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# Comparative Analysis of Effective Onset Rainfall and Intra-Seasonal Variability over Minna and Sokoto, Nigeria

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**Abstract**
This paper analysed and compared the effective onset rainfall and its intra-seasonal variability in Minna and Sokoto using daily rainfall data from the archives of Nigerian Meteorological Agency (NIMET) for the period of 35 years (1981-2015). The onset date of rain, trends and intra-seasonal variability were determined using a drought monitoring and early warning (EW) methodology based on an intra-seasonal rainfall monitoring index (IRMI). The uncertainty in the onset date from one season to another were also determined by subtracting the succeeding onset date from the previous. The results demonstrate distinction in the effective onset date over the two stations as the onset date were earlier in Minna. The pattern in the onset date were similar as the earliest (1997) and late (1987) onset year were the same indicating interconnectivity in the rainfall regime across the two stations. The effective onset date showed a downward trend implying tendencies toward early onset date at the two stations. The intra-seasonal rainfall analysis showed an increased frequency of intense and distribution of rainfall in years with early onset rainfall at the two stations. As the beginning of seasonal rainfall in the two stations are basically different, this should signal a need for specific cropping type in each stations.

**Keywords:** Onset, Intra-seasonal Variability, IRMI, Dry Spell

## Introduction

The socio-economic activities of people in semi-arid and sub-humid Sub-Saharan Africa (SSA) largely depend on agriculture. Calzadilla *et al.* (2013) reported that more than 85% of crops land in SSA is rainfall dependent. Although effort are underway to improve the rain fed agriculture, Bayer *et al.* (2014), suggest that the system is likely to remain the major source of staple food in SSA. The start of rain-fed agriculture largely depend on onset rainfall. Previous studies (Mupangwa *et al.*, 2011; Calzadilla *et al.*, 2013; Milgroom & Giller, 2013) suggested that rainfall variability is a major problems confronting rain-fed agriculture. Mupangwa *et al.* (2011), reported fluctuation in onset of rainfall from one year to another over SSA.

In the semi-arid and sub-humid Nigeria rainfall variability raise uncertainty in the estimate of effective start of the season. It is reported that the variability in the rainy season onset and cessation can pose socio-economic and developmental challenges as they threaten food security and induce poverty (Lacombe *et al.*, 2012). Amekudzi *et al.*, (2015), also agreed that irregular and

significant delays in rainfall affect the overall food production in the larger part of the Sahel and sub-humid West Africa. On their part Mugalavai *et al.*, (2008) reafirm the relevant of onset dates for the planning of agricultural activities within a season. Thus, information on the effective date of onset rainfall and its intra-seasonal variability is crucial to the success of rain-fed agricultural activities.

Numerous studies have been conducted in Nigeria and other part of Sub-Saharan West Africa in the recent past to estimate and gain insight in onset of rainfall (e.g. Omotosho *et al.*, 2000; Odekunle, 2004; Oguntunde *et al.*, 2014; Amekudzi et al., 2015; Matthew *et al.*, 2017; Agidi, *et al.*, 2018). Although there has been considerable work on aspects of the rainfall in relation to agriculture over Nigeria, most of this has been mainly concerned with total rainfall, mean rainfall, onset, cessation and length of growing season with relatively little pertaining directly to intra-seasonal variability.The intra-seasonal variability is fundamental as high frequency of damaging dry spells within the growing season could be detrimental to crops (Mugalavai *et al.*, 2008). To gain information on the post onset events within a season is significant as cumulative rainfall does not fully explain impacts on agriculture (Usman & Reason, 2004). In most instance a few heavy rainfall events lead to an erroneous impression that a growing season is good.

This study was designed to assess and compare fluctuations in the onset and intra-seasonal variability using historical daily rainfall data from Minna station in sub-humid Nigeria and Sokoto station in semi-arid savanna. The study also assessed the trends of wet periods and dry spell over the two stations. The relationships between the derive indices over the two station were determine to ascertain if changes in sub-humid area result in similar to changes in semi-arid savanna.

