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Application of Remote Sensing and GIS for the Study of Rainfall Distribution in Nigeria from 2000-2019

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Abstract: A change in rainfall is one of the most critical factors determining the overall impact of climate change. To understand the rainfall pattern and trend properly, adequate and biased-free data is needed. Nigeria today has inadequate weather observations stations, which leads to bias on its data figures. To overcome this challenge, this research used data obtained from remote sensing satellite (TRMM)and analyzed using GIS application (IDRISI Taiga). The Trend analysis and Coefficient of Variation analysis (CV) covering 2000 to 2019 in Nigeria was performed. The result shows that areas that receive lesser amount of rainfall experiences higher annual rainfall variability between years of observations. It was also discovered that proximity to Atlantic Ocean and topography contributed greatly to the rainfall characteristics in Nigeria. Despite the spatial differences in rainfall trends, rainfall received across the study period in Nigeria is consistent. It was recommended that use of higher spatial resolution data will provide more accuracy in the study of the spatio-temporal distribution of rainfall in Nigeria. Researchers should adopt the use of remote sensing and GIS for their studies due to its numerous advantages.

Key words: Rainfall・Remote Sensing・GIS・Trend Analysis・Coefficient of Variation・Nigeria

INTRODUCTION

Rainfallis a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change [1]. Therefore, adequate rainfall data is needed for the study of climate pattern. Nigeria today has about fifty-four (54) weather observations stations existed which provide measurement of rainfall amount for different locations across Nigeria [2]. With this inadequate number of stations, there is high tendency of bias in the weather and climateobservation that may also affect climate predictions. Moreover, the World Meteorological Organization (WMO) request its member countries (including Nigeria), to ensure adequate monitoring of its weather by making sure that the gap between two weather stations is not more than 50km [3]. However, the Nigeria Meteorological Agency (NiMet) is yet to attain this level in their station network density. Provisions of the adequate weather stations will cost a lot during implementation and continuous monitoring of those stations which makes it difficult.

To overcome the above mentioned challenges, remote sensing technologyshould be applied. Remote sensing is a process of acquiring data from a distance of an object, area or a phenomenon by analyzing the data through instruments without being in contact with the object or area which is/are being examined. Remote sensing technology provides a synoptic view of the surface area of interest, thereby capturing the spatial variability in the attributes of interest. A major advantage of remote sensing technology is that it can obtain information about an area of interest that is difficult to access or inaccessible. Remote sensing has enabled us to monitor natural resources on a continental, even on a global scale. It is also the only realistic and cost-effective way of acquiring data over a large area [4]. In this research, data obtained by Tropical Rainfall Measurement

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Mission (TRMM) and Global Precipitation Measurement (GPM) as Weather Observation Satellites owned by National Atmospheric Systems Administration (NASA) was used to observedstatio-temporal changes in rainfall distribution in Nigeria From 2000 to 2019. The Geographical Information System (GIS) was also adopted for the analysis.

MATERIALS AND METHODS

The Study Area: The study is on Nigeria, which share boundaries withRepublic of Benin in the west, Niger Republic in the north, Chad in the northeast, Cameroon in the east and Gulf of Guinea in the south. The areais geographically located between latitudes 4° and 14° north and between longitudes 2.5° and 15° east, occupying about 923, 768 km^2 (Figure 1). The vegetation of Nigeria reflects its climatic and topographic characteristics. Paramount influences are the rainfall gradient, the relative humidity and the seasons. Thus, dominant vegetation types range fromForest of the south to the Savannah of the north [5]. Nigeria is endowed with arable land and fresh water resources when viewed as a whole with approximately 61 million hectares of the land cultivable while the total renewable water resources is about 280 km^3/year which include river Niger, river Benue, lake Chad, Osun river, Hadejia River, Bonny river and a host of others. Nigeria has a wide diversity of soil under different ecological conditions and with different levels of fertility. The different soils are a function of prevailing climatic condition, vegetative cover and topography of the area among others [6].

