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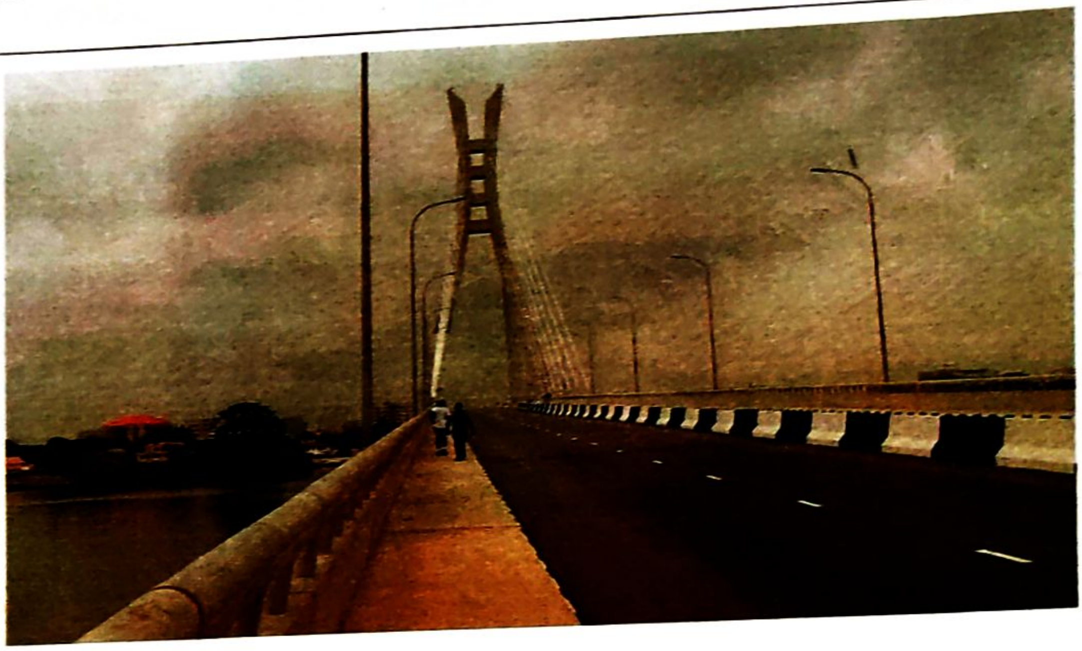

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THE GEOGRAPHICAL PERSPECTIVES

Inter-Seasonal Variability in the Quality of Rainfall in Minna, Niger State, Nigeria[1]

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Abstract

Rainfall certainly remains a critical challenge controlling smallholder farmers in Nigeria also Inter-seasonal rainfall variability is an important aspect in full comprehensive study of rainfall variability as it affects the moisture quality. This study examined the inter-seasonal variability in the quality of rainfall in Minna, Niger State. Daily rainfall records periods of fifteen years (2000-2014) were used to derived onset, cessation dates, length of the rainy season, and frequencies of breaks, annual rainfall total and Moisture Quality Index (MQI) values which were also subjected to time series analysis. Result of the analysis reveals that effective onset dates were characterized by inter-seasonal fluctuations as the trends inclined toward early onset (early June to mid-May). Despite the early onset, it indicates that rainfall in Minna is characterized with breaks which sometimes result to mild drought after effective onset. Similarly, cessation dates are now shifting towards mid-October from late September which implies longer length of rainy season. This is confirmed by trend analysis of the growing season which indicates an increase from about 125 to 150 days. Moisture quality analysis shows that breaks play significant role in the seasonal moisture quality for sustainable agriculture and livelihood. The inter-seasonal variability of rainfall across the study area triggered seasonal weather-related hazards such as drought and flash flood which calls for a quick action plan so as to help farmers properly plan ahead of their planting season thereby reducing agricultural related disaster and intensifying sustainable food production.

Keywords: Dry spell, onset dates, cessation dates, length of rainy season, IRMI.

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Introduction

Rainfall certainly remains a critical challenge controlling smallholder farmers in Sub-Saharan African countries. In this part of Nigeria where agricultural activities especially crop production is solely dependent on highly unpredictable and sporadic seasonal rainfall, the volume, timeliness, distribution and duration of rainfall in each season are of major concern to the worrying farmers (Ndamani and Watanabe 2014). It is also important to note that the subject of seasonal rains constitute the most important modulator of socio-economic activities in semi-arid and dry sub-humid areas of Nigeria. In Minna, peasant crop farming is a major economic activity whose fortune can easily be affected by fluctuations in the rainfall regime. Thus, the socio-economic wellbeing of the inhabitants is largely a function of the performance of the seasonal rains (Usman and Abdulkadir 2013).

