SPATIAL VARIATION AND PATTERN OF DAILY RAINFALL INTENSITY IN THE MIDDLE BELT REGION OF NIGERIA

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ABSTRACT
The study analyzed the spatial variability of daily rainfall intensity in the Middle Belt region (MBR) of Nigeria for 46-year period (1961-2006). Daily rainfall (≥0.3mm) data were collected from eight synoptic weather stations in the study area. Daily rainfall intensity were classified into six categories using percentiles (P) namely; extremely light (≤ P10), light (P11 - P20), moderately light (P21 – P50), moderately heavy (P51 – P80), heavy (P81 – P90) and extremely heavy (> P90). To compute the percentile threshold values of the intensity categories, the population of rain days was first extracted and then ranked. The threshold values of the percentiles were extracted for each of the six categories among the eight stations and the annual number of daily rainfall for each station were then determined. The result showed a zonal pattern of increase in annual number of days for extremely heavy and heavy events from eastern to western parts of the MBR. There are enclaves of high annual rain days for the light and moderate categories in Jos plateau. The study concludes that the spatial variation will have tremendous impact on water resources and crop production as well as hazards of erosion and flooding.

KEYWORDS: Orographic effect, Moisture, Enclaves, Percentile, Extreme rainfall.

1. INTRODUCTION

Daily rainfall is accumulated 24-hr rainfall amount. Daily rainfall intensity has resultant effect on the agricultural practices and production of the Middle Belt Region (MBR) of Nigeria. Moisture availability for crop use is provided by daily rainfall input, an adjustment in the occurrence of daily rainfall intensity will lead to adjustment in agricultural productivity within the region. Excess daily rain at harvest can affect grain crops quality. Variability in daily rainfall intensity affects water infiltration and percolation impacting on underground water aquifers and subsequent availability of water for domestic and industrial uses. Other issues of water resources such as those considered in the planning and construction of hydraulic structures like dams, reservoirs, drainage canals, culverts and bridges are all dependent to a large extent on variability of daily rainfall intensity especially, occurrences of extreme events (Oyediran, Kayode and Feyi, 2001).

The Middle Belt Region of Nigeria contains the two major rivers in the country-Rivers Niger and Benue. The low lying valleys of these rivers are prone to annual flooding, therefore increasing intensity of daily rainfall will have an adverse effect on the occurrence of flood within the valleys of these two major rivers. Relatedly, the region also contains the north central highland and the eastern highlands which are watersheds for many rivers and streams. Both rainfall intensity and runoff factors are considered in assessing water erosion problem (Wall, Baldwin and Shelton, 2003). A rainfall of high intensity will give more runoff, this is because less of the high intensity rainfall will infiltrate into the soil in contrast to low intensity rainfall. These factors feature prominently on the slopes of highlands in the Middle Belt affecting the rate of erosion occurrence.

Changes in global temperature have tremendous direct and indirect impact on global precipitation. As global temperature change, atmospheric moisture, precipitation and atmospheric circulation also change as the whole system is affected. Radioactive forcing alters heating, and at the earth's surface this directly affects evaporation as well as sensible heating. Further increases in temperature lead to increases in the moisture holding capacity of the atmosphere at a rate of about 7% per degree centigrade (Trenberth and Stepaniak, 2003). As the climate changes and sea surface temperatures (SSTs) continue to increase, the environment in which tropical storms form is changed. Higher SSTs are generally accompanied by increased water vapours in the lower troposphere, thus the moist static energy that fuels convection and thunder storm is also increased. Together, these effects alter the hydrological circle, especially characteristic of precipitation i.e. amount, frequently, intensity, duration and type as well as precipitation extremes (IPCC, 2007).

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Previous studies have shown that storm frequencies and intensities over both hemispheres have changed over the second half of the 20th century. General features of the change include a pole ward shift in storms track location and increased storm intensity. Significant increasing trends of storms over both the pacific and Atlantic are found in eddy meridians velocity variance at 300hpa and other statistics (Chang and Fu, 2002; Paciorek, 2002). Increases in storm track activity have also been reported by eddy statistics based on National Centre for Environmental prediction (NCEP)/ Atmospheric Research (NRA) data. Hurricanes and typhoons currently form from pre-existing disturbances only where SSTs exceed about 26°C and, as SSTs have increased, it thereby potentially expands the areas over which such storms can form.

