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Rainfall Variations as the Determinant of Malaria in the Federal Capital Territory Abuja, Nigeria

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Abstract
This study highlights the increasing interest in identifying the parameters adequate to measure rainfall and wet day's variations as the determinant of malaria occurrences and distribution for a period of twelve months (2012) in the Federal Capital Territory. Satellite data were developed to identify malaria risk area and to evaluate amounts of rainfall and the durations of wet or rainy days conducive to malaria outbreaks at appropriate scales. Secondly, the studies examine the correlation of monthly and annual malaria cases, and rainfall amounts, including wet days with a lag time of one year. The result of correlation analysis shows that relationship exists between the observed weather variables and malaria. The coefficients of determination R^2 of rainfall influencing malaria is 0.3109 (31.1%) and wet days influencing malaria is 0.3920 (39.2%). These results indicate that the rainfall amounts positively correlate with malaria cases with prediction estimate by 78.47% and 88.68% respectively when the peak was August (rainfall) and June (malaria). The study further shows that a significant rainfall variation was identified, and further revealed that certain necessary measures have to be adequately taken to ensure that the existing malaria problems are dealt with and further occurrence is minimized, if not forestalled all together. It is recommended that more attention should be given to weather and climate mechanism that determines the occurrence and distribution of malaria.
Keywords: rainfall, amount, wet day, duration, variation, determinant, malaria, occurrence, distribution, risk map

1.0 Introduction

A rainfall variation is the degree to which rainfall amounts vary across Federal Capital Territory Abuja for a specific time interval, ranging from day, week, months and season of the year. The term is sometimes classified as short-term variations in rainfall amounts with time (Tong & Donald, 2002), which is said to be occurring at all season of the year (Woodruff, Guest & Garner, 2002). More importantly, it is well established amongst the scientific community that the phenomenon of rainfall variability is having devastating influence on the spread and expansion of insect species (mosquitoes) and malaria cases (Hales, Wet & Maindonald, 2002). Malaria is a complex disease caused by a protozoan parasite of the Genus *Plasmodium* (Abeku, 2002) causing fever, anemia and enlargement of the spleen (Gill, 2000). According to Lindsay & Birley (1996) temperature and rainfall influence malaria occurrence, distribution and transmission, further explains that rainfall also lead to the proliferation of stagnant water pools in which mosquitoes and other insects breed. For effective and sustainable malaria control in the Study Area, Colwell & Patz (1998) and Hay (1997) suggested that the remote sensing techniques and climate mechanism classification scheme should be used, which is adopted in this study.

1.1Background of the Study Area

The Federal Capital Territory has Abuja as the capital of Nigeria, with an estimated population of 5 million (NPC, 2006). The Federal Capital Territory lies within latitudes 9^0 20' N and 9^0 25' N of the equator and within longitudes 5^0 45' E and 7^0 39' E (Figure 1.1). The Federal Capital Territory is bordered to the north by Kaduna state, to the east by Nasarawa State, to the south west by Kogi State and to the west by Niger State. At the 2006 census, the city of Abuja Municipality Area Council had a population of 776,298 and an area of 890km², Bwari Area Council has an area of 914 km² and a population of 227,216 as at 2006 and Gwagwalada Area Council which has an area of 1,043 km² and a population of 157,770 at the 2006 census. Others were Kuje Area Council has an area of 1,644 km² and a population of 97,367 at the 2006 census, Kwali Area Council has an area of 1,206 km² and a population of 85,837 at the 2006 census and Abaji Area Council has an area of 992 km² and a population of 58,444 at the 2006 census.

