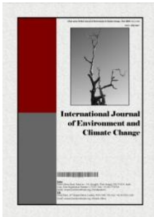

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Assessment of Croplands' Exposure to Climate Variability in the Federal Capital Territory (FCT), Abuja, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author DI designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author SKI managed the analyses of the study. Author JIM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The knowledge of exposure of croplands to climate variability is of paramount importance in adaptive capacity planning to boost food production for the world's growing population. The study assessed the exposure of croplands to climate variability in the Federal Capital Territory (FCT) of Nigeria using Geo-informatics. This was achieved by examining the distribution pattern of climate indices in FCT from 1981-2017, determining the exposure index of croplands in FCT Area Councils and production of exposure map of FCT Area Councils, The spatial scope of this study is the entire arable land in FCT which is made up of six Area Councils. The research is contextually restricted to exposure of croplands to climate variables while other variables remain constant. The selected climatic variables are rainfall, temperature, relative humidity and potential evapotranspiration (exposure indicators). The arable crops in focus are yam, beans and maize while the soil variables selected for the study are: soil erosion, organic carbon content of the soil,

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clay content of the soil and percentage of arable land available for crop production. The temporal scope of the examined exposure indicators (climate variables) was limited to a period of thirty (37) years from 1981- 2017. The result indicates that Bwari has the highest exposure (0.1671) to climate variables while Abaji has the least (0.0868) exposure. AMAC is high (0.1371), Kuje (0.1304) is moderate while Gwagwalada (0.1132) and Kwali (0.1154) have low exposures to climate variability. The implication of this on the referenced crops is that crop yield will be highly reduced in Bwari and optimum in Abaji Area Councils due to their climatic requirement. The power of Geo-Spatial Technology in combining different indices of exposure to produce exposure map was demonstrated in the study.

Keywords: Geoinformatics; exposure; climate variability; evapotranspiration.

1. INTRODUCTION

The Sahelian region of West Africa is already exposed to long periods of heat waves which has made Niger and Burkina Faso most vulnerable [1]. Based on the projected increase in extreme weather event frequency and intensity, West Africa will be at the centre of risk exposure in Africa in the middle of 21st century [2]. This is expected to extend towards the coast by 2050 implicating the vulnerability of northern Nigeria [2]. The southern Nigeria which benefits from sufficient rainfall and soil moisture is faced with land degradation [3].

Land suitability for agriculture in the past were normally measured by its ability for sustained production of crops [4]. Climate variability has the capability to disrupt soil potentials for crop production [5]. Suitable lands for agriculture may be rendered useless due to climate variability or extreme weather events [6]. The vulnerability of croplands is not determined by the nature and magnitude of stress exposure, but by the combination of the farmers' capacity to cope with and/or recover from environmental change [7].

According to Intergovernmental Panel on Climate Change [2,8, 9], there are enough evidences to show that climate variability is already affecting crop yields in many countries of the world at different scales and magnitude. In FCT, high temperature above 30°C causes abscission of flowers and a low pod set which results in yield loss in beans.

Climate variability changes the temperature and rainfall pattern which subsequently affects the planting and harvesting regimes. The Food and Agricultural Organization [10] noted that about 25% of cereals, 37% of root and tubers, and 53% of fruits are lost in developing countries as a result of extreme climatic conditions. FAO 2007 [11] also attributed the development process and poor yields of agricultural products to the inordinate rise in temperature. Extreme meteorological events like high temperature, heavy storms, or droughts were argued to severely disrupt crop production and reduce the effectiveness and duration of pesticide control [12]. International Fund for Agricultural Development [13], concluded that climate change is a threat to rural farmers in developing countries, especially in Africa.

Davenport et al. [14] analyzed the response of Kenyan maize yields to climate change and potential adaptation options by modelling the country-wide yields of maize as a function of rainfall and temperature in a period of increased regional warming and drying (1989–2008). The study observed that maize yield in Eastern Kenya would have increased by 8% (500,000 metric tons) while the magnitude of change was higher in Western Kenya if there were no warming and drying trends as compared to existing yields from 2000 - 2008. The study further predicted a reduced yield of 11% and 7% in Eastern and Western Kenya respectively based on the 2026 – 2040 climatic projection in the region. The study recommended drought tolerant hybrid seeds and fertilizer usage for increased maize yield to mitigate against the increasing warming and drying trends in the country.

Cornforth et al. [15] assessed the impact of climate change on sweet potato in Uganda using the causal network approach. The paper developed a network of drivers through interviews with sweet potato experts. The drivers were combined in form of a network diagram to show the main factors affecting the growth and production of sweet potato. The different variables in the network were weighed using models, data, literature and expert knowledge to know how each of the them affect one another in the system. This was done to predict the likely yield of sweet potato giving the state of the different drivers in the network. The causal network offers a framework for linking climate, human activities and biophysical factors to specific impacts and risk in order to provide policymakers with evidence-based interventions to promote food security and resilience.

The importance of the onset and cessation of rainfall and length of growing season in agricultural production in early warning and preparedness cannot be overemphasized. In order to determine this climate characteristics for Ethiopian agricultural population, Legese et al. [8] embarked on the study “characteristics of seasonal rainfall and its distribution over Bale Highland, Southeastern Ethiopia”. The paper analyzed rainfall data of 1985 to 2014. The study shows that there is high variability of onset and cessation in Belg season than kiremt season. The mean onset and cessation of Belg season over Bale Highland were March 28 and June 10 with mean standard deviation of 19 days, respectively. Kiremt season on the other hand has a mean onset and cessation of July 12 and October 31 with mean standard deviation of 16 and 12 days respectively. The length of growing period (LGP) in Kiremt (major growing season) was 110 days with mean standard deviation of 19 days. The Belg season has the mean LGP as 73 days with mean standard deviation of 26 days. The paper conclusively recommended irrigation infrastructures to assist the traditional rain-fed agricultural practice being enjoyed in the region

Nigeria is a country where majority of the population (70%) depend on climate sensitive agriculture for means of livelihood [16], any climate related challenge in the agricultural sector will pose a threat to their existence [17]. Nigeria is a low-income country where agricultural production depends solely on rainfall and the farmers have little capacity to cope based on their low income [18, 19]. African countries including Nigeria that have their economy solely dependent on weather related agricultural production systems, are particularly vulnerable to climate variability [20]. The recent flooding in different parts of the country and the various prolonged droughts that are currently being witnessed in Northern Nigeria are enough signals of the ravaging effects of climate variability [21].

1.1 Objectives of the Study

The study assessed the exposure of croplands to climate variability in the Federal Capital Territory (FCT) of Nigeria using Geo-informatics. This was achieved by

1. examining the distribution pattern of climate indices in FCT from 1981-2017.
2. determining the exposure index of croplands in FCT Area Councils
3. production of exposure map of FCT Area Councils.

1.2 Statement of Research Problem

Gbetubo and Hassan (2005) noted that most analysis on climate change studies are concerned with effect, impact and adaption. Among such studies in Africa and Nigeria are: evidence of climate change impacts on agriculture and food security in Nigeria (Bello et al, 2012), awareness and adaptation to climate change among yam-based farmers in rural Oyo state, Nigeria (Oluwatayo and Ojo, 2016) and agricultural vulnerability to climate change in eight selected rural settlements in Sokoto State, Nigeria (Atedhor, 2015). Relatively few studies if any analyze the exposure of croplands to climate variability in FCT. Some of the climate change studies within the FCT are: climate variability and crop zones for the Federal Capital Territory, Nigeria [22], post-adaptation vulnerability of cereals to rainfall and temperature variability in the Federal Capital Territory of Nigeria [23], vulnerability of Federal capital Territory of Nigeria (Abuja) to climate change (Hassan and Ishaya, 2010), analysis of growing season rainfall and temperature variability in the Federal Capital Territory of Nigeria [24], effect of climate change on agricultural productivity in Federal Capital Territory using temperature, rainfall and crops data (Aondoakaa, 2012), vulnerability of annual cereals yield to rainfall and temperature variability in the Federal Capital Territory of Nigeria [24] . Despite the wide coverage of the study on vulnerability in the FCT of Nigeria over the years, it was observed that no emphasis has been placed on assessing the exposure of croplands to climate variability in the Federal Capital Territory (FCT) Using Geo-Informatics Technique. It is in view of this note that this study was necessary to bridge the gap observed by most studies in the study area.

a. H_0: The temperature in FCT has no influence on the rainfall pattern in FCT
b. H_0: Climate variables in FCT have no influence on the croplands in FCT.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area lies between latitude $8^0$15' and $9^0$12'north of the equator and longitude 6□27' and 7□23'14" east of Greenwich Meridian 25]. The Federal Capital Territory has a landmass of approximately 8,000 km² [26]. The territory has a population of 3,564,100 people based on 2016 projected population of Nigeria by National Population Commission (NPC) and National Bureau of Statistics (NBS) websites [27] (NPC, 2017).

FCT experiences two weather seasons annually; the warm, humid rainy season and a dry season. There is a brief period of harmattan between the two seasons usually from early December to end of January [27]. The mean sunshine hour between November and April is about 250 hours in the south to over 275 hours in the north-east. This drops to about 125 hours monthly average during the raining season. The maximum temperature during the dry season occurs in the month of March and ranges between 37□C in the south-west to about 30□C in the north-east [24].

The onset of the rain is from about the middle of March and April in the southern and northern parts of the territory respectively [25]. The end of the raining season is around the middle of October in the north and early November in the south [28]. The duration of the raining season (length of raining season-LRS) ranges between 190 days in the north to 240 days in the south. The annual and monthly rainfall viability coefficient ranges between 85% - 117% and 20% - 280% respectively. The amount of rainfall is high in the months of July, August and September which account for about 60% of the total rainfall in the region [26]. The intensity of rainfall is high in the months of July, August and September which account for about 60% of the total rainfall in the region. The mean annual rainfall total ranges from 1145mm to 1631.7mm [29]. The beginning and the end of the raining season is accompanied by thunder and lightning, followed by strong winds and rainfall of very high intensity. There is a general increase in rainfall amount from south to north rather than the more usual decrease in this direction as a result of the influence of the Jos Plateau. This is sequel to its location on the windward side of the plateau [22].

The relative humidity falls considerably in the afternoons in the dry season and rises everywhere in the raining season. The movement of these air masses necessitated the absence of any real cold season in FCT [26].

The parent materials for the formation of FCT soils which are acidic in nature are the crystalline rocks of the basement complex and Nupe sandstones [30]. The crystalline basement complex occupies about two third of the territory in the north why the sandstone covers about one third of the territory in the south. Balogun [25] identified three local soil types in FCT and described them as the alluvial soils, the luvisols and the entisols. The alluvial soils according to Balogun are found on the low-lying areas of main rivers and streams in FCT. The luvisols are soils on the foot plains of inselbergs, wooded hills and mountains. It is a very common feature in the landscape of FCT. The entisols are soils formed on inselbergs and wooded hills.

2.2 Agricultural Production and Socio-economic Activities in FCT

FCT is a transition zone between the grassland to the north and the forest to the south [26]. It therefore shares some of the characteristics of both the forest and savannah (grassland) zones and has the potentials to produce both forest root crops and tubers such as yams and cassava, as well as savannah crops such as grains and cereals. The high agricultural potential in the FCT is exemplified not only by the current level of food crop production but also by the great variety of crops which can be sustained, including, as it does, such crops as roots and tubers (yam), legumes (groundnut and cowpea), grains (maize, sorghum and rice), seeds and nuts (melon seeds and benniseed), animal products (goats, cattle, sheep), fruits and vegetables [24].

2.3 Method of Data Collection

Meteorological (maximum and minimum temperature, rainfall, potential evapotranspiration and relative humidity) data from 1981-2017 were downloaded from the National Center for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) website (https://globalweather.tamu.edu). The website allows you to download daily CFSR data (Temperature, precipitation, wind, relative humidity and solar) in SWAT file format for a given location and time period from 1979-2014. The data was updated till 2017 by Research Data Archive's (RDA) Computational and Information Systems Laboratory (CISL), NCEP Climate Forecast System Version 2 (CFSv2) Monthly Products that was upgraded in March, 2011 [31]. This data can be assessed at: https://rda.ucar.edu/datasets/ds094.2. The Time Series (TS) potential evapotranspiration data was obtained from the Web Processing Service (WPS) of Center for Environmental Data Analysis (CEDA) constructed by Climatic Research Unit (CRU TS 4.01) at a spatial resolution of 0.3 × 0.3 degree. This data can be assessed at: (http://wps-web1.ceda.ac.uk/submit/form?proc_id=Subsetter).

