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Risk Assessment of Climate Variability in the Federal Capital Territory, Abuja, Nigeria

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Abstract

Studies have revealed that the earth is undergoing changes in climate in terms of variations in precipitation and temperature in different parts. These variations have been likened to exponential growth, rapid industrialization, urbanization and transportation in these parts of the earth, causing enormous stress on energy consumption. These have resulted in increased anthropogenic greenhouse gas emissions such as carbon (IV) oxide, methane, nitrous oxide and sulphur oxide. The Federal Capital Territory (FCT), capital of Nigeria – a West African country- is experiencing huge economic growth and as such increased carbon emissions from human activities. Recent studies suggest that the FCT is experiencing diminished average rainfall as well as incidence in floods. This study was therefore set to carry out a risk assessment of rainfall and temperature in the FCT from 1983 - 2010.The purpose of the study is to assess the risks of climate (rainfall and temperature) variability in the Federal Capital Territory by assessing the characteristics of rainfall and temperature in the FCT from 1983 – 2010; determining the trend of rainfall and temperature in the FCT; Identifying the climatic variable(s) that pose significant climate hazard in the FCT; Using a risk analysis technique to determine the risks their likelihood of occurrence and evaluating the risks/ vulnerabilities of the human inhabitants to the climate risks in the FCT. The methodologies adapted for this study is the New Zealand risk assessment method of 1999 which consists basically of three stages; i) Hazard Identification (ii) Risk Analysis (iii) Risk Evaluation. Major findings of the study include; that the climate of the FCT is changing; that total annual rainfall of the FCT has increased significantly with a decadal variability rate of up to 33.5% posing grave risks to the livelihood of the inhabitants; that the risk of flood occurrence in the FCT is moderate; that the present trend of climate pose the most risks on the health of the inhabitants of the FCT; that the adaptive capacity of the FCT to the present trend of rainfall and temperature is very low leaving the inhabitants of the FCT highly vulnerable.

1. Introduction

Of great concern to human life and the ecosystem are the risks associated with changes in climate. Evidences from studies and of observed changes in climate include the rising sea levels, reducing snow cover within the northern hemisphere, increased temperature records and reports of increased desertification by low average annual soil moisture, runoff and rainfall especially in northern, western and southern parts of Africa [1]. These evidences of changes in climate experienced around the earth results from events of climate variability or climate change.

In scientific literature, the usage of the terms; climate variability and climate change are rather synonymous especially in the context of environmental policy; however, they differ in definition. Climate change represents an alteration in the statistical distribution of weather over a lengthy time period (from decades to millions of years). It can also be described as a variation in the average weather or a change in the distribution of average weather activities [2] [3] [4]; On the other hand, climate variability represents a fluctuation in the statistical distribution of the weather of a particular region over a short time period; years to decades, such as weather events initiated by the El Nino and SO (southern oscillation) or the North Atlantic oscillation [5]. Climate variability has been described as a change in the earth's weather from region to region or place to place creating a variety of environments.

Exponential population growth, rapid industrialization, urbanization and transportation, causing enormous stress on energy consumption in cities around the world, has culminated in elevated anthropogenic greenhouse gas emissions (GHG) such as carbon (IV) oxide (CO_2), methane (CH_4), nitrous oxide (NO_x) and sulphur dioxide (SO_2) [2] [3] [4]. The increased atmospheric levels of these greenhouse gases are bound to cause significant variations in daily, seasonal, inter-annual and decadal climatic variability. Historically, meteorological records over the last few decades have revealed a changing global climate attributed to human-induced emissions. [4] projected a rise of 1.4 °C to 5.8 °C in the global temperature by the end of this century. It also predicted a considerable increase in sea level, risking the inundation of the low lying coastal areas. The World Health Organization (WHO) has attributed more than 150,000 deaths with 5 million "disability–adjusted life years" (DALYs) to diseases emanating from varying climatic conditions in the last three decades [6]. With these statistics and statements, climate variability is poised to have increased direct and indirect risk on human health and the environment through various mechanisms. A risk assessment of these different direct and indirect risks and their pathways and mechanism of action would ensure the well being of humans on earth. Risk assessment is referred to as the determination of the probability of occurrence of consequences/risks from an identified hazard and the subsequent management of these consequences/risks [7]. Risk assessment or its management has been described as the process of identifying, analysing, and evaluating or implementing actions to reduce risk to human health and to ecosystems [8]. The terms; risk assessment and risk management are both used to describe the whole process/framework or specific parts of the framework, where risk assessment encompasses an analysis phase and risk management an implementation phase [9]. Due to the inconsistent usage of these terminologies in scientific literature, both terms; risk assessment and risk management has been regarded as been one and the same. However, with regards to consistency the term risk assessment would be adopted in this study. This study follows the Australian and New Zealand Risk Management Standard (Standards Australia and Standards New Zealand, 1999) in ascribing the terms risk analysis where a level of risk is assessed, and risk treatment/ evaluation where a level of risk is reduced through planned intervention. Risk itself is defined by the US Presidential/Congressional Commission on Risk Assessment and Risk Management (USPCC RARM) as the probability that a substance or situation will generate harm under specified conditions. Risk is a combination of two factors: The probability that an adverse event will occur and the consequences of the adverse situation [8].
Risk analysis is the process of assessing these two factors. Risk evaluation/ treatment (sometimes referred to as risk management) is applied to reduce the consequences of adverse events identified by risk analysis.

The population and population growth of an area with regards to carbon emission, has direct correlation with the fluctuation of climate parameters of that area [2] [3] [1]. Hence upon careful observation and proper review of recent studies the researchers gathered that the population of the FCT is growing at an all time high, primarily due to the fact that the FCT is the capital of Nigeria and as such reserves huge economic opportunities for better living standards [10]. This rapid population growth implies a surge in carbon (IV) oxide emission from auto mobiles, generators, deforestation and construction of roads and buildings in the FCT. With this increase in carbon (IV) oxide emission there is bound to be some fluctuation in the climatic parameters of the FCT regardless of its latitudinal and longitudinal.

