

Econometric Analysis of the Relationship between Drought and Millet Production in the Arid Zone of Nigeria: A Case Study of Borno and Yobe States

A.B. ABDULLAHI, A.C. IHEANACHO¹ AND A. IBRAHIM

Department of Agricultural Economics and Extension, University of Maiduguri, Nigeria

¹Corresponding author's e-mail: aciheanacho@yahoo.com

ABSTRACT

This paper reports the relationship between drought and millet production in the arid zone of Nigeria. Time series data spanning from 1970 - 2002 were used for the analysis. Data were recorded for rainfall, output, yield, prices and price index. A supply response model was used to isolate the systematic effect of rainfall on millet production and yield, using ordinary least squares (OLS) estimate. Linear and double-log functions were used as equations for the production and yield response, with R^2 s of 0.86 and 0.77, respectively. The rainfall and trend variables were significant ($P < 0.01$) for both production and yield functions. Rainfall elasticities of production and yield were 0.53% and 0.44%, while trend elasticity of production and yield were 0.717% and 0.137%, respectively. It was recommended that adaptive research based on existing knowledge and practices that would enhance productivity and augment limited inputs be practice. Irrigation development should be adopted as an effective mitigation strategy against drought in the study area.

Key Words: Rainfall; Drought; Millet production; Arid zone; Nigeria

INTRODUCTION

Rainfall variability and drought are the key issues in agricultural production in the arid and semi-arid regions of the world (Varhegen & Keulen, 1999). Drought is a period of inadequate rainfall either in time or in space, which results in crop failure, sufficient to cause a severe shortage of food in a rural population (Betterton & Gadzama, 1987). In many of the sub-Saharan countries including Nigeria, drought and its consequences are historical as well as contemporary problems. It is a periodic phenomenon and its occurrence varies in duration severity and geographical extent (Ogallo, 1997). It is commonly associated with aridity and desertification that is typical of the Sahel (Enabor, 1987). The arid and semi-arid zones of Nigeria are generally considered as drought prone. During the drought of 1972 - 73 in the northeastern Nigeria for instance, about 300,000 animals representing 13% of the livestock population of the region were reported dead, while agricultural yield dropped to between 12% and 40% of the annual averages (Fagbemi, 2002). The effects of drought in terms of reduced food production have been even more severe during 1982 - 84 than 1972 - 74. In some parts of Borno State (Then, comprising Borno & Yobe States) nearly 100% crop losses were recorded (Enabor, 1987).

Millet is one of the most important crops both in production and consumption in Northern Nigeria, where it is mainly produced (Agboola, 1979; CBN, 2001; Abdullahi *et al.*, 2006). Its production is undermined and yield is always made un-certain due to occurrence of drought. While

considerable attention has been given to the causes of drought in Nigeria (Ojo & Oyebande, 1987; Asue, 1987; Akeh *et al.*, 2002) as well as its consequences (Davies, 1987; Enabor, 1987; Fagbemi, 2002) there is inadequate research to empirically measure the relationship between drought and crop production. Millet in particular, is a major crop grown in most drought-affected part of Nigeria. In view of this background, present study was designed to determine the relationship between drought and millet production in the arid zone of Nigeria in an attempt to bridge the gap in drought study in Nigeria. The specific objectives were to: (a) determine the effects of rainfall, prices and technological change on millet production and yield in the study area; (b) estimate the rainfall elasticity of millet production and yield; and (c) estimate the trend elasticity of millet production and yield.

MATERIALS AND METHODS

Study area. The study areas were former Borno and Yobe States of Nigeria. About 60 - 70% of the study areas are under the arid and semi-arid desert-like conditions (Bulama, 2001). It has un-usual climatic peculiarities characterized by erratic and un-reliable rainfall patterns. The rains are of short duration followed by a long dry spell. The annual precipitation is between 400 and 600 mm, which vary from year to year, with a decreasing trend during the last two decades. The study area transverses in two ecological zones: the Sudan Savanna and the Sahel Savanna, where the impacts of human activities (e.g. farming & grazing) and

natural disasters (e.g. drought & desertification) have degraded most of the vegetation covers. The main livelihood of the people is agriculture of which millet is the most important crop both in production and consumption (BOSADP, 2000; YOSADP, 2001).