Inter-seasonal rainfall variability is an important aspect in the full comprehensive study of rainfall variability as it affects the moisture quality. It involves the examination of observable trends in the rainfall parameters as they occur or being experienced in a particular season while the inter-seasonal rainfall variability could be simple defined as a comparative study of the season-to-season variations in rainfall parameters.

With respect to the aforementioned rainfall parameters, it has been observed from past records and literatures that rainfall parameters such as onset and cessation dates as well as length of rainy season (LRS) also known as hydrologic growing season (HGS), are important piece of information for planning the cropping calendar each year (Usman 2000: Tadross et al. 2003). There are other rainfall parameters too that are worthy of note when it comes to determining the quality of rainfall received in a particular place or region, these among many include: breaks, occurrence of dry spells and drought. The inability of farmers to know the real onset dates for their growing season has resulted into several severe losses which aggravates the low standard of living witnessed in Minna and its environs particularly in recent times. The increase in the occurrence of dry spell has also being observed to be increasing on alarming rate as well as the frequent loss of yield which as necessitates the assessment of intra-seasonal variability in rainfall quality. Any observable anomaly in any of these rainfall parameters has grievous implications on crop production and this directly threatens food security as well as the standard of living of the farmers whose source of livelihood solely depends on peasant farming (Usman and Abdulkadir 2013).

This research is therefore necessary so as to check the observable trend in the rainfall parameters as it affects or influences the seasonal variations in the quality of rainfall received in this part of the country. It will be very helpful in proffering solutions to the problems being faced by farmers whose basic source of livelihood lies on how effective and qualitative the amount of moisture received in a particular growing season can sustain their cultivated crops. This will be done with the help of a more suitable index for determination of the real monsoon onset dates, cessation dates and other parameters which is the major target of this study.

The Study Area

Minna is the headquarters of Chanchaga Local Government area and the capital city of the state respectively. It lies between Latitude 09^{0} 40^{1} 7.63^{II} N to Latitude 09^{0} 39^{1} 59.72^{II} N and longitude 06^{0} 30^{I} 0.32^{II} E to Longitude 06^{0} 36^{1} 34.05^{II} N. Minna lies on a valley bed (i.e. lowland) bordered to the east by Paida hill stretching eastwards towards Maitumbi and essentially savannah and quite conducive for farming. It bordered by Wushishi and Gbako to the west, Shiroro to the North, Paikoro to the East and Katcha to the south (Fig 1.2). Minna possesses the tropical continental wet and dry climate based on the Koppen classification scheme and is characterized with two distinct seasons, namely the wet season which begins around March and runs through October and as well as a dry season which begins from October to March. Minna has a mean annual rainfall of 1334mm with September recording the highest rain of close to 330mm on the average while the least amount of rainfall occurs in December and January which can be as low as 1mm.

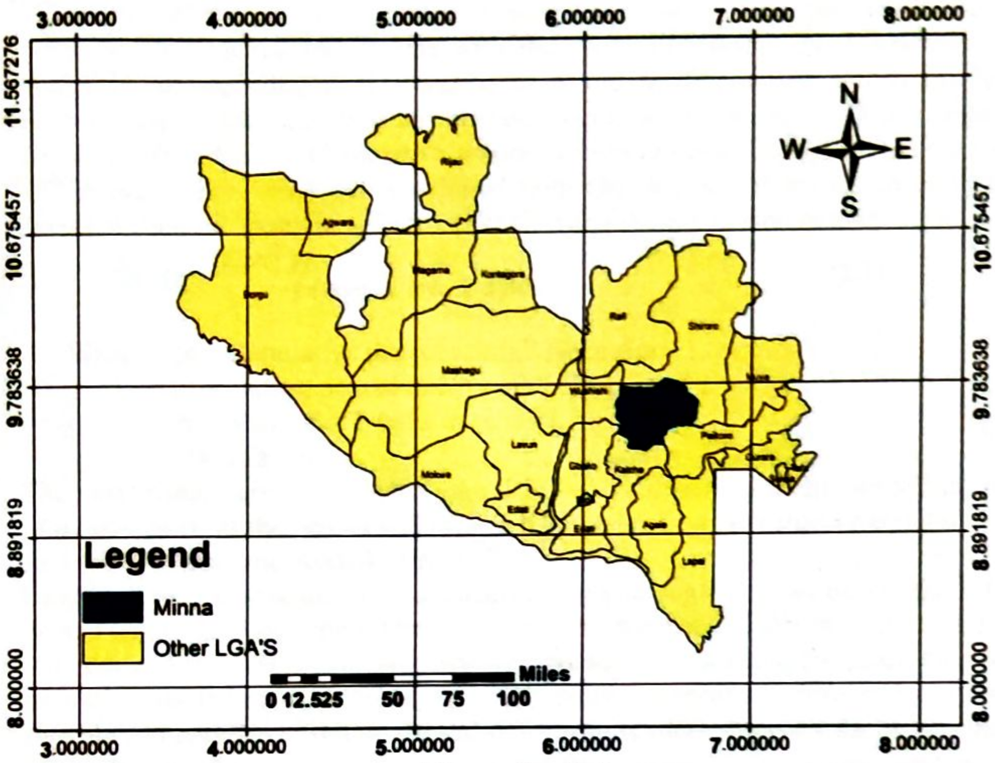

Figure 1: Study area
Source: Department of Geography, 2014.

