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Assessment of Vulnerability of Croplands to Climate Variability in 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. Authors SKI and JIM managed the analyses of the study. Author MA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Despite the wide coverage of study on vulnerability in the Federal Capital Territory (FCT) of Nigeria over the years, it was observed that no emphasis has been placed on assessment of vulnerability of croplands to climate variability using the integrated vulnerability assessment and Geo-Informatics technique. This was achieved by determining the climate variability pattern in FCT from 1981 to 2017, determining the exposure index and the degree of sensitivity of croplands to climate variability, assessing the adaptive capacity of farmers to climate variability, evaluating the vulnerability of croplands to climate variability and developing vulnerability maps of croplands using the information produced. Yam, beans and maize were used as referenced crops in this study. Indicators were generated and analyzed on the three components of vulnerability: exposure, sensitivity and adaptive capacity. The study used the mixed research design. The Analytical

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Hierarchy Process was used to assign weight to the indicators. The weights were used to generate the exposure, sensitivity and adaptive capacity indices which were used to generate the vulnerability index map. Aggregate vulnerability index (AVI) was finally determined from the weighted sum of all indicators and used to produce the vulnerability map of the six Area Councils. The study shows that Gwagwalada Area Council has the highest vulnerability (0.2323) and Abaji Area Council has the lowest (0.005). Kwali and AMAC Area Councils were highly vulnerable to climate variability (Kwali 0.1562, AMAC 0.1565). Kuje Area Council has low vulnerability (0.0273) to climate variability. Bwari Area Council showed moderate vulnerability (0.0982). The implication of the results is that the three crops (maize, beans and yam) will produce moderately at moderate vulnerability while their production will be marginal and optimal at very high and very low vulnerabilities respectively. Crop production will be optimum in Abaji, marginal in Gwagwalada and moderate in Bwari. The study also revealed that vulnerability assessment is essential in determining the varying degrees of vulnerability in different localities. It also provides information that can help researchers, policy makers, private and public institutions in planning location-based adaptation strategies and prioritizing allocating limited resources in FCT. Agriculture should be heavily subsidized in terms of providing irrigation infrastructure to farmers to reduce over-reliance on rain fed agriculture. Installation of early weather warning system manned with expertise should be made available in all the Area Councils to provide timely and accurate climatic information to farmers.

Keywords: Geoinformatics; andicators; weights; vulnerability; aggregate vulnerability inde; exposure; sensitivity and adaptive capacity.

1. INTRODUCTION

Vulnerability (V) is commonly conceptualized as a function of Exposure (E), Sensitivity (S) and Adaptive Capacity (AC) [1]. The term vulnerability is widely used in different disciplines. The difference in the study phenomenon and knowledge background of each discipline makes the understanding and definition of vulnerability to be diverse. The concept was introduced to the field of climate science based on the growing influence of climate change issues. The Intergovernmental Panel on Climate Change (IPCC) First Assessment Report provided a preliminary elaboration of it. In 1996, the IPCC Second Assessment Report gave the definition of vulnerability to climate change as the degree to which a system is susceptible to or unable to cope with adverse effects of climate change (including climate mean, variability and extremes) and it is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity (McCarthy et al., 2001). In 2001, the IPCC Third Assessment Report clearly defined the relationship among climate change exposure, sensitivity, adaptation and vulnerability with the equation: Vulnerability = f (Exposure; Sensitivity; Adaptive capacity).

Global environmental changes tend to have a disproportionate impact on agriculture compared to other parts of the economy. Since agriculture relies directly on natural resources, those who work in agricultural sector are inherently vulnerable to variability in climate, water availability and landuse [2,3]. Such changes can have a multitude of biophysical and social consequences that are often difficult to predict. While some farmers will anticipate changes and reap benefits, others will face increasing vulnerability unless efforts are made to strengthen their adaptive capacity and enhance the resilience of agricultural ecosystems [4-6].

The IPCC [7] reported that land surface temperatures across most Africa have increased by 0.5°C or more during the last 50–100 years while there is a decrease in annual rainfall over the past century. This has affected the health, livelihoods and food security of people in Africa.

Karmakar et al., [8] identified climate as one of the most important factors affecting the formation of soil with important implications for their development, use and management perspective in relation to soil structure, stability, water holding capacity, nutrient availability and erosion. In the same vein, Al-Kaisi and Helmers [9] observed that raindrops hit the ground as fast as 20 miles per hour. These raindrops hitting the bare soil surface dislodges soil particles and splashes them 3 to 5 feet away. Most of these particles don't leave the field; they clog surface pores, which in turn reduce water infiltration, increases water runoff, and increases soil erosion. According to Onwuka and Mang [10] the soil which constitutes a major storage for heat is indispensable for the maintenance of plant life, affording mechanical support, supplying nutrients and water. The soil temperature is a catalyst for many biological processes. Soil temperature influences soil moisture, aeration, organic carbon and availability of plant.

Africa as a whole is one of the most vulnerable continents due to its high exposure and low adaptive capacity to climate variability [1]. Africa's food production systems are among the worlds' most vulnerable because of extensive reliance on rain-fed agricultural systems, high intra and inter-seasonal climate variability, recurrent droughts and floods that affect both crops and livestock and persistent poverty that limits the capacity to adapt [11]. Climate variability is very likely to have an overall negative impact on yields of major cereal crops across Africa, with strong regional variability in the degree of yield reduction [12].

Agriculture is the single largest employer of labour in the world, providing livelihoods for 40% of the global population [13]. According to the United Nations General Assembly [14], agriculture is the largest source of income for poor rural households. Agriculture plays a great role in the livelihood of rural communities in many African countries. In Nigeria, crop production remains the major driver of the agricultural sector of the economy as it accounts for 91.97% of overall growth of the sector [15]. In the third quarter of 2017, Agriculture contributed 24.44% to GDP (NBS, 2017). In terms of employment, agriculture is by far the most important sector of Nigeria's economy, engaging about two-third of the labour force (Bola, 2007) [16]. Research shows that Nigeria has over 80 million hectares of arable land [17]. About 30.7 million hectares (76 million acres), or 33% of Nigeria's land area, are under cultivation (FAO, 2004). These croplands contribute significantly to national food self –sufficiency through agriculture by accounting for over 90% of total food consumption requirements [16]. Nigeria's diverse climate, from the tropical areas of the coast to the arid zone of the north, make it possible to produce virtually all agricultural products that can be grown in the tropical and semitropical areas of the world.

According to Dasgupta et al [18], the distinctive characteristics of rural areas make them uniquely susceptible to the impacts of climate variability because of their existing vulnerabilities caused by poverty, lower levels of education, isolation and neglect by policymakers as well as their greater dependence on agriculture and natural resources. However, rural people in many parts of the world including Nigeria have, over the years, adapted to climate variability or at least learned to cope with it [17]. They have done so through farming practices and use of wild natural resources (often referred to as indigenous knowledge or by similar terms), as well as through diversification of livelihoods and through informal institutions for risk-sharing and risk management. Similar adaptations and coping strategies can, given supportive policies and institutions, form the basis for adaptation to climate change, although the effectiveness of such approaches will depend on the severity and speed of climate change impacts [18].

Hassan [19] noted that crop production is the back bone of the economy of the Nigeria's Federal Capital Territory as nearly 90% of the population depends either directly or indirectly on it for their livelihood. FCT is one of the largest and most fertile agricultural lands in the country [20]. By reason of its location and its climate, soil and hydrology, FCT has the capacity to produce most of Nigeria's staple crops. Thus, cereals, legumes, root and tubers, oil seeds and nuts, fruits, fibres and others such as vegetables and sugar cane can be profitably grown in FCT. The great potential of agriculture in providing food for the populace and contributing to the Nigerian economy necessitated the study on the assessment of vulnerability of croplands in FCT to climate variability using Geo-Informatics. This is done to know the impact of climate variability on the arable land use for crop production thereby devising the adaption measures to apply in combating the climate anomalies.

1.1 Aim and Objectives

The study assessed the vulnerability of croplands to climate variability in the Federal Capital Territory (FCT) Abuja, using the integrated vulnerability approach and Geographic Information System (GIS). This was achieved by;

1. determining the climate variability pattern in FCT from 1981 to 2017.
2. determining the exposure of croplands to climate variability
3. determine the degree of sensitivity of croplands to climate variability.
4. assessing the adaptive capacity of farmers to climate variability.

5 evaluating the vulnerability of croplands to climate variability and developing vulnerability maps.

