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Research article

Comparing smallholder farmers' climate change perception with climate data: the case of Adansi North District of Ghana

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ABSTRACT

This study adopted mixed methods design and employed questionnaire and interview to investigate climate trends and smallholder farmers' perception of climate change as well as the relationship between climate data and farmers' perception, and the determinants of perception in Adansi North District of Ghana. The study randomly and purposively selected 378 respondents and 41 key informants, respectively. Descriptive, inferential, trend and thematic analysis were employed. Results showed that the majority of smallholder farmers have observed increase in intensity (96.8%) and duration (94.7%) of temperature, and delay onset (82.8%) and early cessation (89.2%) of rainfall as well as increase in wind intensity (79.4%). Climate data also revealed rising trends of rainfall, wind speed and temperature. Nevertheless, there was no significant relationship between farmers' perception and climate data. Information from family and friends and government, particularly local institutions and extension service significantly influence farmers' perception. In addition, television and radio were significant predictors of farmers' perception. The study recommends intensification of climate education, mass awareness and capacity development programmes.

1. Introduction

Sub-Saharan Africa (SSA) is highly vulnerable to climate change due to the overdependence of economies in this region on climate sensitive sectors particularly agriculture (AGRA, 2018, 2014; IPCC, 2018). Agriculture in this part of the world is mostly rain-fed and subsistence. The low adaptive capacity of smallholder farmers, who constitute the majority of the labour force (80%) in the agriculture sector also increases vulnerability to climate change (AGRA, 2018; FAO, 2012). In addition, high poverty rate, conflicts, poor management of natural resources and low socioeconomic development increase vulnerability in SSA (African Union, 2010; AGRA, 2014; Connolly-Boutin and Smit, 2016). Nevertheless, agriculture continues to play a significant role in the livelihoods of households in sub-Saharan Africa, and serves as a stimulus for economic growth, providing food security and assisting in poverty reduction (African Union, 2010; AGRA, 2018, 2014). In Ghana, for instance, the sector absorbs the highest proportion of the Ghanaian total employed population, with about 44.7% of the labour force employed in agricultural sector (MOFA, 2016).

Notwithstanding, climate change poses a great threat to agriculture in SSA, as the agriculture system is rain-fed with less irrigation. According to Adebisi-Adelani and Oyesola (2014), SSA has about 95% of its agriculture being rain-fed, while in Ghana only about 3% of arable land is under irrigation (MOFA, 2016). Studies have reported that climate change and extreme weather events such as floods, droughts and soil erosion led to drastic reduction in crop yields (IPCC, 2018), which affected food prices (Wossen et al., 2018). The spread of pests and diseases such as fall armyworms, black fungus gnat, goat and sheep pox, African swine, Newcastle and foot and mouth disease in SSA has been associated to climate change (African Union, 2017, 2010; FAO, 2018). In addition, excessive heat due to climate change leads to heat stress in livestock, which affects growth and reproduction (Dhar Chakrabarti, 2015; Thornton, 2010; Thornton and Herrero, 2015). Reduction in wool and milk has also been associated to climate change (Dhar Chakrabarti, 2015).

In Ghana, Stutley (2010) reported that climate change, particularly, floods and droughts caused about 6.3% and 9.3% reduction in maize and rice production respectively, thereby increasing food insecurity, poverty and livelihood challenges particularly at the grassroots, where livelihood and food security are dependent mainly on agriculture. This is troubling because of the critical role of smallholder farmers in food security in Africa. For instance, according to the Food and Agriculture Organization

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((FAO 2012)), smallholder farmers in SSA manage about 80% farmland and contribute about 80% of food supply. The situation is not different in Ghana, where smallholder farmers, who cultivate about 2 ha of land, contribute about 80% of food production (MOFA, 2016).

Nevertheless, smallholder farmers in Africa in general and Ghana in particular face challenges in accessing reliable and accurate climate information (Chepkoech et al., 2018; Hirons et al., 2018), needed for adaptation and meteorological disaster preparedness. The lack of access to climate data for agricultural activities increases vulnerability and exposes farmers to the adverse impact of climate change, thereby creating the urgent need to disseminate reliable and accurate climate information to already vulnerable smallholder farmers. The Intergovernmental Panel on Climate Change (IPCC) asserts that future impact of climate change will likely be high in vulnerable societies particularly in Africa (IPCC, 2018). This is problematic as climate change will disrupt the agriculture system in Africa and affect food security and livelihood of smallholder farmers. Hence, addressing the menace of climate change through adaptation and mitigation is paramount in development policies and programmes in Africa. However, the success of adaptation and mitigation depends to a large extent on the successful understanding of climate change, which requires a deeper understanding of the values of climate parameters and the corresponding extreme weather events as well as how smallholder farmers who are highly vulnerable to climate change understand and perceive these changes (Ayanlade et al., 2017).

Indeed, a substantial body of literature has deepened our understanding of climate change (Bindoff et al., 2013; IPCC, 2014, 2018). In Ghana, studies have extensively examined climate change impacts and adaptation strategies (Adu et al., 2018; Asravor, 2017; Gyampoh et al., 2009; Nkegbe et al., 2017; Wossen and Berger, 2015; Yaro et al., 2014). Other studies have also analyzed monthly, seasonal and/or annual trends of rainfall and temperature (Campion and Venzke, 2013; Issahaku et al., 2016; Kabo-Bah et al., 2016; Logah et al., 2013; Nkrumah et al., 2014; Nyatuame et al., 2014), while others have examined climate change perceptions (Acquah et al., 2015; Cobbinah and Anane, 2016; Limantol et al., 2016; Ndamani and Watanabe, 2015). For instance, in the Savannah region of Ghana, Acquah et al. (2015) note that farmers' perception of climate change entailed rising temperature and erratic rainfall. Limantol et al. (2016) also report warming temperature, decrease in rainfall amount, intensity and duration, and frequent droughts, as the perception of smallholder farmers in Ghana. These are consistent with studies in Ethiopia (Mengistu, 2011), India (Tripathi and Mishra, 2017) and Mali (Sanogo et al., 2016), where smallholder perceive rising temperature, decrease in rainfall and frequent droughts.

Knowing the perception of smallholder farmers enable policy makers to have a deeper understanding of the realities of climate change at the local level, which is essential for policy formulation and implementation. Nevertheless, there is a gap between policies and local realities, as policies are framed using national and/or regional scenarios, which are mostly devoid of local context. For instance, climate change policies in Ghana are aim at reducing the vulnerability of the agriculture sector and hence smallholder farmers (MESTI, 2013, 2012; Sarpong and Anyidoho, 2012), who constitute the bulk of the labour force in agriculture (MOFA, 2016). Nevertheless, smallholder farmers are hardly involved in policy formulation and implementation, neither are their experiences and local knowledge mainstreamed into national polices (Sarpong and Anyidoho, 2012). According to Fleurbaey et al. (2014), policies are effective and more likely to be accepted if beneficiaries are involved in formulation and implementation. For climate change policies to effectively address the challenges of smallholder farmers, there is the need to understand local realities and experiences of smallholder farmers, in relation to national and/or regional scenarios (climate data). This concurs with Briggs' (2013) assertion that policies that seek to improve local development cannot exclude local knowledge and perception.