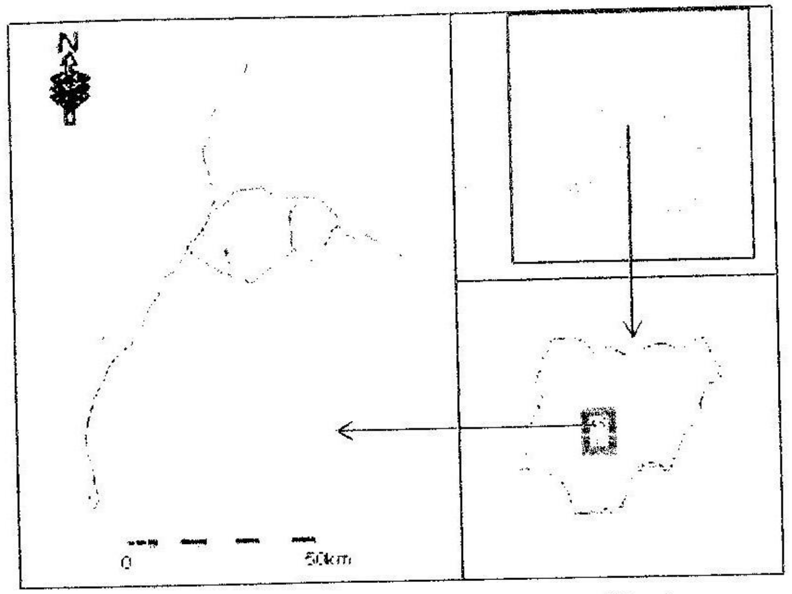

Figure 1. The map of Federal Capital Territory, Nigeria

1.2 Statement of Research Problem

Different methods of assessing the influence of variations in rainfall amounts on insect-borne disease particularly malaria of the same area could produce appreciable variant results, which is capable of misleading climatologist and health scientists. As the Institute of Medicine (IOM) has noted, the influences are complex and inter-related and these interactions complicate the attribution of effects (IOM, 2008). In addition to the confounding explanations, there are acknowledged methodological in ascribing the changes in range and incidence of malaria to rainfall variation, primarily because of the weakness and fragmentation of health information systems and the limited sources of long-term data sets. As a result of this, an experimental approach for different data set from various climatic mechanisms, remote sensing and geostatistical information system is necessary to provide a standard guideline and interpretability model for specific applications.

1.3 Aim and Objectives

The aim of the study is to analyses how variations in rainfall amounts and wet or rainy days influence the occurrence and distribution of malaria in the Federal Capital Territory Abuja, Nigeria. To achieve the above aim of the study, the specific objectives were as follows:

1) To map the spatial distributions of malaria in the study area
2) To calculate and plot the temporal distributions of malaria cases for 2012.
3) To evaluate variations in rainfall amounts and duration of wet day in the study area.
4) To examine the influence of rainfall and wet days on malaria occurrences in the study area
5) To attempt to develop a risk map of malaria distribution in the study area.

2.0 Climate studies

Experimental studies have shown that irregular change in weather conditions are accompanied or followed by increases in the incidence of the disease (Githeko *et al.*, 2000). It can be said that, high intensity of rain amount is associated and linked with the spread of the malaria vector from endemic areas in Paraguay to Argentina (Cook, 1995). According to Houghton, Ding & Griggs (2001) an increase in temperature, rainfall and humidity in some months in the North and West Africa countries has been associated with an increase in the incidence of plasmodium falciparum malaria. In North-East Punjab, malaria epidemics increased fivefold in the year following an El-Nino event (Philip and Rozenboom, 1993), while in Sri Lanka the risk of malaria epidemics increased fourfold during El-Nino year. Olaniran (1991) attempted to map six spatial rainfall anomalies of which above average rainfall occurs over southern Nigeria but below average rainfall over the northern part of the country. Olaniyan further confirms that, the central area of the country receives above average rainfall while the coastal and extreme northern parts of Nigeria receive below average rainfall. This translates to a progressive increase in mean rainfall intensity over southern Nigeria thereby affording the opportunities of developing insect-species habitats (Adefolalu, et al., 2001). In general, the correlation coefficient analysis is another criterion generally used in the study of the rainfall variabilions (Shih, 1982) to determine the spatial distribution of total rainfall depth using spatial correlation analysis (Fennessey, et al., 1986). Shope (1990) focused primarily on those vectors–borne diseases that could relocate in temperate and Arctic regions given global warming:

dengue and yellow fever, malaria and St. Louis encephalitis *leishmaniasis* (Levitus, *et al.*, 2001). Malaria and yellow fever will continue to expand its effect worldwide, particularly in the developing and underdeveloped nations (Lorenz, 1993).