The data collected on the croplands are related to soil erosion, organic carbon content of the soil, clay content of the soil used as proxy for water retention capacity of the soil, land use/land cover data obtained from the analysis of Landsat 8 image of 2016, data on population and data on age dependency ratio. The soil data on organic carbon content (kg/m2) and water holding capacity were obtained from the updated FAO/UNESCO digital soil map of the world (Africa), now Harmonized World Soil Database (HWSD) published in 2006 at a resolution of 1 kilometer. The Landsat satellite image of 2016 was obtained from the United States Geological Survey (USGS). The Shuttle Radar Topography Mission (SRTM) data used as proxy for soil erosion was also obtained from the USGS. The data on population density and age dependency ratio were obtained from the websites of National Population Commission (NPC) and National Bureau of Statistics (NBS) at https://www.nigerianstat.gov.ng 2017.

2.4 Method of Data Analysis

Statistical computations of sums, monthly and annual averages were performed on secondary data obtained for exposure (rainfall, temperature, relative humidity and evapotranspiration). Time series analysis was carried out on these datasets using Microsoft Office Excel to present them over time. The mean monthly and annual climate variables in FCT were determined for all the Area Councils using Microsoft office excel. The climatic elements with the highest and lowest record in all the Area Councils were evaluated for each month. The annual variability of all the climatic elements were also determined from the annual mean of the climate variables. The variability in climate was determined by the differences between long-term statistics of climatic variables calculated for different periods [32]. Pearson product moment correlation analysis was used to show the relationship between temperature and rainfall, climate variables and soil variables within the period. The student's t test was used to test the significance of the result from the correlation. The climate data analysis is inevitable in order to confirm the certainty of climate variability over time (trends and variability analysis).

The method applied by Ishaya et al. [23] and Anandhi et a. [33] in calculating exposure index was adopted in this research for the determination of Croplands exposure index to climate variability in FCT. (1981-2017) were divided by each year's average temperature, rainfall, evapotranspiration and relative humidity.

Exposure Index =

$$\frac{\dfrac{\sum_{k=1}^{Ns} W_{k,j} \sum_{j=1}^{Nc} \sum_{i=1}^{Ny} C_{k,j,i}}{Ny}}{C_{k,j,i}} \qquad (1)$$

where, Ck,j,i are the values of a change factor (at the ith year, for a jth Climatic Factor (CF) representing the kth stressor) at an individual meteorological station, or are the averaged meteorological time series for a region for the designated temporal domain. Ny, Ns and Nc represents the number of years in the temporal domain, number of stressors and number of CFs respectively. Wk,j are the weights provided for the jth CFs representing kth stressor. The numerator in the Eq. 1 represents the average value of the CF for a normal time-period.

The indicators selected for exposure are temperature, rainfall, potential evapotranspiration and relative humidity. Exposure Index (EI) = 1 means, there is no exposure of the system due to climate variability and change. EI deviating from 1 either in increasing or decreasing trend indicates that the system is exposed to climate stressors. According to Anandhi [33], the higher the deviations, the higher the exposures.

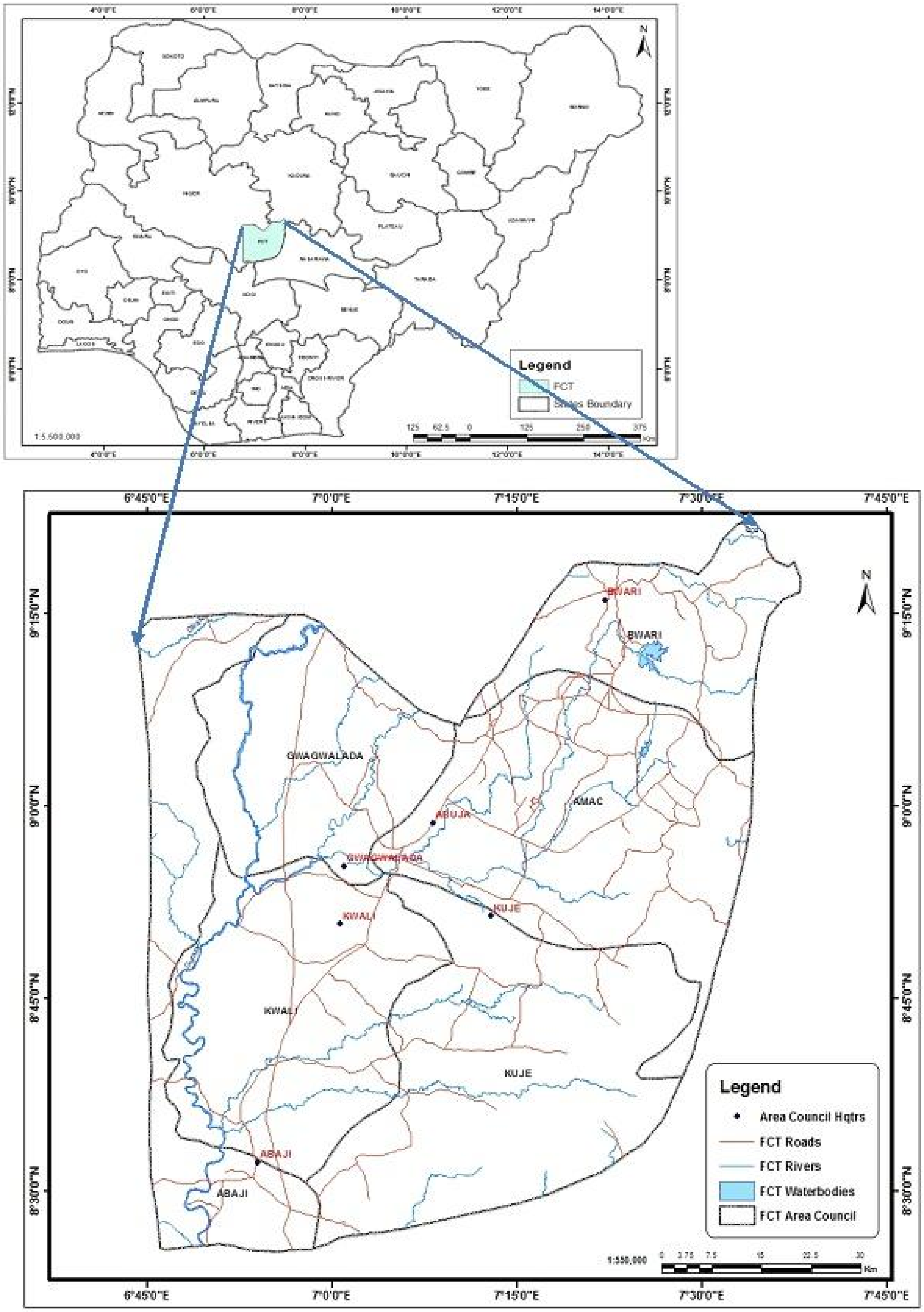

Fig. 1. The study area showing the six area councils

The assessment of croplands vulnerability to climate variability in FCT was done through the Analytical Hierarchy Process (AHP). This requires normalization (since they are in different units and scales) and weighting for the variables to be compatible [34]. Based on the methodology developed by the United Nations Development Programme [35] for the calculation of Human

Development Index (HDI), the values of all the indicators were normalized to values between 0 and 1. If vulnerability increases with increase in the value of the indicator, the normalization is achieved by the formula:

$$Yi = Xi-MinXj / MaxXj-MinXj \quad (2)$$

On the other hand, if vulnerability decreases with increase in the value of the indicator, the normalization is achieved by the formula:

$$Yi = MaxXj-Xi / MaxXj-MinXj \quad (3)$$

where, Yi is the normalized value of jth indicator with respect to ith Area Council (i=1, 2…, n), Xi is the actual value of the indicator with respect to ith Area Council, Min Xj and Max Xj are the minimum and maximum values respectively of jth indicator (j=1,2, …, n) among all the Area Councils.

The weighting was done by adopting the approach by Saaty, 2006, 2008, 2010 [36,37,38] in assigning weights to indicators by averaging the indicator values. The consistency measure, otherwise known as eigen value was arrived at using the matrix multiplication function =MMULT() in excel. The consistency index was calculated by subtracting the number of variables (n) from the sum of the eigen value and dividing the result by (n-1).

The formula is given by:

$$\text{Consistency Index (CI)}=(\lambda max-n)/(n-1) \quad (4)$$

The consistency ratio was obtained by dividing the consistency index by the random index. The index calculation was done by multiplying the normalized indicator score by the normalized weight of the indicator obtained through the pairwise comparison in AHP.

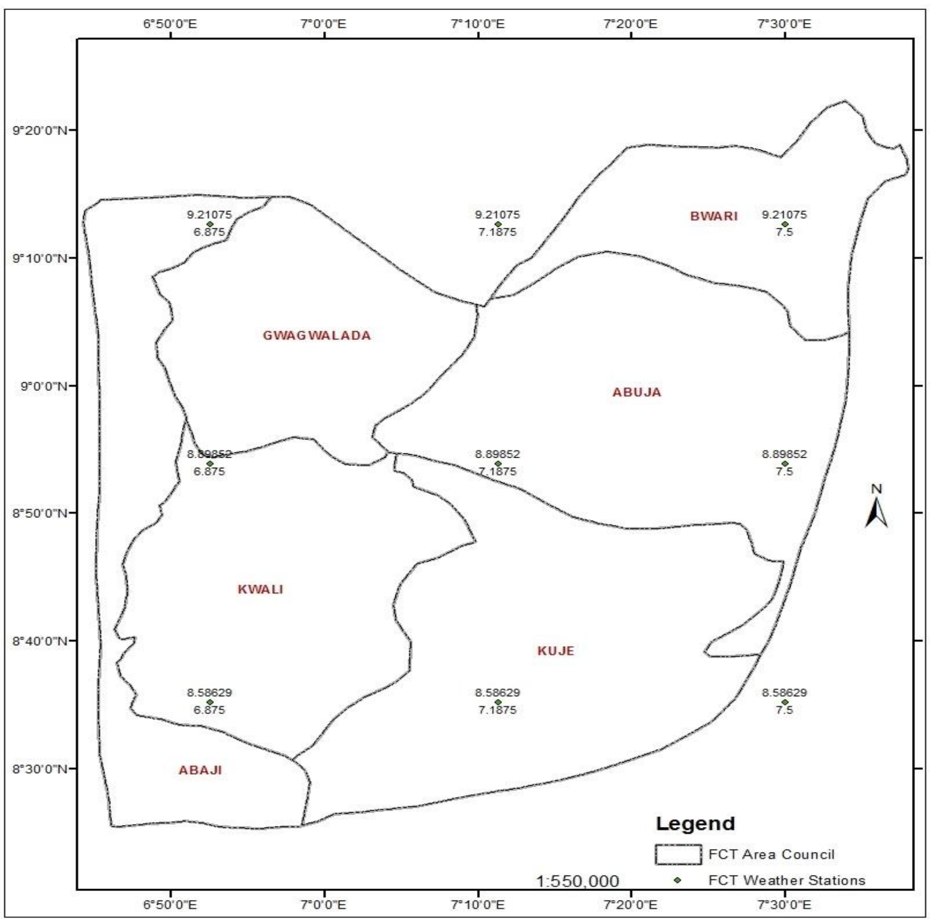

Fig. 2. Climate Forecast System Reanalysis of Weather stations in FCT
Source: Author, 2018