However, in Ghana, no attempt has been made to link or compare climate data with smallholder farmers' climate change experiences and perception. We argue that climate change policies that embrace both national and local experiences is strongly needed, to drive sustainable adaptation strategies to climate change. According to Abid et al. (2015) and Fadina and Barjolle (2018), smallholder farmers' perception of climate change significantly influence their choice of adaptation. Thus, the type of adaptation strategies of smallholder farmers are more often than not, based on the extent of changes observed (Sultan and Gaetani, 2016). However, smallholder farmers in Ghana have misconceptions of climate change (Cobbinah and Anane, 2016), which affects effective and sustainable adaptation. Smallholder farmers' misconception of climate change range from anger of gods due to negligence of cultural norms and practices, to witchcraft and natural causes (Cobbinah and Anane, 2016).

According to Sultan and Gaetani (2016), phase 3 and 5 of the Coupled Model Intercomparison Project (CIMP3 and CIMP5) exhibit low skills in projecting variability in West African Monsson. To this end, Biasutti (2013) indicates that projection of the Sahel's wet and dry conditions, has faced uncertainties, due to the shortcoming of existing models. Inaccuracy in projection in West Africa has been associated to the response of coupled models to both direct and indirect radioactive forcing of carbon dioxide in the atmosphere (Giannini, 2010). Nevertheless, Biasutti et al. (2009) note that while coupled models have enhanced a better understanding of monsoon precipitation and atmospheric circulation in West Africa, particularly in the 21st century, the same models reveal inconsistencies in future projection. In Ghana, Nkrumah et al. (2014) also noted that climate measuring instruments produce inaccurate data, which makes it difficult to understand local reality and the extent of changes. For instance, the study reported gaps in rain gauge data in Ghana and identified imbalances and underestimation of rainfall in Ghana by the Regional Climate Model (RegCM3). Intuitively, climate policies based solely on climate data may not achieve their intended objectives as they fail to understand and incorporate local reality and the extent of changes at the grassroots as well as the perceptions of smallholder farmers. Thus, it is imperative for studies to explore climate data in relation to local realities of climate change, as perceived by smallholder farmers. This paper, therefore, examines smallholder farmers' climate change experiences and perception in relation to longitudinal climate data and analyzes the correlation between perception and climate data as well as the factors influencing smallholder farmers' perception. The findings from the study contribute immensely to a better understanding of climate change in Ghana and advances climate change and adaptation policies. The subsequent sections of the paper present materials and methods, findings and discussion as well as conclusion.

2. Materials and methods

2.1. The study design and area

The study adopted a convergent parallel mixed methods approach, which allowed the simultaneous collection of quantitative and qualitative data (Creswell, 2014). The choice of mixed methods was premised on the assumption that a social phenomenon like climate change required a blend of quantitative and qualitative approaches to have a deeper understanding of the subject matter. Moreover, the adopted approach also helped to understand climate change from the natural settings of the participants, which is critically essential for fit-for-purpose policies and adaptation.

The study was conducted in the Adansi North District of Ghana, which is located in the Ashanti region of Ghana (see Figure 1) and covers a surface area of 853.63 sq. km (GSS, 2010). The district exhibits the characteristics of the Semi-Equatorial climate and the semi-deciduous forest agro-ecological zone: high temperate and rainfall. Average temperature is about 27 °C while average annual rainfall ranges between 1250-1750mm (GSS, 2014). Located in the semi-deciduous agro-ecological zone, the district has major and minor raining seasons, which reinforce the major and minor planting seasons, respectively, and a dry season. The major rainfall season starts from April to July while the

Figure 1. Map of Ghana showing the Ashanti Region and the Adansi North District. Source: GSS (2014).

minor raining season spans September to November. Dry season in the district also starts from late November to March. February and March are the hottest months in the district. Relative humidity is high in the Adansi North District, about 80% and 20% in the rainy and dry seasons respectively (GSS, 2014).

The climatic and ecological characteristics of the district favour agriculture activities such as crop and livestock. As a rural district, agriculture is the major economic activity, employing about 77% of the labour force, with services and manufacturing employing about 15% and 8%, respectively (GSS, 2014). The district is characterized by subsistence farming, high poverty, low income, poor access to essential resources, and high dependency rate, thereby portraying the existence of high vulnerability in the district. Notwithstanding the vulnerability and the changes in climate in the district (GSS, 2014), there is no reliable climate data for data the Adansi North District, which poses challenges to policy makers in making decisions necessary to address climate change. Implicitly, regional and/or national climate scenarios influence local policies for climate change, hence the need to compare local realities and experiences of smallholder farmers in the Adansi North District to regional climate data.

2.2. Sample size, sampling techniques and instruments

As a mixed methods study, both simple random and purposive sampling techniques were applied in the selection of respondents and participants for quantitative and qualitative data collection, respectively. Using the district population census data as the sample frame, and guided by Krejcie and Morgan's (1970) statistical table for sample size selection, 378 respondents in 15 communities, were randomly selected from a target population of 17,696 agriculture households in the district. In addition, 41 key informants were purposively selected for interviews. The key informants included 15 district agriculture officers and 26 smallholder farmers. The inclusion and exclusion criteria for key informants included years of farming experience, length of stay in the district, knowledge of climate change and willingness to participate in the study. Questionnaire survey and semi structured interview guide were the main data collection instruments. The questionnaire aided in the collection of quantitative data while the interviews collected qualitative data which aided in a deeper understanding of the perception and experiences of smallholder farmers in their natural setting.

2.3. Data collection procedure

Both primary and secondary data were collected. Secondary data for the study consisted meteorological (rainfall, wind speed and temperature) and census data collected from the Ghana Meteorological Agency in Accra and the Planning Department of the Adansi North District Assembly, respectively. The lack of climate data at the district level necessitated the use of regional (Ashanti region) climate data from 1988 to 2017 for temperature and rainfall, and 2001 to 2017 for wind speed. Using regional climate data as a proxy for the Adansi North District may not provide vividly the extent of changes in the district, as different communities exhibit difference in climate. Nevertheless, districts in the Ashanti region portray fairly similar characteristics, typical of the semi-deciduous forest agroecological zone of Ghana (MOFA, 2016), hence justifying the appropriateness of using regional data as a proxy for the Adansi North District, located in the region. In addition, the Ashanti region has one synoptic station located in Kumasi, which was used for the study. Primary data was collected from smallholder farmers and district agriculture officers from April to September, 2018. Prior to data collection, the Institutional Review Board of the Pan African University approved the study. Five research assistants were recruited and trained on the modalities for questionnaire administration. The two-day training of the research assistants ensured uniformity in questionnaire administration and enhanced the credibility of the data collected (Bryman, 2012).

