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Application of Percent of Normal Precipitation Method for Meteorological Drought Intensity Assessment and Its Impact on Agricultural Production

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Authors' contributions

This work was carried out in collaboration among all authors. Author AAS designed the study and performed the statistical analysis. Author WSW wrote the protocol and the first draft of the manuscripts. Author AIT managed the literature, analysis as well as the final version respectively. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To study the application of percent of normal precipitation method for meteorological drought intensity assessment and its impact on agricultural production.
Place and Duration: The study was conducted in Yola South Local Government Area (LGA), of Adamawa Sate Nigeria during the year 2020.
Methodology: Drought intensity was assessed using Percent of Normal Precipitation method (PNP) using forty (40) years of rainfall data (1987-2017) obtained from Upper Benue Development Authority, Yola (UBRBDA). In addition, data on the negative impact of drought intensity on agricultural production were obtained from the well defined and structured questionnaires administered randomly to the fifty (50) selected farmers in the area where simple descriptive statistic was used in the analysis of the sourced data.
Results: It revealed that out of the forty years under study, the extremely wet condition was reoccurred in six years (15%), very wet season (5%), while moderately wet conditions had

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experienced in 14 years (35%) and normal condition was identified in 16 years (40%) respectively. Under dry conditions it was found that only moderately dry condition had ever occurred in 2 years (5%) only. For the drought impact on agricultural production most farmers (55 %) perceived that drought does not happen every year in the area. However, it occurs with seasonal variability mostly in the months July-August which last for 1-2 weeks as agreed by (55%) of the farmers. Majority of the farmers (60 %) in the area revealed that the level of the drought impact on agricultural production was high affecting crop yield (18%), drying of dams, reservoirs and lakes and outbreak of crops' pest and diseases (12 %). In contrast other effects include soil degradation, loss of profit and capital, loss of employment opportunities, dead of livestock and starvation and drop in the water table and drying of soils with (6%) each of the respondents respectively. Similarly, the use of early matured crops (30%), Early planting (18%), Delay planting (16 %) and water harvesting (12 %) were adopted as mitigation strategies towards curtailing the negative impact of drought impact on their agricultural production in the area.

Conclusion: The application of PNP method towards the assessment of drought intensity revealed important information of drought intensity which can serve as a valuable knowledge towards effective drought monitoring and proper agronomic mitigation strategies on its negative impact on agriculture in the area for optimum and profitable production. The application of another drought index is imperatively recommended for comparision and validation towards finding reliable information on drought in the area.

Keywords: Agricultural; application; drought; impact; intensity normal precipitation; meteorological; production.

1. INTRODUCTION

Drought is an insidious natural hazard that results from lower levels of precipitations than what is considered normal [1] When this phenomenon extends over a season or a more extended period of time, precipitation is insufficient to meet the demands of human activities and the environment. Drought is an insidious natural hazard with severe implications for the economic well being of the farming community [2]. There is no single definition of drought, and there is no reliable methodology for its quantification [3]. It may be said in most general terms that drought is every reduction of precipitation concerning the normal (average) quantity of precipitation in a given climatic zone. This by itself makes drought the most complex hydrological event that affects all climatic zones, with varying duration, intensity and frequency.