The monthly rainfall is often intensified during the months of July, August and September. The variation in precipitation between the driest and the wettest month is averaged around 259mm, temperature also varies by 5.2^0 C throughout the year (climate-data.org). In terms of ethnicity and culture, the three principal ethnic groups of the state are the Nupe, the Gwari and Hausa. Other groups include the Koro, Kadara, Kamuku, Pangu, Bauchi, Fulani, Dukawa, Gade, Godara, Ganagana, Dukawa, Mauchi, Ayadi, Ingwai, Dibo, Kadanda, Gulengi, Abishiwa and Shigini (Aminu, 2010).

Materials and Methods

Daily rainfall records were obtained from the Geography Department, Federal University of technology and Nigerian Meteorological Agency, Minna for periods of fifteen years (2000-2014). From this record, the rainfall pattern for the city and the parameters derived (such as onset dates, cessation dates, length of rainy season, breaks, annual total rainfall and moisture quality) as earlier mentioned in the previous chapter were estimated for the year under review. These were derived using intra-seasonal rainfall monitoring index (IRMI) of Usman and Abdulkadir (2013) and moisture quality index (MQI) of Usman (1999).

Derivation of Indices

Onset dates, Cessation dates Length of rainy season (LRS) and breaks.

Observed daily rainfall totals were aggregated into pentad totals. As described in Usman (1999), any pentad with less than 5mm of rainfall was taken as a break. The first of May (the 25^{th} pentad of the year from first of January) was taken as the pentad of reference for this research. This choice was in line with the views of Usman and Abdulkadir (2013). This choice of the beginning of May was based on the identification of Sultan and Janicot (2000) of mid-May as the first time an increase occurs in the positive rainfall slope in Sudano-Sahelian West Africa.. Cumulative amount of rainfall and the highest pentad total since the 25^{th} pentad were noted and combined with the number of breaks to compute an Intra-seasonal Rainfall Monitoring Index (IRMI) using the expression below;

$$\textbf{IRMI}= (Cpt^2) / (hpt \; X \; Nb \; X \; 100) \qquad \textbf{(1.1)}$$

Where Cpt= cumulative pentad rainfall since April 1,
hpt = highest pentad total rainfall since April 1,
Nb = number of breaks in rainfall,
100 = a factor.

The onset dates were derived using the IRMI which implies that the 'actual' or 'real' onset of rains was taken as the pentad within which the index is greater than or equal to 1 ($\geq$1), for the first time (Usman and Abdulkadir, 2013).

Length of the rainy season was obtained by subtracting the onset pentad from the cessation pentad and multiplying the difference by 5 (i.e., number of days in a pentad). The choice of this index over other previously reviewed rainfall-only scheme for examining variability in seasonal rains is because it combines both quality and spread of rains and as a result makes it suitable and possible to follow the soil moisture situation necessary for plant germination and establishment closely. Another reason for the choice of this index was its efficacy for moisture quality examination and monitoring. Usman and Abdulkadir (2013),

Any 5-days rainfall sum (pentad) that is less than 5mm of rain was taken as a break (Usman, 2000).

Moisture Quality

This was estimated using the Monsoon Quality Index (MQI) of Usman (1999) which is a measure of the quality of rainfall received in terms of both annual amount and seasonal spread.

Daily rainfall data acquired for the period of 2000 to 2014 for Minna was also utilized for MQI. The daily data were subsequently grouped into 73 pentads (5-days) totals while monthly totals were also been made available from the daily amounts. MQI was computed for each season independently removing the need for long-term measures such as the means, standard deviations, etc. Inter-seasonal variability in the quality of rainfall received will then be ascertained by comparing the values for the years under study.

MQI was computed thus;

$$MQI = \frac{(r_{mmi} * Nb_i)}{(R_i)^2} \qquad (1.2)$$

Where i = year indentifier

r_{mm} = highest monthly rainfall total

R = Annual rainfall total

Nb = Number of 'breaks' in rainfall. A break is taken as any pentad period with less than 5mm of rain (Usman, 2000b).

The index will be small if the annual amount is high and the rains are not concentrated in any month-in other words, if the spread of the rain is good. Thus, it can be said that the smaller the index, the better the season quality-wise since the wellbeing of the agriculture is tied strongly to the amount and distribution of the rains (Usman, 2000b). Similarly, the index will be highest for the year with the smallest annual total and the most concentration of the rains in any single month.

