ISSN No:-2456-2165

Geospatial Evaluation of Carbon Dioxide Pollutant Concentration in Federal Capital Territory, Nigeria

V. T. Salami[1*], S. H. Ahmad[1], G. K. James[1], I. M. Jega[1], O. I. Adedeji[1], O. O. Ajayi[1], O. Akintola[1], M. C. Ekwe[1], F. Adamu[1], U. Sanusi[1]
[1]Strategic Space Applications Department, National Space Research and Development Agency, Abuja, Nigeria

Abstract:- This study investigates atmospheric carbon dioxide (CO_2) pollution high risk zone with hot spot map and annual seasonal variation for a period of eleven years between 2005 and 2016 in the Federal Capital Territory (FCT). This paper is aiming to evaluate spatial distribution of carbon dioxide (CO_2) pollutant concentration in the Capital City of Nigeria. This investigation was carried out in the Federal Capital City of Nigeria from 2005 to 2016 to examine contribution of carbon dioxide emission in deferent land use and land cover. The dissertation utilized satellite imagery from NigeriaSat-X of 2012 with spectral ranges 0.52 to 0.62µm, 0.63 to 0.69µm and 0.7 to 0.9µm respectively. The three bands (i.e. Green, Red and Near infra-red) are closely related to those of bands 2, 3 and 4 of Landsat-7. Source of air quality data for carbon dioxide is from Giovanni NASA data base (global data source) with resolution of 0.5 by 2.5 degree. NigeriaSat-X image was used to digitize the road, classified into various land use/land cover (i.e. built up, bare surface, farmland, rock outcrop, vegetation and water body) carbon dioxide pollution concentration now link to these land use/land cover to know the highest contributor among the feature and high zone risk in the Federal Capital Territory. Concentration of carbon oxide pollution is rising steadily over the years from 376.6 to 402.2 parts per million (ppm). Current level of CO_2 is 402.2 ppm in 2016. High concentration level of carbon dioxide observed in AYA junction, which the high risk zone and the most contribute feature of CO_2 to the atmosphere as a result of traffic congestion in that area. Lower Usuma Dam and Jabi-lake is the area with low level of carbon dioxide pollution and the least contributor of carbon dioxide to the atmosphere. It is recommended that rising of CO_2 concentration is in the risk zone in FCT. Therefore, there is urgent attention to address the rising of concentration with forestry and land use practices which can hold a considerable mean for counteracting the effect of carbon dioxide emissions, help to prevent further rising carbon dioxide concentration.

Keywords:- *Carbon Dioxide Concentration, Variation, Risk Zone, Remote Sensing, GIS.*

I. INTRODUCTION

The Federal Capital Territory (FCT) has been experiencing high level pollution carbon dioxide (CO_2); due to high rate of deforestation to arable farm and others agricultural land and rapid infrastructural development, that can cause increase in carbon dioxide emission as concerned with greenhouse gas. Disturbances of land in converting from one land use/land cover to another can expose the soil to environmental problem like erosion, leaching of nutrient and cause the area not to act as carbon sink. It is common knowledge that certain amount of carbon dioxide (CO_2) occurs naturally in the Earth's atmosphere, there are several human activities that increase levels of the greenhouse gas that has led to unambiguous rises of atmospheric carbon dioxide from concentration of 180 part per million (ppm) before industrial era to 402.2 ppm of present level Keeling et al (2009). There is apparent observation that this is being driven by human activities the rising of carbon dioxide emissions are from one land cover-use to another and burning of fossil fuel (Hegerl *et al,* 2007). However, effect of rising concentration of carbon dioxide is posing great concerned as the concentration rises to about 45 percent (45%) from preindustrial period, concentration is continuously rising due to human activities. Rising concentration of carbon dioxide pollution and the emission have become challenges for public authorities in the state; ecosystem of Nigeria Federal Capital is threatening with environmental problem and serious health risks for humans.

Rising Concentration of Carbon dioxide has become worrisome, in the areas, because high levels of carbon dioxide can lead to health problems such as headaches. Carbon dioxide levels may indicate high levels of other harmful air pollutants such as volatile organic compounds which contribute to air pollution. Now, it necessary to carry out accurate mapping of Carbon dioxide pollution distributions in urban city to determine the sources and to reduces the concentration level. Carbon dioxide pollution monitoring for urban population is significant important, because in the past urban cities have been major sources of pollutants and supported a large number of people most especially in concentrated areas (Health Effects Institute 2001). This paper aims to evaluate spatial distribution of the carbon dioxide pollutant concentration data in the Nigeria Federal Capital City.

