The African Journal of Agricultural Research Vol. 5(23), pp. 3273-3278, 4 December, 2010
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR08.455
ISSN 1991-637X ©2010 Academic Journals

Full Length Research Paper

Effects of El Nino/Southern Oscillation (ENSO) on rainfall characteristics in Katsina, Nigeria

Ojonigu Friday Ati[1]*, Edwin O. Iguisi[2] and Saidu O. Mohammed[1]

[1]National Centre for Remote Sensing, Jos, Plateau State, Nigeria.
[2]Department of Geography, Ahmadu Bello University, Zaria, Kaduna State.

Accepted 25 August, 2010

Annual rainfall amount, onset and termination dates, duration of the rainy season, the number of wet and dry days and August rainfall characteristics in Katsina, Nigeria were compared between the ENSO years, La Niña years and normal years over a period of 31 years (1972 - 2002). In ENSO years annual rainfall amount is lower than the long term mean, onset is later and the termination of the rainy season is earlier than the normal years. Duration is shorter during ENSO years than other years and August rainfall is lower in ENSO years. Generally, precipitation index (PI) indicates that ENSO years particularly 1972/73 and 1982/83 coincided with drought years in the area. Since there is some empirical relationship between ENSO and rainfall in Katsina, Nigeria, it would be possible to predict extreme rainfall events like drought if the periodicity of ENSO can be understood.

Key words: El Niño, Southern Oscillation, La Niña, drought, rainfall, precipitation index, agriculture.

INTRODUCTION

Katsina is located on latitude 13°01’ N and longitude 07°41’ N (Figure 1). It has an average rainfall of 623 mm. Generally, the climate varies considerably according to months and seasons. They are a cool dry (harmattan) season from December to February; a hot dry season from March to May; a warm wet season from June to September; and a less marked season after rains during the months of October to November, characterised by decreasing rainfall and gradual lowering of temperature (Adamu, 2000).

Agriculture is the main economic activity of this town. In Katsina as in other parts of the savannah, agriculture is largely rainfed. Therefore, most of the farming activities take place during the rainy season between June and September. A wide range of crops are grown, which includes cassava, yam, potatoes, maize, millet, cow pea, soya beans, rice, groundnut, sugar cane and cotton among others. There is also abundant livestock and poultry.

In general, the Sudanian zone where Katsina is located is marginal in terms of rainfall. Rainfall variabilities are inter-annual variability of rainfall, this zone is subject to high (Iwegbu, 1993; Ati, 1996). Because of the large frequent dry spells, resulting in severe and widespread droughts, capable of large scale destruction of plants, animals and human life. Drought has wrought unparallel hardship on the economy of affected nations, seriously impairing their rural economy and disrupting their socio-cultural structures because of resulting famine, starvation, disease, and rural migration (Glantz and Katz, 1987). However, scientists have been trying to seek the reason for the high variability in rainfall and how the characteristics of the rainy season in the area can be fairly accurately predicted.

One of the reasons given for the failure of the rains sometimes is the occurrence of El Niño/Southern Oscillation in the eastern South Pacific Ocean (Adedoyin, 1989; Dublin-Green et al., 1999; Nwilo and Asangwe (1999).

El Niño/Southern Oscillation is the occasional increase in sea-surface temperature in the eastern Pacific Ocean near the coast of Peru in South America. During El Niño the trade winds relax in the central and western Pacific leading to a depression of the thermocline in the eastern

*Corresponding author. E-mail: nigu30@yahoo.com.

