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A Review on the Effects of Drought on Millet Production in Nigeria

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Abstract

Drought is a global phenomenon that has a widespread impact on agriculture, among the poor and the rich countries as well as the developed and the developing ones. Drought occurs in virtually all climatic zones, but their characteristics and impacts on society vary significantly by regions and countries. The underlying causes of drought can be related to changing weather patterns manifested through the excessive buildup of heat on the earth's surface, meteorological changes which results in a reduction of rainfall and reduced cloud cover, all of which results in greater evaporation rates. The resultant effects of drought are exacerbated by human activities such as deforestation, overgrazing, and poor cropping methods, which reduce water retention of the soil, and improper soil conservation techniques, which lead to soil degradation. Drought has been occurring in Nigeria, especially in the North-eastern region for decades. The impact is significant in developing countries, especially those in Africa, because its economy is predominantly rain fed and fundamentally dependent on the vagaries of weather. Pearl millet is one of the most important cereals in the dry sub-humid and semi-arid zones of Nigeria. The effect of drought is posing threat to millet production in Nigeria, especially the dry-sub-humid region where rain fed farming is the major means of livelihood. In drought period/areas, the importance of drought tolerant millet varieties that could tolerate terminal drought cannot be overstated. The International Institutes in collaboration with the national research institutes have developed and released varieties of millet that are drought tolerant and some of the varieties have earliness attributes which enable the varieties to drought tolerant. Constraints to the adoption of drought tolerant millet varieties include physical, biological and socio-cultural factors. Drought is the most devastating constraint that occurs at any stage of growth in pearl millet production. This paper, therefore, recommended that the farmers and other stakeholders including the government need to put in place strategies/policies that can be implemented to tackle the effects of drought in Nigeria.

1. Introduction

Drought is the deficiency or abnormal deficit of water in an area during a specific period [45, 46]. This means, its occurrence varies spatially and temporally. Apart from this variation, the degree of drought severity also varies temporally and spatially. A consequence of drought period can have collapse of agricultural production. For

example, subsistence farmers are more likely to migrate during drought because they do not have alternative food source [15]. Areas with population that depend on subsistence farming as a major food source are more vulnerable to drought which triggers famine, hunger, malnutrition, acute food shortage and under nutrition among large section of the population [2]. Drought is a global phenomenon that has a widespread impact on agriculture, including poor and the rich countries as well as the developed and the developing ones. Drought occurs in virtually all climatic zones, but their characteristics and impacts on society vary significantly by regions and countries. The impact is significant in developing countries especially those in Africa, because its economy is predominantly rain fed and fundamentally dependent on the vagaries of weather [12]. The occurrences and re-occurrences of draught have been reported in Nigeria for decades [1]. However, of recent the occurrences have increased, while gradually the occurrences have spread south ward especially to the Sudan zone of Nigeria. At the same time the severity of drought in Sahel zone has increased [46, 47].

Pearl millet *(pennisetumglaucum*) is the most important and probably having the greatest potential among the millet varieties. It is a robust, quick growing cereal with large stems and leaves which are tall and vigorous with exceptional grain and yielding potentials. It is one of the most important crop and a staple food for millions of people in arid and semi-arid ecologies around the world [14]. Pearl millet is the most important dry land food crop of West Africa. Ojediran *et al*. [43] ranked pearl millet as the most important cereal in the dry sub-humid and semi-arid zones of Nigeria. Pearl millet is well adapted to growing areas characterized by drought, low soil fertility and high temperature. It performs well in soils with high salinity or PH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops would not survive [43]. According to Izge, and Song [32], improved pearl millet is one the most drought resistant grains in commercial production. It is able to grow in areas that experience frequent period of dry weather during either the vegetative or reproductive phases. Improved pearl millet appears to be more tolerant of sandy and acidic soils than other summer grains crop. Grace *et al.* [26] reported that pearl millet germinates well at soil temperature of 75-90°C and can be grown on the wide variety of soils ranging from clay, loams to sands.