1.2 Research Hypothesis

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
c. H_0: Climate variables do not influence crop production in FCT

1.3 Statement of Research Problem

Most of the studies on climate change in Nigeria are concerned with effects, impacts and adaptions [21]. Among such studies in Africa and Nigeria are: evidence of climate change impacts on agriculture and food security in Nigeria [22], awareness and adaptation to climate change among yam-based farmers in rural Oyo state, Nigeria [23] and agricultural vulnerability to climate change in eight selected rural settlements in Sokoto State, Nigeria [24]. 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 [19], post-adaptation vulnerability of cereals to rainfall and temperature variability in the Federal Capital Territory of Nigeria [25], vulnerability of Federal capital Territory of Nigeria (Abuja) to climate change [26], vulnerability of annual cereals yield to rainfall and temperature variability in the Federal Capital Territory of Nigeria [12], analysis of growing season rainfall and temperature variability in the Federal Capital Territory of Nigeria [27], effect of climate change on agricultural productivity in Federal Capital Territory using temperature, rainfall and crops data [28]. Despite the wide coverage of climate studies in FCT of Nigeria over the years, it was observed that no emphasis has been placed on assessing the vulnerability of croplands to climate variability in the Federal Capital Territory (FCT) using the integrated vulnerability approach and 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.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area (Fig. 1) lies between latitude 8^{0}15’ and 9^{0}12’north of the equator and longitude 6^{0}27’ and 7^{0}23’14” east of Greenwich Meridian [20]. The Federal Capital Territory has a landmass of approximately 8,000 km^2 of which the actual city occupies about 512 km^2 [29]. 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 (NBS, NPC, 2017). It confronts two weather conditions annually. These are warm, humid rainy season and a dry season, which experiences a brief interlude of harmattan occasioned by the North East Trade Wind [29]. The mean sunshine hour between November and April is about 250 hours in the south to over 275 hours in the north-east [20]. 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 370C in the south-west to about 300C 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 [20]. The end of the raining season is around the middle of October in the north and early November in the south [30]. The duration of the raining season (length of raining season-LRS) ranges between 190 days in the north to 240 days in the south [31]. The annual and monthly rainfall viability coefficient ranges between 85% - 117% and 20% - 280% respectively [20]. 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 [31]. The relative humidity falls considerably in the afternoons in the dry season and rises everywhere during the raining season. In the raining season, the afternoon humidity can be as high as 50%, but it is as low as 20% during the dry season [20]. The warm and moist tropical maritime air mass from the Atlantic moves from south-west to north-east direction while the warm and dry tropical continental air mass from the Sahara moves from north-east to south-west in opposite direction. The movement of these air masses dictated the absence of any real cold season in FCT [29].

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. The crystalline basement complex occupies about two third of the territory in the north while the sandstone covers about one third of the territory in the south. Balogun [20] 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.

