lente et al., 2022; Omari et al., 2017; Osei and Stein, 2017). Nonetheless, grazing livestock feed on short grasses and shrubs that mostly serve as a fodder. Harvest from shea, dawadawa, mango (*Mangifera indica*) and baobab are a source of income to inhabitants in the district. Leaves and herbs are used for medicinal purposes, whereas wild animals are hunted for games. Fishes are also hunted in rivers and streams for food and income in the district. Dead shrubs and trees are used as fire-wood for fueling household heating systems. Portions of fertile farmland are used to produce food crops. Some skillful inhabitants use straws and canes for artisanal designs in forms of hats, baskets and mats. Stems of trees and shrubs are also used for making pestle and mortar, which are used for pounding materials. In this case, the benefits from the agroecological environment can collectively be considered as agroecosystem services (Zabala et al., 2021).

The topography of land is more plane or gently undulating. The low water table, streams and perennial Black Volta River (Lente et al., 2022) present an opportunity for irrigation of high value short-seasonal crops in the

dry season better than it will be during the rainy season, when floods normally destroy people's properties. Hence, fish-farming practices can suffer the risks of floods in the rainy period, although dams or dugouts are used for small scale irrigation and domestic purposes. Streams, rivers, dams and dugouts also serve as sources of drinking water to livestock, which are mostly kept in local open-housing or free-range systems.

Weather conditions in Nandom District. A 31-year historical daily data for rainfall (or precipitation) and temperatures for a period from 1984 to 2014 were obtained from the Ghana Meteorological Agency (GMet) for their weather station at Babile (10031'10''N, 2050'06'' W) in the Nandom District. The climate data taken from the station at Babile were 65% available, whereas those from Lawra station had high gaps with only about 13% availability (Grimes et al., 1999; Hengl et al., 2004, 2007; Nkrumah et al., 2014; Odeh et al., 1995). Unfortunately, rainfall and temperature data at the GMet station for the period from 2015 to present are currently unavailable, because of lack of record. The nighttime and the daytime temperatures were considered to be the minimum and maximum, respectively. The mean monthly and annual rainfall, and temperature were analyzed for temporal variability and trends, which were compared to those of the perceptions of respondents regarding changes in the climatic variabilities and their associated extreme events in the study area.

Selected communities for the study

This research was part of the Adaptation at Scale in Semi-Arid Regions (ASSAR) Project in semi-arid areas of Africa and Asia. In West Africa, the project was on the dry sub-humid areas in the Upper West Region of northern Ghana and the Wa-Bobo-Sikasso transect in southern Mali. In the Upper West Region of Ghana, two main districts *viz.*, Lawra and Nandom Districts, were selected for the ASSAR projects. Stakeholder engagement was done in Nandom between to obtain valuable information about selection of farming communities for the study. Therefore, the study communities were chosen based on suggested guidelines by stakeholders and experts. The randomly selected communities included Billengangn, Gengenkpe, Ketuo and Naapaal (Lente et al., 2022). They were at distances between 2.87 and 12.55 km away from the perennial Black Volta

River for the fact that these communities were more prone to the effects of events of floods due to the overflow of the river. Therefore, the river was considered for its influence on adaptation and livelihoods of people across communities.

Design, sampling techniques and data collection

This study adopted participatory rural appraisal (PRA) approach for research survey (Chambers, 1994). Hence, the design included a tool kit for interactive techniques in report of Chambers (1994) and Ayivor (2012) which allowed for incorporation of more new techniques that could tackle more new research problems that arose. The interdisciplinarity of the method was useful for explaining multifaceted concepts such as climate change, vulnerability, or adaptation to audience. Therefore, participants were to freely contribute ideas (Ayivor, 2012). The discussions were controlled by a modified checklist of questions. The PRA approach included survey questionnaires for face-to-face interviews, key informant interviews (KII), and focus group discussions (FGD) (Ayivor, 2012). Hence, qualitative and quantitative data were collected according to the methods used in literature (Antwi et al., 2015; Antwi-Agyei et al., 2012, 2021; Etwire et al., 2013), after ethical clearance (Ethical Protocol Number ECBAS028/15-16 from the University of Ghana) and consent of participants were obtained.

Interviewing smallholder farmers' households. The number of smallholder farmers' households that should be interviewed in order to achieve 5% maximum error distribution among randomly selected communities were estimated according to procedures by Yamane (1967) and Antwi et al. (2015) as in equation 1:

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

Where, n = estimated sample size required, N = total number of households in a community and the preferred maximum error margin, $e = 0.05$. In March 2016, semi-structured questionnaires were used to randomly interview the selected farmers' households across the selected communities, similar to the approach used by Harris et al. (2010). By this questionnaire, respondents were also able to give reasons why they could not adopt some available adaptation strategies. Data obtained from 194 sampled households across the selected communities generated evidence-based details in this study.