Changes in atmospheric moisture, cloud cover and storm frequency will have tremendous impact on rain rates. Wilcox and Donner (2007) used a convection scheme which includes an explicit representation of meso-scale circulations and an alternative formulation of the closure, exhibits, among other differences, an order of magnitude more tropical rain events above the 5 mm/ h rate compared to the RAS simulation. Their simulation demonstrates that global atmospheric models can be made to produce heavy rain events, in some cases even exceeding the observed frequency of such events. Additional simulations reveal that the frequency distribution of the surface rain rate in the Global Circulation Model (GCM) is shaped by a variety of components within the convection parameterization, including the closure, convective triggers, the spectrum of convective and meso-scale clouds, and other parameters whose physical basis is currently only understood to a limited extent. Furthermore, these components interact nonlinearly such that the sensitivity of the rain-rate distribution to the formulation of one component may depend on the formulation of the others (Wilcox and Donner 2006).

In this study, the spatial variation and pattern of daily rainfall intensity, 24-hr or 1day rain rates is assessed in the Middle Belt Region of Nigeria. The specific objectives are to classify daily rainfall intensity categories in the MBR and to map the spatial variation of the daily rainfall intensity categories.

2. STUDY AREA

The Middle Belt Region is a unique geographical and climatological region of Central Nigeria (Anyadike, 1987). It is a transitional region between southern and northern Nigeria. In this study, the Middle Belt Region is defined to cover the six states within the North central geo–political zone and Adamawa and Taraba states. This definition uses the northern state boundaries of Niger, FCT, Nasarawa, Plateau,Taraba and Adamawa as the northern limit of the region. The Middle Belt region as defined is located within latitude $6^{o}24^{1}$ to $11^{o}30^{1}$ N and longitude $2^{o}42^{1}$ to $15^{o}00^{1}$ E. This covers a total land area of about 333 815 Km^2. The area occupies about 36.14 % of the total land area of Nigeria (Figure 1).

The Middle Belt region is found within the tropical wet and dry climate (Aw) according to Koppen-Geiger climate classification (Kottek et al, 2006). It is the zone of gradual change in climate character from the wetter equatorial margin towards the drier polar ward regions. Two seasons are experienced in the region. The dry season, which starts from late November to March and wet season, which prevails from April to October. The wet season is characterized by the tropical maritime air mass which brings rainfall and wet conditions to the region.

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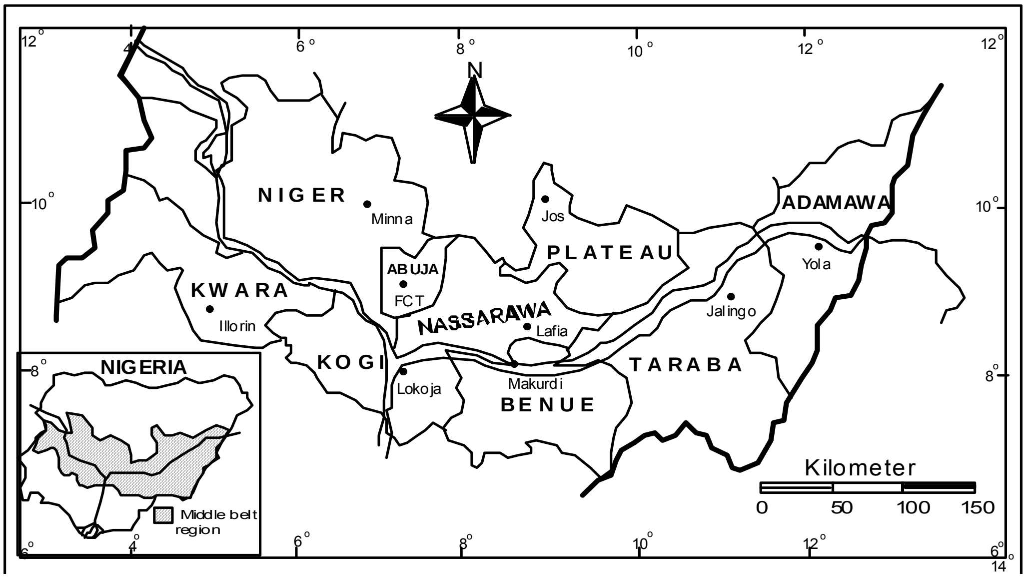

