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Impacts of Changing Climate on Maize Production in the Transitional Zone of Ghana

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Abstract

This study sought to assess the challenges and opportunities that come with climate change and variability impacts on maize farming in the Nkoranza South Municipality in the Transitional Zone of Ghana. The mixed method approach (qualitative and quantitative) was used in collecting the data. Rainfall data obtained from the Ghana Meteorological Agency (GMet) indicated that the dry cell between the major and minor rainy seasons was getting wetter and the two seasons were gradually merging whereas the first and last quarters of the year were getting drier over the last couple of decades. The situation over the last five years (2010-2015) had worsened as the amount of total rainfall had reduced by 22% compared to the 30 year period between 1960 and 1982. The results of the study showed that farmers had perceived changes in climate in the form of decreasing rainfall, rising air temperatures and seasonal changes in rainfall pattern which were affecting their maize farming operations. The major setbacks within the area were deficit in rainy days and intermittent erratic rainfall affecting maize production. The major opportunity available to farmers in the face of changing climate in this agroecological zone was cashew production. About 76.8% of the respondents had diversified into cashew farming as a result of rainfall failure and strong resistance of the cashew trees to changing and variable climate.

Keywords

Climate Change, Variability, Maize Production, Transitional Zone, Cashew Farming

1. Background to the Study

There is now unequivocal evidence that the climate of the Earth has demonstrably warmed up since the pre-industrial era and that most of the warming over the last 50 years is very likely to have been as a result of increase in Greenhouse Gases (GHGs) concentrations in the atmosphere [1].

Three major physical impacts of climate change, according to IPCC (AR4) in Ghana, are temperature rise, changing rainfall regime towards a longer dry season and a varnishing wet season. [2] also underscored the fact that there has been a noticeable shift in the rainfall pattern in Ghana towards a longer dry season and the disappearance of short dry spells between major and minor seasons. The Ghanaian agricultural-dependent economy has thus suffered severe economic consequences [3]. Agriculture is the pillar of Ghana's economy providing employment to the masses in the rural areas and sustaining the vast majority of the population. Only about 0.89% of the country's arable land, equivalent to 23,657 hectares (ha) is cultivated under irrigation, benefitting only rice production [4] [5].

According to [6], maize yields in Ghana are low compared to that of developed countries. The national average yield is about 1.6 mt per hectare as compared to a country like Brazil (6.10 $t \cdot ha^{-1}$). This is primarily due to the inadequate input of fertilisers and non-existing irrigation facilities in the maize production areas [7].

Among the staples cultivated in the country, maize has been identified as one of the most essential food crops within the grains [8]. Maize is grown on more than 997,661 hectares across all the various agro-ecological regions in Ghana [8].

Generally, high temperatures have been reported as detrimental to grain yields [9]. It was projected that [6] maize yields would drop from its estimated level (2000) 0.5 to 6.9 in the year 2020. The study of [10] indicated that each day's temperature above 30˚C would reduce the final yield by 1% under optimal rain-fed conditions, and by 1.7% under drought conditions. In the transition (where Nkoranza is located) and forest belts, though droughts are not the main drawback, variations in rainfall deficits, particularly in the number of rainy days pose new challenges to rural livelihoods [11]. There is a decrease in the farming season in several places as well as a gradual waning of the secondary growing season in the transition zone [12] [13].

2. Materials and Methods

The study was conducted in the Nkoranza South Municipality in the Brong Ahafo Region of Ghana. The Municipality lies within the wet semi-equatorial region of Ghana. It is located in the transitional zone between the savannah woodland of northern Ghana and the forest of the south. The Municipality lies within longitudes 1˚10W and 1˚55W and latitudes 7˚20''N and 7˚55''N [14]. It shares common boundaries with Nkoranza North District to the north, Techiman Municipality to the west, Offinso North to the south and Ejura-Sekyere-Dumase to the south-east [14].

The eastern part of the Municipality is mainly characterised by savannah woodland and the southern part is principally marked by forest regrowth, made up of shrubs and grasses. It has a mean annual rainfall level, ranging between 800 - 1200 mm, relative humidity, ranging between 55% - 90% and the average annual temperature of 26˚C [14].

