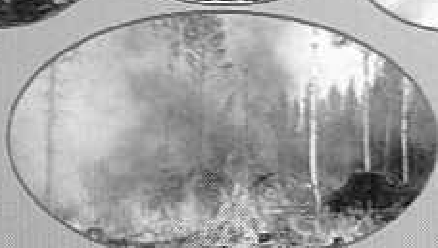
UNIVERSITY OF AGRICULTURE ABEOKUTA, NIGERIA

PERTURBATIONS IN THE PLANT ENVIRONMENT: THE THREATS AND AGRO-CLIMATOLOGICAL IMPLICATIONS FOR FOOD SECURITY



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Delivered by

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College of Environmental Resources Management (COLERM)

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PERTURBATIONS IN THE PLANT ENVIRONMENT: THE THREATS AND AGRO- CLIMATOLOGICAL IMPLICATIONS FOR FOOD SECURITY

By

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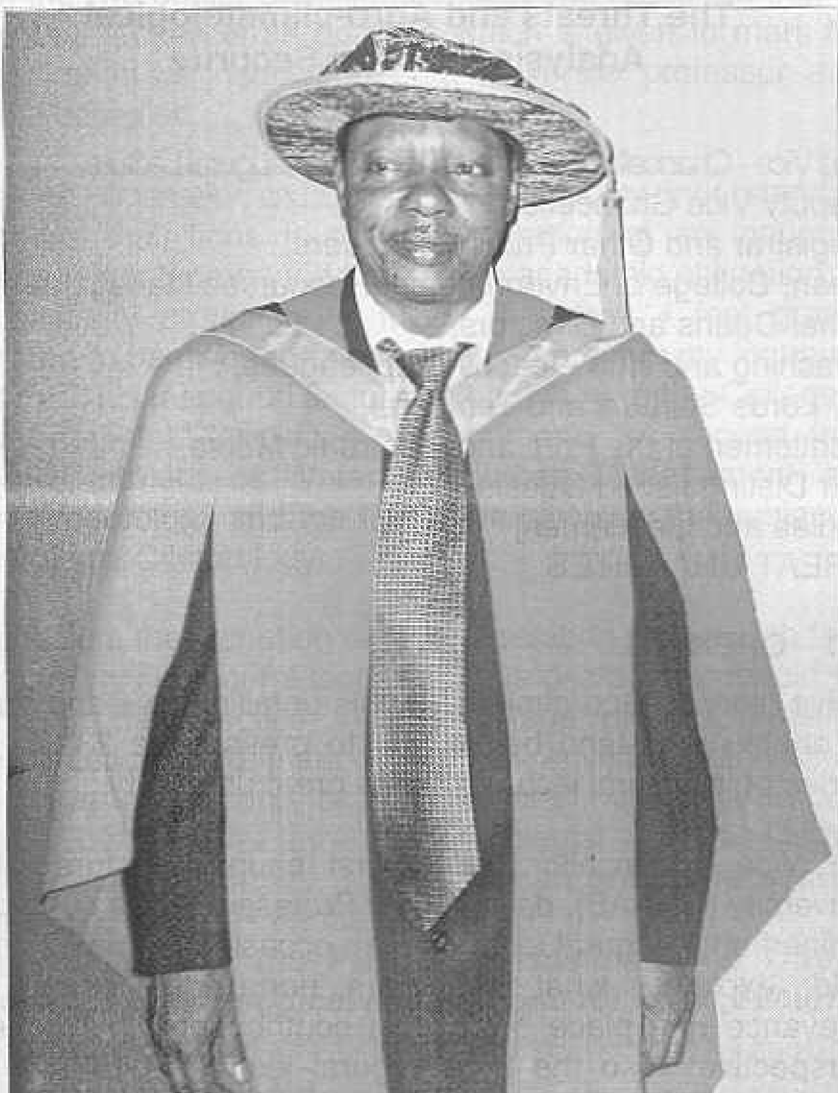

Professor Niyi Jonathan Bello, Ph.D, M.Sc, B.Sc.
(Professor of Agricultural Climatology)

Perturbations in the Plant Environment: The Threats and Agro-climatological Analysis for Food Security

The Vice - Chancellor and Chairman of this Inaugural Lecture,
Deputy Vice Chancellors,
Registrar and Other Principal Officers,
Dean, College of Environmental Resources Management,
Other Deans and Directors,
Teaching and Non –teaching Colleagues,
My Lords Spiritual and Temporal,
Gentlemen of the Print and Electronic Media,
Our Distinguished Guests,
Ladies and Gentlemen,
GREAT UNAABITES

1.0 OPENING

I give glory to God almighty for his unfailing love and grace to enable me stand before you to present the 23rd in the series of inaugural lectures of this great university.

Mr. Vice – chancellor, Sir, the first inaugural lecture in this university (UNAAB), delivered by Professor Julius A. Okojie, defined an inaugural lecture as an occasion to survey one's field, explain what has been done, demonstrate its relevance and place one's own contributions into general perspective. Also the 8th inaugural lecture in UNAAB by Professor B. A. Ola Adams defined an inaugural lecture as contributions to knowledge in one's area of specialization to the development of the society. It is noteworthy that the definition provided by Professor O. J. Olaniran, at the 25th inaugural lecture of the University of Ilorin is not different from the two earlier definitions except that he added that an inaugural lecture is an address which is given to mark the inauguration or installation of a university professor at a formal occasion.

The Vice - Chancellor, and Distinguished guests, my understanding of these definitions is that presentation of an inaugural lecture is not time bound but it is an academic obligation for a university professor to fulfill. Therefore, I feel greatly honored to be given the opportunity to present my inaugural lecture. This inaugural lecture is the fifth from the College of Environmental Resources Management, the second from the Department of Water Resources Management and Agrometeorology and the first to be given on the subject of Agricultural Climatology.

Right from the inception of my preparation and search for a topic for this inaugural lecture, I have decided to uphold the trend of the practice in the College of Environmental Resources Management to talk on environmental issues that have implications for the survival of mankind on planet earth. Therefore, as an Agro-climatologist who had his root in Physical Geography, I have chosen and, hereby stand before you to speak on the topic titled:
Perturbations in the Plant Environment: The Threats and Agro-climatological implications for Food Security.

2.0. THE GENESIS

Mr. Vice–Chancellor, Sir, the genesis of the plant environment complex is clearly documented in the book of Genesis, and the genesis of perturbation in it is also traceable to the book of Genesis in the Holy Bible. In Genesis chapter 1, verse 3-10 and according to Moses (1450 BC), God said let there be and one after the other there existed, within 48 hours, the basic environmental factors and climatic elements (light, the firmament and clouds, water and water vapor and the land and soil) that are required for plant growth and survival. Then God said let the earth bring forth grass, the herb that yield seed and the fruit trees that yield fruit according to its kind whose seed is in itself on the earth and it was so (Genesis 1:11).

The order of emergence of the component of the plant environment appeared very logical scientifically. Therefore, we can say that the Biblical view of creation of the plant environment is not in conflict with the scientific concept of seed germination and plant growth. In particular, the Holy Bible referred to the sun as the greater light to rule over the day and to be an index for season. Similarly research findings in climatology have constantly maintained that the energy from the sun accounts for more than 99.7% of the energy that is used to produce weather and climate of the atmosphere (Lockwood, 1979). Consequently climate appeared as the dominant component of the plant environment (Fig. 1).

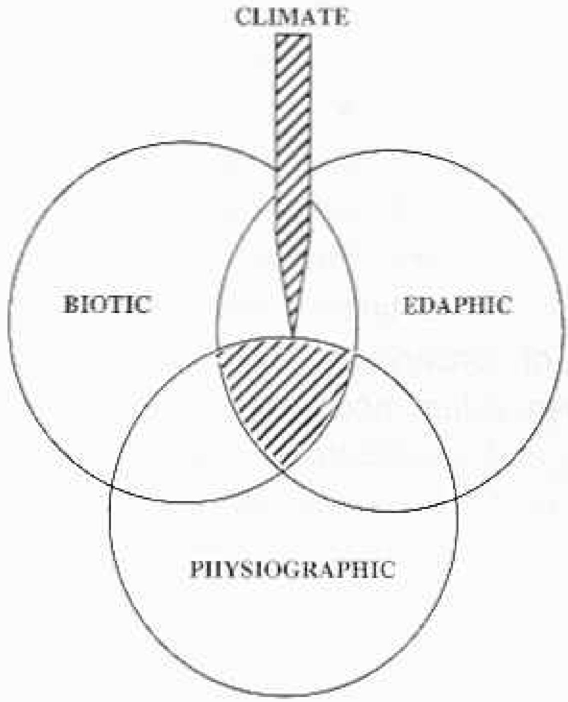

Fig. 1: Components of the plan Environment showing unique position of climate

As indicated by the intersecting circles, climate stands out as a nucleus interacting simultaneously with all the other components of the plant environment consisting of the edaphic (soil characteristics), biotic (organic consumers and decomposers), and physiographic (terrain / topographical characteristics) components of the environmental systems.