2.1 Malaria studies

Malaria is caused by a protozoan parasite of the Genus *Plasmodium* (Abeku, 2002), complex disease causing fever, anemia and enlargement of the spleen, and results in cerebral complications (Molyeux, 1997). Malaria is transmitted by the bite of infected female mosquitoes of the Genus Anopheles. The transmission cycle is only between man and mosquitoes (Bouma, Dyec & Vander, 1996). Man acts as the intermediate host or reservoir and the mosquitoes is the vector. Bouma (1997) explains how protozoan parasites of the Genus *Plasmodium* have to undergo complex development and multiplication processes both in man and mosquito before they can be further transmitted. Only Female mosquitoes are of importance for disease transmission, as they need a blood meal for *oviposition* (Gill, 2000). Malaria is distributed not only in all developing countries, but is present on almost the entire land surface between the latitudes 40^0 and 60^0 S (Greenwood, 2003). However, the distribution is not uniform and depends mainly on climate, altitude, population density and the specific environmental requirements of the mosquito's species (Hay, 2003). Hales (1999) identified the highly malaria endemic areas as follows: sub-Sahara Africa, Central America and the northern part of South America, the Indian subcontinent and South East Asia. In recent time, malaria epidemics and endemics cases have been observed (WHO, 2000), however, this cannot only be explained by the increasing human population. To a large extent, this is also due to the increasing number of water resource development projects, such as irrigation and drainage schemes or hydro-electric dams (Hubelek & Halouzka, 1999). However, malaria transmission is not related to water resources development projects only (Hayes, Maxwell & Woodzik, 1997), untreated open water surfaces and drains can be a stability for breeding sites for the vectors (Krogstad, 1996). Increased precipitation (rainfall) has the potential to increase the number and quality of breeding sites for vector such as mosquitoes, tick and snail, and density of vegetation, affecting the availability of resting sites (Dutta & Dutt, 1998).

2.2 Remote sensing studies

The advent of satellite remote sensing technique, which come to existence in 1970 (Ache, Grieco, Andre & Roberts, 2006), as the tool for the surveillance of habitats, densityes of vector species and predication of the incidence of diseases has opened up new vistas in the epidemiology of Malaria and other vector–borne diseases (Hay, 1997). Multispectral data from the satellite *probatoire d' observation de la Terre* (SPOT) was engaged in the mapping of mosquito presence in Belize, Canada (Rogers, Myers & White, 2002). The use of high spatial resolution imagery for mapping and identification of features has improved tremendously (Hugh-Jones, 1997). With traditional methods (such as manual gathering of data) being inadequate for control and eradication of vector-borne diseases, the science of remote sensing (RS) and geographic information systems (GIS) has a potential to combat these diseases with the development of risk maps. The risk maps should possibly indicate areas where human populations reside or settle (Syed & Usery, 2001). However, vector of Malaria (mosquito) depend much more on climate and other meteorological variables, of which in the real sense could be used in predicting malaria epidemics (Rogers, *et al.*, 2002). Remote sensing techniques was used to map insect species distribution for the past two decades (Sithiprasasna *et al.*, 2005), to complex techniques that link satellite derived seasonal environmental variable to vector biology (Stoney, 1998). Application of remote sensing data in epidemiology involves retrieving environmental variables that characterize the vector ecosystem such as land cover, temperature, humidity or vapour pressure, and precipitation (Rogers, 2006). However, measuring meteorological and climate variables near the surface is more difficult, and frequently, empirical methods are used (Kraig & Snow, 2002). Techniques to map disease occurrence and risk from satellite data therefore require at least some understanding of the relationships between a vector–borne disease and the air, land, and water environment in which it occurs (Hay *et al.*, 2002). The first research component of National Aeronautics and space Administration (NASA), Global Monitoring and Diseases Prediction Programme (GMDPP) investigated population of anopheles freeborn mosquitoes in rice fields of California Larval population were sampled fortnightly through the period of rice development while an airborne Multispectral Scanner (MSS) simultaneously collected data with spectral and spatial resolution designed to simulate that of the Landsat thematic mapper (Eastman, 1999).

3.0 Materials and Methods

The materials and methods used in carrying out this research are concisely enumerated; Acquisition and Development of data base, Ground truthing and validation of Remote Sensing Data, and Statistical approach.

3.1 Acquisition and Development of data base

The climate data were acquired from Nigerian Meteorological Agency (NIMET), health data from the Public Health Departments of the Federal Capital Development Authority (FCDA), Health Department of each Area Council and related agencies like MDGs-FCT office for twelve months periods in 2012. The satellite data

collected for the study includes, 2001 Landsat-7 ETM 345 image of the Federal Capital Territory (Gilruth, et al, 2002).

3.2 Ground truthing and validation of Remote Sensing Data

The result of the ground truthing from the study area was also used as training sites for supervised classification of the satellite images. With the aid of On-Screen digitizing module of archmap 10.1 software, the malaria risk zone were marked and stored as factor file. Consequently, the research used visual and digital interpretation for the interpretation and analysis satellite images.

3.3 The statistical approach

In this approach, the 2012 distribution of vectors of malaria were statistically matched to 2012 rainfall amounts and, provided a multivariate description of present day areas of disease risk. Additionally, each of the monthly malaria cases was correlated with accumulative rainfall amounts (R1-R12) recorded during the month of January to December (twelve months).

