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The Impact of Climate Change on Rainfall Patterns in Ghana: A Zoning Adaptation Strategy through Developing Agroforestry

Mohammed Suabir Zubairu^{1*} Wei Li¹ Amatus Gylbag² Michael Asiedu Kumi¹
Akhtar Hussain Lashari¹

1. School of Environment, Beijing Normal University, Beijing, 100875, China

2. Chinese Academy of Agricultural Science (CAAS), Institute of Environment and Sustainable Development in Agriculture (GSCAAS), Beijing, 100875, China

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ABSTRACT

As a developing country in Africa, the effect of climate change is one of the sufferings of Ghana. The effect is much felt in rainfall variability because of the country over reliance on rainfall for agriculture. While various researches have studied the impact of climate change in Ghana, few among them have extended to its impact on rainfall pattern across all the ecological zones in the country. The trends in the rainfall from seven selected meteorological stations across all the ecological zones were analyzed using data from the NASA satellite. The Mann-Kendall and Sen's Slope Test were used for the analysis. The study found decreasing trend in most of the monthly and yearly rainfall pattern across the ecological zones, and suggested cashew agroforestry as a zoning adaptation strategy.

1. Introduction

Global warming as an outcome of climate change is being projected to influence modifications in acidification, humidity and precipitation patterns^[1]. In view of this, the overall effect on global life support systems resulting from climate change remains unclear. Extreme rainfalls leading to flooding occur in parts of world while the Mediterranean and other areas experience decrease in rainfall leading to drought conditions^[1]. Also^[2], anticipated an increase in global mean temperatures between the range

of 1.4 and 5.8 °C by the end of 20th century with a resultant sea level rise as glaciers are melting. Current studies however reveal that aspects of climate change are close to the upper boundary of IPCC's estimates as predicted by many. For example, an increase in sea level is far ahead of IPCC's projection of 30 cm^[3].

The concern of developing countries about the changing climate especially in Africa is aggregating because of their vulnerability to it. Climate change is seen in Africa as the number one threat to development and sustainable

**Corresponding Author:*

Mohammed Suabir Zubairu,

School of Environment, Beijing Normal University, Beijing, 100875, China;

Email: abomiforsure@yahoo.com

growth. Consequently, to achieve the Millennium Development Goals, African countries must be in the capacity to address the negative effects of climate change else their effort may be seen as a failure. According to Felix and Franklin^[4], in the midst of the continents which are affected mostly by climate change, the least contributor is Africa, however, climate change effects is commonly visible in Africa because of its overreliance on rainfall for agriculture, coupled by indicators such as weak adaptive capacity and widespread poverty. Changes in rainfall patterns are among the long-term impacts of climate change that causes reduction in agriculture production as it reduces food security. Reduction in agricultural production as a consequent effect of climate change retards the growth of African countries as chunk of the nation's income of most countries in Africa emanates from agriculture. Furthermore, most people in Africa rely on the agriculture sector as their means of livelihood^[5].

Out of 180 countries, Ghana ranks 108 for GHG emission per capital^[6] which contributes only 0.07% of emissions globally^[7]. Yet, the country is more vulnerable to global climate change. For climate vulnerability, out of 181 countries, Ghana is ranked 101. Again, Ghana is ranked the 68th country most vulnerable and the 85th least ready country to fight the effects of climate change^[8].

Also, USAID^[9] climate change projections show larger uncertainty regarding change in rainfall as estimation for future precipitation change is predicted at a range between -3% to +7%. Annual total precipitation for the year 2100 is also projected to vary from -15% to +16% when compared to current annual rainfall as a commonly cited example is a 4% national decrease by 2040. Again, in some regions, an initial increase of rainfall predicted by Panthou et al.^[10] follows a decrease in most regions over a long period.

Ghana's climate change effects are similar to those witnessed all over the globe. Evidence in Ghana shows that, levels and patterns of rainfall are increasingly becoming erratic and generally reducing across all the ecological zones^[11]. The country's economy will suffer the impacts of climate change due to its reliance on sectors like agriculture, forestry and energy which are sensitive to climate. Based on a climate observation baseline for 20 years, cereal crop like maize yields are predicted to decrease by 7% in 2050. Available data over the last 30 years also shows a 2.1 mm rise in sea-level per year, which also shows that by the year 2020, 2050 and 2080 there will be a rise in sea-level from 5.8 cm to 16.5 cm and finally 34.5 cm respectively^[12].

In Ghana, climate change vulnerability is higher; the situation is worsened by low adaptive capacity com-

binated with the interaction of numerous factors^[13, 14]. Consequently, the major economic sectors in Ghana are likewise defenseless against climate change while the vulnerability is made worst by prevailing developmental challenges like poverty, limited access to capital, failed governance, lack of technology, ecosystem degradation and in some cases conflict^[15]. In Ghana, food security and agricultural production is already severely affected by change in climate^[16]. Many parts of Ghana which were once forest lands have been converted by climate change into semi-arid conditions that make cultivation of crops impossible^[17].

The loss of forest lands has undoubtedly caused a rise and increase in CO₂ because the forest once served as the basket of CO₂ capture. Reportedly, climate change in parts of East Africa has reduced the length of traditional growing seasons as well as forced some areas completely out of production^[18]. Projection by IPCC^[19] shows a reduction in the yield of crops in some countries in West Africa to as high as 50% by 2020 and as high as 90% by 2100 fall net revenue of crop. This will undeniably affect food security in the continent and possibly result in an entire global migration of people. It is already reported in some parts of Somalia and Kenya that climate change has intensified water problems and projected to bring about water shortage in new areas especially in West Africa^[20]. This may displace whole communities and consequently put pressure on the remaining lands. It is only a matter of time that a looming food and water crises will be unveiled.

In trying to fight climate change problems, Ghana's presence at the Earth Summit in Rio de Janeiro in June 1992 appended its signature on climate change at the United Nations Framework Convention (UNFCCC), after the Convention came into being on May 9, 1992^[21]. One of the main physical impacts of climate change identified by World Bank^[22] is rainfall. Adjei et al.,^[23] reported that there is a change in the rainfall pattern of Ghana to a vanishing wet and longer dry season. The country continuously experience the negative effect of the changing climate in the areas of health problems, agricultural systems, floods in coastal areas coupled with erosion and decreasing level of water in the Akosombo dam (which adds 80% of electricity to Ghana's grid), resulting from the consequent reduction in precipitation^[24]. The negative effects of the changing climate that is worsening the country's economy is as a result of the low capacity in carrying out adaptive responses to solve environmental problems and costs of climate change socio-economically^[25,26].

