AN ESTIMATION OF RAINFALL ANOMALY INDEX AND ITS IMPACT ON CROP PRODUCTION IN YOLA AND ENVIRONS

Sadiq A.A., Suleman M. Umar and Mohammed U. Bello

Department of Agricultural Technology, Adamawa State Polytechnic, Yola. P.M.B 2146 Adamawa State Nigeria.

ABSTRACT: *Rainfall anomalies of a given geographical area over a long period is considered as the major hydro-meteorological variable that caused climatic change and also a dominant factor affecting crop production which requires ardent attention of research. The paper aimed to estimate rainfall anomaly index and its impacts on crop production in Yola and environs. The climatic raw data for the periods of forty (40) years were computed and estimated using rainfall anomaly index (RAI_{10}) techniques developed by van Rooy. The findings revealed that the study area falls under wetness conditions for the period of 19 years, normal wetness occurred in 6 years and dry conditions were estimated in 15 years which mostly occurred in the recent decades (2002, 2003, 2004, 2005, 2006, 2007, 2008, 2011 and 2013) which signifies apparent climatic change of rainfall deficit and consequently affects crop growth respectively. However, 2016 and 2012 were estimated as extremely and very wet conditions that led to exacerbated flooding in the area which damaged hundred hectares of farmlands. Farmers in the area are therefore recommends to use an improved seeds variety with low water use efficiency and drought resistant crop varieties with the aim of coping with dryness conditions. Similarly, farming on flood prone areas should be avoided and preventing measures on sediment deposition should also be considered recommendable.*

KEYWORDS: Anomaly, Crop Production, Impact, Index, Estimation, Rainfall, Yola

INTRODUCTION

In recent years, the study of rainfall characteristics has attracted attention, especially because extreme weather conditions and possible climatic changes have been observed (Livada and Asimakopoulos, 2005). Rainfall exhibits both spatial and temporal variability at all spatial and temporal scales that are of interest in flood hydrology (Ball *et al.,* 2019). Climatic changes in a geographical area may be detected by examining long time series of precipitation variability. From the point of view of water resources management, this variable influence directly the water availability and water demand and requirement for optimum crop production. Most of the ecosystems in the tropics are extremely sensitive not only to the annual rainfall amount but also to other aspects of seasonal rainfall, such as the arrival of rain at the beginning of the wet season, which determines the timing of important life stages of crop plant such as leaf flushing and flowering; and the wet season length, which contributes to the timing of leaf fall and thus the total transpiration period (Borchert, 1994: Schwartz 2003) , The same rainfall seasonality, with its associated drought and flood risks, also poses huge challenges to local populations, making agricultural efforts and sustainable management of soil and water resources more difficult (Wani *et al.,* 2009: Rockstrom *et al.*, 2003).

Rainfall changes, water availability and timing are key factors controlling biogeochemical cycles, primary productivity, phenology crop groeth and regulating agricultural production (Briggs and Knapp, 1995; Walther G-R. *et al* 2002; Austin *et al*, 2004; Huxman, et al,2004; Singh and Kushwaha, 2005:; Wani, et al.2009; Dirzo, et al,. 2011). Moreover, the effects of climate change over a long period are likely to influence water resources, agriculture, land use, environmental sustainability and the society (Tigkas *et al.*,2013). Similarly, even after crops: seeds have been planted: sown, they will still require favourable rainfall conditions during the early stages in order to eliminate crop failure (Omotoshoa *et al.*, 2000). In this context climate change can intensify existing pressures and extreme events, thereby increasing risk, vulnerability and uncertainty of water systems (Loukas *et al.*, 2008; WWAP, 2009).

Despite the fact that the causes of this climate change are not absolutely clear, according to the Inter-governmental Panel on Climate Change (IPCC, 2007).However, there is no single definition of drought, and there is no reliable methodology for its quantification (Lidija *et al.*,2015) .It may be said in most general terms that drought is every reduction of precipitation with respect to the normal (average) quantity of precipitation in a given climatic zone. The positive or negative sign is related to the positive or negative precipitation anomalies are highly essential to be estimated (Lidija *et al.*, 2015). Similarly, flood is also considered as threats on agricultural production and human activities which is also inclined to anomalies of rainfall. Therefore, reasonable knowledge of the date of rainfall cessation enables the prediction of the length of the growing or rainy season, which is most useful for the selection of crop varieties, crop matching and cropping sequences (Kowal and Knabe, 1972).

Many indices for rainfall estimation and prediction have been proposed. The use of rainfall anomaly index (RAI) as a single hydro-climatic index for the estimation of wetness and dryness conditions of climatic change has been proposed for this research paper considering the small area, uniformity of the land areas with similar ecological properties or soil properties and limited or unavailability of hydro-meteorological data in the study area. Hence, the proper assessment and prediction of excess rainfall (wetness condition) and rainfall deficient (dryness condition) and its impacts on agricultural production will be very helpful for reducing the effects of both conditions on crop production for necessary adjustment and action for sustainable food production in the study area. Therefore, in order to ensure maximum and sustainable agricultural productivity, as well as efficient water resource management practices, reliable estimation of rainfall anomalies with identifying and classifying wetness and dryness conditions using the mean monthly and annual precipitations, are quite very important and timely. In addition to that, it is very important to provide a short analysis of the risk of the ongoing drought and flood phenomenon and how it may affect the agricultural activities caused by the rainfall anomalies in the area. Thus, this paper saddled with an estimation of rainfall anomaly index and its impacts on crop production in Yola and environs.

Study Area

The study was conducted in Yola South LGA and Environs of Adamawa State, Nigeria which lies on latitude 090 14’N and 090 20’N of the equator and longitude 120 25’E and 120 28’E of the Greenwich meridian with an average annual rainfall of 850 mm-1000 mm with over 41% of rain falling in August and September. Temperature also has a significant temporal variation in the study area; with an average maximum temperature of 42 ^{0}C with an average relative humidity of about 29% (Adebayo, 1999; Upper Benue River Basin Authority, Yola, Nigeria. 2018).