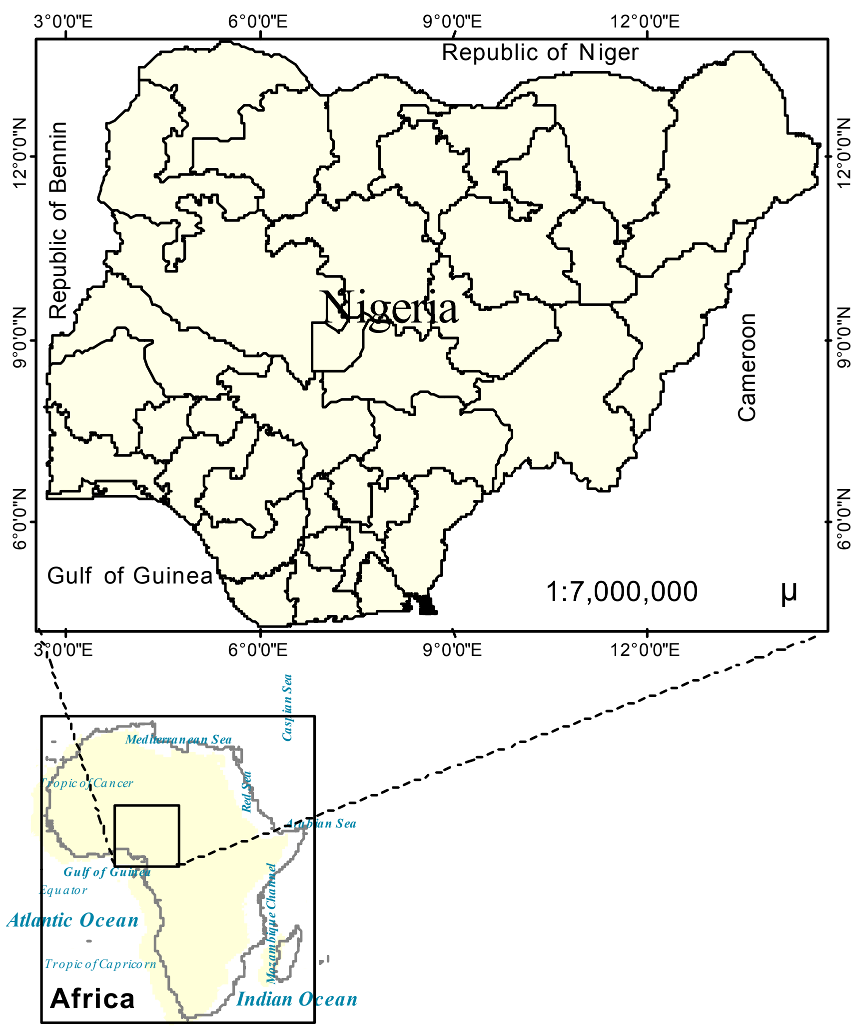

Fig. 1: The Study Area
Source: FAO, (1995) [6]

Nigeria, like the rest of West Africa and other tropical lands, has only two seasons. These are the dry season and the rainy season. The dry season is accompanied by a dust laden airmass from the Sahara Desert, locally known as Hammatan, or by its main name, The Tropical Continental (CT) airmass, while the rainy season is heavily influenced by an airmass originating from the south Atlantic ocean, locally known as the south western wind, or by its main name, The Tropical Maritime (MT) airmass. These two major wind systems(trade winds) modifies climate of Nigeria especially rainfall, which is the key climatic variable. Topography plays a significant role in local climate only around the Jos Plateau and along the eastern border highlands [7].

Data Collection and Processing: The rainfall data for this research was satellite observations called Tropical Rainfall Measuring Mission (TRMM), managed and archived by National Atmospheric Systems Administration (NASA) as downloadedfree via the website: https://giovanni.gsfc.nasa.gov/giovanni/. The downloaded data (twenty images as Time Average Map) is in GeoTIFF format, imported and converted toIdrisi raster format for geo-spatial analysis (IDRISI Version 16.05, 2009). The downloaded images have passed through all the necessary corrections by the data management body before archiving. The data was 0.25° (27km), monthly resolutions with variable name (3B43v7). The single downloaded image represent 12 months average rainfall (January to December), totaling 20 images from 2000 to 2019.