Data collection and model specification. Time series data spanning from 1970 - 2002 was used for the analyses. Data were collected on rainfall, production, yield, prices and price index were collected from the statistical publications of the Central Bank of Nigeria (CBN), Federal Office of Statistics (FOS), National Agricultural Extension Research and Liaison Services (NAERLS), Federal Ministry of Agriculture and Natural Resources (FMANR), Borno and Yobe State Agricultural Development Programmes (ADPS) as well as Journals, Articles, annual reports, Bulletins and other relevant publications. The effect of drought on millet production was largely mediated through the short-run impact on yield. The systematic impact of rainfall was isolated using a supply response model adapted by Teklu *et al.* (1991). The supply response function is specified as follows:

$$Q_{mt} = \alpha_0 + \alpha_1 \text{RAIN}_t + \alpha_2 (\text{RAIN}_t)^2 + \alpha_3 P_{mt-1} + \alpha_4 P_{st-1} + \alpha_5 T + U_t$$

Where

Q_{mt} = Output or yield of millet in period t (in tones)

RAIN_t = rainfall index in period t

$(\text{RAIN}_t)^2$ = Square of rainfall index in period t, representing diminishing effect of higher than normal rainfall.

P_{mt-1} = Lagged deflated price of millet (₦/tonne⁻¹)

P_{st-1} = Lagged deflated sorghum price (₦/tonne)

T = Time trend (years)

U_t = Random error term in period t

$\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4$ and α_5 are parameters estimated.

The model isolates the systematic effect of rainfall through estimation of rainfall elasticity of production and yield, using time series data. It however explicitly ignores important factors, such as agricultural inputs, the tendency to reduce production following a bumper harvest and the year to year variation in areas planted.

Different functional forms were tried. The choice of the best functional form for the regression analysis was based on the number of significant variables and the values of R^2 and the *a priori* expectation of the signs of the coefficients. The *a priori* expectation was that the rainfall index and the time trend would be positively related to millet production.

Regression computed from the original time series data indicates the presence of autocorrelation. Durbin's two-step method for estimating autocorrelation coefficient (Durbin, 1960) was used to transform the data. The advantages of the Durbin's method are that it provides estimates, which have optimal asymptotic properties; more efficient for sample of all sizes and is applicable to any

order of autoregressive scheme (Abdullahi, 2005).

Variables of model. Output or yield (Q_{it}) represents the total output or average yield of millet for Borno and Yobe State of Nigeria per period (year). Other supply response studies use hectares cultivated to determine the response of farmers' to change in prices and non-price incentives. This is because hectares cultivated are always within farmer's control (Gaya, 2004). Since output or yield is affected by both farmers' reaction and other factors beyond farmers' control such as climatic variation, the output or yield would be a better measure in this study.

Rainfall index (RAIN_t). To calculate the rainfall index, the average annual rainfall for the study area was first estimated. The long-term average defined by the meteorological department was standardized at 100. The rainfall index is then given by:

$$\text{RAIN}_t = \frac{\text{Average rainfall in a given year} \times 100}{\text{Long term average}}$$

Since agricultural drought is not only tied to the amount of rainfall, but also the timing and distribution of the rain (Ashley, 1993; Abdullahi, 2005), the average was taken for the month of May June, July and August. This coincides with the relevant period for millet production in Nigeria (Agboola, 1979). Rainfall deficit was used as a proxy for drought in this study, because rainfall is the most important climatic variable for indicating drought in the arid and semi-arid tropics (Sivakumar, 1991; Ashley, 1993). It is also single most important climatic factor that determines the agricultural potential of Sub-Saharan countries, particularly those in Africa (Teklu *et al.*, 1991; Ashley, 1993; Ogallo, 1997).

Square of the rainfall index (RAIN_t)². This is the square of the rainfall index. The rainfall index is meant to capture the effect of drought on millet production, while the square of the rainfall index (RAIN_t)² captures the effect of higher than normal rainfall, which has diminishing effect on crop production (Teklu *et al.*, 1991).

Lagged millet price (p_{mt-1}). The average farm gate price per tonne was used. In order to remove the effect of inflation over time, price index was used to deflate the own price of millet. The use of lagged (previous year) price was based on the assumption that previous year's price exerts significant influence on present production plans (Haruna & Kushwaha, 1998; Gaya, 2004).

Lagged sorghum price ratio. Since millet and sorghum are two competing crops in northern Nigeria (both in cultivation & in diet) (Abdullahi, 2005), sorghum was chosen as a competing crop for millet. It measures the effect of the price of sorghum on millet production.