## Material and Methods

### Data Required

The daily rainfall data for the period of 35 years(1981-2015) from globally referenced meteorological stations at Minna and Sokoto was acquired from the archives of Nigerian Meteorological Agency (NIMET).

### Data Analysis

To achieve the aim of this study, a drought monitoring and Early Warning (EW) methodology based on an Intra-seasonal Rainfall Monitoring Index (IRMI) developed by (Usman & Abdulkadir, 2013) was adopted. The rainfall value was aggregate into five days interval (pentad) start from 1st May (25th pentad) to 27th October (60th pentad) in each year. IRMI was computed on a pentad-by-pentad basis from the 1stMay using the equation expressed as:

$$IRMI = \frac{(Cpt)^2}{(hpt \times Nb \times 100)} \qquad \text{(Eq. 1)}$$

$Cpt$ = cumulative pentad rainfall since 1st May
$hpt$ = the highest pentad total rainfall since 1st May
$Nb$ = number of breaks in rainfall (pentads with <5mm of rainfall) and
100 = a factor

The effective onset of rains is taken as the pentad within which the IRMI is ≥1 for the first time. After this point, the index rises gradually as the rains become steady and then falls as the rains cease (Usman & Abdulkair, 2013). As IRMI is computed on a pentad-by-pentad basis, the value of each pentad become a measure of the amount and spread of rain received and thus a good indication of the moisture situation. IRMI is classified to indicate abundant, adequate, deficient, very deficient and extremely deficient moisture conditions following the methods outline by Usman & Abdulkadir, (2014) (see Table 1).

To classify the wet periods and dry spell as the season progress the IRMI drought-monitoring scheme was groups into two (2). A pentad value was classify as wet periods if the IRMI value was ≥1 while a pentad was classify as dry spell if the IRMI value was <1.

Generally, the onset pentad in each year for the stations and frequency of wet and dry spell were subjected to linear trend analysis.

$$Y = a + bx \qquad \text{(Eq. 2)}$$

**Table 1. IRMI based drought-monitoring scheme**

| On set classification categories IRMI ranges | IRMI classes | Rainfall receipt (moisture supply condition) | Hazard |
|---|---|---|---|
| IRMI>10 | 1 | Abundant (high rainfall total within short time spans) | Flood |
| 1<IRMI≤10 | 2 | Adequate | No drought, No flood |
| 0.1<IRMI≤1 | 3 | Deficient | Mild drought |
| 0.01<IRMI≤0.1 | 4 | Very deficient | Severe drought |
| IRMI≤0.01 | 5 | Extremely deficient (low rainfall totals over long time spans) | Very severe drought |

Sources: Adapted from Usman and Abdulkadir (2014)

## Results and Discussion

### The IRMI Onset Series at Minna and Sokoto, Nigeria

The real onset date over Minna and Sokoto is depicted in Figure 1. The results demonstrated a similarity in pattern of onset date between the study areas. An example worth noting is in 1987 the onset date in Minna was worst off around 30th of June (40 pentads). Similar to the trend at Minna, Sokoto witness the worst onset date in 1987, around 5th August (49 pentads). In a related pattern, the earliest onset date within the consider period in Minna was1997, around 5th May (25 pentads). Similarly, the earliest onset date in Sokoto was 1997, around 15th May (27 pentads).

The year 1999, 2002, 2013 and 2014 all demonstrated similar pattern between Minna and Sokoto. The similarity in the onset date at Minna and Sokoto stations suggest interconnectivity in the rainfall regime across different ecological zones. Although there is near uniform similarity in the pattern of onset rainfall, the onset date are however early at Minna station in the lower latitude. The Sokoto station show high variability in onset date on an inter-seasonal scale. The implication of this finding demonstrates that failure in rainfall system in one ecological zones could lead to failure in another ecological zone. Bello, (1996) and Oguntunde et al., (2014) suggest that the upward progression of inter tropical discontinuity (ITD) from the coast is responsible for variation in the onset date across stations in different ecological zones. This finding also showed consistency with numerous studies in recent past across Africa (for example Recha et al., 2012; Oguntunde et al., 2014; Dunning et al., 2016).

