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Comparing Farmers' Perceptions of Climate Variability with Meteorological and Remote Sensing Data, Implications for Climate Smart Agriculture Technologies in Ghana

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Abstract: In-depth knowledge of smallholder farmers' perception of changing climate variables such as recurrent and protracted droughts, late onset of rainfall, early cessation of rainfall and their coping adaptation strategies are very significant in designing climate resilient agriculture among smallholder food crop farmers in sub-Saharan Africa (SSA). This paper examines smallholder farmers' perceptions of climate variability vis-á-vis meteorological and satellite remote sensing data and their implications for climate smart agriculture technologies. Integration of meteorological, satellite remote sensing and farm-level data were used. Multistage sampling procedure was used to select four towns, eight communities and 398 smallholder food crop farmers. Spearmans' rank correlation coefficient and Standardized Precipitation Index were used to assess the distribution of climate variables. In addition, three vegetation drought characteristic indices, Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI) and Water Supply Vegetation Index (WSVI) were used to examine drought conditions within the basin. The results indicated that smallholder farmers in the Offin river basin perceived recurrent and prolonged droughts, rising temperatures, late onset of rainfall, early cessation of rainfall, increasing dry spells, reduction in the length of rainfall season and shorten cropping season as a main indicators of climate variability. The findings further revealed that farmers' perceptions on climate variability strongly agrees with meteorological and satellite remote sensing data which not only demonstrated rising temperature and frequent and prolonged droughts but also late onset and early cessation of rainfall and reduction in growing season rainfall. Smallholder food crop farmers in the Offin river basin have a high awareness of variation in climate condition and have taken coping strategies to reduce the effects of climate change and climate variability. Smallholder food crop farmers in the basin have also adopted climate smart agriculture technologies such as crop management techniques, integrated soil and nutrient management practices, tillage and residue management, small scale irrigation systems, inland valleys cropping and renewable energy systems to increase agricultural productivity and build resilience to climate variability. The policy implication is that, smallholder food crop farmers' knowledge on climate variability should be considered as a practical input in designing and planning climate variability coping adaptation and mitigation strategies.

Keywords: Climate Variability, Smallholder Farmers, Perceptions, NDVI, Lower Offin River Basin

1. Introduction

Smallholder farmers form the majority of rain-fed crop production in Africa. These smallholder farmers are estimated to be 36 million in Africa and 500 million worldwide. They produce more than 80% of the household food consumed daily [1]. Unfortunately, the production capacity of these farmers has been affected by changing climatic conditions through rising water and food shortages and proliferation of crop pests and diseases. Research has indicated that by 2030, the negative effect of climate change and climate variability on agriculture production will be more severe across all the countries of the world [2]. Climate variability already has an antagonistic influence on agricultural yield and food security due to its chronic effect on the reduction of soil moisture, faster depletion of soil organic matter, premature drying of grains and increased heat stress [3, 4]. Intergovernmental Panel on Climate Change (IPCC) [5] predicts that with increases of 1.5–2.5°C, about 20%–30% of plant and animal species are expected to be at risk of extinction [5-7] with consequences for agricultural productivity and household food security in the developing countries [8].

Developing nations, especially those in sub-Saharan Africa are more vulnerable to the effects of climate change and climate variability [9], this is because of their geographical location and climatic conditions, high dependence on agriculture, natural resources-driven activities, and weak adaptive capacity to the change in climate [10]. According to IPCC [11], climate variability is causing water stress and poses a severe threat to food security in many countries in Africa. Stanturf et al. [12] indicated that droughts in many African countries have demonstrated the effects of climate variability on food production. Rowhani et al. [13] noted that climate variability had had impacts on crop production in Tanzania. Food crop production is highly sensitive to changes in rainfall and droughts which may be heightened in Ghana under climatic changes. The rate of climate variability may exceed the rate of adaptation for food crops, and this creates higher concern for food security.

To build and enhance the resilience of smallholder food crop farmers to climate change and climate variability, climate-smart agriculture technologies (CSA), a concept developed by Food and Agriculture Organization (FAO) to accelerate sustainable agricultural development (SAD) towards the attainment of household food security is an innovative coping adaptation strategy. Climate-smart agriculture technologies comprised of three main pillars: (1) sustainably increasing agricultural productivity and incomes; (2) adapting and building resilience to climate change and climate variability (3) reducing and/or removing greenhouse gases emissions. At the farm level, CSA aims to support food production systems, strengthen livelihoods systems and promote household food security by improving the management and the use of natural resources.