2.1. Data Collection

Both primary and secondary data were used in obtaining the data. With regards to primary data, two focus group discussions were organized in two communities (Donkro Nkwanta & Aboasu) within the Municipality. Twelve key informants comprising seven maize farmers, two sub-chiefs, one meteorologist from GMet-Wenchi branch, one agricultural extension officer from Nkoranza South Municipal Assembly and the 2015 best farmer of the Municipality were also interviewed. Secondary data consisted of meteorological data (rainfall and temperature) from GMet which covered 1960 to 2014. This data (rainfall) was divided into two tranches, 1960 to 1982 and 1988 to 2014. Some data between 1983 and 1987 were unavailable and so were not used for the analyses. Rainfall data over the last five years (2010 to 2014) as well as temperature data from 1983 to 2014 were analysed in determining current rainfall trends in the study area. Maize production data (2010-2015) was also obtained from the assembly of the Municipality for analysis.

2.2. Study Design

The study relied on survey, qualitative interviews and focus group discussions (FGD) to obtain essential field data from the selected farming communities. The survey was administered among some selected maize farming communities in the Municipality of which purposive and accidental sampling techniques were used to enhance diversity of the respondents. The purposive technique was used to obtain the farming communities, percentage of male and female farmers as respondents, and selection of key informants. The key informants were made up of the aged, chiefs, a meteorologist and an agricultural officer. Any farmer chanced upon was also given the opportunity to answer the questionnaire (Accidental sampling technique).

The survey questions included close-ended as well as a few open-ended questions, most of which sought information on respondents' perception on climate change and variability, farm size, variety of maize cultivated, farming system, application of fertiliser and other coping strategies meant to reduce the effects of low yields. The survey was conducted face-to-face with the respondents in different locations and in different communities. The questions were read and translated into Akan (the main local language) for the respondents to answer.

In all, 12 key informants were interviewed to gain information about their views on climate change and variability impacts on maize farming in the Municipality. Seven of the respondents were maize farmers; three were elders from the chief's palace whose ages were between 65 and 73 years (the aged) and the rest were farmers. At least, one respondent came from each of the five farming communities in the study area. Apart from these key informants, one of the Municipal Agricultural Officers was also interviewed. Lastly, a staff of Ghana Meteorological Agency (GMet, Wenchi branch) was interviewed. The questions in these qualitative interviews were unstructured, but were administered with the help of an interview guide. The themes covered were similar to those in the questionnaire survey, but were more interactive and probing, seeking information on climate change and variability of the study area, adaptation of the farmers, etc. with ample opportunity for the informants to provide extensive personal narratives. The interviews were done in the participants' homes or residences and were tape-recorded with their permission and later transcribed.

Two FGDs were organised at the end of the data collection in two communities. Averagely the two FGDs were made up of three females and seven male farmers. The focus groups dealt with the changing climate and variability in the area, its impacts both positive and negative on their livelihoods, their adaptive capabilities to alleviate the challenges posed by the changing climate and economic/financial assistance they received elsewhere (if any) to support themselves. All the deliberations were videoed with the permission of the discussants and later transcribed. The selection was made based on how well they answered questions during the survey (**Figure 1**).

3. Results and Discussion

3.1. Demographic Information on Maize Farmers

Table 1 provides basic information about the maize farmers selected for the questionnaire survey. The respondents were made up of male (70%) and female (30%) maize farmers. The number of respondents was proportional to the population of each community. Sixty percent of the respondents were Bonos (indigenes of the Brong Ahafo Region of Ghana), 33.6% were settlers from the northern part of Ghana, 3.6% Asantes and 2.3% representing Fulanis and Ewes (Bonos, Asantes, Ewes and Fulanis are all tribes in Ghana). The majority of the maize farmers (51.8%) rented lands for farming, whilst a few of them (20.5%) worked on their own lands. Several of the farmers (44.5%) had farmlands of size less than 2 hectares (ha) with about 55.5% of the respondents with farmlands greater than 2 ha. Ninety-seven percent of the respondents practised monoculture which was the dominant farming system among the maize farmers within the Municipality with 2.3% of the respondents practising intercropping or mixed cropping. Eighty-seven percent of the respondents sowed *aburohoma*, a variety of maize prevalent in the Nkoranza South Municipality. Even though approved seeds like *obaatampa* and *omankwa* were available on the market, most farmers preferred the traditional variety to these new cultivars which were approved to be drought resistant and early maturing hybrids.