On the other hand the efficiency of drought protection is very low [4]. Thus, like other hazards, droughts can be characterized in terms of their severity, location and duration [5]. There is practically no climatic area in which droughts of various intensities have not occurred in past decades, mostly as a result of the most significant threat facing the world in the 21st century: climate changes and timing [5]. They are mostly based on hydrological parameters (discharges and water levels) and meteorological parameters (precipitation and air temperatures). Meteorological drought is the earliest explicit event in the process of occurrence and progression of drought. Rainfall is the primary driver of meteorological drought. There are numerous indicators based on rainfall that is being used for drought monitoring [6]. Rainfall deviation from normal -a long term mean, is the most commonly used indicator for drought monitoring. Therefore, the type of impacts relevant in a particular drought monitoring and early warning context is often a crucial consideration in determining the selection of drought indicators [5]. Drought must be considered a relative, rather than the absolute, condition. Droughts are regional in extent and each region has specific climatic characteristics. The amount, seasonality and form of precipitation differ widely between each of these locations [1]. There are also many different methodologies for monitoring drought. However, none of the methods currently in use can be considered universal, or correct. The selection of a method in a given area depends on available data and on the capability of a method to estimate in the best possible way the occurrence of drought in time and space, and its variability [7]. That is why criteria for selecting the best drought analysis method would be: independence with concerning geographic and climatic characteristics of an area, including extreme climatic conditions (desert or polar conditions), physical foundations of a method, and simplicity of calculation [4]. In Yola South LGA which is the study of this work there are quite number of research works on drought analysi and its characterization using different indices such as rainfall seasonality index (RSI) by [8]. Rainfall Anomaly Index (RAI) by [9] and Rainfall Decile Index (RDI) by [10]. However, no any attempt that was made to apply the use of percent of normal precipitation indices towards study drought intensity and variability in the area. Therefore, to this end, this research work has selected the use of percent of normal precipitation (PNP) for the drought intensity analysis due to its simplicity and the geo-physical homogeneity of the area as well the available historical rainfall data.

The percent of normal precipitation (PN) or precipitation anomaly, it is a simple method that is used for rapid drought frequency analysis. It can be considered satisfactory if a more extended series of precipitation data is available (no less than thirty years), and if it is applied within a single region with similar geographical characteristics [3]. Conversely, As [11] explained, one of the disadvantages of using the percent of normal precipitation is that the mean, or average, precipitation is often not the same as the median precipitation, which is the value exceeded by 50% of the precipitation occurrences in a long term climate record. The reason for this is that precipitation on monthly or seasonal scales does not have a normal distribution. Use of the percent of normal comparison implies a normal distribution where the mean and median are considered being the same. Drought indices have been developed from known values of selected parameters to present a quantitative description of droughts [2].The information on the timing of droughts, drought intensity, drought duration, spatial extent of a specific drought episode and analysis of the risk of the phenomenon and its likely effect on agricultural production is highly imperative. Thus, Information on drought intensity can be presented in a several different ways including the use of the drought indices particularly percent of normal precipitation (PNP).Therefore, to assess the meteorological drought severity in the area rainfall as the primary parameter of meteorological drought was selected and developed as it appeared as the dependent variable of PNP indices respectively. Thus, this research work aimed at the application of percent of normal precipitation for meteorological drought intensity assessment and its impact on agricultural production in Yola South LGA, of Adamawa State Nigeria.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Yola South LGA and Environs of Adamawa State, Nigeria which lies on latitude 09^{o} 14’N and 09^{o} 20’N of the equator and longitude 12^{o} 25’E and 12^{o} 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% [12,13].

2.2 Application of Percent of Normal Precipitation (PNP)

The percent of normal precipitation (PN) or precipitation anomaly is based on the relationship between the monthly precipitation and average monthly precipitation in the period under study. It is a simple method that is used for rapid drought frequency analysis, and can be considered satisfactory if a longer series of precipitation data is available (no less than thirty (30) years), and if it is applied within a single region with similar geographical characteristics. It would be difficult to compare locations that are far away from one another, as anomalies are defined in relation to a given location (weather station) separately [3]. It is calculated by dividing actual precipitation by normal precipitation—typically considered and multiplying by 100% [14]. This can be calculated for a variety of time scales, including monthly, seasonal, annual, or water year. Normal precipitation for a specific location is considered to be 100%.

$$\text{PNP}=\frac{\text{actual precipitation}}{\text{normal precipitation}} \times 100 \qquad \text{(Eq 1)}$$

Meteorological data of rainfall for forty (40) years (1978-2017) obtained from Upper Benue River Basin Development Authority (UBRBDA) were computed using the above PNP formula. Thus, the observed 40 years period is considered long enough for drought analysis purposes [6,15].The limit values of the PNP were classified as explained by [14] as depicted on Table 1.