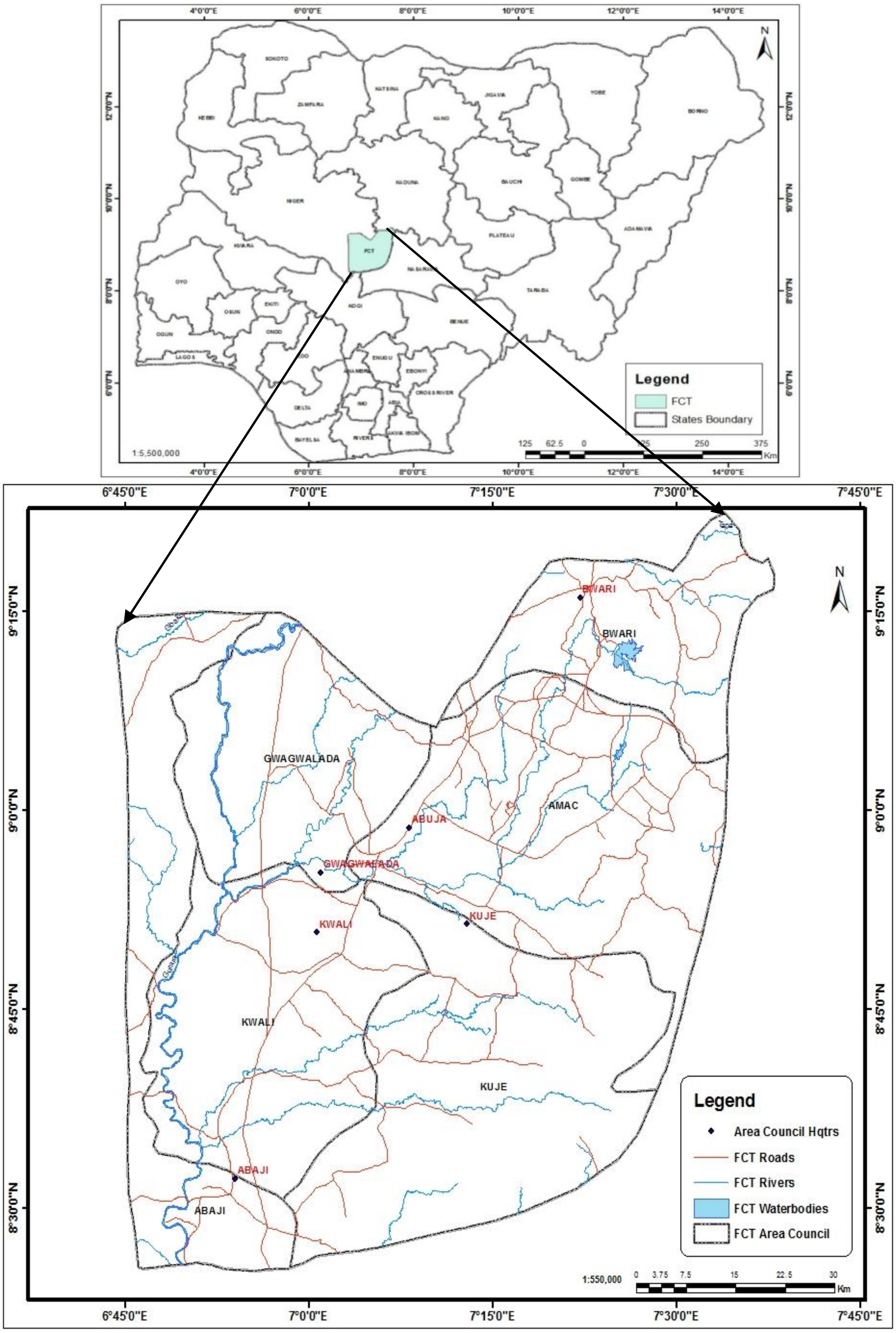

Fig. 1. The study area showing the six area councils

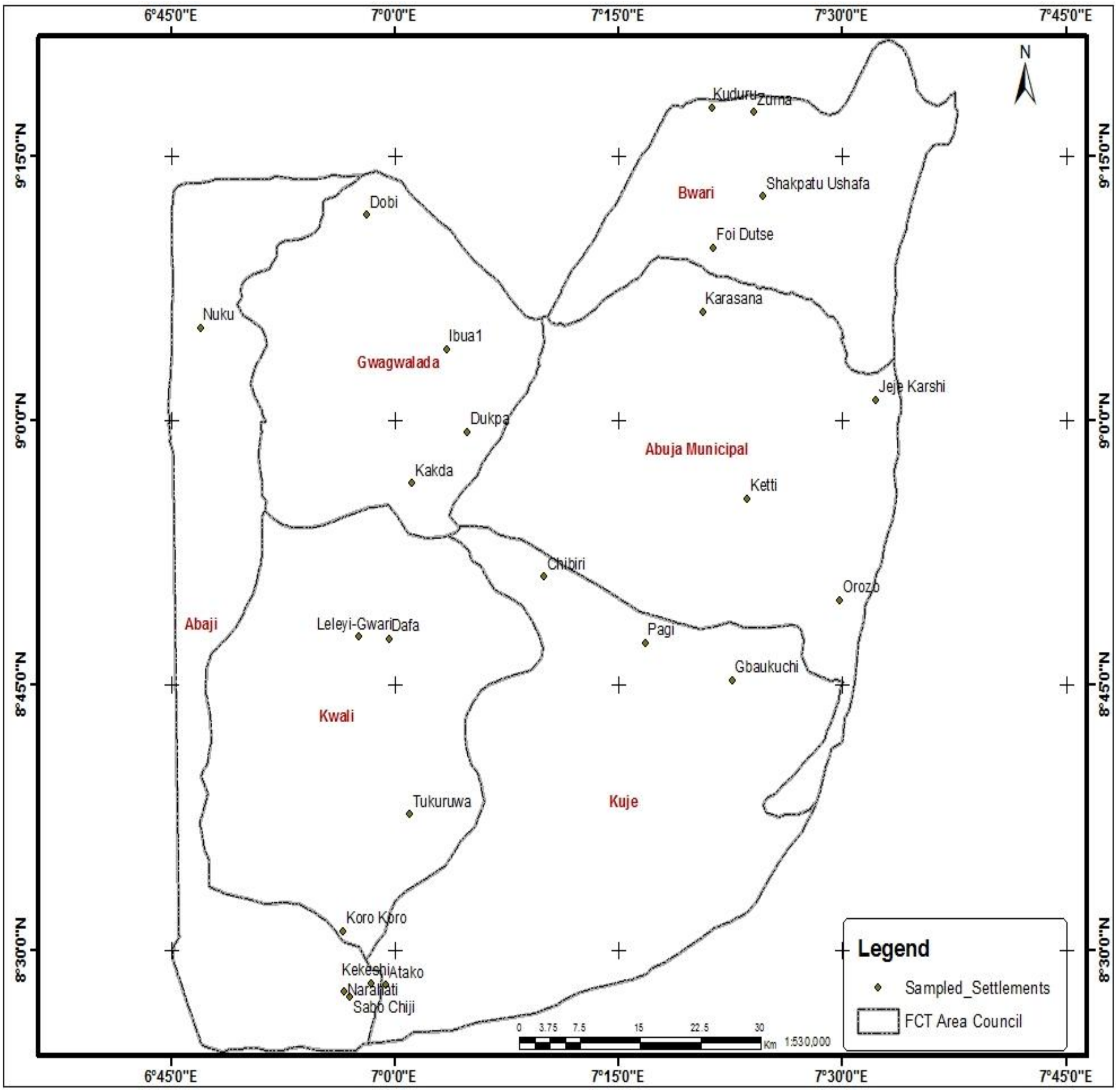

Fig. 2. Sampled farm settlements in the study area
Source: Author, 2018

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 [29]. 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 [12].

2.2 Data Collection and Analysis

Table 1 shows the data types and sources. Table 2 shows the monthly mean of climate variables (temperature, rainfall, relative humidity and potential evapotranspiration). Relevant information on socio-economic characteristics of the farmers were obtained by personal interviews and questionnaires. Tables 3, 4 and 5 show the long term mean of vulnerability components of exposure, sensitivity and adaptive capacity respectively.

Table 1. Data types and sources

S/N	Data	Types	Year	Source	Scale
1	GPS Locations of farm settlements	Primary	2018	Field work	
2	Rainfall, Temperature, Relative Humidity, Potential Evapotranspiration	Secondary	1981-2017	NCEP Climate Forecast System Reanalysis, Climatic Research Unit (CRU TS 4.01)	
3	Population Density Age Dependency Ratio	Secondary	2016	National Population Commission (NPC) and National Bureau of Statistic (web) 2016	
4	Soil Organic Carbon, Soil Water Holding Capacity and Topography	Secondary	1995	FAO, Digital soil map of Africa	
5	Financial, Social, Human, Physical and Natural Capital (Socio-economic data)	Primary	2018	Field work: through the administration of 240 copies of questionnaires in 24 farm settlements (4/area council) at 40 copies per area council	
6	Administrative map of FCT	Secondary	2000	Office of the Surveyor General of the Federation (Abuja)	1:50000
7	SRTM	Secondary	2016	USGS Earth Explorer. www.landcover.org	30m
8	Landsat image	Secondary	2016	https://glovis.usgs.gov	30m
9	Crop production	Secondary	2018	FCT-Agricultural Development Project	

Table 2. 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 3. Long-term exposure indicators in FCT area councils (1981 - 2017)

Area Councils	Temperature (^0C)	Rainfall (mm)	Evapotranspiration (mm)	Relative. humidity (%)
Abaji	28.438	1361.908	3.870	55.7
AMAC	26.691	1666.315	4.296	61.4
Bwari	26.040	1932.458	4.361	60.8
Gwagwalada	28.734	1255.329	4.227	57.7
Kuje	27.991	1497.199	4.113	61.3
Kwali	28.876	1305.470	4.063	59.5

Source: Derived from CFSR Data (1981-2017)

Table 4. Sensitivity indicator scores in FCT area councils

Area council	Erosion	Organic carbon	Clay	Cropland	Population density	Dependency ratio
Abaji	183.84	14.77	17.74	29.92	149.80	94.17
AMAC	403.54	13.60	17.94	14.28	1112.00	55.28
Bwari	607.20	18.41	19.84	12.93	635.80	70.65
Gwagwalada	200.70	12.29	16.52	45.61	385.40	79.86
Kuje	337.47	19.45	20.97	8.73	149.90	89.75
Kwali	173.65	15.51	17.51	25.67	181.10	92.68

Source: Compiled from various sources by the Author

Table 5. Average score of adaptive indicators in FCT area councils

Area councils	Financial/11	Social/8	Physical/14	Human/15	Natural/12
Abaji	81.2727	75.2500	72.3571	92.9333	114.7500
AMAC	87.5455	75.8750	102.5714	96.3333	119.8333
Bwari	79.5455	83.8750	101.7143	98.1333	99.7500
Gwagwalada	100.0909	91.1250	105.5000	101.8000	114.7500
Kuje	82.7273	63.5000	90.2857	92.0667	122.6667
Kwali	98.3636	89.3750	98.2857	96.4000	113.0833
Sum	529.5455	479.0000	570.7143	577.6667	684.8333

Source: Author, 2018

Table 6. Description of assets and indicators of adaptive capacity of farmers

S/No	Assets	Indicators
1	Human	Education, farm labour, knowledge of climate risk and agriculture and vocational training.
2	Social	Information, community support, extended families and formal or informal social-welfare support
3	Physical	Access to services and facilities (road, market, school and medical centre), equipment, irrigated land and house quality
4	Natural	Land ownership, soil and Reliable water resources.
5	Financial	Savings from crop sales and off-farm income, salaries, remittances or pensions and loans groups

Source: DFID [32]

2.3 Methods of Data Analysis

Statistical computations of sums and averages were performed on secondary data obtained for exposure (rainfall, temperature, relative humidity and evapotranspiration), sensitivity and adaptive capacity indicators using Microsoft office excel version 16. Time series analysis was carried out on the climatic datasets to present them over time. The mean monthly and annual climate variables in FCT were determined for all the Area Councils. 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 [33]. 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. [25] and Anandhi et al., [34] 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 =

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

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 equation 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 [35], the higher the deviations, the higher the exposures.

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. 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 (Tables 7, 8 and 9). If vulnerability increases with increase in the value of the indicator, the normalization is achieved by the formula:

Yi = Xi−MinXj / MaxXj−MinXj…………..… eq 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…………………..………...(eq 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.

Table 7. Normalized climatic variables (Exposure indicators) of FCT area councils

Area councils	Temperature	Rainfall	Evapotranspiration	Relative Humidity	Exposures rank (Mean)
Abaji	0.8456	0.1574	0.0000	0.0000	**0.25075 (6)**
AMAC	0.2294	0.6070	0.8663	1.0000	**0.67568 (2)**
Bwari	0.0000	1.0000	1.0000	0.9005	**0.72513 (1)**
Gwagwalada	0.9501	0.0000	0.7265	0.3563	**0.50823 (5)**
Kuje	0.6881	0.3572	0.4948	0.9941	**0.63355 (3)**
Kwali	1.0000	0.0740	0.3924	0.6768	**0.53580 (4)**

Source: Author, 2018

Table 8. Normalized sensitivity indicators in FCT area councils

Area council	Erosion	Organic carbon	Clay	Cropland	Population density	Dependency ratio	Sensitivity rank
Abaji	0.023	0.654	0.725	0.425	0.000	1.000	**0.471 (5)**
AMAC	0.530	0.817	0.682	0.850	1.000	0.000	**0.647 (1)**
Bwari	1.000	0.146	0.254	0.886	0.505	0.395	**0.531 (2)**
Gwagwalada	0.062	1.000	1.000	0.000	0.245	0.632	**0.490 (3)**
Kuje	0.378	0.000	0.000	1.000	0.000	0.886	**0.377 (6)**
Kwali	0.000	0.551	0.778	0.541	0.033	0.962	**0.477 (4)**

Source: Author, 2018

Table 9. Normalized score of adaptive indicators in FCT area councils

Area Councils	Financial	Social	Physical	Human	Natural	Mean adaptation/rank
Abaji	0.91593	0.57466	1	0.91096	0.34545	**0.7494 (1)**
AMAC	0.61062	0.55204	0.08836	0.56164	0.12364	**0.3873 (4)**
Bwari	1	0.26244	0.11422	0.37671	1	**0.5507 (3)**
Gwagwalada	0	0	0	0	0.34545	**0.0691 (1)**
Kuje	0.84513	1	0.45905	1	0	**0.6608 (2)**
Kwali	0.08407	0.06335	0.21767	0.55479	0.41818	**0.2676 (5)**

Source: Author, 2018

The weighting was done by adopting the approach by Saaty, [36-38] 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:

Consistency Index (CI)=(λmax–n)/(n– 1) …………………………………………...equ (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.