The percentage of farmers who applied fertilisers on their crops was 71.4%. About 17.4% of the respondents did not apply fertilisers and the famers who occasionally applied fertilisers were 10%. Only few of the farmers (12.7%) enriched their crops with organic fertilisers.

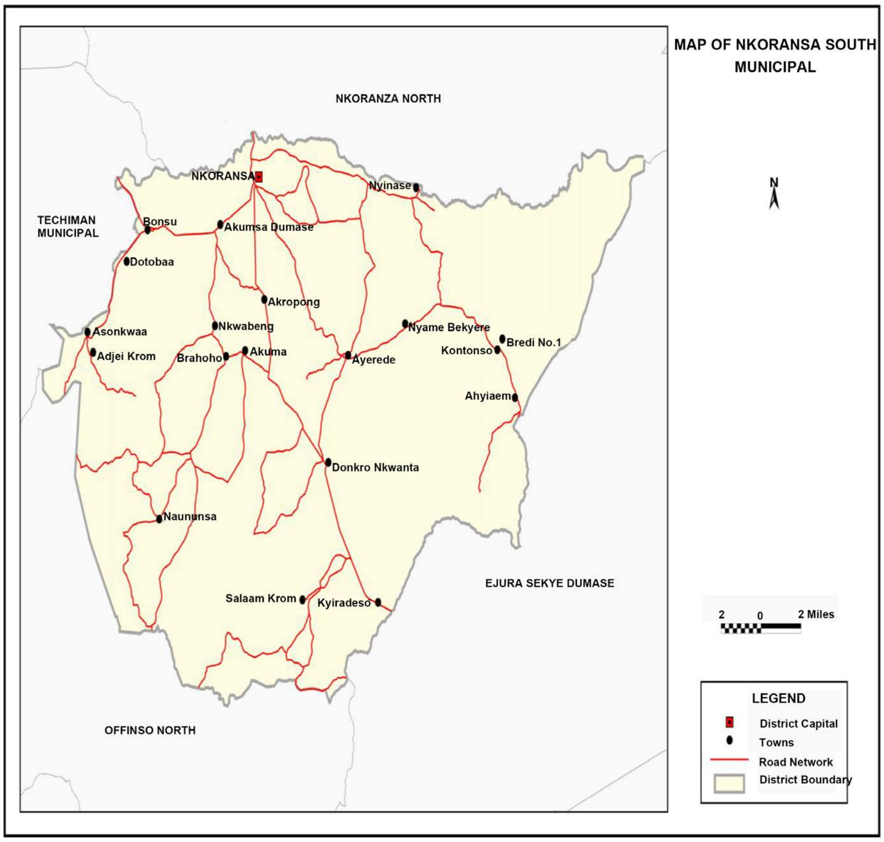


Figure 1. A Map of Nkoranza South Municipality showing the study area.

Table 1. Demographic information of farmers.

Community	Gender		Farm size			Level of education				Place of birth	
	M	F	<2 (ha)	2 - 4 (ha)	>4 (ha)	None	Basic	SHS	Tertiary	Native	Alien
Aboasu (35)	28	7	34	32	34	37	46	14	3	31	69
Asuoano (30)	24	6	43	37	20	30	60	7	3	90	10
D/Nkwanta (95)	57	38	49	20	31	25	59	8	8	47	53
Kyekyewere (30)	24	6	37	30	33	27	63	10	0	30	70
Kyiradeso (30)	21	9	50	30	20	33	53	7	7	30	70
Total (220)	**154**	**66**	**44%**	**27%**	**29%**	**29%**	**57%**	**9%**	**5%**	**46%**	**54%**

Twenty-nine percent of the respondents had not received any formal education with only 5.5% of the respondents having attained tertiary level education. Most of the respondents were Junior High School (JHS)/Middle School graduates, representing 40.9% of the respondents. Data from the survey indicated that males (8.2%) were better educated than females. About 34.8% of the female farmers had not received formal education, whereas 26.6% of the males had no formal education. A study in Pakistan [15] revealed that if producers are educated, it enhances the application of best farming practices in tomato production.