[11] examined climate variability and crop yield and observed that the FCT experienced diminishing amounts of rainfall from 1986 – 2005. The author emphasized on the need for improved agricultural input within the FCT as population growth is bound to distort climate variables and consequently impact crop yield in the territory. Also worrisome is the incidence of flash floods in the last decade which claimed lives and destroyed agricultural farmlands and property [12]. Nigerian Meteorological Agency (NIMET) and the daily times newspaper both reported that these floods displaced people exposing them and making them vulnerable to a number of health threatening factors an occurrence never experienced in the preceding decades [13] [14].
Having initiated a global, regional and national experiment on climate variability and change, it would not be advisable to wait decades for sufficient empirical evidence to describe the consequences on a local scale. It is therefore important to carry out risk assessment of climate variability on human inhabitants at the local level, to fill in the gap (using the Federal Capital Territory (FCT) as a case study) as research is inadequate at this level.
It is also necessary to carry out a risk assessment of climate variability on the human inhabitants of the FCT as part of a proactive approach in line with the tenet of the Bruntland Commission of 1985, the 1992 Rio Summit and the 1997 Kyoto Protocol for sustainable environmental development. The health risks and implications of not conducting a risk assessment of climate variability could be catastrophic and have multiplier effect [11].Therefore, the study is aimed at creating public awareness with specific reference to the immense potential of risk assessment as a tool for mitigating and adapting to future scenarios.

2. Methodology

2.1 The Study Area

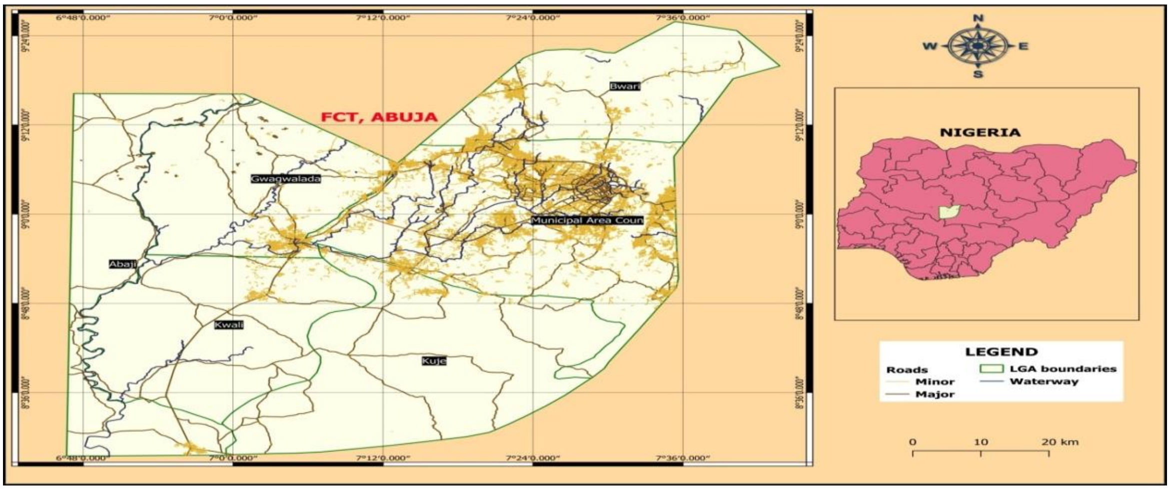

Figure 1: Map of the study area
(Source: Researchers, 2010)

2.2 Location and Size

The Federal Capital Territory (FCT) is the capital of Nigeria. It was created in 1976 and officially became Nigeria's capital on December 12, 1991. The FCT territory is located in the middle of the country and has a land area of 8,000 square kilometers. The FCT is bounded by Kaduna State on the northern axis, on the west by Niger State, on the east and south-east by Plateau State, and on the south-west by Kogi State. The territory falls within latitude 7° 25' N and 9° 20° North of the Equator and longitude 5° 45' and 7° 39' E [10].

2.3 Data Type and Source

The research relied primarily on secondary quantitative data analysis adapting the Australian and New Zealand risk assessment standards /method of 1999. The standard/method involves three processes namely; Hazard identification, Risk analysis and Risk evaluation. Quantitative data was most relevant for analysis in this study because of their peculiarity and more so to the method and techniques adopted. The analytical method and techniques adopted in this study is the most suitable because they aim to investigate issues in-depth instead of providing simple superficial description of the issues [15].

The researchers assessed daily rainfall and temperature records of the Federal Capital Territory (FCT) for 27 years (1983 – 2010) compiled by meteorologists of the Nigerian Meteorological Agency (NIMET). More importantly was the fact that NIMET has synoptic stations. Synoptic stations are stations occupied by full time professional observers who conduct continuous monitoring of weather events and make hourly instrumental observation of weather elements on which data is needed for synoptic chart compilation or weather maps utilized in weather forecasting [16].

2.4 Data Collection

At NIMET stations, observation is made at specific observing hours. Primary synoptic hours are 0000 (midnight), 0600 (6am), 1200 (noon) and 1800 (6pm) Greenwich mean time. Additional observations were made at other times between the four main times, often hourly or at three hours intervals. This procedure is in line with World Meteorological Organization (WMO) standards [17]. Daily rainfall and temperature measurements were taken by NIMET meteorologists and averages drawn to give daily readings which were inputted as data into the computer for record keeping. The temperature data of the study area was taken using a thermometer. The thermometer was used to determine the temperature of the surrounding air. The rainfall data of the study area was taken using rain gauge. The amount of rain that falls ata specified time is expressed as the depth of water it would produce on a large, level impermeable surface. Data was expressed in millimetres. Rainfall measurement was conducted on a daily basis. Prior to rainfall measurements, certain precautions were put in place to counter the effects of obstructions, wind, splashing and evaporation for accurate data collection.

2.5 Data Analysis

Mean and standard deviation were used to examine the individual climate parameters. Temporal comparisons were carried out to test for significant differences in the climatic parameters using analysis of variance (ANOVA). If significant value ($P \leq 0.05$) were obtained in the ANOVA, Duncan multiple range (DMR) test was performed to determine the location of significant differences. To assess the time series-climatic parameters relationship, regression analysis was adopted. The climatic parameters were taken as the dependent variable while the time series represented the independent variable. The ANOVA and regression were performed using SPSS excels respectively. All analyses were considered significant at 95% confidence level.