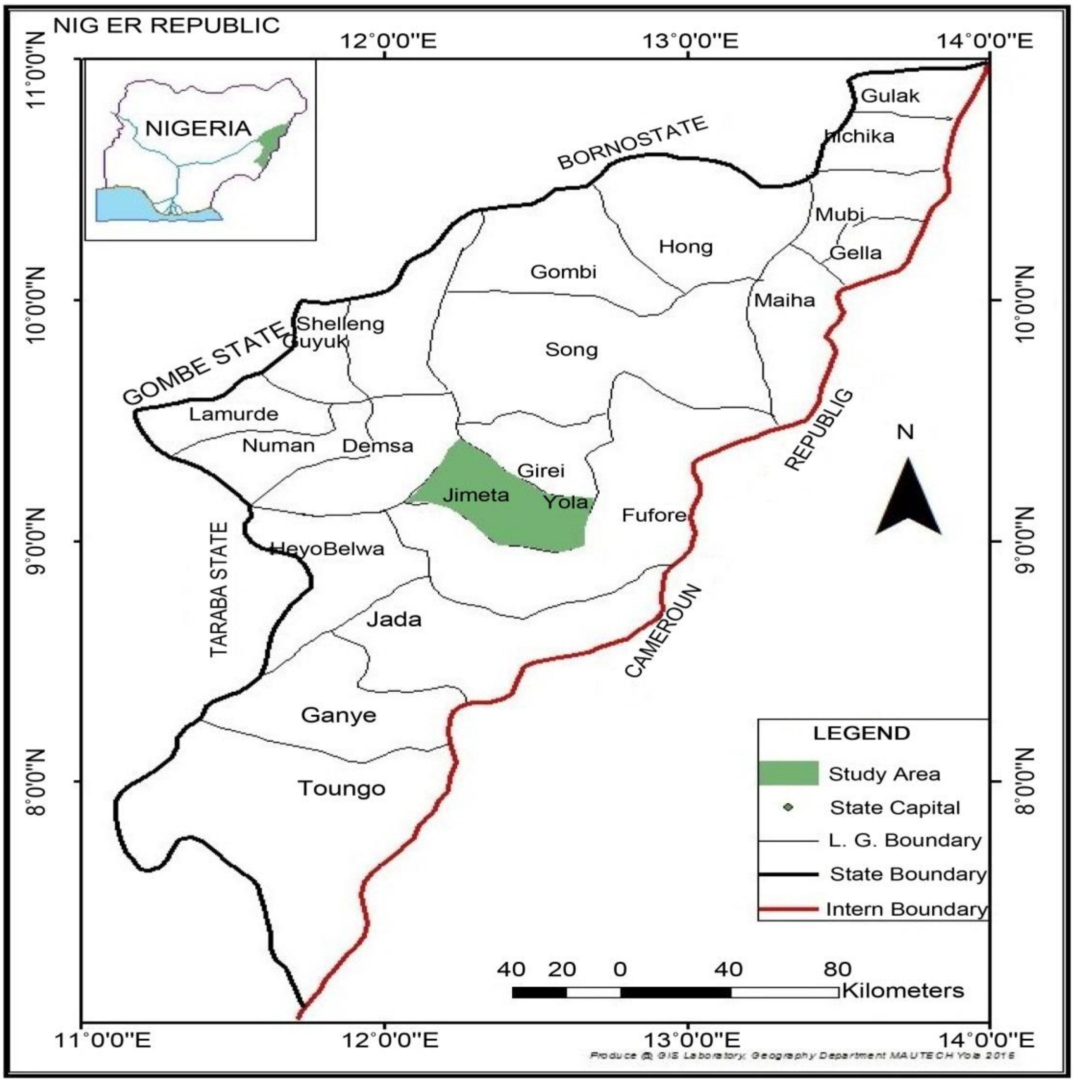

Figure 1: The Study Area.

Source: Adapted from Alkasim et al., (2018)

RESEARCH METHODOLOGY

The computations of rainfall anomaly index (RAI) were achieved using rainfall data obtained from Upper Benue River Basin Development Authority (UBRBDA), Yola Adamawa State Nigeria for the periods of forty (40) years (1978-2017). Rainfall Anomaly Index (RAI) developed by van Rooy (1965) was used in depicting periods of dryness and wetness in the area. In this technique, the precipitation values for the period of study were ranked in descending order of magnitude with the highest precipitation being ranked first and the lowest precipitation being ranked last. The average of the ten highest precipitation values as well as that of the ten lowest precipitation values for the period of study was calculated. The positive and negative **RAI** indices are computed by using the mean of ten extremes. The formular for calculating positive RAI (for positive anomalies) is given by;

$$\textbf{RAI} = +3\,\frac{P-\overline{P}}{\overline{M}-\overline{P}}$$

Let $\overline{M}$ be the mean of the ten highest precipitation records for the period under study, $\overline{P}$ the mean precipitation of all the records for the period, and the **P** precipitation for the specific year.

The formular for calculating negative RAI (for negative anomalies) is given by;

$$\textbf{RAI} = -3\,\frac{\overline{P}-P}{\overline{m}-\overline{P}}$$

Let $\overline{m}$ be the mean of the ten lowest precipitation records for the period under study. Then the negative RAI (for negative anomalies) for that year

The arbitrary threshold values of +3 and – 3 have been assigned to the mean of the ten most extreme positive and negative anomalies respectively (Samuel et al., 2003). The positive or negative sign is related to the positive or negative precipitation anomalies.