Time trend. The time trend was used as a proxy for technology in a supply function analysis (Thiele, 2003). Technological change is expected to take place over time and to influence agricultural production. The time trend was, therefore used as a proxy for technology, especially mechanization, increased input use and the use of high

yielding and drought resistant varieties (Teklu *et al.*, 1991; Majumdar, 2000; Thiele, 2003).

Estimation of rainfall and trend elasticities. The rainfall and trend elasticities were estimated as follows:

$$E_rP_m = \frac{\% \text{ change in production or yield}}{\% \text{ change in rainfall}}$$

$$= \alpha_1 \times \frac{RAIN_t}{\bar{Q}}$$

Where

E_rP_m = Rainfall elasticity of millet production or yield

α_1 = Rainfall parameter

\bar{RAIN}_t = Mean rainfall

\bar{Q} = Mean production or yield

Similarly,

$$E_tP_m = \alpha_5 \times \frac{\bar{T}}{\bar{Q}}$$

Where

E_tP_m = Trend elasticity of production or yield

α_5 = Trend parameter

\bar{T} = Mean trend

\bar{Q} = Mean production or yield.

RESULTS AND DISCUSSION

Parameters of production response for millet in Borno/Yobe states of Nigeria. Different functional forms

were tried for the analysis. These include linear, semi-log, double log and exponential. Two functional forms were chosen for the analysis. Linear function was chosen for the production response, while double log was chosen for the yield response. The choice of the lead equations was based on both econometric and statistical criteria (i.e. t-test, R^2 , F-ratio & the Durbin-Watson statistics).

Table I presents the summary of the production response result. The result shows that the rainfall and the trend variables were significant ($P < 0.01$) and conformed to the *a priori* expectation of the signs of the coefficients. The significance and positive coefficient of the rainfall term means that as rainfall increases, production of millet increases, while during drought years (when rainfall decreases), millet production declines.

The significance of the trend variable means that area cultivated and technology have increased over time and affected production positively. Similarly, in line with Teklu *et al.* (1991) and ICRISAT/FAO (1996) millet production in recent years was largely accounted by increased labour use and area cultivated.

Yield response and elasticity to drought. The result in Table II also indicate that the rainfall and trend variables were significant ($P < 0.01$). Since double log function was chosen as the lead equation, the coefficients are therefore direct elasticities (Olayide & Heady, 1982). Thus a 1% increase in rainfall is associated with 0.45% increase in millet yield, since the yield is measured per constant land area (hectare) over time, the yield trend measure the effect

Table I. Multiple regression estimates of the parameters of the millet production response model

Variable	Parameter	Coefficient	Standard Error	t-ratio
Constant	α_0	-16.639	41.886	-0.397 ^{NS}
Rainfall index ($RAIN_t$)	α_1	3.137	0.486	6.456**
Square of rainfall index ($RAIN_t$) ²	α_2	-0.024	0.033	-0.176 ^{NS}
Lagged deflated millet price (P_{Mt-1})	α_3	-0.115	.142	-0.814 ^{NS}
Lagged deflated Sorghum price (P_{St-1})	α_4	-0.032	0.203	0.193 ^{NS}
Time trend (T)	α_5	21.885	2.776	7.882**
Diagnostic Statistic				
F ratio = 43.55				
Durbin Watson = 2.075				
$R^2 = 0.862$				
Adjusted $R^2 = 0.842$				

Source: Time series data, 1970 - 2002. ** Significant ($P < 0.01$). ^{NS} Not significant.

Table II. Multiple regression estimates of the parameters of the millet yield response model

Variable	Parameter	Coefficient	Standard error	t-ratio
Constant	α_0	-1.363	0.346	-3.935**
Rainfall index ($RAIN_t$)	α_1	0.435	0.089	4.888**
Square of rainfall index ($RAIN_t$) ²	α_2	-0.036	0.041	-0.878 ^{NS}
Lagged deflated millet price (P_{Mt-1})	α_3	-0.04129	0.089	-0.462 ^{NS}
Lagged deflated Sorghum price (P_{St-1})	α_4	-0.019	0.217	-0.089 ^{NS}
Time trend (T)	α_5	0.122	0.044	2.810**
Diagnostic Statistic				
F ratio = 27.0				
Durbin- Watson = 2.201				
$R^2 = 0.794$				
Adjusted $R^2 = 0.765$				

Source: Time series data, 1970 - 2002. ** Significant ($P < 0.01$). ^{NS} Not significant.