2.6 Method of Risk Assessment Adapted/ Procedure of Analysis
The risk assessment method adapted for analysis in this study involves three stages as follows;

2.6.1 Hazard Identification
This was the first and crucial stage of the method because unless a hazard is identified it will not be considered for consequent risks. This step sought to determine the climate character that pose significant hazard.

2.6.2 Risk Analysis
This stage of the method sought to analyze the climate variable(s) identified to pose significant climate hazard by determining the consequent risks, their likelihood of occurrence as well as classify the risks. This was carried out using the event tree technique.

2.6.3 Risk Evaluation
This is the final stage of the method and it is centered on what is to be done in terms of specific management strategies to reduce and/ or adapt to the determined risks and their likelihood of occurrence as well as reducing the vulnerability of the human inhabitants to the climate risks.
Furthermore, the significance level of the variables was classified using a risk matrix to ascertain the risk level as shown in Table 1

Table 1: **Risk Matrix showing Risk levels**

STATISTICAL SIGNIFICANCE/ PROBABILITY OF OCCURENCE (Threshold values)	RISK LEVEL
0.00 – 0.024 or (0 – 2.4%)	Low
0.025 – 0.044 or (2.5% – 4.4%)	Moderate
0.045 ≈ 0.05 – 1 or (4.5% ≈ 5% - 100%)	High

Where tilde (≈) indicates approximately.

3.Results and Discussion

3.1 Climate Character (s) that Pose Significant Climate Hazard in the FCT

Table 2: **Relevant Climate characters and their respective Risk Level**

Climatic Variables	Standard Deviation	Statistical Significance	Risk Level
Total Rainfall	176.23	0.1201 or 12.01%	High
Average Rainfall	25.03	0.1513 or 15.13%	High
Maximum temperature	0.4	0.0121 or 1.21%	Low
Drought Index	0.015	0.0171 or 1.71%	Low

KEY: Where Significant = P = ≤ 0.045 ≈ 0.05 – 1 or (4.5% ≈ 5% and above) = High Risk

The results presented in Table 2 showed that out of the relevant climate variables assessed for the period under review, maximum temperature and drought index had low levels of risk as a result of climate variability in the FCT while total rainfall and average rainfall had statistically significant variability (up to 5%) which according to the risk matrix depicts high risk levels, making the climate variables that pose significant hazard to the FCT residents. However, the results from the time series analysis further revealed risk levels of the climate variables.

Table 3: **Total Rainfall Statistics**

Study Period	Total Rainfall	Mean	Rate of Variability (Standard Deviation)	Statistical Significance	Risk Level
1983–1990	11112.08	1389.01	126.26	9.08	High
1991- 2000	14420.09	1442.09	140.90	9.77	High
2000 –2010	15524.4	1552.44	202.71	13.05	High

Table 3 showed that there was progressive and significant increase in the risk level and rainfall totals experienced in the FCT from the first decade through the third decade. It also revealed that total rainfall volume increased considerably from 11112.08 mm in the first decade to 14420.09 mm in the second decade, with increased variability rate of 9.08% to 9.77% respectively. It also showed that total rainfall increased from 14420.09 mm in the second decade to 15524.4 mm in the third decade with even more alarming increase in variability rate from 9.77% to 13.05% respectively representing a 33.5% increase in its risk level. These increases in total rainfall amount and variability rate imply that there is a lot of rainfall at a particular time, meaning that the FCT is experiencing increased rainfall intensity. This in itself puts in perspective the reason for the incidence in floods and subsequent degradation of land by erosion in the FCT. It is important to note that increased rainfall does not translate to adequate rainfall distribution which is particularly important in agriculture [18] [11]. The risks of increased rainfall totals are grave and are experienced today in the FCT and around the world [1]. FCT residents are therefore at high risks of increasing total rainfall amounts.

Table 4: **Average Rainfall Statistics**

Study Period	Mean	Rate of Variability (Standard Deviation)	Statistical Significance	Risk Level
1983–1990	148.66	24.78	16.66	High
1991- 2000	173.19	23.20	13.39	High
2000 –2010	170.86	26.93	15.76	High

Table 4 revealed that average rainfall varied upward from 148.66 mm in the first decade to 173.19 in the second decade. However, there was a decline in the rate of variability from 16.66% to 13.39% respectively indicating a reduction in the risk levels. This is said to be good especially for agriculture because the farmers during the second decade experienced improved and greater crop yield compared to the first decade [11]. This trend can be attributed to the increased average rainfall and a decline in its variability. However, the third decade experienced a slight decline in average rainfall and an increase in variability rate resulting to increased risk levels. Though there was a decline in average rainfall from the second decade to the third and an increase in their respective variability rates, the figures remain better than those of the first decade. Table 3 data also revealed that the FCT is in no eminent threat of progressive and significant risk levels from the average rainfall; unless of course total rainfall continues to increase as shown in Table 3, but this time with reducing rate of variability thereby resulting in the frequency of flood and related disasters.

Table 5: **Average Maximum Temperature (^{O}C) Statistics**

Study Period	Mean	Rate of Variability (Standard Deviation)	Statistical Significance	Risk Level
1983–1990	32.59	0.3	0.92	Low
1991- 2000	33.16	0.37	1.11	Low
2000 –2010	32.93	0.29	0.88	Low

Table 5 revealed that the average maximum temperature of the FCT increased from 32.59 ^{O}C in the first decade to 33.16 ^{O}C in the second decade. The first decade also saw its variability rate increase from 0.92% to 1.11% in the second decade. This increase in temperature and variability rate experienced in the FCT in the second decade was also recorded around the earth as been the hot decade of the century [1]. However, due to the location of the FCT, its climate is tropical meaning it experiences lots of sunshine leading to temperatures that are high but not extreme (40 ^{O}C and above) [16]. The average temperature and variability rate as shown in Table 4 indicated that the FCT residents are not vulnerable to physiological dysfunctions, heat strokes, heat exhaustion and heat cramps and ocular cataract judging from parameters [19]. However, it must be noted that excessive ultraviolet ray exposure from sunlight is hazardous to the human skin and could cause skin burns and skin cancer [16]. However, this may also vary with skin texture and duration of exposure. The FCT is located in Sub-saharan Africa and as such its residents are largely dark skinned. Dark skin is a consequence of increased dermal layer melanin production and this helps to reduce effectively the risks/ vulnerability to ultraviolet ray exposure. However specific clothing type such as cotton should be worn by the FCT residents to reduce ultraviolet ray expose as well help improve thermal comfort. In terms of agriculture, crops such as cereals, legumes and fruits grown in the FCT would continue thrive because the average temperature is still within adequate thermal range for crop production [18] [11].