It is very likely that in the beginning there was ecosystem integrity in the plant environment and the direct impact of the climate on plant as well as its indirect impacts, through its effects on the soil and biotic components, did not constitute any form of perturbation to the system. All interactions among the various components and man's activities must have taken place without violating the creator's law of conservation and sustainability (Gen 2:15-17). But when Adam and eve disobeyed God's law of conservation and sustainability, they realized they were naked and started plucking fig leaves to cover their nakedness (Gen 3:6-7).

Although the Holy Bible did not give an account of hectares of animal plants defoliated by Adam and Eve before they started using skin (Gen 3:21), and so, it is quite plausible that their action marked the beginning of deforestation and exposure of the local terrestrial ecosystems to higher solar radiation. Consequently the modification of the energy and water balances must have been triggered off at a micro scale and this was probably, the onset of perturbations in the plant environment.

3.0. AN OVERVIEW OF CURRENT STATUS

Today, man's interference with the terrestrial ecosystems has increased significantly through deforestation, industrial and agricultural practices, including hunting, forest burning and grassland, fuel wood exploitation, charcoal and oil extraction, burning of fossil fuel, production of cement and all forms of earth quarrying and mining. These activities have led to the emission of greenhouse gases into the atmosphere. Table 2 shows that the major greenhouse gases affected by human activities have increased since the pre-industrial concentration in the atmosphere.

According to global atmospheric watch, the concentrations of greenhouse gases in the atmosphere have changed the chemistry of the atmosphere as well as the thermal and aerodynamic characteristics of the earth's surface. These changes have implications for the energy balance of the earth and the atmosphere.

4.0 THE GLOBAL ENERGY BALANCE AND EFFECT OF GREENHOUSE GASES

Mr. Vice - Chancellor Sir, in order to put the perturbations that have been set in motion in the atmosphere in a clear perspective, it is necessary to give an illustration of the global energy balance (Figure 2.), and then discuss briefly the effect of increasing greenhouse gases on the earth's energy balance. We should note that the sun has a surface temperature of about 6000° K and it is about 149 000,000 kilometers from the earth surface, and it takes the rays of the sun just 10 minutes to reach the earth's surface. If not for the reflection and absorption of the shortwave radiation particularly the absorption of the harmful ultra-violet rays by ozone (O_3) in the atmosphere, no live would have remained on earth. Figure 2 shows the expected mean annual heat balance of the whole earth.

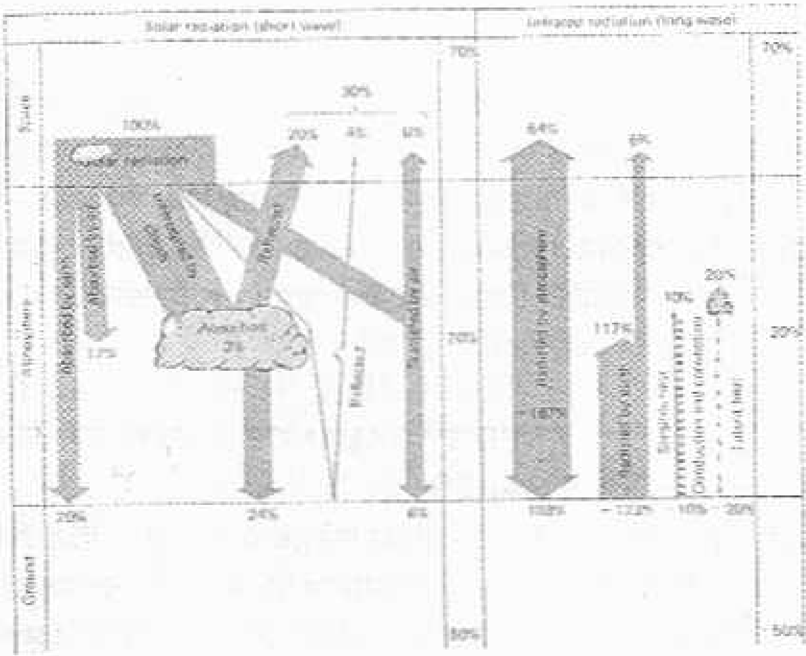

Figure 2: The Mean annual heat balance of the whole Earth (From Eagleman, 1980)

Table 1: The major green house gases affected by human activities

Traits	Key greenhouse gases affected by human activities					
	CO_2 (*Carbon Dioxide*)	CH_4 (*Methane*)	N_2O (*Nitrogen Oxide*)	CHC-11 (*Chlorofluoro-Carbon 11*)	NFC-23 (*Hydrofluoro-Carbon-23*)	CF_4 *Perfluoro-Methane*
Pre-industrial concentration	~280ppm	~700ppb	~270ppb	Zero	Zero	40ppt
1998 concentration	365ppm	1745ppb	314ppb	268ppt	14ppt	80ppt
Rate of increase[a]	1.5ppm/yr[c]	7.0 ppb/yr[a]	0.8 ppt/yr	-1.4 ppt/yr	0.55 ppt/yr	1 ppt/yr
2007Estimated concentration[b]	**375ppm**	**1794ppb**	**319ppb**	**277ppt**	**10ppt**	**87ppt**
Lifetime (years)	5 to 200yr	12yr[d]	114yr[d]	45yr	260yr	> 50,000yr

Note:

a) Rate of increase over the period 1990 to 1999 was 1.5ppm/yr for CO_2 and about 7.0 ppb/yr for CH4.

b) 2007 estimated concentration

c) If current trends continue, CO_2 concentration could reach about 5000ppm by the end of twenty-first century.

d) This lifetime has been define as an "adjustment time" that takes into account the indirect effect of the gas on its own residence time

Source :ICPC (2001)

In Figure 2, the incoming solar radiation assigned 100 units (%) amounts to 0.5 cal/cm^2/min.(1.95 g-cal/cm^2/min or 8.1x10^{9}J/m^2/min). About 20% of the incident solar energy is absorbed primarily by ozone(3%), water vapor and aerosols (17%), while from satellite data, 30% are reflected back to space as reflection by cloud tops(20%), earth surface(4%) and scattering by air(6%).What is left are absorbed by the land-water surface and later emitted as long-wave terrestrial radiation. On the average the surface looses as much energy as it receives from the sun such that the shortwave radiation (a) is balanced by the long-wave (infrared) radiation (b) at the top of the atmosphere (-70 +70), in the atmosphere (20-20), and at the surface (50-50). If this balance is maintained there would have been no noise about global warming and climate change since the naturally occurring green house gases in the atmosphere have not led to thermal stress on the earth surface. But due to human-induced increasing concentration of greenhouse gases in the atmosphere, the earth is unable to get rid of energy at the rate it receives from the sun (Figure 3).

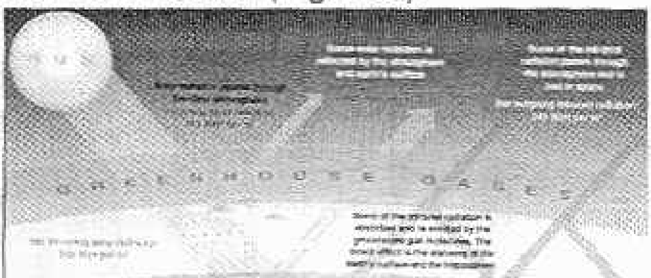

Figure 3: Illustrating the science of perturbation in the atmosphere and Heat load on the terrestrial ecosystems (From UNFCCC, 2003).