Table 1. Monthly mean of climate variables in FCT area councils

Maximum Temperature (^{0}C)													
Area Councils	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**Mean**
Abaji	38.76	40.69	41.33	39.71	36.36	33.59	30.02	28.30	30.06	33.39	36.75	37.46	35.53
AMAC	37.12	38.93	39.25	37.38	34.23	31.42	28.05	26.46	28.11	30.57	33.97	35.48	33.41
Bwari	36.49	38.16	38.46	36.65	33.35	30.49	26.97	25.40	27.31	29.93	33.64	34.96	32.65
Gwagwalada	39.35	41.47	42.06	40.21	36.82	34.20	30.80	28.92	30.26	33.12	36.59	37.76	35.97
Kuje	38.82	40.97	41.16	39.03	35.57	32.87	29.56	27.89	29.17	31.70	35.25	36.98	34.91
Kwali	40.05	42.25	42.57	40.43	36.91	34.30	30.96	29.09	30.29	32.91	36.58	38.19	36.21
Mean	38.43	40.41	40.80	38.90	35.54	32.81	29.40	27.68	29.20	31.94	35.46	36.81	34.78
Minimum Temperature (^{0}C)													
Area Councils	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**Mean**
Abaji	18.43	19.69	21.93	23.80	23.42	22.47	21.48	21.19	21.66	21.87	20.70	19.44	21.34
AMAC	16.46	17.61	20.48	22.74	22.29	21.37	20.58	20.42	20.72	20.59	18.78	17.57	19.97
Bwari	16.37	17.24	19.61	21.89	21.65	20.85	20.03	19.78	20.14	20.00	18.21	17.38	19.43
Gwagwalada	18.12	19.57	22.37	24.30	23.73	22.70	21.75	21.52	21.94	22.13	20.85	19.08	21.50
Kuje	17.68	19.29	22.33	23.86	23.25	22.20	21.32	21.18	21.54	21.64	20.19	18.34	21.07
Kwali	17.72	19.66	22.87	24.53	23.88	22.75	21.81	21.61	22.01	22.24	20.93	18.46	21.54
Mean	17.46	18.84	21.60	23.52	23.04	22.06	21.16	20.95	21.33	21.41	19.94	18.38	20.81
Mean Temperature (^{0}C)													
Area Councils	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**Mean**
Abaji	28.60	30.19	31.63	31.76	29.89	28.03	25.75	24.74	25.86	27.63	28.73	28.45	28.44
AMAC	26.79	28.27	29.86	30.06	28.26	26.39	24.32	23.44	24.41	25.58	26.38	26.53	26.69
Bwari	26.43	27.70	29.04	29.27	27.50	25.67	23.50	22.59	23.72	24.96	25.93	26.17	26.04
Gwagwalada	28.73	30.52	32.21	32.26	30.28	28.45	26.27	25.22	26.10	27.62	28.72	28.42	28.73
Kuje	28.25	30.13	31.74	31.44	29.41	27.54	25.44	24.53	25.35	26.67	27.72	27.66	27.99
Kwali	28.89	30.96	32.72	32.48	30.39	28.52	26.39	25.35	26.15	27.58	28.76	28.33	28.88
Mean	27.95	29.63	31.20	31.21	29.29	27.44	25.28	24.31	25.27	26.67	27.70	27.59	27.79

Rainfall/Precipitation (mm)													
Area Councils	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**Mean**
Abaji	0.66	2.54	18.63	96.77	144.71	186.18	256.50	301.28	275.81	74.74	3.96	0.12	113.49
AMAC	2.02	5.46	24.65	112.81	187.78	200.64	325.92	365.68	315.83	116.04	8.38	1.12	138.86
Bwari	1.81	5.72	24.09	114.17	205.07	233.02	386.33	445.02	366.05	141.50	8.80	0.89	161.04
Gwagwalada	0.73	2.40	15.72	116.37	144.80	174.72	228.53	263.52	237.55	67.18	3.56	0.25	104.61
Kuje	2.04	5.26	26.23	123.46	175.65	190.97	263.89	304.71	288.93	107.80	7.17	1.10	124.77
Kwali	1.28	2.69	17.63	123.80	151.57	175.35	230.34	267.00	248.67	81.65	4.89	0.61	108.79
Mean	1.42	4.01	21.16	114.56	168.26	193.48	281.92	324.53	288.81	98.15	6.13	0.68	125.26
Relative Humidity (%)													
Area Councils	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**Mean**
Abaji	23.52	29.59	40.52	52.02	62.94	70.38	79.57	83.02	80.66	72.16	47.22	26.71	55.69
AMAC	28.29	36.09	46.51	57.19	68.34	75.75	84.17	86.71	84.99	79.47	56.46	32.31	61.36
Bwari	26.49	33.12	44.13	57.14	69.33	77.31	85.58	88.12	86.07	79.41	53.06	29.74	60.79
Gwagwalada	26.3	33.55	43.61	53.13	63.37	70.36	79.26	82.63	81.34	74.44	53.35	31.2	57.71
Kuje	30.44	38.03	47.47	56.25	66.33	73.77	82.02	84.78	83.82	77.91	59.31	35.74	61.32
Kwali	29.75	37.18	45.95	54.06	63.82	70.91	79.64	82.84	82.04	75.4	57.21	35.49	59.53
Mean	27.47	34.59	44.7	54.97	65.69	73.08	81.71	84.69	83.15	76.46	54.44	31.87	59.4
Potential Evapotranspiration (mm)													
Area Councils	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**	**Mean**
Abaji	4.74	5.14	5.06	4.56	3.70	3.19	2.77	2.69	2.93	3.37	3.98	4.30	3.87
AMAC	5.51	5.96	5.63	5.02	4.00	3.39	2.89	2.71	3.07	3.68	4.66	5.03	4.30
Bwari	5.66	6.12	5.79	5.09	3.98	3.34	2.86	2.69	3.09	3.72	4.78	5.21	4.36
Gwagwalada	5.32	5.78	5.49	4.94	4.03	3.36	2.92	2.77	3.09	3.66	4.54	4.81	4.23
Kuje	5.18	5.62	5.39	4.83	3.82	3.27	2.85	2.72	3.02	3.56	4.37	4.73	4.11
Kwali	5.04	5.47	5.25	4.80	3.91	3.30	2.88	2.74	3.05	3.52	4.24	4.58	4.06
Mean	5.24	5.68	5.44	4.87	3.91	3.31	2.86	2.72	3.04	3.58	4.43	4.78	4.16

Source: Summarized from climate forecast system re-analysis [CFSR] (1981-2017)

Table 2. Long term mean of climatic variables in FCT area councils (1981-2017)

Area Councils	Temperature(^{0}C)	Rainfall (mm)	Evapotranspiration (mm)	Relative Humidity (%)
Abaji	28.438	1361.908	3.870	55.69
AMAC	26.691	1666.315	4.296	61.36
Bwari	26.040	1932.458	4.361	60.79
Gwagwalada	28.734	1255.329	4.227	57.71
Kuje	27.991	1497.199	4.113	61.32
Kwali	28.876	1305.470	4.063	59.53

Source: Summarized from CFSR (1981-2017)

3. RESULTS AND DISCUSSION

3.1 Maximum Monthly and Annual Temperature

The mean monthly maximum temperature in FCT Area Councils (Table 1) reveals that Kwali and Gwagwalada have the highest maximum temperature of 42.57°C and 42.06°C respectively in the month of March for the study period. Bwari and AMAC have the least of 25.40°C and 26.46°C respectively in the month of August for the same period. Abaji and Kuje recorded 41.33°C and 41.16°C in the month of March and 28.30°C and 27.89°C in the month of August respectively. The temperature trend is in upward direction based on the trend analysis performed on the dataset. On the average, Kwali and Bwari Area Councils have the highest (36.2°C) and the lowest (32.65°C) annual maximum temperature respectively throughout the study period. The highest annual mean maximum temperature was recorded in 2005 (36.97°C) and the lowest was in 1992 (32.97°C). The mean for the study period was 34.78°C. The implication of this for arable crops is that these temperature ranges are too high for beans maize and yam. Temperature above 35°C reduces yield in Maize [39], high temperature above 30°C causes abscission of flowers and a low pod set which results in yield loss in beans [40] and yam does not require more than 30°C to produce optimally [41].

3.2 Minimum Monthly and Annual Temperature

The mean monthly minimum temperature in FCT Area Councils show (Table1) that Kwali and Gwagwalada have the highest minimum temperature of 24.53°C and 24.30°C respectively in the month of April of the study period. Bwari and AMAC have the least of 16.37°C and 16.46^{0}C respectively in the month of January of the same period. Abaji and Kuje recorded 18.43°C and 17.68°C in the month of January and 23.80°C and 23.86°C in the month of April respectively. The minimum temperature trend is also in the upward direction based on the trend analysis performed on the dataset. On the average, Kwali and Bwari have the highest (21.54°C) and the lowest (19.43°C) annual minimum temperature respectively throughout the study period. The highest annual mean minimum temperature was recorded in 2013 (21.60°C) and the lowest was in 1989 and 2000 (20.17°C). The mean for the study period was 20.81°C. Temperature below 20°C impedes the growth of yam [42] causes delay in maturity and empty mature pods to develop in beans [40] and reduces growth and development in maize [39]. The above scenario implies that the arable crops in question are vulnerable to extremely low climate variability and hence, low yield.

3.3 Mean Monthly and Annual Temperature

The mean annual temperature in FCT Area Councils (Fig. 3) showed that Kwali and Gwagwalada Area Councils have the highest temperature of 32.72°C in the month of March and 32.26°C in the month of April respectively for the study period. Bwari and AMAC Area Councils have the least of 22.59°C and 23.44^{0}C respectively in the month of August. Abaji and Kuje also recorded 24.74°C and 24.53°C in the month of August. The two Area Councils (Abaji and Kuje) have 31.76°C in April and 31.74°C in the month of March respectively. The temperature trend is also in the upward direction based on the trend analysis performed on the dataset (Fig. 4). The highest annual mean temperature (Fig. 5) was recorded in 2005 (29.15°C) and the lowest was in 1992 (26.53°C). On the average, Kwali Area Council has the highest mean temperature of (28.88°C) within the period while Bwari (26.04□C) recorded the lowest. The mean for the study period is 27.79□C. The temperature variability (Fig. 6) showed a sharp increase from 1999 through 2006. These years were the warmest years during the study period. The year 1999 is a global indicator of sharp climate shift [32]. Year 2005 recorded the highest variability in temperature with Abaji, AMAC, Gwagwalada, Kuje and Kwali Area Councils having a variability of 1.42□C, 1.26□C, 1.20□C, 1.40□C, 1.39□C and 1.45□C respectively above average. The lowest temperature variability was observed in year 1992 where Abaji, AMAC, Bwari, Gwagwalada, Kuje and Kwali Area councils had a variability of -1.21□C, -1.25□C, -1.07□C, -1.36□C, -1.34□C and -1.39□C respectively below average. The mean temperature for the study period is suitable for all the three arable crops growth and development. The temperature variability in either direction (above or below average), impedes crop growth and development as they are either above or below the threshold temperature range for optimal crop production in all the three crops under investigation.

3.4 Mean Monthly and Annual Rainfall

The months of July through September received the highest rainfall during the study period with the peak in the month of August (Fig. 7). Bwari, AMAC and Kuje Area Councils received the highest rainfall from May through October with the peak of 445.02mm, 365.68mm and 304.71mm respectively in the month of August. The months of January and December received the least rainfall of 1.42mm and 0.68mm respectively. The rainfall per annum is on reducing trend as shown on the trend analysis performed on the rainfall data (Fig. 8). The mean annual rainfall for the study period (Fig. 9) showed that Bwari Area Council received the highest annual rainfall of 1,932.46mm while Gwagwalada received the least of 1,255.33mm. The highest mean annual rainfall was recorded in 1988 (2325.42mm) and the lowest was 2000 (570.86mm). The mean for the study period is 1503.11mm. In terms of variability (Fig. 10), year 1988 recorded the highest variability in rainfall with Abaji, AMAC, Bwari, Gwagwalada, Kuje and Kwali having a variability of 750.29mm, 876.39mm, 1138.56mm, 787.65mm, 746.56mm and 634.37mm respectively above average. The lowest rainfall variability was observed in year 2000 where Abaji, AMAC, Bwari, Gwagwalada, Kuje and Kwali had a variability of -917.42mm, -1001.67mm, -1294.21mm, -720.82mm, -905.28mm and -754.14mm respectively below average. The mean rainfall for the study period is suitable only for yam production as this is beyond the rainfall requirement for beans and maize production. This makes the cropland vulnerable to both beans and maize. The rainfall variability above average impedes crops growth and development as they are above the threshold rainfall requirement range for optimal crop production in all the three crops under investigation. The overall implication of this is reduced yield in year 1988. The negative rainfall variability in year 2000 will have a positive impact in the growth, development and production of maize and beans and negative impact on yam production.