Table 6: **Drought Index Statistics**

Study Period	Drought Index	Rate of Variability (Standard Deviation)	Statistical Significance	Risk Level
1983–1990	0.883	0.0111	1.25	Low
1991- 2000	0.876	0.0118	1.34	Low
2000 –2010	0.884	0.0190	2.14	Low

Where Drought Index (Hassan, 2008): Threshold values;
= < - 2.8 --------------- Severe
= ≥ - 2.8 to ≤ 2.8 ---- Optimum
= > 2.8 --------------- Saturated

Table 6 revealed that even though the drought index for the first decade varied downward from 0.883 to 0.876 in the second decade, its variability rate increased from 1.25% to 1.34%. Table 6 also showed that the drought index experienced an increased from 0.876 in the second decade to 0.884 in the third decade, as well as an increase in their respective rates of variability. The progressive however not significant increase in variability rate as shown in Table 5, is explained by the continuous increases in the rate of variability of total rainfall with average rainfall and its variability rate not nearly enough to stabilize evapotranspiration in the FCT. However, what is to be noted from table 5and 6 is that even though there was a progressive increase in the rate of variability and risk level within the decades, it was not significant and the risk levels remained low throughout the study

period. The drought index for the study period was within the drought index range of -2.8 to 2.8 as developed by [11]. This in other words means that the FCT is at no risk of agricultural drought.
These findings were similar to a report by [11] which stated that the average rainfall of the FCT is on the decline the drought index is still within normal range and agricultural crop yield is not in eminent risk of drought. The author also stated that even as average rainfall declined, the crop grown (maize, cowpea, soyabean, groundnut, cassava and yam) within the six (6) council areas of the FCT continued to see an increase in their production. This however may be attributed to increased intensity of farming practices in the FCT and/ or the fact that the average rainfall received in the FCT is still within range for the optimum production of crops grown in the area, likewise that of average temperature [16] therefore posing no or low risk to the human inhabitants of the FCT.
The results of the time series analysis showed that total rainfall was the climate variable identified to pose significant climate hazard to the FCT residents because of the progressive and significant increase in its variability rate. This progressive and significant increase variability of total rainfall in the FCT has the potential of leading to a permanent change in the total rainfall and subsequently average rainfall experienced in the FCT resulting to frequency in flood and related disasters. Results of risk analysis of total rainfall variability conducted to determine the consequent risks on the FCT residents is presented as follows;

3.2 Risks and their Likelihood of Occurrence

Scenario 1a: Above average total rainfall (qualitative analysis)

Figure 2 is a qualitative event tree analysis considering a scenario of above average total rainfall in the FCT