Existing literature show that, traditionally, Ghanaian farmers adopt strategies to cope with the variability and the changes in the climate in response to the syndrome

of climate change [27] but their efforts are not enough. For instance, during periods of drought, local farmers in northern Ghana adapt to making gardens irrigated from small ponds and wells [28]. During seasons of bad harvest, people adapt to alternative livelihoods by gathering and selling shea nuts, dawadawa, fishing and hunting, or migrate to wetter zones [29]. There has also been an advocate for improved land use system by the ministry of agriculture which has partially been adopted by local farmers in their farming practices. Climate change is also managed through agricultural diversification. A number of international NGOs such as the German Society for Technical Cooperation (GTZ), Netherlands Climate Assistance Programme (NCAP), and others have been committed to combat climate change in Ghana. Though their efforts have created much awareness about climate change, their interventions have not brought much change. Because of the overreliance of the Ghana's economy on agriculture which is highly not resistant to change in climate and climate variability, it is essential to adapt to a reliable and effective method of combating climate change in the country. Despite the changing climatic conditions, which have come with extreme poverty, malnutrition and death, Ghana and other African countries do not currently have an abrupt response to the problem [27]. The search hence is still on for better and more efficient adaptation strategies that will particularly increase African food production.

Specifically, this paper provides an insight into climate change in Ghana and suggests a robust adaptation framework which couples cashew farming and lifestyle change strategies, to holistically confront climate change. The paper further outlines various climate scenarios with respect to changing regional precipitation patterns in Ghana, and simulates a modeled response through agroforestry approaches mainly by cashew growing.

2. Materials and Methods

2.1 Study Area

Ghana, with an estimated population of 31 million [30] lies between latitude 4°44' S and 11°15' N and longitudes 1°12' E and 3°15' W. The country is bordered to the West by Cote d'Ivoire, to the East by the Republic of Togo, the South by the Gulf of Guinea and the North by Burkina Faso. The total land mark of Ghana is 238,533 km² with an Exclusive Economic Zone (EEZ) of 110,000 km² of the sea, forming the territorial area of Ghana. The country is influence by the tropical humid climatic conditions and it experiences two major seasons; the rainy and the dry season. The dry season causes harmattan, a wind that blows along the northwest coast of Africa which is dusty

and dry. The annual mean minimum rainfall is 900mm which occurs around the South-eastern corner of Ghana (Accra-Aflao) while the annual mean maximum rainfall is about 2000mm and occurs in the South-western part (Axim). Mean maximum temperature ranges from 30°C-35°C and mean minimum temperature is from 21°C-23°C. The mean annual evapo-transpiration rate of 190mm is the highest and occurs in the North while 80mm is the lowest and occurs in the southern part of country [31]. Geographically, Ghana has five ecological zones. They are the Savannah (Sudan, Guinea and Coastal), Forest-Savannah Transitional Zone, The Semi-Deciduous Forest Zone, Moist Evergreen and the Wet Evergreen (Rain Forest Zone) as shown in Figure 1.

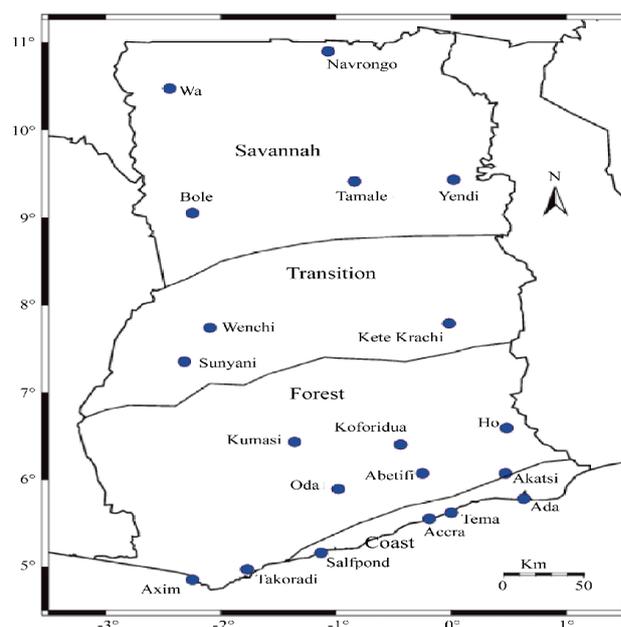


Figure. 1 Map of Meteorological stations across the ecological zones

2.2 Data Collection and Analysis

Table 1. Selected meteorological stations and their coordinates

Stations	Elevation (m)	Latitude (N)	Longitude (E)
Wa	3230	10.022	-2.519
Navrongo	2030	10.941	-1.091
Tamale	1730	9.427	-0.849
Wenchi	3400	7.737	-2.106
Keta-Krachi	1220	7.798	-0.051
Ho	1580	6.609	0.459
Kumasi	2930	6.697	-1.629

Monthly rainfall data of seven meteorological stations

in Ghana for the period of 37 years (1981-2018) selected from the five ecological zones of the country was collected from the NASA satellite website. Statistical analysis of rainfall, identification of trends using Mann-Kendall test, estimation of magnitude using Sen's slope estimator and trend results were compared with regression analysis.

2.3 Rainfall Analysis

Analysis of rainfall was done as monthly and annual for all the ecological zones. The rainfall data was computed using The Mann-Kendall Test and Sen's Slope Estimates (MAKESENS Excel Template application) for investigating the spatiotemporal trends in rainfall pattern for the areas under study.

2.3.1 Steps for Trend Analysis

The analysis of the trend was carried out in three steps. The detection of the presence of decreasing or increasing trend is the first step and was done using the nonparametric Mann-Kendall test. The next step is estimating the slope or magnitude of a linear trend using the nonparametric Sen's Slope estimator and the last step is the development of regression models.

2.3.2 Calculation of the Mann-Kendall Test

This study adopted a non-parametric statistical technique (Mann-Kendall trend analysis) to detect monotonic trends in a time series. The Mann-Kendall test [32] is generally distribution-free, and does not assume any special form for the distribution function of the data [33]. The technique is robust and has low sensitivity to abrupt breaks due to inhomogeneous time series [34, 35], and has been used in recent studies for trend detection [36-41]. Excel template, MAKESENS application [32] was used to detect and estimate trends in the time series of the annual values. The following formula was used in calculating the Mann-Kendall test statistic S :

$$S = \sum_{t=1}^{N-1} \sum_{j=t+1}^N \text{sgn}(x_j - x_t) \tag{1}$$

Where x_j and x_t are the annual values in years j and t , $j > t$ respectively, and N is the number of data points. The value of $\text{sgn}(x_j - x_t)$ is computed as follows:

$$\text{sgn}(x_j - x_t) = \begin{cases} 1 & \text{if } (x_j - x_t) > 0 \\ 0 & \text{if } (x_j - x_t) = 0 \\ -1 & \text{if } (x_j - x_t) < 0 \end{cases} \tag{2}$$

This statistics represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples ($N > 10$), the test

is conducted using a normal approximation (Z statistics) with the mean and the variance as follows:

$$E[S] = 0 \tag{3}$$

2.3.3 Analysis of Rainfall Trend Using Mann-Kendall Test and the Sen's Slope Estimator in Ghana

$$\text{var}(S) = \frac{1}{18} \left[N(N-1)(2N+5) - \sum_{p=1}^q t_p(t_p-1)(2t_p+5) \right] \tag{4}$$

Here q is the number of tied (zero difference between compared values) groups, and t_p is the number of data values in the p^{th} group. The values of S and $\text{Var}(S)$ are used to compute the test statistic Z as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{var}(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{var}(S)}} & \text{if } S < 0 \end{cases} \tag{5}$$

The presence of a statistically significant trend is evaluated using the Z value. A positive value of Z indicates an upward trend and its negative value a downward trend. The statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from the standard normal cumulative distribution tables. The Z values were tested at 0.05 level of significance.