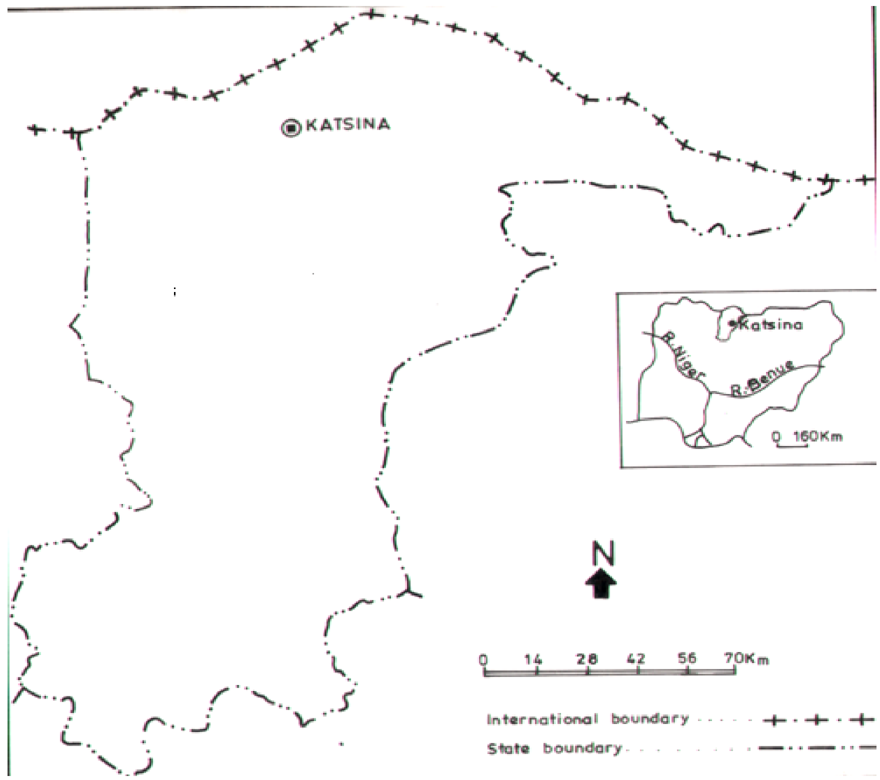

Figure 1. Map of Katsina State showing Katsina station (inset is the map of Nigeria showing Kaduna State.

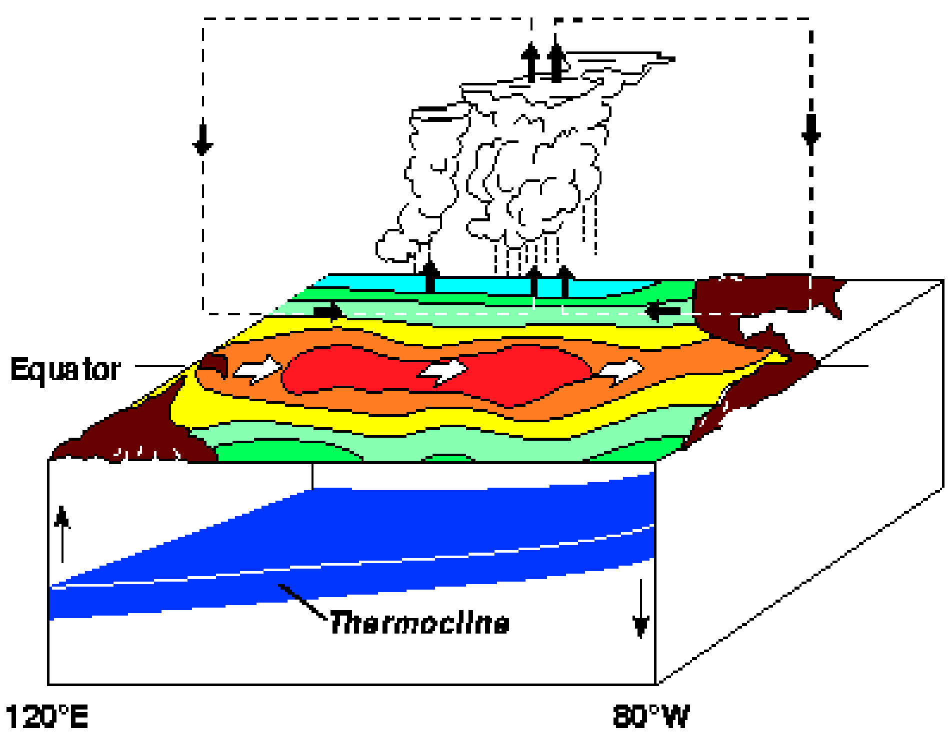

Figure 2. Circulations over the eastern Pacific Ocean under El Niño conditions.
Source: http://www.pmel.noaa.gov/tao/elnino/nino_normal.html#nino.

Pacific, and an elevation of the thermocline in the west (Figure 2). This reduces the efficiency of upwelling to cool the surface and cut off the supply of nutrient rich water below the thermocline to the euphotic zone, leading to a rise in sea surface temperature and a drastic decline in primary productivity. This would adversely affect higher trophic levels of the food chain, including commercial fisheries in the region.