Despite the vulnerability of crop farmers to climate variability, there is, however, little knowledge on the farmers' perception to climate variability and the extent to which their perceptions correspond with climate data and satellite remote sensing observation and their adoption of climate smart agriculture is not known. Pelham [14] indicated that farmer's perceptions about climate variability in developing countries are still rather low compared to the developed world.

A study by Kotei et al. [15] showed that insufficient knowledge about climate change and its impact on agricultural production is a setback to sustainable agriculture in most developing countries including Ghana. However, there are studies that have sought to establish a relationship between effects of climate variability and people's perceptions.

Moreover, the findings gave varied results. Becken et al. [16] in Nepal and Adimassu et al. [17] in Ethiopia established that communities are not always scientifically accurate in their assessment of climate variability. In South Africa, Gandure et al. [18] found that smallholder farmers' perceptions of high rainfall variability were supported by meteorological data while their perceptions on onsets of rainfall were at variance with meteorological data. The implication is that perception of climate variability if not verified with empirical data, can lead to misinformation. In Offin River Basin, there is a little knowledge on smallholder crop farmers' perception to climate variability. Also, the extent to which crop farmers perceptions consistent with meteorological and remote sensing data is not known. This paper examines farmers' perceptions on climate variability vis-á-vis meteorological and remote sensing data in the Lower Offin River Basin.

2. Materials and Methods

2.1. Study Area

The Lower Offin River Basin is located between latitude 5°30′N to 6°64′N and longitude 1°30′W to 2°15′W. A large proportion of people in the basin live in rural communities, with crop production as their main economic activity. The Lower Offin River basin has a bi-modal rainfall pattern with major rainy season from March to July. The minor rainy season also begins in September and ends in November which is proceeded by dry season (Figure 1). The mean annual minimum temperature is 22°C, while maximum temperature is 33.2°C.

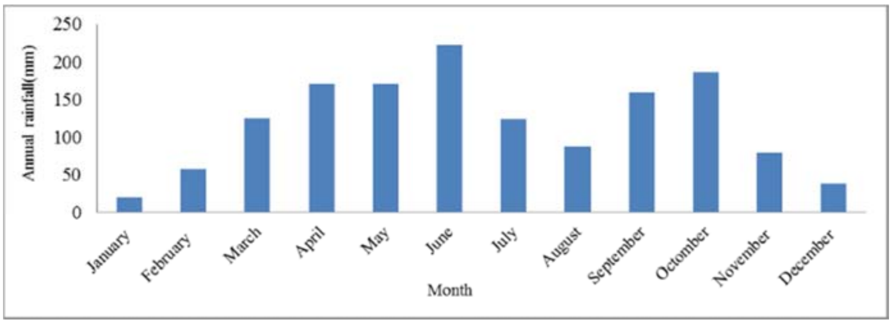

Figure 1. *Average Monthly Rainfall from Six Stations in the Lower Offin River Basin (1983-2012).*

2.2. Survey

The 30 years' climate data from six weather stations from 1983-2012 were obtained from Ghana Meteorological Service Department, Kumasi. Five weather stations, Dunkwa, Obuasi, Manso Adubia, Nkawie and Nyinahin are within the basin while Sefwi Bekwai is 15 km in the Southern part from the Lower Offin River Basin. Thematic Mapper and Enhanced Thematic Mapper Plus for 1986, 2002, 1986 and 2015 were used to determine the vegetation drought characteristics. Multistage sampling procedure was used to select 4 towns, 8 communities and 398 smallholder farmers in the Lower Offin River Basin. Four towns namely; Dunkwa, Jacobu, Manso Adubia, and Nyinahin were purposively selected. Sample size was estimated using a formula proposed by Yamane [19] Equation (1).

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

Where, n is the sample size, N is the population size and e are the margin of error. With 5% margin of error, from a population of 68,471, the sample size was estimated as 398.