The estimated MQI values were then interpreted according to the MQI classification table of Usman (2000) where class 1 corresponds to the "good" rainfall performance with MQI value of <0.005 while the class 5 corresponds to the "extremely poor" rainfall performance with MQI value >0.02 as indicated in table 1.

Table 1: MQI Classification

MQI Class	MQI Value	Rainfall Performance	Drought Category
1	<0.005	Good	No Drought
2	≥0.005<0.01	Fair	Mild Drought
3	≥0.01 <0.015	Poor	Severe Drought
4	≥0.015<0.02	Very Poor	Very Severe Drought
5	>0.02	Extremely Poor	Extremely Severe Drought

Source: Usman (2000b).

Statistical Analysis

The derived onset, cessation dates and length of the rainy season and frequencies of pentad breaks, annual rainfall total and MQI values were all subjected to time series analysis. Linear trend lines, estimated mean values and best fit trend line equations were also plotted for each rainfall parameter and presented graphically by means of EXCEL software.

Results and Discussion

Table 2 presents the result of the inter-seasonal rainfall variability analysis of all the rainfall parameters of discussion in this study for the 15 years period under review. The onset dates were the first to be estimated for each year using the earlier discussed methodology, followed by the respective cessation dates. The length of rainy season estimated for the whole period displayed quite an healthy variation which is typical of a sudano-sahelian location. Other parameters presented on the table include the estimated number of breaks, annual rainfall total received, the highest monthly total rainfall received, cases of dry spell alongside drought occurrences and the MQI values for each year.

Table 2.: Inter-seasonal analysis of rainfall parameters from year 2010-2014

YEARS	INTER-SEASONAL RAINFALL VARIABILITY ANALYSIS								
	Onset Dates	Cessation Dates	LRS (days)	Number of breaks	Annual Rainfall Total (mm)	Highest Monthly Total (mm)	Dry Spell	Drought	MQI
2000	4-Jun	13-Oct	135	9	1274.2	308.50	-	-	0.0017
2001	9-Jun	23-Sep	110	10	1363.9	331.7	-	-	0.0018
2002	19-Jun	23-Sep	100	8	1158.7	260.6	-	-	0.0016
2003	4-Jun	3-Oct	125	8	1048.0	213.1	-	-	0.0016
2004	25-May	13-Oct	145	8	1119.8	241.5	-	-	0.0015
2005	10-May	8-Oct	155	12	1076.5	294.2	3	1	0.0030
2006	15-May	23-Oct	165	6	1423.2	360.5	-	-	0.0011
2007	10-May	23-Sep	140	7	1414.4	330.2	-	-	0.0012
2008	15-May	13-Oct	155	7	1297.7	333.6	1	-	0.0014
2009	25-May	23-Oct	155	7	1403.8	497.6	1	-	0.0018
2010	30-May	23-Sep	120	5	1201.7	260.9	-	-	0.0009
2011	15-May	23-Oct	165	4	992.2	301.8	-	-	0.0012
2012	20-May	3-Oct	140	4	1540.35	376.9	-	-	0.0006
2013	14-Jun	13-Oct	125	10	1078.3	222.4	1	-	0.0019
2014	10-May	8-Oct	155	7	1225	347.5	-	-	0.0016
2015	30-May								

Source: Author's Work, 2015.

Onset Dates

Onset date were identified and this are not the first day of rain falls but the time a place receives an accumulated amount of rainfall sufficient enough to sustain cultivation of crops; this is why it is so important to the farmers. Figure 2 gives the graphical representation of the monsoon onset dates in Minna with about 10 years out of the 16 years analysis having their onset dates in May.