- These are Specific Objectives to Accomplish Aim of this Research Are

A. Estimation of carbon dioxide (CO2) pollutant concentration from satellite sensor measurement over the Federal Capital Territory.
B. Examine the major causes of carbon dioxide pollutant in Federal Capital Territory
C. Evaluation of carbon dioxide pollutant variation trend from 2005 to 2016
D. Assessment of carbon dioxide pollutant impact on human health and the environment.
E. Determination of relationship between carbon dioxide quality data obtained from satellite sensor and land use/land cover impact.

II. THE STUDY AREA

Federal Capital Territory (FCT) is located at latitude 9.23^0 N and 9.36^0 N of the Equator and longitudes 6.74^0 E and 7.62^0 E and average Elevation of 537m (Figure 2). The FCT population is 1,402,201 (2006 population census) the (FCT) has a land area of 923,768 square kilometres (Km^2), which is more than two and halftimes Lagos state land mass area. The Federal Capital Territory shared boundary with Kaduna State, Niger State, Plateau State, and Kogi State.

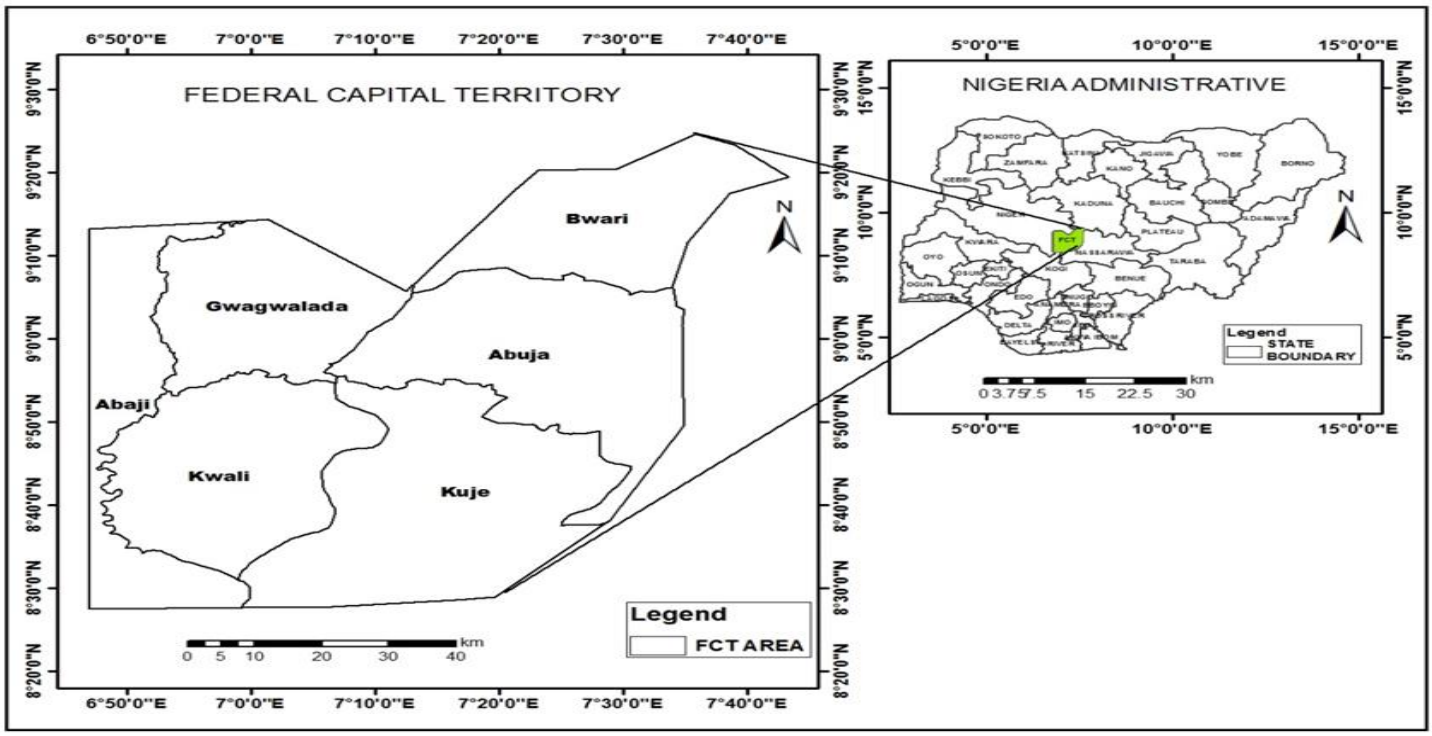

Fig 1:- The Map of the Study Area map

- *Weather and Climate*

The Federal Capital Territory (FCT) weather is always warm and most of the time the sun shines bright. FCT temperature varies from 26 degree Celsius (^{0}C) and 40 degree Celsius. Abuja weather is a "Tropical wet and dry weather" The rainy season starts in the end of March or beginning of April and ends in October ending or early November. During these months the climate is quite humid and the temperature drops to around 26 to 30 degree Celsius. It gets "cold" at night time with temperatures down to around 20 degrees Celsius (20^0) but can also be chilly and get as low as 14 ^{0}C. After a chilly night the day temperature will normally reach around 30 degrees Celsius (30^0). (https://nordichotelabuja.com/abuja-weather/).