Figure 1. The location of the Middle Belt Region of Nigeria
Source: After Longman school atlas (2009)

3. MATERIALS AND METHODS

3.1 Data

The data used in the study were daily rainfall data (≥ 0.30mm). Daily rainfall data were obtained from 8 synoptic weather stations in the Middle Belt region for a 46-year period (1961 – 2006). The data are acquired at the Nigerian Meteorological Agency Operational Headquarters, Oshodi, Lagos. The 8 synoptic weather stations are selected because of geographical spread and data availability covering the study period (Figure1 and Table 1).

3.2 Classification of daily rainfall intensity

The classification of daily rainfall into six categories namely extremely light, light, moderately light, moderately heavy, heavy and extremely heavy according to the quantitative method of Tarhule, Zakari and Lamb (2009) was used to classify daily rainfall (Table 2). The procedure of classifying daily rainfall intensity using percentiles (Tyubee, 2009) shows that the raw population of daily rainfall events from the eight stations was first extracted for the 46- year period. The population of rainfall was then ranked in a descending order and the six intensity categories were determined based on percentile thresholds (Table 2).

Table 1. Meteorological stations selected for the study.

Station	Code	Latitude (N)	Longitude (E)	Elevation (m)
Bida	65112	9^o06^1	6^o01^1	142
Ibi	65145	$8^o\ 11^1$	9^o45^1	108
Ilorin	65101	8^o29^1	4^o35^1	307
Jos	65134	9^o38^1	8^o52^1	1286
Lokoja	65206	7^044^1	7^054^1	204
Makurdi	65271	7^o45^1	8^o32^1	92
Minna	65123	9^o37^1	6^o32^1	259
Yola	65167	9^o14^1	12^o28^1	186

Source: Nigerian Meteorological Agency, Lagos (2011)

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Table 2. Classification of daily rainfall intensity.

Percentile threshold	Rainfall status
X < 10	Extremely light
10 < x ≤ 20	Light
20 < x ≤ 50	Moderately light
50 < x ≤ 80	Moderately heavy
80 < x ≤ 90	Heavy
X > 90	Extremely heavy

Source: Adapted from Tarhule, et al, (2009)

3.3 Study variables

The study variable, annual number of rainy days (mm/day) was summed for each of the six intensity categories for each of the eight synoptic stations. The annual number of rain days is summed from the monthly total of rain days for each intensity category (mm/day).

3.4 Data analysis

The spatial variation in daily rainfall intensity was investigated by interpolating the 46-year mean number of days for each intensity category. The arrangement of the isolines was used to assess the patterns of the spatial variation of daily rainfall intensity in the study area.

4. RESULTS AND DISCUSSION

Extremely light and light events (figure 2 and 3) showed an enclave of higher annual number of rain days of 17 and 10 days over the Jos plateau where the annual number of rain days decrease to 7days and 8days to the western and northeastern parts of the country. The higher number of days is related to the orographic effect of the Jos plateau where the rainfall is more frequent compared to intensity. The situation in Makurdi is explained as one of the rainfall abnormalities over Nigeria. An abnormal rainfall condition first observed and referred to as rainfall peculiarity by Adedokun (1965). It is a known fact that in Nigeria rainfall generally decreases from the coast to north eastern Nigeria. Latitudinally, the decrease of annual rainfall is about 389mm per latitude inland from the coast. Makurdi – Yola axis with mean annual rainfall of 1093 and 516mm respectively are relatively lower than their latitudinal values (Makurdi lat. $7^0 45^1$N and Yola, lat. $9^0 14^1$N) (Adedokun, 1965). The occurrence of many light events as observed in the study may be responsible for the abnormality as the annual totals are a summation of the daily events.