Table 1: The classification of the index used by van Rooy (1965) is as follows

S/n	RAI	Class description
1	≥ 3.00	Extremely wet
2	2.00 to 2.99	Very wet
3	1.00 to 1.99	Moderately wet
4	0.50 to 0.99	Slightly wet
5	0.49 to –0.49	Near normal
6	-0.50 to –0.99	Slightly dry
7	-1.00 to –1.99	Moderately dry
8	-2.00 to –2.99	Very dry
9	≤-3.00	Extremely dry

Source: van Rooy (1965)

RESULTS

Table 2: Estimated Positive Rainfall Anomaly Index RAI_{10} for the highest Value (M) from 1978-2017

S/N	YEARS	RAI_{10} Highest Value (M)	Index classification of van Rooy (1965) for the highest Value (M)
1	1978	1.182	Moderately wet
2	1979	-2.594**	Very dry
3	1980	2.166	Very wet
4	1981	0.067	Near normal
5	1982	0.480	Near normal
6	1983	-0.945**	Slightly dry
7	1984	0.744	Slightly wet
8	1985	0.7366	Slightly wet
9	1986	-0.623**	Slightly dry
10	1987	-4.940**	Extremely dry
11	1988	2.935	Very wet
12	1989	0.964	Slightly wet
13	1990	-2.117**	Very dry
14	1991	-1.375**	Moderately dry
15	1992	0.713	Slightly wet
16	1993	0.987	Slightly wet
17	1994	-0.158**	Near normal
18	1995	2.882	Very wet
19	1996	1.495	Moderately wet
20	1997	0.874	Slightly wet
21	1998	1.754	Moderately wet
22	1999	3.514	Extremely wet
23	2000	0.287	Near normal
24	2001	-0.327**	Near normal
25	2002	-5.374**	Extremely dry
26	2003	-2.878**	Very dry
27	2004	-2.580**	Very dry
28	2005	-2.597**	Very dry
29	2006	-3.263**	Extremely dry
30	2007	-0.568**	Slightly dry
31	2008	-2.407**	Very dry
32	2009	2.544	Very wet
33	2010	2.544	Very wet
34	2011	-2.129**	Very dry
35	2012	2.964	Very wet
36	2013	-2.040**	Very dry
37	2014	1.6082	Moderately wet
38	2015	0.9020	Slightly wet
39	2016	6.370	Extremely wet
40	2017	-0.234**	Near normal

*** Negative Rainfall Deviation of Dryness Conditions.*

Table 3: Years of occurrence of Wet, Dry and Normal Conditions in Yola South LGA from 1978-2017 (40 years) using the highest (M) RAI_{10} values.

Index Classification of Van Rooy (1965)	Years
Extremely wet	1999 and 2016
Very wet	1980, 1988,1995, 2009,2010 and 2012
Moderately wet	1978, 1996, 1998 and 2014
Slightly wet	1984,1985, 1989, 1992, 1993, 1997 and 2015
Near normal	1981,1982, 1994, 2000,2001 and 2017
Slightly dry	1983,1986 and 2007
Moderately dry	1991
Very dry	1979, 1990, 2003, 2004, 2005, 2008, 2011 and 2013
Extremely dry	1987, 2002 and 2006

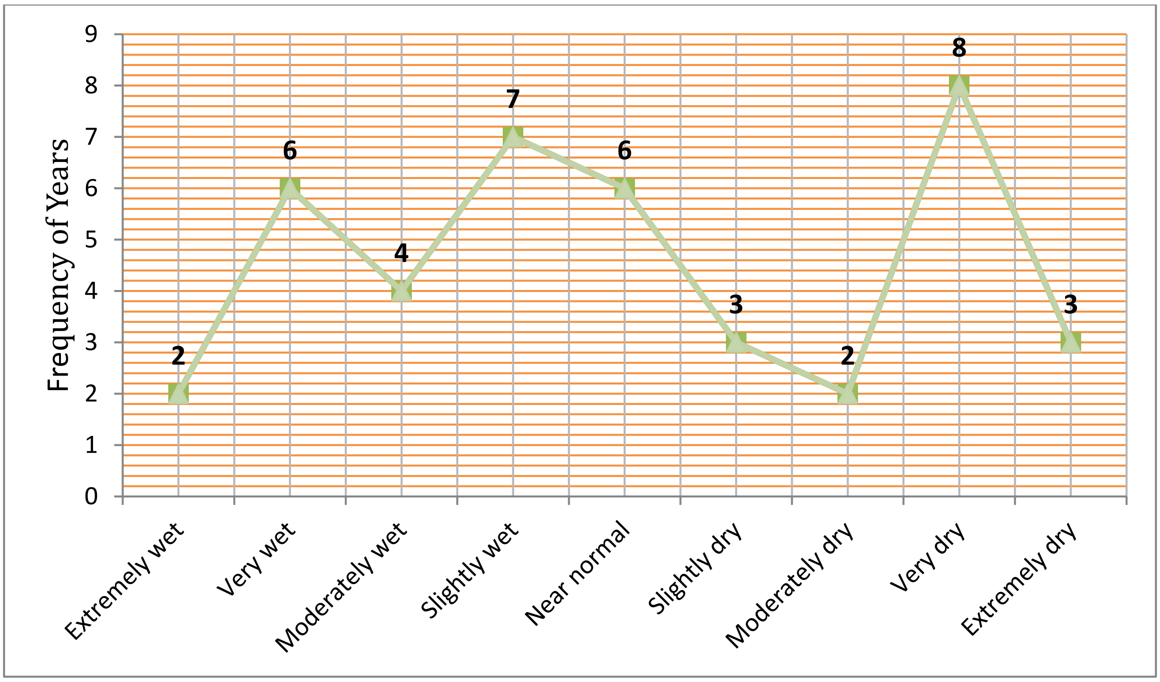

Figure 1: Frequency distribution of rainfall anomaly index of Wet, Dry and Normal Conditions in Yola South LGA from 1978-2017 (40 years) using the highest (M) RAI_{10} values.

