MODELING CLIMATIC VARIATION PARAMETERS OF NIGERIA USING THE STATISTICAL DOWNSCALING APPROACH

OLUSINA, J.O. & O.M. ODUMADE
DEPARTMENT OF SURVEYING & GEOINFORMATICS,
FACULTY OF ENGINEERING, UNIVERSITY OF LAGOS,
AKOKA, LAGOS, NIGERIA.
AWOFEKO A.A (QUEST CONS. LTD)

1.0 INTRODUCTION

- Climate unpredictability and change in climatic parameters have direct influence on environment and human existence.
- A negative change in the climate, always have its corresponding dysfunctional impacts on man and the ecosystem globally or locally.
  - ✓ Flooding, poor agricultural yields, famine, and even death are some of the catastrophic effects of drastic climate change.
- Knowledge and information on the climatic variation parameters in an environment is very vital for environmental study assessment and proper planning.
- The most crucial factors about the concept of climate change are:
  - ✓ the time periods involved
  - ✓ the degree of variability that the change is subjected to
  - ✓ the duration and
  - ✓ impact of such variability on man and the ecosystem (Odjugo, 2010; Kalkstein and Vailimont, 1987; McQuire, Macon, Kilburn, 2002; Nwafor, 2006).
- Nigeria is already being plagued with diverse ecological problems, which have been directly linked to the on-going climate change.

2.0 STUDY AREA

•Nigeria is 923,768km² of which:

-910,768km² is land,

-13,000 km² is water.

Figure 1. Map of Nigeria (Wikipedia, 2012).

Nigeria's total boundaries are 4,047km in length:

-the border with Benin is 773 km,

-with Cameroon is 1,690km,

-with Chad's is 87km, and

-with Niger is 1,497km.

-Nigeria's climate is characterized by strong latitudinal zones,

-becoming progressively drier as one moves north from the coast,

-marked by two seasons (dry and rainy seasons), the dry season is also known as Harmattan (Wikipedia, 2012; The Library of Congress Country Studies, 1991).

3.0 METHODOLOGY

In this research, the following methodology was adopted:

3.1 Data Acquisition:

•Past and Future climate data acquired from WORLDCLIM model and Nigeria Meteorological Service (NIMET).

- Worldclim Model Data:
  - ✓ Worldclim data was chosen and downscaled from Global Circulation Models.
  - ✓ The data were in *.clm* and *.cli* formats
  - ✓ The database was accessed through Diva-GIS.
  - ✓ The datasets obtained were:
    - o Past Climate (Minimum Temperature, Maximum Temperature, Mean temperature, Precipitation) 1950-2000.
    - o Future Climate (Minimum Temperature, Maximum Temperature, Mean temperature, Precipitation) 2000-2050.

- Meteorological Climate Data:
  - ✓ Data was acquired from Nigeria Meteorological Service (NIMET), Oshodi Lagos State ,
  - ✓ For four meteorological stations (Lagos, Owerri, Port Harcourt, Bauchi).
  - ✓ The datasets includes:
    - o Maximum and Minimum Temperature (1950-2000)
    - o Rainfall (1950-2000)

- The maximum and minimum temperatures were in degree Fahrenheit,
- converted to degree Celsius, and
- the rainfall was in Inches, but was converted to Millimeters.

3.2 Data Processing

- The datasets from Worldclim (*.clm* and *.cli* files) were extract to obtain the Bioclim world maps in grid file (both the past and future climate data).

- A gridfile consists of two separate files *.GRI* and *.GRD*, both integrated in DIVAGIS as one file.

- A total of ninety-six (96) grid maps created:
  - ✓ Past dataset (1950-2000) and
  - ✓ Future dataset (2000-2050).
  - ✓ The climate grid maps were created by selecting the desired parameters:
    - o minimum, mean and maximum temperature and
    - o rainfall as output for the different months in a year.
    - o the grid (raster) maps created were converted to shape-file.

3.2.1 Data Manipulation in ArcGIS

- The various shape-files were in Geographic Coordinate System (GCS), WGS 1984.
- Nigeria boundary map was overlaid on the shape-files to query regions within its boundary.
- The various Average Temperature and Rainfall for each Local Government Area (LGA) were extracted and exported to Microsoft Excel.

3.2.2 Working with Meteorological Data

- The data obtained from NIMET were daily data:
  - ✓ minimum temperature, maximum temperature, and
  - ✓ rainfall for the four different stations over a period of 50 years (1950-2000).
- Monthly data were obtained by averaging the daily data for temperature data and summation for the rainfall data.
- For the various meteorological stations, the local data from NIMET was compared with the past climate data obtained from Worldclim model, and
- Analysis were carried out using Microsoft Excel.