Having derived the weighted vulnerability indices of component indicators (exposure, sensitivity and adaptive) for each of the Area Councils, they were aggregated into a single index in order to compare the Area Councils for their relative cropland vulnerability to climate variability. The net effect of exposure, sensitivity and adaptive capacity components of vulnerability were calculated to produce a single index that resulted into composite/aggregate vulnerability index which was used to produce the composite vulnerability map of FCT. According to Varadan and Kumar [39], this is necessary to compare the Area Councils for their relative cropland vulnerabilities to climate variability within the study period. In order to produce the composite vulnerability index of FCT Area Councils to climate variability, this study adopts the methodology of Sehgal et al., [40]. The vulnerability model is given by:

Vulnerability = Exposure + Sensitivity – Adaptive Capacity…………………..…equ (5)

In this relationship, higher net values indicate higher vulnerability and vice versa. The net values were therefore used to rate the Area Councils from very low to very high vulnerabilities. These sub-indices were added together to form the Aggregate Vulnerability Index. The sub and aggregate index values of vulnerability were categorized into very high, high, moderate, low and very low classes. A GIS tool was used to map both the sub and aggregate indices of vulnerability to generate the climate vulnerability map of croplands in FCT.

3. RESULTS AND DISCUSSION

3.1 Climate Variability Pattern in FCT from 1981 to 2017

3.1.1 Temperature

There was a sharp increase in temperature variability from 1999 through 2006 (Fig. 3). These years were the warmest years during the study period. The year 1999 was a global indicator of sharp climate shift [33]. Year 2005 recorded the highest variability in temperature with Abaji, AMAC, Gwagwalada, Kuje and Kwali Area councils having a variability of 1.42^{0}C, 1.26^{0}C, 1.20^{0}C, 1.40^{0}C, 1.39^{0}C and 1.45^{0}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^{0}C, -1.25^{0}C, -1.07^{0}C, -1.36^{0}C, -1.34^{0}C and -1.39^{0}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. The overall implication of this is reduced yield in year 1992 and 2005.

3.1.2 Rainfall

Year 1988 recorded the highest variability in rainfall (Fig. 4) with Abaji, AMAC, Bwari, Gwagwalada, Kuje and Kwali having a variability of 750.29 mm, 876.39 mm, 1138.56 mm, 787.65 mm, 746.56 mm and 634.37 mm respectively above average. The lowest rainfall variability was observed in year 2000 where Abaji, AMAC, Bwari, Gwagwalada, Kuje and Kwali had a variability of -917.42 mm, -1001.67 mm, -1294.21 mm, -720.82 mm, -905.28 mm and -754.14 mm 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

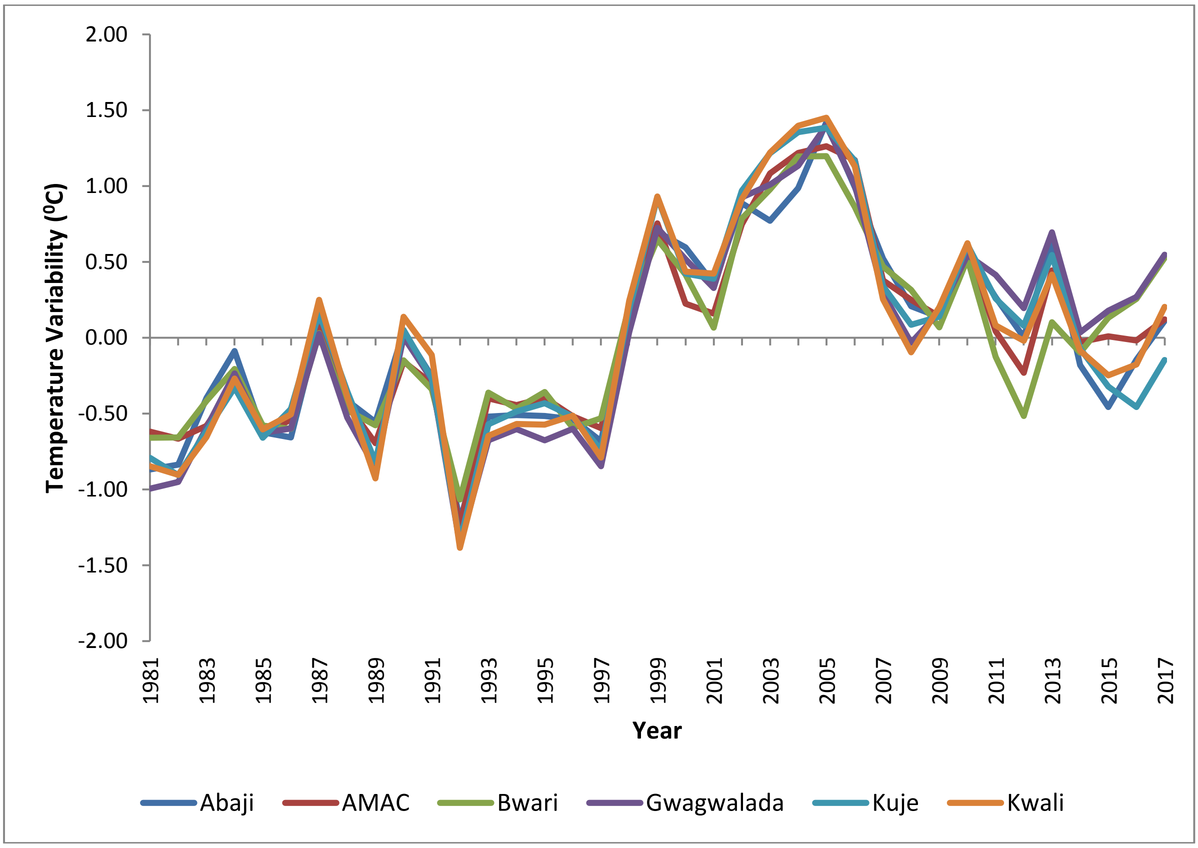

Fig. 3. Mean temperature variability (^{0}C) in FCT area councils
Source: Derived from CFSR data (1981-2017)

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 was 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 thereby making the yam crop vulnerable.

3.2 Relative Humidity

The relative humidity variability (Fig. 5) 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. According to Tamil Nadu Agricultural University [41] very high or very low relative humidity affects high grain yield. High relative humidity reduces CO_2 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.

3.3 Potential Evapotranspiration

The potential evapotranspiration variability (Fig. 6) was on its highest 1983 and 1985 and on its lowest in 1991. According to [41] 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.

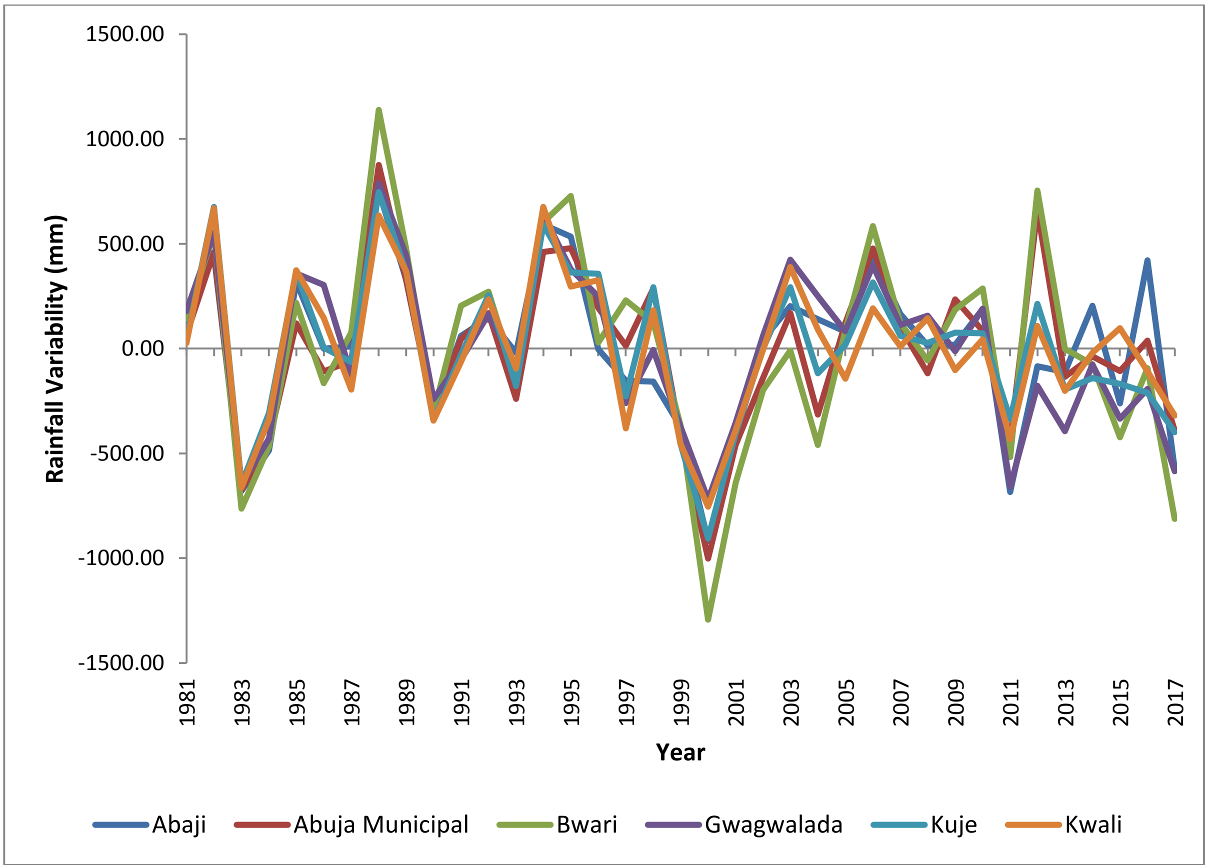

Fig. 4. Rainfall variability (mm) in FCT area councils

Source: Derived from CFSR data (1981-2017)