RESULTS AND DISCUSSION

To map out Spatio-temporal rainfall distribution across Nigeria, trend analysis on time series file was executed using Earth Trends Modeler (ETM) on IDRISI Taiga software.The rainfall data are remotely sensed by TRMM and associated satellites. Figure 2a is a mean image derived from image calculator where 20 images were added together and divided the total by the number of images (20). The resultant image was stretched for clearer view of the spatial differences, where it shows that Coastal areas (South-west and South-south), Cameroon Highland and North-central Plateau received more rainfall compared to other areas. Comparatively, North-eastern region receives lesser amount of rainfall. This confirmed that proximity toTropical Maritime air mass from Atlantic Ocean determines rainfall rate [8]. Similarly, the result shows that topography of the land plays a role in rainfall distribution [9].

Figure 2b describes Coefficient of Variation (CV)which is the ratio of the standard deviation to the mean. The higher the CV, the greater the level of dispersion around the mean and vice versa. It is generally expressed as a percentage. The Rainfall data was subjected to the measurement of relative variability to determine the spread of seasonal changes across the study area using CV formula (Equation 1). The CV equation was applied on IDRISI software using Image Calculator.

$$CV = \delta/\mu \times 100 \quad (1)$$

where:

CV = Coefficient of Variation
?? = Standard Deviation
μ = Mean (average)
(Everitt, 1998) [10]

Spatially, North-east of Nigeria appeared to have higher CV compared to other regions. The CV value ranges from 6.48 to 38.58. This shows that areas that receives lesser amount of rainfall experiences higher annualrainfall variability between years of observations (Figure 2b).

The result of the trend analysis shows that South-south, North-west and North-east experiences positive trend which denotes increase in rainfall rate, while other regions experiences negative trend (Figure 2c). Figure 2d is a reclassified r image where areas with positive and negative trends were shown.This result contradict was contradictory and it was discovered that there were transitions from dry to wet (upward shift) across all climatic zones of Nigeria [11].

Figure 3a shows that there was fluctuation in the quantity of rainfall received across Nigeria. The graph was the result when mean pixel values were obtained from individual annual images and importing them to EXEL. The line graph was also drawn from scatter graph to determine general linearity of the rainfall data where the result shows zero, even though 2006 and 2015 appeared to have highest and lowest rainfall values respectively (Figure 3b). Figure 3c was the monthly patter of rainfall distribution which confirms the result on Figure 3a. In a general term, from 2000 to 2019, rainfall rate in Nigeria is consistent despite the effect of global climate change.