2.3.4 Sen's Slope Estimator

To estimate the true slope of an existing trend (as change per year) the Sen's nonparametric method is used. The Sen's method can be used in cases where the trend can be assumed to be linear.

$$f(t) = Qt + B \tag{6}$$

Where Q is the slope, B is a constant and t is time. To get the slope estimate Q , the slopes of all data value pairs is first calculated using the equation:

$$Q_t = \frac{x_j - x_k}{j - k} \tag{7}$$

Where x_j and x_k are data values at time j and k ($j > k$) respectively. If there are n values, x_j in the time series will be as many as many as $N = n(n-1)/2$ slope estimates Q_i . The Sen's estimator of slope is the median of these N values of Q_i . The N values of Q_i are ranked from the smallest to the largest and the Sen's estimator is

$$Q = Q \left[\frac{(N+1)}{2} \right], \text{ if } N \text{ is odd} \tag{8}$$

Or

$$Q = \frac{1}{2} \left(Q \left[\frac{N}{2} \right] + Q \left[\frac{(N+2)}{2} \right] \right), \text{ if } N \text{ is even} \tag{9}$$

To obtain an estimate of B in Equation f(t) the n values of differences $x_i - Q_t$ are calculated. The median of these values gives an estimate of B.

2.3.5 Simple Linear Regression Analysis

The “simple linear regression” model is in equation form of $Y=mX+C$, where, Y = rainfall, X = time in years, m = slope coefficients and c = least square estimates of the intercept. The sign of the slope defines the direction of trend variable: increasing if the sign is positive and decreasing if the sign is negative. We used t test to determine the linear trends were significantly different from zero at the 5% significant level.

3. Results and Discussions

Table 2. Trend of monthly mean distribution of rainfall in Ho station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	1.53		0.214	-0.187	0.698	-0.084	0.600
FEB	0.53		0.134	-0.662	0.901	-0.372	0.690
MAR	-0.40		-0.265	-1.699	1.412	-1.489	0.907
APR	-1.23		-0.758	-2.334	0.890	-1.992	0.422
MAY	-1.79	+	-1.043	-2.822	0.586	-2.397	0.122
JUN	-0.96		-1.106	-4.029	1.442	-3.284	0.825
JUL	-1.06		-0.854	-3.483	1.430	-2.948	0.693
AUG	-2.36	*	-1.717	-4.624	0.212	-4.030	-0.279
SEP	-1.06		-1.261	-4.699	1.440	-3.834	0.908
OCT	-1.58		-1.182	-2.819	1.035	-2.272	0.324
NOV	1.33		0.295	-0.355	0.915	-0.148	0.802
DEC	-0.03		-0.011	-0.590	0.420	-0.372	0.286
ANNUAL	-2.74	**	-7.919	-15.165	-0.549	-14.066	-2.111

From table 2, we concluded that only the month of May and August of Ho Station shows significant trend. The rest of the months show no significant trends. There is 99% significant trend in the annual value. In accordance

to the Mann-Kendall Z and Sen’s Q test, all months with the exception of January, February and November show a decreasing trend. At the lower limit of 99% and 95% confidence levels, all the months and annual values show decreasing trend. At the upper limit of 99%, all the months show increasing trend with the exception of the annual value whereas at 95% confidence level all the months show increasing trend with the exception of August and the annual value.

Table 3. Trend of monthly mean distribution of rainfall in Keta-Krachi station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	1.45		0.178	-0.123	0.587	-0.049	0.440
FEB	0.63		0.153	-0.469	0.776	-0.291	0.622
MAR	-0.25		-0.191	-1.654	1.238	-1.212	0.950
APR	-0.80		-0.416	-1.691	1.264	-1.348	0.774
MAY	-1.23		-0.862	-2.652	0.887	-2.203	0.493
JUN	-1.86	+	-1.522	-3.873	0.680	-3.176	0.067
JUL	-1.23		-0.953	-3.405	1.426	-2.830	0.722
AUG	-1.76	+	-2.233	-4.709	0.792	-4.247	0.101
SEP	-1.11		-0.974	-4.084	1.444	-3.130	0.606
OCT	0.75		0.515	-1.479	2.295	-0.873	1.786
NOV	0.25		0.029	-0.666	0.900	-0.537	0.646
DEC	-0.67		-0.063	-0.386	0.207	-0.284	0.135
ANNUAL	-2.11	*	-5.122	-12.372	1.547	-10.079	-0.383

From table 3, we can conclude that most of the months of Keta-Krachi Station show insignificant trend except June and August which shows significant trend at 5% level of significance. There is also a significant trend in the annual value. According to the Mann-Kendall Z and Sen’s Q test, only the months of January, February, October and November show increasing trend. At the lower limits, all the months and the annual value show decreasing trend at 99% and 95% confidence level. At the upper limits, all the

months show increasing trend at 99% and 95% confidence levels with the exception of the annual value at 95% confidence level.

Table 4. Trend of monthly mean distribution of rainfall in Kumasi station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	1.43		0.239	-0.214	0.642	-0.081	0.549
FEB	0.05		0.040	-1.092	1.055	-0.781	0.760
MAR	-0.48		-0.266	-1.945	1.673	-1.605	1.092
APR	-1.71	+	-1.419	-3.552	0.821	-3.012	0.245
MAY	-1.84	+	-1.881	-4.875	0.641	-3.898	0.126
JUN	-1.21		-1.063	-4.974	1.858	-3.916	0.827
JUL	-2.06	*	-2.070	-4.385	0.457	-3.928	-0.270
AUG	-2.59	**	-2.211	-4.658	-0.007	-3.899	-0.707
SEP	-1.33		-1.521	-4.931	1.496	-3.929	0.744
OCT	0.03		0.073	-2.874	3.212	-1.932	2.329
NOV	1.26		0.771	-0.782	2.092	-0.440	1.800
DEC	-0.18		-0.041	-0.542	0.447	-0.395	0.328
ANNUAL	-2.06	*	-8.757	-20.897	1.821	-17.724	-0.713

From table 4, we can conclude that most of the months of Kumasi Station show insignificant trend with the exception of April, May, July and August. The annual value also shows significant trend. According to the Mann-Kendall Z and Sen's Q test, eight of the months (March, April, May, June, July, August, September and December) show decreasing trend whereas the remaining four months (January, February, October and November) show an increasing trend. At the lower limits of 99% and 95% confidence levels, all the months and the annual value show decreasing trend. At the upper limit of 99%, all the months and the annual value with the exception of August show increasing trend whereas at 95% confidence level, all the months with the exception of July and August and the annual value show decreasing trend.