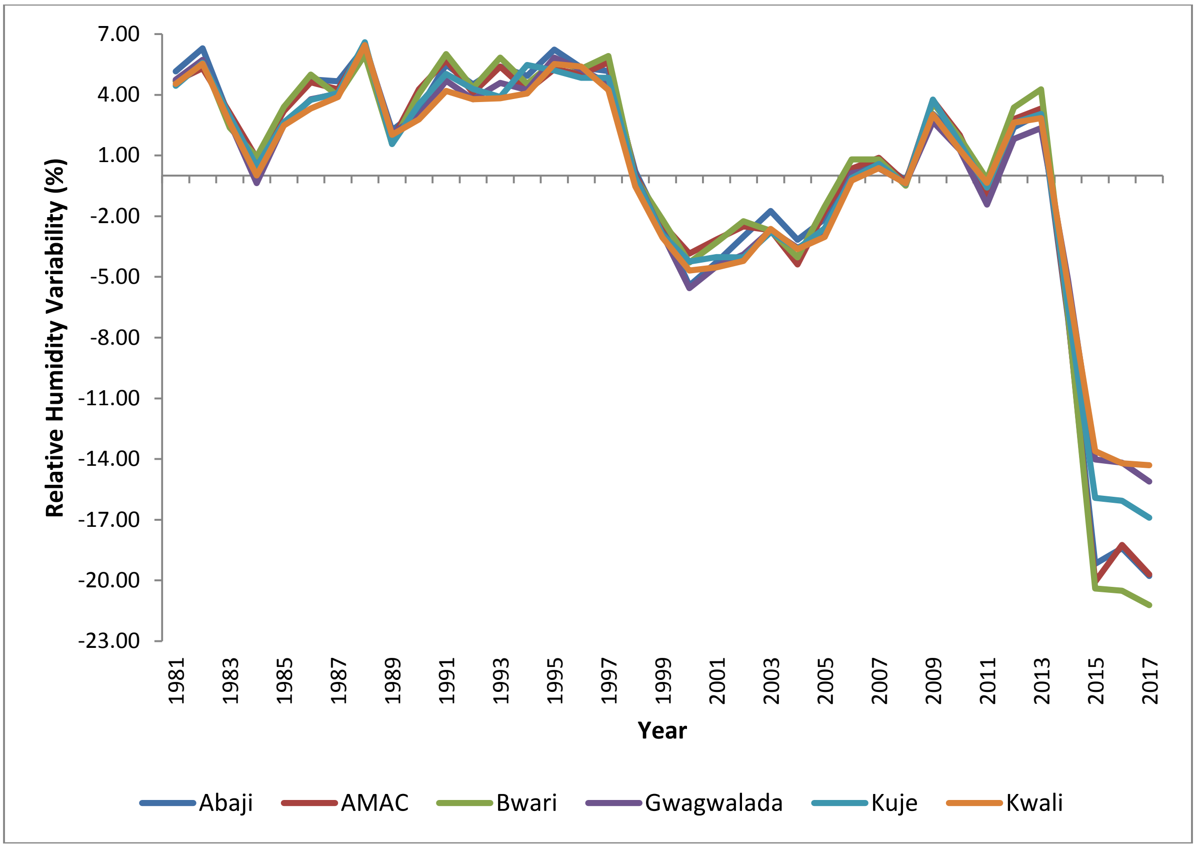

Fig. 5. Relative humidity variability (%) in FCT area councils
Source: Derived from CFSR data (1981-2017)

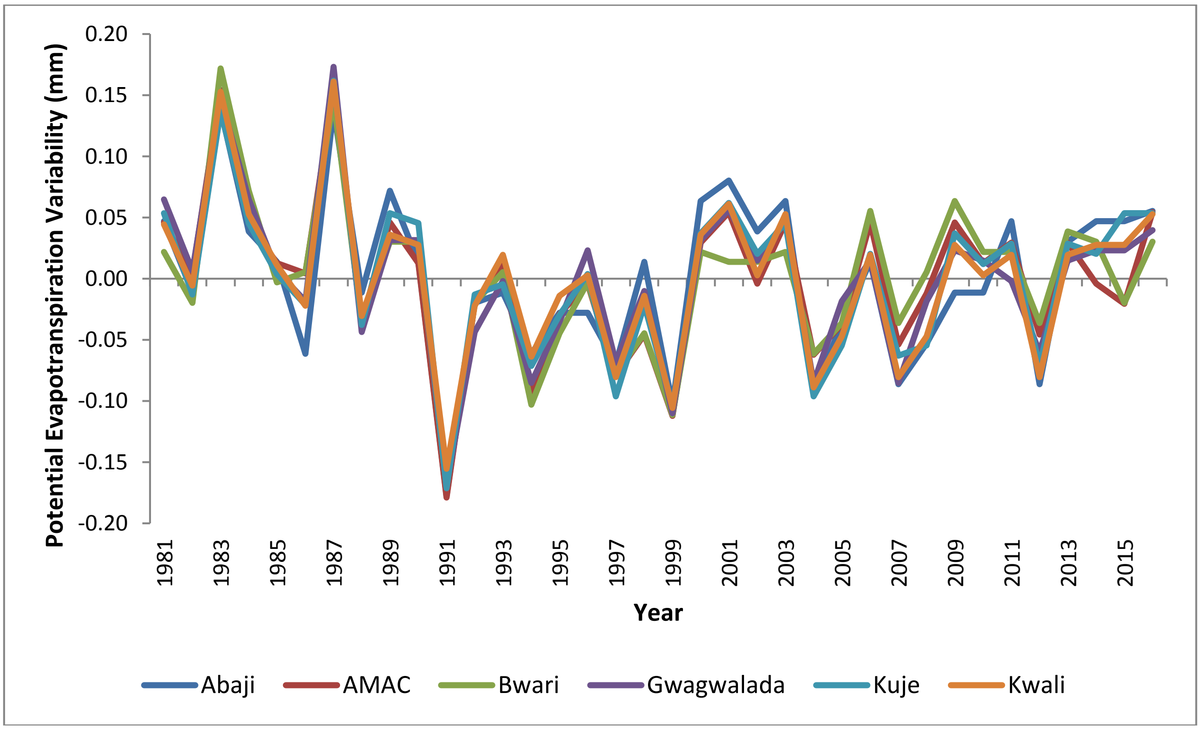

Fig. 6. Potential evapotranspiration variability in FCT area councils
Source: Derived from CFSR data (1981-2017

Table 10. Calculated weight, eigen value and consistency measure of exposure

Indicators	Temp	Rainfall	Evapotran-spiration	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 11. Normalized exposure (AHP) index of FCT area councils from 1981-2017

Area council	Temperature *weight	Rainfall *weight	Evapotranspiration *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.