El Niño/Southern Oscillation (ENSO) affects not only regional and global climate but also ecosystems in and around the tropical pacific and the economies of several countries (Latif et al., 1998). Reports from Australia (Pittock, 1975; Coughlan, 1979; McBride and Nicholls, 1983), New Zealand (Salinger, 1982), Peru (Caviedes, 1975), Africa (Ojo, 2001; Ojo and Oni, 2001), South Africa (Tyson, 1986; Lindesay, 1988), Zimbabwe (Ismail, 1987) and USA (Handler, 1990; Quiros, 1983; Rienecker and Moores, 1986) lend credence to this belief.

Rainfall trends in Africa between 1901 and 1985 have been shown by Hastenrath (1984) and Folland et al. (1986) to be directly influenced by contrasting patterns of sea surface temperature (SST) anomalies on global scale.

In Nigeria, not much is known about the effect of ENSO on the climate in general and rainfall characteristics in particular. Some authors have also tried to link ENSO to climate anomalies in the sudano-sahelian zone of Nigeria. Dublin-Green et al. (1999) and Nwilo and Asangwe (1999) assert that Nigerian climate experience a lot of change during El Niño events.

An empirical study of the effect of ENSO on rainfall characteristics in Katsina, Nigeria would, therefore, be of great importance to farmers because of the variability associated with rainfall in this region.

This study investigates the behaviour of rainfall characteristics during ENSO years in comparison to non-ENSO years in Katsina.

MATERIALS AND METHODS

Rainfall data for 31 years (1972 - 2002) from Katsina was used for this study. Onset dates were calculated using the hybrid method by Ati et al. (2002) and the termination date was calculated as the last decade with rainfall less than 25 mm. Duration is the difference between the onset date and the date of termination. Wet and dry days were counted for each year. These were also counted for August and the rainfall amount for August was determined by summing the rainfall for the month.

The precipitation index (PI) was calculated for all the years and the number of drought years identified during El Niño, La Niña and normal years. Precipitation Index is a measure of dryness of any given year.

The precipitation index is calculated as

$$PI = (\mu)/SD$$

Where

x = seasonal rainfall for the years and station.

μ= average seasonal rainfall (of the period specified for the station).

SD = the seasonal standard deviation.

PI measures the intensity of drought as follows:

Extreme drought PI= < -1.65

Severe drought PI= < -1.28

Moderate drought PI= < -0.84

(Downing et al., 1988; Mutiso et al., 1990; Agnew, 2000 all in Mortimore, 2000).

The long-term mean for each of the characteristics was calculated and compared with the yearly data. Cramer's test was used to determine if there is any difference between the means of ENSO, La Nina and normal years. ENSO and La Nina and Normal years are identified based on the Southern Oscillation Index (SOI). SOI is the standardized pressure anomaly difference between the eastern Pacific (measured at Tahiti: 17°S, 150°W) and the western equatorial Pacific (measured at Darwin, Australia: 12°S, 131°E), normalized with respect to the mean annual standard deviation. Under normal conditions, SOI ranges from +1 standard deviation to -1 standard deviation. Departures on the negative side, that is, < -1, are associated with ENSO while positive deviations, that is, > +1 indicate La Niña conditions. This criterion was used in literature to identify El Niño**,** La Niña, and normal conditions. To classify an El Niño year, the change in sea level pressure must be equal to 10 mb between Tahiti and Darwin. This study used ENSO years already in literature on the internet (World Wide Web: http://apollo.lsc.vsc.edu/classes/met130/notes/chapter10/elnino.html).

RESULTS

Precipitation index (PI)

From Table 1 moderate droughts were experienced in 1982, 1994, 1995 and 1997, severe droughts in 1972, 1973 and 1983 and extreme droughts in 1986, 1987, 1991, 1992 and 1993 in Katsina during ENSO years. There were no droughts in La Niña years. For normal years extreme drought occurred in 1984, 1985 and severe drought in 1996.

It indicates there are more droughts during ENSO (92%) than during La Niña (0%) and normal (25%) years. In fact there was no drought in Katsina in La Niña years.

Rainfall characteristics

The result of analysis of rainfall characteristics for Katsina is presented in Table 2. From Table 2, it is clear that annual rainfall for 12 (92%) out of the 13 ENSO years were below the long term mean. In La Niña years, 5 (83%) out of the 6 years were below the long-term mean. In normal years, 3 (25%) out of the 12 years have rainfall amounts below the long-term mean.

It is evident that there are more ENSO and La Niña years with means less than the long-term mean compared to normal years.