4.0 Results

4.1 Spatial Distribution of malaria

Figure 2 shows the total estimate of malaria occurrence and distribution in each Council Areas of Federal Capital Territory as 4,770 cases in 2012, of which the mean percentage have been estimated out of total malaria cases as follow; Abuja municipal Area council 14%, Gwagwalada Area Council 15%, Kwali Area Council 16%, Abaji Area Council 17%, Bwari Area Council 19% and Kuje Area Council 21% indicating steady graduation of colour according to malaria cases, with Kuje Area Council been the most affected. The results buttress those of Ache, Grieco & Masuoka (2006) and Draeger, W.C., Holm, T.M., & Thompson, R.J. (1997), that stresses the importance of acquiring disease burden or mortality information for mapping which is largely based on clinic, hospital, or national mortality registry data. The study indicates that this type of information is sufficient to plan health care expenditures and directs the health care resource allocation needs.

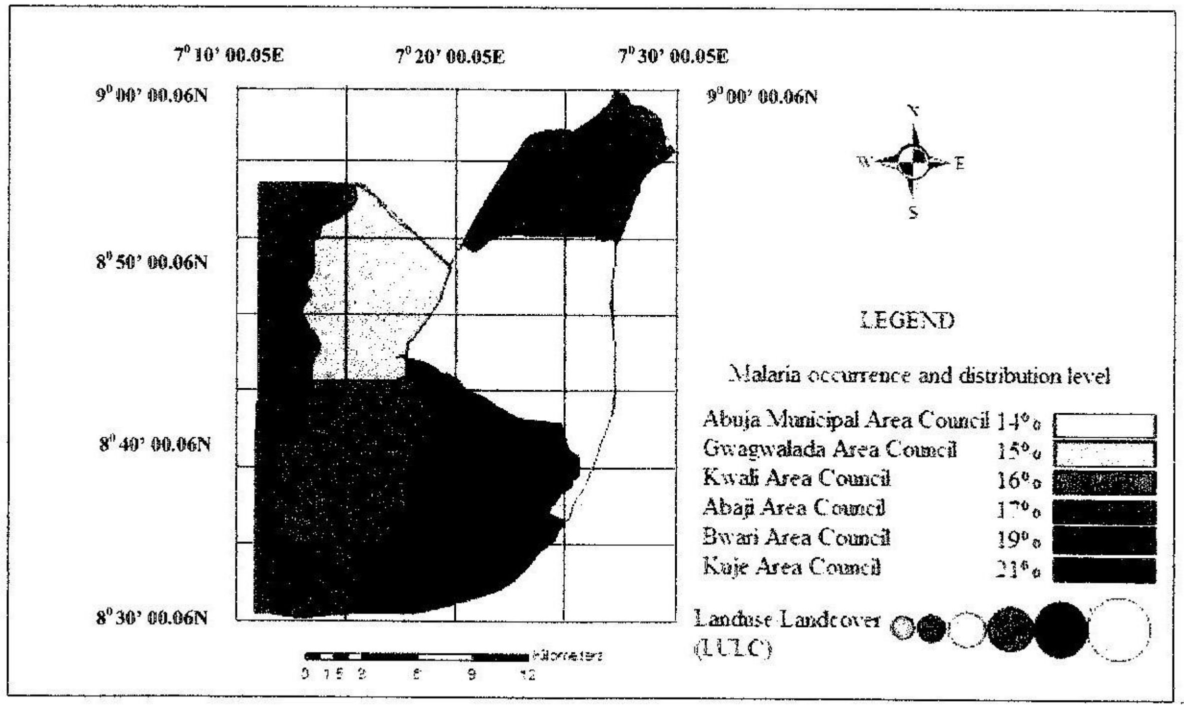

Figure 2. The Malaria occurrences and distribution at the Councils Area level in the FCT, 2012

4.2 Temporal Distribution of malaria

Figure 3 shows the highest malaria cases in the study areas, of which the month of June recorded 540 cases in the year 2012 and the lowest of 250 cases was recorded in March of the same year. The Figure 3 also shows the

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differential spatial distributions of recorded malaria cases between January to December with the distribution value ranging from 250 to 540 cases in the FCT, On a general note, the high concentration of malaria cases can be identified between April and October (rainy season) and low malaria cases is reported in the month of November, December, January, February and March (dry or cool seasons) of the study area. The results confirms those of Bouma (1996), who explains that malaria cases always accelerate in rainy seasons in the tropical nations of the world.