Since drought affect very large areas for period of months or years, it has devastating effects on agricultural production, leading to food shortages and food insecurity, which leads to famine and hunger. Consequently, the economy of the other sectors are invariably affected, because money flow from agriculture to other sectors becomes reduced, due to poor agricultural outputs caused by droughts. During the drought of 1972-1973, in the northeastern part of Nigeria for instance, agricultural yield dropped to 40% of the annual averages [19]. During the 1983 drought year, in some parts of Borno state, nearly 100% crop losses were recorded [18]. This paper was designed to review the effect of drought on millet production in Nigeria, under the following sections: concept of drought; causes of drought; overview of effects of drought on crop production; empirical review on the effects of drought on millet production; adoption and constraints to the adoption of drought tolerant millet varieties. Then, conclusion was drawn based on the paper.

2. Concept of Drought

Definitions of drought might be categorized as either conceptual or operational. Therefore, drought occurs with varying frequency in all regions of the globe, in all types of economic systems and in developed and less developed countries. The approaches taken to define drought also reflects regional differences as well as differences in ideological perspectives [12]. Their impacts also differ from one to another, depending on the social context in which drought is occurring. Definitions of drought are of two types: conceptual and operational.

2.1. Conceptual Definitions of Drought

This is referring to those definitions formulated in general terms to identify the boundaries of the concept of drought [20, 54]. Conceptual definitions of drought provide little guidance to those who which to apply them to current (i.e, real-time) drought assessment, but rather help understand the meaning of drought and its effects. For example, drought is a protracted period of deficient precipitation which causes extensive damage to crops resulting in loss of yield [5, 17].

2.2. Operational Definitions of Drought

This refers to an attempt to identify the onset, severity, and termination of drought episode [24, 46]. Estimation of potential impact is included in some operational definitions. An operational definition, for example, would be one that compares daily precipitation values to evapotranspiration (ET) rates to determine the rate of soil moisture depletion and express these relationships in terms of drought effects on plant behavior at various stages of crop development. Operational definitions can also be used to analyze drought frequency, severity and duration for a given historical period. Such definitions require data on hourly, daily, monthly or seasonal moisture deficiency, or rain departure from normal (i.e. expected) in order to identify when drought occurred [17, 54]. While operational definition help identify the drought's beginning, end and degree of severity, it also specify the degree of departure from the precipitation average over some time period. This is usually accomplished by comparing the current situation with the historical average. The authors added that an operational definition for agriculture may compare daily precipitation and evapotranspiration to determine the rate of soil moisture depletion and express these relationships in terms of drought effect on plant behavior. Such definitions require weather

data on hourly, daily; monthly and possibly impact data e.g. crop yield [34]. Climatology of drought for a given region provides a greater understanding of its characteristics and the probability of reoccurrence at various level of severity. Information of this type is beneficial in the formation of mitigation strategies. This paper clustered the operational definitions of drought into four types; meteorological, agricultural, hydrological and socio-economic [54].

2.3. Definitions of Drought

There are some indicators that experts use to determine if a condition can be called a drought. These indicators help local authorities, states or governments use to plan and release appropriate relief resources to affected areas. The following are some of the common scenarios of droughts:

2.3.1. Meteorological Drought

This kind of drought is usually determined by the general lack of moisture in the weather such as lack of precipitation, and the play of other weather conditions such as dry winds, high temperatures and so on. It is expressed in relation to the *average* conditions of the region over a long period of time. It is usually an indicator of potential water crisis if the condition is prolonged. Meteorological drought can begin and end immediately. Meteorological drought is defined on the basis of the degree of dryness in comparison to a normal or average amount and the duration of the dry period [40]. Definition of meteorological drought must be region specific, since the atmospheric conditions that result in deficiencies of precipitation are highly region specific [25]. Variety of meteorological definitions in different countries illustrates why it is not possible to apply a definition of drought developed in one part of the world to another. For instance, the following definitions of drought have been reported by Donald [17]: in U.S less than 2.5mm of rainfall in 48hrs, in UK fifteen consecutive days with daily precipitation less than 0.25mm, in Libya when annual rainfall is less than 180mm and in Bali a period of six days without rain. Data sets required to assess meteorological drought are daily rainfall information, temperature, humidity, wind velocity and pressure and evaporation.

2.3.2. Agricultural Drought

This is when atmospheric moisture is reduced to the extent that soil moisture is affected [17]. In this case, crops and animals are affected and evapotranspiration is also affected. This links various characteristics of meteorological to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced ground water or reservoir levels [40]. Crop water demand depends on prevailing weather condition, biological characteristics of the specific crop, its stage of growth, and physical and biological properties of the soil. A good definition of agricultural drought, should account for the susceptibility of crops during different stages of crop development [17]. Deficient topsoil moisture at planting may hinder germination, leading to low plant population per hectare and a reduction of yield. Data sets required to assess agricultural drought are soil texture, fertility, and soil moisture, crop type and crop water requirements and climate.