Table 5. Trend of monthly mean distribution of rainfall in Navrango station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	-0.86		-0.001	-0.005	0.001	-0.003	0.001
FEB	0.73		0.011	-0.032	0.231	-0.010	0.181
MAR	-0.98		-0.153	-0.652	0.275	-0.530	0.183
APR	0.13		0.071	-1.141	1.417	-0.833	0.969
MAY	-0.03		-0.028	-1.346	1.235	-1.040	1.033
JUN	-0.68		-0.378	-1.754	1.038	-1.465	0.697
JUL	-0.03		-0.011	-2.240	2.195	-1.667	1.622
AUG	1.01		1.077	-2.177	4.056	-1.147	3.372
SEP	0.20		0.190	-1.821	2.723	-1.454	2.077
OCT	0.38		0.228	-1.358	1.653	-0.921	1.274
NOV	-1.07		-0.066	-0.295	0.057	-0.227	0.027
DEC	-1.81	+	-0.002	-0.013	0.000	-0.010	0.000
ANNUAL							

From table 5, we can conclude that all the months of Navrango Station show insignificant trend with the exception of December that shows a significant trend at 10% significant level. There is no significant trend in the annual value. According to the Mann-Kendall Z and Sen's Q test, all of the months with the exception of February, April, August, September and October show decreasing trend. At the lower limit, all the months show decreasing trend at 99% and 95% confidence levels whereas at the upper limit, all the months show increasing trend at 99% and 95% confidence levels.

Table 6. Trend of monthly mean distribution of rainfall in Tamale station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	3.06	**	1.357	0.156	2.429	0.539	2.135
FEB	-1.35		-0.039	-0.127	0.051	-0.105	0.023
MAR	-1.47		-4.252	-17.181	3.632	-15.035	1.756
APR	-1.61		-0.197	-0.701	0.189	-0.612	0.063
MAY	-1.56		-0.079	-0.242	0.062	-0.200	0.029
JUN	-1.31		-0.003	-0.023	0.010	-0.017	0.005
JUL	-1.33		-1.107	-3.964	1.631	-3.095	0.755
AUG	-0.58		-0.203	-1.240	0.593	-0.880	0.385
SEP	-0.26		-0.033	-0.383	0.304	-0.312	0.235
OCT	-0.68		-0.306	-1.220	0.701	-0.954	0.461
NOV	-0.09		-0.001	-0.045	0.038	-0.033	0.025
DEC							
ANNUAL							

From table 6, we can conclude that there is no significant trend in the annual value. All the months of Tamale Station show no significant trend with the exception of January which shows a significant trend at 99% significant level. According to the Mann-Kendall Z and Sen's Q test, all the months show decreasing trend with the exception of January which shows an increasing trend. At the lower limits of 99% and 95% confidence level, All the months with the exception of January trend whereas December and the annual value show no trend. At the upper limits, all the months with the exception of December and the annual value show increasing trend at 99% and 95% confidence level.

Table 7. Trend of monthly mean distribution of rainfall in Wa station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	-0.92		-0.002	-0.045	0.008	-0.027	0.003
FEB	0.11		0.003	-0.164	0.224	-0.111	0.152
MAR	-0.30		-0.079	-0.820	0.625	-0.579	0.416
APR	0.15		0.128	-1.211	1.463	-0.828	1.164
MAY	-0.26		-0.194	-1.401	1.186	-1.041	0.752
JUN	0.45		0.204	-1.293	1.848	-0.866	1.537
JUL	0.05		0.078	-1.571	1.678	-1.118	1.367
AUG	-0.43		-0.345	-3.198	2.509	-2.471	2.012
SEP	0.23		0.242	-2.148	2.551	-1.562	1.905
OCT	0.96		0.489	-0.842	1.917	-0.459	1.412
NOV	-0.21		-0.021	-0.355	0.261	-0.311	0.174
DEC	-1.40		-0.004	-0.057	0.010	-0.041	0.003
ANNUAL	0.83		1.890	-4.190	7.726	-2.797	5.992

From table 7, we can conclude that all the months and the annual value of Wa Station show no significant trend. According to the Mann-Kendall Z and Sen's Q test, the months of February, April, June, July, September and October show increasing trend. The remaining months show decreasing trend. At the lower limits, both the 99% and 95% confidence level of all the months and annual value show decreasing trend whereas both the monthly and annual values at the upper limits show increasing trend at 99% and 95% confidence level.

Table 8. Trend of monthly mean distribution of rainfall in Wenchi station from 1981-2018

Time series	Test Z	Sig.	Q	Qmin99	Qmax99	Qmin95	Qmax95
JAN	0.78		0.064	-0.166	0.362	-0.095	0.290
FEB	0.20		0.033	-0.701	0.947	-0.463	0.632
MAR	-0.73		-0.509	-2.057	1.331	-1.636	0.875
APR	-1.58		-1.077	-2.938	0.746	-2.565	0.271
MAY	-2.44	*	-2.000	-4.107	0.111	-3.536	-0.275
JUN	-2.67	**	-2.337	-4.744	-0.129	-4.017	-0.862
JUL	-1.51		-1.158	-3.370	0.826	-2.797	0.380
AUG	-2.41	*	-1.936	-4.571	0.152	-3.868	-0.224
SEP	-1.66	+	-2.011	-4.602	1.007	-4.125	0.315
OCT	0.78		0.532	-1.623	2.402	-1.064	1.890
NOV	0.96		0.334	-0.664	1.178	-0.379	0.942
DEC	-0.85		-0.085	-0.397	0.188	-0.308	0.119
ANNUAL	-2.51	*	-10.302	-19.382	0.168	-16.602	-2.823

From table 8, we can conclude that four months (May, June, August and September) of Wenchi Station show significant trend. The remaining months show no significant trends. The annual value shows significant trend. According to the Mann-Kendall Z and Sen's Q test, all the months show decreasing trends with the exception of January, February, October and November. At the lower limits all the months and the annual value shows decreasing trend at 99% and 95% confidence level. At the upper limit at 99% confidence level, there is an increase trend in all the months and annual value with the exception of June whereas at 95% confidence level, all the months with the exception of May, June, August and the annual value show increasing trend.