3 (23%) out of the 13 ENSO years had the same onset dates as the long-term mean for Katsina, while 7 (54%) out of the years have later onset and 3 (23%) out of the years, earlier onset. 2 (33%) out of the La Niña years have later onset than the long-term mean, 3 (50%) have the same onset date and 1 (17%) of the years has earlier onset. 5 (42%) out of the normal years had later onset dates than the long-term mean for Katsina while 7 (58%)

Table 1. PI values for El Niño, La Niña and normal years, for Katsina.

El Niño years			La Niña years			Normal years		
Year	PI	Nature	Year	PI	Nature	Year	PI	Nature
1972	-1.63	S	1974	-0.0156	None	1977	-0.41211	None
1973	-1.44	S	1975	-0.605	None	1978	-0.20464	None
1982	-0.99	M	1976	-0.512	None	1979	0.844299	None
1983	-1.42	S	1989	-0.044	None	1980	0.819171	None
1986	-2.57	E	1999	-0.203	None	1981	-0.59896	None
1987	-1.70	E	2000	0.196	None	1984	-1.65112	E
1991	-1.85	E				1985	-2.61373	E
1992	-2.02	E				1988	0.2438	None
1993	-2.48	E				1990	-0.67499	None
1994	-1.12	M				1996	-1.39662	S
1995	-1.26	M				1998	-0.60057	None
1997	-1.00	M				2001	0.336581	None
2002	-0.40	None						

None = No drought; M = Moderate; S = Severe; E = Extreme drought.

Table 2. Comparison of rainfall characteristics with the long-term mean for Katsina.

	ENSO			La Niña			Normal		
	> Mean (%)	Mean (%)	< Mean (%)	> Mean (%)	Mean (%)	< Mean (%)	> Mean (%)	Mean (%)	< Mean (%)
Amount	1 (8)	-	12 (92)	1 (17)	-	5 (83)	9 (75)	-	3 (25)
Onset	7 (54)	3 (23)	3 (23)	2 (33)	3 (50)	1 (17)	5 (42)	-	7 (58)
Termination	3 (23)	2 (15)	8 (62)	4 (67)	-	2 (33)	3 (25)	4 (33)	5 (42)
Duration	4 (31)	-	9 (69)	3 (50)	-	3 (50)	5 (42)	-	7 (58)
Wet days	5 (39)	1 (8)	7 (54)	1 (17)	-	5 (83)	8 (67)	-	4 (33)
Dry days	7 (54)	-	6 (46)	5 (83)	-	1 (17)	4 (33)	-	8 (67)
August wet	5 (39)	2 (15)	6 (46)	-	2 (33)	4 (67)	6 (50)	2 (17)	4 (33)
August dry	6 (46)	2 (15)	5 (39)	4 (67)	2 (33)	-	4 (33)	2 (17)	6 (50)
August amount	3 (23)	-	10 (77)	2 (33)	-	4 (67)	6 (50)	-	6 (50)

out of the years have later onset. Onset dates do not really differ between the years.

2 (15%) out of the 13 ENSO years had the same termination dates as the long-term mean for Katsina while 8 (62%) out of the years have earlier termination and 3 (23%) have later termination. For La Niña 2 (33%) out of the years have earlier termination dates than the long term mean with 4 (67%) having later termination dates than the long-term mean. In normal years, 5 (42%) of the years have earlier termination dates and 4 (33%) have means equal to the long-term mean while 3 (25%) have later termination dates. ENSO years have more years with earlier termination dates compared to La Niña and normal years.

9 (69%) out of the 13 ENSO years have means less than the long term mean while 4 (31%) have means which are more than the long-term mean. For La Niña, 3 (50%) out of the 6 La Niña years have duration less than the long term mean and 3 (50%) have duration more than the long term mean. For normal years the number of years with means less than the long term mean for Katsina is 7 (58%) years.

There are more ENSO years with means less than the long-term mean compared to La Niña and normal years.

In Katsina, 7 (54%) ENSO years have wet days less than the long term mean, 5 (39%) with wet days more than the long term mean and 1 (8%) equal to the long term mean. For La Niña, 5 (83%) out of the 13 ENSO years have wet days less than the long term mean and 1 (17%) with wet days more than the long term mean. In normal years the number of years with means less than the long-term mean is 4 (33%) years while 8 years (67%) have means which are more than the long term mean. In general, there are more La Niña years with wet days less than the long-term mean compared to ENSO and normal years.

Table 3. Results of Cramer's test on the rainfall characteristics between ENSO, La Niña and normal years and the long-term mean.