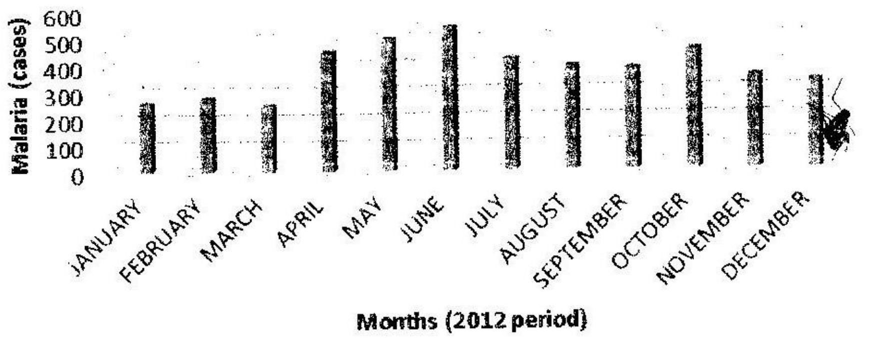

Figure 3. The mean monthly malaria occurrences in the FCT, 2012

Figure 4 shows the distribution intensity of malaria level, ranging from the month of March, April, May, June, July, middle of September and the middle of October indicating green colour recording value of 400-600 level, having the highest malaria cases, while the month of January to December recorded heterogeneous distribution cases indicating in red colour (200-400 level) and January to December also recorded the lowest malaria distribution cases indicating blue colour recorded value of 0-200 level during the 2012 period.

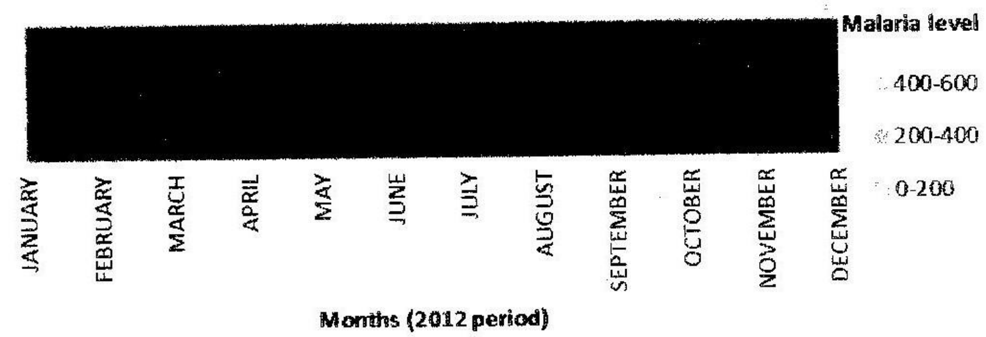

Figure 4. The Mean monthly Malaria distribution level in 2012

4.3 Rainfall amounts influencing malaria occurrences

Figure 5 shows that a corresponding rise in rainfall amounts (Rf) could mean increase in malaria cases (Mc) in the study area; In April (rainfall = 62.8mm and malaria = 450), May (rainfall = 134.1mm and malaria = 500),

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June (rainfall = 164.2mm and malaria = 540), July (rainfall = 217.5mm and malaria = 420), August (rainfall = 262.7mm and malaria = 390), September (rainfall = 253.4mm and malaria = 380) and October (rainfall = 103.2mm and malaria = 450). The Figure 5 also shows that malaria is gradually decreasing from 260, 280, 250 in the month of January, February, March respectively during the periods of dry/cool seasons as a result of low rainfall amounts and, ascending to 450, 500, 540, 420, 390, 380, 450 in April, May, June, July, August, September, October respectively during the periods of wet/rainy seasons when rainfall amounts is high (Craig, *et al.* 1999), and gradually decreasing again to as low as 350, 330 in November and December during the periods of dry/cool seasons when the rainfall amounts is low, indicating that variations in rainfall amount determine malaria occurrences.