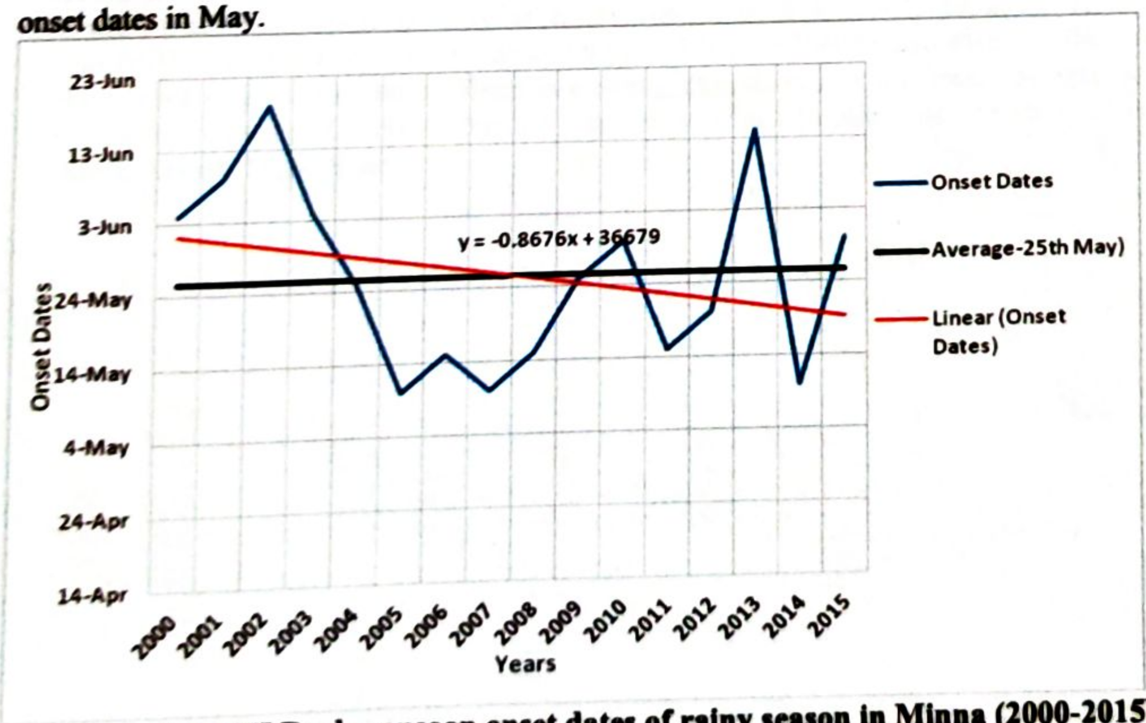

Figure 2: IRMI Real monsoon onset dates of rainy season in Minna (2000-2015).

Early Onsets were recorded in year 2005, 2007 and 2014 which was effective on the 10th of May while late Onsets were recorded in 2002 and 2013 which falls on 19th and 14th of June respectively.

The trend line equation was negative (y = -0.8676x + 36679) which depicts a decreasing trend in the day of occurrence of onset of rains. This implies that there is now a shift from late onset of rains around early June now to mid-May. This result is in correlation with previous studies such as the IRMI Onset Series of Minna and Kano computed by Usman and Abdulkadir, (2013) which also depicted the downward trend in the occurrence of onset dates confirming the shift in trend to early onset of rainfall in Minna. However, despite the early onset, rainfall in Minna is characterized with breaks which sometimes its consecutive occurrence reduces the efficiency of moisture quality in the soil available for plant growth.

With this wide variability display in onset dates in Minna, the average onset date was calculated to be 25th of May as shown in figure 2 with a plus or minus of 10days for forecast purposes. This result is similar to the findings of Sawa and Adebayo, (2011) who estimated that the onset date of rainfall for Northern Nigeria at large is averaged at 20th May. This condition is necessary to give room for the variations noticed from the analysis which implies that the real monsoon onset dates could be expected any moment from the 16th of May (mid-may) to 5th of June (early June).

Cessation Dates:

Cessation dates of rainfall are also very important information of great interest to farmers, agro-meteorologists and hydro-meteorologists. This is the opposite of Onset of rains as it's the termination of effective rainy season. It does not imply the last day rain fell, but when rainfall can no more be assured or be effective for plant growth (Usman and Abdulkadir, 2013).

There are notable variations in the cessation dates of rainfall in Minna. Late cessation were recorded in 2006, 2009 and 2011 as late as 23rd of October, while there were years with record of early cessation as early as 23 September such as 2001, 2002, 2007, and 2010 (Figure 3). The trend line and its equation (y = 0.625x +36802) also displays the changing trend in the cessation of rains. There is a strong indication that the cessation dates are now moving towards mid-October from late September which implies late cessation of seasonal rains in Minna, Niger State.