The greenhouse gases have the following characteristics that have made them become indirect sources of temperature anomaly on the earth surface:

(i) Green house gases may become sufficiently long lived to ascend in to the stratosphere at a height of 16-40 km above the land-water surface, where ozone (O_3) is produced and maintained. The ascent of greenhouse gases particularly Nitric oxide (NO) and Nitrogen dioxide (NO_2) into the Ozone layer serve to catalyze the reaction between mono atomic oxygen (O) and Ozone (O_3), i.e.,

$$O + O_3 \rightarrow O_2 + O2 \quad \text{------------------} \quad (i)$$

This would generally lead to catalytic destruction of ozone by way of reactions (ii) and (iii) below:

$$NO + O_3 \rightarrow NO_2 + O_2 \quad \text{------------------} \quad (ii)$$

$$NO_2 + O \rightarrow NO + O_2 \quad \text{------------------} \quad (iii)$$

The ultimate effect is that the ozone layer deteriorates and becomes thin, and consequently, its absorptive capacity of the harmful ultra-violet rays is weakened. The immediate effect is the outpouring of solar radiation at a higher intensity. Hence, man, plants and animals are at the risk of sun burn and heat wave.

(ii) The second characteristic is that green house gases absorb most of the long wave terrestrial (infrared) radiation emitted upwards by the earth's surface and re-radiate it back to the surface (Fig. 3). Therefore, by increasing the atmosphere's ability to absorb infrared radiation, our greenhouse gas emissions disturb the way in which the climate maintains a balance between the incoming and out going energy. Consequently, the diurnal radiation balance becomes positive.

Since energy can not simply continue to accumulate, the net effect is warming of the earth's surface. The increasing phenomenal warming of the surface and the troposphere at different locations has led to increasing variability and change in climate.

In order to pursue this matter in a logical sequence, the remaining part of this lecture is broadly subdivided into five sections as follows:

(1) The threats;
(2) The causative factors of rainfall variability;
(3) The Lecturer's contributions to Climatological studies and application to Agriculture;
(4) Conclusions; and
(5) Recommendations.

5.0. THE THREATS

It had been predicted almost two decades ago that even if emissions of greenhouse gases into the atmosphere were totally curtailed, the concentration of carbon dioxide, methane, and nitrous oxide in the atmosphere (Fig. 4) that had taken a threatening upward trend up till year 2000 might lead to many years of persistent anomaly in the climate systems before the balance between the incoming and outgoing energy is restored.

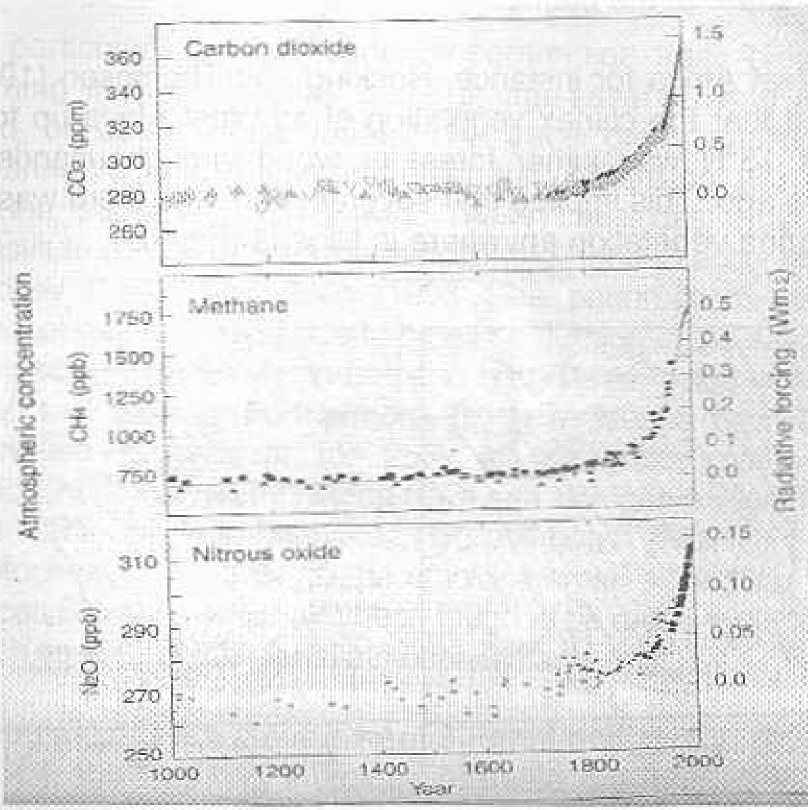

Figure 4: Global atmospheric concentration of three well mixed greenhouse gases. (From IPCC 'Climate change 2001 Technical Summary)

The proportion of global warming caused by the three greenhouse gasses is about 90%; Carbon dioxide (65%) Methane (19%), Nitrous oxide (6%).

Furthermore, Fig. 4 shows clearly that almost irreversible perturbations have been set in motion in the plant environment. Even if we think that the developed countries and multi-national corporations are to blame, there is no doubt that the less developed countries would also have their share of the blame.

In West Africa for instance, Hocking and Thompson (1979) noted that the climax vegetation of all West Africa up to at least 15^0N was either forest or wood land thousands of years ago. This implied that several years ago there was no savanna vegetation anywhere in Nigeria (Fig.5).

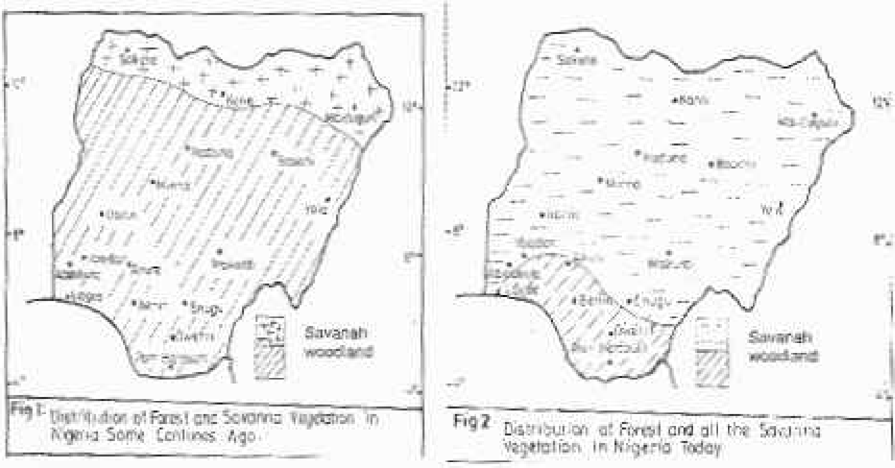

Figure 5: Distribution of vegetation in Nigeria. (i) Some centuries ago and (ii) few years before present (Redrawn from Keay, 1954)

Presently in Nigeria, savanna vegetation covers more than 80% of the total land area, while the relic of forest vegetation including the forest reserves constitute less than 20% of the total surface area of the country. In fact human activities have changed the natural vegetation into different types of savannas. Thus between 1981 and 1990 it was estimated that about 120,000 hectares of forest was lost annually in Nigeria. Worse still, the removal of fuel wood exceeds the regeneration capacity of woodland (Okojie ,1995; Ola Adams, 1998).

In particular, a significant proportion of total biomass burning in Nigeria takes place in the savanna and wood land or open forest areas. The trace grass emitted by savanna vegetation fires and other sources are not absorbed by the subsequent re-growth. These trace gas emissions constitute a net flux into the atmosphere. Indeed according to Lindsey (1992) and Bello (1995), the perturbations to the atmospheric chemistry due to biomass burning in the savanna ecosystem may be comparable in magnitude to the effect of fossil fuel burning. Furthermore, these emissions have been estimated to account for 25% of the global source of atmospheric carbon monoxide (CO) and Nitrogen oxides (N_2O) and 33% of Non-Methane Hydrocarbons (NMHC). Also photochemical reaction in the smoke plumes originating from African Savanna fires have been found to be responsible for as much as 33% of the global atmospheric aerosols.

According to Inter Governmental Panel on Climate Change (IPCC), the warming influence of these greenhouse gases has been estimated to be more than six times as powerful as solar influences. Figure 6 is an illustration of the global warming influence of the greenhouse gases.