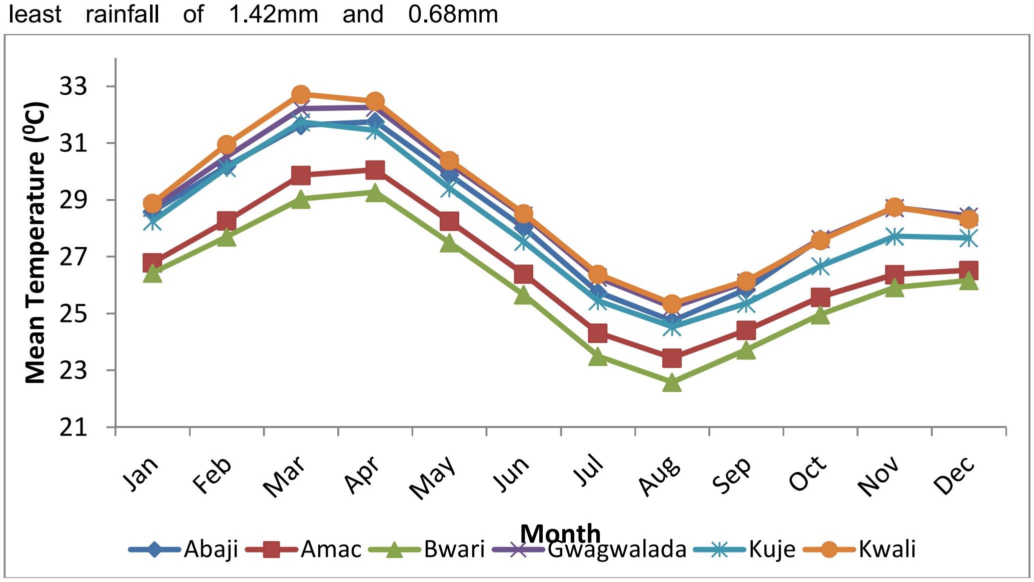

Fig. 3. Mean monthly temperature (°C) variations in FCT area councils
Source: Derived from CFSR data (1981-2017)

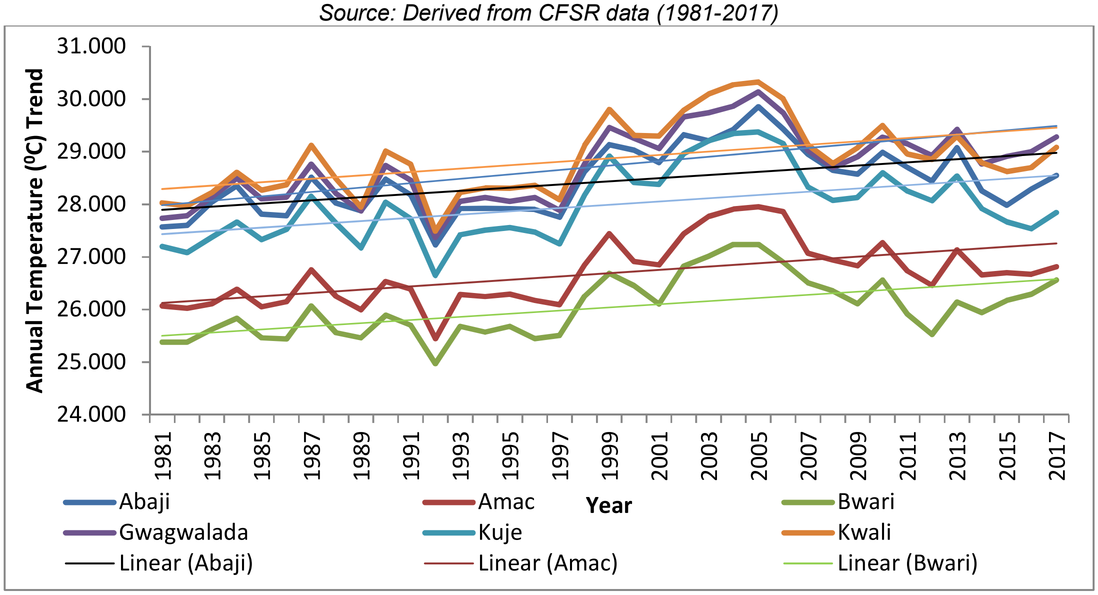

Fig. 4. Mean annual temperature (°C) trend in FCT area councils
Source: Derived from CFSR data (1981-2017)

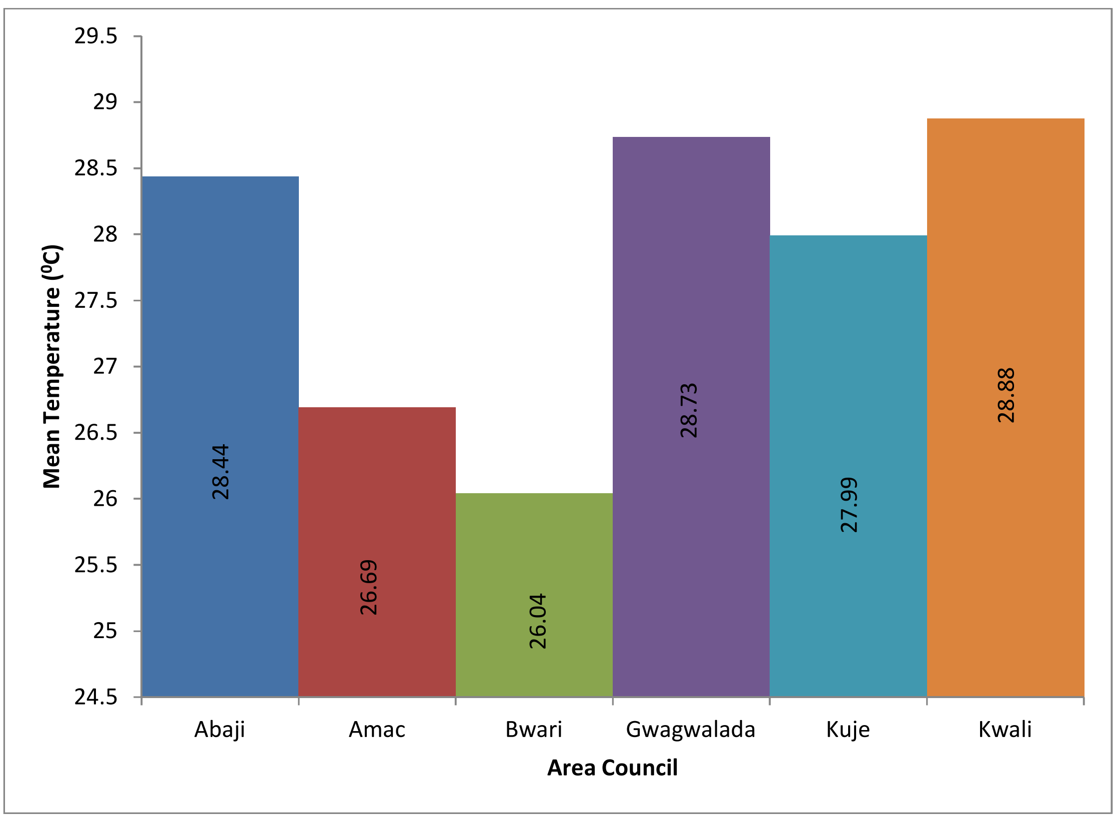

Fig. 5. Annual mean temperature (°C) in area councils in FCT
Source: Derived from CFSR data (1981-2017)

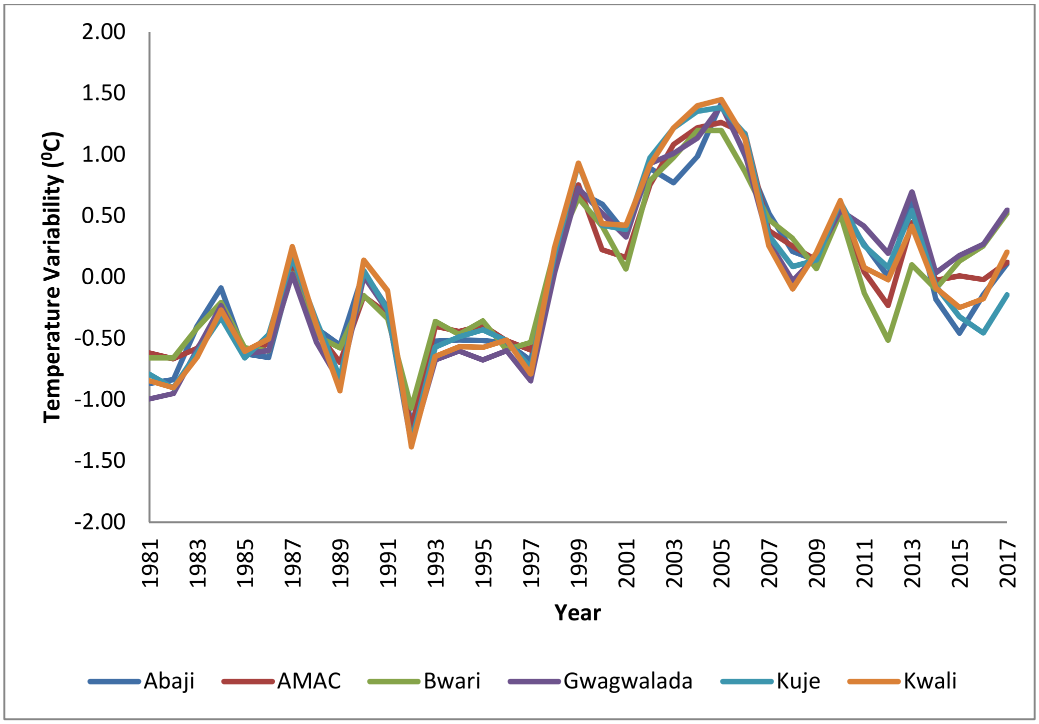

Fig. 6. Mean temperature variability (°C) in FCT area councils
Source: Derived from CFSR data (1981-2017)

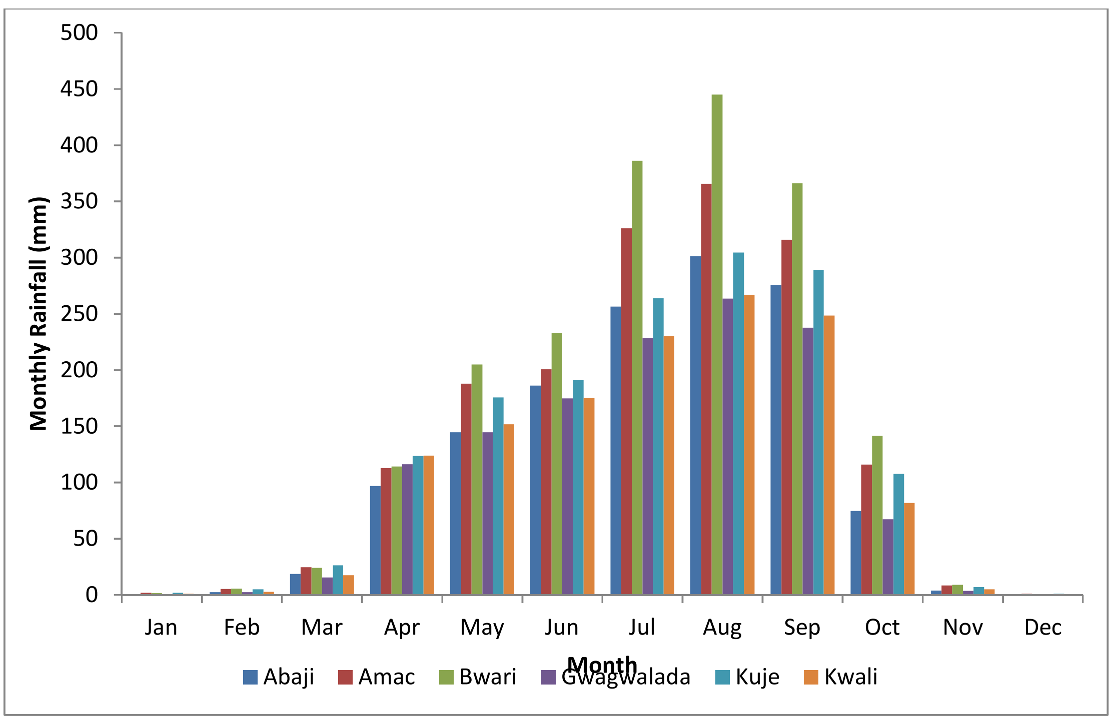

Fig. 7. Mean monthly rainfall (mm) in area councils in FCT
Source: Derived from CFSR data (1981-2017)