3.2. Major Constraints Militating against Maize Farming

According to 39.1% of the respondents, the major challenge which confronted the farmers in the transitional zone was rainfall. This challenge had to do with the late onset of the major and minor rainy seasons and the early cessation of the minor season. Challenges with regard to climate affecting farming might not necessarily be increasing temperatures since the monthly annual air temperatures (range) for the study area from GMet (1983-2010) was between 29.5˚C - 34.3˚C which is within the optimal range (30˚C - 34˚C) for lowland maize in the tropics according to [9]. It was rather the erratic rainfall pattern characteristic of both seasons that had affected crop yields as it was also reported by [16].

Apart from rainfall irregularity, another challenge militating against farming was capital/money according to 30.0% of the respondents. Self-finance was the topmost means of financing maize production in the Municipality. Financial institutions feared the risk of farmers not being able to repay their loans due to erratic or failure of rainfall and thus were not prepared to finance the farmers. For financial support from the banks, farmers needed to provide two guarantors who were on government pay roll but these government workers were also not sure about whether the farmers would be able to pay back the loans due to the uncertainty of rainfall (FGD).

Another challenge facing farmers in the field was pest and disease infestation according to 15.0% of the respondents. The arrival of most of the pests, such as army worms, was detected in the minor season when there were prolonged dry spells. The pests had the capacity to devour large tracks of maize, increasing the production cost of the poor-resourced farmer. Apart from army worm infestation, diseases like maize streak and stem borer were also causing distress to the farmers. The presence of these pests and diseases were facilitated by changing climate in the Municipality (FGD).

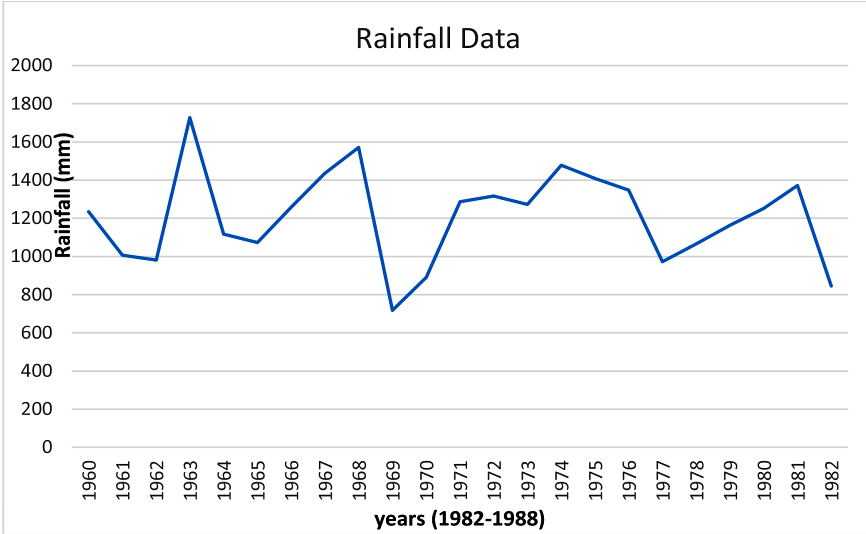
3.3. Coping Mechanisms in Times of Crop Failure

The respondents were asked what they did when their crop (maize) failed; 23% of them reported that they sold other farm produce, 15% of the respondents engaged in trading activities, whereas 12.3% traded in farm animals with about 20.5% of farmers doing virtually nothing. Six percent of the respondents lived on borrowing money from friends and relatives.