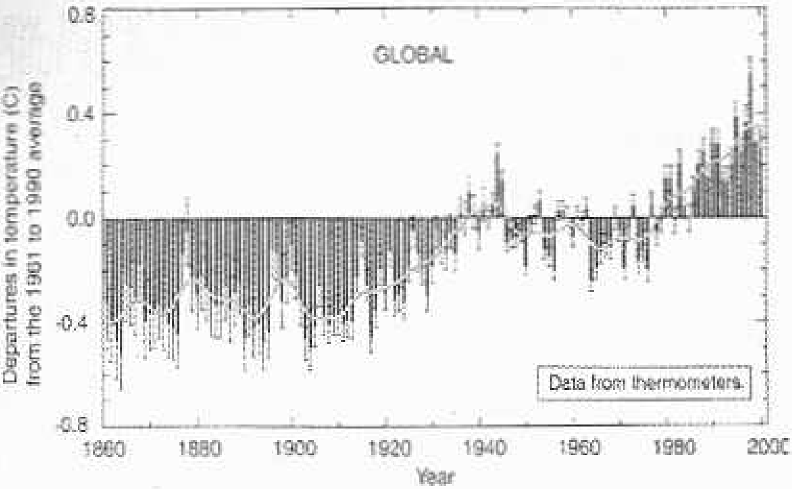

Figure 6: Variation of the Earth' surface temperature for the past 140 years (Source: IPCC"Climate change 2001 Technical Summary")

There is no doubt that the trend of the Earth's surface temperature since 1970 (Fig 6), is a threat to livelihood because its influence on global circulation, vis-à-vis the effects on rainfall distribution and water resources have become more precarious.

Furthermore, the persistent positive anomalies of temperature at locations in the rain forest region of Nigeria since the last two decades
(Bello and Iziguzo,1999; Bello and Ola Adams 2002) have become quite threatening (Fig. 7).

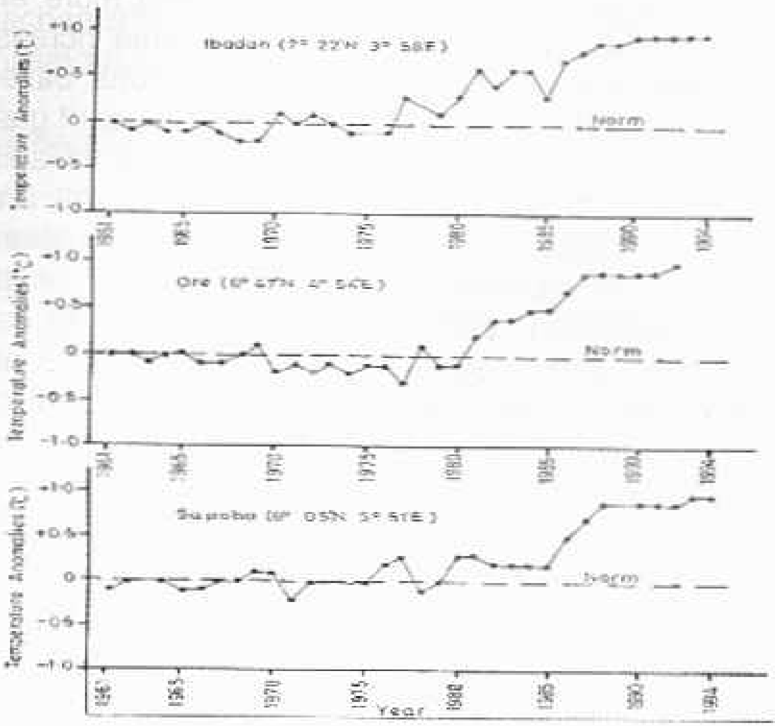

Fig. 7: Mean annual air temperature anomalies for locations in the rain forest region of Nigeria, 1961 – 1994.

Presently, temperature increase of about 0.2- 0.3^{0}C per decade have been observed in the various ecological zones of Nigeria. Also rainfall distribution at both local and regional scales has become increasingly anomalous. Some localities now receive more rainfall than usual while reduction in rainfall and tendency towards a more severe drought has been reported in different parts of the country. Both conditions are detrimental to food crop production. In particular, the beginning of the rainy season at the planting stages and rainfall distribution during the growing season have become more erratic. For more than a decade ago, it had become increasingly clear that the schedule of farm operations based on farmers' accumulated experience and intelligent guesses can no longer match-up with the increasing variability in the onset and cessation of the rain. Worse still, there is also the aspect of increasing biodiversity, erosion and emergence of endemic pest and diseases. All these, when combined with the erratic pattern of rainfall incidence and distribution aggravates the natural ecology of the earth, and constitute serious threats to food security in Nigeria.

The question is: 'What is our present knowledge of the causative factors of rainfall variability in Nigeria?'

6.0 THE CAUSATIVE FACTORS OF RAINFALL VARIABILITY IN NIGERIA

Apart from indirect effects of unsustainable use of the resources of the terrestrial ecosystem, including biomass burning and overgrazing, the causative factors of rainfall variability in Nigeria can be linked to the dynamics and characteristics of the rainfall producing mechanisms. But it should be noted that man's activities have triggered off global environmental change that have modified the factors on which these mechanisms depend. But since the dynamics and characteristics of the rainfall producing mechanisms are directly responsible for the variability in the incidence, distribution and change in seasonal regime of rainfall over time; the understanding of these mechanisms have implication for strategies to adopt in phasing out food insecurity in this country.

6.1 Rainfall Producing Mechanisms in Nigeria

Attempts have been made to study the characteristics of rainfall producing mechanisms in order to provide an explanation for the pattern of rainfall incidence and water availability for agriculture in Nigeria. Notable examples are those of Oguntoyinbo (1981),Ojo (1977), Olaniran (1983a,b), Olaniran and Sumner(1989), Adefolalu (1986), Ayoade (1973), Oladipo (1990), Obasi (1996), and Bello (1996a), to mention a few. Generally the two major surface air masses that influence rainfall occurrence and distribution in Nigeria are the warm Southwesterly air mass (Tropical Maritime air mass) originating from the Tropical Atlantic and the warm dry northeasterly air mass (Tropical Continental air mass) from the Sahara desert. The boundary zone between the two air masses over the ocean is referred to as the Inter-Tropical Convergence Zone (ITCZ), because there is evidence of convergence over the ocean. But over land, the boundary zone is more or less a zone of moisture discontinuity and, so it is referred to as the Inter-Tropical Discontinuity (ITD). The ITD is usually located at the surface as the 15mbar vapor pressure level representing a zone of moisture discontinuity between the moist tropical maritime air mass and the dry tropical continental air mass. The places in the north of the ITD have vapour pressure less than 15mb (Ilesanmi, 1971) and are usually rainless since they are dominated by hot and dry north-easterly airstreams (Tropical Continental air mass) from the Sahara desert. On the other hand, places in the south of the ITD have vapour pressures above 15mb and are characterized by rainfall due to the prevalence of the moist south-westerly winds (Tropical maritime air mass) from the Atlantic Ocean. Thus, at any given time, in a given season, precipitable water is concentrated at places in the south of the ITD. Generally the occurrence, amount and variation of rainfall on a regional scale in Nigeria are often explained in terms of the movement of ITD. However, rainfall variability in Nigeria can be accounted for not only by the erratic migration pattern of the ITD alone; other important rainfall producing systems include (i) Tropical Easterly Jet (TEJ); (ii) Sea Surface Temperature Anomaly (SSTA); (iii) Biogeographical Feedback Mechanism (BFM); and (iv) The *El Nino* /Southern Oscillation (ENSO).

(i) Tropical Easterly Jet (TEJ)

The TEJ is part of the Indian summer monsoon that extends from India to Africa in the Northern Hemisphere summer months. The west-east axis of the TEJ is located between latitude 4-10^0 N and it acts as reinforcement of aridity over the extreme northern part of the country. On the other hand, it causes a belt of above average rainfall in the central part.

(ii) Sea Surface Temperature Anomaly

The SSTA according to Palmer (1986) arises from the warming of the Tropical Atlantic Ocean south of the ITD. Consequently this leads to the weakening of the pattern of circulation of the atmosphere over the tropics. The weakened circulation reduces the intensity of the southwest monsoon flow into West and Central Africa and, consequently the rainfall over southern Nigeria.