Table 1. Limit values of the PNP indices

S/N	PN [18] classification	Limit values
1	Extremely Wet	≥ 115
2	Very Wet	110-115
3	Moderately Wet	100-110
4	Normal	80 to 100
5	Moderately Dry	55 to 80
6	Very Dry	40 to 55
7	Extremely Dry	≤ 40

3. RESULTS AND DISCUSSION

3.1 Calculated Values of the Percent of Normal Distribution

Results on the calculated values of the Percent of the normal distribution for forty years (1978-2017) were depicted in Table 2 and 3. The results revealed that extremely wet condition was identified in six years frequency of 15 % (1980, 1988, 1995, 1999, 2012 and 2016) with the corresponding PNP values of 117.71 %, 115.93 %, 115.64 %, 119.11 %, 116.04 % and 134.82 % respectively. Vey wet condition was recognized in the year 2009 and 2010 (113.75%) and (113.67 %) respectively.

However, according to Ref [9] 2016 and 2012 were estimated as extremely and very wet conditions using Rainfall Anomaly Index method (RAI) which led to exacerbated flooding in the area which damaged a hundred hectares of farmlands. In addition, the result also corroborated with the outcome of [10]. Where the year 1998, 1980, 2009, 2010 and 1995 as Much Above normal of Ninth decile is the rainfall amount not exceeded by 90% while 1969, 1988, 2012, 1999 and 2016 considered as Much Above normal of Ninth decile is the rainfall amount not exceeded by 100% respectively. Moderately Wet seasons were found in the 14 years frequencies of reoccurrences having 35 % (1978, 1981,1982, 1984,1985, 1989, 1992, 1993, 1996, 1997, 1998, 2000, 2014 and 2015) with also a corresponding values of 106.29 %,100.15 %, 102.42 %, 105.09%, 103.71 %, 105.22 %, 108.01 %, 104.60 %, 109.43 %, 101.36 %, 108.64 % and 104.75 % respectively. A similar finding was also reported by [9] who revealed that the year 1978, 1996, 1998 and 2014 were considered moderately wet. Normal percent values were revealed to had occurred in 16 years (40%) out of the 40 years of the study period in the area which are 1979, 1983, 1986,1990, 1991, 1994, 2001, 2003, 2004, 2005, 2006, 2007, 2008, 2011 2013 and 2017 with the percent normal values of 85.52 %, 94.56 %, 96.36 %, 88.14 %, 92.21 %, 98.91 %, 97.98%, 83.96 %, 85.59 %, 85.50 %, 81.84 %, 96.66 %, 86.54 %, 88.07 % and 98.50 % accordingly. Moderately dry was occurred in two years only (5%) 1987 and 2002 having the percent normal values of 72.61 % and 70.23 % respectively. A similar finding of [10] was correlated with this result where in the year 1987 and 2002 were quantified as Much below normal with the first decile is the rainfall amount not exceeded by the lowest 10% defined as Exceptional Drought (D4) classified by [15,16]. In the area however, dry and extremely dry drought conditions were not glaring in the area in all the 40 years of study [9].