The FCT climate follows two main seasons; a dry season and a wet season. You will know what to expect from the weather in FCT. Even in the dry season you will find a lot of green areas, as the soil are very fertile in FCT. FCT in Nigeria weather is great for growing fruits, and in the local markets as well as the supermarkets you will find a fine variety of fruits grown locally all year round. You will always find a delicious selection of watermelons, bananas, pineapples, mangos and many more. The summer in FCT has a good deal of rainfall, while the Harmattan has very little. Average annual mean temperature is about 26 °C in FCT. Annual precipitation here fall around 1389 mm that make the soil good agriculture. (https://en.climate-data.org/africa/nigeria/federal-capital-territory-353/).

III. METHODOLOGY

The materials used for measurement and mapping of carbon dioxide pollutants in Federal Capital Territory FCT) research include; NigeriaSat-X imagery, NigeriaSat-X used for this project was captured on the 8th December, 2012 and was obtained in the Department of Mission Planning Information Technology and Data Management , National Space Research and Development Agency (NASRDA). The NigeriaSat-X image was used to map roads infrastructures and classified the study area into various land use/land covers e.g. settlement; vegetation, rock outcrop, farmland, bare surface and water body in such a way the analysis can be well defined. The NigeriaSat-X, which is Earth observation satellite, has spectral ranges of 0.7-0.9µm, 0.63-0.69µm and 0.52-0.62µm. The three bands (i.e. Near Infra-red, Red and Green) are very close to Landsat-7 feature of bands 2, 3 and 4 respectively.

A. Data Collection

The methodology implemented for processing and analyzing data as shown in Figure 2 is segmented into four main categories. This comprises data collection, processing, data analysis and the production of carbon dioxide concentration pollution distribution map. Nigeria sat-X image was primary data used successfully for the mapping of land use and land cover. Carbon dioxide data of (6) Table 1 Local Government Area in Federal Capital Territory and some strategic locations located at the following location i.e. Abaji, Abuja municipal area council (AMAC), Airport, AYA junction, Abaji forest, Bwari, Gwagwalada, Jabi Lake, Kuje, Kwali and Usuma dam.

S/N	Places	Latitude (^{0}N)	Longitude (^{0}E)
1	Abaji	8.481	6.944
2	AMAC	9.067	7.483
3	Bwari	9.286	7.379
4	Gwagwalada	8.941	7.078
5	Kuje	8.880	7.232
6	Kwali	8.839	7.053
7	Airport	9.006	7.269
8	Usuma dam	9.198	7.414
9	Forest in Abaji	8.531	6.770
10	Jabi lake	9.070	7.421
11	AYA Asokoro	9.051	7.527

Table 1:- Coordinate points of monitoring Locations

The carbon dioxide qualities data component for Federal Capital Territory concentration values was collected from satellite sensor-based from Atmospheric Infra-Red Sounder (AIRS) and source is Giovanni NASA. To obtaining carbon dioxide pollutant data from Giovanni-nasa; Log-on to Giovanni-nasa, Giovanni interface appeared. There is (UTC) under select date range type, on it there is start year and month to end year and month click to compute year and month. Click Atmospheric chemistry, select the variable under select variables, here many types of variables appears then select your desire variable (i.e. Atmospheric chemistry here select carbon dioxide). Under select region (Bounding Box or Shape file) compute your longitude and latitude in this format; East, South, West and North respectively. After this look up to Time series, select Hovmolla, Longitude-Average and click plot data and obtain your data but preferably in part per million (ppm) results can be downloaded by clicking image for proper reading. ERDAS imagine was used to classify Nigeriasat-X image into land use/land cover and Google earth was used to validate the classification because image was captured in 2012 and field work was 2016. Ordinary Kriging in ARC GIS 10.1 was used to performed statistical spatial distribution of CO_2 data. However, the land use and land data images and data layers of carbon dioxide pollutants concentration collected from satellite sensor in the study areas were processed, computed to excel and import to ArcGIS.