Table 4: Estimated Negative Rainfall Anomaly Index RAI_{10} for the lowest value (m) from 1978-2017

S/n	YEARS	RAI_{10} Lowest Value (m)	Index classification of van Rooy (1965) for the lowest Value (m)
1	1978	-1.169	Moderately dry
2	1979	2.566**	Very wet
3	1980	-2.145	Very dry
4	1981	-0.066	Near normal
5	1982	-0.047	Near normal
6	1983	0.934**	Slightly wet
7	1984	-0.736	Slightly dry
8	1985	-0.728	Slightly dry
9	1986	0.616**	Slightly wet
10	1987	4.887**	Extremely wet
11	1988	-2.903	Very dry
12	1989	-0.953	Slightly dry
13	1990	2.094**	Very wet
14	1991	1.372**	Moderately wet
15	1992	-0.705	Slightly dry
16	1993	-0.977	Slightly dry
17	1994	0.156**	Near normal
18	1995	-2.841	Very dry
19	1996	-1.479	Moderately dry
20	1997	-0.865	Slightly dry
21	1998	-1.735	Moderately dry
22	1999	-3.477	Extremely dry
23	2000	-0.284	Near normal
24	2001	0.324**	Near normal
25	2002	5.316**	Extremely wet
26	2003	2.847**	Very wet
27	2004	2.552**	Very wet
28	2005	2.570**	Very wet
29	2006	3.228**	Extremely wet
30	2007	0.562**	Slightly wet
31	2008	2.382**	Very wet
32	2009	-2.516	Very dry
33	2010	-2.516	Very dry
34	2011	2.106**	Very wet
35	2012	-2.932	Very dry
36	2013	2.019**	Very wet
37	2014	-1.590	Moderately dry
38	2015	-0.892	Slightly dry
39	2016	-6.032	Extremely dry
40	2017	0.234**	Near normal

*** Positive Rainfall Deviation of Wetness Conditions*

Table 5: Shows the years of occurrences of Wet, Dry and Normal Conditions in Yola South LGA from 1978-2017 (40 years) using the lowest (m) RAI_{10} values

Index Classification of Van Rooy (1965)	Years
Extremely wet	1987, 2002 and 2006,
Very wet	1979, 1990, 2003, 2004, 2005, 2008 and 2013
Moderately wet	1991,
Slightly wet	1983, 1986 and 2007
Near normal	1981, 1982, 1994, 2000, 2001 and 2017
Slightly dry	1984, 1985, 1989, 1992, 1993, 1997 and 2015
Moderately dry	1987, 1996, 1998 and 2014
Very dry	1980, 1988, 1995, 2009, 2010 and 2012
Extremely dry	1999 and 2016

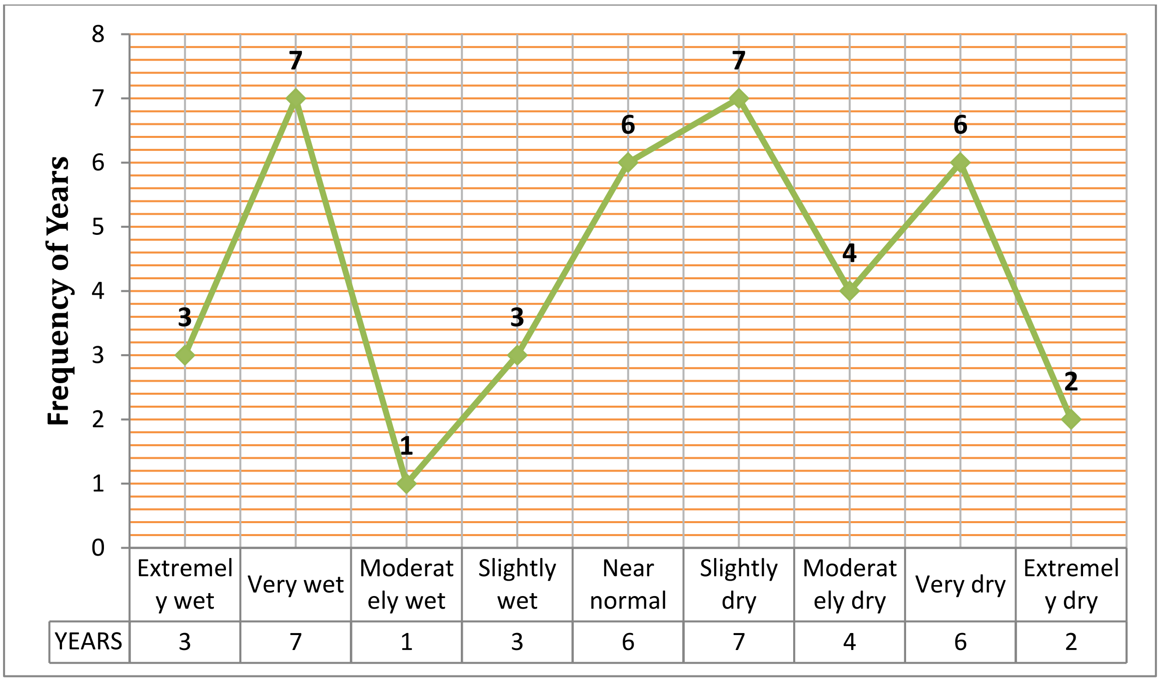

Figure 3: Frequency distribution of rainfall anomaly index of Wet, Dry and Normal Conditions in Yola South LGA from 1978-2017 (40 years) using the lowest (m) RAI_{10} values.

