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Analysis of Perceived Effects of Rainfall Variability on Rice Yield in Lokoja, Kogi State, Nigeria

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Abstract

This study analyzes the perceived effects of rainfall variability on rice production in Lokoja using data on rainfall and rice production from 2013 to 2022, and data on demographic and socio-economic characteristics of farmers as well as their perception on the effects of rainfall variability. The study was done using well-structured questionnaire administered in the study area to the 140 selected respondents, and the Statistical Package for the Social Sciences (SPSS) version 24 was utilized to analyze the data. Results showed that rainfall have significant effects on rice production with varied yield based on rainfall fluctuations in the amount of rainfall with as much rice production of about 4269 $tonha^{-1}$ when precipitation was suitable between about 1250 - 1350mm, but when less than normal precipitation (<1250mm), it reduces the production yield to about 2361 $tonha^{-1}$. Similarly, the results revealed that when the rainfall amount was highest, the total rice production was reduced, with cultivated areas having heavy rainfall resulting in flooding. Results further showed that on average 1282mm of rainfall produced 2693 tons of rice in the study years. About 44% of the respondents refuted early rainfall onset affecting rice production with months such as June, July, and September in some of the years with high rainfall intensity having adverse effects on rice farming, with 43% of the respondent noting that it limited the amount of land available for cultivation, while 26% noted that it reduces rice yield while the remaining 31% noted that it destroys rice stands.

Keywords: Rainfall Variability, Rice Yield, Climatic Conditions, Precipitation, Lokoja.

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Introduction

Rainfall is the amount of precipitation, in the form of water droplets, that falls from the atmosphere to the earth surface. It is an essential component of the hydrologic cycle and plays a crucial role in the distribution of fresh water resources. According to United States Geological Survey (USGS), rainfall is the liquid precipitation that reaches the surface of the earth as drops larger than 0.5 millimeters (0.02 inches) in diameter. However, rainfall variability refers to the degree of variation in the amount, frequency, and intensity of rainfall over a specific area and time (Alexander and Julie, 2009). It is an important aspect of climate variability and it is influenced by various factors including atmospheric circulation patterns, oceanic processes, and local processes and this can have significant impacts on ecosystems, agriculture, water resources, and human livelihoods (Trenberth, 2011).

Rice (*Oryza sativa*) is a staple food in many nations of Africa and other parts of the world. For roughly half of the human population, this is the most essential staple meal (Imolehim and Wada, 2000). According to Saka and Lawal (2009), more than half of the world's population relies on rice to meet around 80% of their nutritional needs. Rice crop is a significant agricultural product in terms of food production and consumption in many nations, particularly in Asia and Africa (Matsuda 2009; Auffhammer, Ramanathan and Vincent, 2012). It is also a significant source of income for many people living in developing nations. As a staple item for people's everyday lives, rice production has a significant impact on global food security (Ara, Lewis, and Ostendorf, 2017). Over 4.7 billion people worldwide eat rice as their primary source of nutrition, and demand is predicted to increase in the next years (Asada and Matsumoto, 2009; Homma, Shiraiwa, and Horie 2014; Akinbile, Ogunmola, Abolude, and Akande, 2020). In addition to ensuring national food security, rice also helps to generate money and jobs in Lokoja and throughout the nation. Farmers around the nation cultivate the crop in a variety of production ecologies (Lokoja inclusive).

Rice is normally grown in water-flooded fields in more than 95 countries and plays a vital role in feeding large sections of Kogi State population. Rice needs a significant amount of water, estimated to be around 500 to 600 mm, and in Lokoja, crop production is dominantly rain-fed and its performance is dependent on rainfall and its erratic pattern which causes crop failures and food shortages (Devereux, 2000). The start and end of the rain, seasonal rainfall patterns of rainfall distribution, frequency, and the probability of the length of a dry spelling the growing season are key factors affecting the planning, establishment and management of crops in Lokoja (Solomon et al., 2015).

Rainfall is one important climatic factor that affects agricultural yield. Similar to many other impoverished countries, agricultural methods in Nigeria, notably in Lokoja, heavily rely on rainfall. Rainfall is a form of precipitation that is very prominent in the tropical region. Rainfall characteristics such as onset and cessation, amount, seasonality, intensity, duration and frequency are very important. It is observed that the various level of rainfall variability regime warned about possible effect on Agriculture productions. Therefore, Le Barbé et al (2002) pointed out the declining rate of inter-annual rainfall variability in West Africa. The declining trend of annual rainfall in Lokoja has been a major concern in the area most especially the agricultural sector of rice in the economy and this cause might probably lead to food crisis. The climate of Lokoja and its environs falls into koppen-Aw, this means it is the warm continental type (Olatunde and Ukoje, 2016). It is very salient to understand rainfall pattern and trend of a place as it of great importance and relevance as well as being a chief climatic parameter that influence crop production and other socioeconomic activities of a region (Animashaun, Adeoye, Otache, and Abatan, 2020).