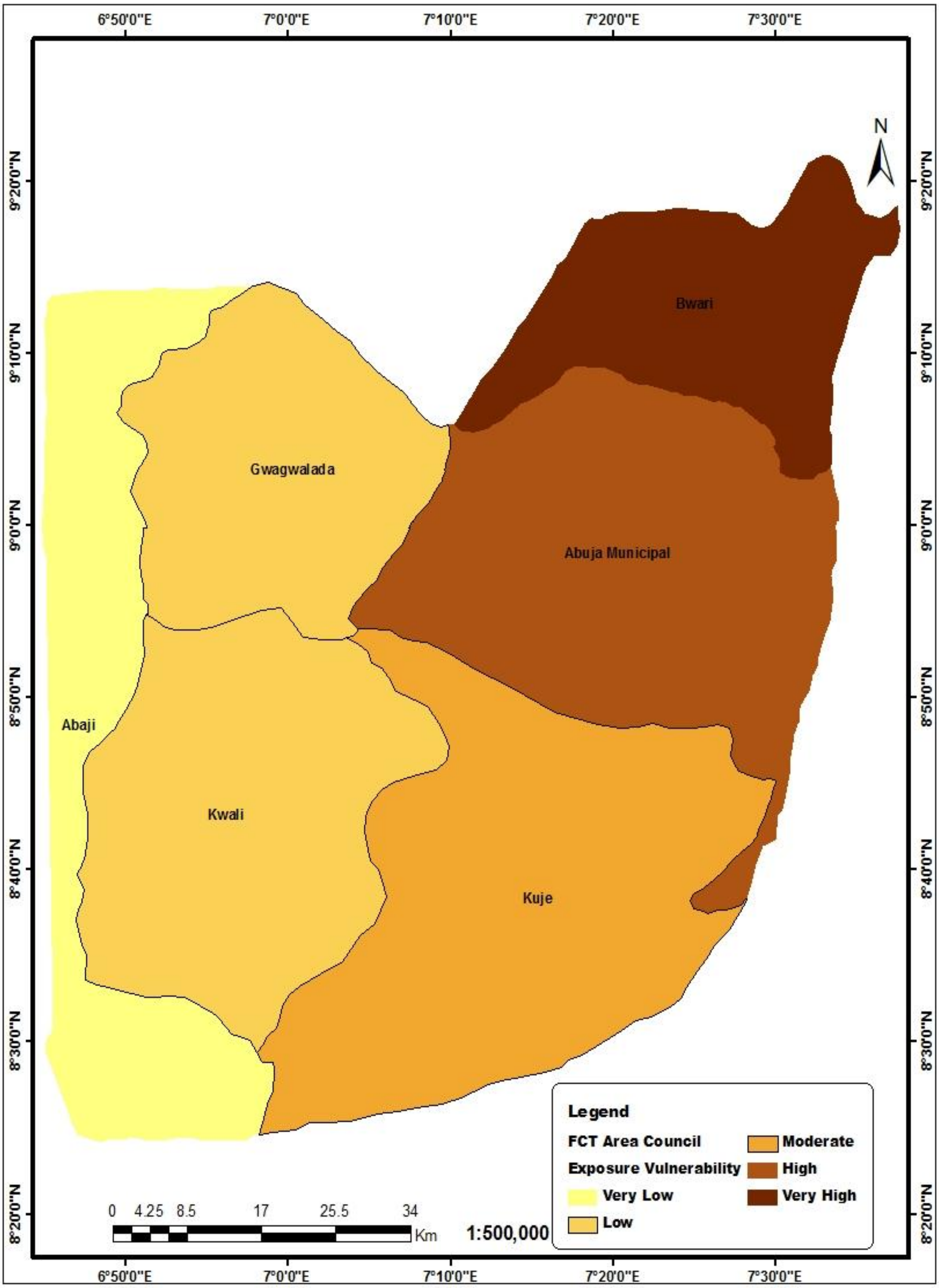

Fig. 7. Exposure of FCT area councils to climate variability
Source: Author, (2018)

Table 12. Calculated weight, eigen value, consistency measures of sensitivity

Indicators	Organic Carbon	Clay	Erosion	% cropland	Pop Den	Dep. Ratio	Weight	E.V	C.I	C.R
Organic Carbon	0.472	0.592	0.375	0.381	0.328	0.395	0.424	6.543	0.109	0.088
Clay	0.157	0.197	0.208	0.381	0.234	0.237	0.236	6.701		
Erosion	0.052	0.039	0.042	0.042	0.016	0.026	0.036	6.387		
Cropland	0.157	0.066	0.125	0.127	0.234	0.237	0.158	6.565		
PopDen	0.067	0.039	0.125	0.025	0.047	0.026	0.055	6.058		
Dep.Ratio	0.094	0.066	0.125	0.042	0.141	0.079	0.091	6.376		

Source: Author, 2018

Table 13. Normalized sensitivity (AHP) index of FCT area councils from 1981-2017

Area Council	Carbon *weight	Clay *weight	Erosion *weight	Cropland *weight	Pop den *weight	Dep ratio *weight	Sensitivity index/rank
Abaji	0.2772	0.1711	0.0009	0.0671	0.0000	0.0912	**0.1012**
AMAC	0.3464	0.1608	0.0193	0.1340	0.0551	0.0000	**0.1193**
Bwari	0.0617	0.0599	0.0363	0.1398	0.0278	0.0360	**0.0602**
Gwagwalada	0.4238	0.2359	0.0023	0.0000	0.0135	0.0576	**0.1222**
Kuje	0.0000	0.0000	0.0137	0.1577	0.0000	0.0808	**0.0420**
Kwali	0.2337	0.1835	0.0000	0.0853	0.0018	0.0877	**0.0986**

Source: Author, 2018

3.4 Exposure of Croplands to Climate Variability in FCT (1981-2017)

Fig. 7 shows the exposure of FCT area councils to climate variability. It was shown from the map that Bwari has the highest exposure (0.1671) to climate variables while Abaji has the least (0.0868). AMAC (0.1371) was high, Kuje (0.1304) was moderate while Gwagwalada (0.1132) and Kwali (0.1154) had 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 as these cause low pod set and abscission [42]. 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.

3.5 Sensitivity of Croplands to Climate Variability in FCT (1981-2017)

In terms of sensitivity (Fig. 8), it was shown from the map that Gwagwalada (0.1222) has the highest sensitivity to climate variability while Kuje (0.0420) has the least sensitivity. AMAC (0.1193) was high, Abaji (0.1012) and Kwali (0.0986) were moderate while Bwari (0.0602) was low in sensitivity. The three crops will produce moderately at moderate sensitivity while their production will be marginal and optimal at very high and very low sensitivities respectively. Crop production will be moderate in Abaji and Kwali, marginal in Gwagwalada and optimum in Kuje.

3.6 Adaptive Capacity of Croplands to Climate Variability in FCT (1981-2017)

Table 14 shows the adaptive capacity rankings of farmers in FCT area councils. From the table, it was observed that farmers in Abaji (0.17194) had the highest adaptation capacity followed by farmers in Kuje (0.14514). High adaptation capacity was revealed for farmers in Bwari (0.12042). Low adaptation was recorded in AMAC (0.08626) and Kwali (0.05274) and the least adaptation was documented in Gwagwalada (0.00660).

Fig. 9 shows the adaptive capacity of FCT Area Councils. In terms of this component of vulnerability, Gwagwalada is the most vulnerable and Abaji the least. Kwali has high while AMAC is low in terms of adaptive vulnerability; Kuje and Bwari have low vulnerability. The three crops will produce moderately at moderate adaptation while their production will be marginal and optimal at very low and very high adaptations respectively. Crop production will be optimum in Abaji, marginal in Gwagwalada and moderate in Bwari.

3.7 Composite Vulnerability Map of FCT Area Councils

Fig. 10 shows the composite vulnerability of FCT area councils to climate variability. It was observed that Gwagwalada has the highest vulnerability and Abaji has the lowest. The reason was that Gwagwalada was high in both exposure and sensitivity but low in adaptive capacity. Abaji was low in exposure, high in sensitivity and highest in adaptive capacity. Kwali and AMAC were both high in exposure, moderate in sensitivity and very low in adaptive capacities. The two Area Councils (Kwali and AMAC) were therefore high in their vulnerabilities. Kuje Area Council was high in exposure, low in sensitivity and high in adaptive capacity. This made Kuje to have low vulnerability. Bwari Area Council was highest in exposure, low in sensitivity, high in adaptive capacity and therefore moderate in vulnerability. The three crops will produce moderately at moderate vulnerability while their production will be marginal and optimal at very high and very low vulnerabilities respectively. Crop production will be optimum in Abaji, marginal in Gwagwalada and moderate in Bwari in terms of vulnerabilities.