Table III. Presents the productions and yield elasticities of millet for Borno/Yobe States

Response Variable	Elasticity (%)
Rainfall Index:	
Production	0.531
Yield	0.435
Time Trend:	
Production	0.717
Yield	0.122

Source: computed from table 1 and 2

Note: price elasticities were not computed because of non-significance of the variables

of technology only (Teklu *et al.*, 1991). Thus a 1% increase in the present technology is associated with 0.37% increase in yield.

The elasticities measure the percentage change in production or yield to a 1% change in rainfall index or trend variable. The results indicated that a 1% increase or decrease in rainfall is associated with 0.531% and 0.435% increase or decrease in production and yield, respectively. The higher production elasticity over yield elasticity indicates that production is more sensitive to drought than yield. This agrees with the findings of Teklu *et al.* (1991). The production and yield elasticity of millet to a 1% change in the rainfall index was reported as 0.3%, 0.16%, 0.56% and 0.53%, 0.5% and 0.32% for Sudan (Aggregate), Kordofan region and Darfur region, respectively.

The National estimates were less than the regional estimates. This means that the effects of drought on crop production may be more severe over a small geographical area than large areas. This is plausible, because larger areas tend to vary in rainfall and production pattern than smaller ones. The trend elasticities for production and yield were 0.717% and 0.137%, respectively. The higher trend elasticity of production over yield trend elasticity is largely accounted for by an increase in area cultivated than by the increase in technology over time. Similarly, ICRISAT/FAO (1996) reported that the recent years increase in millet production in Africa was mainly due to increase in cropped area. Yield has failed to increase or have even declined, because production was pushed into more marginal areas and poorer soils, even in areas that are already drought prone. The trend elasticity of yield however, measures only the effect of increase in technology over time. Thus, a 1% increase in present millet production technology in the study areas is associated with 0.137% increase in yield. This indicates that the level of millet production technology is low. Similarly, Thiele (2003) examined the effects of prices and non-price factors on agricultural production in Sub-Saharan Africa. The study reported that among the non-price factors, the coefficient of the time trend points toward low productivity in 9 out of the 10 sampled countries (including Nigeria), while a dummy variable shows that the agricultural growth of six countries has been impaired significantly by drought episodes. ICRISAT/FAO (1996), also reported that most of the world's millet area remains

under traditional systems. Few farmers apply fertilizer or use improved moisture conservation practices. They further reported that in Sub-Saharan Africa, low rainfall and drought are responsible for food insecurity and also constrain the adoption of improved technology. Farmers at the margins of subsistence find risky to invest in new technology. A growing proportion of farmers however, are beginning to adopt new varieties, because only a small investment is required to change seed (ICRISAT/FAO, 1996). This could probably be the reason for the slow rise in yield.

CONCLUSION AND RECOMMENDATIONS

Rainfall variability and drought have been a major factor affecting millet production in the arid zone of Nigeria. The higher rainfall elasticity of production and yield suggest that millet production in the study area is largely a function of rainfall. Recent increase in millet production in the study area is largely associated with expansion of cultivated area rather than increase in yield. Since millet a relatively drought resistant crop is affected by drought to such an extent (as evident in the rainfall elasticity of production & yield), increase in millet production and sustainable agriculture in this marginal rainfall area of Nigeria requires the use of improved technology such as fertilizer, high-yielding, early-maturing and drought resistant varieties, improved moisture conservation practices and irrigation development. We therefore recommend the need for adaptive research, technology and extension in relation to crop production in the arid zones of Nigeria.