DISCUSSION

Positive Rainfall Anomaly Index (RAI_{10}) for the highest (M) values in 40 years (1978-2017)

The rainfall anomalies for the periods of forty years (1978-2017) of the highest (M) were presented on table 1. The results shows that the extremely wet rainfall anomaly was found to had occurred in the year 1999 and 2016 with the corresponding values of 3.514 and 6.370, very wet anomaly was experienced in 1980,1988, 1995, 2009, 2010 and 2012 with a recorded values of 2.166, 2.935, 2.882, 2.544, 2.544 and 2.964 respectively. For the moderately wet anomaly was estimated to had occurred in the year 1978, 1996, 1998 and 2014 with anomaly values of 1.182, 1.495, 1.754 and 1.608, slightly wet anomalies were predicted to be long within the period of study occurred in 1984, 1985, 1989, 1992, 1993, 1997 and 2015 with a recorded values of 0.744, 0.736, 0.694, 0.713, 0.987, 0.874 and 0.902 correspondingly. Similarly, rainfall anomaly near normal was estimated with prolong years; 1981, 1982, 1994, 2000, 2001 and 2017 having values of 0.067, 0.480, -0.158, 0.287, -0.327 and -0.234 accordingly. On the aspect of dryness anomalies of rainfall within the period of study (40 years), the results also revealed that in the years 1983, 1986 and 2007 slightly dry anomaly was occurred with estimated values of -0.945, -0.623 and -0.568, while moderately dry condition was found to had occurred in 1991 having value of -1.375. The most prolong condition was found to be very dry rainfall anomaly for the periods of 8 years (1979, 1990, 2003, 2004, 2005, 2008, 2011 and 2013) with an estimated values of -2.594, -2.117,-2.878, -2.580, -2.597, -2.407, -2.129 and -2.040 respectively. The extremely dry anomaly was found in the year 1987, 2002 and 2006 with anomalies values of -4.940, -5.374 and -3.263 correspondingly.

Negative Rainfall Anomaly Index (RAI_{10}) for the Lowest (m) in 40 years (1978-2017)

The rainfall anomalies for the periods of forty years (1978-2017) of the lowest (m) were presented on table 2. The results shows that the extremely wet rainfall anomaly was occurred in the years of 1987, 2002 and 2006 with anomaly values of 4.887, 5.316 and 3.228, very wet anomaly conditions was observed to be most prolong (7 years) within the period of study; 1979, 1990, 2003, 2004, 2005, 2008 and 2013 with the corresponding values of 2.566, 2.094, 2.847, 2.552, 2.570, 2.382 and 2.019 respectively. 1991 was estimated as the only year with the moderately wet anomaly, while slightly wet condition was revealed to had occurred in the year 1983, 1986 and 2007 with anomaly values of 0.934, 0.616 and 0.562 and near normal anomaly values of -0.066, -0.047, 0.156, -0.284, 0.324 and 0.243 were estimated with corresponding years of 1981, 1982, 1994, 2000, 2001 and 2017 accordingly. With respect to dryness conditions, slightly dry condition was observed to be most prolong also (7 years) in the years of 1984, 1985, 1989, 1992, 1993, 1997 and 2015 having anomaly values of -0.736, -0.728,-0.953, 0.705, -0.977, -0.865 and -0.892, moderately dry condition was assessed to occurred in four years (1987, 1996, 1998 and 2014) within the period of study with anomaly values of 4.887, -1.479, -1.735 and -1.590 while very dry anomaly was depicted in the year; 1980, 1988, 1995, 2009, 2010 and 2012 , -2.145, -2.903, -2.841, -2.516, -2.516 and -2.932 correspondingly and the extremely dryness anomalies using lowest (m) values was found in 1999 and 2016 with a negative anomaly values of -3.477 and -6.032 respectively.

In addition, the average Rainfall Anomaly Index (RAI_{10}) for the positive and negative highest values (M) was calculated as follows;

Highest Positive values (M) = 34.516 ÷ 19 (years of which positive anomalies occurred within the study period) = 1.917 m***oderately wet***

Highest Negative values (M) = 36.430 ÷ 15 (years of which negative anomalies occurred within the study period) = -2.428 ***very dry***

Highest Near Normal values (M) = 0.115 ÷ 6 (years of which normal anomalies occurred within the study period) = 0.019 ***Near normal***

Impact of Rainfall Anomaly Index (RAI_{10}) on Crop Production in Yola South LGA

The impact of an estimated rainfall anomaly index (RAI_{10}) on agricultural production can be viewed from the two perspectives namely; impact of wetness and dryness conditions on agricultural production. The wetness conditions are defined in terms of excessive water as floods scenarios while dryness conditions are defined in terms of insufficient water as drought. Thus, flood and drought both possessed direct and indirect impact on agricultural production.

The Impact of Wetness Conditions (Flood) on Crop Production

Agriculture still remains the major important sector of economy in Nigeria most especially in the current government as it is also remaining the major primary functions of people along river Benue of Yola and environs. However, the farming system in the area has been associated with different problems of which flooding (and drought) is the most apparent and most destructive as well (Sadiq *et al.*, 2019a). It was revealed that 2016, 1999 and 2012 were the years with the highest total amount of rainfall experienced (1260.1, 1113.3 mm and 1085.2 mm) in the 19 years of wetness conditions as depicted on table 3. These years were among the most vulnerable flooded years which adversely affect agricultural production in past decades. The high total amount of rainfall experienced in these years had led to the soil wetness where both the soil micro and macrospores were filled-up thereby reducing infiltration rate and consequently increasing excessive rate of water run-off, which subsequently resulted to river flooding on farmlands in the study area. Thus, excess water is expressed in form of floods and poor drainage (Ayoade, 1988). Thus, Flooding of agricultural land that occurs after seeding can be as costly as flooding before seeding, and possibly more costly to the individual who has incurred production expenditures (Jay and Donald, 1977). The ability for plant roots to tolerated long period of being submerged in flood water depends on the period of year the flood event occurred, duration of the flood event, species sensitivity to flooding and type of soil the plants grow on (dormant growing plants are more tolerant to flooding than actively growing plants). According Nigeria Hydrological Service Agency in their Annual Flood Outlook (NIHSA: AFO: 2013), reported that the utmost floods of 2012 occurred within the flood plains of the rivers Niger, Benue and their tributaries, where between July and October rivers overflowed their banks than normal over the years, submerging thousands of hectares of farmland, settlements and infrastructure. In 2012 alone, Nigeria recorded a total estimated loss of N 2.29 Trillion (National Emergency Management Agency, NEMA: 2013 in NIHSA; AFO; 2016). Similarly, over the decade, it was observed that in the year 2012 Adamawa state experienced an unprecedented flooding scenario as a consequence of natural weather and hydro-climatic variables that transpired above normal level if compared with the past data in the decade with a large extent of vulnerability leading to devastating loss of lives, properties, farmlands, displacement and negatively affecting the socio-economic activities in the state. (Sadiq and Hena, 2018). The extent and degree of flooding varies from farm to farm and from year to year resulting in a large number of losses of farmlands and farm produce respectively.