3.2.3 Modelling Nigeria's Future Climatic Variation Parameters

- The past Worldclime data for Nigeria are shown in (1950-2000) Figures 2a -2c.
- The differences between the past NIMET data (1950-2000) and the Worldclime data were very close: for Min. Temp. ±1.30ºC; Max. Temp ±0.64ºC and Rainfall ± 8mm (Figures 3a – 3c).
- Polynomials were derived with their R^2 value from the Best-Fit trendlines (Figure 4).
- The differentials were applied to the future temperature and rainfall from the Worldclim model to obtain the database for the future temperature and rainfall for Nigeria (Figure 5).

4.0 RESULTS AND ANALYSIS

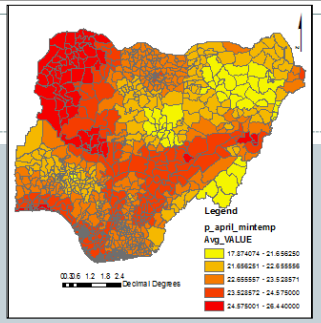

Figure 2a. April PAST Minimum Temp. (Worldclim).

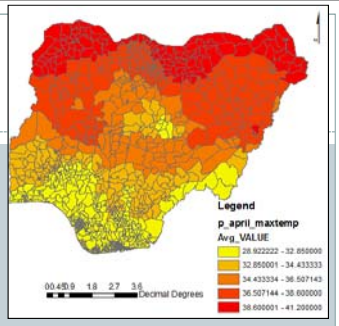

Figure 2b. April PAST Maximum Temp. (Worldclim).

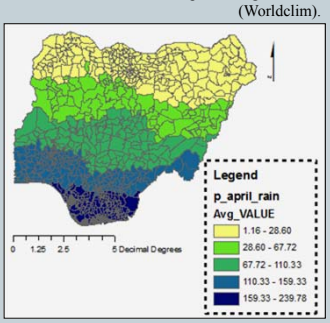

Figure 2c. April PAST Rainfall (Worldclim).

4.1 Comparison of Worldclim Data and Local Metro Data (NIMET)

- Sample results of the comparison between the Past NIMET Bauchi data (1950-2000) and the Past Worldclime data model are shown in Figures 3a – 3c.

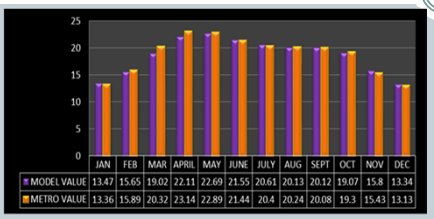

Figure 3a. Comparison between Worldclim and Meteorological (NIMET) data of Bauchi Minimum Temperature (℃).

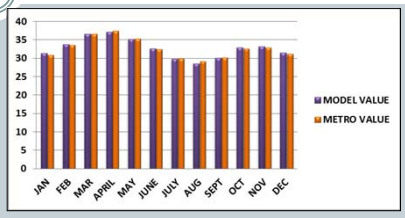

Figure 3b. Comparison between Worldclim and Meteorological (NIMET) data of Bauchi Maximum Temperature (℃).

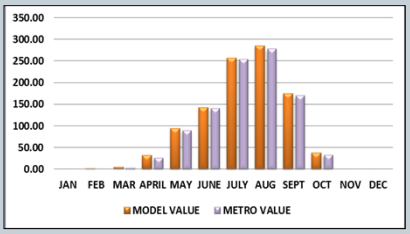

Figure 3c. Comparison between Worldclim and Meteorological (NIMET) data of Bauchi Rainfall (mm).

4.2 Modelling Future Climate Base-Map

•For the Future Bauchi Maximum Temperature, a Polynomial of Order 6 gave the "Best-Fit" as shown in Figure 4.

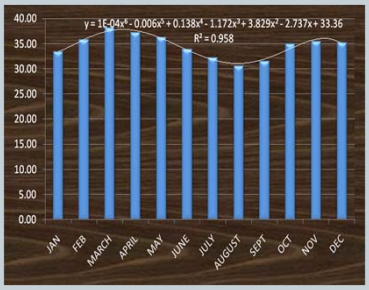

Figure 4. Model of Bauchi Future Maximum Temperature (°C)

The equation of the model is:

$y = 1E\text{-}04x^6 - 0.006x^5 + 0.138x^4 - 1.172x^3 + 3.829x^2 - 2.737x + 33.36$

where: $R^2 = 0.958$

R^2 represents the root mean square ≈ 1.

'Y' " the output: maximum temperature;

'X' " the months: January to December.

•Models were also developed on other factors: minimum temperature and rainfall, for other states and local governments in Nigeria.

•The spatial joining of the different climate maps of each month resulted in the production of twelve (12) base maps.

•For every Local Government Area (LGA), base maps for each month with the following attributes were created:

1. Mean Temperature
2. Minimum Temperature
3. Maximum Temperature
4. Rainfall (Precipitation)

Figure 5. Future September Base-map for Nigeria.