REFERENCES

- Abdullahi, A.B, A.C. Iheanacho and A. Ibrahim, 2006 "Econometric Analysis of the Effect of Drought on Millet production in the arid zone of Nigeria". *Proceeding of the 19th Annual Conference of Farm Management Association of Nigeria*
- Abdullahi, A.B., 2005. "Economic Analysis of the Effect of the Drought on millet production in the Arid Zone of Nigeria Un-published *M.Sc Thesis*, Department of Agricultural Economics and Extension University of Maiduguri, Nigeria
- Agboola, S.A., 1979. *An Agricultural Atlas of Nigeria*. Oxford University press, UK
- Akeh, E.L., N.S. Nnoli, S. Gbayiro, F. Ikehua and S. Ogumbo, 2003. "Meteorological Early Warning System (EWS) for Drought Preparedness and Drought Management in Nigeria". Nigeria Meteorological Service Report, Lagos
- Ashley, J., 1993. Drought and Crop Adaptation. In: Rowland, J.R.J. (ed.), *Dry Land Farming in Africa*. Macmillan-Education Ltd, London
- Asue, I.P., 1987. "Drought Occurrences in Selected Areas of Sahel-Sudan Nigeria". Un-published *M.Sc Thesis*, Department of Geography, University of Maiduguri, Nigeria
- Betterton, C. and N.M. Gadzama, 1987. "Effects of Drought on Public Health". In: *Ecological Disasters in Nigeria: Drought and Desertification*. Published by the Federal Ministry of Science and Technology, Lagos, Nigeria
- BOSADP, 2000. Borno State Agricultural Development Programme *Crop Production Statistics BOSADP Bulletin*, 24: 1-10
- Bulama, M.A., 2001 "The Effects of Drought and Desertification on Agricultural Production in the Northern state of Nigeria".

- Proceedings of the 19th Northern States House of Assembly Conference on Agriculture and Environment*
- Davies, J.H., 1987. "Effect of Drought on Food and Fibre Production in Nigeria". In: *Ecological Disasters in Nigeria: Drought and Desertification*, Pp: 173–80. Published by the Federal Ministry of Science and Technology, Lagos, Nigeria
- Durbin, J., 1960. "Estimation of Parameters in Time Series Regression model" *J. Royal Stat. Soc.*, 22: 139–53
- Enabor, E.E., 1987. "Socio-economic Aspect of the Effect of Drought on Natural Resources and the Environment". In: *Ecological Disasters in Nigeria: Drought and Desertification*, Pp: 210–2. Published by the Federal Ministry of Science and Technology, Lagos, Nigeria
- Fagbemi, K., 2002. "Disaster Management and Data Needs in Nigeria". National Emergency Management Agency (NEMA), Lagos, Nigeria
- Gaya, H.I.M., 2004. "A Study of Farmers' Supply Response to Cotton Production in Nigeria: 1970 - 2000". Un-published *M.Sc. Thesis*, Department of Agricultural Economics and Extension, University of Maiduguri, Nigeria
- Haruna, U. and S. Kushwaha, 1998. "A study of Hecterage Response of Sorghum to Selected Economic Parameters in Bauchi State". *Proceedings of Farm Management Association of Nigeria Held at Abubakar Tafawa Balewa University, Bauchi, Nigeria*
- ICRISAT/FAO, 1996. *The World Sorghum and Millet Economics: Facts, Trend and Outlook*. Pradash, India and Rome, Italy
- Majumdar, S., 2000. "Drought and GDP". FAO Research, Extension and Training Division Research Report
- Ogalo, A.L., 1997. "Post-impact Syndromes and Drought Response Strategies in Sub-Saharan Africa". *Int. J. African Stud.*, Issue No. 2, March, 1997
- Olayide, S.O. and E.O. Heady, 1982. *Introduction to Agricultural Production Economics*. Ibadan University Press
- Ojo, O. and I. Oyebande, 1987. "Trends in the Occurrence and Severity of Drought in Nigeria". In: *Ecological Disasters in Nigeria. Drought and Desertification*, Pp: 18–54. Published by the Federal Ministry of Science and Technology, Lagos, Nigeria
- Sivakumar, M.V.K., 1991. "Drought Spells and Drought Frequencies in West Africa". Research Bulletin No. 13. ICRISAT, Patancheru, India
- Teklu, T., U.J. Braum and E. Zaki, 1991. "Drought and Famine Relationships in Sudan: Policy Implication". International Food Policy Research Institute (IFPRI) Research Report 88
- Thiele, R., 2003. "Price Incentives, Non-price Factors and Agricultural Production in Sub-Saharan Africa: A Cointegration Analysis". *Proceedings of the 25th International Conference of Agricultural Economists*. Durban, South Africa. 16th–21st August
- Varhegen, J.A. and V.H. Keulen, 1999. "Analysis of Rainfall Variability and Agricultural Risk in Sub-Saharan Africa". Conference on Climate Variability and Food and Fibre Production. The University of Reading, U.K. September
- YOSADP, 2001. *Yobe State Agricultural Development Programme Crop Production Estimates*. Annual bulletin

(Received 27 February 2006; Accepted 30 June 2006)