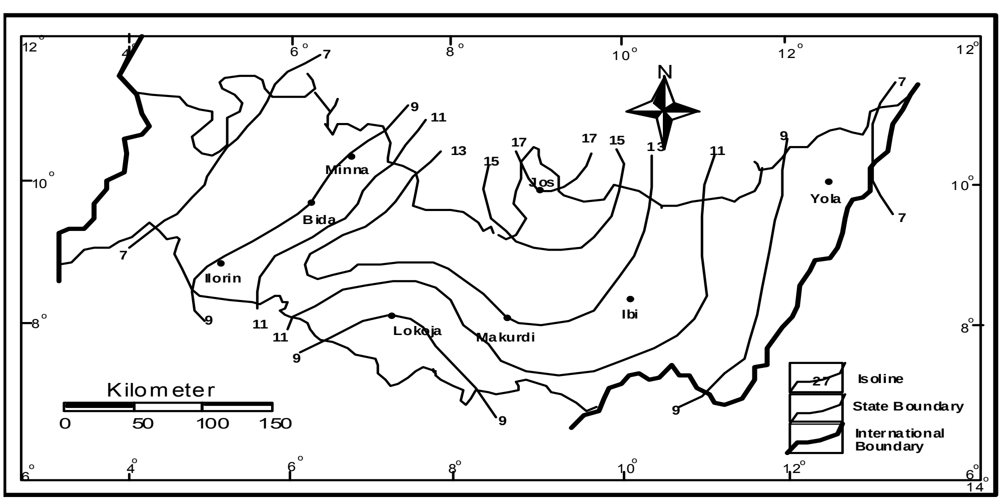

Figure 2: Variation in mean annual number of extremely light rains in the Middle Belt region.

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Source: Authors fieldwork (2013)

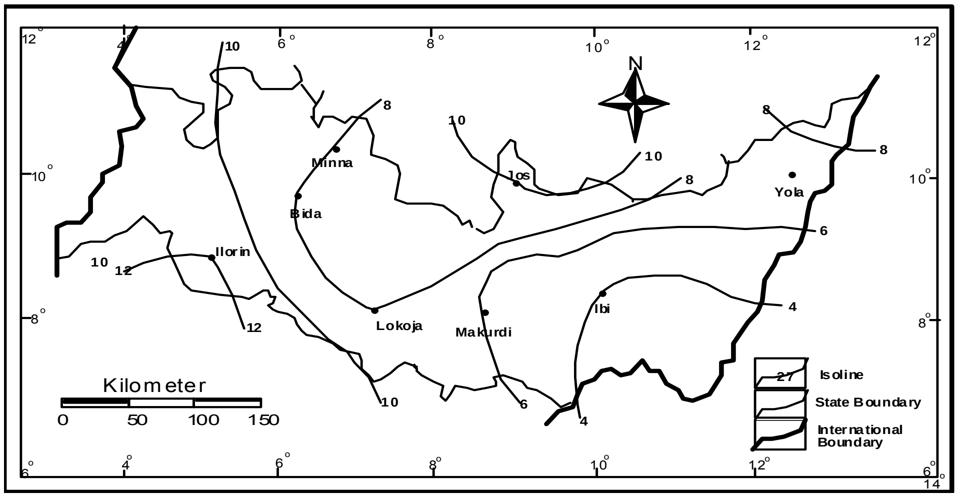

Figure 3: Variation in mean annual number of light rains in the Middle Belt region.
Source: Authors fieldwork (2013)

Daily rainfall intensity pattern of moderately light and moderately heavy categories in the MBR also showed a zonal pattern. The annual number of moderately light intensity rain days decreases from32 days for Jos plateau to 20 days in the western and eastern parts of the study area, however moderately heavy intensity values increase from 21 days in the eastern to 30 days in the western parts of the region. The result of the pattern of spatial variation in rain days of moderately light and moderately heavy (figures 4 and 5) showed the influence of elevation on number of rain days.