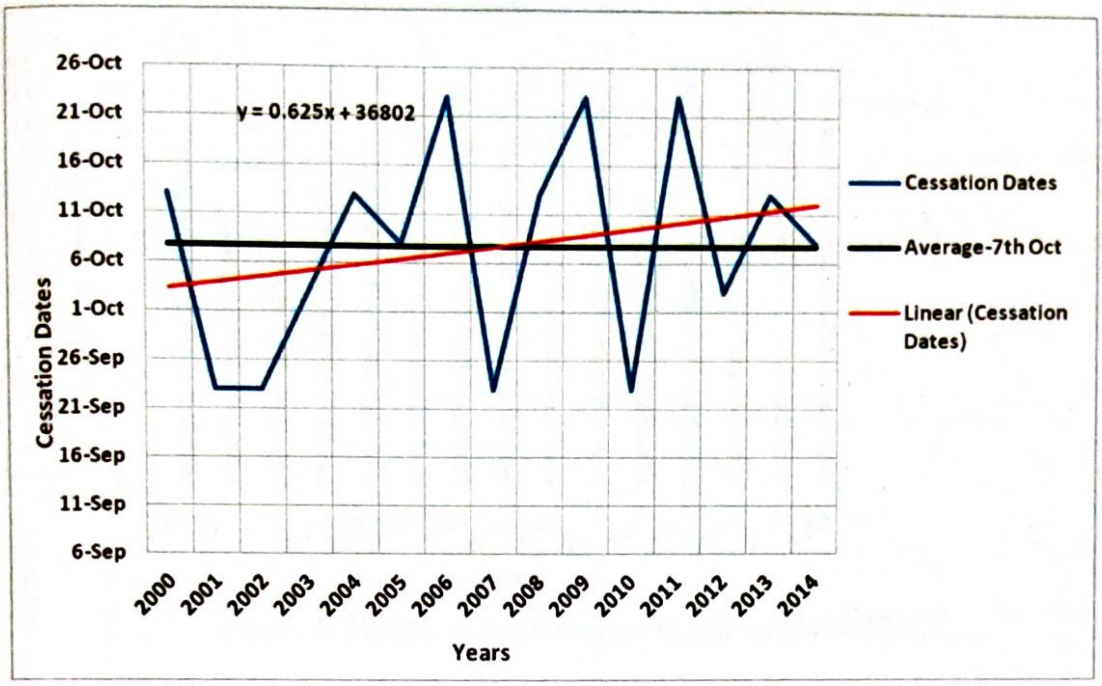

Figure 3: Cessation dates of rainy seasons in Minna (2000-2014)

The average cessation date of the rains in Minna stands at 7th of October. Considering the plus or minus 10 days predictive margin, this implies that effective rainfall ceases around 27th September which is close to the findings of Sawa and Adebayo (2011) to 17th of October as the case may be. In their result, the average expected cessation date for the Northern Nigerian region was estimated to be around 20-25th of September using the Ogive method.

Length of Rainy Season

The period between the onset and cessation of rain in a particular season is the length of the rainy season. Figure 4 shows the variations in the length of rainy days also known as length of growing seasons for the years under review. This was calculated by subtracting the onset pentad from the cessation pentad and the result multiplied by 5. As indicated in figure 4, the average LRS stands at 139 days which is equivalent to 20 weeks of rainfall. This was also confirmed from previous studies, the closest similar result was the 130days estimation of Sawa and Adebayo (2011).

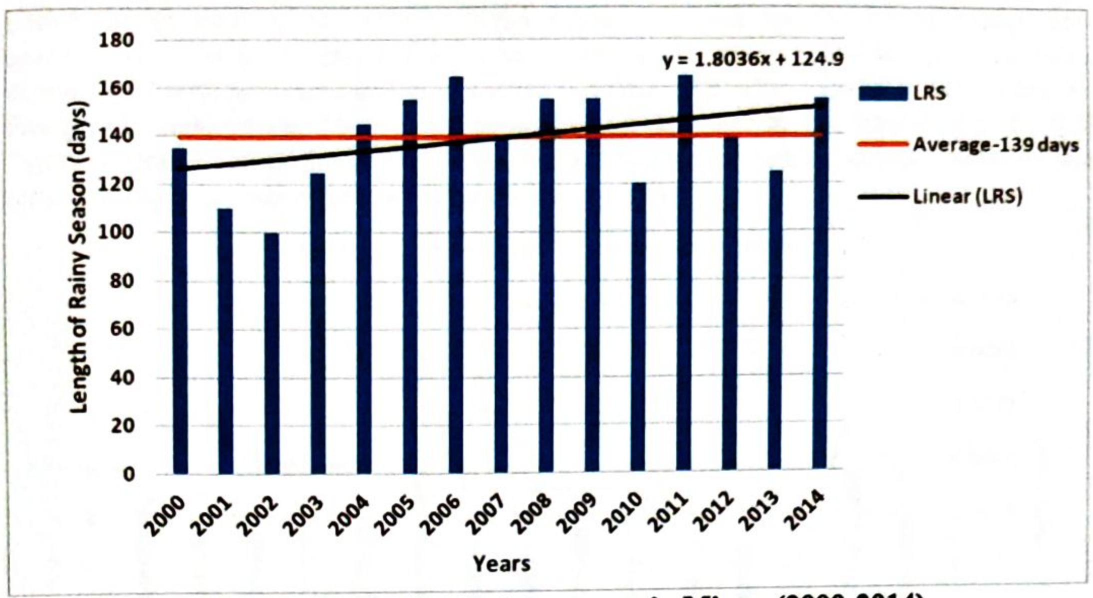

Figure 4: Length of rainy seasons in Minna (2000-2014).

The trend line depicts an increasing trend with the equation (y = 1.8036x + 124.9). The implication of this trend is that there is now an increase in the duration of rainfall received in Minna, Niger State from around 125 to 150 days of rainy season (fig4.3). The highest LRS within the 15year data was recorded in 2006 with a total of 165 days while the least was recorded in 2002 which was 100 days. The late Onset (19th June) as well as the early cessation (23rd September) in rainfall for the year 2002 was responsible for this short LRS.