3.1 Zoning Adaptation to Climate Change through Agroforestry

Agroforestry is progressively acknowledged as a system of land management that can be used as an alternative measure for mitigating and adapting changes in climate and simultaneously tending considerably to lot of the difficulties that subsistence farmers confront. Agroforestry provides different benefits to the environment and liveli-

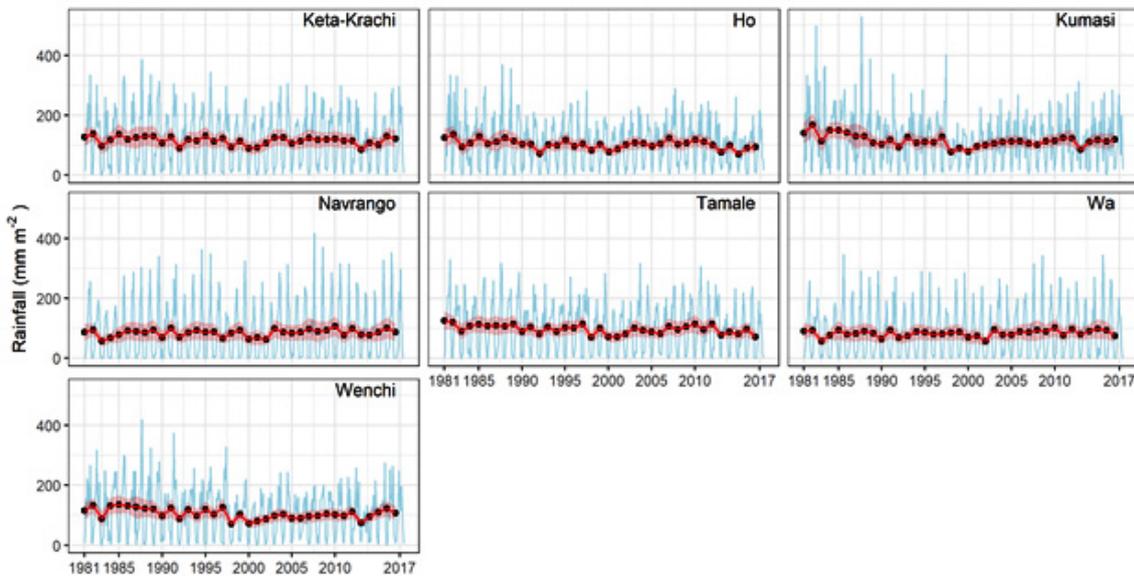


Figure 2. Graphical trends of rainfall pattern of all the meteorological stations

hoods, as it assists in mitigating climatic changes and also help farmers in adjusting to harsh and changing weather conditions^[43].

Climate change increases risk in agriculture through dry spells, pests and flood. Farmers can keep living on a piece of land depending upon how they adjust well to the risks of change in climate. Agroforestry for climate adaption at the farm level improves resilience and at the landscape level can take numerous forms. For instance, agroforestry can decrease air pollution and improve both warming and cooling of the climate, creating a resilient microclimate for crops and livestock^[44]. It also increases water security through improved infiltration to soils and groundwater^[45], protecting water catchments and watersheds. Again, agroforestry practices are suitable for landscape restoration due to its potential in improving soil properties and water availability to plants. Furthermore, trees provide a number of ecosystem services like water regulation, climate buffering, soil fertility, erosion and flood control, as well as food, fodder, medicine and wood—all vital for resilience to climate change and reduce vulnerability of local people^[46,47].

Agroforestry is equally important because it can enhance livelihoods in smallholder farming systems through diversified income and cash crop systems (e.g. cocoa, coffee, cashew and nuts), increase food security and improve access to nutritious food. Trees on farms can also help the farmers decrease the economic recovery time after natural disasters^[48].

Significant amounts of GHGs can be reduced or removed through agroforestry practices which have the

potency of increasing carbon storage in biomass above-ground and below-ground and in soil organic carbon^[43].

Agroforestry is widely practiced in the world, and its visibility is increasing at national levels within international institutions. Nevertheless, there are numerous barriers working at different scales that are preventing a broad-scale implementation of agroforestry practices, such as inefficient markets, unclear land-rights, limited access to knowledge and finance with lack of intersectoral collaboration^[49]. Despite plans to expand agroforestry practices, significant gaps exist between countries' ambitions and their capabilities to measure, report and verify agroforestry actions^[50]. There is a need to advance strategies, frameworks and indicators at all levels to measure agroforestry diversified systems and climate benefits.

The United Nations Framework Convention on Climate Change (UNFCCC) and other international organizations and scientific panels are stressing the importance of using sustainable land management systems, such as agroforestry, to generate multiple environmental and socio-economic benefits^[43,51,52]. The implementation of agroforestry can help countries reach their goals related to climate change adaptation and mitigation, reforestation as well as SDG-targets related to food and water security. Analysis by CGIAR revealed that, as at June 2018 over a third (59 of 147) of developing countries had proposed agroforestry as a climate change mitigation activity for achieving their Nationally Determined Contributions (NDC) under the UNFCCC^[50]. Therefore, agroforestry can be a resilient land management solution with cross-cutting benefits for both adaptation and mitigation to climate change. Initially

in Africa, cashew was used in afforestation schemes or around forest demarcations to serve as fire protection barrier [53]. Now, the “poor man’s crop, rich man’s food” as it is been referred is grown for its nuts and recognized as one of the most important tropical crop [54].

Cashew was introduced to Africa from Brazil in the seventeenth century. As a profitable tree crop, cashew grows on very poor sandy soils, is drought-tolerant, and is normally intercropped with cultivated food crops such as cassava (*Manihot esculenta* Crantz), thus serving as a buffer against failure of rainfed annual crops in a context of climatic uncertainty [55]. With its moderate demand on soil characteristics and high tolerance to external conditions, cashew has been planted in poor soils for fertility recovery in lands depleted by yearly crops and to prevent erosion. Also, because it can be intercropped with both perennial and annual herbs as well as shrubs and trees, coupled with its hardiness and use as cover in fallow periods to regain fertility loss by soil makes it ideal to be used in agroforestry [55, 56]. Given the tree’s rusticity, its cultivation in soils depleted by fire as well as other crops like groundnuts, maize and upland rice is encouraged [54].

According to Ayanlade et al., [58], farmers respond to changes in environmental conditions by selecting crops suitable for a new conditions. In such a situation, farmers divert to alternative adaptive strategy by cultivating other crops which have different moisture requirement [59, 60]. In the context of Ghana, changes in climate affects rainfall pattern leading to the diminishing of growth of some crops while in the case of cashew it is rather increasing its growth suitability. This is a clear indication that cashew as agroforestry crop can serve as an adaptive measure to climate change in many parts of the country.

Again, according to ICCO [61], for optimum growth and yield of cocoa, rainfall amount of less than 100mm should not be experienced for more than three months in a year. In the case of cashew, a yearly rainfall of 1000mm is sufficient for its production. Its well-developed root system makes it drought tolerant. Furthermore, in a model profiled for 1.0ha cashew cultivation, it is evident that heavy rainfall evenly distributed throughout the year is not favorable for cashew. It needs a climate conditions with a well-defined dry season and rainfall.