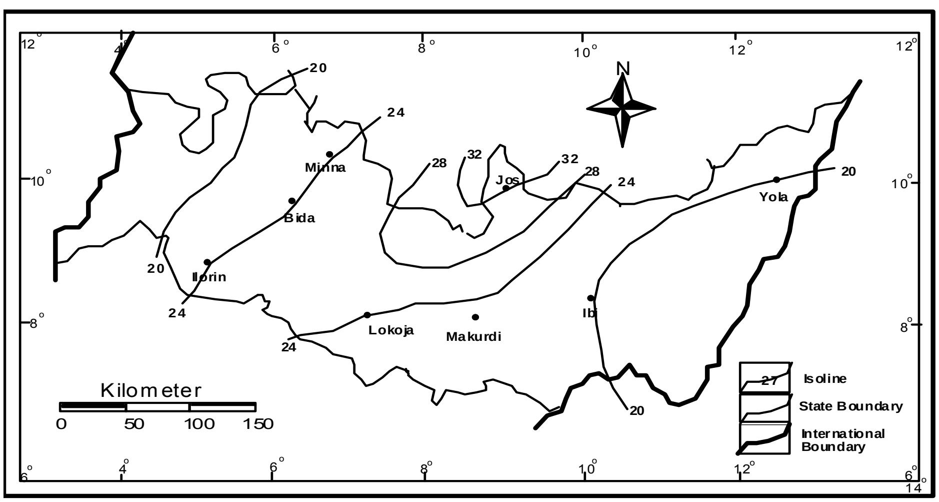

Figure 4: Variation in mean annual number of moderately light rains in the Middle Belt region.
Source: Authors fieldwork (2013)

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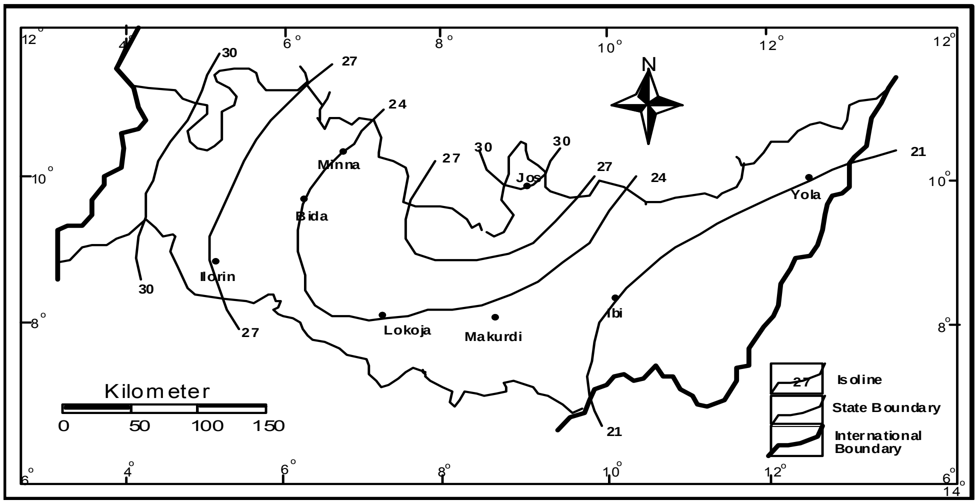

Figure 5: Variation in mean annual number of moderately heavy rains in the Middle Belt region.
Source: Authors fieldwork (2013)

The pattern of daily rainfall intensity categories of heavy and extremely heavy events (figures 6 and 7) is at variance to the patterns observed in figures 2 to 5. Low annual number of heavy rains (8 days) and extremely heavy rains (8 days) were observed over the Jos plateau. The annual number of rain days for both heavy and extremely heavy intensity categories increase to 10 days (western part) and decrease to 7 days (eastern part).