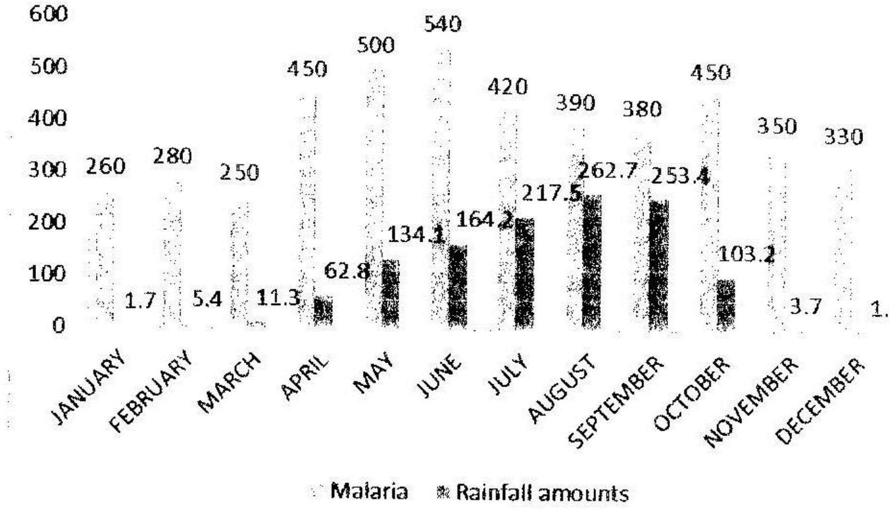

Figure 5. The determination of Rainfall amounts and malaria cases in 2012

4.4 Wet days influencing malaria occurrences

The Figure 6 shows that the mean monthly durations of wet day is gradually ascending from April to August during the periods of rainy/wet season when malaria cases is also on the rise, descending again to October during the period of rainy/wet season when malaria cases are very high in the study areas. It can be observed that there is no presence of wet day in the cool/dry seasons, particularly in the month of January, February, March, November and December of 2012 period. The Figure 6 also explains that durations of wet days is an indication that wet days determine more malaria occurrences in the Federal Capital Territory, Abuja.

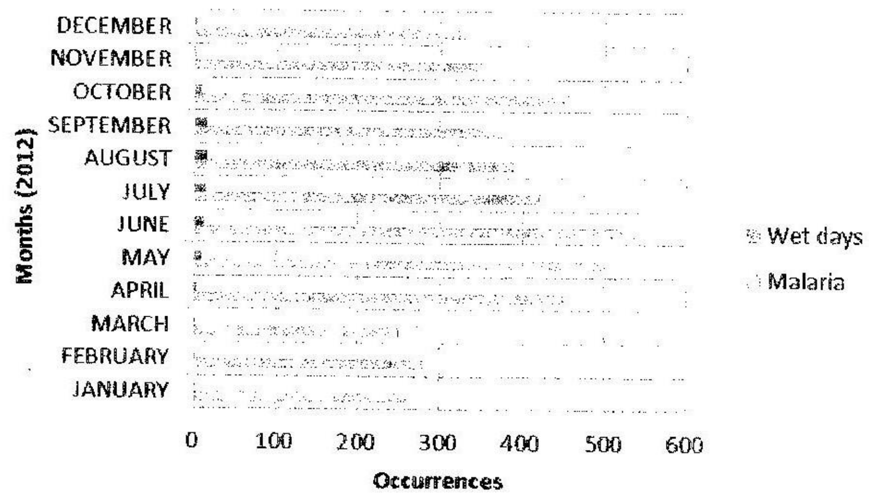

Figure 6. The determination of duration of wet days and malaria cases in 2012

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4.5 Spatial Risk Mapping of Vulnerable Area

The mapping of risk endemic areas is used to determine the level at which malaria is expanding and affecting the urban/rural dwellers in the study areas. Figure 7 shows different patterns of malaria endemic level displayed on the LandSAT-7 ETM+ satellite imagery of Federal Capital Territory; low endemic 500-750 cases, endemic 751-950 cases and high endemic 951-1500 cases. The Figure 7 confirm that Kuje area council shows a better representations of a highly risk endemic area (dark red) concentrated toward south east of the study area. The mid-endemic area (light red) can found at the North East, North West, South West and Central part of the study area, particularly Bwari, Kwari and Abaji area council. Abuja municipal and Gwagwalada area council as the least endemic area (bright red) situated at the North Central extending toward the Eastern part of the study area.