The roads networks of Abuja (FCT) were digitized from NigeriaSat-X image in order to assess CO_2 concentration from road traffic. The data undergo geo-referenced, so that, interpretation of data can be easier. UTM WGS (Zone 31^0 N) coordinate system was used in such a way it can be coherent with the world data. Some of the benefits offered by Remote Sensing and Geographic Information System {i.e. ArcGIS 10.1 and ERDAS imagine}

program as well Nigeriasat-X imagery, and Carbon dioxide quality data from satellite sensor was used to view and analyze the concentration of CO_2 pollutant and link with classified Land used/Land cover of the study areas to determine concentrated polluted areas in order to identify pollution hot spot and pollutant contributor of Land Use and Land Cover in Federal Capital Territory).

B. Data Analysis

The ordinary Kriging was algorism performed for analysis of carbon dioxide data obtained from global data for this work. Ordinary kriging is well known method of interpolation for spatial statistical model. In statistics, for any Spatial Analyst Tools, Kriging methods of interpolation are very similar to that of inverse distance weighted (IDW) method of interpolation Oliver, M. A. (1990). Therefore, under suitable condition, estimation weight with Kriging always selected unbiased using variance estimator is minimal. This algorism is commonly used in spatial analysis for distribution of pollution across geographical study areas to know most polluted and less polluted areas. Statistical annual concentration of carbon dioxide was calculated from monthly values recorded from satellite sensor and each annual concentration map was used for the production of pollution map. Simple statistics method or formula was used e.g. $Y = \Sigma \frac{FX}{NX}$ Equation 1 Where Y is annual mean Carbon dioxide′s concentration, FX is concentration multiply by number of occurrence and X is the number of occurrence.