Climatic factor, mainly rainfall and temperature have a direct impact on the cultivation of rice crops (Alam, et al, 2011; Panda, et al, 2019; Abbas and Mayo, 2021), and any changes to these climate parameters may have a significant impact on the yield and production of rice crops as well as the economic, social, and environmental sustainability of a nation (Alam et al., 2011; Panda et al., 2019). Lokoja region and virtually all other areas in Nigeria are mostly involved or practice rain-fed rice production. As a result, apart from the socio-economic problems facing farmers cultivating rice, climatic variability constitutes a major limiting factor in rice production in the region due to the practice of rain-fed agriculture.

Although the effects of rainfall variability have been studied in earlier studies, the full solutions are still not fully known. Previous studies mostly analyzed the impact of the climate. This evidence found in previous research shows that the features of rainfall variability and their impact on rice yield vary from place to place and region to region. Thus, this research is aimed at analyzing farmer perceptions on rainfall variation, its effects on rice production in the study area as well as proposing ways to improve the production of rice in the region, with a specific objective of; examining the variation of rainfall pattern in the, investigating the annual rice production, and also ascertain farmers' perceptions of rainfall variability on rice yield in the study area.

The research is limited to areas where farming of rice takes place in Lokoja such as Kpata, Kabawa, Adankolo, Serikin-noma, Gadumo, and Ganaja village most especially areas that are on the floodplain of River Niger-Benue and this is because they are the major rice producing area in Lokoja metropolis. The study considered rainfall variability for 10 years (2013 - 2022). The focus of the study is mainly on rainfall as a climatic variable which affect rice farming in the area excluding other climatic variables such as temperature, sunshine duration and intensity, amongst others due to the fact that rainfall is one of the most important climatic element that affect rice production and little or no study have been conducted regarding rainfall and rice production in the study area.

Review of Empirical Literature

Several literatures have treated issues concerning climatic effect on crop production. Most of these researches focused on the effect of climate change on crop production with little or no attention on climate variability and farmer perceptions. However, Odeniyi, Ibitunde and Olaniyi (2020) examine the effects of climate variability on rice production in Nigeria from 1970-2016. Secondary data were employed, years of study extended from 1970-2016 (47 years). Time series data were extracted from Nigerian Meteorological Agency (NIMET) and annual rice production was collected from National Bureau of Statistics. Results reveal that there were fluctuations over the period of study with alternating fall and rise such that in the sub period of 2010-2016, high mean rainfall of 799.10mm and a low mean rainfall of 641.97mm was recorded respectively in the sub-period of 1980-1989, thereby resulting in average of 702.39mm rainfall amount over the period of study.

Nwaobiala and Adesope (2013) in their study which assessed determinants of smallholder rice production systems in Ebonyi State, Nigeria. A purposive and multistage random sampling techniques was used to select agricultural blocks, circles and rice farmers. Data for the analysis were collected from a structured questionnaire and a Cobb-Douglas regression model was also employed in the study. The results showed that the positive determinants of output of upland rice were age, faming experience, farm size, variable inputs and capital was negative, while in the case of swamp rice, the Cobb-Douglas regression estimates showed that coefficients of education, labor cost, farm size, variable inputs and farm income were positively signed and capital was also negative.

Similarly, Saliu et al., (2015) in their study examined the probable effect of rainfall variability on average yield of rice in Nigeria during a 22-year period (1992-2013). The mean annual rainfall data from major rice producing states and national average rice yields were analyzed using descriptive statistics and regression models. The results from the analysis from the study showed that mean rainfall was adequate for rice production in all vegetation grouping except Sudan savanna, where rainfall was less than the prescribed minimum quantity for rice production.