(iii) Biogeographical Feed Back Mechanism

Studies on BFM (Rasool, 1984; Farmer and Wigley, 1985) agree that reduction in rainfall combined with human and animal activities, such as, overgrazing could reduce the vegetation cover and increase the reflectivity or albedo of the land surface. Thus, when there is increase in albedo, the heat balance of the surface-atmosphere system will also change, thereby, leading to increased divergence in the lower atmosphere and reduced uplift over the higher albedo regions. The ultimate effect of these changes is less rainfall nd persistent drought condition. In particular, BFM has led to reinforcement of the drought conditions over the northern part of Nigeria.

(iv) The *El Nino* /Southern Oscillation (ENSO)

The warming of the water along the west coast of South America was named *El Nino* in the late 19th century by Peruvian fishermen (*El Nino* means Christ Child in Spanish) because every year around December, the water along the Peruvian coast would warm up, lasting only a few months. Every few years, that seasonal warming is repeated and intensified.

Although the name *El Nino* originally referred to local ocean conditions along Peru's coast, the term has been expanded to represent all sea surface warming. In essence, the larger the temperature increase, the more wide spread and destructive is the worldwide impact of *El Nino*. The cooling Phase of *El Nino* is called *La Nina*. *El Nino* is associated with changes in sea level pressure at locations across the Pacific basin between Darwin (Australia) and Tahiti. When sea-level pressure is high near Tahiti, it is low at Darwin and vice versa. So this process is called the Southern Oscillation. Therefore, the two processes, *El Nino* (referring to the phenomenon in the ocean) and Southern Oscillation (a process in the atmosphere over the ocean) interact to form what is called *El Nino* /Southern oscillation (ENSO). ENSO has been shown to relate strongly to variation in Nigerian rainfall (Olaniran, 2002).

However, it should be noted that rainfall variability in Nigeria can be easily explained with reference to the ITD model. The position of the ITD fluctuates seasonally and five weather Zones associated with the dynamics of the ITD (Ganier, 1968; Ojo, 1977) have been established in north and south of the ITD in Nigeria (Fig. 8).

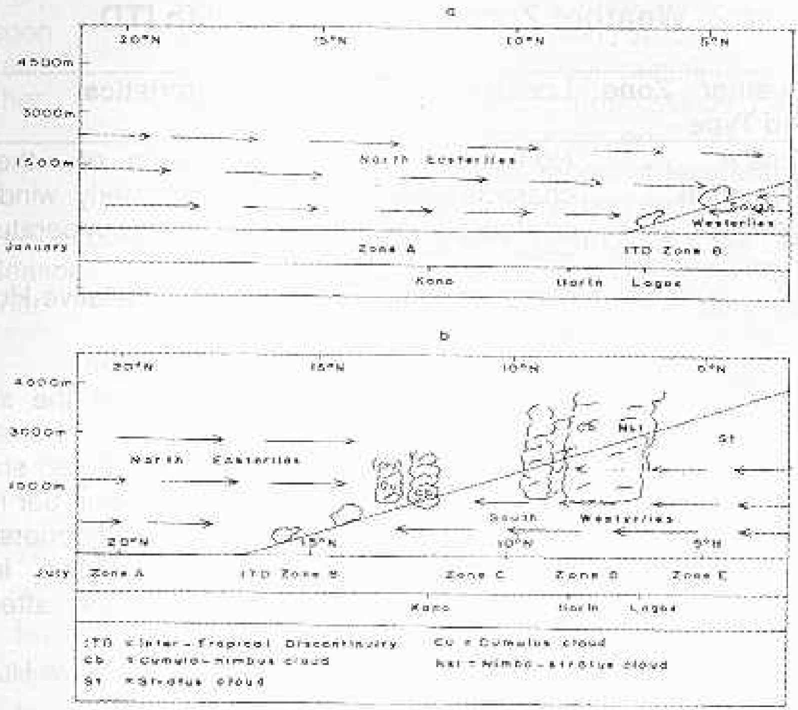

Figure 8: **The ITD and the weather zones in an idealized atmospheric cross section from South to North over Nigeria (Ojo,1977).**

6.2 The Characteristics of the ITD Weather Zones

The major characteristics of the five weather types associated with the north-south migration and vice-versa of the ITD over Nigeria are presented in Table 2.

Table 2: Weather Zones Associated with ITD.

Weather Zone and Type	Location and Major Characteristics
Zone A: Harmattan Weather	North of the surface position of the ITD, characterized by Dry, North-easterly winds, dry air, few clouds no rain, Maximum temperature 30-35°C, Minimum temperature 12-18°C, Relative Humidity is less than 40%, Visibility is poor because of dust haze
Zone B : Dry Sub- Humid Weather	Located at about 300km south of the surface position of ITD, characterized by humid air, occasional cumulus cloud and scattered showers of little total rainfall of about 25-50mm per month, rains produced from isolated thunderstorms. Winds change from Southwesterlies in the mornings to Northeasterlies in the afternoon, Maximum temperature 30-35°C, Minimum temperature 18-24°C, Relative Humidity 60-90%
Zone C: Disturbance Lines Weather	Lies south of Zone B and about 300-1300km South of the surface position of the ITD, is characterized by humid air, more clouds than in B and rain that are greater in amount and more regular; associated with moderate to high rainfall from organized lines of thunderstorms known as Disturbance lines, Rainfall is about 120-200mm per month, Maximum Temperature 27-32°C, Minimum temperature 18-24°C Relative Humidity 65-95%.

Table 2 Continued

Zone D : Monsoon Rainfall Weather	Lies south of Zone C and about1300-1600km South of the surface position of the ITD, is characterized by heavy monsoon rainfall (300-350 mm per month) from monsoon depression, humid air, more cloudy skies and rainfall on most days, Small diurnal range of temperature, High relative humidity of more than 80%.
Zone E : Little Dry Season Weather	Located south of Zone D and is more than 1600km south of the surface position of the ITD, is characterized by humid air, overcast skies with stratus and stratocumulus clouds, low to moderate rainfall (125-175mm per month) from stratiform clouds. Maximum Temperature 21-27^{o}C, Minimum temperature 18-21^{o}C, Relative Humidity 65-95%

Weather type A is characterized by dry harmattan weather, while weather type B is characterized by dry but humid weather. Weather C type is associated with thunderstorms and squall lines /disturbance lines that give intense rainfall of relatively short duration. In other words, rainfall that is spatially discontinuous is associated with weather C while weather D type is the monsoon weather known for its steady and continuous rain and drizzles which may last for 8-12 hours or more. Finally, Weather E type is characterized by humid, though relatively dry weather and it is the so called little dry season phenomenon of July/August which is typically experienced in the southern part of the country. However, the so called little dry season could change to a condition of localized but continuous rainfall accompanied by flooding in the month of July in some years.

Indeed, it is not all the five weather types that are experienced in all parts of the country. For instance, weather type A is only briefly experienced at the coast (Table 2) while weather types D and E are confined to the southern parts of the country, particularly at location south of latitude 10^0 N. Generally speaking, weather type A prevails with higher intensity over much of the northern parts of the country, from November to March or April while most of the southern parts experience weather types A intermittently from late December to early February. During December to early February, the ITD is located in the southern part of the country but as from February in a given, year the northward migration of the ITD must have begun in earnest. Consequently, as from late February to early April weather type B, characterized by little rainfall is experienced in the southern parts, while in most parts of the north weather type A prevails. During this period weather type C is experienced along the coastal areas particularly the Niger Delta area.

By the month of July, the ITD has attained a mean position around latitude 17^0 N (Fig. 8). Thus, during this time weather types A and B are usually located somewhere outside the northern border of the country. Precisely from May to October, weather types B and C prevail over the northern parts of the country, while in the southern parts weather types C, D and E prevail in varying duration and frequencies. It implies that by July in a given year, the rain must have become fully established in all the ecological

Zones of Nigeria. In a good year for the northern part, the intensity and residential time of the rain-bearing southwesterly may be so pronounced that the ITD is able to advance inland as far as latitude 22-25^0 N in August.