2.3. Meteorological Data

Spearman's rank correlation coefficient *(R_{sp})* and Standardized Precipitation Index (SPI) were used for the analysis of rainfall, temperatures and droughts in the Lover Offin River Basin. The Spearman's rank correlation coefficient is presented in Equation (2).

$$R_{sp} = 1 - \frac{6 \times \sum_{i=1}^{n} \left(D^2\right)}{n \times \left(n^2 - 1\right)} \tag{2}$$

Where n is the total number of data; D is the differences between chronological order numbers. In the testing process, null hypothesis, H0: Rsp=0 (there is no trend), against the alternate hypothesis, H1: Rsp < > 0 (there is a trend) using Equation (3).

$$t_1 = R_{sp} \sqrt{\frac{n-2}{1 - R_{sp}{}^2}} \tag{3}$$

Where R_{sp} is the Spearman coefficient and t_i is student's distribution. At a significance level of five percent (two - tailed), two-sided critical region, $\bigcup$, of t is bounded by Equation (4)

$$\{-\infty, t\{\upsilon, 2.5\%\}\} \bigcup \{t\{\upsilon, 97.5\%\}, +\infty\} \tag{4}$$

Where; υ =n - 2 degrees of freedom. The null hypothesis is accepted if t_t is not contained in the critical region. In other words, the time series has no trend as in Equation (5).

$$t\{\upsilon, 2.5\%\} < t_t < t\{\upsilon, 97.5\%\} \tag{5}$$

The SPI was calculated using Equation (6).

$$SPI = \frac{X_{ij} - X_{im}}{\sigma} \tag{6}$$

Where, σ is the deviation of rainfall, X_{ij} is the annual rainfall in year *t*, X_{im} is the long-term mean rainfall.

2.4. Vegetation Drought Characteristics

The thermal bands of Landsat images of 1986, 2002, 2008 and 2015 were used to determine Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Vegetation Condition Index (VCI) and Water Supply Vegetation Index (WSVI) in the Lower Offin Basin as proxy to evaluate droughts. The radiances (L_λ) were calculated using Equation (7).

$$L\lambda = \frac{\left(L_{\max\lambda} - L_{\min\lambda}\right)}{\left(QCAL_{\max\lambda} - QCAL_{\min\lambda}\right)} \times \left(QCAL - QCAL_{\min\lambda}\right) + L_{\min\lambda} \tag{7}$$

Lλ is the spectral radiance at the sensor's aperture in watts per steradian, µm and m^2. L_{max} λ and L_{min} λ are spectral radiance scales to QCALmax and QCAL min respectively, QCAL is the quantized calibrated pixel value in DNs and QCALmin and $QCAL_{max}$ are the minimum value (1) and maximum value (255) quantized calibrated pixel respectively.

$$Tb = \frac{K_2}{In\left[\frac{K_1}{L\lambda} + 1\right]} \tag{8}$$

The brightness temperature (Tb) was determined by applying inversion of Planck's law as in Equation (9)

$$P\lambda = \left[\frac{NDVI_{ave} - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}}\right]^2 \tag{9}$$

Tb is the effective brightness temperature (K), K_1 and K_2 are the calibration constants 1282.71 and 666.09 watts per steradian, µm and m^2.

Land surface emissivity (ε) was estimated using Equation (10)

$$\varepsilon = 0.004 \times p\lambda + 0.986 \tag{10}$$

where *Pλ is* Brightness temperature (Tb) was then combined with surface emissivity (ε) to derive the land surface temperature (LST) in Equation (11)

$$LST = \frac{Tb}{1 + \left(\lambda + \frac{Tb}{\rho}\right) \times In\varepsilon} \tag{11}$$

Where; λ is the wavelength of emitted radiance (λ=11.5μm), ρ=hc/σ=1.438 ×10^{-2} (mK), σ is the Stefan Boltzmann (1.38 ×10^{-23}J/K), h is the Planck's number (6.626 × 10^{-34}Js), c is velocity of light (2.998 ×108 m/s) *ln* natural logarithm. The VCI was determined using Equation (12).

$$VCI = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NVDVI_{\min}} \times 100 \quad (12)$$

Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) were used to determine Water Supply Vegetation Index (WSVI) in ArcGIS 10.6.

3. Results and Discussion

3.1. Trend of Annual and Seasonal Rainfall in the Basin

The results indicated that mean annual rainfall increased by 11.2 mm made up of 1.5 mm, 3.7 mm and 6.7 mm, dry season rainfall, minor and major season rainfall respectively (Figure 2). The results show an apparent increase of annual and seasonal rainfall pattern (Figure 2), which could influence crop growth and crop productivity in the Basin.