The result obtained from the analysis of onset and cessation dates as well as length of rainy season for the inter-seasonal rainfall variability in Minna shows clearly that there is a strong relationship between them. From the analysis, if the onset is early and there's late cessation of rain, this will result into a longer rainy season which also means a longer growing season. The reverse is the case for late onset and early cessation of seasonal rains. Considering year 2006, the onset was as early as 15th of May while the effective rainfall was terminated as late as 23rd of October. This explains why the rainy season was as long as 165days which is equivalent to almost 24 weeks of rainfall (6months). The same scenario was experienced 5 years later in 2011 with the same onset date and cessation date, 15th May and 23rd October respectively.

Short LRS were recorded in years with late onset and early cessation of rain. This is clearly pictured in the statistics obtained for 2002 rainy season. Rainfall was not effective until 19th June (fig2) and ceases as early as 23rd of September that year (fig3). This is the reason why 2002 recorded the least days of rainy season as low as 100days which is 65days (9 weeks) shorter than the length of rainy season estimated for 2006 and 2011 as graphically presented in figure 4. Another similar case was recorded in 2001 as well, with an estimated 110days of rainfall also clearly depicted in figure 4.

Moisture Quality

According to Usman (2000), when the MQI value is small, it indicates that the season receives quality moisture which will eventually boast the crop performance for such a season and the reverse is the case for high MQI values. From the graph (fig. 5), it was so glaring that the increased number of break in 2005 (12 breaks) accounted for the high MQI value of

0.0030 which doubled the average MQI value computed for the 15years inter-seasonal analysis. The year alone recorded 3 dry spells and a drought case. But the case was different in year 2012 with the least number of breaks recorded within the 15years space (4breaks) and this greatly reduced the MQI value computed for the year to the least record of 0.0006. Figure 5 clearly shows the relationship between number of breaks and the moisture quality received for the season estimated using moisture quality.

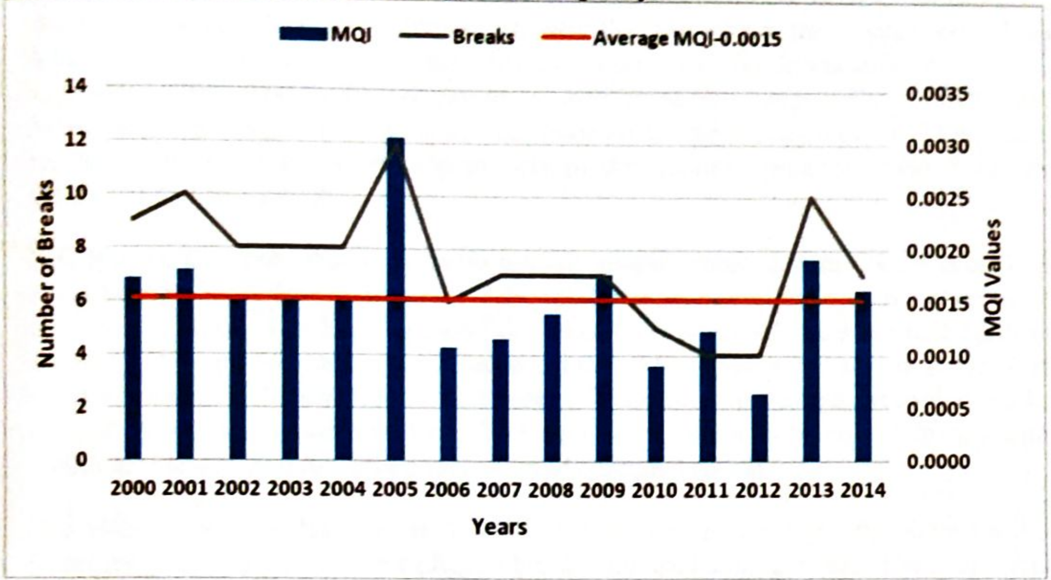

Figure 5: Monsoon Quality Index value and number of break occurrence in Minna (2000-2014).

Although MQI analysis is not a function of number of breaks only, it also includes the integration of highest rainfall monthly total and the annual rainfall total received in a particular year, but the result so far have clearly shown the significant role the occurrence of breaks plays in determining the quality of moisture received within the planting season. Furthermore, the analysis of break occurrence formed the basis for the investigation of dry spell and drought occurrence which is a research considered in another paper.