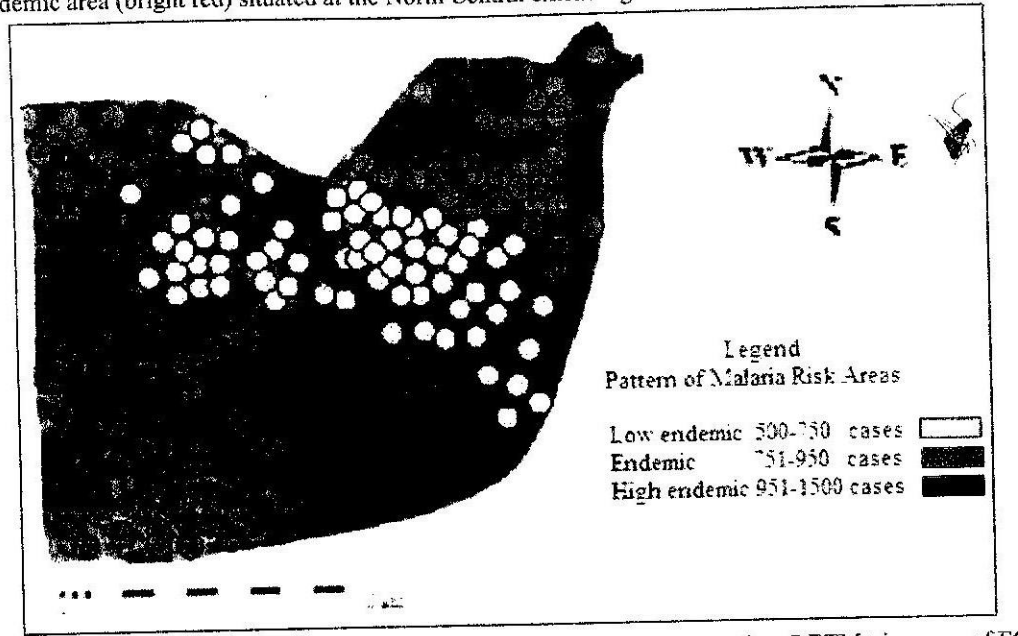

Figure 7. The spatial mapping of malaria endemic areas using 2007 Landsat-7 ETM+ imagery of FCT

4.6 Correlation between malaria and rainfall

Figure 8 shows positive relationship between rainfall amount and malaria, of which the coefficients of determination R^2 of rainfall amounts and malaria cases is 0.3109 (31%). These results indicate that rainfall correlate with malaria in the study area and show a high strength in their relationship. Therefore, the study concludes that both values are statistically significant. The findings of this study corroborate that of Akinremi, McGinn, Boyle & Forth (1999), who is of the view that there is an upward trend in the relationship between rainfall and mosquito-borne diseases such as malaria.

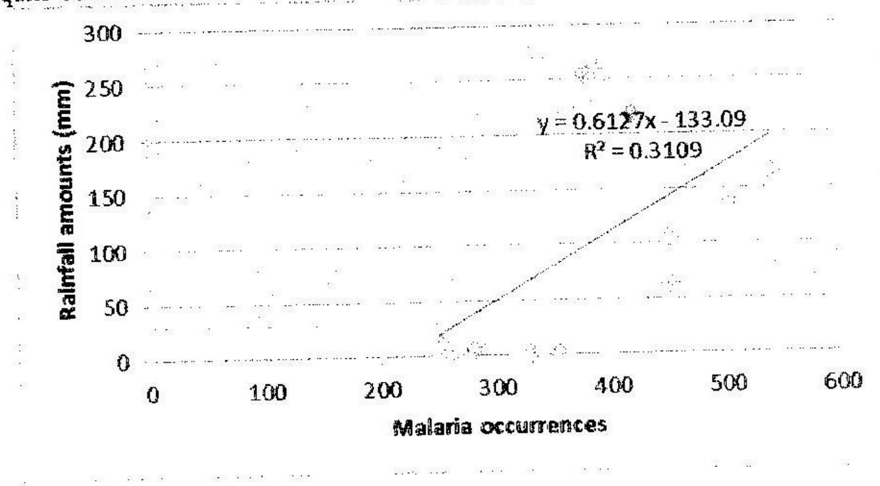

Figure 8. The statistical analysis of Malaria with respect to rainfall in the FCT, Abuja

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4.7 Correlation between malaria and wet days

Figure 9 shows that relationship exists between wet days and malaria cases. The Figure 9 also indicates that the coefficients of determination R^2 for the wet days against malaria cases are 0.3920 (39%). This result further explains that durations of wet days correlate to malaria with high strength of confidence level in their relationship.

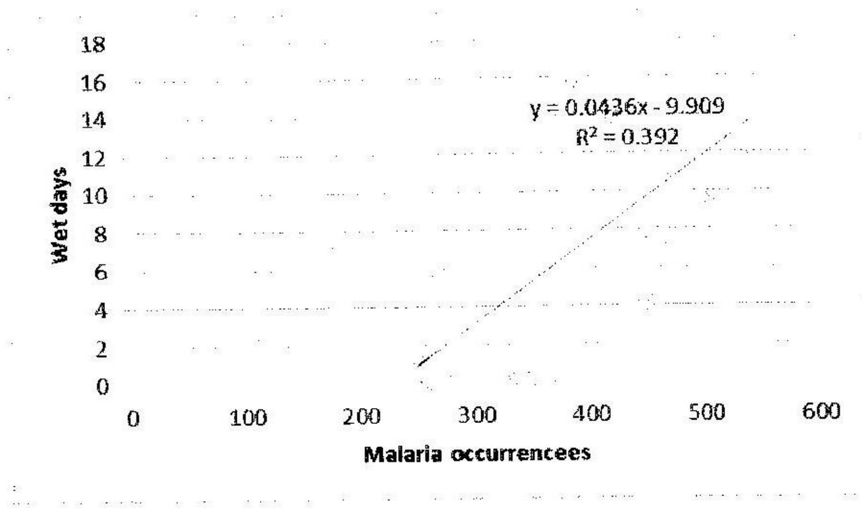

Figure 9. The statistical analysis of Malaria with respect to wet days in the FCT, Abuja