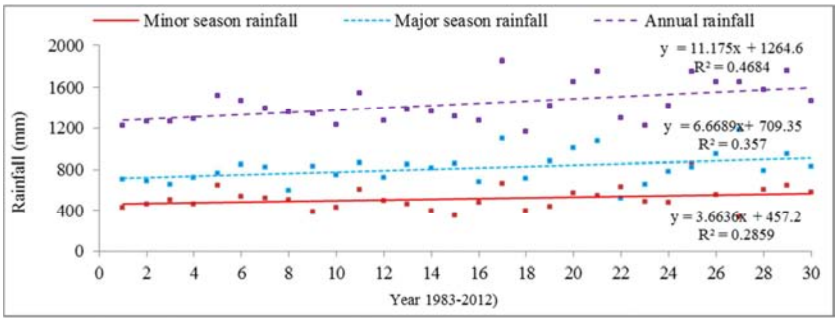

Figure 2. *Annual and Seasonal Rainfall Trend in the Lower Offin River Basin (1983-2012).*

Spearman rank correlation analysis of rainfall pattern demonstrated that mean annual and seasonal rainfall were positive and increasing significant trends (Table 1). However, while Nkwaie and Manso Adubia areas depicted increasing trend Nyinahin, Obuasi and Dunkwa areas had no specific trend with Sefwi Bekwai having a decreasing trend.

Table 1. *Standard Deviation, Coefficient of Variation and Trend Analysis of Rainfall in the Offin River Basin.*

Station /season	Mean	STD	CV	Correlation coefficient	Trend coefficient	Remarks
Nkwaie	1282.00	202.93	15.83	0.66	4.63	Increasing
Nyinahin	1637.30	532.00	32.51	0.26	1.45	No trend
Manso Adubia	1262.70	167.26	13.24	0.53	3.26	Increasing
Sefwi Bekwai	1480.60	146.75	10.18	-0.04	-0.22	Decreasing
Obuasi	1483.60	263.10	17.73	0.17	0.92	No trend
Dunkwa	1519.70	393.30	25.88	0.24	1.30	No trend
Overall Mean	1436.30	189.90	13.30	0.51	3.13	Increasing
Dry season	112.00	45.20	118.23	0.38	2.15	Increasing
Minor season	504.20	110.40	40.20	0.39	1.26	Increasing
Major season	803.20	148.20	21.40	0.39	2.27	Increasing

STD=standard deviation; CV=coefficient of variation in percentage

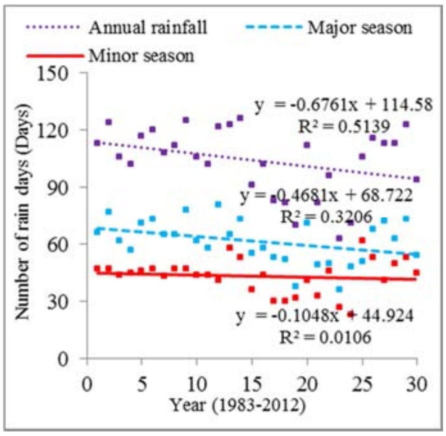

Figure 3. *The Number of Rain Days in the Offin River Basin (1983-2012).*

3.2. Seasonal Rainfall Characteristics in the Basin

The annual and seasonal rainy days were found to be decreasing (Figure 3). The length of major and minor growing season has shown to be decreasing (Figure 4), thus resulting in decreasing length of major and minor growing seasons.

The decrease in the length of growing season could lead to failure of seasonal rainfall to sustain crop growth to reach maturity stage. Collier et al. [20] found out that climate variability result in reduced length of the growing season.