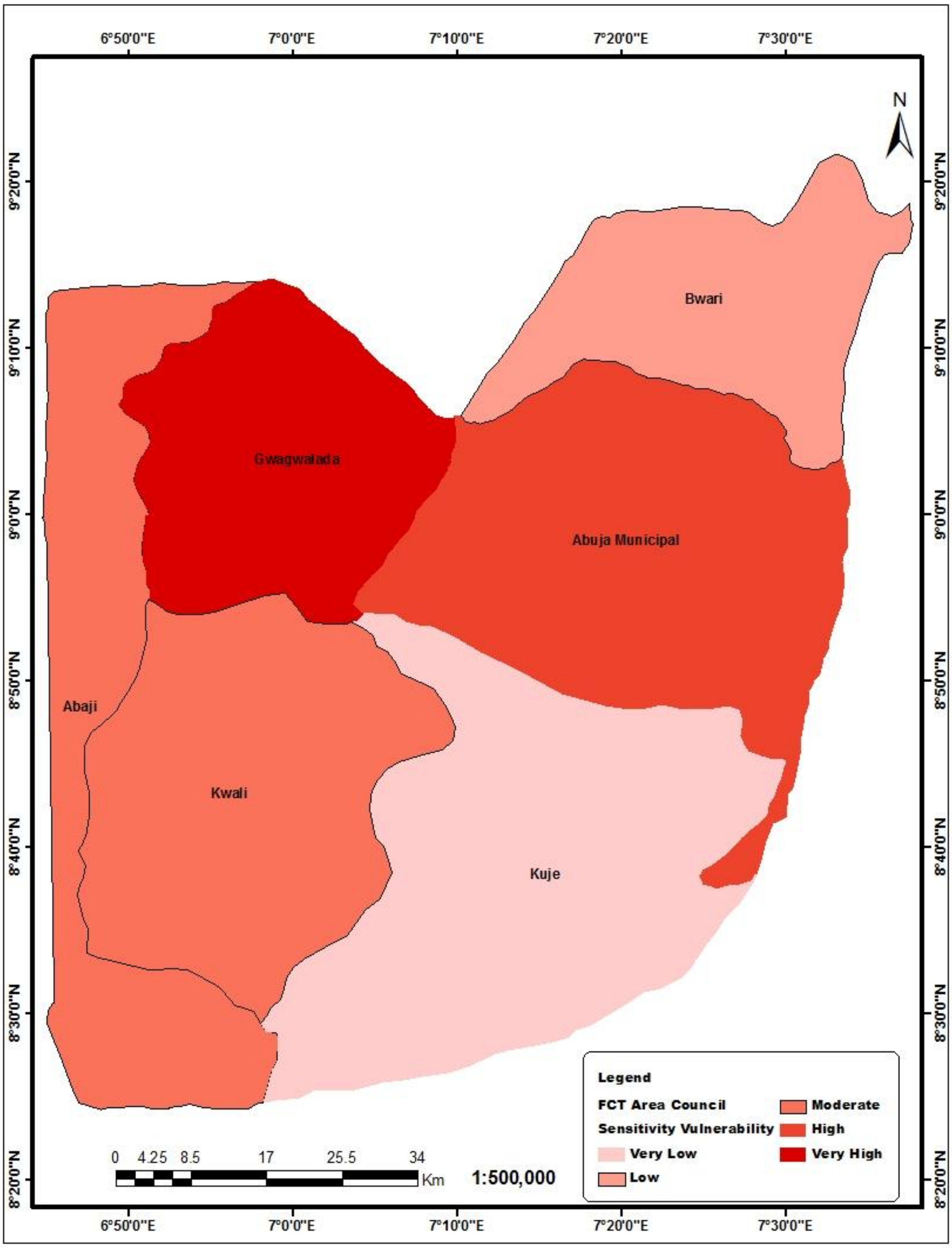

Fig. 8. Sensitivity of FCT area councils to climate variability
Source: Author, 2018

Table 14. Calculated weight, eigen value and consistency measures of adaptation

Assets	Finance	Social	Physical	Human	Natural	Weight	Eigen Value	CI	CR
Financial	0.4286	0.1579	0.4086	0.6164	0.2432	**0.3709**	**1.1822**	**0.0239**	**0.0213**
Social	0.1429	0.0526	0.0195	0.0411	0.0270	**0.0566**	**1.2947**		
Physical	0.1429	0.3684	0.1362	0.0685	0.4054	**0.2243**	**0.7153**		
Human	0.1429	0.2632	0.4086	0.2055	0.2432	**0.2527**	**0.9288**		
Natural	0.1429	0.1579	0.0272	0.0685	0.0811	**0.0955**	**0.9746**		
Sum							**5.0956**		

Source: Author, 2018

Table 15. Normalized adaptive capacity (AHP) index of FCT area councils from 1981-2017

Area councils	Financial *weight	Social *weight	Physical *weight	Human *weight	Natural *weight	Adaptive index/rank
Abaji	0.33976	0.03253	0.22427	0.23016	0.03300	**0.17194 (1)**
AMAC	0.22650	0.03125	0.01982	0.14190	0.01181	**0.08626 (4)**
Bwari	0.37094	0.01486	0.02562	0.09518	0.09551	**0.12042 (3)**
Gwagwalad	0.00000	0.00000	0.00000	0.00000	0.03300	**0.00660 (6)**
Kuje	0.31349	0.05661	0.10295	0.25266	0.00000	**0.14514 (2)**
Kwali	0.03119	0.00359	0.04882	0.14017	0.03994	**0.05274 (5)**

Source: Author, 2018

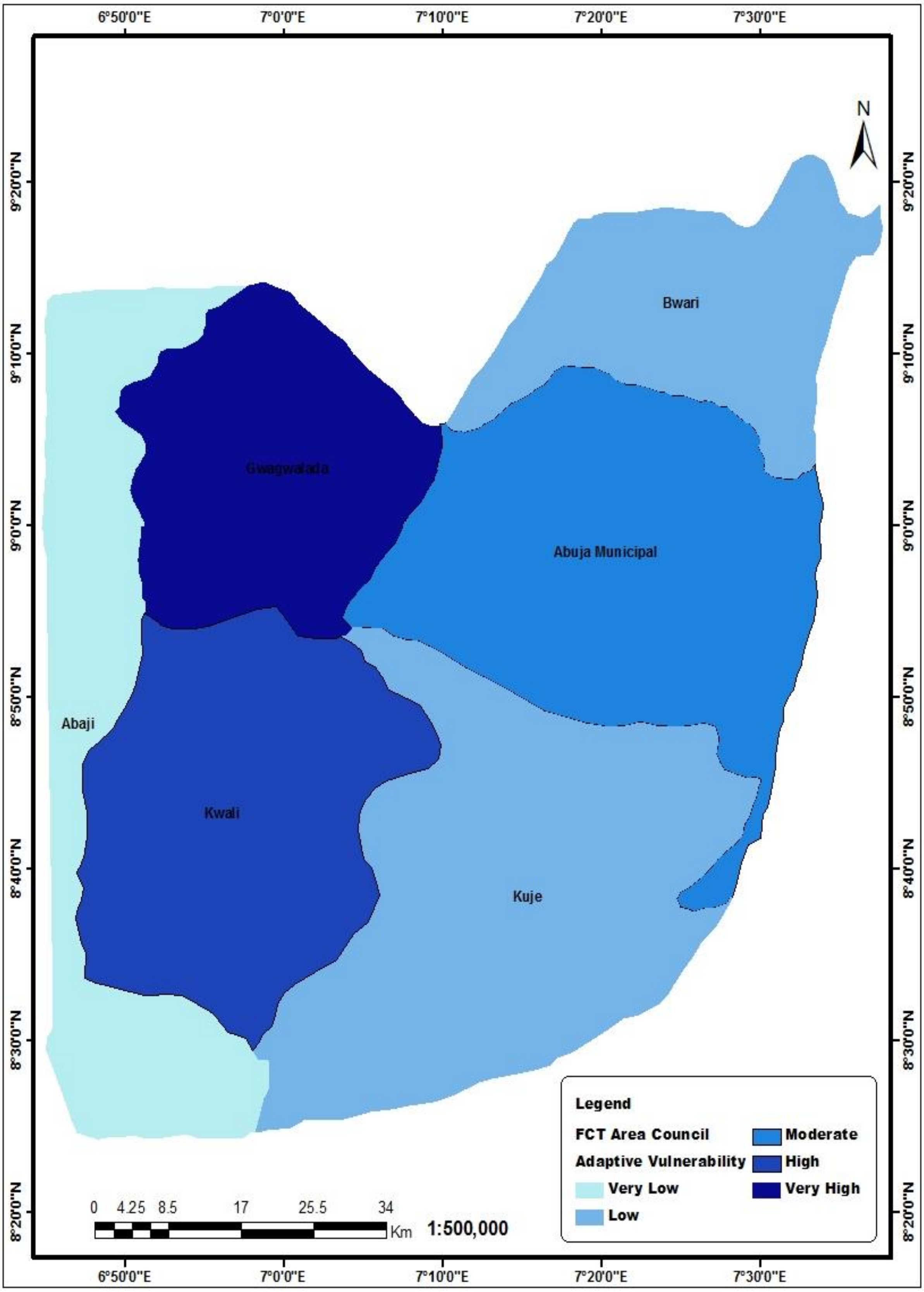

Fig. 9. Adaptive capacity of FCT area councils to climate variability
Source: Author, 2018