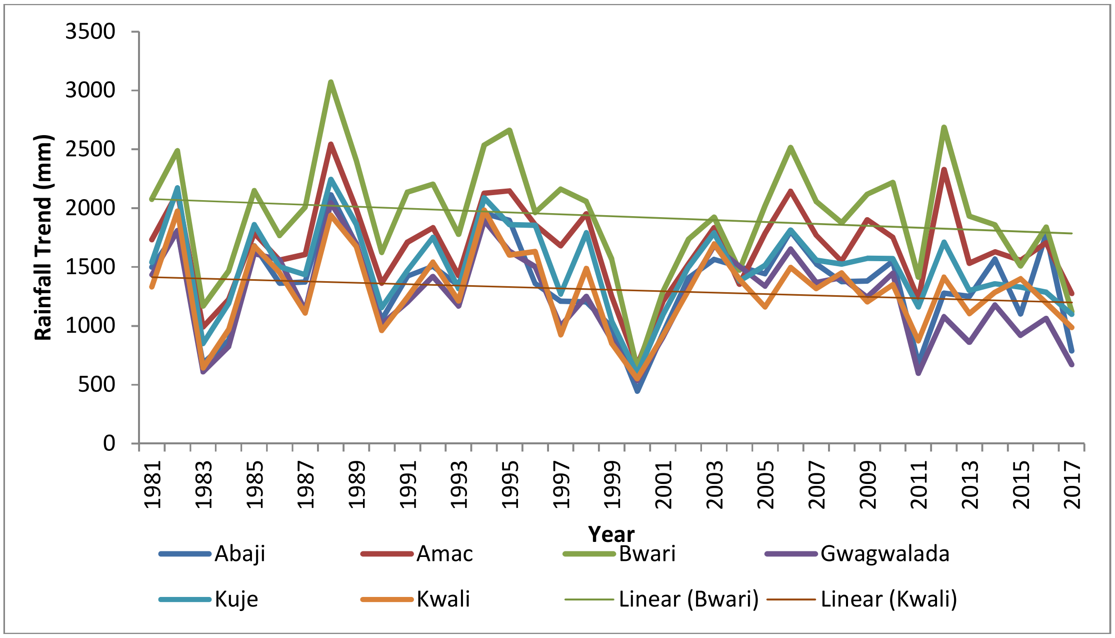

Fig. 8. Annual rainfall (mm) trend in FCT area councils
Source: Derived from CFSR data (1981-2017)

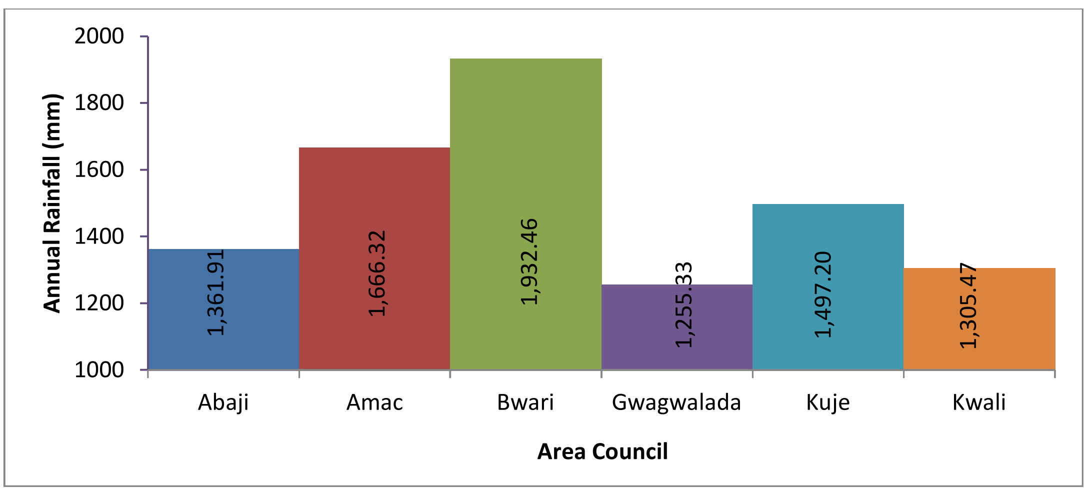

Fig. 9. Mean annual rainfall (mm) in area councils of FCT (1981-2017)
Source: Derived from CFSR data (1981-2017)

3.5 Mean Monthly and Annual Relative Humidity

The months of July through September received the highest relative humidity during the study period with the peak in the month of August (Fig. 11). Bwari, AMAC and Kuje received the highest relative humidity from May through September with the peak of 88.12%, 86.71% and 84.78% respectively in the month of August. AMAC is highest in October. The months of January and December received the least relative humidity of 27.47% and 34. 59% respectively during the study period. The mean annual relative humidity for the study period (Fig. 12) showed that AMAC received the highest annual relative humidity of 61.36% while Gwagwalada received the least of 55.69%. The highest mean relative humidity was recorded in 1988 (65.79%) and the lowest was in 2017 (41.56%). The relative humidity variability was high from 1985 through 1997 and low from 1998 through 2006. It was on its lowest in 2015 and highest in 1988 in all the Area Councils (Fig. 13). According to Tamil Nadu Agricultural University [43] very high or very low relative humidity affects high grain yield. High relative humidity reduces CO2 uptake and evapotranspiration which consequently affects the translocation of food materials and nutrients, increases heat load in plants and facilitates stomata closure. High incidence of insect pest and diseases are also associated with high relative humidity. The above scenario results in crop failure and food insecurity.

3.6 Potential Evapotranspiration

The months of June through October received the lowest potential evapotranspiration during the study period with the lowest of 2.69mm in the month of August by Abaji and Bwari Area Councils (Fig. 14). Bwari, AMAC and Gwagwalada received the highest potential evapotranspiration from November through April with the peak of 6.12mm, 5.96mm and 5.78mm respectively in the month of February. The potential evapotranspiration per annum is on the reducing trend as shown on the trend analysis performed on the potential evapotranspiration data. The mean annual potential evapotranspiration for the study period (Fig. 15) showed that Bwari received the highest annual potential evapotranspiration of 4.36mm while Abaji received the least of 3.87mm. 1983 and 1987 have the highest potential evapotranspiration of 4.31 mm while 1991 recorded the least of 3.98 mm. The mean for the study period was 4.16 mm. The potential evapotranspiration variability (Fig. 16) was on its highest 1983 and 1985 and on its lowest in 1991. According to (TNAU, 2016) very high or very low potential evapotranspiration affects grain yield. High potential evapotranspiration increases CO_2 uptake and facilitates the translocation of food materials and nutrients, reduces heat load in plants and enhances the opening of the stomata, thereby increase crop yield. High potential evapotranspiration reduces the incidence of insect pest and diseases. The higher the potential evapotranspiration, the higher the yield in grains. Low potential evapotranspiration is associated with high relative humidity which results in crop failure and food insecurity. Based on the above, Area Councils with high potential evaporation will have high grain yields while those with low potential evaporation will have low yield under standard condition.

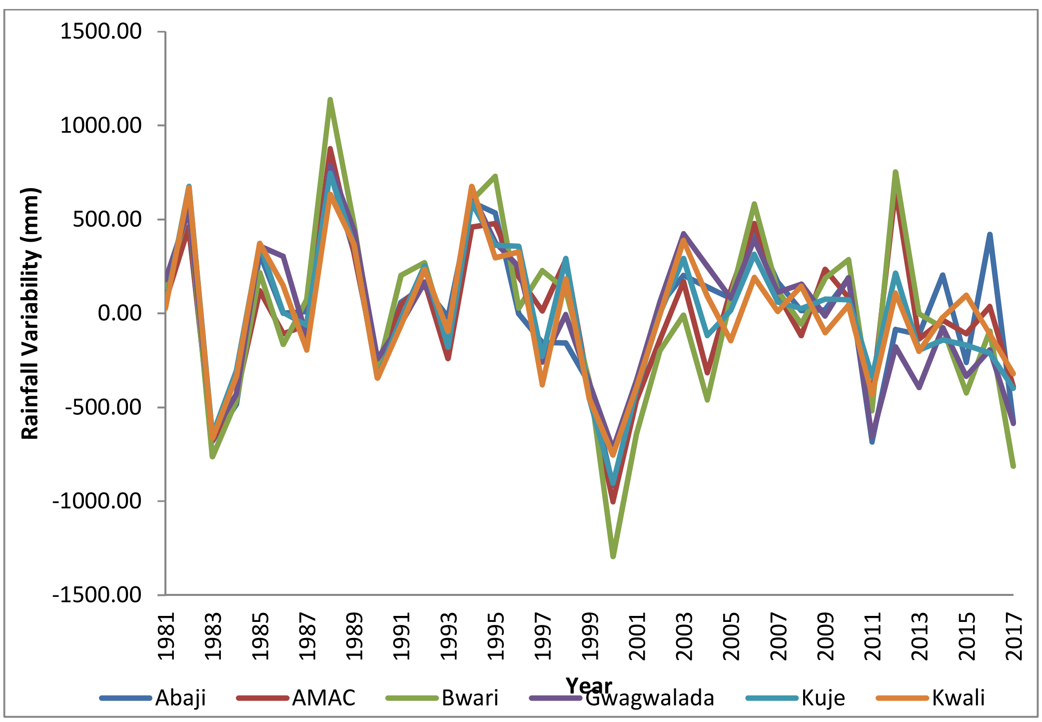

Fig. 10. Rainfall variability (mm) in FCT area councils
Source: Derived from CFSR data (1981-2017)

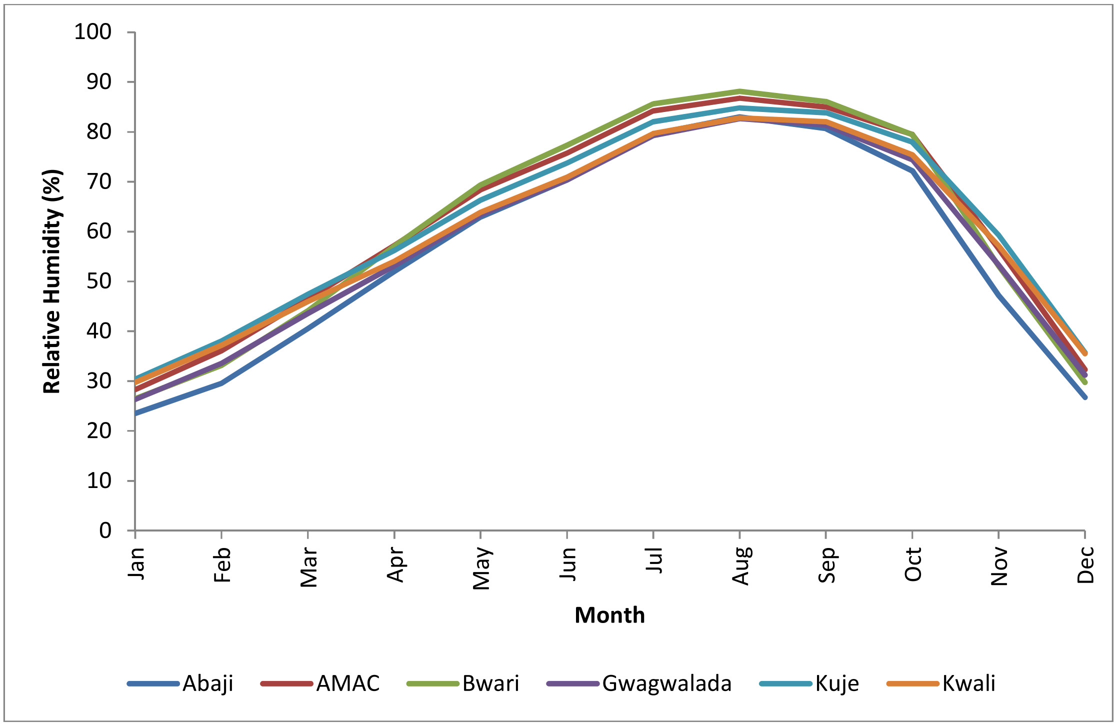

Fig. 11. Mean monthly relative humidity of FCT area councils
Source: Derived from CFSR data (1981-2017)