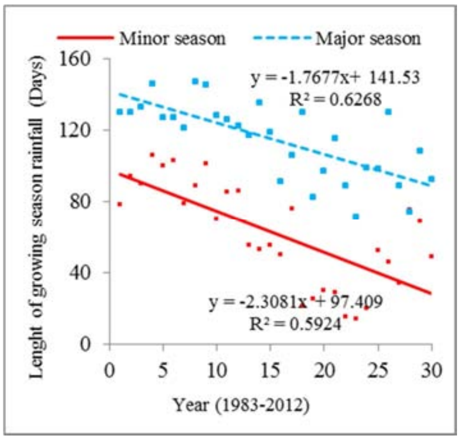

Figure 4. *Length of Growing Season in the Offin River Basin (1983-2012).*

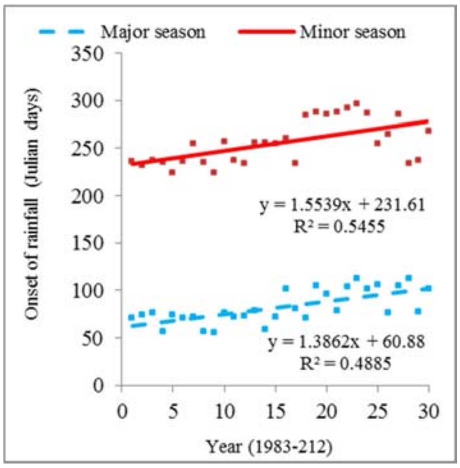

Figure 5. *Onset of Rainfall in the Lower Offin River Basin (1983-2012).*

The onset dates of major season and minor season rainfall have shifted to later dates (Figure 5). The cessation dates for major and minor season's rainfall were found to have shifted to earlier dates (Figure 6). The increased late onsets of rainfall reduce the length of growing season rainfall, increase dry spells and shorten duration of cropping period thereby affecting soil moisture availability, planting dates and crop production. Kangalawe [21] in Tanzania found that changing climatic conditions have resulted in delays and fluctuations in rainfall onset.

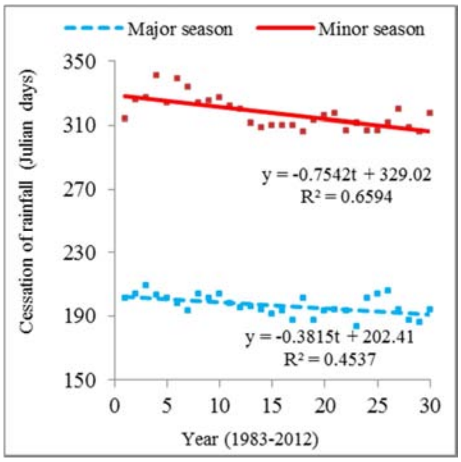

Figure 6. *Cessation of Rainfall in the Lower Offin River Basin (1983-2012).*

3.3. Trend of Temperatures in the Area

The maximum mean annual temperature increased by 0.01°C per year (Figure 7) whereas minimum mean annual temperature increased by 0.05°C per year (Figure 8) between 1983 and 2012. Although both the maximum and minimum temperatures increased, the rate of minimum temperature increase was higher than that of maximum temperature in the basin. A study by Poudel and Shaw [22] in Nepal found that minimum temperature was increasing at a faster rate than the maximum temperature. The findings also agree with IPCC [23] that since 1950s both maximum and minimum temperatures have increased and the rate of minimum temperature increase is higher than that of maximum temperature increase.

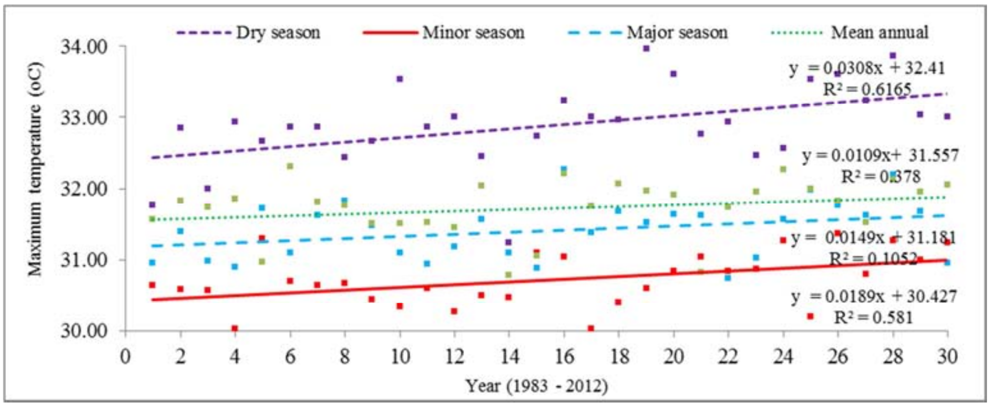

Figure 7. *Annual and Seasonal Maximum Temperatures in the Lower Offin River Basin (1983-2012).*