Focus group discussion. The FGD was used to facilitate interaction among all the selected participants according to Ayivor (2012) and Jenkins et al. (1998). It focused on details related to the research themes, which included (i) the trends in weather data, (ii) smallholder farmers' adaptations for livelihoods, and (iii) available options for adaptation against climate change. Therefore, surveyed households were randomly chosen from the selected communities to form 14 focus groups: their ages of participants ranged from 20 to 82. The ratio of males to females in 10 groups formed in three study communities (Lente et al., 2022), which included Billengangn (10°51'40.972" N, 2°44'55.133" W), Gengenkpe (10°49'21.220" N, 2°51'00.587" W) and Ketuo (10°54'16.756" N, 2°48'01.874" W), was 1:1. However, because there were more females than males in Naapaal community (10°52'14.191" N, 2°48'54.291" W), the ratio of males to females in 4 groups was approximately 2:3. In April 2016, a list of questions (or unstructured questionnaires) was used to seek information (i.e., personal views) from group discussants. Pieces of information obtained from the various groups were used to support and validate data obtained following interviewing farmers' households.

Interviewing key informants. The KII involved interviewing people who could provide experts' views, ideas, and insights about a particular subject for the study (Ayivor, 2012; Kvale, 1996). Therefore, heads/directors of the Nandom Deanery Integrated Rural Development Programme (NANDIRDEP), Nandom District Assembly (NDA), Department of Agriculture of the Ministry of Food and Agriculture (MoFA), the National Disaster Management Organization (NADMO), Naapaal Community Opinion Leaders (NCOL), Community Development Department (CDD), Environmental Protection Agency (EPA), Billengangn Traditional Authority (BTA), Business Advisory Centre and Rural Enterprise Programme (BAC-REP), and the Naapaal Traditional Authority (NTA) were interviewed using a checklist of questions. This is because these heads or directors of the aforementioned institutions were key informants in the Nandom District. Using unstructured questionnaire, pieces of information obtained from the key informants. The details gathered from the informants were used to confirm and validate details collected from interviewing smallholder farmers' households.

Data analysis

Measured rainfall and temperature data. Yearly fluctuating weather cycle was estimated from historical

climate data. In addition, pooled data for annual mean temperatures and annual rainfall were examined to establish linear regression functions for the relationship between (i) weather elements and ‘increasing number of years from 1984 to 2014’ and (ii) annual mean rainfall and annual mean temperature. Using R-software (v. 3.3.2) developed by R Core Team (2016), the intercepts, the coefficients (or slopes) and coefficient of determination (R^2) of the linear equations were tested for significance at P -values ≤ 0.05 .

The deviation of yearly rainfall from the average annual rainfall in the period from 1984 to 2014 was calculated to examine the distribution of rainfall variability. In addition, rainfall anomaly index (RAI) was calculated for each year, according to the modified models in equations 2 and 3 (Costa and Rodrigues, 2017; Freitas, 2005):

$$\text{RAI} = 3 \left[\frac{N - \hat{Y}}{H - \hat{Y}} \right]$$

≥ 0 , for positive anomaly index, when $\hat{Y} < N$ or $\hat{Y} < H$

(2)

$$\text{RAI} = -3 \left[\frac{N - \hat{Y}}{L - \hat{Y}} \right]$$

< 0 , for negative anomaly index, when $\hat{Y} > N$ or $\hat{Y} > L$

(3)

Where, N = yearly rainfall for each year in the series from 1984 to 2014, \hat{Y} = yearly average rainfall observed in the period from 1984 to 2014, H = average of the ten highest yearly rainfall within the period from 1984 to 2014; L = average of the ten lowest yearly rainfall in the 1984 to 2014 series. The values of RAI were then used to classify the weather conditions in each year, using the interpretations of RAI ranges in recent reports (Araújo et al., 2009; Costa and Rodrigues, 2017): above 4 = extremely rainy or ‘extremely humid’ year; 2 to 4 = very rainy; 0 to 2 = rainy; -2 to 0 = dry; -4 to -2 = very dry; below -4 = extremely dry year.

Perceptions about climate “change-induced risks” and weather events by smallholder farmers’ households. The rating scale used by Nyantakyi-Frimpong and Bezner-Kerr (2015) was applied to analyze household

perceptions about climate change and variability in the Nandom District. The Likert scale (Likert, 1932) is a statement concerning an event and an evaluative part of a list of response categories ranging from “strongly agree” to “strongly disagree”. The respondents indicated their level of agreement or disagreement for each given statement in respect of climate-related and extreme weather events in their communities. Using R-software (v. 3.3.2) developed by R Core Team (2016), non-parametric chi-square analysis for ‘goodness-of-fit for equal expectation’ was used to examine distribution of ranked perceptions of respondents about the impacts of climate change and variability in the study area. However, a descriptive statistic was used to convert frequencies (i.e., quantitative data) obtained into percentages.

Results

Rainfall and temperature data from Nandom District

Data for yearly fluctuating weather cycle in the district is presented in Figure 1. In the greater part of the year, a long dry period (or season) is observed in Nandom District. The historical weather data collected from Ghana Meteorological Agency (GMet) reveals that the mean monthly rainfall in the period from October to April is 25 mm (Figure 1). Wet season seems to be from ‘April-May’ to ‘September-October’ (Figure 1): it is generally a short period. Each year, the highest monthly rainfall (i.e., about 224 mm) is observed in August (Figure 1). Temperature widely varies from 15 to 40 °C, depending on daytime, part of the year, and nighttime (Figure 1). Cold dry northeasterly-trade wind (i.e., Harmattan) causes nighttime temperatures to decline to *ca.* 15 °C in December-January (Figure 1). Nandom District is characterized by dusty windy weather condition during the Harmattan season.