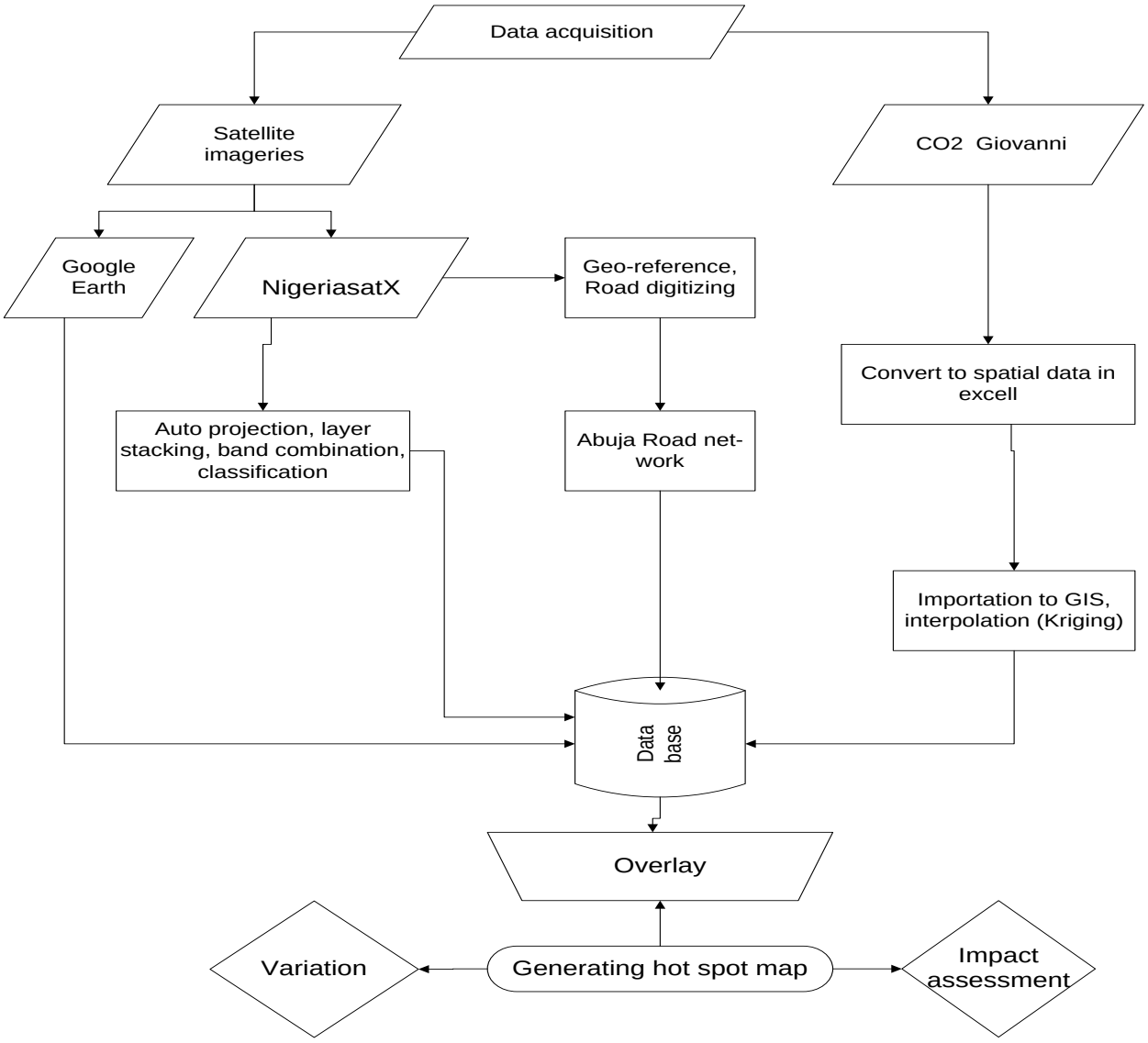

Fig 2:- Methodology flowcharts

IV. RESULTS

These are the results of carbon dioxide pollutant concentration (global data source) obtained from satellite sensor measurement for different locations, linked with coordinate's points of the study areas majorly Local Government Headquarters and some special locations. The analyses of these results are shown in table 2, Figures 3 and 4 Figure 5 shows land use/land cover of study areas in which various locations were linked to satellite sensor for obtaining carbon dioxide data.

Results in Table 2 shown the concentration of carbon dioxide in various land use and land cover in Federal Capital Territory for which their coordinates were linked to global data of satellite sensor-based from Giovanni NASA website. All the generated maps were carried out from Table 2 Carbon dioxide concentration started from 376.6 part per million (ppm) to 402.2 part per million (ppm) during the period of monitoring (2005 to 2016). From the results it was observed that AMAC, Bwari and AYA Asokoro are in threshold level of 400,400 and 400.2 part per million (ppm) respectively.

S/N	places	Years											
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Abaji	377.6	380	380.9	383.2	386.3	388.9	390.9	392.5	394.4	396.7	398.8	402
2	AMAC	377.4	380.2	381.9	384.1	386.8	389.1	391	392.8	395.2	396.8	400	401
3	Bwari	377.4	380.2	381.9	384.1	386.8	388.6	391	392.8	395.2	396.8	400	401
4	Gwagwalada	377.6	380	380.9	383.2	386.3	388.8	390.8	392.5	394.4	396.6	398.8	402
5	Kuje	377.6	380	380.9	383.2	386.3	388.8	390.9	392.6	394.4	396.6	398.8	402
6	Kwali	377.6	380	380.9	383.2	386.2	388.7	390.8	392.5	394.3	396.7	398.8	402
7	Airport	377.4	380.2	381.9	384.1	386.8	389.2	391	393.2	395.2	396.5	399.9	401
8	Usuma Dam	376.6	379.3	380.5	382.8	385.8	387.7	390.2	392.3	393.8	396.1	397.9	400.6
9	Abaji Forest	377.3	379.7	380.8	383.2	386.2	388.7	390.9	392.5	394.3	396.7	398.7	400.8
10	Jabi lake	376.6	379.3	380.5	382.8	385.8	387.7	390.2	392.3	393.8	396.1	397.8	400.6
11	AYA	378.2	380.4	382	384.2	386.9	389.2	391	393.1	395.3	397	400.2	402.2

Table 2:- Concentration of carbon dioxide in Federal Capital Territory from 2005 to 2016 (Source: fieldwork)

Spatial variation of carbon dioxide concentration pollutant for different types of land use and land cover for a period of twelve years as we can see in Figure 4.1 which is representatives of monitoring locations in Federal Capital Territory. The highest point in the curve is AYA Asokoro, which is the most traffic congestion location in the Federal Capital Territory; this area can also be concluded as highest contributor of carbon dioxide pollutant concentration in the study area. Built-up or settlement is the next land use and land cover contributed to atmospheric carbon dioxide concentration pollutant, these areas include; Abaji, Abuja (AMAC), Airport, Bwari, Gwagwalada, Kuje and Kwali. The least contributor of land use and land cover to atmospheric carbon dioxide pollutant concentration as we can see in Figure 3 graph, its comprises of forest (Abaji forest), Jabi Lake and Usuma Dam. These land use and land cover, are not only least contributor to carbon dioxide pollutant concentration to atmosphere but they also sink carbon from atmosphere according to some finding. Result from Figure 3 also shown that in 2015; AMAC, AYA Asokoro, Airport and Bwari areas were above 400 parts per million (ppm). In the same vein, all the study areas in federal Capital Territory steps above threshold limit. Another finding from Figure 3 was that concentration of CO2 rising steadily from 376.3 to 402.2 part per million (ppm), which may have a very huge significant adverse effect to human health and Ecosystem of study areas.