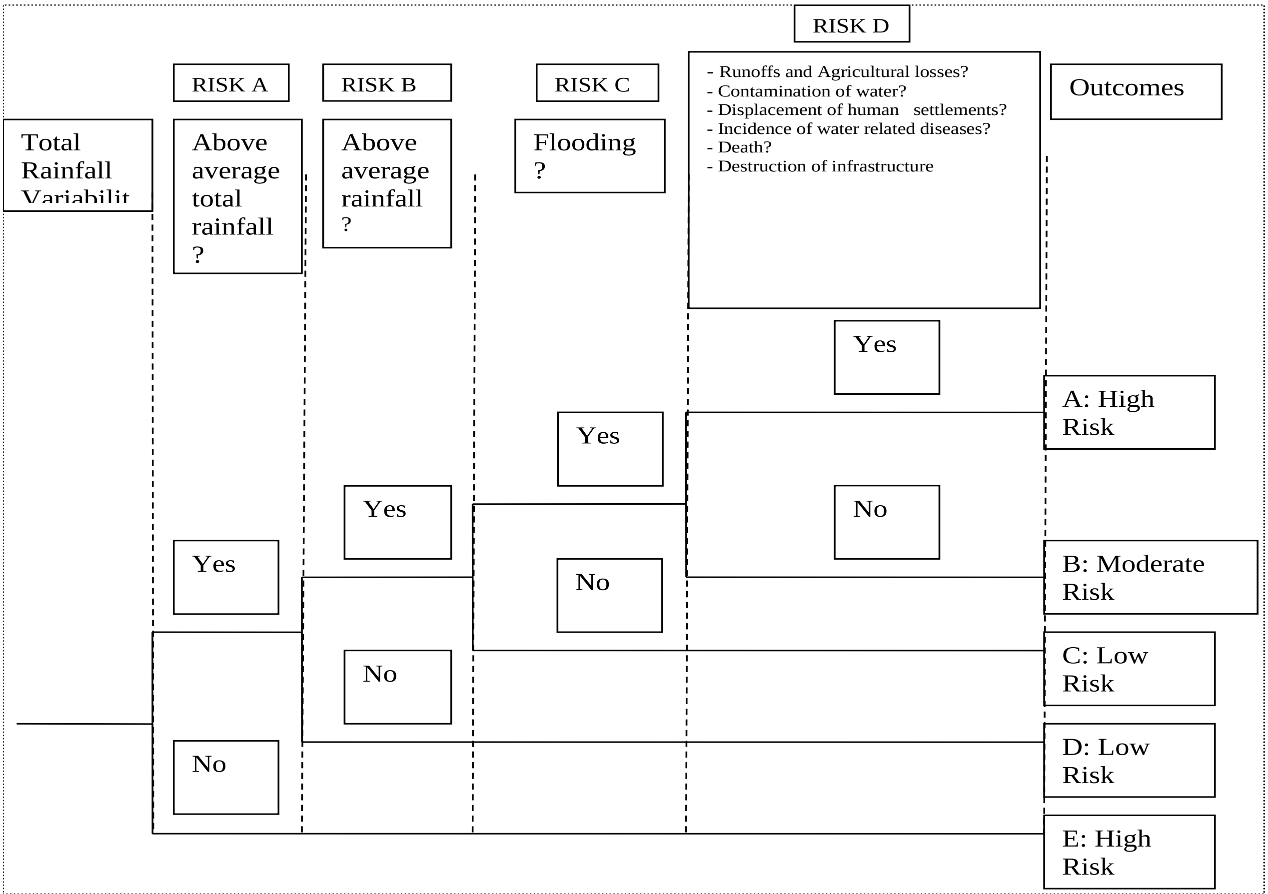

Figure 2 Qualitative event tree analysis of above average total rainfall in FCT, Nigeria

The qualitative event tree analysis (Figure 2) showed there is a probability of high risk (outcome A) from an event of "RISK D". It also shows there is moderate risk when there is an event of flooding but no event of "RISK D". In this case there may be little harm done to other aspects of the ecosystem. Outcome C showed a low risk in a case where there is above average rainfall but no flooding. Outcome D showed a probability of low risk in the event of above average total rainfall but no above average rainfall. Finally outcome E depicted a case of high risk where is below average total rainfall.

Scenario 1b: Above average total rainfall (quantitative analysis)

Figure 3 is a quantitative event tree analysis considering a scenario of above average total rainfall in the FCT

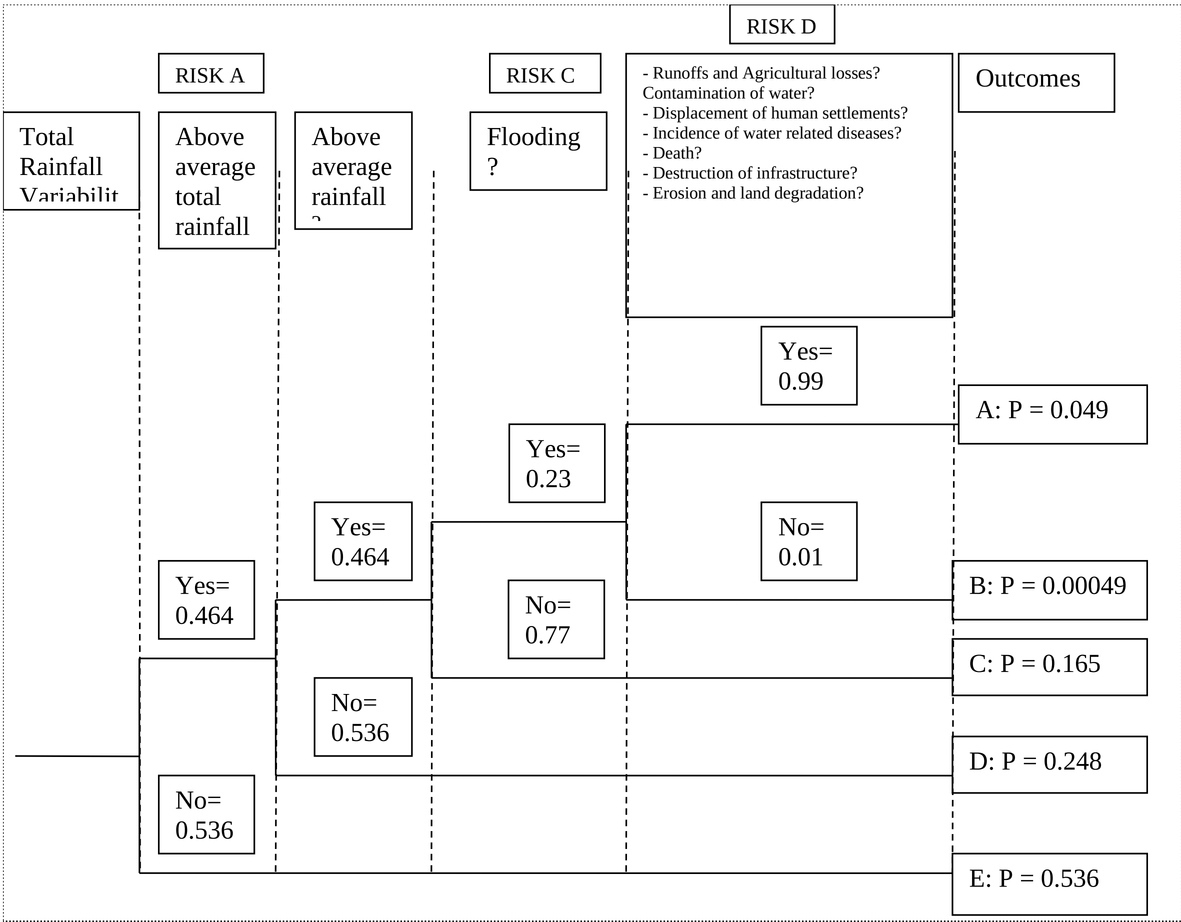

Figure 3 Quantitative event tree analysis of above average total rainfall in FCT,

Key:

STATISTICAL SIGNIFICANCE/ PROBABILITY OF OCCURENCE (Threshold values)	RISK LEVEL
0.00 – 0.024 or (0 – 2.4%)	Low
0.025 – 0.044 or (2.5% – 4.4%)	Moderate
0.045 ≈ 0.05 – 1 or (4.5% ≈ 5% - 100%)	High

Where tilde (≈) indicates approximately

Looking at the event tree analysis in figure 3, there were a number consequent risks/ outcomes leading from above average total rainfall from an event of total rainfall variability which were considered as follows;

A) A 0.049 probability of "RISK D" occurrence from an event of above average total rainfall from total rainfall variability in the FCT annually. The implication of this was that the human inhabitants of the FCT are at high risk of 4.9% of "RISK D" in the event of an above average total rainfall in the FCT.