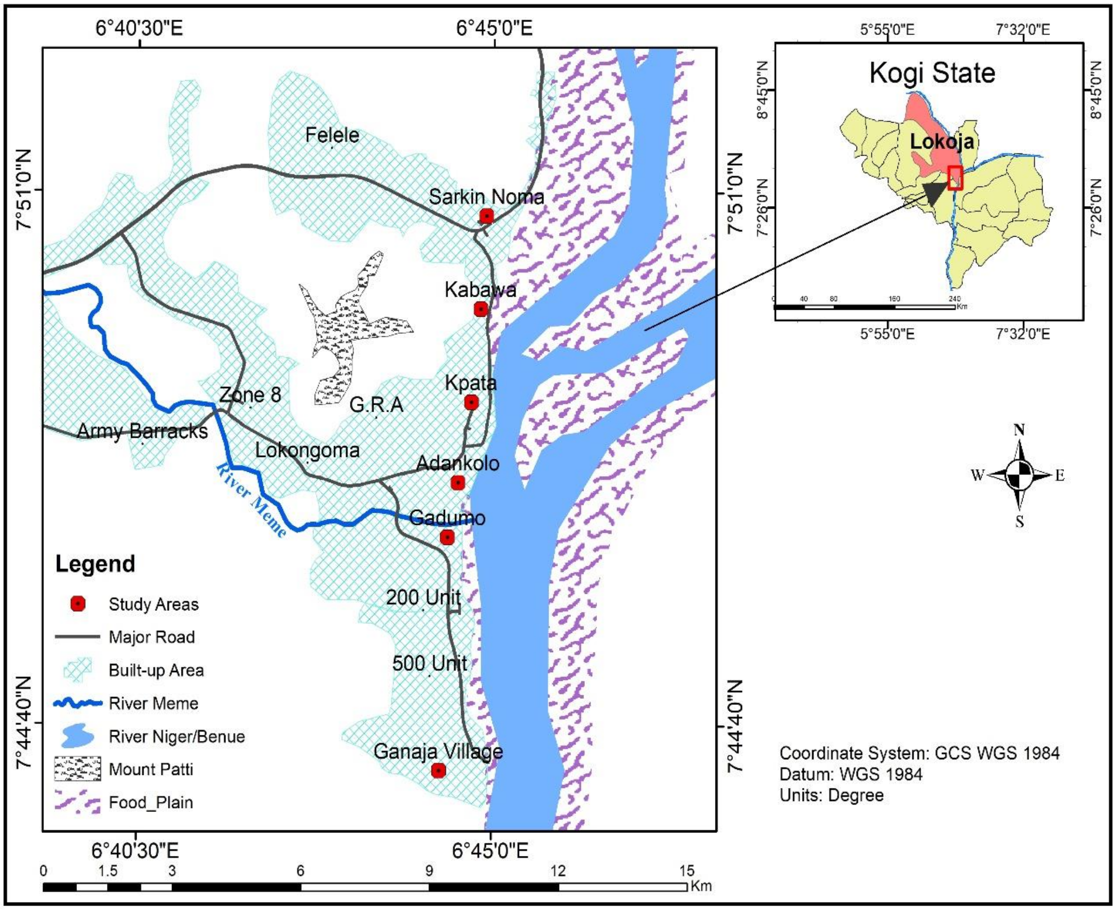
Also, Oniah and Chukwuemeka (2019) in a similar study examined farmer's perceptions of the effects of climate variation and their mitigation strategies in rice production in Cross River State, Nigeria. The purposive and proportionate random sampling techniques were adopted to select rice farmers for the study with questionnaire used as one of the instruments for data collection for the study. The study concludes that climate variations influenced rice production in the state as the climate parameters of rainfall, temperature and relative humidity, sunshine hours and wind were observed by the rice farmers to affect their rice output negatively. The farmers perceived the variations in temperature, rainfall and sunshine as major climate variables having serious threats in rice farming activities in the state. As a measure to reduce their negative effects, they adapted to planting rice at different dates, delay rice planting and cultivating rice with other crops to diversify production.

Methodology

The study area is the capital of Kogi State. It is located on between latitude 7°49'N and 7°51'N of the Equator and longitude 6°41'E and 6°45'E of the Greenwich Meridian (Figure 1). The town lies on the western bank of the River Niger at an altitude between 45 and 125 metres (Lokoja Master Plan 2005; Alabi, 2009). The climate of Lokoja is characterized by wet and dry Aw type of climate as classified by Koppen. It has annual rainfall of 1016 mm and 1524 mm ninety percent (90%) of which falls between April and October (Ifatimehin and Oloninisi, 2017). The average annual temperature rarely falls below 30.7°C with February and March being the hottest months (Ifatimehin, Ishaya and Ujoh, 2010). The two major groups of rocks that abound in Lokoja are Cretaceous Sedimentary Rocks and Basement Complex (Ifatimehin, Ishaya and Ujoh, 2010). drainages of the study area are the Rivers Niger and Benue. The other minor drainages are the Rivers Meme and Osara that also drains into the River Niger. These are seasonal streams except for rivers Niger and Benue (Ifatimehin, Ishaya and Ujoh, 2010).