The seasonal temperatures over the period (1983–2012) have increased (Figures 7 and 8). However, there is an apparent difference between dry season and major season maximum temperature while there are virtually no differences in that of the minimum temperature in the Basin. Increase in temperature adversely affect food crop yield by making heat and water stress a limiting factor for crop growth and development. Increase in temperature increases evapotranspiration rate of plants and chances of severe drought conditions. Increases in temperatures will increase soil temperatures which will in turn affect plant metabolism through the degradation of plant enzymes, limiting photosynthesis and affecting plant growth and yields [24].

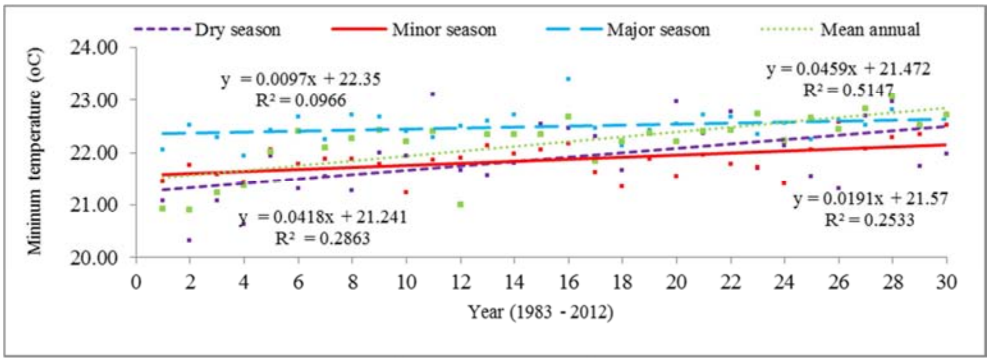

Figure 8. *Annual and Seasonal Minimum Temperatures in the Lower Offin River Basin (1983-2012).*

The statistical analysis of temperature data using spearmen rank correlation coefficient also confirmed the rising trend of both minimum and maximum temperatures in the Lower Offin River Basin (Table 2) and this can disrupt a wide range of natural processes.

Table 2. *Standard deviation, coefficient of variation and trend analysis of temperature from 1983-2012.*

Station/season		Mean	STD	CV	Correlation coefficient	Trend coefficient	Remarks
Nyinahin	Min	22.2	0.46	2.07	0.66	4.62	Increasing
	Max	31.4	0.32	1.01	0.54	3.37	Increasing
Manso Adubia	Min	21.9	0.80	3.64	0.43	2.53	Increasing
	Max	31.3	1.16	3.70	0.24	1.27	No trend
Sefwi Bekwai	Min	22.4	0.77	3.43	0.40	2.32	Increasing
	Max	33.0	1.04	3.21	0.60	4.00	Increasing
Obuasi	Min	22.6	0.92	4.14	0.62	4.24	Increasing
	Max	32.0	0.87	2.74	0.42	2.23	Increasing
Dunkwa	Min	22.4	0.39	1.75	0.69	5.01	Increasing
	Max	32.0	0.31	0.97	0.32	1.80	No trend
Overall mean	Min	22.3	0.51	2.32	0.60	4.00	Increasing
	Max	33.2	0.80	2.59	0.30	2.26	Increasing
Dry season	Min	21.9	0.77	3.50	0.39	2.69	Increasing
	Max	32.9	0.58	1.77	0.41	2.46	Increasing
Minor season	Min	22.4	0.41	1.58	0.67	5.10	Increasing
	Max	30.4	0.33	1.10	0.58	3.69	Increasing
Major season	Min	22.8	0.34	1.78	0.64	4.23	Increasing
	Max	31.4	0.40	1.23	0.32	2.36	Increasing

3.4. Landsat Derived Vegetation Drought Characteristics

Landsat based drought characteristics were analyzed as a proxy to evaluate drought conditions. Results showed that land surface temperature, both minimum and maximum increased. The mean NDVI values obtained in 2008 and 2015 depicted healthy vegetation conditions compared with 1986 and 2002 which exhibited more vegetation stress and droughts (Table 3). conditions (Table 3). The WSVI and VCI values also showed that 1986 and 2002 experienced vegetation moisture stress, an indication of drought condition prevailing in the basin with negative impacts on soil moisture and crop yields.