Station	ENSO	La Niña	Normal
Amount	-4.92	1.65	3.16
Onset	4.63	0	0
Termination	-4.85	1.61	-1.21
Duration	-2.22	1.29	0.81
Wet days	-2.84	0.50	3.39
Dry days	3.87	-0.50	-2.48
August wet	0	1.05	2.75
August dry	0	-1.05	0
August amount	-3.88	1.48	1.76

In Katsina, 7 (54%) ENSO years have dry days more than the long term mean and 6 years (46%) with wet days more than the long term mean. For La Niña 5 (83%) out of the ENSO years have dry days more than the long term mean and 1 year (17%) with dry days less than the long term mean. In normal years the number of years with means more than the long-term mean are 4 (33%) years while 8 years (67%) have means which are less than the long term mean. In general, there are more La Niña years with dry days more than the long-term mean compared to ENSO and normal years.

6 (46%) of the ENSO years have number of wet days in August below the long-term mean, 5 (39%) above the long term mean and 2 (15%) equal to the long term mean. For La Niña, 4 (67%) of the years have number of wet days in August below the long-term mean and 2 (33%) equal to the long term mean. For normal years, 4 (33%) have number of wet days in August below the long-term mean, 6 years (50%) above the long term mean and 2 years (17%) equal to the long term mean. Number of wet days in August does not significantly differ for the years.

6 (46%) of the ENSO years have number of dry days in August above the long-term mean, 5 (39%) below the long term mean and 2 (15%) equal to the long term mean. For La Niña 4 (67%) of the years have number of dry days in August above the long-term mean and 2 (33%) equal to the long term mean. For normal years 4 (33%) have number of dry days in August above the long-term mean, 6 (50%) below the long term mean and 2 (17%) equal to the long term mean. Number of dry days in August does not significantly differ for the years.

The rainfall amount in August for 10 (77%) out of the 13 ENSO years were below the long-term mean and 3 (23%) were above the long term mean. For La Niña 4 (67%) out of the 6 years were below the long-term mean and 2 (33%) were above the long term mean for Katsina. In normal years 6 (50%) out of the 12 years were below the long-term mean and 6 (50%) were above the long term mean It is evident that there are more ENSO years with means less than the long-term mean compared to La Niña and normal years.

Test of difference between the means of the rainfall parameters, using Cramer's test, in ENSO, La Niña and normal years, and the long term mean for the period 1972 - 2002 (31 years)

The means of ENSO, La Niña and normal years were compared with the long-term mean to see if there is any significant difference between them using Cramer's test statistic (t_k). The results are presented in Table 3.

From Table 3, it can be observed that all the characteristics showed statistically significant difference between ENSO years and the long-term mean except for the number of wet and dry days in August. There was no significant difference between La Niña years and long-term mean for all the characteristics. For normal years there was significant difference between their means and the long-term mean for annual amount, number of wet and dry days and number of wet days in August.

DISCUSSION

Precipitation index for ENSO, La Niña and normal years reveal that there were more droughts during ENSO years than during La Niña and normal years. In fact, during La Niña, which is the direct opposite condition to El Niño, most of the years indicated by the analysis are known as drought years.

In general, the influence of ENSO is noticeable on the annual rainfall totals with lower amount than the long-term mean. Earlier dates of termination of the rainy season were also experienced during ENSO. ENSO years also experienced shorter duration of the rainy season and lower amount of rainfall in August compared to the long term mean.

The implications of the findings of this study on agriculture in Katsina, Katsina State of Nigeria are far-reaching. Fundamentally, El Niño years are precursors to drought incidence in this part of Nigeria. Consequently, this can lead to crop failure, livestock loss, reduced income to farmers and social displacement of people, among others. Preparing for an El Niño year (drought we are able to evolve a dependable predictive model, also have far-reaching implications on man and environment. Some of these include: making provisions for irrigation and special types of seedlings.

Conclusion

The first goal of the Millennium Development Goals (MDGs) of the United Nations is to eradicate extreme poverty and hunger. The target is to halve between 1990 and 2015, the proportion of those whose income is less than 1$ a day (UN, 2006). At the local level, there is the Nigeria's Economic Empowerment and Development Strategy (NEEDS) with the goal of wealth creation, employment generation, poverty reduction and value reorientation (Akpobasah, 2004). These goals cannot be achieved without a well developed agricultural sector. For now agricultural production is largely rain-fed and under whatever improvement, agriculture will still depend very much on rainfall. It has been proved that ENSO has influence on critical rainfall parameters in Katsina. Plans on improving agriculture and water resources in the area must take into consideration the monitoring of the occurrence of ENSO.