B) A 0.00049 probability of flooding without "RISK D" from above average total rainfall in the event of total rainfall variability in the FCT. This represented a 0.049% chance of flooding without "RISK D". The implication of this is a 99.95% confidence (High risk) that there will be an occurrence of 'RISK D' impacting the livelihood of the human inhabitants of the FCT whenever there is flood occurrence.

C) A 0.165 probability of above average total rainfall without flooding from above average total rainfall variability in the event of total rainfall variability in the FCT, meaning there is a 16.5% chance of having above average total rainfall without flooding in the FCT.

D) A 0.248 probability of above average total rainfall without above average rainfall in the event of total rainfall variability in the FCT, meaning there is a 24.8% chance of having above average total rainfall without above average rainfall in the FCT.

E) Represents a 0.536 probability of below average total rainfall in the event of total rainfall variability in the FCT. This represents a 53.6% chance of below average total rainfall in the FCT annually.

Furthermore, the analysis showed that the probability of flood occurrence in the event of total rainfall variability is 0.049. These outcome probabilities are conditional upon the event of above average total rainfall. Therefore, to estimate the probability of flooding in the FCT for the period under review in the event of total rainfall variability, the probability of flood occurrence in the event of above average total rainfall was multiplied by the probability of the event below average total rainfall which gave 0.026 probability of flood occurrence in the FCT. While to estimate the probability of "RISK D" in the event of total rainfall variability for the period under review, outcome A (probability of "RISK D" in the event of above average total rainfall) was multiplied by the probability of below average total rainfall which gave 0.026 probability of "RISK D" in the event total rainfall variability in the FCT.

In essence, these statements implied that there was a 4.9% risk (high risk) of flood in years where above average total rainfall is expected in the FCT; and a 2.6% risk (moderate risk) of flooding in the FCT as a result of total rainfall variability. Similarly, there was a 4.9% risk of "RISK D" from an event of above average total rainfall in the FCT and a 2.6% risk of "RISK D" from total rainfall variability. This implied that there is high risk of 'RISK D' impacting the human inhabitants in the FCT from flood occurrence in years where above total average rainfall is expected while there is a moderate risk of its impact on the human inhabitants of the FCT from flood occurrence in event of total rainfall variability in the FCT.

Scenario 2: Below average total rainfall (qualitative analysis)

Figure 4 showed a qualitative event tree analysis determining possible risks from an event of below average total rainfall.

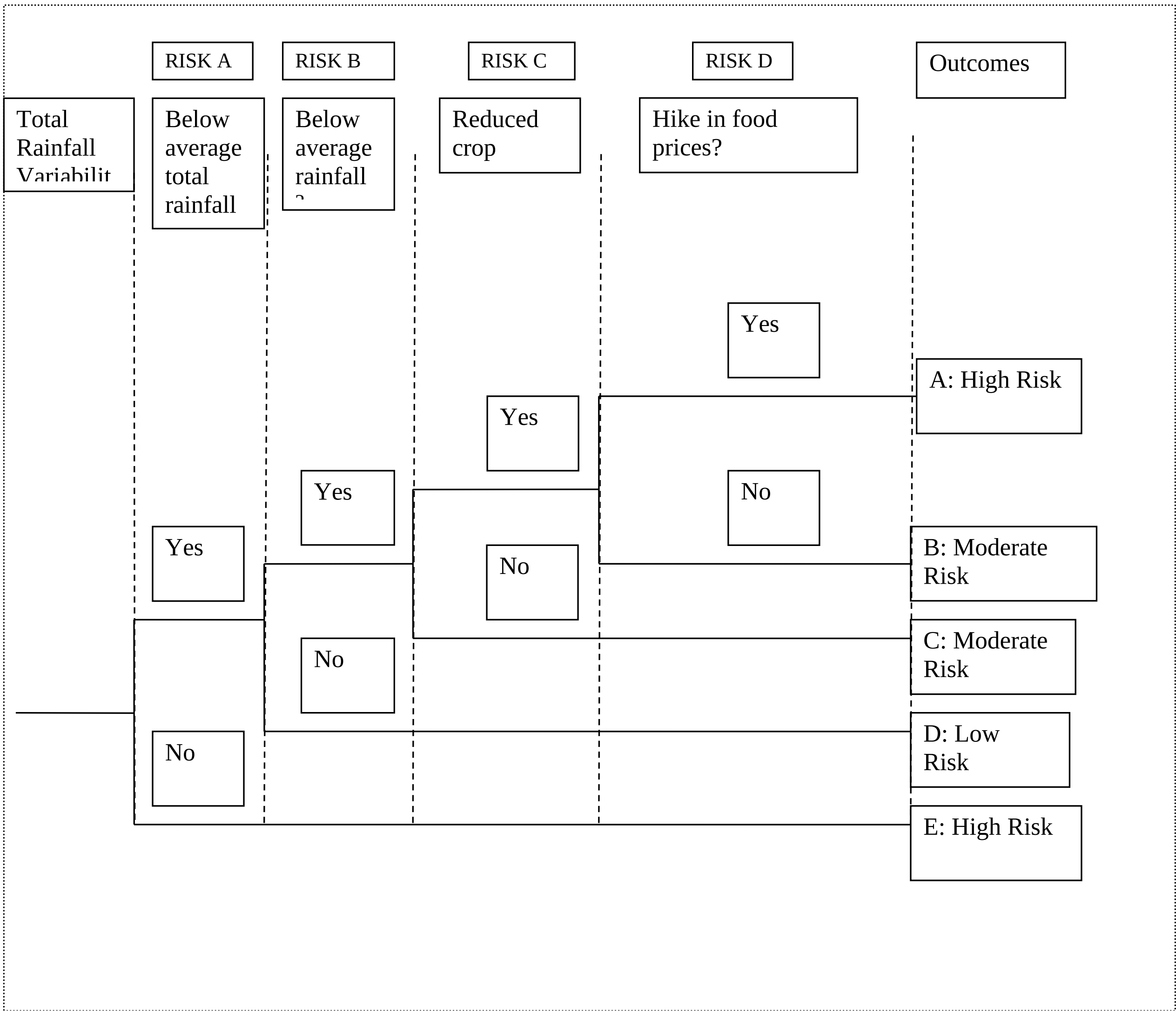

Figure 4 Quantitative event tree analysis of below average total rainfall in FCT, Nigeria