It is a known fact that erosion is a two-way problem; loss of soil fertility and thickness of the eroding soil (on-site problems) and the addition of unwanted sediments in the depositional sites (off-site problem). (Sadiq and Tekwa, 2018). According to Sadiq *et al.* (2019a) explained that farming is highly intensive along river Benue flood plains of Yola and environs where small scale farmers utilizes the available fertile farmlands cultivating food crops such as maize, rice seasonally with an average profitable yield. They further explained that in the study area, the floods have removed significant amount of topsoil on farm lands (on-site effects), while some parts of the farmlands were deposited with sediment damaged crops as shown in plate 1 and 2 respectively.

Plate 1: Shows the apparent effects of off-site erosion caused by river flooding damaging crops in the study area (Adopted from Sadiq *et al*.,2019a).

Plate 2: Shows the apparent effects of on-site erosion caused by river flooding on farmlands in the study area (Adopted from Sadiq *et al*.,2019a).

The results also revealed that the hundred hectares of farmlands had been affected by flood and this led to negative impacts on the farming community members who engaged primarily in farming activities with low monthly average income. In terms of farm output, majority of the respondents in the area suffered individual loss of more than 61-80 % as a result of flood. Thus, yield was revealed to have reduced with more 70 % due to flood damaged (Sadiq *et al.*,2019a). Similar result was reported by Sadiq *et al*., (2019b) Many farmlands both arable and agro-foresting were detached by soil creeping, solifluction and covered by siltation effects where hundreds of hectares of farmlands where been lost seasonally. In addition, Sadiq and Faruk (2020) conducted a research from the five selected areas in the study area, the results obtained at Yolde pate, Wuro-chekke and Anguwan Tabo farm locations shows that loamy clay sediments were deposited to an average depth ranges from 25cm-75cm over period of 10-19 years covering about 15-60 hectares of land where irrigation farming are intensively carried out which has positive impact on their farming activities. Conversely, at Mbamba and Bole farm locations were assessed to had coarse sandy sediment depositions over fertile clayey soil (see plate 3 below) to an average depth of 35-40 cm for a period of 5-7 years wrapping a range of 2-9 hectares of fertile land with a negative impact of 60 % damaged of their productivity. Thus, the impact may be positive or negative. Positive impact entails the fertile sediment that support both rainy season and irrigation farming activities while negative impact when the infertile sediments are deposited on fertile productive arable land which impaired farming activities (Sadiq and Faruk, 2020). The impact of sediment deposition depends on the characteristics of the original soil, rate of deposition, type of material, and depth of deposition (USDA, 1996).

Plate 3: Coarse sandy soils deposited on fertile loamy and clayey soils on farm location in the study area. *(Adopted from Sadiq and Faruk, 2020)*

Table 6: The annual rainfall amount for the 19 years of wetness conditions of the study area.

S/n	Years	Annual Rainfall Amount (mm)	RAI Class Description
1	1978	993.4	Moderately wet
2	1980	**1044.1**	**Very wet**
3	1984	970.9	Slightly wet
4	1985	970.5	Slightly wet
5	1988	**1083.5**	**Very wet**
6	1989	982.2	Slightly wet
7	1992	969.3	Slightly wet
8	1993	983.4	Slightly wet
9	1995	**1080.8**	**Very wet**
10	1996	1009.5	Moderately wet
11	1997	977.6	Slightly wet
12	1998	1022.8	Moderately wet
13	1999	**1113.3**	**Extremely wet**
14	2009	**1063.2**	**Very wet**
15	2010	**1062.4**	**Very wet**
16	2012	**1084.6**	**Very wet**
17	2014	1015.3	Moderately wet
18	2015	979	Slightly wet
19	2016	**1260.1**	**Extremely wet**

Source: UBRBDA, Agromet, Station Yola (2018).

The Impact of Dryness Conditions (Drought) on Crop Production

From the result obtained using the rainfall anomaly under the arbitrary threshold positive values (+3) of ten highest precipitation years (M) it was revealed in forty years from 1978-2017 (40 study period), fifteen (15) years were assessed to falls between slightly dry to extremely dry conditions as depicted on fig 2 respectively. In fifteen (15) years of dryness, highest frequencies of years were observed to be very dry condition with the period of 8 years (fig 2). The trend changes from wetness conditions to dryness conditions was mostly occurred in the recent two decades where most of years were considered as dry (2002, 2003, 2004, 2005, 2006, 2007, 2008, 2011 and 2013). Conversely, using the rainfall anomaly under the arbitrary threshold positive values (-3) of ten highest precipitation years (m) it was revealed in forty years form 1978-2017 (40 study period) about 19 years were falls under negative threshold values of slightly dry to extremely dry conditions while 14 years estimated in the range of slightly wet to extremely wet conditions respectively. Therefore, the reduced changed in wetness conditions with a gross increased in dryness conditions is an apparent indication of climatic change in the study area which has an adverse impact on agricultural production. Moreover, drought in Yola South LGA, drought disrupts crop growth, reduces grazing land, and threatens permanent soil degradation. According to Sadiq (2019) revealed that Njuwa lake is subjected to seasonal drying which sometimes lead reduction of crop yield due to insufficient of water at flowering stage. He further explained that Njuwa lakes is an ox-bow lake, which used to host the annual Njuwa fishing festival, until recently when it dried up mainly as a result of siltation effects. Likewise, some farmers along river Chochi which directly takes water to Njuwa lakes in the area used the river as water source for irrigation. Even though, the river is seasonal in nature which dries up before the onset of rainy season as a result of artificial rejuvenation constructed by the federal government to established River Chochi Irrigation Project since 1998 and abundant (see plate 5), yet not been completed to curtail the insufficient of water source in the study. Apparent drought impacts were depicted in the study area on plate 4 below;

Plate 4: Drying of Njuwa lake, farmlands and River Chochi due to drought hazards in the area. (Adopted from Sadiq, 2019).