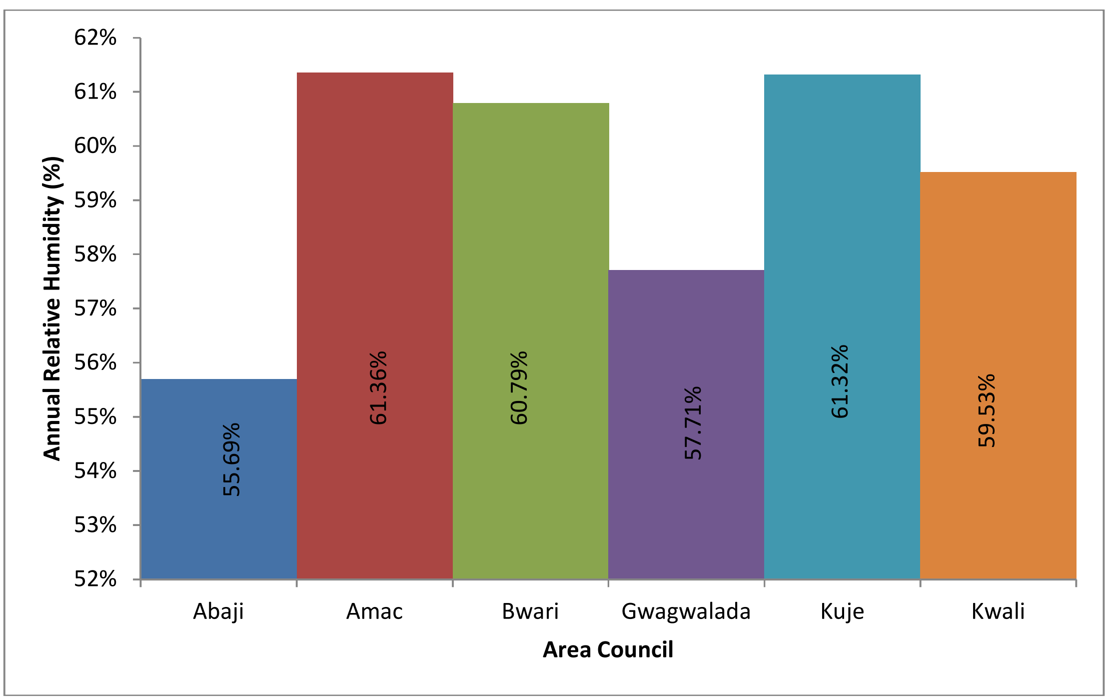

Fig. 12. Mean annual relative humidity of FCT area councils
Source: Derived from CFSR data (1981-2017)

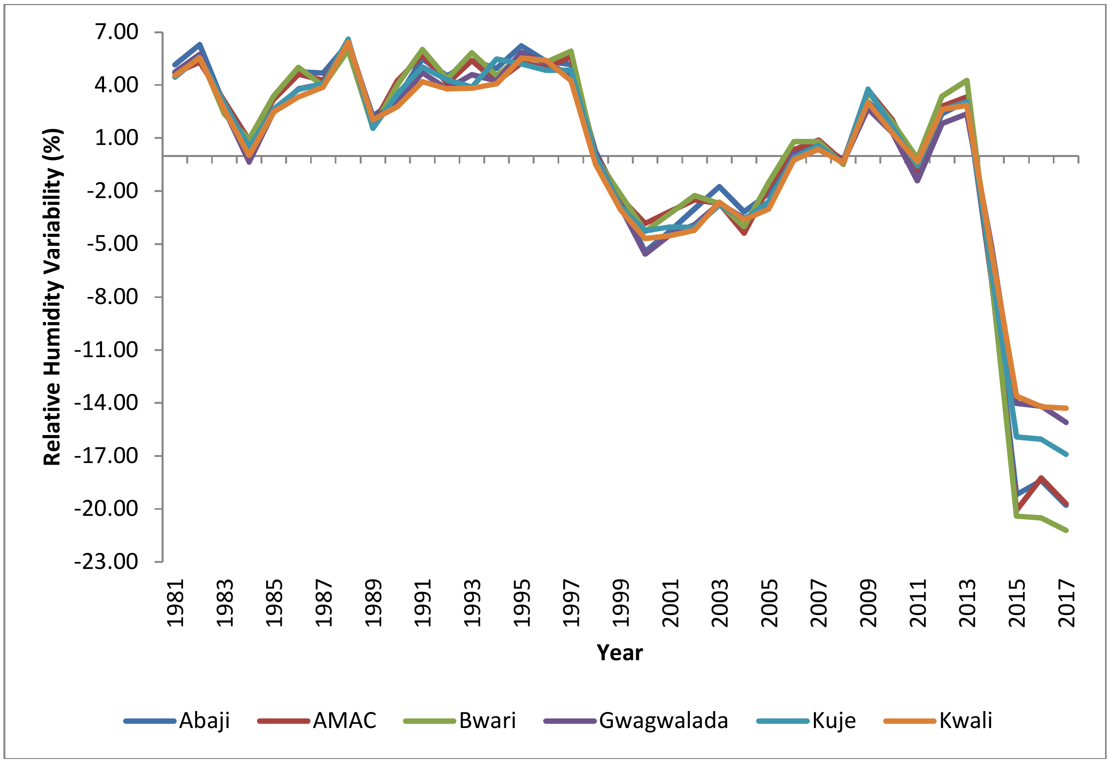

Fig. 13. Relative humidity variability (%) in FCT area councils
Source: Derived from CFSR data (1981-2017)

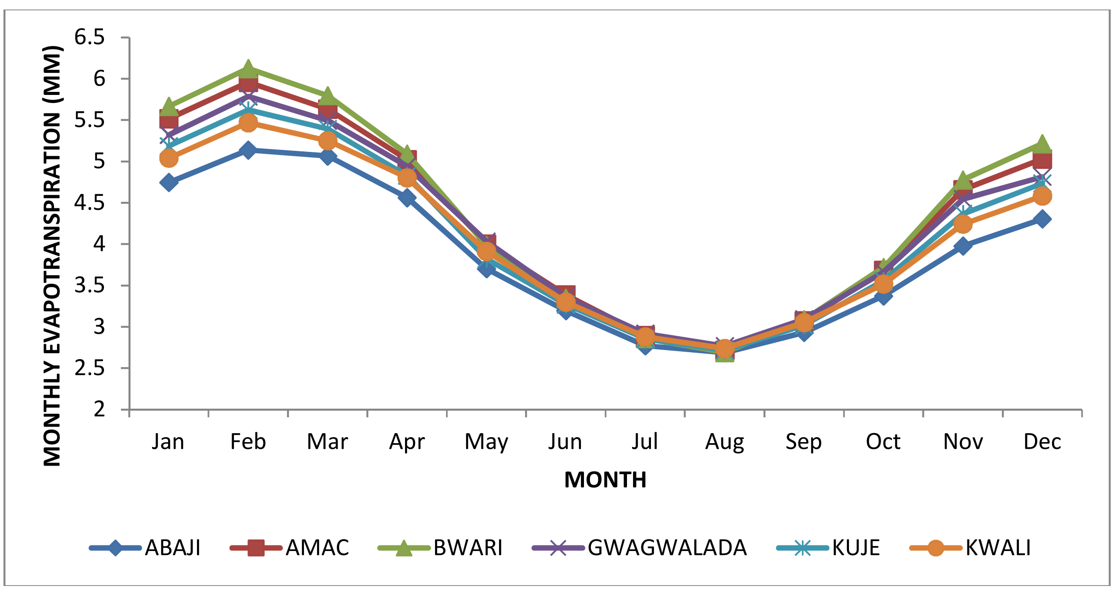

Fig. 14. Mean monthly evapotranspiration (mm) of FCT area councils
Source: Derived from CFSR data (1981-2017)

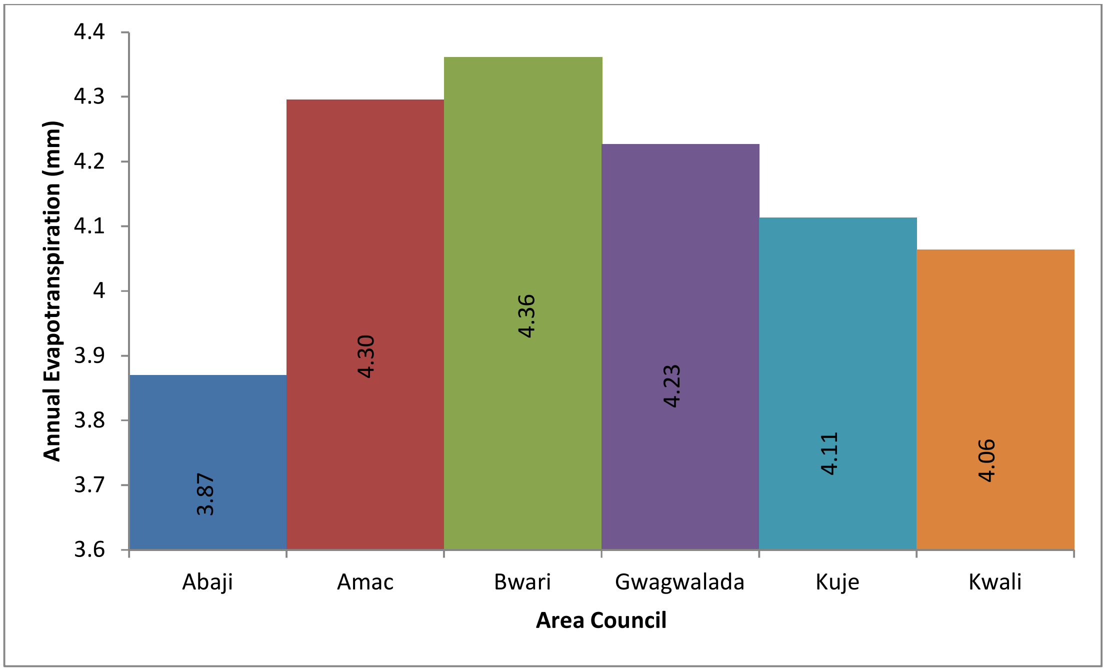

Fig. 15. Mean annual potential evapotranspiration (mm) of FCT area councils
Source: Derived from CFSR data (1981-2017)

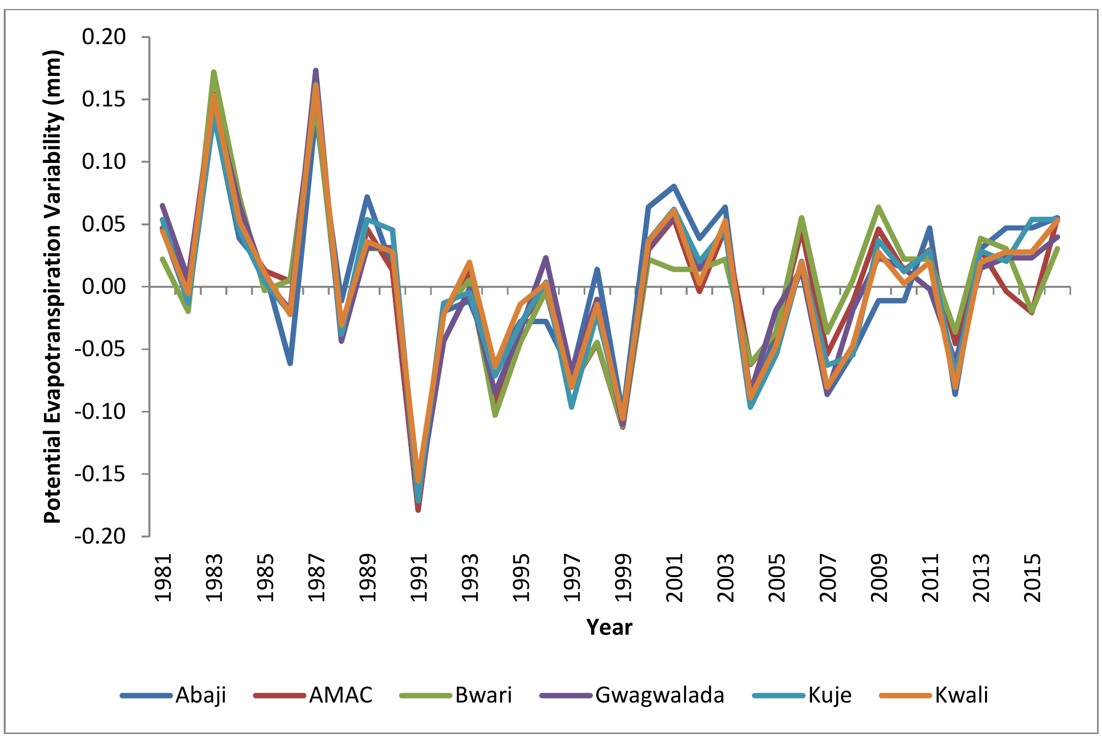

Fig. 16. Potential evapotranspiration variability in FCT area councils
Source: Derived from CFSR data (1981-2017)