Initial permission was sought from gatekeepers including the District Director of the Ministry of Food and Agriculture, community Chiefs, Chief farmers and committee chairpersons, which paved way for seeking informed consent from respondents and participants. Written and/or oral informed consent were sought from smallholder farmers and district agriculture officers. Voluntary participation was also adhered to and the respondents/participants received detailed information on the objective of the study to avoid deception. The questionnaire was administered in the households of smallholder farmers. In the case of interviews, the participants chose the venue and mode of interview. Face-to-face and telephone interviews were conducted based on the preference of the participants. All the smallholder farmers preferred face-to-face interviews, which were conducted in their homes while in the case of officers, face-to-face and telephone interviews were conducted. Face-to-face interview of officers occurred at venues such as home, shop, workplace and farm. An interview lasted for about 45 min to an hour and all interviews were tap recorded after seeking permission from the participants. All interviews were conducted in local language (Twi), even though some officers used both Twi and English.

2.4. Data analysis

Quantitative primary data was coded, entered and analyzed in Statistical Package for Social Sciences (SPSS) version 20 while meteorological data was analyzed in Excel (2013) and Addinsoft XLSTAT 2016. In the case of meteorological data, the last-observation-carried-forward approach was adopted to fill missing data (Chepkoech et al., 2018), while missing data in quantitative primary data was filled through frequency analysis. Average seasonal, monthly and annual climate values were calculated from the meteorological data, which contained daily recordings. Preliminary analysis such as normality and outlier tests were performed using line graph, box and scatter plots.

In addition, descriptive statistics were calculated using frequencies and percentages, and inferential statistics such as independent sample t-test and one-way analysis of variance (ANOVA) were also calculated using demographic independent variables (such as age, years of farming experience, education) and dependent variable (perception). The study, also, checked for homogeneity of variance which exceeded 0.05, and according to Pallant (2016), homogeneity of variance greater than 0.05 indicates that homogeneity of variance assumption has not been violated. The effect size for t-test and ANOVA was also computed, in addition to multiple regression analysis (probit). Perception variable was converted into binary variable to enable probit regression analysis. Prior to the computation of the regression, multicollinearity and heteroscedasticity assumptions were checked. A simple correlation matrix was computed to ascertain multicollinearity of the variables in the model (see Table 1). Gujarati (1995) establishes a rule of thumb which says that, multicollinearity is a serious problem when the correlation coefficient between two variables is 0.8 or above. We also tested to find out whether heteroscedasticity was present in the model using a Breusch-Pagan test. The results show that the null hypothesis of constant variance should be rejected ($\chi^2(8) = 35.7; p < 0.001$). In effect, the White covariance matrix, which provides consistent estimates of standard errors, was computed so as for the t and F tests to be asymptotically valid.

Perception variable, which were measured in five-point Likert scale were aggregated into continuous variable for the purpose of inferential analysis (t-test and ANOVA) (Kothari, 2004). For meteorological data, linear regression, Mann Kendall test and linear plots were employed to investigate climate trends (Chepkoech et al., 2018; Kabo-Bah et al., 2016; Li et al., 2018; Longobardi and Villani, 2010; Mkonda and He, 2017; Nyatuame et al., 2014). Mann Kendall test, which assumes that meteorological data set is randomly ordered and independent (Chepkoech et al., 2018; Jaiswal et al., 2015), aided in testing the hypothesis that there is no trend in climate, using rainfall and temperature as proxies. Non-parametric linear regression and linear plots also aided in examining patterns and relationships in climate data (rainfall and temperature) while Pearson product-moment correlation aided in examining the relationship between climate data and smallholder farmers' climate change perception.

In the case of qualitative data, thematic analysis was manually employed. According to Braun and Clarke (2014), thematic analysis involves coding, identification and organization of themes as well as description. The recorded interviews were transcribed from the local language (Twi) to English after which the transcripts were shared with participants, which enhanced participants' validation and ensured that the meanings they attached to their social world were not distorted. The transcripts were then coded and perused carefully and continuously to identify and organize patterns and emerging themes (Creswell and Plano Clark, 2018; Saldaña, 2015). Attention was paid to the differences, similarities and frequency of views, in the organization of themes. Verbatim quotes were used to represent the meanings participants attached to climate change.

3. Findings and discussion

3.1. Demographic characteristics of respondents

Table 2 presents the demographic characteristics of smallholder farmers. More than half of the respondents were males (64%). The majority of the smallholder farmers (59%) have basic education qualification, even though 25% of them have no formal education. About 42.3% of the smallholder farmers have more than 30 years of farming experience while 28.8% were 51–60 years old.

3.2. Climate trends

Figure 2 presents the trends of rainfall in the Ashanti region of Ghana. As shown in Figure 2a, the major and minor rainfall seasons show an increasing trends in rainfall, even though, the minor season shows a higher magnitude of increase (3.32mm) in rainfall than the major season (1.59mm). Similarly, there is an increase in annual rainfall in the region as revealed by the trend line in Figure 2b, with an even higher magnitude of 5.08mm. The oscillatory pattern of rainfall shows that the highest rainfall over the past 30 years was received in 2007 (1794.9mm), indicating the wettest year, while 1996 was the driest year over the same period with a rainfall of 1040.9mm (see Figure 2b). For seasonal trends (see Figure 2a), 2002 and 2007 received the highest rainfall of 990.4mm and 740.1mm, respectively, for major and minor rainfall seasons. According to the Ministry of Environment, Science, Technology and Innovation (MESTI) (2013), Ghana observed

Table 1. Results of multicollinearity.

	Perception	Age	Gender	Education	Experience	Television	Radio	Family & Friends	Government	Personal Exp
Perception	1									
Age	-0.0045	1								
Gender	-0.0016	-0.0034	1							
Education	-0.0633	-0.0313	0.2211	1						
Experience	-0.1026	0.3297	-0.0016	0.0206	1					
Television	-0.1447	0.0335	0.0800	0.0395	0.0153	1				
Radio	-0.0975	0.1623	0.1684	-0.0380	0.1095	0.3105	1			
Family & Friends	0.1459	0.0334	0.0322	-0.0766	-0.0717	0.2919	0.1765	1		
Government	0.1455	0.0481	0.0698	0.0298	-0.0866	0.2432	0.1490	0.4883	1	
Personal Exp	-0.0434	0.1248	0.0385	-0.0030	0.1491	0.2987	0.4228	0.1970	0.0809	1

Table 2. Demographic characteristics of respondents.