In such instance, the southern Sahara will experience weather type B and the Sahel will enjoy weather type C, while most of the northern Nigeria as far south of latitude 10-12^0 N might experience weather type D and the rest of the country below latitude 10^0 N down south, experience weather type E characterized by the phenomenon known as the 'little dry season 'or the 'July/August break'. During this period, the Southwesterlies become deflected into Westerlies which bring little or no rain. This causes rainfall to increase eastwards over southern Nigeria during the July-August period (Olaniran 1988a,b).

As from September, the ITD retreats southwards such that between October and early December, weather type B returns to the southern parts while weather type A has gained residence everywhere in the north. Finally between December and early February, the ITD has attained a mean position around latitude 4^0 N and weather type A is located north of its position, while the other four weather types are located to the south of the surface position of the ITD. It should, however, be noted that the constancy and dynamics of the ITD do not just follow a simple and regular pattern every season in Nigeria. The ITD is erratic in its south-north advance and north-south retreat. It moves in a series of surges, stagnations, delayed or early retreats and advances.

Consequently, some years are associated with restricted northward advance of the ITD as well as early retreats leading to abrupt cessation of the rains and drought in many parts of the country. On the other hand, there could be a considerable northward advancement of the ITD such that many parts of the country experience late cessation, longer duration of the rains and, consequently a wet year. These patterns of rainfall alone appear as significant threats to food security.
Agroclimatological / Agrometeorological analyses and modeling of rainfall characteristics have been developed to contribute to measures aimed at eliminating food insecurity amidst the incessant perturbations in the plant environment.

Agroclimatology / Agrometorology is a scientific discipline that straddles the field of climatology and meteorology on one hand and the agricultural science on the other. It is practically the application of climatology/ meteorology to specific problems in agriculture, including crop and animal production, fisheries and forestry. Therefore, it is concerned with the many interrelationships between agriculture and climate. Within this flexible field of work, agroclimatological research tend to focus on the investigation of the fundamentals of plant-climate relationships not only to identify analogous areas for crop production, but to evaluate the present land use and climate and come up with the climatic potential and suitability of the area for improved crop and animal production, as well as, the introduction of other cultivars. Because of the increasing variability and change in climatic parameters, as well as the intensity and frequency of meteorological events, such as, droughts, floods and heat waves, agroclimatology is therefore very crucial to the provision of operational services for the agricultural, livestock, forestry, and fisheries sector.

7.0 CONTRIBUTIONS OF THE INAUGURAL LECTURER TO CLIMATOLOGICAL STUDY AND ITS APPLICATION TO AGRICULTURE

7.1 Background information

I started my research career in 1983 under the guidance of the first theoretical and applied climatologist in the Department of Geography (Professor O. J. Olaniran), University of Ilorin. During the discussion of my research interest with him in early 1983, he called my attention to the rate at which environmental degradation was going on in the savanna eco-climatic region of this country. Our main concern was that plants growing in soils remain relatively immobile, but the environment about the plant kept on changing and, worse still, such changes are exacerbated by fluctuating climatic parameters particularly rainfall characteristics that have influenced crop yields annually in this country. In the course of our discussion I recalled the incidence of the country-wide drought that had persisted since 1970. Thereafter, I developed a research focus from the need to make some contributions to our understanding of rainfall characteristics and their effects on agriculture in Nigeria.

Mr. Vice - Chancellor, Sir, and distinguished ladies and gentlemen, agricultural production in this country is largely rain-fed and, even where irrigation is practicable, the level and time of application of irrigation also depends on rainfall amount and distribution. In order to make meaningful contribution to the influence of rainfall on food security in this country, my research studies in the last two decades have focused on rainfall climatology of Nigeria, particularly, the variability and change in rainfall characteristics and their implications for agriculture.

Thus, my research efforts have concentrated on analyzing the characteristics of rainfall and some inter-correlated hydro-thermal meteorological parameters; by adopting both the parametric and holistic approach as appropriate,

I have tried to explore the impact of these parameters on food crops during the different phenological stages.

Attempts have been made in my research studies to examine the following and their effects on crop growth and schedule of farm operations in Nigeria:

(i) Variability and change in seasonal rainfall;
(ii) Reliability of the onset and cessation of the rains for accurate schedule of farm operations;
(iii) Rainfall anomaly and stochastic modeling of the characteristics of the onset and cessation of the rains;
(iv) Rainfall adequacy for some major food crops in Nigeria; and
(v) Crop-Weather Modeling.

7.2 Variability and Change in Seasonal Rainfall in Nigeria

In view of the fact that rainfall is seasonal in Nigeria and there are distinct wet and dry seasons, the march of rainfall through the year is an important aspect of rainfall climatology of the country. Therefore, it is necessary to quantify the seasonality of rainfall so as to understand better the variability and change in seasonal rainfall regime in the country. In order to ascertain whether there is a significant change in seasonal rainfall regime in Nigeria, Bello (1998a) derived the indices of rainfall seasonality for two time periods 1930 – 1961 and 1962 – 1993, and examined the spatial and temporal variations. The results (Figure 9) show that the indices of rainfall variability for the 1930-1961 period is not consistent with that of 1962-1993 climatological period.

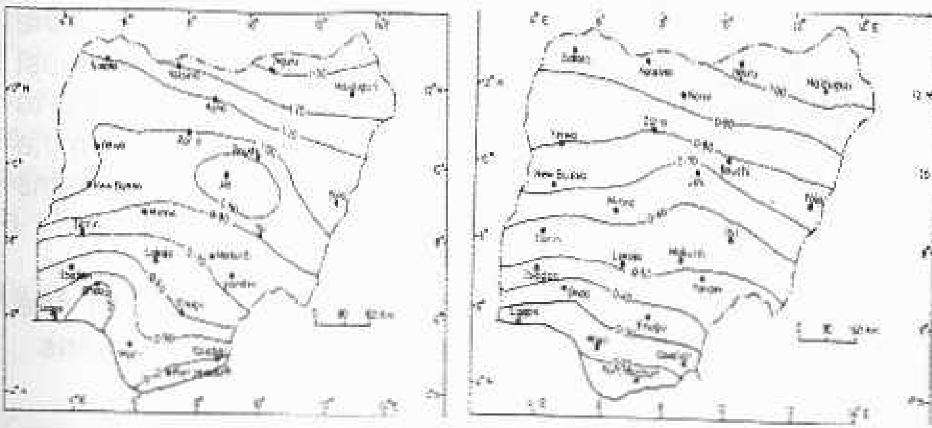

Fig. 9: Index of rainfall seasonality for Nigeria, 1930 -61 and 1962 - 93

The interpretation of the results is that there has been a decline in the rainfall regime in all the ecological regions of

Nigeria and associated with this is the incidence of abnormal dry periods during the rainy season even in the coastal areas. The implication to the cultivation of annual food crops is that farmers have to accurately synchronize their farming calendars with the rainfall regime. But we observed that farmers might fail to achieve this because the constraint posed by rainfall in Nigeria is not limited to the decline in rainfall regime, the variability in rainfall amount and its distribution is further compounded by variability in onset, cessation and duration of the rainy season as well as increasing temperature and rate of the drying out (Potential Evapotranspiration) of the plant environment. Consequently, the agricultural activities are affected throughout the growing season.

In particular, we found out that the onset and cessation of the rains are usually marred by dry spell of varying magnitude. Therefore, farmers find it extremely difficult to accurately determine the reliable beginning and end of the rainy season. Consequently, the farm operations in most parts of the country are usually wrongly phased, leading to low yields. This observation prompted me to examine further the reliability of the onset and cessation of the rains in Nigeria

7.3 Reliability of the Onset and Cessation of the Rains for Accurate Schedule of Farm Operations

Mr. Vice-Chancellor, Sir, the thermal and aerodynamic anomalies in the earth-atmosphere systems have generated abnormal evapotranspiration rates that have led to different categories of agricultural droughts, ranging from partial to absolute in the plant environment. It became clear

that the determination of reliable onset and cessation of the rains vis-à-vis the start of the growing season in Nigeria can no longer be based on accumulated rainfall method.
Therefore, using relevant climatic data analyzed for periods ranging from 35-60 years, attempts have been made (Bello, 1989a; 1996a, b; 1997a, b; 1999a) to determine reliable onset and cessation of the rains within the framework of rainfall-potential evapotranspiration (P-PE) model, quantitatively expressed as:

$$\sum(P-0.5\ PE) > 0$$

In order to ensure the reliability of the predicted date in view of the current trends of dry spells in Nigeria, the model was modified (Bello, 1996a) by ensuring that a dry spell of five days or more did not occur in the week of the date of onset. Also, on the other hand, it was ensured that a dry spell of 5 days or more did not preceed the week of the estimated date of cessation of the rains. The results of this model are presented in Table 3.
The remarkable achievement of this model (Table 3) is that it produced specific dates of the onset and cessation of the rains as well as the time interval and duration of moisture regime that are critical to a reliable schedule of farm operations in the different agro-ecological regions of Nigeria.