3.7 Correlation between Selected Climate Variables and Soil Variables in FCT

The correlation analysis of temperature and rainfall was moderately negative on monthly (-0.61) and highly negative on annual (-0.82) time scale. This was confirmed to be statistically significant at 95% confidence level as chance occurrence was ruled out. The calculated value of 2.43 and 2.83 were higher than the critical value of 2.23 and 2.78 respectively obtained on monthly and annual time scale. The alternative hypothesis is accepted. The implication of this is that the lower the temperature, the higher the rainfall and vice versa. This finding is in line with Nkuna and Odiyo [44] on the relationship between temperature and rainfall variability in the Levubu sub-catchment, South Africa and Madden and Williams [45] on the correlation between temperature and precipitation in the United States and Europe.

There was high positive correlation (0.82) between rainfall and soil erosion in the study area. This was statistically significant at four (4) degree of freedom and 95% confidence level as the variation is not by chance occurrence. The calculated T is 2.86 while the critical value is 2.78. Hence, the null hypothesis is rejected. The rainfall in FCT influences soil erosion in FCT. Temperature varies negatively with soil erosion in the study area with a correlation coefficient of -0.88. The calculated T is 3.65 while the critical value is 2.78 at four (4) degree of freedom. The alternative hypothesis is accepted. Therefore, soil erosion reduces with increasing temperature in FCT.

In terms of the organic carbon content of the soil in the study area, there was low positive correlation between rainfall and soil organic carbon with a correlation coefficient of 0.42. The temperature varies negatively low with soil organic carbon at a correlation coefficient of -0.30. The study corroborates the work of Critchley and Klaus [46] which stated that organic matter levels in soil are often low under hot climatic conditions due to the rapid rates of decomposition. Both variations are not statistically significant as they occur by chance. This was validated by the calculated and the critical values of both variables at 95% confidence level and four (4) degree of freedom. The calculated values of T for rainfall/soil organic carbon (0.94) and temperature/soil organic carbon (0.65) were lower than the critical value of 2.78.

The clay content of the soil used as proxy indicator for soil water holding capacity has a moderate correlation with rainfall and low correlation with temperature. While rainfall is moderately positive with a correlation coefficient of 0.5, temperature is negative with a correlation coefficient of -0.40. Both variations are not statistically significant as they occur by chance. This was validated by the calculated and the critical values of both variables at 95% confidence level and four (4) degree of freedom. The calculated values of T for rainfall/clay content of the soil (1.14) and temperature/clay content of the soil (0.88) were lower than the table value of 2.78

Exposure Index of Croplands to Climate Variability in the FCT of Nigeria.

On the average, none of the Area Councils have a threshold value below 1. Most of the Area Councils are on the border line while the remaining are on different levels of exposure in terms of temperature, potential evapotranspiration and relative humidity stressors. All the Area Councils are exposed to precipitation stressor as the index values of all the Area Councils are more than one. The implication of this is that the rainfall variations in FCT Area Councils are more than the water requirement for the arable crops under investigation, consequently, the reduction in crop output. On yearly basis, there are variations.

Table 3. Long term exposure index of FCT area councils to climatic variables 1981-2017

Area council	Temp	Rainfall	Evapotranspiration	Rel. humidity	Threshold
Abaji	1.000	1.113	1.000	1.019	1.000
AMAC	1.000	1.066	1.000	1.015	1.000
Bwari	1.000	1.089	1.000	1.018	1.000
Gwagwalada	1.001	1.115	1.000	1.010	1.000
Kuje	1.001	1.072	1.000	1.011	1.000
Kwali	1.001	1.086	1.001	1.077	1.000

Source: Author, 2018

3.8 Exposure of Croplands to Climate Variability in FCT

Considering temperature as indicator of exposure to climate variability (Table 4), Kwali and Gwagwalada Area Councils recorded the highest exposures (1.0000) and (0.9501) respectively. Abaji Area Council is high (0.8456) while Kuje Area Council is moderate (0.6881) in their exposures. AMAC Area Council is low (0.2294) and Bwari Area Council recorded the lowest (0.0000). Kwali Area Council is therefore the most vulnerable followed by Gwagwalada Area Council. The analysis further revealed that Abaji and Kuje Area Councils have high and moderate vulnerabilities respectively while AMAC and Bwari Area Council have low and lowest vulnerabilities respectively. This implies that crop yield will be reduced in Kwali and Gwagwalada while AMAC and Bwari will have optimum yield of the referenced crops

Looking at rainfall as indicator of exposure to climate variability as shown in Table 5 above, Bwari Area Council has the highest exposure (1.0000) while Gwagwalada Area Council has the lowest exposure (0.0000). AMAC has moderate exposure (0.6070) while the exposure of Kuje Area Council is low (0.3572). Abaji (0.1574) and Kwali (0.0740) Area Councils also have very low exposures. The vulnerability trend from lowest to highest is therefore Gwagwalada, Kwali, Abaji, Kuje, AMAC and Bwari.The implication of this on the referenced crops is that cropland in Bwari will result in low crop yield while the cropland in Gwagwalada will have low yields.

Potential evapotranspiration exposure is highest in Bwari Area Council (1.0000) and lowest in Abaji Area Council (0.0000). AMAC (0.8663) and Gwagwalada (0.7265) Area councils have high evapotranspiration exposures while Kuje (0.4948) and Kwali (0.3924) Area Councils have low exposures. The vulnerabilities are equivalent to the corresponding exposures in each of the Area Councils. Based on this, there will be high yield of the crops in Bwari as high evaporation favours the growth and development of these crops. There will be poor yields in Abaji because of the low evaporation.

Relative humidity exposures are highest in AMAC (1.0000) and lowest in Abaji (0.0000) Area Councils. It recorded high values in Kuje (0.9941) and Bwari (0.9005) Area Councils, moderate in Kwali Area (0.6768) Council and low in Gwagwalada (0.3563) Area Council. The vulnerability ratings are equivalent to the corresponding exposures in each of the Area Councils. The implication of this for the crops is that high relative humidity reduces crop yields through high diseases infestations in crop and reduced photosynthesis activities. In the light of this, Area Councils that have high exposure like AMAC and Bwari will be highly vulnerability, while Abaji and Gwagwalada will have high crop yields.

Table 4. Normalized climatic variables of FCT area councils

Area councils	Temperature	Rainfall	Evapotranspiration	Relative humidity	Mean exposures/rank
Abaji	0.8456	0.1574	0.0000	0.0000	0.25075(6)
AMAC	0.2294	0.6070	0.8663	1.0000	0.675675 (2)
Bwari	0.0000	1.0000	1.0000	0.9005	0.725125 (1)
Gwagwalada	0.9501	0.0000	0.7265	0.3563	0.508225 (5)
Kuje	0.6881	0.3572	0.4948	0.9941	0.63355 (3)
Kwali	1.0000	0.0740	0.3924	0.6768	0.5358 (4)

Source: Author, 2018

Table 5. Pairwise comparison matrix of exposure indicators

Indicators	Temperature	Rainfall	Evapotranspiration	Relative humidity	Sum
Temperature	1.00	0.33	5.00	7.00	13.33
Rainfall	3.00	1.00	3.00	5.00	12.00
Evapotranspiration	0.20	0.33	1.00	7.00	8.53
Rel. humidity	0.14	0.20	0.14	1.00	1.49
Sum	4.34	1.87	9.14	20.00	35.35

Table 6. Calculated weight, eigen value, consistency index and consistency ratio of exposure indicators

Indicators	Temp	Rainfall	Evapotrans piration	Relative humidity	Weight	Eigen value	CI	CR
Temperature	0.2303	0.1786	0.5469	0.3500	0.3264	0.8187	0.0106	0.0117
Rainfall	0.6908	0.5357	0.3281	0.2500	0.4512	1.1884		
Evapotranspiration	0.0461	0.1786	0.1094	0.3500	0.1710	0.7737		
Rel. humidity	0.0329	0.1071	0.0156	0.0500	0.0514	1.2510		
Sum						4.0317		

Source: Author, 2018

Table 7. Normalized exposure index of FCT area councils from 1981-2017

Area Council	Temperature *Weight	Rainfall *Weight	P. Evaporation *Weight	Relative Humidity *Weight	Exposure Index	Rank
Abaji	0.2760	0.0710	0.0000	0.0000	0.0868	6
AMAC	0.0749	0.2738	0.1481	0.0514	0.1371	2
Bwari	0.0000	0.4512	0.1710	0.0463	0.1671	1
Gwagwalada	0.3101	0.0000	0.1242	0.0183	0.1132	5
Kuje	0.2246	0.1612	0.0846	0.0511	0.1304	3
Kwali	0.3264	0.0334	0.0671	0.0348	0.1154	4

Source: Author, 2018

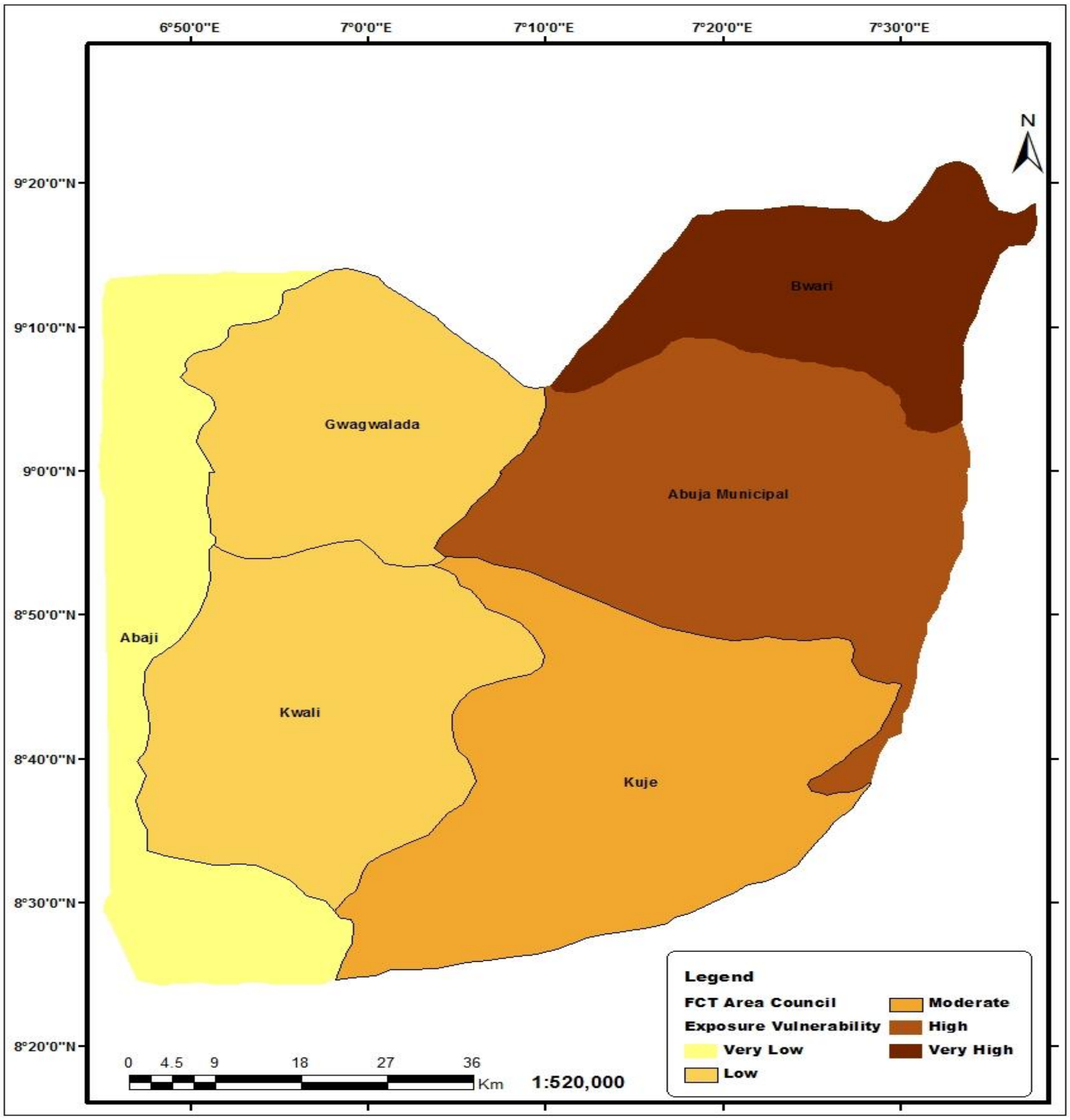

Fig. 17. Exposure of FCT Area Councils to Climate Variability
Source: Author, (2018)