Category	Frequency (N = 378)	Percentage (%)
Sex		
Male	242	64
Female	136	36
Education		
Never attended	96	25.4
Primary	34	9.0
JHS/Middle	223	59
SHS/SSS	13	3.4
Tertiary	10	2.7
Adult education	2	0.5
Years of farming experience		
1-5	28	7.4
6-10	39	10.3
11-15	33	8.7
16-20	51	13.5
21-25	34	9.0
26-30	33	8.7
>30	160	42.4
Age categories		
20-30	13	3.4
31-40	54	14.3
41-50	97	25.7
51-60	109	28.8
61-70	74	19.6
>70	31	8.2

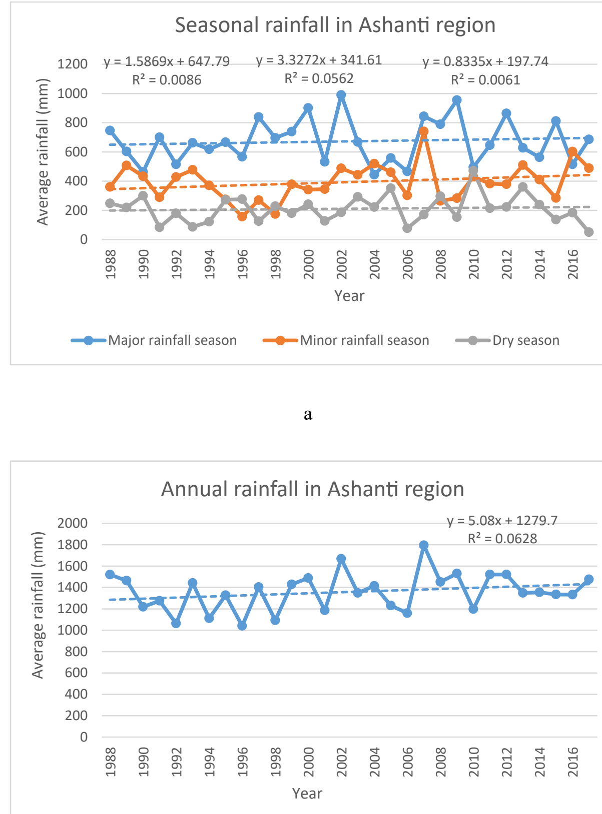


Figure 2. (a) Trends of seasonal rainfall; (b) Trends of annual rainfall.

decreasing rainfall pattern from 1960s. However, as posited by IPCC (2007), a unit increase in temperature may account for 1–3% increase in precipitation. Rising temperature in Ghana may therefore be responsible for the increasing rainfall trends observed in this study. Studies have also projected increasing rainfall across West Africa (Bindoff et al., 2013; IPCC, 2007). Increasing rainfall offers opportunity for smallholder farmers to increase agriculture production. For instance, increasing rainfall in the minor raining season will be suitable for the cultivation of early maturing crops, due to brevity of the minor rainfall season. Nevertheless, excessive rainfall leads to flood and erosion, which affects crop production (IPCC, 2018).

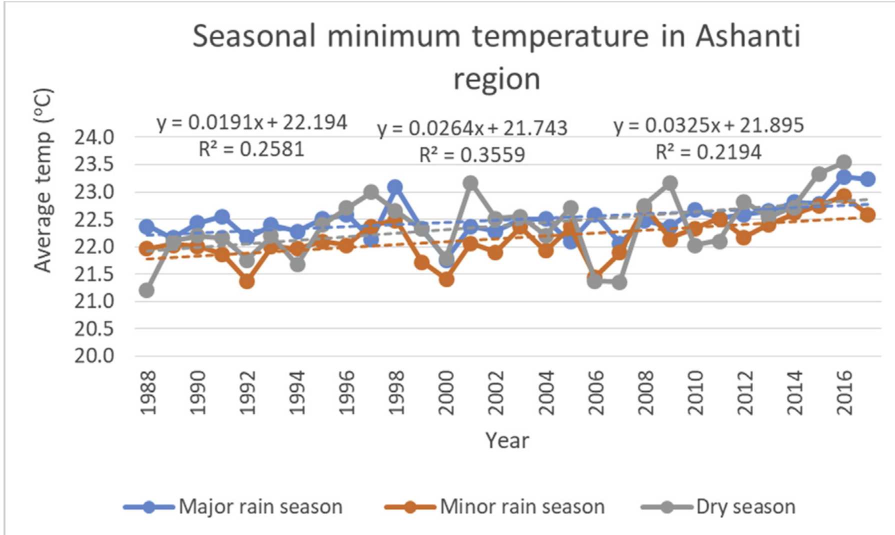
In Figure 3, the trends of minimum temperature are presented. The results show an increase in minimum temperature for major and minor rainfall seasons as well as dry season and annual temperature. The magnitude of increase is higher in minor rainfall (0.02 °C) and dry (0.03 °C) seasons than major rainfall season (0.01 °C). Intuitively, temperature in Ghana is high during the dry season due to the absence of rainfall (Padi, 2017). Figure 4 also shows rising seasonal and annual maximum temperature. These findings are consistent with previous studies which revealed rising temperature in Ghana (Campion and Venzke, 2013; Issahaku et al., 2016; Logah et al., 2013). High temperature provides conducive environment for C_3 and C_4 crops such as rice and sugar cane. Nevertheless, high temperature leads to high evapotranspiration in crops, which reduces agricultural productivity (IPCC, 2018). Studies have also reported that rising temperature negatively affects reproduction and growth in livestock as well as exposes livestock to forage and water challenges (African Union, 2010; Bindoff et al., 2013; Dhar Chakrabarti, 2015). Rampant spread of pests and diseases have also been associated with the changing climate (African Union, 2017; FAO, 2018).

In Figure 5, seasonal and annual trends of wind speed are presented. The results show an increasing trend of wind speed for major rainfall season, with a magnitude of 10.9 knots and a decreasing trend for both minor rainfall (-0.22 kts) and dry (-0.36 kts) seasons (see Figure 5a). There is also an increase in annual wind speed, as shown in Figure 5b. Padi (2017) reports that high windstorm accompany intense rainfall during the major raining season. Unlike the Savannah region where windstorm is high during the dry/harmattan season, the Ashanti region observes a fairly decrease in windstorm during both minor rainfall and dry seasons (Padi, 2017).

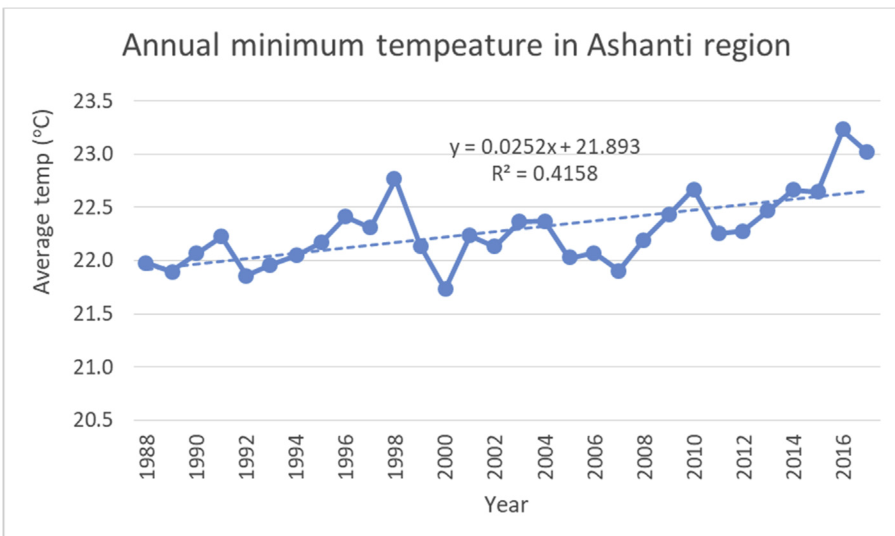
The results of the Mann Kendall and linear regression tests, which tested the hypothesis that there is no trend in rainfall and temperature are presented in Table 3. Mann Kendall test revealed significant trends in minimum and maximum temperature, at $p = 0.001$ and $p = 0.021$, respectively. These findings were also revealed by the regression results which showed that the trends of minimum and maximum temperature were significant at $p = 0.001$ and 0.006 respectively. Similar observations have been reported by a study in Kenya (Chepkoech et al., 2018).