Nature of observed variability and trends in temperature and rainfall data

Both temperatures and rainfall vary with months throughout a year (Figure 1). Positive or negative values of ‘deviation’ from the mean annual rainfall for the period from 1984 to 2014 were congruent with rainfall anomaly index (RAI) (Table 1). An increase (or rise) in annual rainfall agrees with positive values of RAI for rainy (or humid) year. Similarly, a decline in the amount of annual rainfall, with reference to the mean yearly rainfall for the period from 1984 to 2014, corroborates the negative values of RAI for the

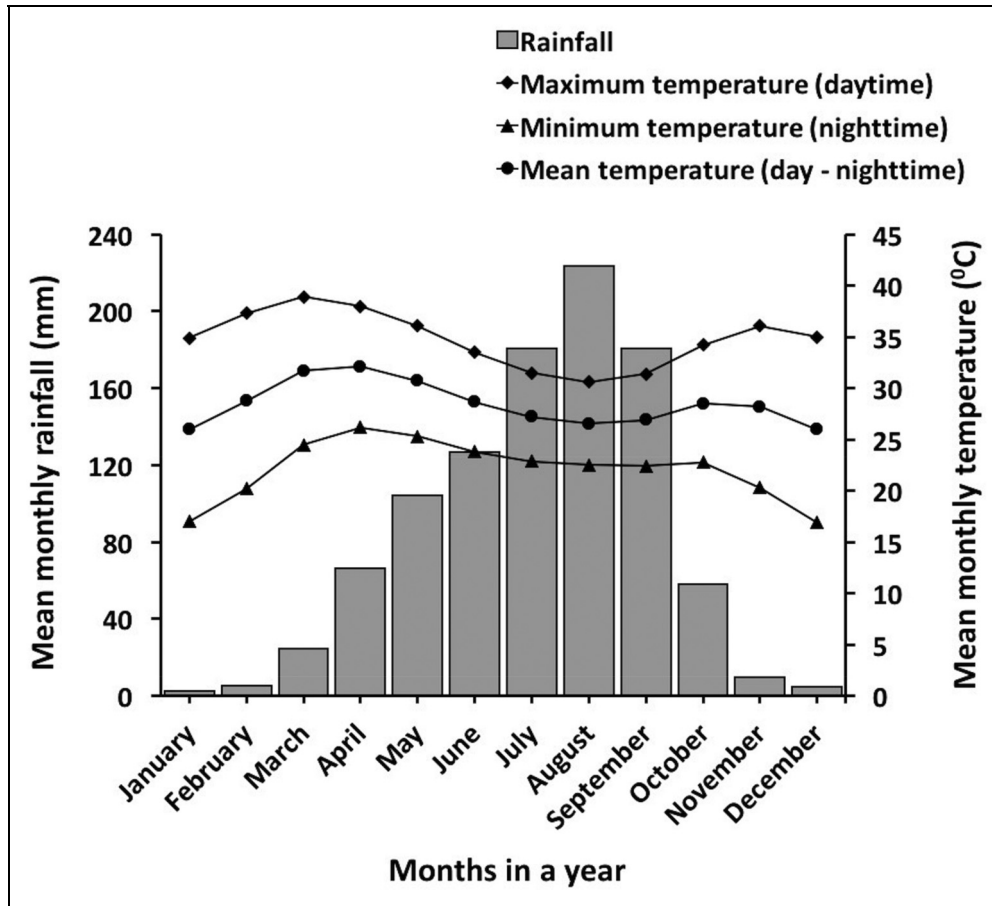


Figure 1. Yearly temperature variabilities and seasonal annual rainfall cycle in semi-arid environment in Nandom District in northwestern Ghana. Data pooled from 1984 to 2014 were used to create details about weather conditions presented here.

magnitude of dry weather conditions (Table 1). However, the nature of weather appeared to be better in the period from 1984 to 2009 than it was from 2010 to 2014. The low values of RAI (i.e., -0.812 to 0.643) in the period from 2010 to 2014 have shown that weather conditions in the Nandom District varied from 'slightly rainy to slightly dry' (Table 1). Thus, slightly dry weather events could depict the severity of climate change in the study area.

Temperatures (in daytime to nighttime) directly increase insignificantly with an increasing number of years in the period from 1984 to 2014 (Figure 2(a) to (c); Table 2). On the other hand, annual rainfall is inversely related to increasing number of years (Figure 2(d); Table 2). In effect, an increase in mean annual temperature will be expected to gradually cause a marginal decline in annual rainfall (Figure 2(e); Table 2). Nonetheless, estimated values of the intercept (in Table 2) for the linear regression

equations in Figure 2(a) to (d) are significant, except that of Figure 2(e). Linear models with such large values of intercept have partially supported an increase in temperatures (Figure 2(a) to (c); Table 2) or a decline in annual rainfall (Figure 2(d); Table 2); it is directly related to climate change as the number of years increases, although the values of coefficients of these models are insignificant (Table 2). In the case of the linear regression function (in Figure 2(e)), which annual rainfall was inversely related to mean temperature, both the intercept and coefficient are not significant (Table 2). Hence, the decline in yearly rainfall with increasing annual mean temperature (Figure 2(e)) is not partially or strongly supported by sufficient evidence in Table 2. Hence, the inverse linear model in Figure 2(e) is not reliable to predict a progressive declining trend in annual rainfall as annual mean temperature increases. However, the model (Figure 2(e)) seems to strongly support the

Table 1. Measure of variability in yearly rainfall, with reference to the observed mean annual rainfall ($\hat{Y} = 987.38$ mm) for the period from 1984 to 2014. Rainfall anomaly index and characterized weather condition in each year have been included.