The mean exposure shows that, croplands in Bwari have the highest exposure (0.7251) followed by croplands in AMAC (0.6757). Moderate exposure was recorded in croplands in Kuje Area Council (0.6336). Low exposure was observed in Gwagwalada (0.5082) and Kwali (0.5358). Abaji recorded the least exposure (0.2508). The vulnerability ratings are equivalent to the corresponding exposures as the referenced crops will be highly vulnerable in Bwari and least vulnerable in Abaji.

3.9 Climate Vulnerability Exposure of FCT Area Councils

The exposure index values above (Table 7) were used to produce the exposure map of FCT (Fig. 17). In terms of exposure, it is shown from the map that Bwari has the highest exposure (0.1671) to climate variables while Abaji has the least (0.0868) exposure. AMAC (0.1371) is high, Kuje (0.1304) is moderate while Gwagwalada (0.1132) and Kwali (0.1154) have low exposure to climate variability. Based on this result, the three arable crops production will be affected differently as they thrive optimally under different climatic conditions. For instance, cowpea production does not require high rainfall and temperature. Over exposure to rainfall and temperature will reduce yields due to low pod set and abscission [40]. The three crops will produce moderately at moderate exposure while their production will be marginal and optimal at very high and very low exposures respectively. Crop production will be optimum in Abaji, marginal in Bwari and moderate in Kuje.

4. CONCLUSION

The study highlighted the distribution pattern of climate variables in FCT Area Councils within the study period and produced the exposure index of all the Area Councils. Over exposure to climate variables like temperature, rainfall, relative humidity and evapotranspiration has negative effects on crop growth, development and production. The output of the study showed that Bwari Area Council has the highest exposure while Abaji Area Council has least exposure. The trend analysis on both temperature and rainfall during the period showed that temperature is on increasing trend while rainfall is decreasing. The study has revealed that the most vulnerable areas are those with high climate exposure. The study also demonstrated the capability of Geographic Information System (GIS) in transforming different variables of exposure into map.

5. RECOMMENDATION

In view of the findings of this study, the following recommendations are articulated: Crop farmers in FCT should be encouraged to plant trees at intervals in their farms as this will provide shade and improve water infiltration into the soil. Early weather warning system manned with competent hands should be made available in all the Area Councils to provide timely and accurate information to crop farmers when the need arises. Physical infrastructures like schools, health care facilities and market should be provided for the crop farmers to improve on their adaptive capacities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mechiche-Alami A, Abdi AM. Agricultural productivity in relation to climate and cropland management in West Africa. Sci Rep. 2020;10:3393. Available:https://doi.org/10.1038/s41598-020-59943-y
2. IPCC. Climate Change 2014: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (Cambridge, UK); 2014.
3. Busby JW, Cook KH, Vizy EK, Smith TG, Bekalo M. Identifying hot spots of security vulnerability associated with climate change in Africa. Climatic Change. 2014;124:717–731. Available:https://doi.org/10.1007/s10584-014-1142-z)
4. FAO. Land quality indicators and their use in sustainable agriculture and rural development. FAO Land and Water Bulletin. 1997;5:212.
5. Enete AA, Amusa TA. Challenges of agricultural adaptation to climate change in Nigeria: A synthesis from the literature. Field Actions Science Reports. 2010;4. URL:http://journals.openedition.org/factsreports/678
6. Deressa T, Hassan R, Adamu T, Yusuf M, Ringler C. Analysing the determinants of farmers' choice of adaptation measures and perceptions of climate change in the Nile Basin of Ethopia. International Food Policy Research Istitute(IFPRI) Discussion paper No 00798. Washington DC; IFPRI; 2008.
7. Wisner B, Blaikie P, Cannon T, Davis I. At risk: natural hazards, people's vulnerability and disasters, 2nd edn. Routledge, London; 2004.
8. Legese W, Koricha D, Ture K. Characteristics of seasonal rainfall and its distribution over Bale highland, Southeastern Ethiopia. J Earth Sci Climate Change. 2018;9:443. DOI: 10.4172/2157-7617.1000443
9. Intergovernmental Panel on Climate Change. Impacts, adaptation and vulnerability. Contribution of Working

Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2007.
10. Food and Agricultural Organization. The state of food insecurity in the world, monitoring progress towards the world food summit and millennium development goals. Viale delle Terme di Caracalla, 00100 Rome, Italy; 2004.
11. Food and Agricultural Organization. Adaptation to climate change in agriculture, forestry and fisheries: Perspective, Framework and Priorities; 2007.
12. Olesen JE, Bindi M. Consequences of climate change for European agricultural productivity, land use and policy. European Journal of Agronomy. 2002;16(4):239-262.
13. International Fund for Agricultural Development.: Annual report: Enabling poor rural people to overcome poverty; 2008.
14. Davenport F, Funk C, Galu G. How will East African maize yields respond to climate change and can agricultural development mitigate this response; 2018.
15. Cornforth RJ, Young HR, Todman LC, Miret JA, Shepherd TG, Petty C, et al. 'Assessing the impact of climate change on sweet potato in Uganda', GCRF sweet potato catalyst, Policy brief no. 1, Walker Institute, May 2020, WIBN/0520/01. Zenodo; 2020.
Available:http://doi.org/10.5281/zenodo.3836642
16. Onwutuebe CJ Patriarchy and women vulnerability to adverse climate change in Nigeria. journals.sagepub.com/home/sgo; 2019.
DOI: 10.1177/2158244019825914
17. Nwaiwu IUO, Ohajianya DO, Orebiyi JS, Ibekwe UC, Lemchi JI, Onyeagocha SUO, et al. Climate change trend and appropriate mitigation and adaptation strategies in Southeast Nigeria. Global Journal of Biology, Agriculture and Health Sciences. 2014;3(1):120-125.
18. SPORE. Spore special issue on climate change. Technical Centre for Agricultural and Rural Cooperation (CTA); 2008.
19. DFID. Sustainable livelihoods guidance sheets. Natural Resources Policy and Advisory Department, London; 2000.
20. Dinar A, Hassan R, Kurukulasuriya P, Benhin J, Mendelsohn R. The policy nexus between agriculture and climate change in Africa. A synthesis of the investigation under the GEF/WB Project: Regional climate, water and agriculture: Impacts on and adaptation of Environmental Economics and Policy in Africa, University of Pretoria. South Africa; 2006.
21. Apata TG, Ogunyinka AI, Sanusi RA, Ogunwande S. Effects of global climate change on nigerian agriculture: An empirical analysis. Paper presented at the 84th Annual Conference of the Agricultural Economics Society, Edinburgh; 2010.
22. Hassan SM. An analysis of the impacts of rainfall variability and crop zones classification for the federal capital territory, Nigeria; 2012.
23. Ishaya S, Hassan SM, James SE. Post-adaptation vulnerability of cereals to rainfall and temperature variability in the Federal Capital Territory of Nigeria. Ethiopian Journal of Environmental Studies and Management. 2014;532-547.
24. Ishaya S, Hassan SM. Analysis of growing season rainfall and temperature variability in the federal capital territory of Nigeria. Nigeria Journal of Tropical Geography. 2013;4(2):471-490.
25. Balogun O. The federal capital territory of Nigeria: A geography of its development; 2001.
26. Adekayi PE. Climate of federal capital territory. In: P. D. Dawan (Ed.) Geography of Abuja: Federal Capital Territory, Famous/Asanlu publishers, Minna. 2000;9-22.
27. National Bureau of Statistics [NBS]. Nigerian gross domestic product report (Q3); 2017.
28. Dawan PD. {Ed}. Geography of abuja, federal capital territory. Department of Geography, University of Abuja; 2000.
29. Ishaya S, Mashi SA.. Using GIS to map fadama areas in the central abuja, Nigeria; 2008.
30. Alhassan MM. "Soils of the FCT" In: Dawam, P.D. (Ed.) Geography of Abuja, Federal Capital Territory. Famous/Asanlu. 2000;32-40.
31. Saha SS, Moorthi H, Pan X, Wu J, Wang. NCEP climate forecast system version 2 (CFSv2) monthly products. Research Data Archive at the National Center for

Atmospheric Research, Computational and Information Systems Laboratory; 2012. Acailable:https://doi.org/10.5065/D69021ZF. 5830 University Research Court, College Park, MD, USA.
32. Abbadi GR. Impact of climate variability on agriculture in ping river basin, Thailand, a dissertation submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Remote Sensing and Geographic Information Systems; 2013.
33. Anandhi A, Steiner JL, Bailey N. A system's approach to assess the exposure of agricultural production to climate change and variability. Climatic change. 2016;(136):647–659. DOI 10.1007/s10584-016-1636-y
34. Bunruamkaew K. How to do AHP analysis in excel; 2012.
35. Report.UNDP, New York, USA; 2006.
36. Saaty TL. Fundamentals of decision making and priority theory. Pittsburgh, Pennsylvania: RWS Publications; 2006. ISBN 0-9620317-6-3
37. Saaty TL. Decision making for leaders: The analytic hierarchy process for decisions in a complex world. Pittsburgh, Pennsylvania: RWS Publications; 2008. ISBN 0-9620317-8-X
38. Saaty TL. Principia mathematica decernendi: Mathematical principles of decision making. Pittsburgh, Pennsylvania: RWS Publications; 2010. ISBN 978-1-888603-10-1
39. Oyekanmi AA. Arable crop production – Cereals: PCP 505 Crop Production II Arable.Federal University of Agriculture, Abeokuta, Ogun State; 2009.
40. Liebenberg A, J {Ed}. Dry bean production. Compiled by Directorate of Agricultural Information Services, Department of Agriculture in cooperation with ARC-Grain Crops Institute, South Africa; 2002.
41. Mohammed AB, Zakari D, Megudu M, Sandra INI. Impact of climate change on yam production in Abuja, Nigeria. International Journal of Science, Environment and Technology. 2014;3:2.
42. Olanrewaju RM, Sadauki AA. Effect of climate on yam tuberisation in the guinea savannah ecological zone of Nigeria: The case study of Kwara State. Ethiopian Journal of Environmental Studies and Management, EJESM. 2012;5(2). DOI: http//dx.doi.org/10.4314/ejesm. v5i2.4
43. Tamil Nadu Agricultural University (TNAU). Agrometeorology: Relative humidity and plant growth; 2016.
44. Nkuna TR, Odiyo JO. The relationship between temperature and rainfall variability in the Levubu sub-catchment, South Africa. International Journal of Environmental Science. 2016;1.
45. Madden RA, Williams J. The correlation between temperature and precipitation in the United States and Europe. Monitory Weather Review No. 1978;106:142-147.
46. Critchley W, Klaus S. Water harvesting: A manual for the design and construction of water harvesting schemes for plant production; 1991.

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