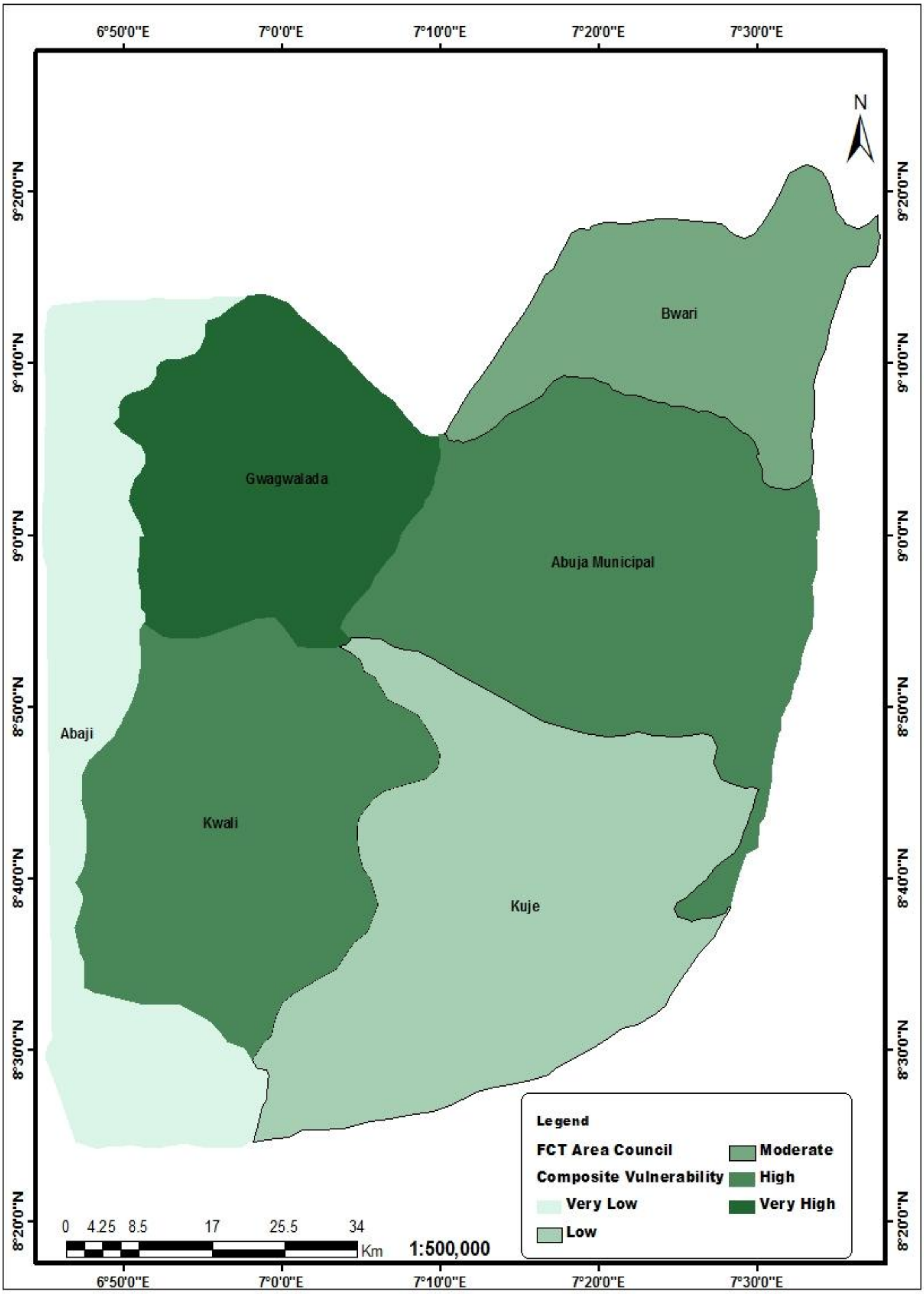

Fig. 10. Composite vulnerability of FCT area councils to climate variability
Source: Author, 2018

Table 16. Composite vulnerability index of FCT area councils

Area councils	Exposure index	Sensitivity index	Adaptive index	CVI/rank
Abaji	0.087	0.101	0.172	**0.0161 (6)**
AMAC	0.137	0.119	0.086	**0.170 (2)**
Bwari	0.167	0.060	0.120	**0.107 (4)**
Gwagwalada	0.113	0.122	0.007	**0.229(1)**
Kuje	0.130	0.042	0.145	**0.027 (5)**
Kwali	0.115	0.099	0.053	**0.161 (3)**

Source: Author, 2018

4. FINDINGS

The mean monthly temperature in FCT Area Councils (Table 2) showed that Kwali Area Council has the highest temperature of 32.72^{0}C in the month of March while Bwari Area Council has the least temperature of 22.59^{0}C in the month of August of the study period. The mean temperature in FCT for the study period was 27.79^{0}C. Bwari Area Council has the highest rainfall of 445.02 mm, relative humidity of 88.12% in the month of August and potential evapotranspiration of 6.12 mm in the month of February while Abaji Area Council has the least rainfall of 0.12mm, relative humidity of 27% in the month of December and potential evapotranspiration of 2.69mm in the month of August. Mean annual rainfall and relative humidity in FCT during the study period were 1503.11mm and 59% respectively while the mean potential evapotranspiration was 4.16mm. The trend analysis of both annual temperature and rainfall data during the period showed that temperature was on increasing trend while rainfall was on reducing trend.

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 (valid) at 95% confidence level as chance occurrence was ruled out. The calculated T 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 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 [43] on the relationship between temperature and rainfall variability in the Levubu sub-catchment, South Africaand Madden and Williams (1978) 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 (valid) 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. Soil erosion varies negatively with temperature 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.

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 soil organic carbon varies negatively low with temperature at a correlation coefficient of -0.30. 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 table 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

The continuous increase in temperature and decrease in rainfall in FCT has little or no influence on the production of the selected crop in FCT. The correlation analysis of the selected crop (maize, beans and yam) and climate variables (temperature, rainfall and relative humidity) showed that crop production was on increasing trend despite climate variability. This was also confirmed by the crop production data (1990 - 2017) obtained from the FCT Agricultural Development Project (ADP). The study corroborated the work of Hassan [19] who attributed the increasing crop production to length of raining season (LRS) and the population involved in agriculture. The increasing trend in crop production could also be attributed to improvement of crop technology.

When consideration is based on exposure, sensitivity and adaptive capacity of farmers, Bwari Area Council recorded the highest exposure in terms of rainfall, relative humidity and potential evapotranspiration while Abaji Area Council recorded the lowest. On the average, none of the Area Councils have a threshold value below 1 in exposure. 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 rainfall/precipitation stressor as the index values of all the Area Councils are more than one. On yearly basis, there are variations. In term of sensitivity, Gwagwalada Area Council has the highest and Kuje Area Council has the least. The result on adaptive capacity showed that Abaji Area Council has the highest adaptive capacity while Gwagwalada Area Council has the lowest adaptive potential.

The Composite Vulnerability Index (CVI) map showed that Gwagwalada Area Council has the highest vulnerability while Abaji Area Council has the lowest. Kwali and AMAC Area Councils recorded high vulnerability. Bwari has moderate vulnerability while Kuje Area Council has low vulnerability.

The overall implication of these findings is that farmers in Gwagwalada with very high vulnerability are in urgent need of assistance on the modalities of boosting their adaptive potentials. They need expert support in human, physical, financial, social and natural capital development to be able to overcome the impact inherent in climate variability. The same applies to farmers in AMAC and Kwali. Bwari with moderate vulnerability requires some level of external assistance to overcome the variability, while Kuje will adjust and prevail to the given variability by using their assets and do not need external assistance. Abaji doesn’t require any level of external assistance.

5. CONCLUSION

The study has confirmed that the most vulnerable areas are those with high climate exposure and sensitivity, but low adaptive capacity. This was observed in Gwagwalada Area Council. Gwagwalada, the most vulnerable Area Council in FCT was high in climate exposure and sensitivity but very low in adaptive capacity. Abaji, the least vulnerable Area Council has low climate exposure and sensitivity but highest in adaptive capacity.

The composite vulnerability index developed through the integrated approach helped to overcome the inherent problems associated with individual indicators in terms of precision, reliability, accuracy and validity. The study has also demonstrated the capability of geospatial technology (Geoinformatics) in cropland vulnerability studies. The potentials of integrated analytical methods (multi-indicator) in handling vulnerability studies due to its ability to combine biophysical, socio-economic and meteorological data to assess cropland vulnerability was also demonstrated in the study.

6. RECOMMENDATION

Although, it was observed that climate variability has little or no influence in crop production in FCT from this study, the following recommendations are articulated to overcome the occurrence of extreme climate events in the future.

1. Farmers in Kwali and Gwagwalada area councils should be encouraged to plant trees at intervals in their farms as this will provide shade and improve water infiltration into the soil.
2. Agriculture should be heavily subsidized in FCT in terms of providing irrigation infrastructure to farmers in Gwagwalada to reduce over reliance on rain fed agriculture.
3. Microcredit scheme should also be made available to farmers to boost their agricultural production output.
4. Diversification into off-farm activities by farmers should be encouraged so that they can have enough financial assets to boost their farm activities in times of failure and

overcome the adverse effects of climate variability.

5. Early weather warning system manned with competent hands should be made available in all the Area Councils to provide timely and accurate information to farmers when the need arises.
6. Physical infrastructures like schools, health care facilities and market should be provided for the farmers to improve on their adaptive capacities.
7. The indigenous adaption measures to climate variability by farmers in each Area Council should be encouraged.
8. Farmers should also be trained on sustainable agricultural practices to preserve and protect croplands from the negative impact of climate variability

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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