In view of this and in the context of Ghana, the transitional and the Northern zones which are the major food producers of the country are those greatly disturbed by the impact of the changing climate because of their proximity to the Sahara Desert and their over reliance on rainfed agriculture. Crops like cocoa and maize once grown in these areas are now failing but these same areas proves to be suitable for cashew agroforestry based on a study con-

ducted in the country as shown in Figure 3. Lands once covered by trees are now bare either with or without grass due to bushfire, deforestation, desertification, bad farming practices among others. The consequent effects of these are rainfall variability, post-harvest losses, loss of soil fertility and extreme weather conditions among others. Cashew potential benefits as highlighted can help immensely in dealing with these climate change issues when adapted through agroforestry in these areas of Ghana.

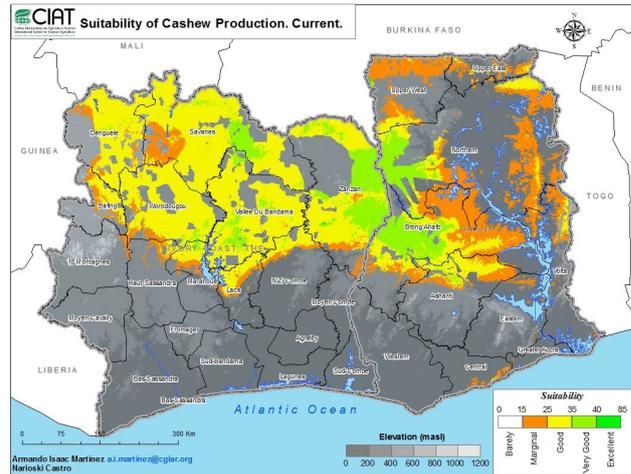


Figure 3. Current area suitability of cashew production in Ghana and Cote D’ivoire

Source: (CIAT, 2011).

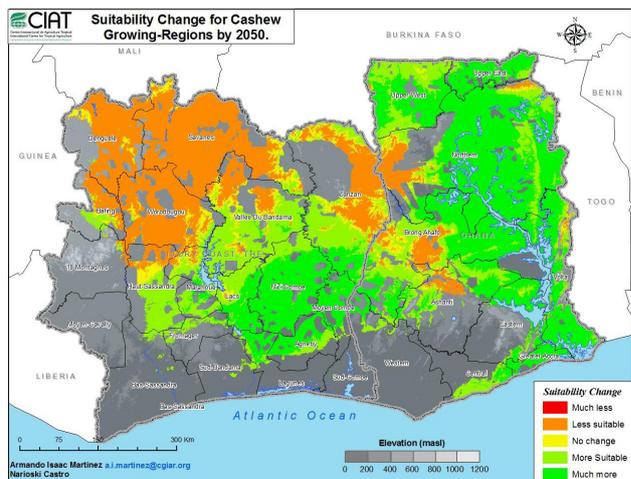


Figure 4. Projected future area suitability for cashew production

Source: (CIAT, 2011).

4. Conclusion

Ghana is a seriously sensitive country to climate change due to lack of agricultural diversification and reliance on the production of crops like cassava, cocoa and maize that

are sensitive to climate change. To ascertain the trend in the country's rainfall pattern, we analyzed more than 30 years rainfall data selected from the five ecological zones of Ghana from the cities of Ho, Keta-Krachi, Kumasi, Navrongo, Tamale, Wa and Wenchi. This means that depending on the result based on geographical location, we can conclude by stipulating the trend of rainfall in these cities beyond the whole country. Knowing Ghana as an Agric-based country, most of the populace earn their livelihood from agricultural events. However, every agriculture activity is highly dependent on rainfall. In this study, we try to find out the trends in rainfall of 7 divisional cities across the climatic zones. The Z value of MK Test represents both positive and negative trend in the area. Sen's Slope is also indicating increasing and decreasing magnitudes of slope in correspondence with the Mann-Kendall Test values. Majority of the months of the stations showed no significant trends. Some months showed upward trends along with some significant values. The effect of the climate change is clear as it can be seen that there are a lot of variability in the rainfall patterns across the country. This corresponds to the climate change projection of the country which shows large uncertainty concerning the change in rainfall. But our study of the country shows that adapting to agroforestry practice through cashew farming will be viable in adapting and mitigating climate change as larger portion of the country is and will be suitable for the growth of cashew in the future although there is variability in the rainfall pattern. The prevailing climatic conditions and the rainfall pattern in the country suggest that future shift to cashew agroforestry is likely. There is therefore the need for Ghana to redesign its research and extension support systems to include both technical and institutional dimensions so as to enhance collective adaptive capacity for climate change. This will go a long way to enable the country achieve the Sustainable Development Goals 2.4, 13.2 and 15.3 respectively.

References

- [1] Cramer, W., Guiot, J., Fader, M., Garrabou, J., Gattuso, J.P., Iglesias, A., Lange, M.A., Lionello, P., Llasat, M.C., Paz, S., Penueles J. Climate change and interconnected risks to sustainable development in the Mediterranean. *Nature Climate Change*, 2018, 8(11): 972-80.
DOI: <https://doi.org/10.1038/s41558-018-0299-2>
- [2] Kumar, P., Tokas, J., Kumar, N., Lal, M., Singal, H.R. Climate change consequences and its impact on agriculture and food security. *International Journal of chemical studies*, 2018, 6(6): 124-33.
- [3] Kulp, S.A., Strauss, B.H. New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nature communications*, 2019, 10(1): 1-2.
DOI: <https://doi.org/10.1038/s41467-019-12808-z>
- [4] Asante, F.A., Amuakwa-Mensah F. Climate change and variability in Ghana: Stocktaking. *Climate*, 2015: 78-99.
- [5] Adjei-Mensah, K.; Kusimi, J.M. Dwindling water supply and its socio-economic impact in Sekyere Kumawu District in Ashanti Region of Ghana: public opinion on the role of climate change. *GeoJournal*, 2019: 1-8.
DOI: <https://doi.org/10.1007/s10708-019-10026-0>
- [6] Asumadu-Sarkodie, S., Owusu, P.A., Hung, Y.T. The Impact Assessment of Energy, Agriculture and Socioeconomic Indicators on Carbon Dioxide Emissions in Ghana, 2020. DOI: https://doi.org/10.1142/9789811207136_0005
- [7] WRI, 2017. <http://cait2.wri.org/>
- [8] GAIN index summarizes a country's vulnerability to climate change and other global challenges in combination with readiness to improve resilience. 2016. <http://index.gain.org/country/ghana>
- [9] USAID. Climate Change Risk Profile: Ghana, 2017. <https://www.climate-links.org/resources/climate-change-risk-profile-ghana>
- [10] Panthou, G., Lebel, T., Vischel, T., Quantin, G., Sane, Y., Ba, A. Ndiaye, O.; Diongue-Niang, A.; Diopkane, M. Rainfall intensification in tropical semi-arid regions: The Sahelian case. *Environmental Research Letters*, 2018, 13(6): 064013.
DOI: <https://doi.org/10.1088/1748-9326/aac334>
- [11] Lawson, E.T., Alare, R.S., Salifu, A.R., Thompson-Hall, M. Dealing with climate change in semi-arid Ghana: Understanding intersectional perceptions and adaptation strategies of women farmers. *GeoJournal* 2020, 85(2): 439-52.
DOI: <https://doi.org/10.1007/s10708-019-09974-4>
- [12] Sanneh, E.S. Climate Change Adaption. In *Systems Thinking for Sustainable Development*. Springer, Cham, 2018: pp. 41-53.
DOI: https://doi.org/10.1007/978-3-319-70585-9_5
- [13] Adger, W.N., de Campos, R.S., Mortreux, C., McLeman, R., Gemenne, F. Mobility, displacement and migration, and their interactions with vulnerability and adaptation to environmental risks. *Routledge handbook of environmental displacement and migration*, 2018: 29-41.
- [14] Thomas, K., Hardy, R.D., Lazrus, H., Mendez, M., Orlove, B., Rivera - Collazo, I., Roberts, J.T., Rockman, M., Warner, B.P., Winthrop, R. Explaining differential vulnerability to climate change: A social