The vegetation of the area falls within the Guinea Savannah zone, with tall grasses and some trees. These grasses and tress are greenish and blossom during the rainy season with fresh leaves, but wither during the dry seasons. There are also gallery forests along water courses as well as secondary and reserve forests in the study area (Ocheja, 2005). The study area has three major types of soil namely; Ferruginous, Lithosols and Hydromorphic soils (Bukola, Funsho and Omoyeni, 2013). The Terrain at Lokoja is uneven. As low as 46 metres of relief can be found in some places, but as high as 458.3 metres can be found in other places, such as the Mount Patti area. Lokoja has a population of about 77,516 in 1991, which increased to 791,000 in 2022 (World Bank Population Projection, 2020). Given the existence of geologic features like sedimentary rocks and aluminum along the river beds, farming activities are carried out extensively and this helps in agricultural productivity (Jaiyeoba, 2017).

Figure 1: *Map showing the study area*



Source: GIS Laboratory, Geog. Dept., Federal University, Lokoja

Techniques of Data Analysis

Data on rainfall (mm) in the study area was sourced from Nigerian Meteorological Agency (NIMET), Lokoja, data on rice production was sourced from the archive of ADP office Lokoja, Nigeria in which the both data covers a period of 10 years (2013-2022). Data on the farmers' perceptions on how variation in rainfall affects rice yield in the study area was generated through administration of a well-structured questionnaire to rice farmers in the study area. Since there is no appropriate information on registered farmers in the study area, a reconnaissance survey was done by going to the field in order to get some demographic information data regarding the rice farmers in the different selected neighborhoods in the study area. The determination of the appropriate sample size for the administration of questionnaires to the randomly selected respondents in the study area was obtained using Isreal

(1992) formula which is given as; $n = 2\left[\frac{N}{1+N\,(e)^2}\right]$ and the number of questionnaires to be administered in each area using proportionate estimation.

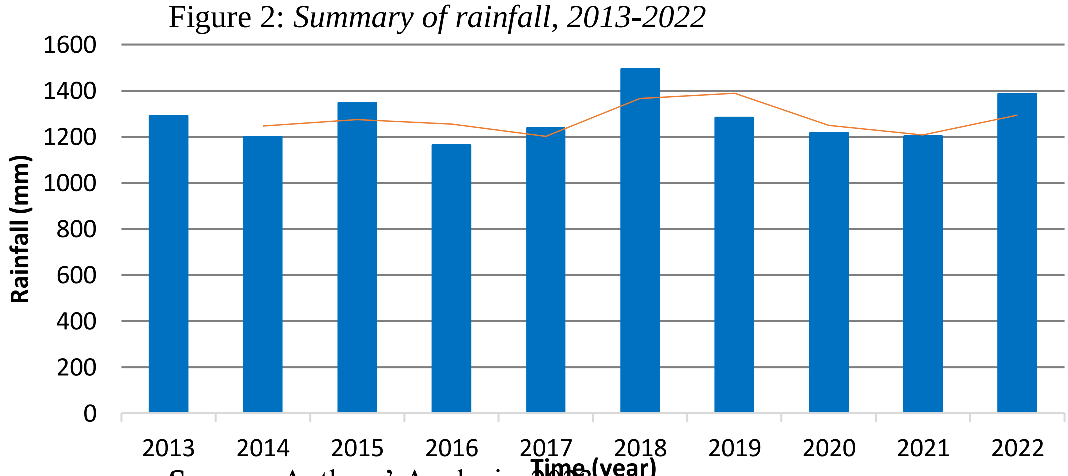
Results and Discussions

Variation of Rainfall Pattern

Findings revealed that, the average rainfall experienced between year 2013-2022 is 1282.02mm. The highest amount of rainfall in this study year (2013-2022) was experienced in May, 2018, 2022 and 2015 (1494.6mm, 1384.3mm and 1347mm) respectively. Rainfall trend in the study area during these periods fluctuates from one year to the other as presented in (Figure 2). These findings about rainfall variability as it pertains to Lokoja confirms the findings of Animashaun, Adeoye, Otache and Abatan (2020), and Olatunde and Adejoh (2017) which reported that there was rainfall anomaly in the study area.