3.2 Nature of the Intensity of Drought Conditions

The conditions of drought intensity are shown on Table 4. The results revealed that about 55% of the farmers in the area conceived that drought occurs every year most especially in the recent decades affecting agriculture and the ecosystem. Thus, [9] reported similar findings that 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. The remaining 45 % of the farmers did not agreed with drought reoccurrence every year in the area. This explains the reason why the area is considered under natural drought hazards seasonally. Ref.[16] also reported that the recurring droughts in Alberta seriously decrease crop yields and thus harm the whole Alberta agriculture industry. Similarly, most of the farmers (65%) are aware about the drought hazards as they affect their crop performance and productivity and 35 % of them perceived unawareness hazards of drought in the area. This finding correlated with results of [17] who revealed that in Adamawa State about 69.2 % of the farmers were aware of the climatic hazards affecting their crop yield and they do little to reduce the impacts of these hazards on their crops. The months of July-August were assessed to have more reoccurrences of drought scenario in the area by about 55% of the farmers while 45 % perceived to have occurs mostly in the months of May-June respectively. This result is not in conformity of the findings of [1]. [18,17] revealed that the month of May and June in the Northern part of the state is characterized by drought conditions. However, in the year 2019 and 2020 drought was occurred in the month of August in the study located in the central zone of the state respectively. For the drought durations most farmers (55%) agreed that to have experienced drought intensity for a period of 1-2 weeks while 45 % of them conceived to had last for more than 2 weeks in the area. For example, last year 2019 drought had occurred from 4th August-29th August, 2019 while this year the area experienced drought for two weeks from

Table 2. Calculated values of the Percent of a normal distribution from 1978-2017 (40 Years)

S/N	Years	Total (mm)	No. Of rainy days	PN (%)	Rating
1	1978	993.4	64	106.29	Moderately Wet
2	1979	799.3	55	85.52	Normal Condition
3	1980	1044.1	63	117.71	Extremely Wet
4	1981	936.1	66	100.15	Moderately Wet
5	1982	957.3	52	102.42	Moderately Wet
6	1983	884.1	65	94.56	Normal Condition
7	1984	970.9	65	103.88	Moderately Wet
8	1985	970.5	65	103.84	Moderately Wet
9	1986	900.6	57	96.36	Normal Condition
10	1987	678.7	62	72.61	Moderately Dry
11	1988	1083.5	74	115.93	Extremely wet
12	1989	982.2	69	105.09	Moderately Wet
13	1990	823.8	58	88.14	Normal Condition
14	1991	861.8	69	92.21	Normal Condition
15	1992	969.3	64	103.71	Moderately Wet
16	1993	983.4	69	105.22	Moderately Wet
17	1994	924.5	74	98.91	Normal Condition
18	1995	1080.8	69	115.64	Extremely Wet
19	1996	1009.5	60	108.01	Moderately Wet
20	1997	977.6	73	104.60	Moderately Wet
21	1998	1022.8	73	109.43	Moderately Wet
22	1999	1113.3	61	119.11	Extremely Wet
23	2000	947.4	68	101.36	Moderately Wet
24	2001	915.8	77	97.98	Normal Condition
25	2002	656.4	72	70.23	Moderately Dry
26	2003	784.7	62	83.96	Normal Condition
27	2004	800	71	85.59	Normal Condition
28	2005	799.1	68	85.50	Normal Condition
29	2006	764.9	64	81.84	Normal Condition
30	2007	903.4	72	96.66	Normal Condition
31	2008	808.9	72	86.54	Normal Condition
32	2009	1063.2	71	113.75	Very Wet
33	2010	1062.4	81	113.67	Very Wet
34	2011	823.2	71	88.07	Normal Condition
35	2012	1084.6	81	116.04	Extremely Wet
36	2013	827.7	67	88.56	Normal Condition
37	2014	1015.3	71	108.64	Moderately Wet
28	2015	979	69	104.75	Moderately Wet
39	2016	1260.1	68	134.82	Extremely Wet
40	2017	920.6	65	98.50	Normal Condition

Table 3. Years of occurrences and frequency distribution of percent of normal precipitation of Yola South LGA from 1978-2017 (40 Years)

S/N	PN Classification [18]	Years of occurrences	Frequency	Percent (%)
1	Extremely Wet	1980, 1988, 1995, 1999, 2012 and 2016	6	15
2	Very Wet	2009 and 2010	2	5
3	Moderately Wet	1978, 1981,1982, 1984,1985, 1989, 1992, 1993, 1996, 1997, 1998, 2000, 2014 and 2015	14	35
4	Normal	1979, 1983, 1986,1990, 1991, 1994, 2001, 2003, 2004, 2005, 2006, 2007, 2008, 2011 2013 and 2017	16	40
5	Moderately Dry	1987 and 2002	2	5
6	Very Dry	Nil	0	0
7	Extremely Dry	Nil	0	0