The trends analysis of onset pentad for the two stations shows a downward trend. This implies the tendency towards early onset of rain over the two stations. Additionally, the tendency toward early onset rain may probably lead to an increase in the length of growing season as previous studies suggest significant positive relationship between the onset and the length of the season (Sivakumar, 1989; Oladipo & Kyari, 1993; Omotosho et al., 2000). The trends in the onset of rainfall are linked with recovery of the monsoonal precipitation in West Africa and the tendencies are also projected to continue in the twenty-first century (Sultan & Gaetani, 2016).

The uncertainty in the start of the season between the years under this study is depicted in Figure 2.The inter-seasonal variability of the onset pentad showed positive if the succeeding onset year were earlier to the preceding onset year. It is however positive if the reverse is true. In the two study areas, Sokoto appears more variable than Minna. This finding is consistent with Usman and Abdulkadir (2014) that reported low variability in the onset of rainfall at Minna station. The implication of this is that uncertainty at the start of the rainfall is less in Minna relative to Sokoto station.

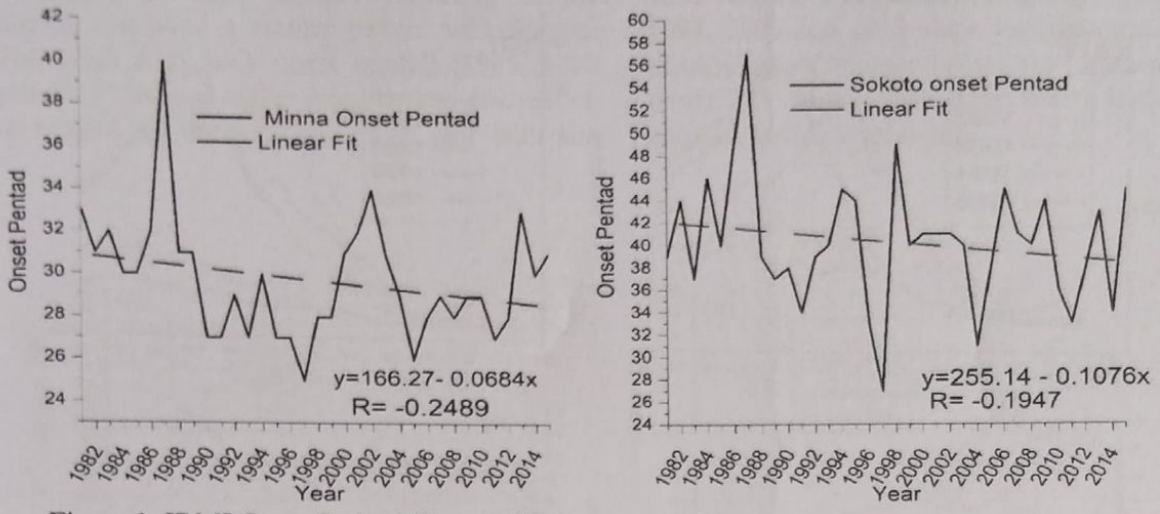


Figure 1: IRMI Onset Series Minna and Sokoto

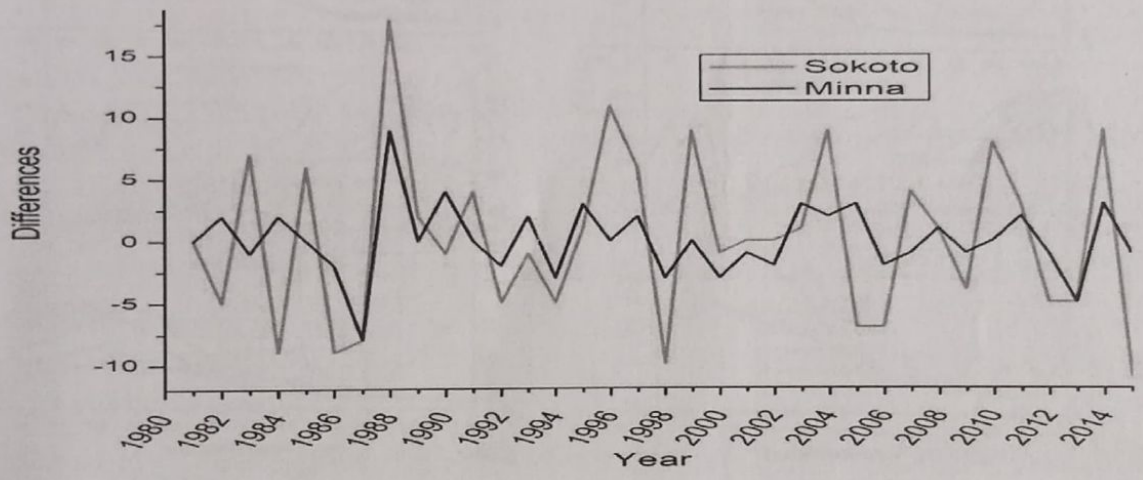


Figure 2: Changes in Inter-seasonal Onset Series of Minna and Sokoto

**Intra-Seasonal Rainfall Monitoring Index of Sokoto and Minna**

The intra-seasonal variability of the rainfall in Sokoto is shown in Figure 3(a-g) and Minna in Figure 4 (a-g). In Sokoto, the result demonstrate high rainfall intensity and distribution in years (1983, 1991, 1997, 2010 and 2014) with early onset date of rainfall. This imply that years with early onset rainfall can be taken advantage of by rain-fed farmers. This, therefore, confirmed other studies that the length of the rainy season is more dependent on the rainfall onset than its cessation ( Sivakumar, 1989; Omotosho *et al.*, 2000). On the contrary, least rainfall intensity and distribution were recorded in those years (1980, 1984, 1985, 1986, 1987, 2008, 2009, 2013 and 2015) with onset rainfall above 40 pentad. The implication of this is that damaging frequency of dry spell ($0.01<IRMI\leq0.1$ and $IRMI\leq0.01$) were common for example 1980 and 1987.