The extent of fluctuation determines the rate of excess rainfall or insufficient rainfall which may trigger incidence of flood or drought that may constitute a major threat to tonnage of rice yield. Additionally, the fluctuation in rainfall pattern paves way for diversification of crop limiting the ability to adapt to changing climate conditions and reducing overall agricultural resilience. These variations and fluctuations in the monthly and yearly amount of rainfall affect rice production in the study area as the major area of rice production is rain fed.

Figure 2: *Summary of rainfall, 2013-2022*



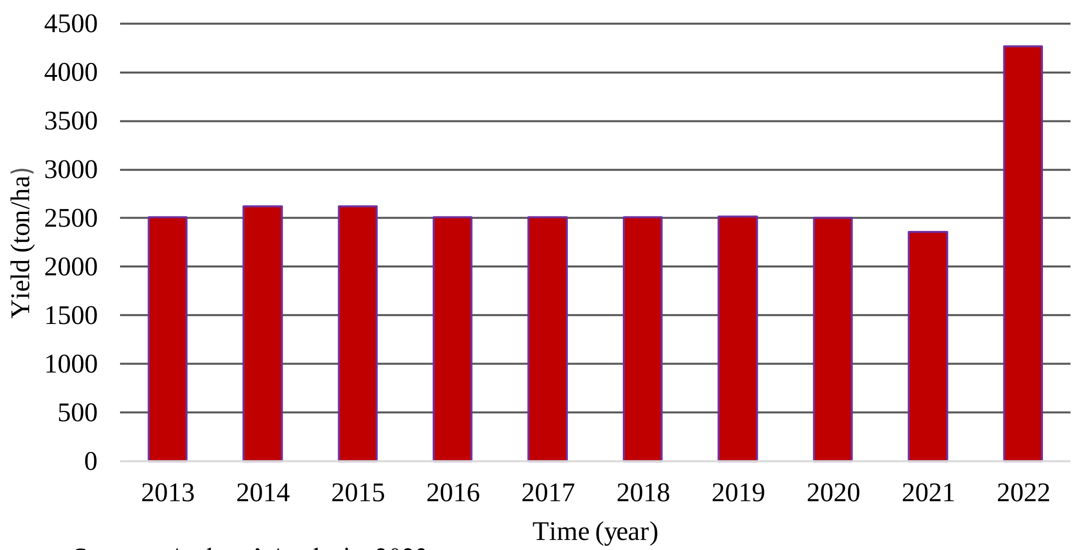
Source: Authors' Analysis, 2023

Annual Rice Production in the Study Area

The annual rice production rate was also analyzed using rice production data for 10yearss (2013-2022). Findings revealed that the annual productivity level varied between 2361 $tonha^{-1}$ and 4269-ton ha^{-1}, with an average productivity level of 2693 ton ha^{-1} during the study year. the fluctuation in rice yield in the study area is as a result of the fluctuation in rainfall variation pattern. Rice production increases with the year with high rainfall (2015 and 2022) except year 2018 which is due to heavy rainfall that might lead to destruction of rice stand and flooding which limit rice production in the study area.

Major areas of rice production are rainfed, thus large proportion of the variability in yield is attributed to rainfall as a major climatic element in crop growth (Figure 3). Similarly, when the rainfall is above normal it affects the area of land cultivated as a result of flooding leading to decrease in rice yield. The result from this study correlate with the study of Odeniyi et al (2020) on the effects of rainfall and temperature on rice production in Nigeria. The result from the study revealed that increase in rainfall leads to increase in rice production.