•Figures 6a – 6d show April Future Nigerian Climate maps (Minimum, Maximum, Mean Temperatures and Rainfall) for all the Local Government Areas (LGAs).

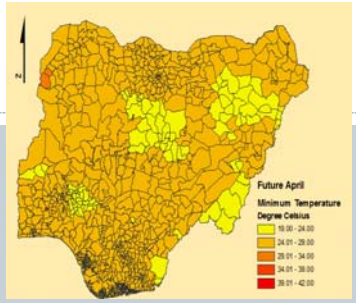

Fig. 6a. April Future Minimum Temperature.

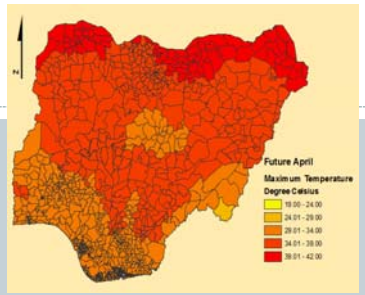

Fig. 6b. April Future Maximum Temperature.

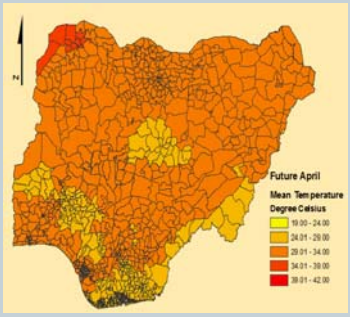

Fig. 6c. April Future Mean Temperature.

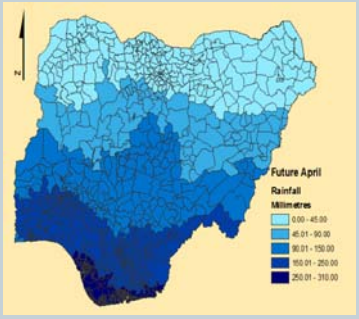

Fig. 6d. April Future Rainfall.

•This was also achieved for all months, making a total of 48 maps produced.

4.3 Predicted Changes in Future Rainfall and Maximum Temperature for Nigeria

Changes that will occur over time in temperature and rainfall were calculated.

MONTH	Range of Rainfall Change (mm)	Range of Max Temperature Change (°C)
JANUARY	-1 to 32.5	0.7 to 2.2
FEBRUARY	-1.9 to 7.8	-0.5 to 2.15
MARCH	-10 to 63.9	0.1 to 2.22
APRIL	1.2 to 73.5	-1.59 to 1.74
MAY	-24 to 60.4	-0.08 to 2.03
JUNE	-192 to 198	-0.84 to 1.32
JULY	-117 to 144	-0.2 to 2.48
AUGUST	-98 to 89	0.55 to 3.32
SEPTEMBER	-88 to 70.5	0.32 to 1.56
OCTOBER	-50 to 159	0.39 to 2.33
NOVEMBER	-4.3 to 128.5	0.13 to 2.3
DECEMBER	0 to 105.16	0.7 to 2.2

Table 1. Range of the Changes in Rainfall and Maximum Temperature for every month in every part of the country.

•The negative sign indicates a decrease while the positive sign indicates an increase.

•Maps indicating these changes, not range of changes, were also created (Figures 7a – 7b).

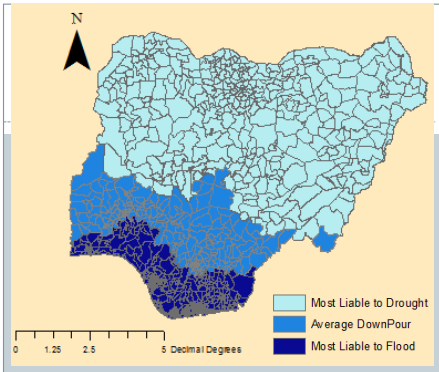

Figure 7a. Map showing Projected Distribution of Rainfall

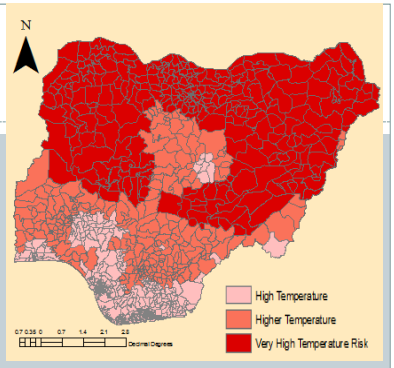

Figure 7b. Map showing the Projected Maximum Temperature

5.0 ANALYSIS

•With respect to the predicted changes in Rainfall and Temperature in Nigeria, for 2000-2050, the following analysis could be made:

(1) The Maximum Temperature-Change Maps indicate a general increase in temperature in every part of the country.