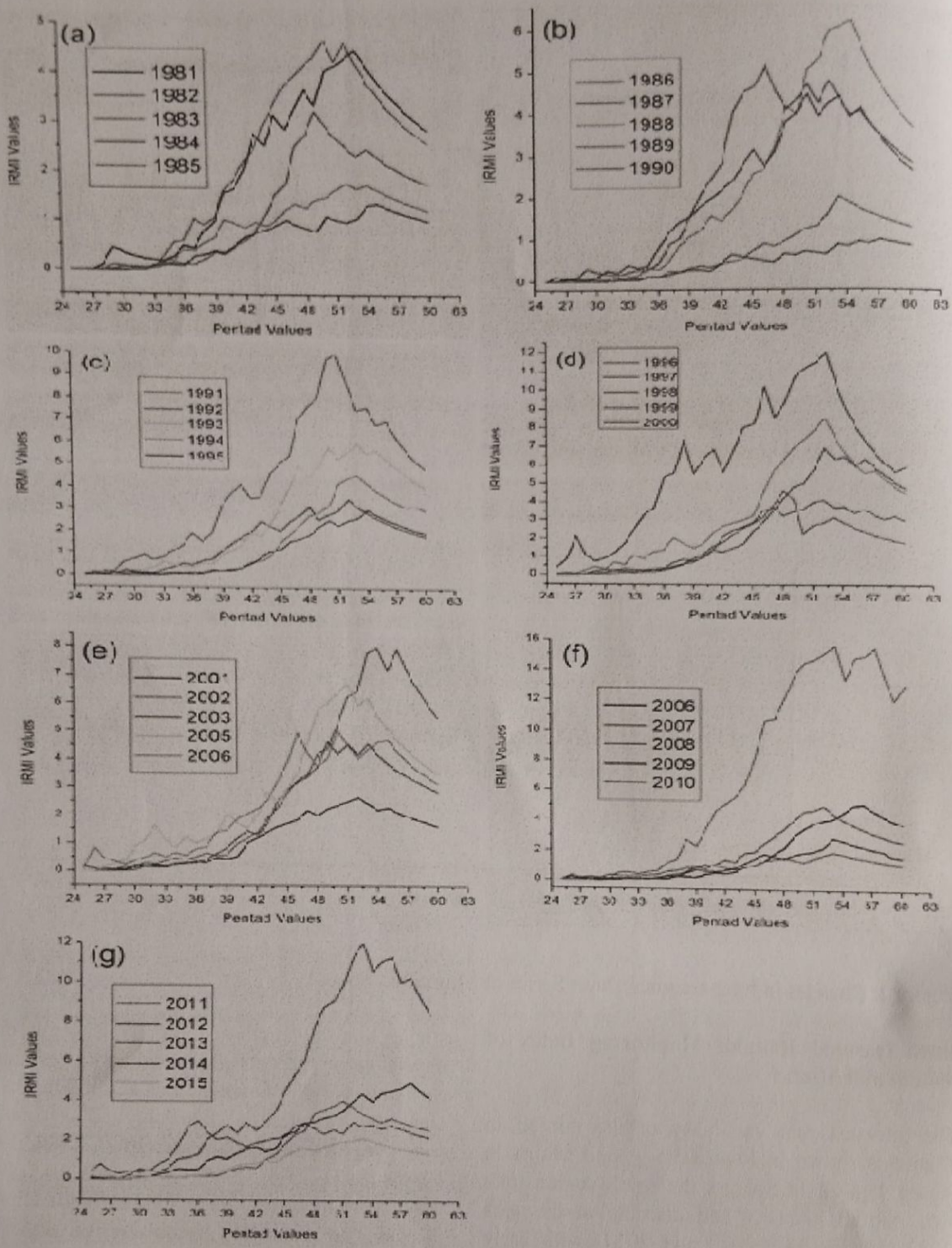


Figure 3 (a-g): Sokoto seasonal IRMI pattern

In Minna, the intra-seasonal variability of the rainfall displayed a similar pattern with Sokoto. The years with early onset rainfall (1985, 1990 and 2012) showed higher intensity and distribution of rainfall. In the contrary, those year with late onset rainfall (>40 pentad) for example year 1987, 1994, 2009 and 2013 show less seasonal rainfall distribution. Comparatively, the intra-seasonal rainfall in Minna station appeared less erratic compare to Sokoto station.