4.8 Discussion and Analysis of Results

A close examination of the classified maps (Figures 2-4) indict malaria as the most vulnerable disease and shows high endemic quality level, particularly at the Federal Capital Territory, Abuja with the peak month of June recording 540 cases and May 500 cases respectively. The detail classification of the reported rainfall amounts and duration of wet days value (Figures 5-6) shows that malaria occurrences is determine by precipitation variables (rainfall amounts). The study also confirms that, Kuje area council has recorded high mortality of 1,001.7 cases, Bwari 906.3 cases, Abaji 810.9 cases, Kwali 763.2 cases, Gwagwalada 715.5 cases and the least of 667.8 cases is reported in Abuja municipal area council of which the result were displayed on LandSAT-7 ETM+. The regression analysis conducted shows that rainfall and malaria, wet days and malaria has a positive relationship indicating high strength in their confidence level of which rainfall/malaria has 0.3109 (31%) and wet days/malaria is 0.3920 (39%). This classification and mapping algorithm adopted for verification of rainfall-malaria produced the best result in this research. In addition, the result shows the classification accuracy index of rainfall amounts determining the breeding, feeding and resting periods of adult malaria vector ranging from April-October and November-March respectively (Table 1). In the same vein, classification accuracy index shows that, the rainy/wet seasons (April-October) manifest highest malaria cases, while lower malaria cases result from the dry/cool season (November-December) of the Federal Capital Territory (Table 1). On a general note, the vectors of malaria shows accuracy index of determination with respect to rainfall in the month of January as 22.1 (5.55%), February 23.2 (5.83%), March 23.5 (5.90%), April 37.5 (9.42%), May 44.6 (11.20%), June 45.5 (11.43%), July 34..9 (8.77%), August 33.8 (8.50%), September 33.3 (8.36%), October 37.5 (9.42%), November 32.3 (8.11%) and December 29.9 (7.51%), this further confirm rainfall amounts and duration of wet days as the determinants of malaria in the study area in 2012.

Table 1. The classification accuracy index of determinant

Disease and Vector (%)	Mean average Rainfall amounts (RF) Algorithms (mm) Jan. 1.7	Feb. 5.4	Mar. 11.3	Apr. 62.8	May 134.1	Jun. 164.2	Jul. 217.5	Aug. 262.7	Sept. 253.4	Oct. 103.2	Nov. 3.7	Dec. 1.2	Total (%)
Mosquitos breeding period	4.3	4.3	4.3	10.0	12.0	12.0	10.0	10.0	10.0	10.0	7.0	6.0	100
Mosquito feeding period	2.3	3.0	4.0	11.0	13.0	15.0	9.0	8.5	8.2	11.0	8.0	7.0	100
Mosquito resting period	10.0	10.0	10.0	7.14	7.14	7.14	7.14	7.14	7.14	7.14	10.0	10.0	100
Malaria occurrences	5.5	5.9	5.2	9.4	10.48	11.32	8.8	8.2	8.0	9.4	7.3	6.9	100
Total	22.1	23.2	23.5	37.5	44.6	45.5	34.9	33.8	33.3	37.5	32.3	29.9	

5.0 Conclusion

The study has shown that, with accurate mapping of malaria distribution cases using LandSAT-7 ETM+ satellite imagery, the vector's breeding sites can be identified and estimated. Similarly, remote sensing technique can be used to analyzing landuse (LU) and landcover (LC) in order to determine vegetation, water and built-up areas toward identifying the insect species habitat and malaria endemic areas. Secondly, there was a significant variations of rainfall amounts and durations of wet day from January to December, 2012. It highlighted the possible rainfall amounts and durations of wet day that can influence the occurrence and distribution of malaria in the Federal Capital Territory, Abuja, Nigeria. Increased rainfall, more breeding sites, increased size of vector population, increased vector survival due to increased duration of wet days/humidity and more potential habitats for vectors. In the same vein, increased durations of wet days also increases in container-breeding mosquitoes because of more water storage and higher numbers of vectors will breed in wet beds. However, this study further demonstrates the effectiveness of estimating the correletion of rainfall and malaria statistically.

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