(2) From the Rainfall-Change Maps:

- ✓ the Northern regions will experience decrease in rainfall during the wet season
- ✓ the Southern regions will experience increase in rainfall during the wet season.

(3) During the wet season, especially between the months of April and October, areas along the coast will experience an average monthly increase of 100mm rainfall e.g. Eti-Osa and Ibeju-Lekki (Lagos State), Ogun Water-side (Ogun State), Warri-South (Delta State) and Ibeno (Akwa-Ibom State) – Figure 7a.

(4) Northern region will experience an average monthly decrease of 90mm in rainfall, between the months of June and September e.g. every part of North-West, 95% of North-East and 50% of North-Central- Figure 7a

(5) Figure 7b shows the variation in Maximum Temperature of different parts of the Country:

- ✓During the Dry season, areas marked 'Very High Temperature Risk' indicates regions with maximum temperature of above 37 degree Celsius (°C). This region covers every part of North-West, 80% of North-East and 30% of North-Central.

6.0 CONSIQUENCIES OF CLIMATE CHANGE

(1) Rainfall:

The increase in rainfall, especially along the coastal areas may experience the following possible effects:

- ✓Increase in Sea-level and inundation of wetlands and low-lying lands along Nigerian coast.
- ✓Erosion of beaches (e.g. Ibeno Beach in Akwa-ibom and Lekki in Lagos Island),
- ✓Intensified flooding of coastal areas (e.g. in Lagos State, Delta State and Cross-River) during storm.
- ✓Increase in salinity of rivers, bays such as Tarkwa Bay along Lagos Harbour and groundwater.

(2) Health

✓Health disorders are expected at higher temperature in regions with very high temperature risk e.g. Sokoto, Bauchi, Zamfara, Katsina, Kano, Jigawa, Niger, will likely experience high rate of morbidity, heart failure, bronchitis, peptic ulcer, adrenal ulcer, glaucoma, goiter, eczema, and herpes zoster are liable to these regions.

✓In areas along the coast with high risk of intensified flooding, there will likely be risk of some infectious diseases, particularly those diseases that are spread by mosquitoes and other insects.

(3) Drought- Nigeria as a nation may experience the following as a result of drought in future:

(a) Economic Losses

✓Loss of national economic growth, slowing down of economic development, damage to crop quality, less food production, increase in food prices, increased importation of food (at higher costs), insect infestation, plant diseases, loss from dairy and livestock production, unavailability of water and feed for livestock which leads to high livestock mortality rates, increased predation, range fires and wild land fires, damage to fish habitat, loss from fishery production, income loss for farmers and others affected,

✓Unemployment as a result of production declines, loss to recreational and tourism industry, loss of hydroelectric power, loss of navigability of rivers and canals.

(b) Environmental and Social

✓The Northern region may witness an increased desertification, damage to animal species, reduction and degradation of fish and wildlife habitat, lack of good and drinking water, disease, increased number and severity of fires, wind and water erosion of soils, food shortage, heat, mental and physical stress, water user conflicts, social unrest, inequity in the distribution of drought relief, loss of cultural sites, reduced quality of life which leads to changes in lifestyle, increased poverty and population migrations.

7.0 CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

•This research was carried out to be able to predict what the future weather, temperature and rainfall, conditions will be in Nigeria for the next 50 years (2000-2050).

•From the work, climate change scenarios indicate that the climatic variability currently being experienced is likely to increase and intensify in future. Droughts, floods and storms are likely to increase in both frequency and intensity.

•By this prediction, Nigeria will fit into the following categories of extreme events:

- ✓Warmer and more frequent hot days and nights over most land areas;
- ✓Warm spells/heat waves-frequency increases over most land areas;
- ✓Heavy precipitation events-frequency (or proportion of total rainfall from heavy falls) increases over most areas; and
- ✓Area affected by droughts may increase.

•The on-going climate change and its associated global warming are expected to cause characteristic climate patterns in different climatic regions and will have its negative impact on the ecosystem. Therefore, changes in climate factors such as temperature and rainfall should not be taken for granted in Nigeria.

7.2 Recommendations

•In general, Nigeria like many developing nations, will need to prepare adequately for the negative impact of climate change.
•All hands must be onboard (e.g. government agencies, private sector, civil societies and individuals)
•Researchers must be involved in modeling climate change periodically,
•Government agencies must create the awareness through information dissemination e.g. early warning, financial and logistic supports, while
•The local communities must cooperate with other stakeholders.

It is therefore recommended that:

➢the various projected climate maps and database developed, should present a platform for all concerned disciplines to better understand our climate system and to offer a means to access, plan and implement sustainable programs that will assist in combating these changes and to make our nation less vulnerable, and

➢as more climatic data are available, further research needs to be carried out to model variations based on decades, yearly, monthly and daily.