Year	Deviation from the mean (\hat{Y})		Rainfall anomaly index (RAI)	
	Value	Interpretation	Value	Classified weather condition based on RAI range (Costa and Rodrigues, 2017)
1984	-0.2261	Decline	-3.5974	Very dry year
1985	-0.0138	Decline	-0.2188	Slightly dry
1986	0.1906	Rise	3.4942	Very rainy or 'very humid'
1987	0.0178	Rise	0.3271	Slightly rainy
1988	-0.0742	Decline	-1.1806	Dry
1989	0.0996	Rise	1.8253	rainy
1990	-0.3498	Decline	-5.5647	Extremely dry
1991	-0.0490	Decline	-0.7795	Slightly dry
1992	-0.0171	Decline	-0.2719	Slightly dry
1993	0.1034	Rise	1.8958	rainy
1994	0.0828	Rise	1.5171	rainy
1995	0.2782	Rise	5.1	Extremely rainy
1996	-0.0768	Decline	-1.2225	dry
1997	0.1552	Rise	2.8444	Very rainy
1998	-0.0760	Decline	-1.2096	Dry
1999	0.2344	Rise	4.2961	Extremely rainy
2000	0.2904	Rise	5.3227	Extremely rainy
2001	-0.0423	Decline	-0.6731	Slightly dry
2002	0.0606	Rise	1.1105	rainy
2003	0.0923	Rise	1.6916	rainy
2004	-0.4273	Decline	-6.7973	Extremely dry
2005	0.0696	Rise	1.2758	rainy
2006	0.1856	Rise	3.4014	Very rainy
2007	-0.3143	Decline	-5.0008	Extremely dry
2008	-0.2411	Decline	-3.8359	Very dry
2009	0.0794*	Rise	1.4558	Humid
2010	0.0176*	Rise	0.3234**	Slightly rainy
2011	0.0351*	Rise	0.64270**	Slightly rainy
2012	-0.0362*	Decline	-0.5764**	Slightly dry
2013	0.0026*	Rise	0.0468**	Slightly rainy
2014	-0.0510*	Decline	-0.8117**	Slightly dry

RAI: Estimated annual rainfall anomaly index, according to equations 2 and 3;

*From 2009 to 2014, positive and negative values of deviation were almost equal to zero: they were between -0.1 and 0.1;

**From 2010 to 2014, we considered weather conditions to be 'slightly rainy to slightly dry', because the positive and negative values of RAI were so small i.e., between -0.813 and 0.643.

fact that annual rainfall anomaly (in Table 1) from year to year is unpredictable.

Smallholder farmers' perceptions about climate change and variability in Nandom District

With regards to the impacts of rainfall on livelihoods, the KII and FGD revealed that low, erratic and unpredicted rainfall patterns were the major challenges to crop production. According to participants, low rainfall had caused drought and, in most cases, led to poor crop growth.

They also cited heavy rainfall as the main cause of flooding, which in most cases washed away premature crops and livestock. These were summed up by a participant as:

"Too little or too much rainfall at wrong times affect crops and livestock and create food shortage and poverty".

Another key informant supported the above assertion by stating that: "*The cropping system of about eighty (80) percent of smallholder farmers in the*