Table 3. *Landsat Derived Vegetation Drought Characteristics in Lower Offin River Basin.*

Year	LST		NDVI			VCI		WSVI		
	Min	Max	Min	Max	Mean	Value	Level	Min	Max	Mean
1986	19	30	-0.07	0.24	0.08	47	Drought	-0.003	0.012	0.003
2002	19	30	-0.37	0.04	0.06	49	Drought	-0.018	0.002	0.005
2008	20	33	-0.17	0.36	0.10	53	Normal	-0.004	0.015	0.007
2015	22	35	-0.56	0.37	0.10	71	Normal	-0.024	0.017	0.008

3.5. Farmers Perception on Climate Variability

Farmers perceived droughts, rising temperatures, late onset of rainfall, early cessation of rainfall, increasing dry spells, reduction in the length of rainfall season and shorten cropping season as indicators of climate variability (Table 4).

High number of farmers (99.2%) perceived increasing temperature (Table 4). In comparing farmer's perception on temperature with temperature from meteorological data (Figure 9 and Table 2) and remote sensing data (Table 3), an apparent increase was observed. Thus, farmers' perception regarding temperatures is supported by empirical evidence. Nyanga et al. [25] in Zambia found that most farmers perceived temperatures to be increasing. With regards to rainfall 82.2% of farmers indicated that rainfall had declined. The farmer's perception that rainfall had decreased was found to be at variance with climate data (Figure 3) and (Table 1). This finding suggests that farmers do not always perceive rainfall trend accurately and thus stakeholders should develop educational plan tailored to meet the climatic information needs of farmers particularly rainfall. A variation in farmers' perceptions on rainfall has also been reported by Adimassu *et al.* (17) in Ethiopia where farmers perceived a decreasing rainfall, contrary to historical data. A significant number of farmers in the Basin (97.5%, 100%, 100% and 100%) reported late onset of rainfall, early cessation of rainfall, declined in number of raining days and reduction in growing season respectively (Table 4). In comparison with meteorological data, rainfall season starts late; there has been early cessation of rainfall; number of rainy days has reduced; there is a reduction in the length of growing season rainfall resulting in the reduction of the length of cropping period (Figures 3-6). Therefore, smallholder farmer's perceptions on seasonal rainfall characteristics were found to be consistent with climatic trend analysis in the basin. All the farmers (100%) and (99.2%) of smallholder farmers perceived droughts and intermittent dry spells (Table 4). In comparing farmers' perception on droughts with meteorological data (Figures 7 and 8) and remote sensing-based vegetation drought data (Table 3) indicated that farmers' perceptions on prolonged droughts agrees with empirical analysis. The accurate observation of draughts and dry spells by crop farmers brings into perspective that smallholder farmers correctly perceive weather conditions in relation to food crop production and thus influence their cropping activities in the area.

Table 4. *Smallholder Farmer's Perception of Climate Variability in the Lower Offin River Basin.*

Climate variables	Lower Offin Basin n=398	Town			
		Nyinahin n=100	Manso n=88	Jacobu n=84	Dunkwa n=126
Increase temperature	395 (99.2)	99 (99)	88 (100)	82 (97.6)	126 (100)
Decrease temperature	3 (0.8)	1 (1.0)	0.0 (0.0)	2 (2.4)	0 (0.0)
Increase in rainfall	71 (17.8)	18 (18)	21 (24)	15 (17.9)	17 (13.5)
Decline in rainfall	327 (82.2)	82 (82)	67 (76)	69 (82.1)	109 (86.5)
Decline in rainy days	398 (100)	100 (100)	88 (100)	84 (100)	126 (100)
Late onset of rainfall	388 (97.5)	90 (90)	88 (100)	84 (100)	126 (100)
Early onset of rainfall	10 (2.5)	10 (10)	0.0 (0.0)	0 (0.0)	0 (0.0)
Early cessation of rain	398 (100)	100 (100)	88 (100)	84 (100)	126 (100)
Late cessation of rain	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 (0.0)
Short growing season	398 (100)	100 (100)	88 (100)	84 (100)	126 (100)
Increase in drought	382 (96.0)	96 (96)	88 (100)	79 (94.0)	119 (94.0)
Increased dry spell	39 5 (99.2)	99 (99)	88 (100)	82 (97.6)	126 (100)
Decrease in drought	16 (4.0)	4 (4.0)	0 (0.00)	5 (6.0)	7 (4.6)