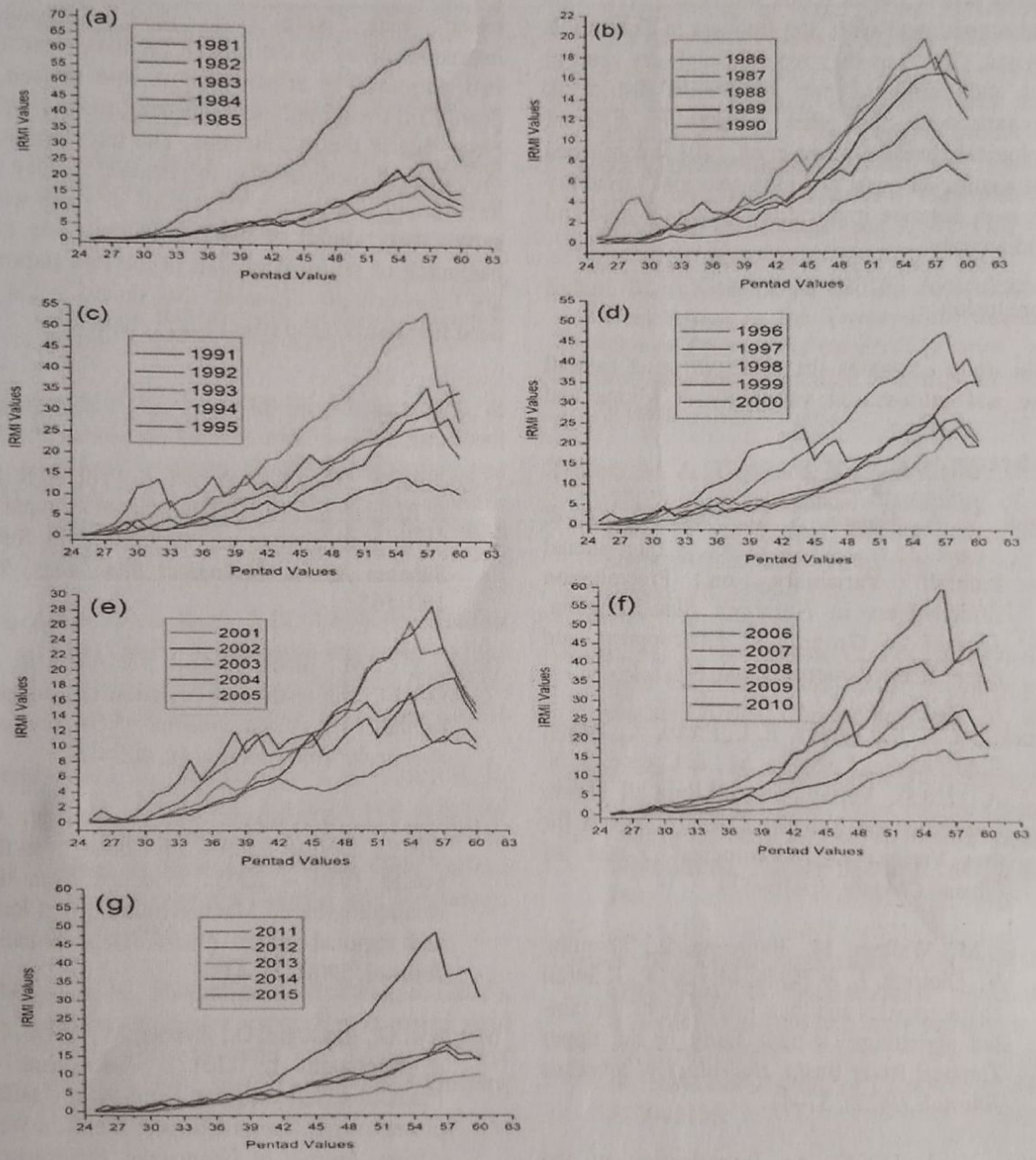


Figure 4 (a-g):Minna seasonal IRMI pattern

The general patterns of intra-seasonal rainfall in the two stations are similar to findings of (Tadross *et al.*, 2005).They reported an increased frequency of more intense rainfall over northeast Madagascar in years with early onset rainfall. Although the pattern of onset and intra-seasonal rainfall are similar in the two stations, the dry spell are more prevalence at Sokoto station in semi-arid savanna than at Minna station in the sub-humid area. This is also consistent with the findings of Sorecha & Bayissa, (2017) as they reported high dry spell in arid and semi-arid part of Babile district in comparison to the other districts in different ecological zones. Omoyo *et al.*, (2015) confirmed that significant onset and intra-seasonal variability has high negative implications on crops yield and food security.

## Conclusion

This study compares the effective onset rainfall date and intra-season variability at Minna and Sokoto stations. Daily rainfall data for the period of 35 years were utilised. The drought monitoring and early warning (EW) methodology based on an intra-seasonal rainfall monitoring index (IRMI)in addition to linear trends were employed for data analysis. The results demonstrate distinction in the effective onset date over the two stations as the onset date were earlier in Minna. The pattern in the onset date were similar as the earliest and late onset year were the same indicating interconnectivity in the rainfall regime across the two stations. The effective onset date showed a downward trend implying tendencies toward early onset date at the two stations. The intra-seasonal rainfall analysis showed an increased frequency of intense and distribution of rainfall in years with early onset rainfall at the two stations. As the beginning of seasonal rainfall in the two stations are fundamentally different, this should signal a need for specific crop type in each stations.

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