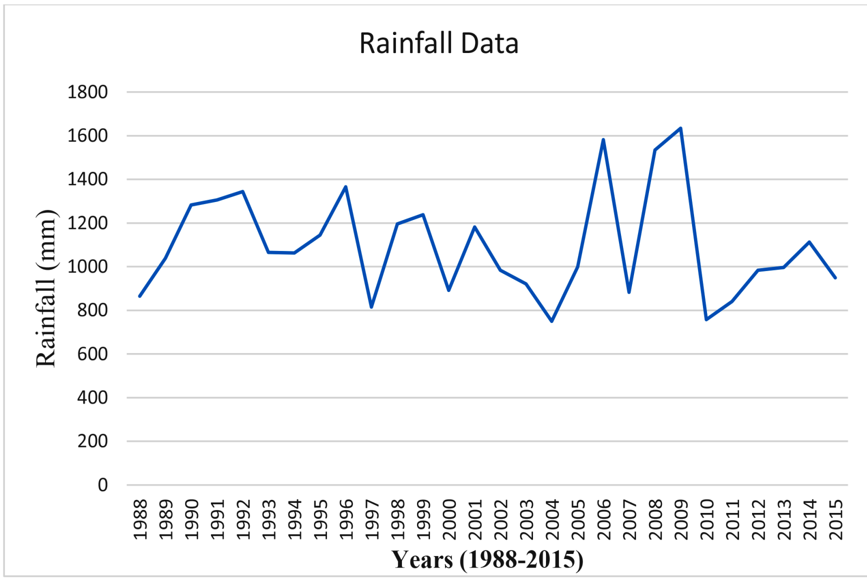
3.4. Analysis of Rainfall Data of Nkoranza South Municipality (1960-2015) Depicting the Regime of Climate Change and Variability in the Study Area

Figure 2(a) & **Figure 2(b)** cover the precipitation trend for the study area (Nkoranza South Municipality) from 1960-2015. 1983 to 1987 did not appear in the tables/figures because there were lots of blank cells (data) within this period.

Precipitation was low in the early 1960s but rose steadily in the mid-1960s, falling suddenly in the 1970s. Rainfall, however, progressively rose and somewhat stabilised in the mid-1970s and declined again in the early 1980s. There



(a)



(b)

Figure 2. (a) Rainfall data for Nkoranza South Municipality (1960-1982). (b) Rainfall data of Nkoranza South Municipality (1988-2015). Source: Computed from GMet data.

was no clear pattern from 1988 to 2015. It was also obvious that from 1988 to 2015, the rainfall amount hardly crossed 1000 mm unlike the period between 1960-1982. This confirms the farmers' perception that the current rainfall pattern is rather irregular and unpredictable.

The averages of 1960-1982 were higher than that of the present, 1988-2014 (**Table 2(b)**). From the months of January to March, the mean of 1960-82 was greater than that of 1988-2014. The farmers were right that lately, the amount of rainfall in March had drastically fallen as the amount from 1960-1982 (**Table 2(a)**) was well over 100 mm (114.7 mm), whereas the average amount for the period between 1988 and 2014 had reduced to 71.0 mm, which most probably

Table 2. (a) Average monthly rainfall 1960-1982 for Nkoranza; (b) Average monthly rainfall 1988-2014 for Nkoranza; (c) Average monthly rainfall for the past 5 yrs (2010-2014) for Nkoranza; (d) 2015 Annual Rainfall Figures for 2015.

(a)

month	J	F	M	A	M	J	J	A	S	O	N	D	Avg.
mm	10.8	46.0	**114.7**	129.8	154.0	154.0	116.6	**72.7**	192.2	169.9	37.0	11.4	**100.7**

(b)

month	J	F	M	A	M	J	J	A	S	O	N	D	Avg.
mm	7.1	35.1	**71.0**	148.2	159.0	174.0	97.7	**79.9**	162.1	141.1	20.7	6.8	**91.9**

(c)

month	J	F	M	A	M	J	J	A	S	O	N	D	Avg.
mm	5.0	34.9	**64.5**	121.0	147.5	158.8	80.8	**88.5**	138.3	90.9	8.1	0.0	**78.2**