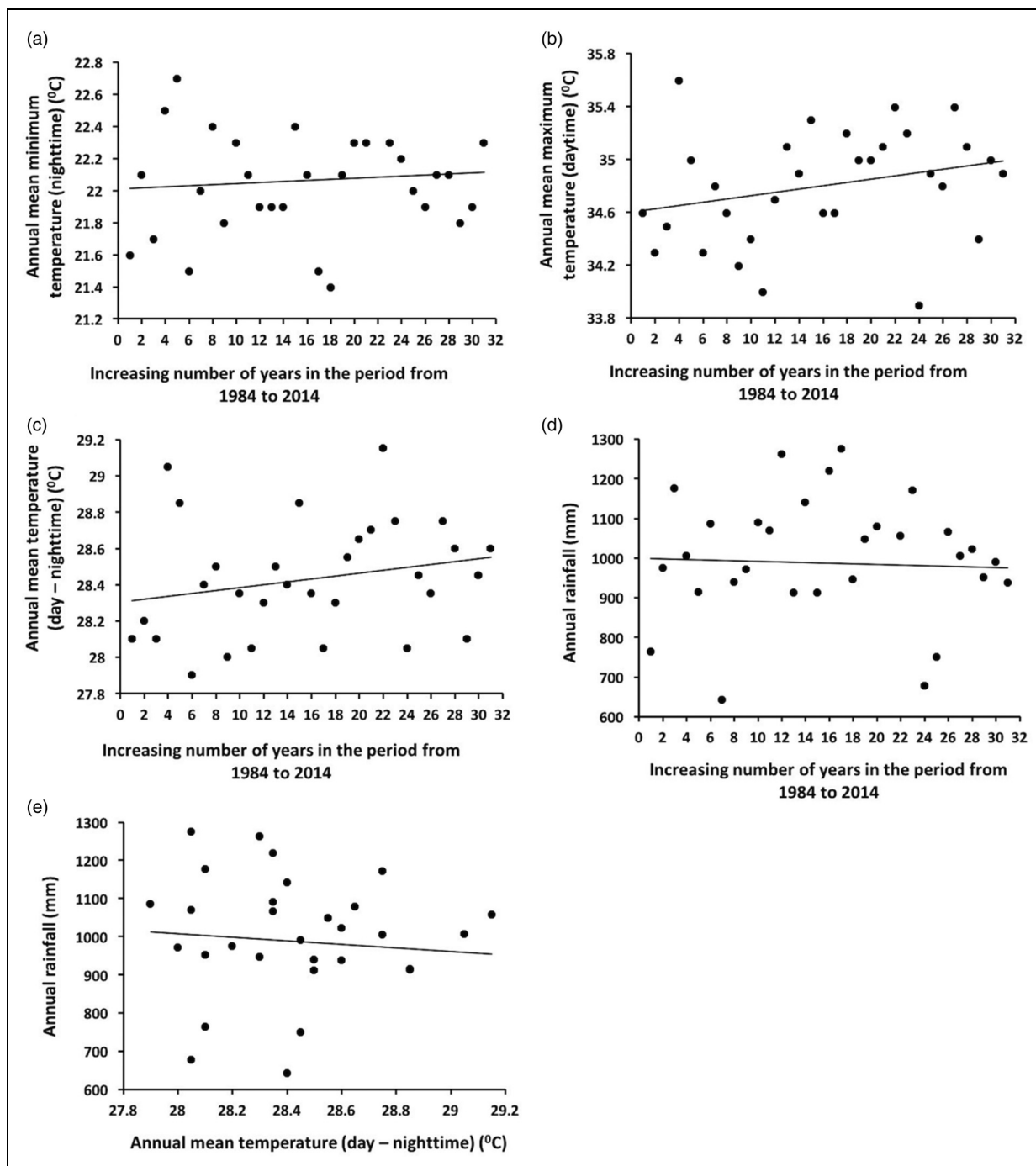


Figure 2. Scatter plots showing the ‘mean predicting line’ for the linear relationship between: (a, b, c) temperatures and increasing number of years; (d) annual rainfall and increasing number of years; (e) annual rainfall and annual mean temperature. Analyses of linear regression function and co-variance for the mean predicting line in (a), (b), (c), (d) and (e) are presented in Table 2.

district is rain-fed, however, rainfall has become erratic and does not support their livelihood activities. The rains set in late in recent years and the untimely cessation of rainfall within the planting season is now a common experience here and disrupts our

cropping systems. This is serious because many of the farmers are incapable of undertaking irrigation farming during the prolonged dry periods”.

Distribution of proportions of respondents (smallholder farmers’ households) across the categorical groups of

Table 2. Analysis of regression functions and covariance for the linear relationships established in Figure 2, following the Shapiro-Wilk test for normality in the data.

The specific image	Intercept (or constant)			Coefficient (or slope)			Analysis of co-variance		
	Mean ± SE	t-test value	P-value of t-test	Mean ± SE	t-test value	P-value of t-test	R ²	F-value	P-value of F-test
Figure 2(a)	22.01 ± 0.1279	172.065 *****	<2 × 10 ⁻¹⁶	0.0034 ± 0.007	0.485	0.631	0.0081	0.2356	0.6311
Figure 2(b)	34.6 ± 0.1512	228.858 *****	<2 × 10 ⁻¹⁶	0.0125 ± 0.0083	1.516	0.14	0.0734	2.297	0.1405
Figure 2(c)	28.31 ± 0.1152	245.678 *****	<2 × 10 ⁻¹⁶	0.0079 ± 0.0063	1.264	0.216	0.0522	1.597	0.2164
Figure 2(d)	999.6 ± 64.0784	15.6 *****	1.22 × 10 ⁻¹⁵	-0.7637 ± 3.4958	-0.218	0.829	0.0016	0.048	0.8286
Figure 2(e)	2300 ± 2851	0.807	0.426	-46.16 ± 100.26	-0.46	0.649	0.0073	0.2119	0.6487

***** denotes that the value of intercept is significant at p-value <0.00001, thereby partially supporting the linear models of the regression lines in Figure 2(a) to (d), except Figure 2(e).

SE: Standard error;

R²: Coefficient of determination.

ranked perceptions is significantly different from the equal expectation (χ^2 -values are in Table 3). The majority of the respondents' perceptions on cases of weather events due to climate change in the semi-arid Sudan savannah in the Nandom District were in the categories of “strongly agreeing and agreeing” or “disagreeing and strongly disagreeing” (Table 3). As a result, 88.2% of the total cases of respondents' perceptions tested against changing weather conditions in Nandom District were in conformity with gauged (or measured) weather elements (in Figures 1 and 2(a) to (c)) and/or the views of both focus group discussants and the key informants who were interviewed. However, the majority of the respondents strongly disagreed to accept the fact that annual rainfall is gradually declining yearly (Table 3). Moreover, similar perceptions of the FGD and the KII were obtained, contrary to the evidence that rainfall declines yearly. These perceptions of farmers' households, FGD and KII were altogether declared as ‘rejected’ (which is about 12% of cases in Table 3), because their perceptions about rainfall did not support the fact that trend in measured (or gauged) annual rainfall is progressively declining marginally as number of years increases (Figure 2(d); Table 2). Nonetheless, perceptions of people about climate change scenarios across the study communities were 88.2% successes in agreement with the weather data (Table 3).