Plate 5: Uncompleted irrigation dam project in the study area meant to curtail drought conditions for effective farming. (Adopted from Sadiq, 2019).

Thus, of all the extreme meteorological events affecting agriculture and forestry, drought is perhaps the most important hazard with serious implications for the economic wellbeing of the farming community (Sivakumar, 2019). In addition, the risk of serious environmental damage, particularly through vegetation loss and soil erosion, as has happened in the Sahel during the 70s, has long term implications for the sustainability of agriculture. (Sivakumar, 2019).

Table 7: Annual rainfall amount for the 15 years of dryness conditions of the study area.

S/N	Years	Annual Rainfall Amount (mm)	Rai Class Description
2	1983	884.1	Slightly dry
3	1986	900.6	Slightly dry
4	1987	**678.7**	**Extremely dry**
5	1990	**823.8**	**Very dry**
6	1991	861.8	Moderately Dry
7	2002	**656.4**	**Extremely dry**
8	2003	**784.7**	**Very dry**
9	2004	**800**	**Very dry**
10	2005	**799.1**	**Very dry**
11	2006	**764.9**	**Extremely dry**
12	2007	903.4	Slightly dry
13	2008	**808.9**	**Very dry**
14	2011	**823.2**	**Very dry**
15	2013	**827.7**	**Very dry**

Source: UBRBDA, Agromet, Station Yola (2018).

Table 8: Annual rainfall amount for the 6 years of near normal conditions of the study area

S/N	YEARS	ANNUAL RAINFALL AMOUNT (mm)	RAI CLASS DESCRIPTION
1	1981	936.1	Near normal
2	1982	957.3	Near normal
3	1994	924.5	Near normal
4	2000	947.4	Near normal
5	2001	915.8	Near normal
6	2017	43117.4	Near normal

Source: UBRBDA, Agromet, Station Yola (2018).

CONCLUSION

Rainfall variability in both temporal and spatial distribution was estimated to be apparent seasonally and annually which imposed serious impact on crop production and other farming operations in the Yola and environs. The negative impact on crop production can be seen as flood and drought effects which vary from year to year due to the intensity, amount and distribution of rainfall anomalies. Most of the years over the fifty (50) years a period of study was estimated with wetness condition with long rainy season which led to exacerbated flood vulnerability on arable lands, submerging farmlands and damaging crops; and deposition of sediments in streams, dams, lakes and reservoirs. Conversely, some were estimated with dry condition over the recorded period of study in the area especially years in the recent two decades due to significant decreased in the amount of rainfall compared with other decades which imposed the area in to drought severity in the region damaging crop and pasture production thereby reducing the ground water recharge, reducing soil water content, lowering water table and drying off soils affecting irrigation farming and livestock management in the area. Therefore, information emanated from this study will be valuable and usable to farmers, soil hydrologist, agronomist and researchers to the relevant government and non-governmental agencies, farming communities, decision makers and planners in effective crop management, soil and water conservation, risk management, irrigation scheduling, water budgeting, dams and reservoirs construction and in making general operational decisions regarding the management of their farming systems for sustainable and profitable crop production for the growing population in the area.

RECOMMENDATION

Based on the findings from this research work, it is therefore recommending the following;

1. Farmers should use an improve seeds varieties with high drought resistivity to suit up with the changing climatic conditions of rainfall deficiency in the area.
2. Similarly, farming activities around flood prone area due to excessive wetness should be relocated to the less vulnerable plains in the study area.

3. For the infertile deposit of sediment on farm land, it is therefore recommending the potential management practices (such as use of chisel and moldboard ploughs), preventive management (improving infiltration rate and minimizing runoff) and conservation practices (dikes, levees, channels constructions) with the aim of minimizing the potential damage to established crops growth respectively.

4. Completion of irrigation project by the federal government to improve water management for effective farming practices should be ardently considered.

5. To provide effective flood and drought information to the farmers and decision makers, there should be improved collaboration among scientists and managers to enhance the effectiveness of observation networks, drought and flood monitoring, prediction, information delivery, and applied research. Such collaboration could help to foster public understanding of flood and drought and preparedness for necessary measures towards ensuring optimum and sustainable food production for the growing population in the study area and the country at large.

REFERENCES

Adebayo AA. (1999). *Climate I (Sunshine, Temperature, Evaporation and Relative Humidity).* In Adebayo AA, Tukur AL, editors. Adamawa State in Maps. (1999). Department of Geography, Federal University of Technology, Yola, Nigeria26.

Alkasim, A.,Hayatu, A.A. and Salihu, M.K. (2018). Estimation of Land Surface Temperature of Yola, North Eastern Nigeria Using Landsat -7 ETM + Satellite Image Energy and Power Engineering, 2018, 10, 449-456 http://www.scirp.org/journal/epe ISSN Online: 1947 3818. ISSN Print: 1949-243X

Austin, A. T. et al. (2004). Water pulses and biogeochemical cycles in arid and semiarid ecosystems. *Oecologia 141, 221_235*

Ayoade, J.O (1988). *Tropical Hydrology and Water Resources.* MacMillan Publishers Ltd. London and Basingstoke.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019). *Australian Rainfall and Runoff: A Guide to Flood Estimation*. Commonwealth of Australia (Geoscience Australia),. ISBN 978-1-925848-36-6 Pp 1.1999.

Borchert, R. (1994). Soil and stem water storage determine phenology and distribution of tropical dry forest trees. *Ecology 75, 1437_1449*

Briggs, J. M. and Knapp, A. K. (1995). Inter-annual variability in primary production in tall grass prairie: Climate, soil moisture, topographic position, and fire as determinants of aboveground biomass. *Am. J. Bot. 82, 1024_1030*

Dirzo, R., Young, H. S., Mooney, H. A. & Ceballos, G. (eds) (2011). *Seasonally Dry Tropical Forests* (Island Press, 2011).