(d)

month	J	F	M	A	M	J	J	A	S	O	N	D	Avg.
mm	0.0	43.9	**113.0**	35.3	88.3	66.1	50.1	**0.0**	214.8	160.8	86.5	0.0	**71.6**

accounted for the reason why majority of the farmers sowed in April (79.1%). Between 1988 and 2014 rainfall averages had appreciated from April to June, with a deficit in July, rising again in August. Currently, the amount of rainfall in November has decreased to the detriment of farmers. This means that presently, crops do not receive much rainfall as compared to 30 years ago. It can also be inferred from Table 2(b) & Table 2(c) that presently, August is getting wetter and the major and minor seasons are progressively merging. It is also clear that the first and the last quarters of the year (January-March as well as October-December) are getting drier over the last couple of decades with the last five years being the worst.

The future seems to be rather bleak looking at the trend in 1960-1982 with almost no rains in November and December (2010-2014). The average total amount of the period 2010-2014 showed a reduction of 22% over the past five years with a decline between 1960-82 (100.7 mm) and 1988-2014 (91.9 mm) of 6%. The month of March which was meant for planting of crops now obtained 64.5 mm (3c) of rainfall against 114.7 mm (3a) in the past buttering farmers assertion that climate had changed.

3.5. Irregularity of Rainfall

On rainfall regularity, the pattern of precipitation in the Municipality is chararcterised by uncertainty. Based on the above tables (Tables 2(a)-(c)) the amount of rainfall in the month of August increased but figures from 2015 deviated from the trend (Table 2(d)). The precipitation received in the August, 2015 farming season was 0.00 mm. Table 2(d) also shows a reduction in rainfall amounts between June and August. This phenomenon (irregularity) might have had a negative effect on maize production in 2015, resulting in the lowest yields (1.5 mt/ha) of maize recorded for the Municipality in the last six years. A report by [6] indicated that even though other contributing factors exist, rising temperature and irregularity in precipitation are the major causes of the continuous reduction in maize yields. Annual rainfall for Nkoranza South Municipality since the 2008/9 farming season for the month of March had never risen above 100 mm but rose to 11 mm in 2015 which confirms that the nature of rains in the transitional zone is irregular. According to [17], declines in total precipitation and increasing irregular rainfall patterns make farming more hazardous, increasing the likelihood of crop failures and reducing agricultural production.

3.6. Perception of Climate Change and Variability among Farmers

All the farmers (100%) interviewed indicated that the pattern of rainfall in the area had changed. Of these, 78% indicated that the nature of the change was erratic. The majority (85.9%) of the respondents established that the severity of this episode was devastating over the past 5 years (2010-2015). This had therefore made their farming operations riskier as there was no irrigation system in the Municipality, bringing farming activities to a near halt whenever the rain failed (**Table 3**).

About 65.5% of the farmers admitted that unguided activities of unscrupulous chainsaw operators had led to the cutting down of trees which might have resulted in reduction in rains. On the other hand, 25.5% attributed the changes in precipitation trend to nature itself and 0.5% of the respondents believed that the changes had come due to excessive emission of GHGs into the atmosphere. Another 5% of the farmers also placed the blame on bushfires whereas 3.2% indicated that they did not know what had caused this change.

When they were further probed about what could be done to reverse the situation of the erratic rainfall, 64.1% responded that there should be afforestation to replace the felled trees. Others (27.7%) had the view that only God could intervene to restore the situation whilst some farmers (5.5%) called for bush fire control. Farmers in the FGDs disclosed that control of bush burning would allow small plants to replace logged trees although this would take a couple of years to establish. About 2.3% of the respondents did not know what could be done to bring the rainfall situation back to normal whereas 0.5% also had the assurance that a ban on burning of fossil fuel would be helpful. This indicates that farmers did have some knowledge about causes of changing climate but the remedies were not within their reach due to population growth and poverty (FGDs).

Table 3. Changing rainfall pattern * response on the time of the changes.