- science review. *Wiley Interdisciplinary Reviews: Climate Change*, 2019, 10(2): e565.
DOI: <https://doi.org/10.1002/wcc.565>
- [15] Dovie, D.B. Integrated climate smart flood management for Accra-Ghana: final technical report, 2020.
- [16] Tumushabe, J.T. Climate change, food security and sustainable development in Africa. In *The Palgrave handbook of African politics, governance and development*, 2018: 853-868. Palgrave Macmillan, New York.
DOI: https://doi.org/10.1057/978-1-349-95232-8_53
- [17] Afriyie-Kraft, L., Zabel, A., Damnyag, L. Adaptation strategies of Ghanaian cocoa farmers under a changing climate. *Forest Policy and Economics* 2020, 113: 102115.
DOI: <https://doi.org/10.1016/j.forpol.2020.102115>
- [18] Haile, G.G.; Tang, Q.; Sun, S.; Huang, Z.; Zhang, X.; Liu, X. Droughts in East Africa: Causes, impacts and resilience. *Earth-science reviews*, 2019, 193: 146-61.
DOI: <https://doi.org/10.1016/j.earscirev.2019.04.015>
- [19] Intergovernmental Panel on Climate Change. *Climate Change. The Physical Science Basis. Summary for Policymakers*; Intergovernmental Panel on Climate Change: Geneva, Switzerland, 2007: 18.
- [20] Pink, R.M. Africa: Kenya, South Africa, Botswana. In *The Climate Change Crisis*. Palgrave Macmillan, Cham, 2018: 125-162.
DOI: https://doi.org/10.1007/978-3-319-71033-4_6
- [21] Ayuk, E.T., Dovie, D.B. Development mainstreaming of climate change and adaptation policies in Ghana. *Climate Change in Ghana*, 2019: 128.
- [22] World Bank. *The Costs to Developing Countries of Adapting to Climate Change: New Methods and Estimates*. Available online: <http://www.worldbank.org/eacc> (accessed on 25th January, 2014).
- [23] Adjei, V., Kyerematen, R. Impacts of Changing Climate on Maize Production in the Transitional Zone of Ghana. *American Journal of Climate Change*, 2018, 7(03): 463.
DOI: [10.4236/ajcc.2018.73028](https://doi.org/10.4236/ajcc.2018.73028)
- [24] Intergovernmental Panel on Climate Change. *Integrating Sustainable Development and Climate Change in the IPCC Fourth Assessment Report (AR4)*; World Meteorological Organization and United Nations Environment Programme: Geneva, Switzerland, 2003.
- [25] Antwi-Agyei, P., Dougill, A.J., Stringer, L.C., Codjoe, S.N. Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. *Climate Risk Management*, 2018, 19: 83-93.
DOI: <https://doi.org/10.1016/j.crm.2017.11.003>
- [26] Leal Filho, W., Balogun, A.L., Olayide, O.E., Azeiteiro, U.M., Ayal, D.Y., Muñoz, P.D., Nagy, G.J., Bynoe, P., Oguge, O., Toamukum, N.Y., Saroar, M. Assessing the impacts of climate change in cities and their adaptive capacity: Towards transformative approaches to climate change adaptation and poverty reduction in urban areas in a set of developing countries. *Science of The Total Environment*, 2019, 692: 1175-90.
DOI: <https://doi.org/10.1016/j.scitotenv.2019.07.227>
- [27] Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., Yanda, P. Africa. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry; O.F. Canziani; J.P. Palutikof; P.J. van der Linden; C.E. Hanson, Eds., Cambridge University Press, Cambridge, 2008.
<http://hdl.handle.net/123456789/913>
- [28] Aniah, P., Kaunza-Nu-Dem, M., Ayembilla, J.A. Smallholder farmers' livelihood adaptation to climate variability and ecological changes in the savanna agro ecological zone of Ghana. *Heliyon*, 2019, 5(4): e01492.
DOI: <https://doi.org/10.1016/j.heliyon.2019.e01492>
- [29] Zaato, P. A. Agricultural lands vulnerability to climate change in the Jirapa district of the Upper West Region, Ghana, Doctoral dissertation, University for Development Studies, Ghana, March, 2020.
<http://hdl.handle.net/123456789/2648>
- [30] Ghana Statistical Service (GSS). *Annual Report*; Ghana Statistical Service: Accra, Ghana, 2020.
- [31] Tamakloe, W. *State of Ghana's Environment-Challenges of compliance and enforcement*, 2000.
https://www.oceandocs.org/bitstream/handle/1834/409/04h_ghana.pdf?sequence=1
- [32] Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T., Amnell, T. Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates MAKESENS-The excel template application. *Finish Meteorological Institute, Helsinki*, 2002.
<https://www.researchgate.net/publication/259356944>
- [33] Yue, S., Pilon, P., Phinney, B., Cavadias, G. The influence of autocorrelation on the ability to detect trend in hydrological series. *Hydrological processes*, 2002, 16(9): 1807-29.
DOI: [10.1002/hyp.1095](https://doi.org/10.1002/hyp.1095)
- [34] Kisi, O., Ay, M. Comparison of Mann-Kendall and innovative trend method for water quality parameters