*Values in bracket are the percentages (%); n=total number of samples

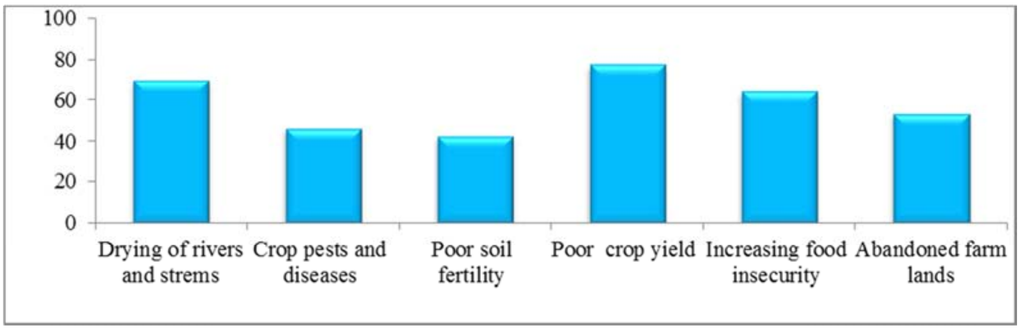

Figure 9. *Farmers' Perception on Impacts of Climate Variability in the Lower Offin River Basin.*

3.6. Perceived Impact of Climate Variability on Crop Yield in the Lower Offin River Basin

About 77.5, 69.0 and 64.3% of farmers noted that climate variability had affected their crop yield, water bodies and food security respectively (Figure 9). The implications are that farmers are conscious of climate variability and the negative effects on their farming activities in the Lower Offin River Basin.

3.7. Climate Smart Agriculture Practices

About 78% of smallholder farmers have adopted climate smart agriculture technologies (Table 5) to sustainably increasing agricultural productivity and incomes. Farmers are adapting and building resilience to climate change at the farm level and reducing greenhouse gases. These practices are novel in protecting and improving the livelihoods of the smallholder farmers and ensuring food security.

Table 5. *Climate Smart Agriculture Practices among Smallholder Farmers in the Offin River Basin.*

Practices	Aim	Detailed	Farmers
Crop management techniques	Sustainably increase farm productivity and income	Farmers grow improved crop varieties (drought resistant, early maturing and high yielding varieties) and changing cropping pattern	78%
Integrated soil - nutrient management	Maintaining healthy soil to enhance soil-related ecosystem services and crop nutrition	Farmers practicing good agricultural practices (GAP) that maintain soil fertility (cover cropping, mulch cropping, crop rotations, growing nutrient-use efficient crop varieties, green manures and intercropping with leguminous crops)	71%
Tillage and residue management	Enhancing soil moisture retention, organic matter and sequestering carbon.	Farmers utilizing residues as mulch in combination with no-till farming and integrated nutrient management (synthetic and organic fertilizer).	63%
Agroforestry	Carbon sequestration and on-farm water retention	Farmer and community-based tree planting and management practices are adopted by farmers	73%
Small Scale Irrigation	Increasing water use efficiency	Farmers practicing small scale irrigation, rainwater harvesting and farm and community-based water management and small-scale irrigation	46%
Integrated renewable energy systems	Increasing energy efficiency/Groundwater development	Farmers using solar energy in extraction ground water, on-farm water harvesting and retention and conservation of moisture;	35%
Inland valleys cropping	Increasing soil moisture and farm productivity	Inland valley rice production system and Integrated water resources management	79%
Integrated crop-livestock systems	Increasing productivity and sustain production	Mixed farming	73%

4. Conclusion

Meteorological, remote sensing data and households' survey were used to analyze the smallholder farmers' perception on climate variability in the Lower Offin River Basin and compare their perceptions with meteorological and remote sensing data. The late onset and early cessation of rainfall, reduction in the duration of cropping season rain have shrunk the length of cropping period making planning for agronomic activities difficult. The study concludes that the farmers in the basin are conscious of their changing farming environment and have adopted climate smart agriculture technologies to enhance the resilience of their farming systems to climate variability.

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