Annual Rainfall Total

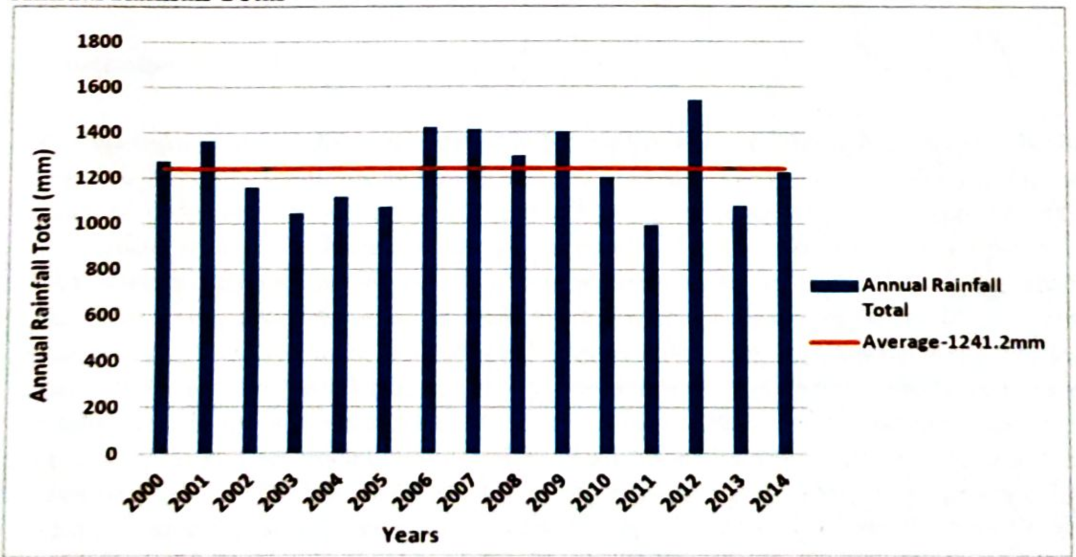

Figure 6: Annual rainfall total for Minna (2000-2014)

From figure 6, a clear representation of the total rainfall received in Minna has been presented for the years under review. The result shows that the average annual total rainfall received in Minna is 1241.2mm with the highest record in 2012 (1540.35mm) while the lowest record was in the previous year 2011 which received just 992.2mm of rainfall for the whole year. This implied that year 2012 is characterized with qualitative moisture sufficient enough for increased crop production. This is confirmed from the MQI value estimated for the same year (0.0006) which from record was the least within the 15years period and by interpretation is the year with the best rainfall performance. The implication of analysis such as this on sustainable livelihood cannot be over emphasized especially in such a city as Minna where the major socio-economic activities revolves round agriculture. This means that rainfall performance goes a long way in dictating the economic situation of the city as well as the standard of living of the people.

It is important to note that increase in rainfall amount coupled with poor seasonal spread could be disastrous. This implies that if the rainfall is so intensified within a short period of time, it could result into flooding especially when there is enough moisture in the soil at that moment. This was the case experienced not just in Minna alone but also in some Northern states of Nigeria in the year 2012 where cases of flood occurrences were recorded. As for the case of Minna, an annual total rainfall of such a magnitude with only 4 breaks recorded within the rainy season is a strong indication of a flooded season.

The inter-seasonal analysis covered major rainfall parameters from the determination of Onset dates, Cessation dates and LRS, to breaks, dry spell among others. The result obtained for onset of seasonal rain in Minna using IRMI is in synchrony with the result of Usman and Abdulkadir, (2013) which also indicated that the real onset dates of rain in this part of the country has shifted from mid-June to mid/late May now which is a strong indication of early onset. A different view as regarding the changing trends in onset dates of rainfall was observed in the work of Sawa and Adebayo (2011) which from their result depicted a scenario of late onset dates. One major reason for this difference might be due to the previous record which was employed in their study. This proves that late onsets were more recorded in the 1970's to 1990's but this study has proved from recent data acquisition specifically from the beginning of the millennium, year 2000 till date that there are now evident changes to the pre-existing trend and this to a very large extent is worthy of note.

Conclusion

The inter-seasonal variability of rainfall in Minna has analyzed through the use of the Intra-seasonal Rainfall Monitoring Index (IRMI) and Monsoon Quality Index (MQI) in this study from all indication proved its worth and efficiency in observing the rainfall trends and fluctuations in the effectiveness of rainfall received in Minna under the 15 years period. The inter-seasonal analysis carried out also brought about indications of the changing trends in the onset dates, cessation dates as well as the length of rainy season in Minna. This is expected to go a long way in providing the farmers with ample information enough to secure and reduce the uncertainties in these important rainfall parameters which dictates crop productivity in the semi-arid zones of Nigeria. The effectiveness of rainfall in Minna to a very large extent relies on the determination of real monsoon onset dates and cessation dates, occurrence and frequency of breaks which has been analyzed through the examination of intra and inter-seasonal variations in the rainfall pattern of Minna and this has been proved to be a major indicator in securing a sustainable food production for the city and the country as a whole.

After thorough examination of inter-seasonal variability of rainfall received in Minna, it is obvious that it calls for a quick action plan so as to help farmers properly plan ahead of their planting season which is a step ahead to achieving a more sustainable food production plan.

Acknowledgement

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