2.3.3. Hydrological Drought

This is when there is a deficiency of surface water and ground water supply in a region, often as a result of less precipitation, excessive reliance on surface water for farming, energy and other needs [6]. This refers to a persistently low discharge or volume of water in stream and reservoirs, lasting for months or years [17]. Hydrological drought is a natural phenomenon, but it may be exacerbated by human activities. Hydrological drought is usually related to meteorological drought and their reoccurrence interval varies accordingly. Change in land use and land degradation can affect the magnitude and frequency of hydrological drought [6]. They added that data sets required to assess hydrological drought are surface-water area and volume, surface runoff, stream flow measurements, infiltration, water table fluctuation and aquifer parameters.

2.3.4. Socio-economic Drought

This type of drought is associated with the supply and demand of some economic goods with element of meteorological, hydrological and agricultural drought [17]. It differs from the other types of drought in that it's occurrence depends on the processes of supply and demand like crops. Socio-economic drought occurs when the demand for economic goods exceeds the supply as a result of a drought related shortfall in water supply [38]. This drought may result significantly in reduced crop production. Data set required to assess socio-economic drought are severity of crop failure, water and fodder requirements.

3. Causes of Drought

The underlying causes of drought can be related to changing weather patterns manifested through the excessive buildup of heat on the earth's surface, meteorological changes which result in a reduction of rainfall and reduced cloud cover, all of which result in greater evaporation rate [4, 55]. The resultant effects of drought are exacerbated by human activities such as deforestation, overgrazing and poor cropping method, which reduce water retention of the soil and improper soil conservation techniques, which lead to soil degradation (American Institution of Biological Science Analysis [5]. Generally, rainfall is related to the amount of water vapour in the atmosphere, combined with the upward forcing of air mass containing water vapour. If either of these is reduced, the result is drought. Some of these causes are discussed as follows:

3.1. Overgrazing

This reduces the usefulness and productivity of land and as a major cause of land degradation and desertification. It also reduces interception of sunlight and plant growth. Plants

become weakened and have reduced root length which makes the plants more susceptible to death during dry weather [53].

3.2. Poor – Cropping Method

This reduces water retention of the soil which leads to increase in the severity and frequency of drought events. Poor land management practiced aggravates effect of drought [7].

Since most African countries, economies are heavily based on agriculture; much of the problem of desertification in rural areas stems from agricultural practices and over land- use system. Inappropriate farming system, such as continuous cultivation without adding supplements, lack of soil and water conservation structures and high incidence of uncontrolled bush fires [29, 49].

3.3. Lack of Rainfall (Precipitation)

Droughts can occur when there is lack of 'expected' precipitation [4, 30]. It should be noted that lack of rain alone does not mean a drought to a certain level. This is because, some regions can go for months without any rain, and that would be 'normal' for them. But, if farmers plant in anticipation of rains and so when the rains do not come and irrigation infrastructures is absent, agricultural drought occurs.

4. Evidence of Drought in Nigeria

Drought has been occurring in Nigeria, especially in the North-eastern region for decades. This means that, it is a reoccurring phenomenon in North-eastern Nigeria. The Sudano-Sahelian region of Nigeria has also suffered a decrease in rainfall in the range of about 3-4% per decade since the beginning of the 19th century [22].

Drought is not a recent phenomenon in Nigeria. Kawu [35] traced that drought is recurrent in Nigeria and has been so for quite sometimes in the past; 1911-13, 1942 -43 and 1972-73. In a relatively more recent revelation, Akeh *et al.* [6] reported that drought has occurred in Nigeria since 1882 up to 1996 and also 1913-16, 1942-45, 1971-73 and 1982-84. Enabor [18] observed that since 1931, the Northern parts of Nigeria have experienced a sequence of 6 to 8 dry years, with one or two years of normal or near normal precipitation in between. Davies [16] reported that the problem of reduced rainfall has afflicted the country over the last 50 years. There are some evidences that the rains are definitely not coming as much and as evenly as in the past. It has been estimated that rainfall in the Savanna region of Nigeria has dropped by over 20% compared with the average of 50 years ago [28].