REFERENCES

Adamu IA (2000). Nigeria: A People United, a Future Assured. State Surveys (Mamman, A.B., Oyebanji, J.O and Peters, S.W. eds). Gabomo: Abuja. 2: 291-302.

Adedoyin JA (1989). “Global-scale sea-surface temperature anomalies and rainfall characteristics in northern Nigeria” Int. J. Climatol., 10: 819-828.

Akpobasah M (2004).”Development strategy for Nigeria”. At a 2-day Nigeria meeting organized by the Overseas Development Institute, London, 16-17 June 2004.

Ati OF, Stigter CJ, Oladipo EO (2002). “A comparison of methods to determine the onset of the growing season in northern Nigeria.” Int. J. Climatol., 22: 731-742.

Ati OF (1996). “A comparison of methods to detect the onset of the growing season and its trends for some stations in the sudan savannah of northern Nigeria. M. Sc Thesis, Department of Geography, Ahmadu Bello University, Zaria.

Cavaiedes CD (1975). “El Niño 1972: Its climatic, ecological, human and economic implications”. Geogr. Rev., 65: 493-509.

Coughlan MJ (1979). “Recent variations in annual-mean maximum temperatures over Australia”. Q. J. Royal Meteorol. Soc., 105: 707-719.

Dublin-Green CO, Awosika LF, Folorunsho R (1999). Climate variability research activities in Nigeria. Nigerian Institute for Oceanography and Marine Research, P.M.B. 12729, Victoria Island, Lagos, Nigeria.

Folland CK, Palomer TN, Parker DE (1986). “Sahel rainfall and worldwide sea temprerature”. Nature, 320: 602-607.

Glantz MH, Kartz RW (1987) “African drought and its impacts: Revised interest in a recurrent phenomenon. Desertif. Control Bull., 14: 22-30.

Handler P (1990). “USA corn yields, the El Niño and agricultural drought: 1867-1988”. Int. J. Climatol., 10: 819-828.

Ismail SA (1987) “Long range seasonal rainfall forecast for Zimbabwe and its relation with El Nino/Southern Oscillation (ENSO). Theor. Appl. Climatol., 28: 93-102.

Iwegbu IA (1993). “Some aspects of the spatial and temporal characteristics of drought in Nigeria: A statistical approach”. Ph. D. Dissertation. Department of Geography, Ahmadu Bello University, Zaria.

Latif M, Anderson D, Barnett T, Cane M, Kleeman R, Leetmaa A, O'Brien J, Rosati A, Schneider E (1998). A review of the predictability and prediction of ENSO”. J. Geophys. Res., 103(7): 14,375-14,393.

Lindesay JA (1988). “Southern African rainfall, the Southern Oscillation and a Southern Hemisphere semi-annual cycle. J. Climatol., 8: 17-30.

McBride,JL, Nicholls N (1983). “Seasonal relationships between Australian rainfall and the Southern Oscillation. Monthly Weather Rev., 111: 1988-2004.

Mortimore M (2000). “Profile of rainfall change and variability in the Kano-Maradi region, 1960-2000. Drylands Research. Working Pap., 25: 1-16.

Nwilo PC, Asangwe CKA (1999). “El Nino: Its development, research and impacts” Infotech March-April,1999, pp. 12, 18.

Ojo S, Oni FO (2001). “African droughts, desertification and famines in relation to ENSO episodes” In El Niño – Southern Oscillation and its Global Impacts. Nkemdirim, L.C (ed). A Publication of the Commision on Climate and the IGU, Bonn, Germany, pp. 182-209.

Ojo S (2001). “Socio-economic impacts of ENSO events in Africa” in El Niño – Southern Oscillation and its Global Impacts. Nkemdirim, L.C (ed). A Publication of the Commision on Climate and the IGU, Bonn, Germany, pp. 210-238.

Pittock AB (1975). “Climatic change and the patterns of variation in Australian rainfall”. Search, 6: 498-504.

Quiros RS (1983). “Relationships among stratospheric and tropospheric zonal flows and the Southern Oscillation”. Monthly Weather Rev., III: 143-154.

Salinger MJ (1982). “New Zealand climate: Scenarios for a warm high-CO_2 world”. Weather Climate, 2: 9-18.

Tyson PD (1986). Climate Change and Variability in Southern Africa”. Oxford U.P., Oxford, p. 220.

United Nations (2006). “The Millennium Development Goals 2006 Report”. Published by United Nations Department of Economic and Social Affairs DESA – June 2006.