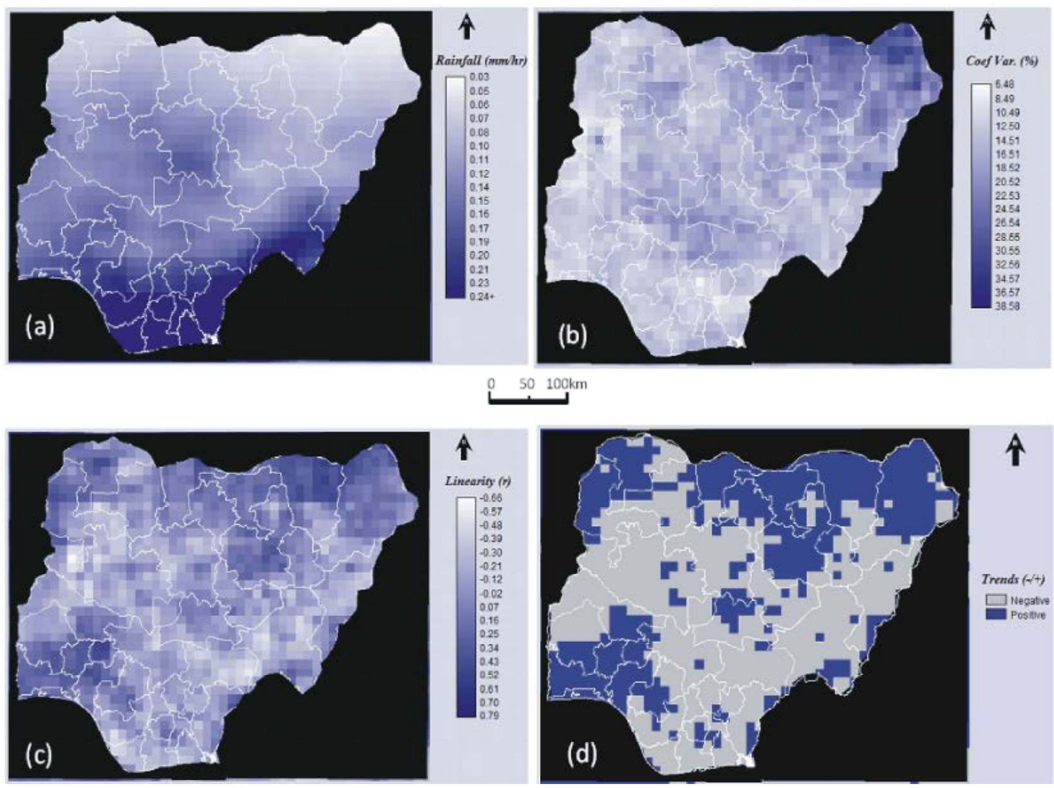

Fig. 2: Spatio-temporal Rainfall distribution in Nigeria from 2000 to 2019
(Source: Adopted and modified from PPS/NASA, 2020) [12]

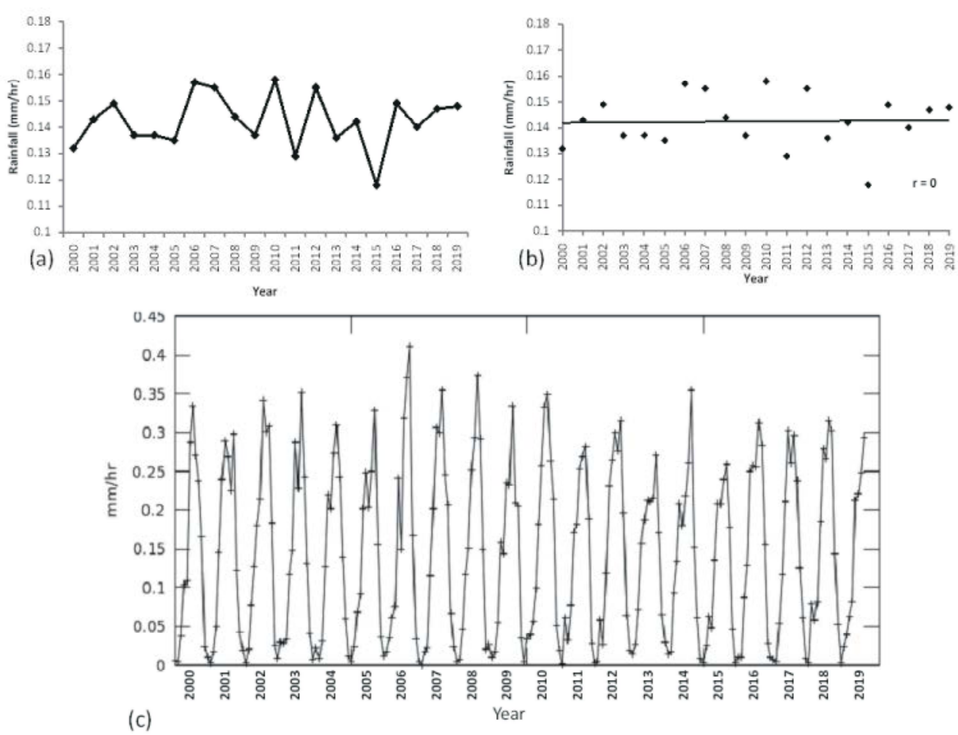

Fig. 3: Pattern and generalized Trend ofRainfall inNigeria from 2000 to 2019
(Source: Authors' Analysis, 2020)

CONCLUTIONS AND RECOMMENDATIONS

This research makes highlight on the spatio-temporal distribution of rainfall in Nigeria from 2000 to 2019 using remotely sensed data. The analysis was conducted using Geographical Information Systems (GIS). It generally proof that application of remote sensing and GIS in the study of rainfall distribution in Nigeria is feasible, it can help to eliminate spatial bias and overcome difficulties in the processes of accessingground rainfall data. The result shows that areas that receive lesser amount of rainfall experiences higher annual rainfall variability between years of observations. It was also discovered that proximity to Atlantic Ocean and topography contributed greatly to the rainfall characteristics in Nigeria. It was concluded that despite the spatial differences in rainfall trends, rainfall received across the study period in Nigeria is consistent. It was recommended that use of higher spatial resolution data will provide more accuracy in the study of the spatio-temporal distribution of climatic variables in Nigeria. Researchers should adopt the use of remote sensing and GIS for the geospatial analysis due to its numerous advantages.

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