Table 4. Nature of drought conditions in the study area

Variables	Percent distribution (%)	
Does drought occur in the area every year	Yes = (55%)	No = (45%)
Are you aware of the drought hazards as they affect crop yields	Yes = (65%)	No = (35%)
Which period does the drought usually occurs seasonally	May-June = (45%)	July-Aug = (55%)
Duration of the drought conditions	1-2 weeks = (55%)	More than 2 weeks= (45%)
What is the level of the drought intensity	Low = (55%)	High = (45%)
What is the level of the drought impact on agricultural production	Low = (40%)	High = (60%)

Table 5. Impact of drought intensity on agricultural production

Impact on agricultural production	Frequency (n= 50)	Percentage (p=100%)
Reduction in crop yield	9	18
Physiological stress and low crops growth	6	12
Drying of dams, reservoirs and lakes	6	12
Loss of profit and capital	3	6
Desertification and loss of some wild animals	2	4
Loss of employment opportunities	3	6
Loss of aquatic animals and fishing activities	2	4
Dead of livestock and starvation	3	6
Abandoning of rain fed farming activities	2	4
Drop in water table and drying of soils	3	6
Loss of pastures, forages and grasses	2	4
Soil degradation	3	6
Outbreak of crops' pest and diseases	6	12

Sunday, 3rd August- 17th August, 2020 respectively. It is a known fact that the complexity of drought lies in the fact that it cannot easily be predicted because it develops slowly, and it is usually noticed when it has already been present for weeks or months. The level of the drought intensity was considered as low with about 55 % of the farmers and 45 % perceived to be high. Conversely, on the level of the drought impact on agricultural production most farmer (55%) agreed to a have high impact on their productivity. In comparison, the remaining 45% of them considered the impact as low to have affected their production in the study area. It is important to note that the impacts of droughts can be as varied as the causes of droughts. Droughts can adversely affect agriculture and food security [5]. A drought impact is an observable loss or change at a specific time [5].

Table 6. Mitigation strategies adopted by the farmers on the impact of drought on crop production

Mitigation strategies	Frequency (n =50)	Percentage (p=100%)
Water harvesting techniques	6	12
Tillage method	3	6
Use of low water potential crop varieties	4	8
Early planting	9	18
Delay planting	8	16
Use of early matured crops	15	30
Mulching techniques	3	6
Water supplement method (semi-irrigation)	2	4

3.3 Impact of Drought Intensity on Agricultural Production

Drought impacts in various ways. The effects of drought may be direct or indirect, singular or cumulative, immediate or delayed [19]. Of all the extreme meteorological events affecting agriculture and forestry, drought is perhaps the most important hazard with serious implications for the economic well being of the farming community [2]. In Yola South LGA, is located in the savannah region of Nigeria with a significant fertile landmass which produces a large proportion of the grains that provide the staple diet to the growing population. Yet the area is frequently under drought attack and this negatively affects food production in the area and is continuously reoccurring most especially in the recent decades [8].