Profile of smallholder farmers: climate change and livelihood-affecting risks

The survey shows that men (52.6 –60.4%) were more than women in the study communities except in Ketuo community, where the women population (70.8%) was more than twice the population of men (29.2%) (Table 4). They are largely smallholder farmers who are older than 20 years. The majority of these farmers (48–60%) have not received formal education. They all have farmland through either renting, personal ownership or the land belongs to the extended family. The cultivated farmland sizes of the majority of the farmers are ≤2 hectares (Table 4). The household size of these farmers was largely between 0 and 11 members (Table 4).

About 89.7% of the respondents (in Table 3) agreed that their livelihood is affected by erratic rainfall. Moreover, during the rainy season (in Figure 1), about 78.9% of the respondents (Table 3) confirmed that they are negatively affected by incidence of heavy rainfall and floods each year due to the overflow of the perennial Black Volta River and its confluences in many communities. Only male household heads in the study communities are traditionally perceived to

Table 3. Perceptions of respondents (smallholder farmers' households) about the trends in weather events and/or the impact of climate change and variability in Nandom District.

S/N	Weather event tested against perceptions of respondents	Percentage of respondents for ranked perceptions					χ^2 - value	p-value β	Validation of perception β	
		Strongly Agree	Agree	Uncertain	Disagree	Strongly disagree				DF \uparrow
1	Rainfall starts earlier in February each year [Reference = Figure 1]	9.3	16.5	4.1	45.9	24.2	4	103.47	$<2.2 \times 10^{-16}$	Accepted
2	Rainfall starts after February every year [Reference = Figure 1]	34.5	40.7	5.2	13.4	6.2	4	106.26	$<2.2 \times 10^{-16}$	Accepted
3	Rainfall ends earlier in November each year [Reference = Figure 1]	36.6	36.6	4.1	16.5	6.2	4	97.60	$<2.2 \times 10^{-16}$	Accepted
4	Rainfall ends after November every year [Reference = Figure 1]	9.3	17.0	7.2	43.3	23.2	4	81.52	$<2.2 \times 10^{-16}$	Accepted
5	Yearly rainy season has become shorter	33.5	43.8	7.2	12.4	3.1	4	121.93	$<2.2 \times 10^{-16}$	Accepted
6	Yearly rainy season has become longer	8.8	9.8	8.2	47.4	25.8	4	111.93	$<2.2 \times 10^{-16}$	Accepted
7	Yearly dry weather conditions are more frequent	27.3	38.7	13.4	17.5	3.1	4	71.52	1.1×10^{-14}	Accepted
8	Stronger windy weather conditions are often observed each year	36.1	40.2	10.8	10.3	2.6	4	111.41	$<2.2 \times 10^{-16}$	Accepted
9	Overflow of Black Volta River and its confluences causes widespread floods in May-September each year [Reference = Figure 1]	31.4	32	18.2	13.9	4.1	4	55.26	2.9×10^{-11}	Accepted
10	Annual rainfall is increasing yearly [Reference = Figure 2(d)]	24.2	29.9	9.3	16	20.6	4	23.99	8.03×10^{-5}	Rejected
11	Annual rainfall is decreasing yearly [Reference = Figure 2(d)]	26.8	18	11.9	36.1	7.2	4	52.24	1.23×10^{-10}	Rejected
12	The start of yearly weather-dependent planting season has changed from April to be in mid-May-June	44.8	37.6	10.8	4.6	2.1	4	152.29	$<2.2 \times 10^{-16}$	Accepted
13	Increasing yearly temperatures [Reference = Figure 2(a) to (c)]	34.5	44	11.9	6.2	3.1	4	128.84	$<2.2 \times 10^{-16}$	Accepted
14	Decreasing yearly temperatures [Reference = Figure 2(a) to (c)]	17	12	10.8	42.3	17.5	4	64.49	3.3×10^{-13}	Accepted
15	Severe drought in the Nandom District	32	37.6	17	10.3	3.1	4	81.72	$<2.2 \times 10^{-16}$	Accepted
16		43.8	35.1	12.9	3.1	5.2	4	131	$<2.2 \times 10^{-16}$	Accepted

(continued)

Table 3. (continued)

S/N	Weather event tested against perceptions of respondents	Percentage of respondents for ranked perceptions				χ ² – value ¶	p-value β	Validation of perception Æ		
		Strongly Agree	Agree	Uncertain	Disagree				Strongly disagree	
17	Flood situation in rainy period affects households' livelihood	51	38.7	4.6	3.1	2.6	4	207.24	<2.2 × 10 ⁻¹⁶	Accepted
18	Drought situation affects livelihood									88.2
19	Percentage of "accepted" perception scenarios									11.8

S/N: Serial number;

¶: Only numbers of respondents in each row were used for analysis of the goodness-of-fit for equal expectation;

DF: Degree of freedom;

χ²: Value of chi-square;

p-value: Probability statistic for significance level for χ²;

β: Observations across the categorical groups are significantly different from the expectation at p-value < 0.0001;

Æ: The majority decision by respondents was declared "**Accepted**", when the perceptions of the majority of the smallholder farmers' households corresponded to the observed weather data and/or the views of the focus groups and the key informants.