ISSN No:-2456-2165

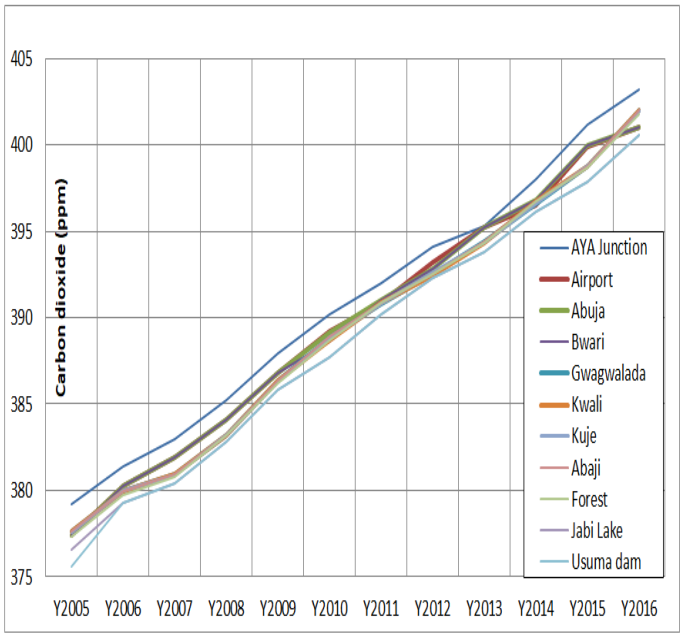

Fig 3:- variation trend of carbon dioxide concentration from 2005 to 2016

Figure 4 shows land use and land cover (LU/LC) of classified study areas in Federal Capital Territory, which includes; Abaji, AMAC, AYA Asokoro, Airport, Bwari, Gwagwalada, Kuje and Kuje. Land use and land cover of these areas were linked to satellite sensor for proper measurement of carbon dioxide pollutant concentration, So as to be able provide map of carbon dioxide concentration map for proper study. The most important thing about this concentration map is that, a complete survey of the study areas can be shown, spatial distribution pattern of carbon dioxide pollution can be seen, areas that are more polluted in the study areas will be known and it will be easier to tackle the problem of CO_2 concentration by reducing the concentration level through the effort of concentration map of carbon dioxide Federal Capital Territory. Carbon dioxide data obtained from sensor and the relationship between urban features or land use/land cover study areas were linked together to produce results of carbon dioxide concentration in Table 2 for the monitoring and modeling of CO_2 pollution to determine the feature contributes most to atmospheric carbon dioxide concentration from spatial distribution pattern. Conversely, rock-out crop was assumed to be part of Forest`s feature and feature like bare-surface to be part of Built-up area of the study areas. Apart from determination of the most feature contributing to CO_2, impact of carbon dioxide to the environment can also be determining how CO_2 concentration has affected the ecosystem of FCT for this period of investigation.

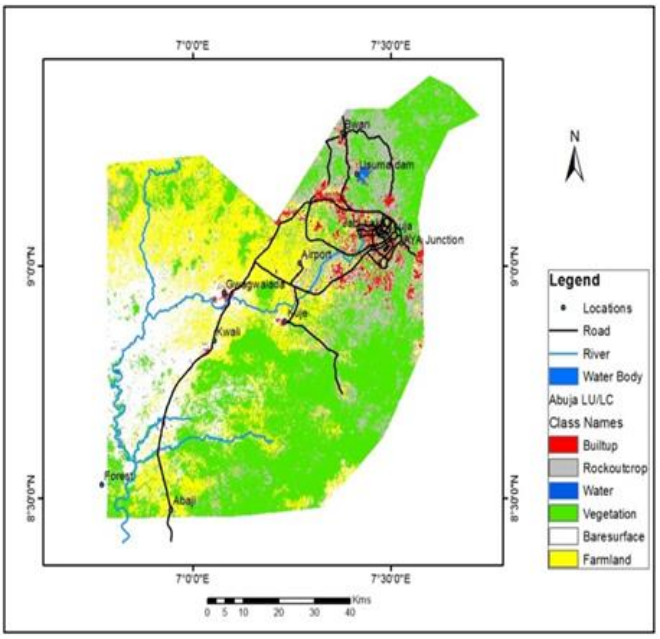

Fig 4 Land use and land cover of the study area

The mean averages of all carbon dioxide concentration maps from 2005 to 2016 were model to produce carbon dioxide pollution hot spot map in Figure 5 This map serves as a direction as to which area to be recommended for some people with a particular ailment to stay or not. Result of the map shows area with high concentration of carbon dioxide and area with low concentration of carbon dioxide, which can also be represented as high risk zone to very low risk zone. The ranges of spatial distribution of this map start from very low risk zone, low risk zone, medium risk zone and high risk zone with particular colour assigned to each. High risk zone for carbon dioxide concentration pollution was assigned with red colour and area with very low risk zone was assigned green colour in the hot spot map in Figure 5 for proper observation of concentration. It can be observed from the map of this concentration that AYA Junction in Asokoro is associated with high level of carbon dioxide concentration according to distribution of result of the map. The feature contributes to carbon dioxide in AYA might due to traffic congestion in this area. Very low level of carbon dioxide concentration was observed in Jabi Lake and Lower Usuma dam. Low level of carbon dioxide pollution was observed in Abaji forest, areas with medium level of carbon dioxide include; Abaji, Gwagwalada, Kuje and Kwali and areas with risk zone level are AMAC, Airport and Bwari in Federal Capital Territory.