Results on the impact of drought intensity on agricultural production were presented in Table 5. Reduction of crop yield was revealed as the major effects imposed by the drought intensity in the area by 18 % of the farmers. Climate change impacts on agriculture include biological effect on crop yield, the resulting impact on prices, production, consumption and the impact on per capital calorie consumption and malnutrition [20]. Droughts lead directly to poor crop yield, [19]. Recurring droughts in Alberta seriously decrease crop yields and thus harm the whole Alberta agriculture industry. The 2001 drought made the Alberta yield lower than that of each of the ten proceeding years, for the 2001 yield was only 84% of the ten-years' mean [16]. Growing water shortages are a particularly important source of yield growth decline [21]. Physiological stress and low crops growth were caused due to drought condition conceived by 12 % of the farmers in the area. Physiological stress and low crops growth also attributed to 10 % of the respondents to had caused negative effects due to insufficient water in the area [22].Rice crop is the major crop grown at Njuwa Lake which requires a sufficient quantity of water for its physiological development from emergence to physiological maturity. Therefore, any form of water deficit will reflect on the crop growth and subsequently to the yield respectively. In Kastina State, crops covering 150 hectares of tomatoes, potatoes, maize, wheat, onions and other vegetables were damaged as they became wilted forcing some farmers to commence early harvest to salvage what they could of the crops [23]. Similarly, about 12 % of the respondents perceived that drying of dams, reservoirs and lakes were affected by the drought hazards. Similar report by [23] indicate that more than 150 irrigation farmers using water from Musawa dam in the central part of Katsina State have lost 30 million Nigerian Naira (about 85,714 US Dollars) following sudden drying up of the dam. Water reduction and drying up of Njuwa Lake is rapid before the onset of rainfall coupled with the low quality of the water, most of the livestock grazing in the area are seriously affected which imposed them moving to river Benue scavenging drinking water [23]. The outbreak of crops' pest and diseases also received 12% out of the respondent as among the second major negative impact of drought intensity in the area. Loss of profit and capital among the farmers was recorded about 6 % to have influenced by the drought intensity. Ref. [24] observed that climate attributes (temperature and precipitation) affect net farm revenue and such impacts can be significantly reduced through adaptation. Continuous droughts stretching over several years in different parts of the world in the past significantly affected productivity and national economies [2]. Likewise loss of employment opportunities among farmers (6%) was caused due to the hazards in the area. Findings in Iraq revealed that scarcity of water had led to increased levels of unemployment [25]. Also 10% of the respondents agreed that the loss of employment opportunities appeared among the effects caused by water scarcity at Njuwa Lake [22]. Generally, food production will be adversely affected by the variability in timing and amount of rainfall and heat stress and the consequence is an increase in food shortages and many farmers could lose their sources of livelihood due to climate change [26,27]. These put a severe strain on the economic development of a nation, either immediately or with a time lag [28,29,19]. In addition, 6 % out of the farmers considered dead of livestock and starvation was affected by the reoccurrences of drought conditions. Droughts lead to the directly to dead of live stock etc [19]. Water scarcity in the area had led crop failure, the decline in fishing activities and livestock starvation which are the primary occupation of the dwellers in the area which directly affects their income and led to poverty growth in the area [22]. Similarly, Monitors in Muthanna have reported that, in some villages, up to 90% of livestock have died as a result of scarce and low quality water supplies [25]. Drop in water table and drying of soils was also agreed by 6 % of the farmers to have caused by the intensity of drought in the area. Quantification of drought impacts can be seen in terms of drying of soil as a result of increased in temperature [19]. The solution to the decline of the water table is an expense which required the construction of standard boreholes with powerful machines which is beyond the financial capability of most of the farmers in the area [22]. Correspondingly, in a number of regions in India water tables have been falling at average rates of two to three meters per year as the number of irrigation wells grows [21]. Similarly, soil degradation on the arable lands was recorded with 6% perception among the respondents imposed by the negative impact of drought leading to low agricultural production in the study area. Thus, drought threatens permanent erosion of the capital and resource base of farming enterprises [2]. About 19 years were falls under negative threshold a value of slightly dry to extremely dry conditions out of the forty years of study which in consequence it disrupts crop growth, reduces grazing land, and threatens permanent soil degradation [9]. 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. Desertification and loss of some wild animals in the area were identified with about 4% of the farmers in the area. Similarly, drought effects had also manifested in the area in terms of vegetation loss subjecting the area into desertification process thereby forcing an indiscriminate movement of cattle by the herdsmen to Cameroon border threatens permanent soil degradation, cracking and drying of soils and disrupts crop growth [30,31,8]. In addition, the risk of serious environmental damage of drouht, 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 [2]. Loss of aquatic animals and fishing activities was perceived by 4 % of the farmers due to drought conditions in the study area. Similarly, loss of fishing grounds appeared as the second most negative effect of water scarcity on Njuwa Lake conceived by 12 % of respondents [22]. Moreover, 4 % of them also conceived that abandoning of rain-fed farming activities by the farmers was due to the drought negative impact forcing most of them to engage in irrigation framing due to its low or minimal natural hazards with total control of water use and management. The direct caused by drought are more complex and lead to changes in land-use practices, abandonment of fertile lands, migration of rural population, heavy pressure on urban areas and so on[19]. Similarly, [32] reported that water scarcity had hit Sokoto State farmers around the border town of Illela where large tracks of land are unfarmed due to the scarcity of water. Loss of pastures, forages and grasses in the area was considered by the farmers (4%) which in turn affect grazing animals in the area. Droughts lead directly to Famine, deterioration of pasture [19]. The implications of decreasing rainfall include reduction in surface water availability, drought, crop failure and scarcity of animal fodders [33]. Understanding how droughts affect people, communities, businesses or economic sectors is key to taking steps towards mitigating the impacts of future droughts [5]. Climate change constitutes a very serious threat to sustainable agricultural production and food security in many parts of the world [33].

