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Rainfall distribution and change detection across climatic zones in Nigeria

Stephen Bunmi Ogungbenro, Tobi Eniolu Morakinyo *

Department of Meteorology, Federal University of Technology, P.M.B. 704, Akure, Ondo State, Nigeria

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ABSTRACT

Nigerian agriculture is mainly rain-fed and basically dependent on the vagaries of weather especially rainfall. Nigeria today has about forty-four (44) weather observation stations which provide measurement of rainfall amount for different locations across the country. Hence, this study investigates change detection in rainfall pattern over each climatic zone of Nigeria. Data were collected for 90 years (1910–1999) period for all the weather observation stations in Nigeria, while a subdivision was made to three (3) non-overlapping climate period of 30 years i.e. 1910–1939, 1940–1969 and 1970–1999. Statistical methods were utilized to justify any change in the average monthly and annual rainfall trend using probability density function and non-parametric tests such as the Pettitt test, Wilcoxon signed-rank test and paired sample test. Results show common change points and transitions from dry to wet (upward shift) in all climatic zones. Statistical tests performed on the data show that rainfall variation over each climatic zone is significant ($p < 0.05$) between pairs of climate periods. Suggestions were therefore made at the end of the study on the use of the contained information for socio-economic improvement and agricultural development of the zones.

1. Introduction

Nigeria's population and economy are linked to climate sensitive activities including rain-fed agriculture. An understanding of current and historical rainfall trends and variation is inevitable to her future development especially in agriculture and hydrological sectors. Previous studies have analyzed rainfall trends over entire or part of Nigeria. For example, Adefolalu (1986) examines trends in rainfall pattern using 70-year period (1911–1980) rainfall data from 28 meteorological stations. Bello (1998) extended the work and compared the seasonality of rainfall distribution in Nigeria for two climate periods, 1930–1961 and 1962–1993. Ati et al. (2009) reported significant increase in rainfall over nine stations in northern Nigeria between 1953 and 2002. The results showed a general decline of dry season's contribution to annual rainfall i.e. dry period is getting drier. More recently, Oguntunde et al. (2011) analyzed rainfall trends over Nigeria using 1901–2002 rainfall data from Global Gridded Climatology of Climate Research Unit Time series (CRU TS.2.1). They concluded that annual rainfall has been reduced significantly over 20% of the landscape and the amount of annual rainfall reduced by 50–350 mm in 64% portion of Nigeria. It is important to state that rainfall of Nigeria and West Africa in generally is influenced by the dynamics of continental air mass and maritime air mass which meet along a slanting surface called Inter-Tropical Discontinuity (ITD) (Odekunle, 2004). Varying degrees of convective activity and precipitation takes place at the south of ITD while little or no cloud development or precipitation occur in the northern part of ITD (Ilesanmi, 1972).

This present study differs from the previous ones in the following perspective; firstly, ground observation data used by Adefolalu (1986) and Bello (1998) was extended to year 1999. Secondly, the statistical approach employed is different and more recent. The present study aims to detect change (transition) point in rainfall pattern over Nigeria on a climatic zone basis using non-parametric statistical analysis. This was performed on the average zonal rainfall to show transitions in wet to dry and dry to wet among three (3) different non-overlapping climate periods of 30 years each ie., 1910–1939, 1940–1969 and 1970–1999. This enables the observation of increase or decrease in rainfall received in each of the climatic zones of Nigeria to be established.

2. Study area

The study area, Nigeria was subdivided latitudinally into three zones: Guinea (coast-8°N), Savanna (8–11°N) and Sahel (11–16°N)

* Corresponding author.
E-mail address: tobimorak@yahoo.com (T.E. Morakinyo).