Figure 3: *Rice yield from 2013 to 2022*



Source: Authors' Analysis, 2023

Effects of Rainfall Variability on Annual Rice Production

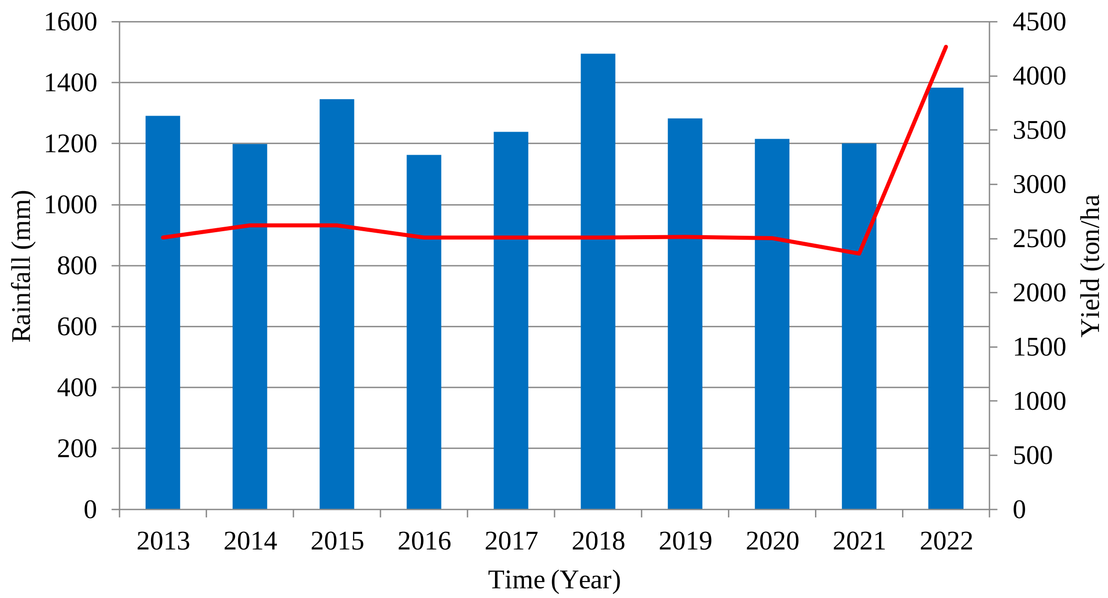
From the analysis, findings revealed that precipitation and rice production are strongly interrelated. It was clearly shown that when precipitation was suitable, the rice production was highest (1250-1350mm) but when less than normal precipitation, that ultimately affects the yield, reducing the rice production (<1250mm). On the other hand, when the precipitation was in highest level, the total rice production was reduced with cultivated areas due to heavy precipitation resulting flood (>1400mm) (Table 1). The impacts of more extreme precipitation and extreme weather events are already felt in Lokoja. These findings about the relationship between rainfall and rice yield confirm the results from the study carried out by Quadir, Khan, Hossain and Anwar (2003) who found out that the fluctuation of rainfall show correspondence with Southern Oscillation Index (SOI) variability but the phase is found to be changing in the most recent decades therefore, rice production largely depends on rainfall amount (Figure 4).

Table 1: *Rainfall, area cultivated and total annual rice yield between 2013 and 2022*

S/N	Year	Area Cultivated (HA 000)	Yield (Metric Tonnes 000)
1	2013	66	166,670
2	2014	75	197,548
3	2015	72	187,880
4	2016	59	148,402
5	2017	50	124,287
6	2018	63	158,238
7	2019	69	173,495
8	2020	51	128,420
9	2021	65	153,920
10	2022	39	164,660

Source: Authors' Analysis, 2023

Figure 4: *Rainfall variability and total annual rice yield between 2013 and 2022*



Source: Authors' Analysis, 2023

Farmers Perception on Rainfall Variability on Rice Yield

The analyses of famers' perception on the effect of rainfall variability on rice production revealed that variation in rainfall have a significant effect on rice production (Table 2). The findings showed that in years when rain incepted as early as January, February and March (2021, 2013, 2015 and 2018), it does not have adverse effect on rice production. Majority, 44.3% of the respondents disagreed that early onset of rainfall affects rice production, 30.7% strongly disagreed, 18.6% are undecided while only 4.3% and 2.1% of the respondents agreed and strongly agreed respectively. Similarly, findings also showed that in years when rainfall inception extends to latter half of April (2017 and 2022) it affected the rate of rice production, as about 38.6% of the respondents agreed to this, 41.4% strongly agreed, 16.4 undecided while the remaining 2.1% and 1.4% disagreed and strongly disagreed respectively.

In the same vein, findings reveled that early cessation of rainfall affects the rate of rice production, while late cessation does not have a significant effect on rice production. For instance, the analysis of rainfall revealed that in some years; 2017 and 2020, the rainfall ceased early without extending to the latter half of October let alone November which should have been the last rainy month. Majority (44.3%) of the respondents agreed that the early cessation of rainfall affects the rate of rice production, 42.1% strongly agreed, 12.1% undecided, while only 1.4% disagreed. Thus, the implication of these findings is that early onset, late onset, increment in the intensity of heavy rainfall, and other characteristics of rainfall have significant effects on rice production, although there is variation overtime. The result from this study agrees with the result of the of Bachama *et al.* (2020) regarding farmers' perception on the effect of rainfall variability in Dadin-Kowa of Gombe, Gombe state. The study indicates that respondents are aware of alterations in climate parameters and the regularities in their manifestation.