Changing rainfall pattern	Response on the time of the changes		Total (%)
	1 - 5 years (%)	6 - 10 years (%)	
Yes	85.9	14.1	100.0
Total	85.9	14.1	100.0

With regard to temperature, when farmers were asked whether air temperatures had increased, stabilised or decreased, 86.8% strongly agreed that air temperatures had then risen. It emerged from the FGDs that air temperatures had been warmer over the past 10 years and even the two cold periods (June-July and December-January) were now short-lived. About 7.7% agreed that air temperatures had changed but not appreciable while 5.5% did not know whether temperatures had changed or not (**Figure 1**). Another 86.8% of the respondents had perceived that the then temperatures were higher than the temperatures for the same area over the past 20 yrs (**Figure 3**).

3.7. Impacts of Climate Variability and Change on Maize Production in the Municipality

The major threats of changing climate were (erratic) rainfall and rising air temperatures (FGD). The intensity of precipitation had reduced but number of rainy days which had declined had a greater effect on crop yields than amount of rainfall. Over the past six years, the intensity as well as number of rainy days in the Municipality had varied from one year to another as shown in **Table 4**. The lowest amount of rainfall over the past six years (2010-2015) was in 2010 (812.3 mm) with the highest in 2013 (1487.2). Some of the rainy days within the year were spread out (it rained on several days) while others were not. For instance, in 2010, rainy days were 85 whereas in 2015, it was only 44. What can be deduced from the rainfall regime over the past six years is that number of rainy days had become more inconsistent than the amount or intensity of rainfall. This confirms a study by [12] that more rainy days with less amount of rainfall does not have much impact on yields. The reduction in rainfall intensity in the study area was in line with a similar study by [18] in Argentina which showed that there had been a perceived reduction in the growing season of maize crops by 27 days, consequently causing a reduction in yields when crop yield (maize) was simulated using version 3 of Hadley Center Coupled Model (HadCM3).

There was a relationship between rainy days and maize production in the Municipality. When rainfall spread over more days, crop yields increased but when rainy days were few with large amounts of rain, crop yields dropped. For instance, in 2010, the amount of rainfall (812.3 mm) was the least among the six years under review; however, average maize yields in the Municipality was 2.0 mt/ha compared to 2011, which had 1270.8 mm of rainfall over 51 rainy days (**Table 4**). In 2011, the average yield was 1.9 mt/ha, yet total cultivated area was bigger (61,231 ha) than that of 2010 (59,616 ha). The farmers who were interviewed hammered the fact that erratic rainfall had been one of their major setbacks, and 2015, for instance, was the worst year. Rainy days had never gone below 50 days over the past six years, but 2015 recorded 44 rainy days which was exceptional (**Table 4**). The farmers complained that in both the major and minor seasons of 2015, the rains started late and the cessation was too early. The minor season's onset was somewhere late in September, ending in mid-October

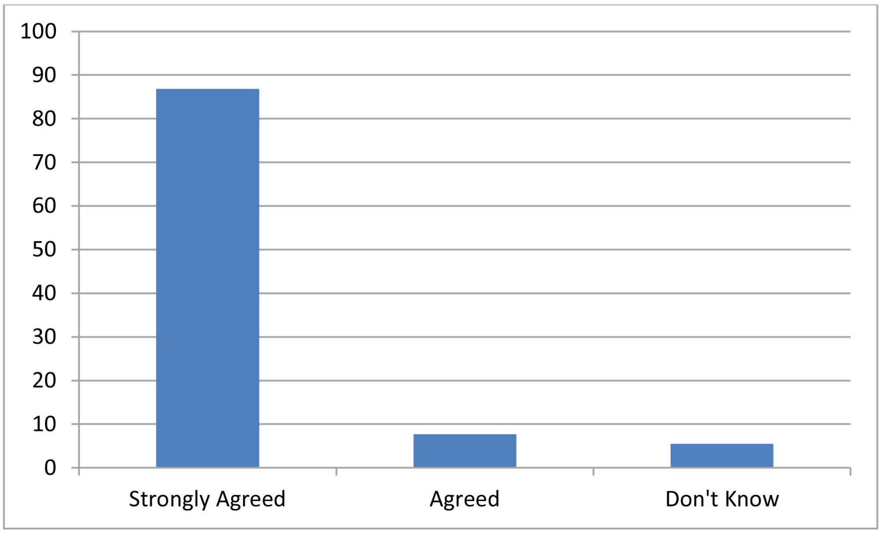


Figure 3. Farmers' perception of changing air temperatures.