From result in Figure 5 we can see how some land use and land cover are contributing to rising concentration of atmospheric carbon dioxide from the data obtained in satellite sensor in Table 2 Traffic point in AYA Junction makes it the highest contributor of carbon dioxide pollutant to atmosphere among the land use and land cover in the study area. Settlement areas are also among the highest LU/LC

ISSN No:-2456-2165

contributor of carbon dioxide concentration to the atmosphere due to clearing of forest for infrastructural development. The least contributor of carbon dioxide pollutant to atmosphere is the water body. It should be clear that this monitoring of Carbon dioxide concentration is afternoon not at night monitoring. The rising levels of carbon dioxide concentration have some positive impact on human health, as well as good condition to the plants and ecosystem.

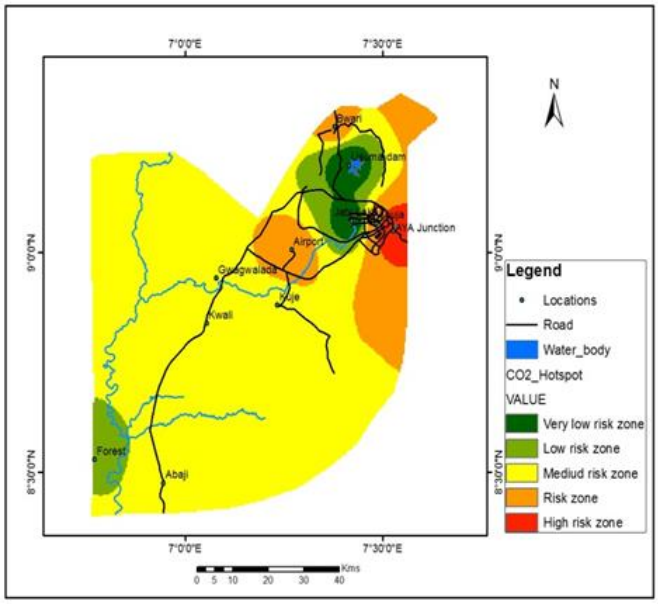

Fig 5:- Concentration Hotspot of Carbon dioxides in the study area

Impact of rising Carbon Dioxide to the Environment[4.2]

The threshold limit for carbon dioxide concentration is 400 parts per million and concentration in study area for this period of investigation is 402.2 parts per million. It means there is a defined range of carbon dioxide concentration in air we breathe. Therefore, what is the effect of too much concentration of carbon dioxide and what is the level that can cause human`s health problems? However, breathing too much carbon dioxide high concentration decrease in blood PH (increased acidity) that resulting in a condition known as acidosis. So, any changes in PH level in the body can cause effects such as headache, respiratory illness, asthma, emphysema and central nervous system (CNS) when expose beyond permissible limit of carbon dioxide concentration of 5000 parts per million (ppm) OSHA (2012). The highest carbon dioxide level in this study is 402.2 ppm and the permissible exposure limit (PEL) for carbon dioxide concentration to be affected by human`s health is 5000 ppm. Then current concentration level of carbon dioxide pollution level in study area may not really post health risk to human`s health but the concentration level can cause negative effect to ecosystem because a rise in concentration of carbon dioxide can lead to degree rise in temperature to the environment.

Concentrations of carbon dioxide in this investigation have been rising steadily from 376.6 to 402.2 parts per million (ppm) without any traces it will come down. Rising carbon dioxide concentration from under 376.6 ppm to 402.2 ppm has a lot of negative impacts in Federal Capital Territory environment. From result in Figure 3 shows there is clear evidence that concentration of carbon dioxide steadily rising to its present level of 402.2 parts per million in Federal Capital Territory. When there is rising in concentration of carbon dioxide in surrounding can also lead to rise in degree Celsius (^{0}C) in temperature of the environment. When temperature is keeping rising, this may have serious effect in ecosystem of an area that could lead to more extreme heat waves to droughts, flooding and force extinction of many species of both plants and animals. There is good reason to think about this catastrophic that may affect human health and our ecosystem.