Table 3: Components and mean duration of moisture regime for the Schedule of farm operations in the different Agro-ecological Regions of Nigeria

Components of Moisture Regime and Model description	Time Interval (Date)	Duration (day)
Forest region		
Preparatory period; $\sum(0.1\ PE < P < 0.5\ PE)$	Feb 3 - Mar 28	54
Onset of the rains; $\sum(P-0.5\ PE) > 0$	March 29	-
Pre Humid period; $\sum(0.5\ PE < P < PE)$	March 29 – May 5	38
Cessation of the rains; $\sum(P-0.5\ PE) > 0$	November 12	-

Table 3 continued

Wet season ; ∑(P >0.1 PE)	Feb 3 - Dec – 5	306
Dry season ; ∑ (P < 0.1 PE)	Dec 6 – Feb 2	59
Moist period; ∑(P > 0.5 PE)	Mar 29 – Nov 12	229
Humid period' ∑ (P > PE)	May 6 – Oct 28	176
Post Humid period; ∑ (PE> P >0.5 PE)	Oct 29 – Nov 12	15
Soil moisture utilization; ∑ (PE > P > 0.1 PE)	Oct 29 – Dec 5	38
Growing season, ∑(0.5PE< P > 0.1 PE)	Mar 29 – Dec 5	252
Southern Guinea Savanna Region		
Preparatory period; ∑(0.1 PE < P < 0.5 PE)	Mar3 - Apr 16	45
Onset of the rains; ∑(P-0.5 PE)> 0	April 17	-
Pre Humid period; ∑(0.5 PE < P <PE)	Apr 17– May 22	36
Cessation of the rains; ∑ (P - 0.5 PE) > 0	October 18	-
Wet season ; ∑(P >0.1 PE)	Mar3 - Nov 15	258
Dry season ; ∑ (P < 0.1 PE)	Nov 16 - Mar2	107
Moist period; ∑(P > 0.5 PE)	Apr 17 – Oct 18	185
Humid period' ∑ (P > PE)	May 23 – Oct 9	140
Post Humid period; ∑ (PE> P >0.5 PE)	Oct 10 – Oct 18	9
Soil moisture utilization; ∑ (PE > P > 0.1 PE)	Oct 10 – Nov 15	37
Growing season, ∑(0.5PE< P > 0.1 PE)	April 17 – Nov 15	213
Northern Guinea Savanna Region		
Preparatory period; ∑(0.1 PE < P < 0.5 PE)	April 5 - May 14	40
Onset of the rains; ∑(P-0.5 PE)> 0	May 15	-
Pre Humid period; ∑(0.5 PE < P <PE)	May 15 - Jun 10	27
Cessation of the rains; ∑ (P - 0.5 PE) > 0	September 30	-
Wet season ; ∑(P >0.1 PE)	April 5 - Oct 22	129
Dry season ; ∑ (P < 0.1 PE)	Oct 23 - April 4	166
Moist period; ∑(P > 0.5 PE)	May 15 – Sept 30	139
Humid period' ∑ (P > PE)	June 11 – Sept 21	103
Post Humid period; ∑ (PE> P >0.5 PE)	Sept 22 - Sept 30	9
Soil moisture utilization; ∑ (PE > P > 0.1 PE)	Sept 22 – Oct 22	31
Growing season, ∑(0.5PE< P > 0.1 PE)	May 15 – Oct 22	159
Sudan Savanna Region		
Preparatory period; ∑(0.1 PE < P < 0.5 PE)	May 6 - June 14	40
Onset of the rains; ∑(P-0.5 PE)> 0	June 15	-
Pre Humid period; ∑(0.5 PE < P <PE)	June 15 - July 11	27
Cessation of the rains; ∑ (P - 0.5 PE) > 0	September 22	-
Wet season ; ∑(P >0.1 PE)	May 6 - Oct 8	156
Dry season ; ∑ (P < 0.1 PE)	Oct 9 - May 5	209
Moist period; ∑(P > 0.5 PE)	June 15 – Sept 22	100

Table 3 continued

Humid period' ∑ (P > PE)	June 12 – Sept 16	67
Post Humid period; ∑ (PE> P >0.5 PE)	Sept 17 - Sept 22	6
Soil moisture utilization; ∑ (PE > P > 0.1 PE)	Sept 17 – Oct 8	22
Growing season, ∑(0.5PE< P > 0.1 PE)	June 15 – Oct 8	116

It is, however, important to note that crop failure can still occur in any ecological region if the calendar of agricultural activities are not accurately synchronized with the components of moisture regime. Therefore, to avoid yield failure in any region, the selection of crop cultivars and mixtures, where feasible, should be based on not only the date of onset of the rains and the duration of the entire wet season, but also on the length of the pre-humid, moist, and humid periods.

The results (Table 4) of further studies at selected locations in each ecological region of Nigeria show the mean date of onset, cessation and duration of the rains. On the average, the duration of the rains vary from 90 days around Nguru and Maiduguri in the north to 225 days in Port-Harcourt in the coastal region.

Table 3 continued

Humid period' $\sum$ (P > PE)	June 12 – Sept 16	67
Post Humid period; $\sum$ (PE> P >0.5 PE)	Sept 17 - Sept 22	6
Soil moisture utilization; $\sum$ (PE > P > 0.1 PE)	Sept 17 - Oct 8	22
Growing season, $\sum$(0.5PE< P > 0.1 PE)	June 15 - Oct 8	116

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Table 4: Mean dates of onset and cassation of the rains in Nigeria

Station	Mean date of onset	Mean date of cessation	Mean Duration (Days)
Port-Harcourt	24 March	4 November	225
Calabar	26 March	4 November	223
Warri	25 March	2 November	222
Ikeja	27 March	1 November	219
Enugu	31 March	29 October	216
Ondo	31 March	21 October	204
Abeokuta	7 April	20 October	196
Ibadan	9 April	20 October	194
Oshogbo	10 April	20 October	193
Yandev	13 April	19 October	189
Markudi	15 April	18 October	185
Lokoja	17 April	16 October	182
Ankpa	12 April	17 October	188
ILorin	18 April	15 October	182
Bacita	22 April	12 October	175
Bida	8 May	12 October	157
Ibi	7 May	13 October	159
Minna	9 May	10 October	155
New Bussa	11 May	6 October	149
Kontagora	12 May	30 September	150
Yelwa	18 May	20 September	134
Kaduna	15 May	28 September	145
Jos	10 May	3 October	146
Yola	14 May	2 October	141
Bauchi	17 May	29 September	135
Zaria	19 May	28 September	132
Gusau	11 June	25 September	106
Sokoto	17 June	20 September	95
Kano	15 June	22 September	99
Katsina	18 June	20 September	94
Potisina	19 June	22 September	91
Nguru	21 June	19 September	90
Maiduguri	20 June	19 September	91

7.4 Rainfall anomaly and stochastic modeling of the Characteristics of onset and cessation of the rains

Mr. Vice - Chancellor, Sir, the magnitude of perturbations that are still in motion in the atmosphere and the feed-back mechanisms from the global atmospheric circulation and weather systems indicate that the planet earth is facing an unprecedented peril. It is disheartening to note that Africa is most vulnerable (WMO, 2007). Rainfall anomaly in the tropics and Nigeria, in particular, appeared as a major threat to food security. As a contribution to the efforts aimed at reducing the vulnerability in Nigeria, Bello (2001) characterized the onset and cessation of the rains into early, normal and late, identified possible anomalies and then applied stochastic model to evaluate the sequences of late, normal and early onset and cessation of the rains so as to determine the persistence of the detrimental parameters.

The results of the analyses done for selected locations in Nigeria are as shown in Table 5 and Figures 10a and b.