3.4 Mitigation Strategies Adopted by the Farmers on the Negative Impact of Drought on Crop Production

The farmers in the area has experienced the gross and rapid reduction of water in the study area in the recent decades have saddled strategically in adopting different ways in order to cope with the situation for proper crop performance [22]. Table 6 depicted the results of the mitigation strategies adopted by the farmers on the impact of drought on crop production. The findings revealed that the use of early matured was adopted by most of the farmers (30%) towards mitigating the negative impact of drought in the area. This result agreed with findings in Iraq which revealed that most agricultural areas identified as water scarce, where many farmers have been forced to change their crops to varieties that require less water, as in Missan (100% of assessed farmers), Basra (99%) and Wassit (96%) respectively [25]. Early planting was perceived by 18 % of the farmers to have used in curtailing the hazards for sustainable food production. Conversely, delay planting was considered as the third mitigation strategy employed by 18 % of the farmers. Moreover, water harvesting techniques received 12 % among the farmers in the area with the aim of extenuating the negative impact drought. Use of low water potential crop varieties attracted 8 % of the farmers. The use of low water potential crop varieties was used by 16 % of the farmers as coping techniques on the insufficient problem of water faced in the irrigation site. Tillage method and mulching techniques each received 6 % of the farmers in the area. Only 4 % of the farmers have adopted that used of water supplement method (semi-irrigation) in curtailing the menace in the area.

4. CONCLUSION

Different drought indices have been used in assessing the intensity and effects of drought on agriculture and the ecosystem of a given geographical area. Among these methods percent of normal precipitation (PNP) is considered as the simplest and effective index for drought identification. In Yola South LGA of Adamawa State Nigeria, the PNP method was adopted with the aim of quantification of drought intensity and its impact on agricultural production. The result revealed that moderately dry conditions were observed in two years with six years of extremely wet seasons respectively. The impact of drought conditions in the area was considered as high which affect crop yield, drying of dams, reservoirs and lakes, livestock starvation, drop in the water Table and drying of soils among others. Farmers have employed various strategies such as the use of early mature crops, early planting, water harvesting etc towards mitigating the menace for adequate food production in the area. Therefore, the used of PNP method in the area provides dependable information on drought scenarios which can be used by the decision-makers on monitoring and providing of workable solutions to the farmers on future drought reoccurrence. Thus, it is therefore recommended the use of another meteorological drought index in the area with the aim of comparing the indices outcome for validation towards providing reliable information on drought in the study area respectively.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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