3.3. Farmers' climate change perception

The climate change perception of smallholder farmers are presented in Table 4. In all, about 90.5% and 87.8% of the farmers perceived that there have been changes in the pattern and season of rainfall, respectively in the district over the past 30 years. In the case of temperature, a vast majority of the respondents (80.7%) perceived that there have been changes in temperature in the district. Similarly, there have been changes in windstorm in the district as reported by 83.1% of the respondents. Climate variables particularly rainfall and temperature have been extensively studied as they are perceived to be significant to the agricultural activities of smallholder farmers (Chepkoech et al., 2018; Nyatuame et al., 2014). However, smallholder farmers revealed during the interviews that the changes in windstorm equally requires attention, as



a



b

Figure 3. (a) Trends of seasoanl minimum temperature; (b) Trends of annual minimum temperature.

windstorm goes beyond just the destruction of agriculture to livelihood assets and resources such as buildings and roofing.

In Table 5, smallholder farmers' experiences of climate change are presented. The majority of the farmers have experienced late onset and early cessation of rainfall in the district as reported by 82.8% and 89.2% of respondents, respectively. Previous studies have reported that smallholder famers in Ghana have observed early cessation and late onset of rainfall (Limantol et al., 2016; Ndamani and Watanabe, 2015). Chepkoech et al. (2018) and (Abid et al., 2015) reported similar findings in Kenya and Pakistan, respectively. The observed changes in climate have affected the predictability of rainfall by smallholder farmers, who require such information for their agricultural activities. A vast majority of the smallholder farmers (94.7%) have also experienced decrease in the duration of rainfall while about 82.5% of the farmers have observed an increase in rainfall intensity. Unpredictability of rainfall by smallholder farmers and decrease in rainfall duration have been reported in existing literature (Abid et al., 2015; Chepkoech et al., 2018; Fadina and Barjolle, 2018).

In consonance with previous studies in Ghana (Limantol et al., 2016; Ndamani and Watanabe, 2015), the majority of the smallholder farmers indicated that they have observed an increase in intensity (96.8%) and duration (94.7%) of temperature in the district over the past 30 years. While about 79.4% of the smallholder farmers have experienced an increase in intensity of windstorm, 76.7% of them have observed a decrease in windstorm frequency. Similar findings have been reported by smallholder farmers in developing economies in Africa and Asia (Abid et al., 2015; Chepkoech et al., 2018; Fadina and Barjolle, 2018). Nevertheless, windstorm has not received significant attention by studies that examined farmers' perception and experiences of climate change.

The qualitative data from household heads (smallholder farmers), Agriculture Extension Agents (AEAs) and District Development Officers (DDOs) provided insight into the changes observed in temperature, rainfall and windstorm in the district. Almost all interview participants agreed that there has been an increase in temperature in recent times. Both officers and household heads concluded that temperature in the district has increased compared to what they knew in the past 30 years.

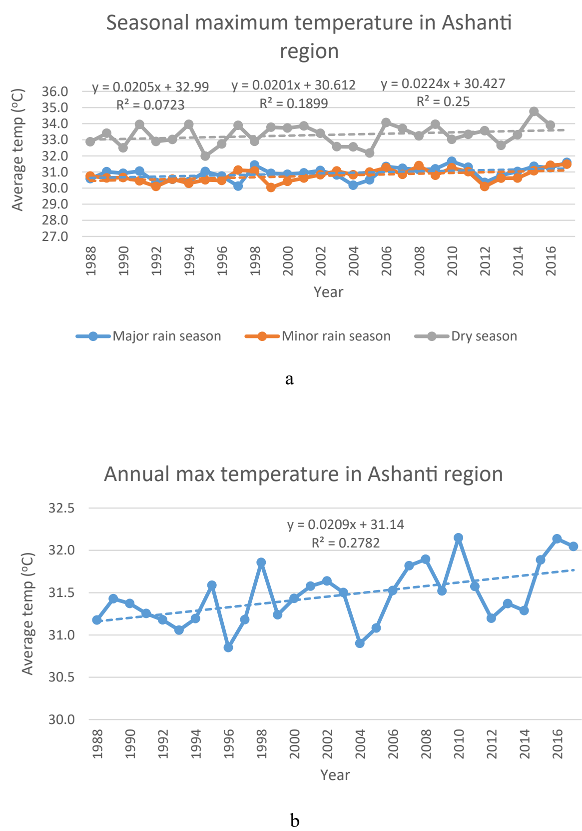


Figure 4. (a) Trends of seasonal maximum temperature; (b) Trends of annual maximum temperature.

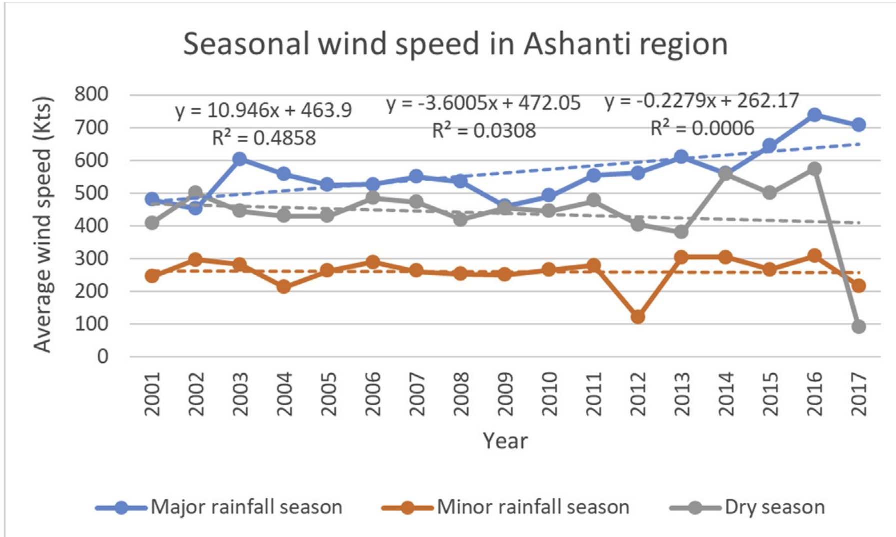
An Extension Agent recounted that "*there is high temperature in the district in recent times as the sun shines very much these times compared to the past 20 to 30 years*" (AEA2). Another Extension Agent indicated that "*at first, high temperature began from 13 h GMT to about 15 h GMT but nowadays even at 8hours GMT, 9hours GMT or 10 h GMT, the weather is very hot. The sun shines a lot, leading to high temperature. The sun also shines for a long time these days*" (AEA1). A household head also revealed that "*it is clear that the temperature has increased in intensity and duration. The temperature is very hot these days compared to the olden days. About 40 years ago when I used to live with my parents as a young boy, we used to stay at home and go to our farm anytime of the day because the temperature was favourable. These days you cannot stay at home and go to the farm anytime because of the high intensity of temperature*" (HH25).