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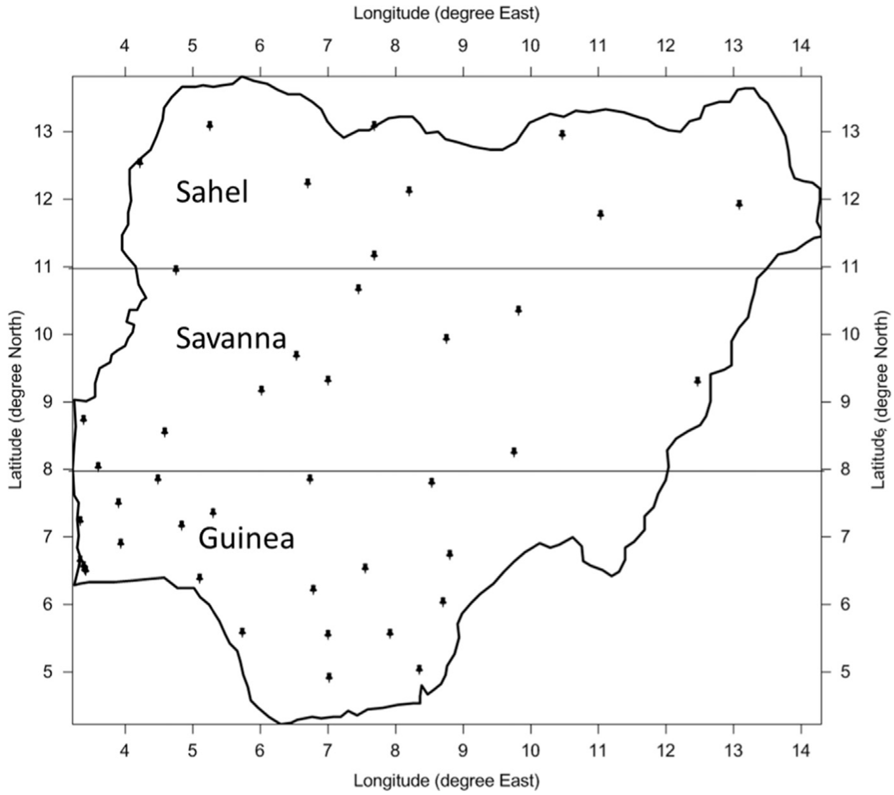

Fig. 1. Meteorological stations and climatic zone division after Omotosho and Abiodun (2007).

Table 1
Utilized Meteorological Stations, and classification to climatic zones after (Omotosho and Abiodun, 2007).

Guinea	Savanna	Sahel
Ikeja, Oshodi (Agromet), Lagos (Roof), Lagos (Marine), Ibadan, Ijebu-Ode, Abeokuta, Oshogbo, Ondo, Benin, Akure, Warri, Onitsha, Port-Harcourt, Owerri, Enugu, Uyo, Calabar, Ikom, Ogoja	Yelwa, Kaduna, Bauchi, Ilorin, Shaki, Bida, Minna, Abuja, Jos, Ibi, Yola, Iseyin, Makurdi, Lokoja	Birni Kebbi, Sokoto, Katsina, Gusau, Zaria, Kano, Nguru, Potiskum, Maiduguri

following Omotosho and Abiodun (2007) as shown in Fig. 1. The names of Nigeria Meteorological Agency (NIMET) stations that falls within each zone are given in Table 1.

3. Methodology

IPCC (2007) proposed a statistical approach to climate and climate change studies and this forms the focal point of this study as an attempt was made to study rainfall distribution over Nigeria.

Ninty-year monthly rainfall values for all the available meteorological stations in each climatic zone of Nigeria were collected from the archive of the Nigerian Meteorological Agency (NIMET) and the annual values over each station were calculated as per equation (1):

$$A = \sum_{i=1}^{12} R_i \tag{1}$$

Where R is the monthly rainfall amount at each station, i is the months of the year, and A is the annual rainfall amount at that station.

Further subdivision was done and the study period was classified into three different non-overlapping climate periods of 30 years each.

Variation exists in rainfall received even between stations that fall in the same climatic zone, hence, for stations that fall in the same zone, zonal averages of rainfall were obtained for stations (1 to j) using relation (2).

$$\overline{R_z} = \frac{\sum_{j=1}^{n} A_j}{n} \tag{2}$$

where $\overline{R_z}$ represents the average annual rainfall for the zone at any given year, and n is the number of meteorological stations in that zone.

The probability density function (PDF) describes the relative likelihood for any random variable to occur at a given point. The probability for the random variable to fall within a particular region is given by the integral of this variable's density over the region. The probability density function is non-negative everywhere, and its integral over the entire space is equal to one. A random variable X has density f, where f is a non-negative Lebesgue-integrable function, if

$$P[a \le X \le b] = \int_a^b f(x)dx \tag{3}$$

the uniform distribution on the interval [0, 1] has probability density $f(x)=1$ for $0 \le x \le 1$ and $f(x)=0$ elsewhere.

The standard normal distribution has probability density

$$f(x) = \frac{1}{\sqrt{2\pi}} x^{-x^2/2} \tag{4}$$