Table 4. Demographic and socio-economic profile of smallholder farmers in the study area.

Factor	Category	Percentage of respondents in the selected rural communities in the Nandom District				Total(n = 194)
		Billengangn (n = 60)	Gengenkpe (n = 48)	Naapaal (n = 62)	Ketuo (n = 24)	
Gender	Male	55	60.4	53.2	29.2	52.6
	Female	45	39.6	46.8	70.8	47.4
Age (in years)	<20	21.7	0	4.8	0	8.2
	20–29	11.7	12.5	9.7	29.2	13.4
	30–39	13.3	20.8	11.3	20.8	15.5
	40–49	18.3	25.0	25.8	16.7	22.2
	≥ 50	35.0	41.7	48.4	33.3	40.7
Level of education	No education	56.7	60.4	48.4	50	54.1
	Primary education	6.7	14.6	0	0	19.1
	Basic education	30	10.5	32.3	25	17.5
	Secondary education	5	8.3	12.9	20.8	5.7
	Tertiary education	1.7	6.3	6.5	4.2	2.6
Household size	0–5	26.7	29.2	35.5	25	29.9
	6–10	58.3	58.3	56.5	45.8	56.2
	≥11	12.5	12.5	8.1	29.2	13.9
Access to credit	Yes	10	0	27.4	20.8	14.4
	No	90	100	72.6	79.2	85.6
Farm size (hectares)	0–2	86.7	66.7	69.4	58.3	73.2
	3–4	8.3	25	25.8	41.7	22.2
	5–6	5.0	6.3	3.2	0	4.1
	≥7	0.0	2.1	1.6	0	0.5
Farmland ownership	Family	86.7	52.1	96.8	95.8	82.5
	Rental	3.3	12.5	0	4.2	4.1
	Personal	10	20.8	3.2	0	9.8

own land to produce crops and rear livestock on it (*interactions with the key informants*). These males tend to fully control farmland that have source of water for irrigation and/or pasture to feed grazing livestock. The male-owned farmlands are mostly bequeathed to another male household head, usually a relative, following the death of the male who previously owned the land (*discussion with focal group discussants*). In this case, females do not have access to productive farmland for crop production or rearing of livestock as a form of adaptation for livelihood against the harsh climate change-related challenges in the study communities in semi-arid Sudan savannah zone in northwestern Ghana. Moreover, smallholder farmers (72.6–100% in Table 4) do not have access to credit facilities to effectively manage soil fertility problems for crop production or for effective irrigation activities along the banks of the perennial Black Volta River during the yearly period of prolonged drought. Thus, the widespread reliance on ‘yearly rainy season (in Figure 1 and Table 3)’ for growing crops often coincides with incidence of floods. The system of poorly housing and

rearing farm animals exposes poultry and grazing livestock to high risk of heavy rainfall. These reared domestic animals are dragged away or killed by speedy overflowing water in rivers (*key informant interviews*).

Discussion

In this study, observed mean annual rainfall was low and marginally fluctuated around 987.38 mm. In effect, dry weather events had been more frequent in the period from 2010 to 2014. On the other hand, significant inverse relationship between rainfall and increasing temperatures was not observed, although annual rainfall showed a weak negative correlation with temperatures. The results also partially supported indications that temperatures were directly related to increasing number of years. Such increasing temperature trend was explained by Klutse et al. (2020) that residual heat during the day has actually been increasing, thereby causing faster warming. However, starting from 1984, annual rainfall has been declining from year to year. Our observations in semi-arid

study area were similar to those in recent reports (Abbam et al., 2018; Asante et al., 2021; Guodaar et al., 2021; Klutse et al., 2020). Weather data from 1984 to 2014 showed that monthly rainfall in the short annual rainy period has been low. Hence, it may be perceived that the low amount of rainfall in the study area could be insufficient to cause floods that can disrupt agronomic activities of farmers and other sources of livelihood in the study area. However, accumulating rainfall in the catchment areas around the main source of the perennial Black Volta River in Burkina Faso can cause widespread overflows of the river and its tributaries in Nandom District. This is primarily because Burkina Faso has semi-arid weather conditions similar to those observed in 'northeastern-to-northwestern' parts of Ghana (Abbam et al., 2018; Nouaceur and Murarescu, 2020). Yearly rainy season in Burkina Faso usually coincides with the rainy months observed in the study area (Nouaceur and Murarescu, 2020). Because floods in the Nandom District occur in the same rainy period in both Burkina-Faso and northwestern Ghana, the interviewed smallholder farmers could wrongly assume that an increase in annual rainfall causes floods in their communities. This study suggests a hypothesis that smallholder farmers, focus group discussants and key interviewed informants could consider occurrence of floods in the short rainy season to be due to an increase in yearly rainfall. Contrary to their perceptions, the gauge data reveal that annual rainfall is steadily declining. Thus, notwithstanding, the accuracy level of perception of smallholder farmers about weather events in the study communities was estimated to be 88.2%. The observed perceptions of farmers about annual rainfall, however, agreed with other results obtained in semi-arid northwestern Ghana (Limantol et al., 2016; Nyantakyi-Frimpong and Bezner-Kerr, 2015).