Table 2: *Perceived Effects of Rainfall Variability on Rice Production*

Variables	Items	Frequency	Percentage
Early onset of rainfall affects rice production	Agreed	6	4.3%
	Strongly agreed	3	2.1%
	Undecided	26	18.6%
	Disagreed	62	44.3%
	Strongly disagreed	43	30.7%
	Total	**140**	**100.0%**
Late onset of rainfall affects rice production	Agreed	54	38.6%
	Strongly agreed	58	41.4%
	Undecided	23	16.4%

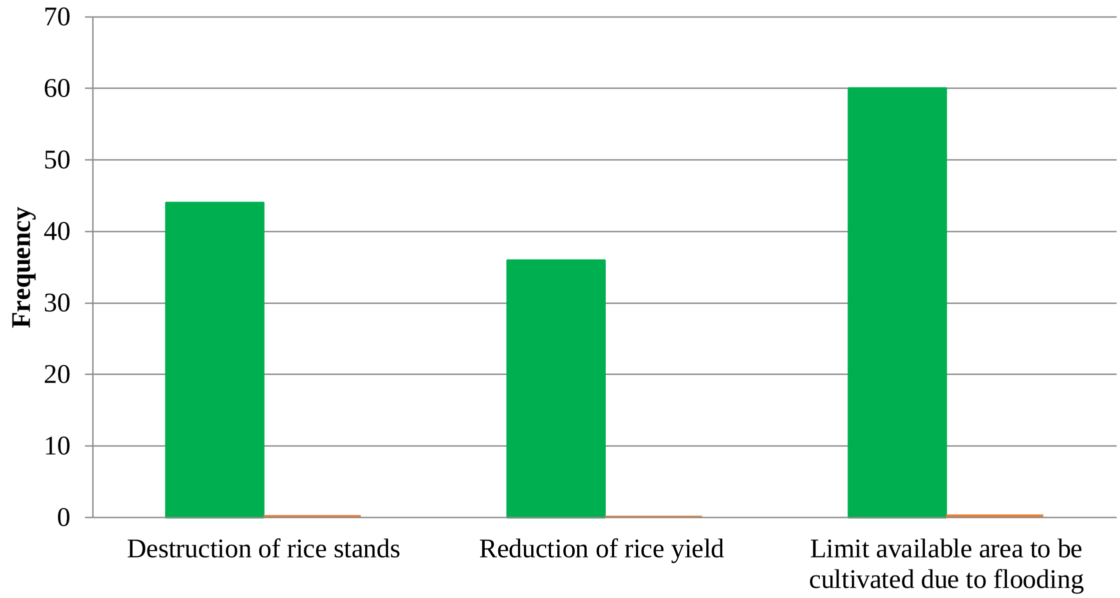
	Disagreed	3	2.1%
	Strongly disagreed	2	1.4%
	Total	**140**	**100.0%**
Irregular rainfall affects rice production	Agreed	60	42.9%
	Strongly agreed	71	50.7%
	Undecided	9	6.4%
	Disagreed	0	0.0%
	Strongly disagreed	0	0.0%
	Total	**140**	**100.0%**
Early cessation of rainfall affects rice production	Agreed	62	44.3%
	Strongly agreed	59	42.1%
	Undecided	17	12.1%
	Disagreed	2	1.4%
	Strongly disagreed	0	0.0%
	Total	**140**	**100.0%**
Late cessation of rainfall affects rice production	Agreed	1	0.7%
	Strongly agreed	3	2.1%
	Undecided	33	23.6%
	Disagreed	68	48.6%
	Strongly disagreed	35	25.0%
	Total	**140**	**100.0%**

Source: Author's Fieldwork Analysis, 2023

Furthermore, finding also revealed that months such as March, June, July and September in some of the years with increase in the intensity of heavy rainfall have adverse on the farming of rice, which majority (42.9%) of the respondent noted that it limits the amount of land available for cultivation, 25.7% noted that it reduces rice yield while the remaining 31.4% noted that it destroys rice stands. This results also confirm the results of the work carried out by Quadir, Khan, Hossain and Anwar (2003), in which their studies concluded that the fluctuation of rainfall show correspondence with SOI variability but the phase is found to be changing in the most recent decades therefore, rice production largely depends on rainfall amount (see Figure 5 below).

Findings also shows in Figure 6 below, also indicated that the effect of August break of rainfall on the rate of rice production is mild as majority (91.0%) of the respondents agreed to this fact as their perception. The implication of this is that mostly short break in the amount of rainfall does not significantly affect crop production as most of the farmers in the study area attested to this in their response which also confirm the study of Saliu et al., 2015.