Huxman, T. E. et al. (2004). Precipitation pulses and carbon fluxes in semiarid and arid ecosystems. *Oecologia 141, 254_68*

IPCC, (2007). Climate Change: *Synthesis Report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 p

Jay A. L and Donald F. S (1997). *Economic impact of flooding on agricultural production in Northeast Central North Dakota*. Department of Agricultural Economics North Dakota Agricultural Experiment Station North Dakota State University Fargo, North Dakota Pp 1-62

Kowal J.M, Knabe D.T. (1972). *An Agroclimatological Atlas of the Northern States of Nigeria*. Ahmadu Bello University Press: Zaria, Nigeria. Pp.15

Lidija. T, Tamara. D, Mihaela, B (2015). Comparison of different drought assessment methods in continental Croatia. *GRAĐEVINAR 67 (2015) 1, 11-22DOI:10.14256/JCE.1088.2014*

Livada, I. and Asimakopoulos, D. N. (2005). Individual seasonality index of rainfall regimes in Greece. *CLIMATE RESEARCH Clim Res Vol. (3). 28: 155–161*.

Loukas A., Vasiliades L. and Tzabiras J., (2008). Climate change effects on drought severity. *Advances in Geosciences, 17:23–29*

Nigeria Hydrological Services Agency:(NIHSA) (2013). *Annual flood outlook* for Nigeria April, (2013). Presented by the Nigeria Hydrological Services Agency on 26th April, 2013.pp 10-26.

Nigeria Hydrological Services Agency:(NIHSA) (2016). *Annual flood outlook* for Nigeria. July, (2016). pp 9-21, 26-35.

Omotoshoa, J. B,. Balogun, A.A and. Ogunjobi, K (2000). Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa using only surface data. *Int. J. Climatol*. 20: 865–880.

Rockstrom, J., Barren, J. and Fox, P. (2003).in Water Productivity in Agriculture: Limits and Opportunities for Improvement (eds Kijne, J. W., Barker, R., & Molden, D. J.) 1127_1143 (CAB International, 2003).

Sadiq A.A and Tekwa, I.J (2018) Soil fertility and Management practices in Mubi region. Published by Life-line international printing press,Yola Nigeria. Pp.3-5, 23-33, 65-70 ISBN: 978- 978-959-589-1

Sadiq A.A, Sulaiman, U. B and Hadi, M (2019b). Assessment of Substantive Causes, Effects and Mitigation Strategies of Flood Scenario inYolaSouth LGA, Adamawa State, Nigeria. *International Journal of Scientific and Research Publications, ISSN 2250-3153.*

Sadiq, A. A. Abdullahi M and Ardo. A. U. (2019a). Assessment of post flood impact on farmlands along River Benue floodplains of Yola and environs. *International Journal of Scientific and Research Publications, vol. 9 (2) Feb. 2019. 679-691. ISSN 2250-3153.http://dx.doi.org/10.29322/IJSRP.9.02.2019.p8684*

Sadiq, A.A (2019). Preliminary study on Rugangye irrigation farming along River Benue Flood Plains in Yola South LGA, Adamawa State Nigeria. *International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 Volume 8, Issue 3, March 2019 pp. 185-198.*

Sadiq, A.A and Faruk, B.A (2020). Impact evaluation of sediment deposition on arable lands of Yola and environs of Adamawa State, Nigeria. *African Journal of Agriculture and Food Science ISSN: 2689-5331 Volume 3, Issue 1, 2020 pp. 22-37.*

Sadiq, A.A and Hena, M.K (2018). A Survey of Dominant Flood Prone Area and Extent in Adamawa State, North-Eastern Part of Nigeria.; *in Proceeding of Environmental Science Technology and Security Challenges in Nigeria. November, 2018.Vol. 2:.2 Pp 137-153.*

Samuel S, Allan H, Huamei Y, Fareeza K and Muhammad A (2003). *Statistical Analysis of Drought Indices and Alberta Drought Monitoring.* Alberta Agriculture, Food and Rural Development. Conservation and Development Research. Pp 1-45

Schwartz, M. D. (ed.) (2003) Phenology: An Integrative Environmental Science. *(Kluwer Academic, 2003).*

Singh, K. P. and Kushwaha, C. P. (2005). Emerging paradigms of tree phenology in dry tropics. Curr. Sci. 89, 964_975

Sivakumar, M.V.K. (2019). *Presentation of Drought Information in Agrometeorological Bulletins.* Agricultural Meteorology Division, World Climate Programme Department, World Meteorological Organization, 7bis Avenue de la Paix, Case postale 2300, Ch-1211 GENEVA 2, Switzerland Tel.: +41 22 730 8380, Fax: +41 22 730 8420, Email: msivakumar@wmo.int

Tigkas. D, Vangelis, H and. Tsakiris, G (2013).The RDI as a composite climatic index *.European Water 41: 17-22, 2013. E.W. Publications*

United State Department of Agriculture (USDA); Natural Resources Conservation Service (1996). Soil Quality Information Sheet Soil Quality Resource Concerns: Sediment Deposition on Cropland USDA Natural Resources Conservation Service April 1996. from Technical Release No. 17, *Geologic Investigations for Watershed Planning, USDA, SCS, 1966)*

Upper Benue River Basin Authority. Hydrological (20180.Year *Book of the Upper Benue River Basin Authority, Yola,* Nigeria.

Van Rooy, M. P., (1965): A rainfall anomaly index independent of time and space. Notos, 14, 43-48.

Walther, G-R. et al. (2002). Ecological responses to recent climate change. *Nature 416, 389_395*

Wani, S. P., Rockstrom, J. and Oweis, T. Y. (eds) (2009). *Rainfed Agriculture?:* Unlocking the Potential (CAB International, 2009).

WWAP - World Water Assessment Programme, (2009). *The United Nations World Water Development Report 3: Water in a Changing World. Paris:* UNESCO, and London: Earthscan.