The main factors that are limiting climate change adaptation in Nandom District include variability in temperature and rainfall patterns, and lack of education (awareness) on adaptation strategies. Dry and slightly rainy years are the major concerns to farmers who depend largely on rainy weather to produce crops. Alternatively, these farmers could possibly farm along the bank of the Black Volta River, which can be used to irrigate and produce crops during the lengthy drought condition for food security against the time of floods.

In this study, we observed that women dominated the study area. Unfortunately, our survey tools did

not assess traditional limitations that could restrict women to ineffective climate change adaptation strategies. However, literature has revealed that there has been an untoward structured traditional insensitivity among men against women, who had been restricted from having access to productive farmland (Yokying and Lambrecht, 2019). According to literature, the inequality gap between men and women in possessing farmland for agriculture could be widespread against the vulnerable women in northern Ghana (Kuusaana et al., 2013; Yokying and Lambrecht, 2019). This suggests the need for future study to examine whether such gender disparity may be similar in Nandom District, when compared to those reported in literature (Kuusaana et al., 2013; Yokying and Lambrecht, 2019). Such a future study may also reveal whether women in the study area will not have access to farmland near the banks of perennial rivers for small-scale irrigation to produce food during the long dry season as a form of preparedness against periods of floods in the rainy season. This future study is suggested because it may reveal whether the men have any alternative livelihood strategies for their women to adapt better against climate change. Furthermore, we observed in this study that lack of awareness among farmers, coupled with perceived costs of certain available strategies for livelihood, tends to limit smallholder farmers from adapting better against observed impacts of climate variability or soil productivity challenges in their communities.

To some extent, some farmers get information about weather on local radios, from the disaster management offices or by relying on relatives, neighbours and the local community leadership. They are so alerted about the onset of rains and expected heavy rainfall in their communities. Nonetheless, livelihood approaches adopted by smallholder farmers against extreme weather events are not robust enough to achieve resilience and sustainability (Asante et al., 2021; Guodaar et al., 2021). Thus, the need to identify appropriate support systems may reduce climate change-induced poverty in the study area.

Perspectives for future directions

Similar to Kosoe and Ahmed (2022), the study revealed that access to climate information (climate services) is needed for effective use of agroecosystem services so that satisfaction and/or benefits smallholder farmers obtain from their agro-ecological environments would sustain their livelihoods and for

effective adaptation against impacts of climate change. In order to improve the livelihoods of smallholder farmers in semi-arid regions such as the study area, the government should consider incorporating the current ecosystem-based management framework policy guidelines as outlined in the Ghana climate change policy into the District Assembly's environmental management plans and actions for implementation by the EPA, Forestry Commission of Ghana (FCG), and the Ministry of Food and Agriculture (MoFA-Ghana). This will provide data for policy formulation, planning and decision making with respect to the management of these services. The limited access to climate information re-enforces the need to intensify awareness creation on climate change especially among rural communities in Ghana. This can be achieved through the Ministry of Information, agricultural extension officers and government media outlets (e.g., radio and television).

Furthermore, the government should take the lead in facilitating the formation of groups or associations among smallholder farmers to build their capacity to access credit facilities. The outcome of this study also highlights the need for government to review the complex nature of land tenure or ownership system among rural communities in northern Ghana, especially those that do not allow women to own lands. Socio-economic policies that will combine subsidized (or funded) credit schemes, effective trainings and awareness may improve farmers' livelihoods. In an effort to reduce crop losses during yearly rainy season when floods are observed, research is needed to develop effective spatiotemporal cost-effective 'low-head-bucket or drum' drip irrigation systems, which are widely used by smallholder farmers in Burkina Faso and other sub-Saharan African countries for production of high value crops during the long dry seasons for livelihoods (Kulecho and Weatherhead, 2006; Maisiri et al., 2005; Ngigi et al., 2000; Venot et al., 2017; Wanvoeke, 2015). Impact of policy to reduce taxes on, or subsidize agricultural inputs such as improved high yielding drought resistant varieties of crops, fertilizers and low-head drip irrigation kits, among others, for smallholder farmers to produce crops in the long dry season requires assessment in semi-arid northwestern Ghana. Socio-economic development programmes aimed at bridging gender disparity gap in farmland tenure should implement the Ghana gender policy (MGCSP, 2015) to focus on educating the traditional leadership in northwestern Ghana so that sustainable local-level patrilineal

by-law can be established to recognize vulnerability of women who are caring for children in such a challenging harsh semi-arid environment. Perhaps, empowering and training affected smallholder female farmers in any identified alternative sources of livelihood may provide them some levels of resilience against risks associated with unfavourable weather in semi-arid northwestern Ghana. However, future research plans should include examining the interface between agroecosystem services and livelihood in the semi-arid northwestern Ghana. Future policies on climate change adaptation should include irrigation farming projects, development and/or provision of improved varieties of staple food crops in smallholder farming communities.

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