An Agricultural Officer recounted on ordeal of high temperature observed in the district. According to the Officer (DDO4): "*There is also hot temperature in the Adansi North District particularly in February and March and this leads to rainfall in the subsequent months. Even in March and April where we receive some rainfall, we still experience high temperature. The high temperature intensifies in May due to the cessation of rainfall. There has also been a change in the duration of temperature in the district. The sun rises very early with high temperature early in the morning. At first, high temperature was observed from midday to about 15 h GMT but it is not so this time around. We experience very hot sun as early as 8 h GMT. The length of sunshine in a day has increased with corresponding high temperature*". The changes in duration and intensity of temperature have been well documented in the literature, both in Ghana and elsewhere (Abid et al., 2015; Chepkoech et al., 2018; Fadina and Barjolle, 2018; Limantol et al., 2016; Ndamani and Watanabe, 2015). Nevertheless, previous studies have not reported the shift in high temperature from midday to early morning, as revealed by the smallholder farmers.

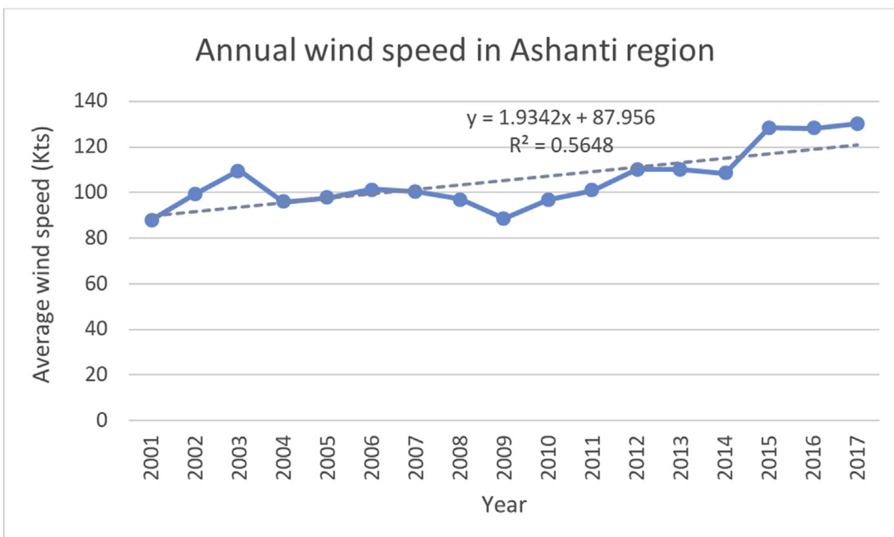
The change in temperature in the district slightly differs from community to community. The difference could be explained by the influence of hills and highlands in the district. A Development Officer stated that "*Fomena, which is the district capital is situated on a hill and therefore it rains a lot there, hence the temperature is not so high in Fomena. However, if you go to those communities that are not situated on highlands, you will observe that the sun shines very much in these areas, leading to high temperature*" (DDO3). Previous studies noted that orographic features influence variability in climate (Longobardi and Villani, 2010; Nyatuame et al., 2014). Although smallholder farmers do not have available data to show the extent of changes in climate, they are able to do so through their prolong experience with the environment. For instance, a participant expressed that "*the district experiences very high temperature. Even though we do not have data on that but we have observed through our farming and environmental activities that the temperature is very high these days*" (DDO4). From above, it is indicative that the Adansi North District has experienced changes in temperature, particularly rise in intensity and increase in duration of temperature. The findings from the qualitative data agree with that of the quantitative data, which showed a rise in temperature.

The lived experiences of the participants revealed phenomenal changes in windstorm in the district, which corroborates the results in Figure 5. For instance, AEA2 intimated that "*I have been in the district since 1994 and I have never witnessed destructive windstorm like it happened this year (2018). The windstorm was heavy and destructive and it ripped off about half of the buildings in this community (Brofoyedru). The windstorm was short in duration but if it had continued for 5 to 10 more minutes, the whole community would have been destroyed. The windstorm occurring this year is of high intensity and is associated with climate change*". Other participants also expressed that the change in windstorm is of great concern in the district. According to a Development Officer "*windstorm is a big issue in the district especially in January, February, and March, which is the windstorm period. During this time, roofs are ripped off and crops particularly plantain, maize and cassava are destroyed. The windstorm in the district is unbearable during the windstorm period*" (DDO2). The windstorm experienced in the district also changes from period to period as revealed by some participants. An Extension Agent expressed that the "*we mostly experiences strong windstorm during rainfall season and when approaching the dry season*" (AEA7). For AEA 5, "*this year (2018) the windstorm has been too strong especially in May and many farmers have complained of the destruction caused by windstorm*". This confirms the rise in windstorm during the major rainfall season, as revealed by the results in Figure 5a. In terms of duration of windstorm, AEA3 revealed that "*sometimes the wind blows for a short period but it is very intense and destructive*".

The interviewees also revealed that there have been changes in onset, cessation, intensity, frequency and duration of rainfall, which are consistent with previous studies (Abid et al., 2015; Chepkoech et al., 2018; Fadina and Barjolle, 2018; Limantol et al., 2016; Ndamani and Watanabe, 2015). According to a household head "we used to start the farming season soon after Christmas some years ago but currently we cannot do that since we need to wait until the rain sets in from March or April" (HH5). Another household head expressed that "*for the past years, the rain started from January, but was not massive. From then, farmers prepare their lands for farming till June-July. However, in recent times and especially in 2018, the rain started very late and was massive*" (HH13). This is consistent with previous studies which showed delay in rainfall season (Chepkoech et al., 2018; Limantol et al., 2016). The delay in rainfall causes a delay in farming activities, as the major and minor rainfall seasons reinforce the major and minor farming seasons in the district (GSS, 2014; MOFA, 2016). The participants have also observed changes in rainfall season in the district. "*Previously, the major raining season peaked in June, July but now we even receive massive rains in April and May*" (HH13). As such, farmers are no longer able to predict rainfall season due to climate change. The majority of participants raised concerns on unpredictability of rainfall due to climate change. For instance, a household head recounted that "*at first, we could predict the month in which the rainy season will start and plan our farming activities accordingly, but now climate change has resulted in changes in rainfall season, thereby making it difficult for us to predict. Our fathers and our forefathers had ideas*



a



b

Figure 5. (a) Trends of seasonal wind speed; (b) Trends of annual wind speed.

Table 3. Mann-Kendall and Regression analysis for temperature and rainfall.