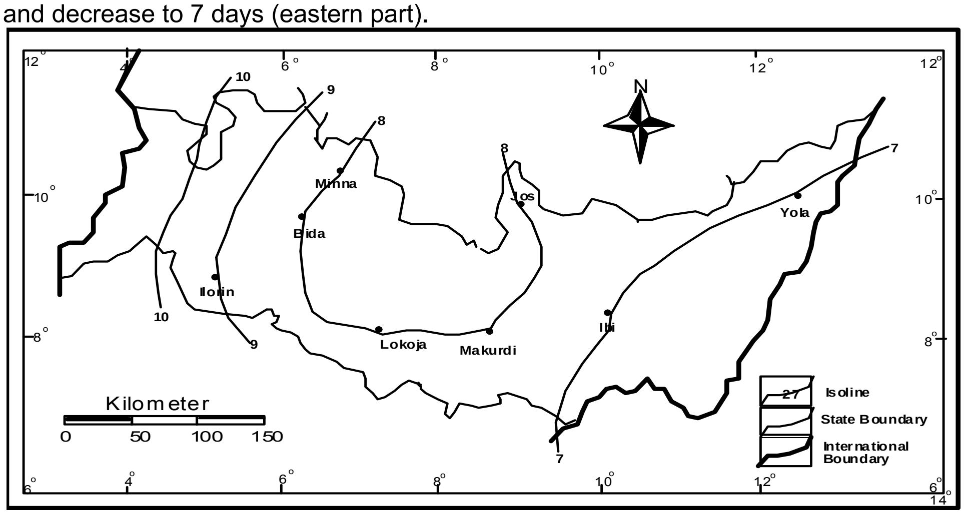

Figure 6: Variation in mean annual number of heavy rains in the Middle Belt region.
Source: Authors fieldwork (2013)

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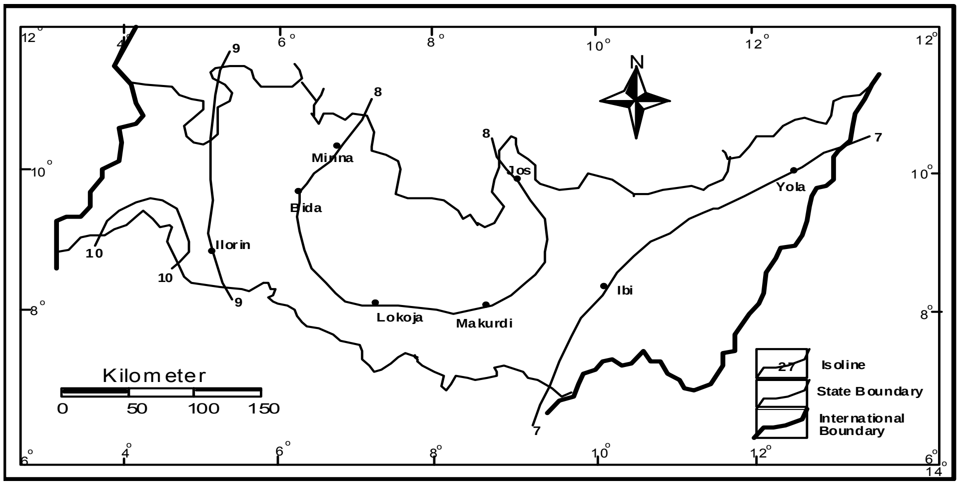

Figure 7: Variation in mean annual number of extremely heavy rains in the Middle Belt region. Source: Authors fieldwork (2013)

The high occurrence of heavy and extremely heavy events in the west is explained by the fact that rainfall in Nigeria is derived from the south-west monsoon air mass which originates from the St. Helena high pressure cell over the South Atlantic Ocean. This wind advects moisture over Nigeria from the south – westerly direction hence showering more (high intensity daily events) at the western part where the wind is heavily moisture laden.

5. CONCLUSION

The spatial variation and pattern of daily rainfall intensity categories in the MBR has shown that annual number of extremely light, light, moderately light and moderately heavy rains are higher over the Jos plateau and decrease to western and eastern parts of the study area. Conversely, the annual number of heavy and extremely heavy rains were least over the Jos plateau and increases towards the western parts of the study area. This is related to orograhpic effect on rainfall and the effect of South west trade winds on zonal distribution of rainfall in Nigeria. This spatial pattern of daily rainfall intensity is confirmed in an earlier study by Tyubee (2005) in the Middle Belt of Nigeria.

AUTHORS' CONTRIBUTION

Author 1 carried out the field work and did the analyses while author 2 designed and supervised the study. Both authors read and approved the manuscript.

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