Figure 5: *Effects of increase in rainfall frequency*



Source: Authors' Analysis, 2023

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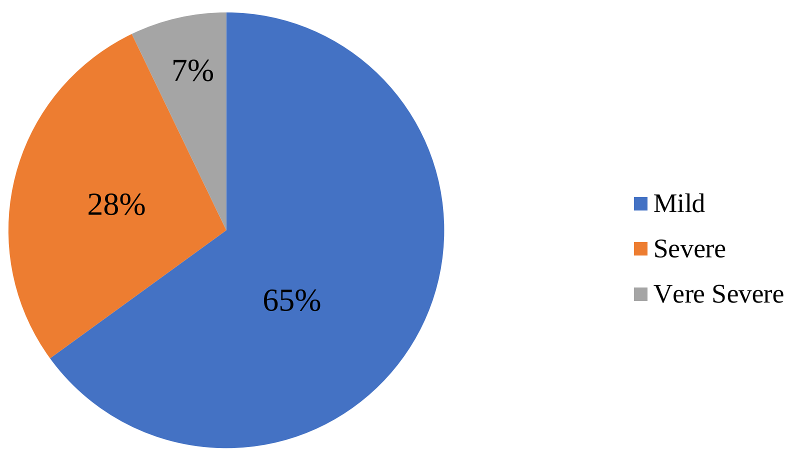

Figure 6: *Effects of August Break on Rice Production*

Conclusion

Findings revealed that the lowest rainfall experienced in the study years was in January, November and December (6.6mm, 5.6mm and 0.5mm), while the highest average rainfall was in July, August and September (173.8, 188.5mm and 277.8mm) compared to other months. Furthermore, findings showed that the annual range of rainfall is between 1163.7mm and 1494.6mm in the study years, with a mean rainfall of

1282.02mm. Similarly, the study shows that the analyses of annual rice production rate in the study area revealed that the annual productivity level varied between 2361 tonha^{-1} and 4269-ton ha^{-1}, with an average productivity level of 2693 ton ha^{-1} during the study year. On average 1282mm of rainfall produce 2693 tons of rice per hectare in the study years. In addition, the analyses of the perceived effects of farmers shows that variability in rainfall have a significant effect on the rice yield as rice production was highest when precipitation was suitable but when less than normal precipitation it reduces the rice production. On the other hand, when the precipitation was in highest level the total rice production was reduced with cultivated areas due to heavy precipitation resulting in flood, destroying rice stands among others. This study concludes that rainfall variability has a significant effect on rice production in the study area.

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Appendix 1: Rainfall Data of the Study area
Source: Authors' Data Collected, 2023

Rainfall Amount (mm)													
YEARS	**JAN**	**FEB**	**MARCH**	**APRIL**	**MAY**	**JUNE**	**JULY**	**AUGUST**	**SEPT**	**OCT**	**NOV**	**DEC**	**SUM**
2013	51.8	0.0	30.0	135.6	186.4	281.4	121.9	145.5	245.6	91.4	0.0	2.5	1292.1
2014	8.1	0.0	37.6	111.3	169.7	181.1	125.5	103.4	379.0	80.3	0.5	2.5	1199.0
2015	0.0	60.7	79.1	30.7	161.4	146.1	240.1	291.6	177.7	151.1	8.5	0.0	1347.0
2016	0.0	0.0	81.8	93.5	176.6	117.6	120.8	350.6	146.0	76.8	0.0	0.0	1163.7
2017	0.0	0.0	0.1	126.4	147.1	194.5	186.6	220.0	288.9	76.0	0.0	0.0	1239.6
2018	0.0	127.8	29.0	81.9	311.7	130.2	196.8	207.5	328.6	81.1	0.0	0.0	1494.6
2019	0.0	1.2	21.8	56.0	80.3	242.8	106.7	189.8	427.9	154.1	2.1	0.0	1282.7
2020	0.0	0.0	76.7	85.5	187.4	225.3	203.5	21.4	307.3	108.9	0.0	0.0	1216.0
2021	6.1	48.3	91.9	30.5	248.7	102.9	137.7	119.6	294.6	99.1	21.8	0.0	1201.2
2022	0.0	0.0	0.0	174.5	100.1	113.0	298.5	235.7	182.1	257.0	23.4	0.0	1384.3
AVGS	6.6	23.8	44.8	92.6	176.9	173.5	173.8	188.5	277.8	117.6	5.6	0.5	