Various studies; Ayoade [11]; Kayode and Francis [36] reported that invisible drought though may not be visible with crops wilting, however does not allow plants to grow at their "optimumrate", inevitably affecting their output. It has been quantified that in 1987, about 5 million metric tonnes of grains valued at over ₦4billion were lost to drought [44]. Drought occurrence, especially the low intensity one is a permanent phenomenon in the Northern region of Nigeria [28].

5. The Effects of Drought on Millet Production in Nigeria

Chopra [14] in his Book titled "Breeding Field Crops", reported that areas with marginal rainfall for example, drought is the most devastating constraints that occur at any growth in millet in semi-arid areas around the world. Drought is the most severe problem the world is facing, which King [37] referred as more serious threat than even global terrorism. Rainfall is the most important determinant of millet crop yield and one of the most limiting factors for production [27, 33]. Rainfall has been the most important determinant of millet crop yields in Nigeria as well as in other part of the West Africa [10]. FAO [21, 51, 52] examined the effects of rainfall variability on millet crop production and concluded that there are many interactions between climate variability and agriculture. Generally, it is very clear that the total rainfall and distribution of rainfall at any location determine the length of growing season in that location. Rainfall variability and drought have been a major factor affecting millet production in Nigeria. The higher rainfall elasticities of production and yield suggest that millet production in Nigeria is largely a function of rainfall than any other factor [23].

The result of the millet production and yield response function indicate that the rainfall variable and time trend were significant [23]. The rainfall elasticities of production and yield were 0.53% and 0.68% respectively, and the estimate of millet losses during the selected drought years showed that millet losses increase. Thiele [51] studied the price incentives, non-price factors and agricultural production in Sub-Saharan Africa. The study reported that among the non-price factors, the coefficient of the time tend points toward low productivity in nine (9) out of the ten (10) sampled countries (including Nigeria) shows that the agricultural growth has been impaired significantly by drought episode. ICRISAT/FAO [31] in a Book titled "The World Sorghum and Millet Economics" also reported that in sub-Saharan Africa, low rainfall and drought are responsible for food insecurity and also constrain the adoption of improved technology. This could probably be the reason for the slow rise in millet yield. Sultan *et al*. [50] in their study on agricultural impacts of large scale variability of the West Africa monsoon stated that drought adversely affect crop production in many Sahelian and Savannah regions of West Africa.

Nigeria is currently losing about 351,000 hectares annually to effect of drought which estimated to be advancing southward at the rate of about 0.6km per year [39]. Odiagor [42] in his special report on desertification in Nigeria also reported that, Nigeria losses about 351,000 hectares of land every year to the effect of drought, a condition which results in decreased millet production in northern Nigeria and

demographic displacement in villages in the north. Northeastern region of Nigeria is increasingly becoming an arid environment at the very fast rate per year occasioned by drought [41]. Consistent reduction in rainfall leads to reduction in millet production [19, 48]. According to Federal Government of Nigerian (FGN) [22], Sudano-Sahelian region of Nigeria has suffered decrease in rainfall in the range of about 3-4% per decade since the beginning of 19th century. Agricultural productivity in Nigeria strongly linked to rainfall variability, because farmers rely on rain fed agriculture. Therefore, water scarcity is a major constraint to cereal production, especially millet that is grown on the marginal lands in the northern part of the country where other crops generally failed.

The effect of drought is posing threat to crop production in Nigeria especially the dry-sub-humid region where rain fed farming is the major means of livelihood [43]. In Northern Nigeria, nearly 100% crop losses were recorded during the drought of 1982-84 [18]. The estimated figure of millet loss was reported by Asue [8] as 1,830,000 tones. The drought of 1971-72 for example reduced agricultural contribution to Gross Domestic Products (GDP) in Nigeria from 18.4% in 1971-72 to 7.3% in 1972-73. The poor millet crop yields or total millet crop failure is due to the effects of drought [3]. The result of the millet production and yield response function indicated that rainfall variable and the time trend were significant [23]. Fagbemi [19] in his study on disaster management and data need in Nigeria indicated that an estimated quantity of millet loss during the 1973 drought was 43% and further reported that the highest millet loss was recorded during the 1984 drought, about 70%, followed by 1987, at 47% loss. The least (16%) was recorded during the 1994 drought. The higher loss in 1984 was largely due to the unprecedented rainfall deficit recorded during the drought year. The rainfall deficit was the highest, 64.5% [19].