Variables	Mann-Kendall test			Regression analysis		
	MK Statistic (S)	*p*-value	Test interpretation	Regression equation	R^2	*p*-value
Annual Rainfall	0.117	0.181	No trend	Y = -7633.08X+4.50	0.048	0.243
Major Season	0.44	0.367	No trend	Y = -934.52X+0.86	0.002	0.807
Minor Season	0.136	0.146	No trend	Y = -6035.92X+3.21	0.052	0.224
Max Temp	0.297	0.021	Trend detected	Y = -3495.77X+7.48	0.234	0.006*
Min Temp	0.434	0.001	Trend detected	Y = -8935.09X+8.52	0.355	0.001*

* *p* is significant at 0.05.

as to when to plant and when not to plant, which enabled them to plan their activities. Nowadays, when you expect rainfall you do not get it and when you do not expect rainfall, it rains. Sometimes too, it rains shortly for a season" (HH1).

An Extension Agent revealed that "*at first, the onset of the rainy season was very early but now we experience late onset. The duration of rainfall has also changed compared to the past 20 years. These days the rains come with high intensity and it mostly rains for short periods too. We never observed these in the past years*" (AEA2). Most of the participants expressed concern on the spate of flood and erosion due to intense rainfall in the district. The researchers also observed gully and sheet erosions in most of the communities in the district, which are footprints of intense rainfall. A participant intimated that the change in rainfall pattern and season has not been continuous over the past years. According to an Extension Agent

Table 4. Respondents' perceptions of climate change.

Variable (changes in)	Strongly Disagree (%)	Disagree (%)	Neutral (%)	Agree (%)	Strongly Agree (%)
Rainfall (pattern)	1.3	6.3	1.9	76.5	14.0
Rainfall (season)	0.8	6.1	5.3	73.8	14.0
Temperature	0.5	6.3	12.4	64.4	16.4
Windstorm	0.8	5.6	10.6	67.1	15.9

Table 5. Nature of observed changes in climate.

Observed changes in rainfall	(%)	N (378)
Early onset of rainfall	17.2	65
Late onset of rainfall	82.8	313
Early cessation of rainfall	89.2	337
Late cessation of rainfall	10.8	41
Increase in rainfall duration	5.3	20
Decrease in rainfall duration	94.7	358
Increase in rainfall intensity	82.5	312
Decrease in rainfall intensity	17.5	66
Increase in temperature intensity	96.8	366
Decrease in temperature intensity	3.2	12
Increase in duration of temperature	94.7	358
Decrease in duration of temperature	5.3	20
Increase in windstorm intensity	79.4	300
Decrease in windstorm intensity	20.6	78
Increase in windstorm frequency	23.3	88
Decrease in windstorm frequency	76.7	290

(AEA8) "*I can say that the pattern of rainfall in the district is biennial. We receive good rainfall every two years. I have been here for the past six years and there are years that rainfall onset was very early with high intensity and in such years it rains a lot throughout the year. There are other years too that rainfall onset is delayed and it rains for a short period, as rainfall retreats very early. In most cases, when the onset is delayed with early cessation, we mostly receive rainfall once in a while when approaching September and October*".

According to AEA3, "*we have two raining seasons in this district. The major season starts somewhere around March to July. All things being equal, it mostly rains in this season. However, the rainfall is unpredictable and erratic. It sometimes delays too. So when you expect rains, you do not get it but when you do not expect rains, you get it. The rainfall we receive too is of short period but of a high intensity with heavy windstorm. This pattern keeps changing every year and every season*". The participants equally expressed the seriousness of changing rainfall pattern in the district. For instance, a Development Officer echoed that "*as for rainfall, the best reference I can give you is the 2016 major rainfall season. I think the Adansi North District had the most serious issue in the Ashanti region that year. Most of the farmers planted their maize in the last week of April to first week of May and we expected to have rains for the next three months but the rainfall suddenly retreated in the last week of June. In July, there was not even a single rainfall for three weeks until the last week of August when we received rainfall*" (DDO1). The participants intimated that there was short but intense drought in 2016, thereby leading to the withering of crops and the subsequent reduction in yields. According to IPCC (2018), drought leads to drastic reduction in yields.

3.4. Relationship between climate data and farmers' perception

The smallholder farmers and district agriculture officers have experienced rising temperature, late onset and early cessation of rainfall as well as increasing rainfall intensity and a decrease in rainfall duration. The results of the trends analysis of rainfall and temperature also showed an increasing rainfall and rising temperature in the Ashanti region. However, the correlation results showed that there is no significant relationship between smallholder farmers' climate change perceptions and meteorological data as shown in Table 6, even though perception has a weak positive correlation with rainfall ($r = 0.051$, $p = 0.320$) and a weak negative correlation with temperature ($r = -0.072$, $p = 0.160$). There is also a negative relationship between rainfall and temperature ($r = -0.078$, $p = 0.129$), which indicates that as temperature increases, there is a reduction in rainfall and vice versa. The lived experiences of the smallholder farmers confirm the relationship between rainfall and temperature, as the farmers reported that they receive less rainfall in the dry season when the temperature is high while during the raining season there is less sunshine with corresponding low temperature. Nevertheless, according to the Bindoff et al. (2013), 1 °C rise in temperature will lead to about 1–3% increase in mean global precipitation.

3.5. Determinants of farmers' perception

The study computed independent-sample t-test and one-way ANOVA to compare how the differences in demographic characteristics of smallholder farmers influence their perception (see Table 7). The results showed that there is no significant relationship between demographic characteristics of smallholder farmers and their climate change perception. For instance, in the case of gender, there was no significant difference in the perceptions of males ($M = 15.67$, $SD = 2.66$) and female ($M = 15.83$, $SD = 2.56$), t (376) = 0.58, $p = 0.566$. Even though, female farmers were slightly positive on their perception of climate change than male farmers, there was a small magnitude in the mean differences of males and females (eta squared = 0.009). The results also showed that there was not significant effect of age [F (5, 372) = 0.44, $p = 0.821$], education [F (5, 372) = 0.39, $p = 0.859$] and years of farming experience [F (6, 371) = 0.78, $p = 0.590$] on perception.

Multiple regression (probit) analysis was computed to further understand the relationship between demographic characteristics of smallholder farmers and their perception of climate change. Unlike the t-test and one way ANOVA analysis, the multiple regression analysis included the sources of climate change information of smallholder farmers (radio, television, personal experience, extension services, and family and friends) in the model (see Table 8). The results of the Chi square showed that the Wald statistics are highly significant($\chi^2(9, 378) = 33.83; p < 0.001$), even though the pseudo $r^2 = 0.0903$.

The results show that information from the media, particularly, television and radio are significantly less likely to influence farmers' perception of climate change. This is partly due to the mistrust among smallholder farmers on the information from the media. In Ghana, Hirons et al. (2018) found that smallholder farmers in cocoa growing areas do not trust information from the media. Similar results were also reported by Chepkoech et al. (2018) who noted that smallholder farmers in Kenya have mistrust in climate information from the media. Nevertheless, Elum et al. (2017) reveal that climate change perception of smallholder farmers in South Africa is shaped by the media. The results from the analysis also show that information from family and friends, and government significantly influence farmers' perception. This might be due to their experience of climate change and proximity to smallholder farmers. For instance, family and friends who experience climate change are more

Table 6. Correlation between climate data and farmers' perceptions.