Table 4. Rainfall & Maize production data for Nkoranza South Municipality (2010-2015).

Year	Rainfall intensity (mm)	Rainy days	Average yield (mt/ha)	Production level (mt)	Total cultivated area (ha)
2010	812.3	85.0	2.0	119232.0	59,616
2011	1270.8	51.0	1.9	116338.9	61,231
2012	1110.7	57.0	2.1	124452.0	59,263
2013	1487.2	70.0	2.0	124899.0	62,494
2014	1131.3	65.0	1.9	115250.0	60,658
2015	949.0	44.0	1.5	83570.0	42,500

Source: Computed from Nkoranza South Assembly data, 2015.

which might have prevented some of the farmers from planting their seeds most likely resulting in a smaller cultivated area (42,500 ha) yielding 1.5 mt/ha in 2015 (**Table 4**). [19] reported that increased variability of precipitation, which is reflected in the high variability in grain yield, was another factor leading to the reduction of crop yields.

3.8. Opportunities Associated with Climate Change and Variability in Nkoranza South Municipality

It was perceived that over the past 20 years, the livelihood of the people in the Municipality had somewhat changed. According to the farmers (FGDs), some varieties of corn, yam, groundnut and cassava were fast disappearing. **Table 4** summarises the benefits farmers had derived from climate variability and change. The majority of the respondents (76.8%) said that cashew production had given them some form of relief. About 66.9% of the cashew farmers were Bonos while 26.6% were from the three northern regions (Busanga, Dagarti, Wale, Kasena, Kusase, Gruma and Frafra). The perceptions of the respondents

Table 5. Response to the time of the changes vs. benefits from climate change variability.

Tribe	benefits from climate change variability					Total
	Cashew production	Animal rearing	Trading	Others (oil palm, plantain, vegetable, melon)	Nothing	
Bono	85.0%	3.0%	0.8%	1.5%	9.8%	100.0%
Asante	87.5%	0.0%	0.0%	12.5%	0.0%	100.0%
Settlers from the North	60.8%	20.3%	1.4%	1.4%	16.2%	100.0%
Others (Ewe & Fulani)	80.0%	0.0%	0.0%	0.0%	20.0%	100.0%
Total	76.8%	8.6%	0.9%	1.8%	11.8%	100.0%

on the sudden expansion of cashew farming in the study area were that it did not demand much time, rainfall and money. The other alternate form of livelihood that helped farmers adapt to the changing climate was livestock rearing as climate variability did not have any great impact on it (livestock); however, its major challenge was pests and diseases (57.1%), followed by theft cases (33.3%). Most of the animals were reared by farmers from the Northern Ghana and this represented 78.9% with the Bonos accounting for 21.1% (Table 5).

4. Conclusions

This study revealed that changes in the onset and cessation of rain coupled with intermittent dry spells had negative effects on maize farming production in the Nkoranza South Municipality, and this posed a great threat to household incomes as most farmers earned their living from farming. Vulnerability of maize production to climate change and variability in this Municipality depended onthe onset of rainfall with respect to the growth stage of the crop. Maize production in the Municipality solely depended on rainfall; hence its variability affected production.

The amount of rainfall had reduced drastically over the last five years to the detriment of maize farming. The major and minor seasons were gradually merging as August had become wetter over the last two-three decades with the exception of 2015. January, February, March, October, November and December were becoming progressively drier in the last 5 - 10 years as compared to three decades ago. This demonstrates clearly that meteorological conditions over the transitional zone would continue to alter negatively at the expense of poor-resourced maize farmers whose farming operations are rainfall dependent.

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Conflicts of Interest

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

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