6. Use of Drought Tolerant Millet Varieties by Farmers

The predominant crops grown in the drought-prone region of Nigeria includes the millet. In drought period/areas which are characterized by erratic and unreliable rainfall in the beginning and towards the end of the season, the importance of drought tolerant millet varieties that could tolerate terminal drought cannot be overstated. The International Institute for Tropical Agriculture (IITA) and the International Centre for Crop Research in Semi-arid Tropics (ICRISAT) in collaboration with the national research institutes such as the Institute for Agricultural Research (IAR), Zaria and Lake Chad Research Institute (LCRI), Maiduguri have released varieties of millet that are drought tolerant and some of the varieties have earliness attributes which enable them to tolerate drought. Table 1 shows the list of varieties released by the Nigerian national research institutes and their characteristics.

Table 1. *Some Improved/drought Tolerant Varieties of Millet Released by IAR, Zaria and LCRI, Maiduguri.*

Millet Crop	Varieties	Attributes	Yield Potential (tons/ha)
IAR, ZariaMillet	Sammil 3	Early maturing and drought tolerant	2.0
	Sammil 6	Early maturing and drought tolerant	2.0
	Sammil 7	Early maturing and drought tolerant	2.0
LCRIMillet	SOSAT	Early maturing, high yielding and drought tolerant	2.0
	LCIC9702	Early maturing, high yielding and drought tolerant	2.0

Source: Abubakar and Yamusa [4]

Izge and Song [32] in a study on pearl millet breeding and production in Nigeria stated that pearl millet breeding in West and Central Africa and indeed in Nigeria has concentrated on the development of open-pollinated varieties (OPVs). Hybrids in Nigeria and elsewhere are likely to have at least 25-30% grain yield advantages over OPVs and hence new herculean and costly initiative have been put in place by Lake Chad Research Institute, Maiduguri, Nigeria that has a pearl millet research mandate to develop hybrids adapted to drier regions. The most popular varieties like SOSAT-C88 for example have been released by Lake Chad Research Institute, Maiduguri, Nigeria. Okeke and Onogwu [44] in a study on farmers adoption decisions for improved pearl millet variety in Northern Nigeria, reported that pearl millet variety in Nigeria seems to be at its lowest ebb, because of perceived high number of farmers who still grow the local varieties which include, Ex-Borno, Ex-Gashua, Ex-Tukur, Gwagwa, Buduma, Buduma-Damasak and Zango. In the same vein, Grace *et al.* [26] conducted a study on selected factors affecting adoption of improved finger millet varieties by small scale farmers in the Semi-Arid Mogotio District, Kenya. They reported that majority (86.4%) of the farmers grew unimproved varieties and only 13.6% grew improved varieties.

7. Constraint to Adoption of Drought Tolerant Millet Varieties

Constraints to the adoption of drought tolerant millet variety are in no way limited to physical and biological factors but also on socio-economic and cultural factors could have direct effect on adoption [32]. Factors like education could enhance adoption of agricultural technologies through greater access to information. Grace *et al.* [26] studied selected factors affecting adoption of millet varieties by small scale farmers in the semi-arid Mogotio district, Kenya. The study reported that farmers would choose to adopt a new technology when certain type of information is available either from other farmers, extension staffs and media among

others. Information from extension workers are particularly important for the adoption of new technologies but not all extension workers are motivated to do their jobs well due to limiting facilities that affect their performance. Okeke and Onogwu [44] reported that distance to sources of technology (where the improved seeds are purchased) had a negative and significant influence on the adoption of improved pearl millet variety by farmers. This implies that farmers who live closer to the source of technology are more likely to adopt the technology compared to farmers who are farther away from the sources of technology. They further reported that this trend is expected, since most of farmers were rural farmers who can hardly travel to distant centres where the technologies are available.

8. Conclusion

The paper established that drought is one of the major factors affecting millet production in the dry-sub-humid region of Nigeria. The increase in millet production in the marginal rainfall areas of Nigeria requires the use of improved technology like improved pearl millet variety, or improved moisture conservation to reduce the effect of drought on millet production. Drought tolerant millet varieties were released by Research Institutes for adoption by farmers, particularly SOSAT – C88 and GB8735 in Nigeria. The paper further established that in drier and areas with marginal rainfall for example, drought is the most devastating constraint that occurs at any stage of growth in pearl millet production.

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