Variables	Perception	Average rainfall	Average temperature
Perception	1	0.051 (0.320)	-0.072 (0.160)
Average rainfall	0.051 (0.320)	1	-0.078 (0.129)
Average temperature	-0.072 (0.160)	-0.078 (0.129)	1

Note: significant values in parenthesis, p is significant at 0.05.

Table 7. Comparing demographic variables with climate change perception.

		Sample size (N = 378)	Perception	df	*p* value
Gender				376	0.566
	Male	242 (65%)	15.67 (2.66)		
	Female *t*	136 (36%)	15.83 (2.56)		
			0.58		
Age				5, 372	0.821
	20–30 years	13 (3.4%)	16.38 (1.39)		
	31–40 years	54 (14.3%)	15.39 (3.14)		
	41–50 years	97 (25.7%)	15.89 (2.40)		
	51–60 years	109 (28.8%)	15.66 (2.62)		
	61–70 years	74 (19.6%)	15.78 (2.83)		
	>70 years	31 (8.2%)	15.73 (2.20)		
	F		0.44		
Education				5, 372	0.859
	No education	96 (25.4%)	15.89 (2.35)		
	Primary	35 (9%)	15.85 (2.15)		
	JHS/Middle	223 (59%)	15.64 (2.84)		
	SHS/SSS	13 (3.4%)	16.23 (1.30)		
	Tertiary	10 (2.6%)	15.00 (3.13)		
	Adult education	2 (0.5%)	16.00 (0.00)		
	F		0.385		
Years of farming experience				6, 371	0.590
	1–5 years	28 (7.4%)	16.00 (2.61)		
	6–10 years	39 (10.3%)	15.26 (3.23)		
	11–15 years	33 (8.7%)	15.97 (2.78)		
	16–20 years	51 (13.5%)	15.61 (2.83)		
	21–25 years	34 (9%)	16.44 (1.71)		
	26–30 years	33 (8.7%)	15.61 (2.81)		
	31 years and above *F*	160 (42.3%)	15.66 (2.62)		
			0.775		

Note. *p* is significant at 0.05.

likely to share or exchange information on the observed changes in climate with other members, which influence their perception. Similarly, the government, in this case local administration including extension officers also influence the perception of smallholder farmers. For instance, extension officers educate smallholder farmers on changing climate, which influence their perception (Aemro et al., 2012; Asare-Nuamah et al., 2019; Debela et al., 2015). Implicitly, smallholder farmers trust information from the people close to them, thereby influencing their perception of climate change. Personal experience also showed positive in influencing the perception of smallholder farmers, although the result was not significant. Studies have reported that personal experience significantly influence farmers' perception of climate chang (Hitayezu et al., 2017), even though Hitayezu et al. (2017) assert that personal experience leads to bias in the perception of smallholder farmers.

Table 8. Predictors of climate change perception.

Variable	Coefficient	Robust Std. Err.	Z	p-value
Age	0.0037	0.0062	0.59	0.556
Gender	0.0521	0.1659	0.31	0.753
Education	-0.1919	0.1892	-1.01	0.310
Experience	-0.6123	0.4226	-1.45	0.147
Television	-0.6687***	0.1856	-3.60	0.000
Radio	-0.4171*	0.2500	-1.67	0.095
Family & Friends	0.4273**	0.1880	2.27	0.023
Government	0.7092**	0.3034	2.34	0.019
Personal Exp	0.1818	0.3003	0.61	0.545
Constant	1.7735	0.5472	3.24	0.001

***p < 0.01, **p < 0.05, *p < 0.1.

4. Conclusion

The study adopted convergent parallel mixed methods design to examine the trends of rainfall and temperature as well as explore smallholder farmers' perceptions of climate change in the rural Adansi North district of Ghana, where subsistence agriculture is the major source of income and livelihood for majority of the people in the district (GSS, 2014). The study further compared farmers' perception with meteorological data which is essential for fit-for-purpose climate change polices and adaptation as well as disaster preparedness in general. In addition, the study investigated the relationship between smallholder farmers' demographic characteristics and their climate change perception as well as the predictors of perception.

It is conclusive from the study that the Adansi North District has observed changes in climate. The findings from the analysis of meteorological data showed that indeed, there have been remarkable changes in climate, marked by rising temperature and rainfall, even though rainfall and temperature trends were oscillatory. Similarly, the smallholder farmers perceived that there have been changes in climate particularly in rainfall, temperature and windstorm. The farmers reported that they have observed late onset and early cessation of rainfall accompanied by reduction in duration of rainfall and an increase in its intensity. For temperature, the farmers have observed rising temperature and the associated increasing intensity and duration of temperature. The lived experiences of both farmers and district agriculture officers confirmed the changes in rainfall and temperature in addition to destructive windstorm.

Another conclusion drawn from the study is that climate change experiences of smallholder farmers and district agriculture officers confirmed the results from meteorological data. As such, we argue that the changes in climate in the Adansi North District are fairly represented by regional climate data, although there was no significant relationship between the lived climate change experiences/perception of smallholder farmers' and regional meteorological data. Therefore, the changes in climate occurring in the Adansi North District are not anyway different from the changes observed in the Ashanti region. The study also found no significant differences in demographic characteristics of smallholder farmers and their perception. Nevertheless, information from family and friends and government, particularly, local institutions and extension service were significant predictors of perception. In addition, information from the media such as television and radio significantly influence farmers' perception. By this, we conclude that information from family and friends, government and the media particularly television and radio shape climate change perception of smallholder farmers.

As climate change perception influences the choice of adaptation of smallholder farmers (Fadina and Barjolle, 2018), the study recommends that climate change education and mass awareness should be intensified particularly in rural communities where misconception is high and farmers have limited capacity to adapt to climate change. To do this, all available media particularly television, radio, extension agents and community information centers, which have gained roots in rural communities should be used. In addition, climate journalism which provides accurate and reliable climate information should be promoted. This will help to increase access to reliable and accurate climate information needed by smallholder farmers for their agricultural activities, as Hirons et al. (2018) found that smallholder farmers in cocoa growing communities in Ghana have challenges in accessing reliable climate information. The study again recommends that the number of meteorological stations should be increased and extended to every district in Ghana. While such approach will boost access to reliable climate information to smallholder farmers, it will equally enhance fit-for-purpose climate change policies at the local level, which is essential for agricultural-based district development agenda. Access to essential resources and capacity development programmes should be intensified particularly in rural communities to increase farmers' adaptive capacity.

The study used Adansi North District as the case study and analyzed climate data using Ashanti region climate data as a proxy, further studies of this nature should be conducted using climate data of the 16 regions or the six agroecological zones of Ghana and larger sample size of smallholder farmers from across the regions or egroecological zones should be included. This will give a deeper understanding of climate trends of regions or ecological zones and smallholder farmers perception of the nature of observed changes in climate, which is paramount for local, regional and national climate change and adaptation policies.

Declarations

Author contribution statement

Peter Asare-Nuamah: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Ebo Botchway: Contributed reagents, materials, analysis tools or data.

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Additional information

No additional information is available for this paper.

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