V. DISCUSSION

The concentration of carbon dioxide pollutant has been rising steadily as observed in Table 2 and Figure 3 respectively. These concentration rises from 376.6 parts per million to 402.2 part per million of its present level, this shows that the concentration is still continuous rising without sign of coming down. It is interesting to note, in this respect, that ongoing rise in concentration of carbon dioxide is a worry that can lead to environmental catastrophic if appropriate step is not taken. There is significant evidence from the spatial variation that carbon dioxide pollution is raising at alarming rate in the Federal Capital Territory, for now no measure put in place to address the problem. The concentration of carbon dioxide in Earth's atmosphere has not been as high as it is now since long before humans existed. Carbon dioxide levels do not necessarily have direct effects on our ability to breathe (at least, at these concentrations). But by transforming the planet, these carbon dioxide concentration levels may dramatically increase pollution and related diseases, potentially slow human cognition, cause extreme weather events (including deadly heat waves), and broaden the ranges of disease carrying creatures like mosquitoes and ticks. Right now, CO_2 concentration levels are still rising rapidly. Higher levels of carbon dioxide concentration can also exacerbate ozone and other pollution levels.

Proper attention need to be paid to rising concentration of carbon dioxide level in the study area because this unambiguous rising concentration if continues may affect environment, pose serious risk to human`s health. Carbon dioxide (CO_2) is one of the key greenhouse gases that contribute to global warming; a little rise in CO_2 level has significant effect in degree (^{0}C) rise in temperature of the environment. Therefore, areas with high level of carbon dioxide i.e. AMAC, AYA Junction, Airport and Bwari need to put proper check. AMAC, AYA Junction, Airport and Bwari were in world standard limit in year 2015. However,

all the study areas were above threshold limit in year 2016 due to many factors. It is common knowledge that certain amount of carbon dioxide (CO_2) occurs naturally in the Earth's atmosphere, there are several human activities that increase levels of the greenhouse gas. "It is a necessary compound in Earth's life cycles". Worldwide, fossil fuels can generate a lot of carbon dioxide concentration by associated with any mechanical transportation. Deforestation: Trees are major organisms for absorbing and removing carbon dioxide emissions from the air. Cutting down of trees and clearance of forest can stop the process of absorbing carbon dioxide from atmosphere. At the same time, altered carbon dioxide availability and enhanced photosynthesis can change the amount of leaf, root and below ground microbial biomass, resulting in changes to ecosystem functioning. Therefore, recent rise in carbon dioxide level in the Federal Capital Territory is known to be mainly due to human activity (anthropogenic).

Human activities have tremendously increased the concentration of carbon dioxide to the atmosphere during the period of this investigation and have now reached dangerous levels. Movement of vehicles in the study area is energy intensive and it uses petroleum based fuels (i.e. diesel, kerosene, petrol, etc.), transport related emissions have risen rapidly, that is why AYA junction is highest contributor of carbon dioxide pollution area because of traffic congestion in the area Smith et al (2000). Forest in many areas in the FCT has been cleared for logging, development, conversion to farms and for land use purposes. Developments bring about clearance of forest and deforestation, when this is done large amount of carbon dioxide stock in the atmosphere. Thereby increase concentration level of carbon dioxide in the environment. Since deforestation reduces amount of trees to sink Carbon dioxide level by natural mean, as a result, concentration of carbon dioxide is gradually accumulating in the atmosphere in the study area, which led to present level of carbon dioxide (402.2 ppm) in Capital City of Nigeria.

VI. CONCLUSION

It can be concluded from the results and analyses that concentration of carbon dioxide is rising steadily from 376.6 parts per million to 402.2 parts per million (ppm) in the Study area (Federal Capital Territory) caused by human inducement. The results show high level of carbon dioxide pollution in AYA Junction, which is high risk zone for carbon dioxide pollution. An area with low level of carbon dioxide concentration was observed in Lower Usuma Dam and Jabi-lake is also the least risk zone of carbon dioxide pollution in the Federal Capital Territory. Movement of vehicles in AYA Junction is energy intensive and it uses petroleum based fuels, transport related emissions have risen rapidly in this area that is why AYA junction is highest contributor to carbon dioxide concentration among other land use and land cover in the study area. Persons with diseases like headache, respiratory illness, asthma and emphysema should not leave in AYA. Although the CO_2 level is above threshold limit in FCT, does not mean we wipe entire CO_2 in the air rather find a means of reducing the concentration. Therefore, forestry and land use practices are holding a considerable mean for counteracting the effect of carbon dioxide emissions; help to prevent further rising carbon dioxide concentration. Carbon dioxide still has positive impact on human health, good condition to the plants and the environment.

ACKNOWLEDGMENT

The Authors acknowledge full support of the Strategic Space Applications Department, Hazard and Environmental Management, National Space Research and Development Agency (NASRDA) Abuja and Nasarawa State University Keffi, Nigeria.

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