- of the Kizilirmak River, Turkey. *Journal of Hydrology*, 2014, 513: 362-75.
DOI: <http://dx.doi.org/10.1016/j.jhydrol.2014.03.005>
- [35] N'Tcha M'Po, Y., Lawin, E.A., Yao, B.K., Oyerinde, G.T., Attogouinon, A., Afouda, A.A. Decreasing past and mid-century rainfall indices over the Ouémé River Basin, Benin (West Africa). *Climate*. 2017, 5(3): 74.
DOI: [10.3390/cli5030074](https://doi.org/10.3390/cli5030074)
- [36] Soro, G.E., Noufè, D., Goula Bi, T.A., Shorohou, B. Trend analysis for extreme rainfall at sub-daily and daily timescales in Côte d'Ivoire. *Climate*. 2016, 4(3): 37.
DOI: [10.3390/cli4030037](https://doi.org/10.3390/cli4030037)
- [37] Luhunga, P.M., Botai, J.O., Kahimba, F. Evaluation of the performance of CORDEX regional climate models in simulating present climate conditions of Tanzania. 2016.
<https://www.researchgate.net/publication/303944866>
- [38] Kabanda, T. Long-term rainfall trends over the Tanzania coast. *Atmosphere*. 2018, 155.
DOI: [10.3390/atmos9040155](https://doi.org/10.3390/atmos9040155)
- [39] Mafuru, K.B., Guirong, T. Assessing prone areas to heavy rainfall and the impact of the upper warm temperature anomaly during March-May rainfall season in Tanzania. *Advances in Meteorology*. 2018.
DOI: <https://doi.org/10.1155/2018/8353296>
- [40] Ayugi, B.O. Tan G. Recent trends of surface air temperatures over Kenya from 1971 to 2010. *Meteorology and Atmospheric Physics*. 2019, 131(5): 1401-13.
DOI: <https://doi.org/10.1007/s00703-018-0644-z>
- [41] Asare-Nuamah P., Botchway E. Understanding climate variability and change: analysis of temperature and rainfall across agroecological zones in Ghana. *Heliyon*, 2019, 5(10): e02654.
- [42] NASA Official: Paul Stackhouse, Jr., Ph.D. Version: 1.0 | Last Modified: 2019/12/18
<http://power.larc.nasa.gov/data-access-viewer/>
- [43] IPCC (Intergovernmental Panel on Climate Change). Climate change and land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for Policymakers, 2019.
- [44] Ellison, D., Morris, C.E., Locatelli, B., Sheil, D., Cohen, J., Murdiyarso, D., Gutierrez, V., Van Noordwijk, M., Creed, I.F., Pokorny, J., Gaveau, D. Trees, forests and water: Cool insights for a hot world. *Global Environmental Change*, 2017, 43: 51-61.
DOI: <https://doi.org/10.1016/j.gloenvcha.2017.01.002>
- [45] Bargués Tobella, A., Reese, H., Almaw, A., Bayala, J., Malmer, A., Laudon, H., Ilstedt U. The effect of trees on preferential flow and soil infiltrability in an agroforestry parkland in semiarid Burkina Faso. *Water resources research*, 2014, 50(4): 3342-54.
DOI: <https://doi.org/10.1002/2013WR015197>
- [46] Verchot, L.V., Van Noordwijk, M., Kandji, S.; Tomich, T., Ong, C., Albrecht, A., Mackensen, J., Bantilan, C., Anupama, K.V., Palm, C. Climate change: linking adaptation and mitigation through agroforestry. Mitigation and adaptation strategies for global change, 2007, 12(5): 901-18.
DOI: <https://doi.org/10.1007/s11027-007-9105-6>
- [47] Mbow, C., Smith, P., Skole, D., Duguma, L., Bustamante, M. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. *Current Opinion in Environmental Sustainability*. 2014, 6: 8-14.
DOI: <https://doi.org/10.1016/j.cosust.2013.09.002>
- [48] Simelton, E., Dam, B.V., Catacutan, D. Trees and agroforestry for coping with extreme weather events: experiences from northern and central Viet Nam. *Agroforestry systems*, 2015, 89(6): 1065-82.
DOI: <https://doi.org/10.1007/s10457-015-9835-5>
- [49] Network Agroforestry. Scaling up Agroforestry: Potential, Challenges and Barriers. A Review of Environmental, Social and Economic Aspects at the Farmer, Community and Landscape Levels, 2018.
- [50] Rosenstock, T., Wilkes, A., Jallo C., Namoi, N., Bulusu, M., Suber, M., Bernard, F., Mboi, D. Making trees count: Measurement, reporting and verification of agroforestry under the UNFCCC. CCAFS Working Paper no. 240. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CAFS), 2018.
<https://hdl.handle.net/10568/98404>
- [51] FAO. The State of the World's Biodiversity for Food and Agriculture, J. Bélanger & D. Pilling (eds.). FAO Commission on Genetic Resources for Food and Agriculture Assessments. Rome, 2019: 572.
<http://www.fao.org/3/CA3129EN/CA3129EN.pdf>
- [52] IPBES. The global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Díaz, S., Settele, J., Brondizio, E.S., Ngo, H.T., Guèze, M., Agard, J., Arneeth, A., Balvanera, P., Brauman, K.A., Butchart, S.H.M., et al. Zayas, C.N. (eds.). IPBES secretariat, Bonn, Germany, 2019.
DOI: <https://doi.org/10.1007/s10531-017-1361-5>
- [53] Goujon, P., Lefebvre, A., Leturcq, Ph., Marcellesi, A.P., Praloran, J.P. Studies on cashew tree. 1973, 151: 27-53. (in French)
- [54] Catarino, L., Menezes, Y., Sardinha, R. Cashew cultivation in Guinea-Bissau-risks and challenges of

- the success of a cash crop. *Scientia Agricola*, 2015, 72(5): 459-67.
DOI: <https://doi.org/10.1590/0103-9016-2014-0369>
- [55] Mitchell, D. Tanzania's cashew sector: constraints and challenges in a global environment. The World Bank, 2004.
- [56] Behrens, R. Cashew as an agroforestry crop. Prospects and potentials. Margraf Verlag, 1996.
- [57] Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., Simons, A. Agroforestry Database: a tree reference and selection guide. Version 4. Agroforestry Database: a tree reference and selection guide, Version 4. 2009.
DOI: <https://doi.org/10.1007/s10708-017-9771-1>
- [58] Ayanlade, A., Radeny, M., Akin-Onigbinde, A.I. Climate variability/change and attitude to adaptation technologies: a pilot study among selected rural farmers' communities in Nigeria. *GeoJournal*, 2018, 83(2): 319-31.
DOI: <https://doi.org/10.1007/s10708-017-9771-1>
- [59] Ajak, B.J., Kyazze, F.B., Mukwaya, P.I. Choice of Adaptation Strategies to Climate Variability among Smallholder Farmers in the Maize Based Cropping System in Namutumba District, Uganda. *American Journal of Climate Change*, 2018, 7(3): 431-51.
DOI: [10.4236/ajcc.2018.73026](https://doi.org/10.4236/ajcc.2018.73026)
- [60] Gruda, N., Bisbis, M., Tanny, J. Impacts of protected vegetable cultivation on climate change and adaptation strategies for cleaner production-a review. *Journal of Cleaner Production*, 2019, 225: 324-39.
DOI: <https://doi.org/10.1016/j.jclepro.2019.03.295>
- [61] ICCO. Growing Cocoa. The origin of cocoa and its spread around the world. Available at: <http://www.icco.org/about/growing.aspx> Accessed: November 10, 2009.
- [62] CIAT (International Center for Tropical Agriculture). Predicting the Impact of Climate Change on Cashew Growing Regions in Ghana and Cote d'Ivoire. Final Report. Decision and Policy Analyses Program, CIAT, Managua, Nicaragua, September, 2011.