Outcome A in Figure 4 shows a probability of high risk when there is a case of hike in food prices resulting from reduction in crop yield. Outcome B shows that when there is reduction in crop yield but no increase in food prices there are moderate risk. Outcome C reveals a probability of moderate risk in the event of below average rainfall but no reduction in crop yield. Outcome D depicts that there are low risk in a case of below average total rainfall without below average rainfall. Outcome E showed that there is high risk in cases of above average total rainfall. On the other hand a quantitative event tree analysis for below average total rainfall could not be considered for the FCT because according to NIMET and ADP there has not been a case of prolonged below average rainfall leading to agricultural drought and whenever there is rainfall deficit farmers augment with artificial sources. Usually the FCT does not have severe event resulting from below average total rainfall such as low productivity or scarcity of food [12]. Though the FCT deals with occasional increases in food prices this is a function of the supply and demand chain and/or the continuous surge in its human population. This could also indicate subsistence agricultural practice in the FCT or lack of interest of the population as well as on the part of government in agriculture to augment for the increasing population [11].

3.3 Risks/ Vulnerabilities of the Human Inhabitants to the Climate Risks in the FCT:

The evaluation of determined risks, their likelihood of occurrence and the vulnerability of the human inhabitants to the climate risks in the FCT was carried out (in terms of assessing and deciding what needed to be done to reduce and /or adapt to the climate risks) for both scenarios considered and results presented in terms of specific management strategies as follows;

3.3.1 Scenario 1: Above average total rainfall

In evaluating for the risks of above average total rainfall from an event of total rainfall variability, it is important to study the statistics of the study period. From Table 4, it was observed that the frequency of average total rainfall (1466.336 mm) increased steadily throughout the three groups (decades) of the study period. The first decade showed that the number of times above average total rainfall was recorded was three (3) while for the second and third decades it was four (4) and six (6) times respectively. Furthermore, flood incidence was recorded in the third decade just as maximal population growth occurred in the FCT [10]. These statistics and statements go to support the facts according to the IPCC that increased human activities directly or indirect influences the climate of a place [1]. However due to the location of the FCT, the risk of flash floods from the distortion of natural drains and inadequate drainage stand apparent to its suburb towns (Kubwa, Gwagwalada) as a result of population surge and poor urban planning.

As the FCT is experiencing a surge in its population growth year on year, its landscape has been impacted upon in an unprecedented fashion. The massive building and construction on daily basis has resulted in huge deforestation and loss of vegetation. On the other hand, the rate of occupation of land and subsequent deforestation causing distortions in the natural drainage and landscape of the FCT by the migrating population is not met by adequate planning on the part of government especially in the suburb towns of the FCT [14]. The implication of government inaction has increased the vulnerability/ risk of the population in these areas of the FCT whenever there is torrential rainfall. The vulnerability of the population to flooding in turn leads to increased risks of "RISK D" (runoffs and agricultural losses, contamination of ground water, incidence of diseases, and destruction of infrastructure, land degradation and even death). It is therefore both important and necessary for this study to recommend strategies that are sustainable to reduce and/ or adapt to the risks of above average total rainfall from an event of total rainfall variability in the FCT.
As earlier identified, population growth has direct influence on the variability of the climate of FCT, hence the study recommends that to cope with this phenomenon the following specific strategies should be taken toward reducing and/ or adapting to the risks of increasing total rainfall variability in the FCT;

Management Strategies

- Eliminating aged (above 10 years) automobiles from the roads of the FCT by introducing carbon emission taxes as it's the practice in the United Kingdom and other developed countries; and cushion the effects by providing mass transit buses that would convey more people at a time to their destinations with lower carbon footprint.
- As much as possible discourage driving by introducing road tax and parking tickets on private motorist. This will help in the reduction of cars on the road and consequently carbon emission. On the other hand, this would serve as wealth generation for government.

- ❖ Reduction of carbon emission from generators. This would be achieved effectively only by the provision of adequate electricity by government as it is done in developed and some developing economies. This is because even if tax is introduced on generators to discourage purchase an alternative has to be provided for or else people must find a way to go around having one.
- ❖ The idea of sustainable development should be taken seriously because even if there is massive deforestation resulting from construction of buildings and roads, it should be done in an environmentally sustainable manner. Therefore, coordinated urban planning must be conducted at all times and at all levels to ensure sustainable planning [4]. This will help in ensuring that when there is torrential rainfall, the rains find its way through properly constructed drains and prevent flooding of the environment and subsequently help in eliminating the occurrence of "RISK D".
- ❖ The FCT population should be encouraged to plant trees and shrubs in their homes, offices and road sites. This will go a long way in reducing atmospheric carbon (IV) oxide concentrations.
- ❖ The technique of cost benefit analysis should be applied to know the cost and benefits of taking decisions such demolishing houses on flood plains and natural drainages.
- ❖ Ultimately population growth must be put to check. This would be achieved by educating families on the advantages of having fewer children as is applicable in China. Also migration to the FCT from other parts of the country in search of better living standards should be checked, by providing the enabling environment for economic growth in those other parts of the country so as to make the FCT less attractive.

The following steps should be taken as contingency to prevent or reduce the occurrence of "RISK D" when the previously stated strategies fail to achieve their objectives;

- ❖ Flood defenses should be provided for flood prone areas to reduce the effects on agricultural farm land (prevention of surface runoffs and soil nutrient leaching), property loss, and destruction of infrastructure and displacement of human settlement.
- ❖ Also responsive emergency systems should be in place to attend to affected population in times of disaster to prevent or reduce the probability of death occurrence as well as in the rescue and evacuation of people trapped in their homes and offices.

3.3.2 Scenario 2: Below average total rainfall

In evaluating the risk of below average total rainfall from total rainfall variability, the indices from the study period revealed that the FCT has had improved rainfall distribution. Studies also indicated that the FCT has not experienced risk (reduced crop yield) from below average total rainfall in the last two decade [11]. It is however imperative to carry out an evaluation (as both a reactive and proactive approach) of the possible risks that could result from an event of below average total rainfall from total rainfall variability as shown in figure 4. The risk of below average total rainfall could be as disastrous as those of above average total rainfall. The specific strategies recommended by this study to mitigate and/ or adapt to these risks include;

Management Strategies

- ❖ Provision of alternative methods of water supply such as irrigation.
- ❖ Development of strategic water management through cutting edge research to develop hybrid crops that would thrive under such conditions.
- ❖ The education of farmers as to when to plant, how to plant and what crop to plant to achieve increased agricultural yield for the planting season.

Furthermore, in a case where the above stated strategies fail and “RISK A” (below average total rainfall) degenerates to “RISK B” (below average rainfall) farmers must take appropriate steps to provide alternative water supply, for example irrigation. However if this proofs futile and there is a case of “RISK C” (reduced crop yield) immediate steps should be taken by government in partnership with private sector to augment food supply in the FCT from other parts of the country, and then have it subsidized for the FCT consumers to prevent “RISK D” (hike in food prices). “RISK D” should be prevented at all cost because even though probability of its occurrence is low, it has serious consequences. Its consequences range from malnutrition, disease, death and food upheavals which have brought done governments. For example between June 2010 and June 2011, world grain prices almost doubled. In many places on this planet, that proved an unmitigated catastrophe. In those same months, several governments fell, rioting broke out in cities from Bishkek, Kyrgyzstan, to Nairobi, Kenya, and most disturbingly three new wars began in Libya, Yemen, and Syria. Even on Egypt’s Sinai Peninsula, Bedouin tribes were in revolt against the country’s interim government and manning their own armed roadblocks [20]. And in each of these situations, the initial trouble was traceable, at least in part, to the pricing of that loaf of bread. If these upheavals were not “resource conflicts” in the formal sense of the term, think of them at least as bread-triggered upheavals. However, these consequences could be prevented through the strategies earlier proffered.

3.4 Summary of Major Findings

The results from this research is in line with earlier reports by [11] [12] which indicated that rainfall variability is the most significant climate problem bedeviling both FCT residents in particular and in the West African region as a whole. Also significant is that the study revealed total rainfall as the climate variable with the most variability rate in the FCT, with increasing percentage variability within the decades of up to 33.5%. This study essentially shows that total rainfall pose the significant climate hazard to the human inhabitants of the FCT; and necessary strategies as recommended in the study should be taken as management measures to reduce and/ or adapt to the risks of total rainfall variability in the FCT. Other findings of the study include;

i) A 0.049 probability of “RISK D” occurrence from an event of above average total rainfall from total rainfall variability in the FCT annually. The implication of this is that the human inhabitants of the FCT are at high risk of 4.9% of “RISK D” in the event of an above average total rainfall in the FCT.

ii) A 0.00049 probability of flooding without “RISK D” from above average total rainfall in the event of total rainfall variability in the FCT. This represents a 0.049% chance of flooding without “RISK D”. This implies that there is a 99.95% confidence (High risk) that there will an occurrence of ‘RISK D’ impacting the livelihood of the human inhabitants of the FCT whenever there is flood occurrence.

iii) A 0.165 probability of above average total rainfall without flooding from above average total rainfall variability in the event of total rainfall variability in the FCT, meaning there is a 16.5% chance of having above average total rainfall without flooding in the FCT.

iv) A 0.248 probability of above average total rainfall without above average rainfall in the event of total rainfall variability in the FCT, meaning there is a 24.8% chance of having above average total rainfall without above average rainfall in the FCT.

v) Represents a 0.536 probability of below average total rainfall in the event of total rainfall variability in the FCT. This represents a 53.6% chance of below average total rainfall in the FCT annually.

vi) A 0.049 probability or 4.9% risk of flooding occurrence in the event of above average total rainfall

vii) A 0.026 probability or 2.6% risk of flood occurrence in the event of total rainfall variability in the FCT
viii) A 0.026 probability or 2.6% risk of “RISK D” in the event total rainfall variability in the FCT.

ix) The perception of the certainty of climate change in the FCT is “High”.

x) The health of the inhabitants of the FCT is most at risk to the changing climate of the FCT.

xi) The present trend of temperature in the FCT is “Very Highly” affecting human comfort.

xii) The adaptive capacity of the FCT towards the present trend of rainfall and temperature is very low.

xiii) The poor is most at risk of the changing climate of the FCT.

xiv) The effect of the present trend of rainfall is disastrous and catastrophic even though its increase is not perceived to be as high as that of present trend of temperature.

3.5 Implication of Findings

The findings in this study imply that there is 4.9% risk (high risk) of flood occurence in years where above average total rainfall is expected in the FCT; and a 2.6% risk (moderate risk) of flooding in the FCT as a result of total rainfall variability. Similarly, there is a 4.9% risk of “RISK D” from an event of above average total rainfall in the FCT and a 2.6% risk of “RISK D” from total rainfall variability. This implies that there is high risk of ‘RISK D’ impacting the human inhabitants in the FCT from flood occurrence in years where above total average rainfall is expected while there is a moderate risk of its impact on the human inhabitants of the FCT from flood occurrence in event of total rainfall variability in the FCT.
Implication of findings from the survey carried out is that the FCT and its inhabitants are highly vulnerable to the risks presented by the present trend of climate in the area, especially their health.

4.Conclusion

This study provided baseline charts and detailed analysis revealing that the climate variable with the gravest risks on the human population of the FCT is total rainfall variability. The implication of this is moderate risk (according to the risk matrix used in classification of risk level in this study) of flood in years of above average rainfall as a result of the vulnerability of suburban towns; Kubwa and Gwagwalada in the FCT. Unlike the city center of the FCT, these suburb towns are experiencing high population growth with inadequate urban planning and as such vulnerable to flood occurrence from the increasing total rainfall amounts. The human population in these suburb towns is however increasingly under risks (moderate) of “RISK D” (incidence of water related diseases like cholera, loss of property, runoffs and erosion, agricultural loss, destruction of infrastructure and ultimately loss of lives.

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