The implication of results in Table 5 is that prolonged duration of effective rains for extended agricultural practice is not feasible in any ecological region of the country since the frequency of occurrence of early onset of the rains and late cessation are extremely low.

Table 5: Frequency of Occurrence of Normal, Early and Late Onset and Cessation of the Rains in Nigeria (1959 – 1993)

Ecological Station	Region	Onset			Cessation		
		Normal	Early	Late	Normal	Early	Lat
	Port Harcourt	25	5	5	28	5	2
	Lagos	25	4	6	28	5	2
	Enugu	24	3	8	28	5	2
Forest	Ondo	23	3	9	28	5	2
	Yandev	22	3	10	28	5	2
Southern	Lokoja	21	2	12	28	5	2
Guinea	Ilorin	21	2	12	28	5	2
Savanna	Ibi	21	2	12	28	5	2
Northern	Yelwa	20	2	14	22	11	2
Guinea	Jos	20	2	13	23	10	2
Savanna	Yola	19	2	14	22	11	2
	Zaria	19	2	14	22	11	2
	Sokoto	18	2	15	21	12	2
Sudan	Kano	18	1	16	21	12	2
Savanna	Nguru	17	1	17	21	12	2
	Maiduguri	17	1	17	21	12	2

Figures 10a and b confirm further that since the end of the last decade, there has been persistent occurrence of late onset and early cessation of the rains at different locations in each ecological regions of Nigeria.

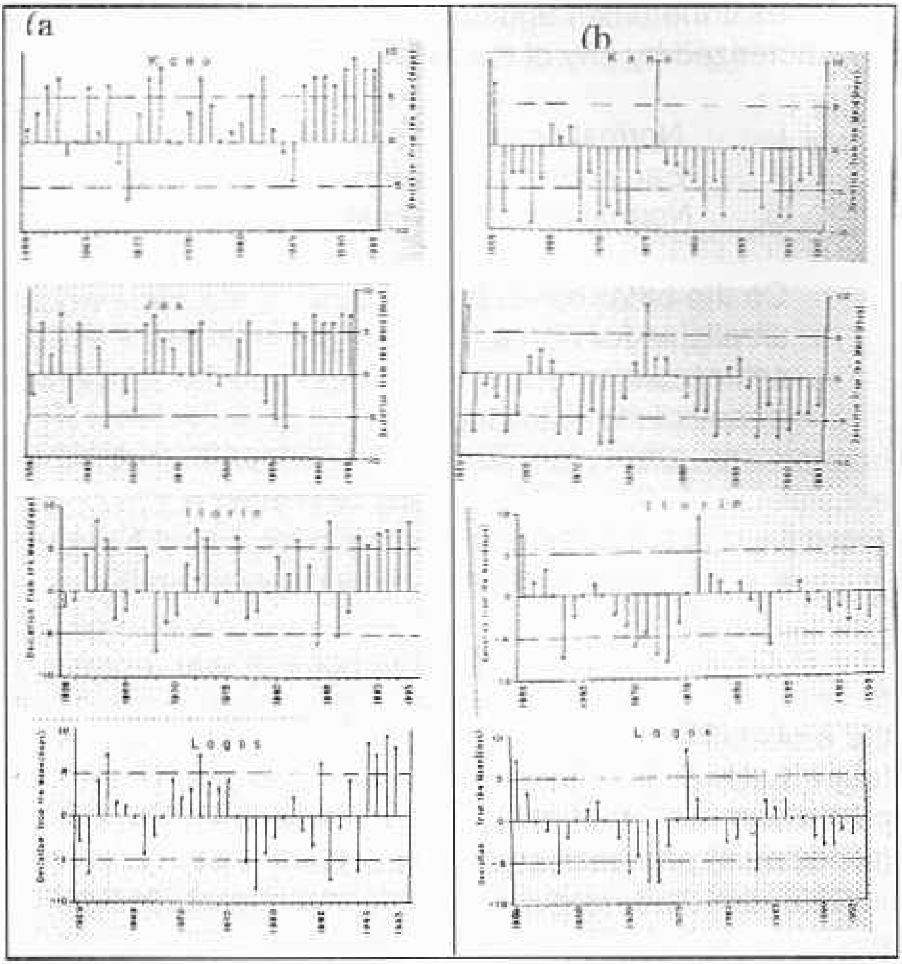


Fig. 10: Deviation of (a)Onset and (b) Cessation of the rains from the norm at different locations in Nigeria.

In order to ascertain whether this trend has significant implication for persistent shortfall in the duration of the growing season, it was proposed (Bello, 2000) that the duration of the rains would be reliable for normal agricultural activities if the onset and cessation of the rains each year is characterized by any of the following combinations:

i. Normal onset and Normal cessation (NN);
ii. Early onset and Normal cessation (EN); and
iii. Normal onset and Late cessation (NL).

On the other hand, the duration of the rains would be unreliable for normal agricultural activities if the onset and cessation of the rains each year is characterized by any of the following:

i. Late onset and Early cessation (LE);
ii. Late onset and Normal cessation (LN); and
iii. Normal onset and Early cessation (NE).

The stochastic modeling of sequences of late, normal, and early onset, and cessation of the rains described in terms of the probability of transition (change) from any initial state 0 (e.g., Late) to state 1 (normal), state 2 (early) or persistence in state 0 (late), generated six transition (conditional) probabilities expressed as:

$$Pij = \begin{array}{c|ccc} & L & N & E \\ \hline L & Q_n & R_n & S_n \\ N & T_n & V_n & W_n \\ E & X_n & Y_n & Z_n \end{array} = \begin{array}{ccc} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{array}$$

The expression above is interpreted to mean that each element (Pij) in the transition probability matrix represents either persistence (e.g., probability of early following early in succession, that is, P_{EE}), or a change in state from a pre-existing state, i into future state, j (e.g., P_{EN} or P_{EL})

Thus, $Q_n = P_{LL}$, $R_n = P_{LN}$, $S_n = P_{LE}$,
$T_n = P_{NL}$, $V_n = P_{NN}$, $W_n = P_{NE}$,
$X_n = P_{EL}$, $Y_n = P_{EN}$, $Z_n = P_{EE}$

Consequently, $Q_n + R_n + S_n = a_{11} + a_{12} + a_{13} = 1$
Similarly $T_n + Vn + W_n = a_{21} + a_{22} + a_{23} = 1$
and $X_n + Y_n + Z_n = a_{31} + a_{32} + a_{33} = 1$

According to Wagoner and Stephens (1970), the general probability of any state to be in another state or persistence in the same state after a specified period, n is designated $Pij^{(n)}$ and iteration of $Pij^{(n)} = \sum^{n}_{r=1} P_{ir}^{\,n-1} P_{rj}^{\,n}$
(n = 1,2,3,........n-1)

The results in Table 6 show clearly that the probability of occurrence of late onset of the rains is higher than the normal and early at locations in all ecological regions of Nigeria. Therefore, farmers are generally advised to be wary of false onset of the rains which may be characterized by sporadic downpours usually during the first quarter (January – Early March) of a given year in the southern parts to around Ilorin and Lokoja in the middle belt. In the extreme north, similar false onset of the rains could occur in May. Such downpours are usually followed by dry spells of varying magnitude and the consequence is agricultural drought and crop failure.

We found out as shown further in Tables 7, that high probability of incidence of shortfalls in the duration of the rainy season for normal agricultural activities appeared imminent at locations in all the ecological regions of Nigeria. This is evident from relatively higher probability of occurrence of late onset of the rains on one hand and, higher probability of early or normal cessation on the other hand. The general implication for farm operation is the adoption of appropriate strategies to alleviate or avoid the adverse effects of the shortfalls in the duration of rainy season at locations in the ecological regions of Nigeria.

Table 6: Steady State Transition Probabilities Of Late, Normal and Early Onset of the Rains In Nigeria.

Station	Steady State Probabilities of Characteristics of Onset			Time taken to attain Statistical Equilibrium (Years)
	Late	Normal	Early	
Port-Harcourt	0.52	0.27	0.21	8
Lagos	0.52	0.27	0.21	8
Enugu	0.52	0.27	0.21	8
Ondo	0.52	0.27	0.21	8
Yandev	0.38	0.31	0.31	8
Lokoja	0.38	0.31	0.31	8
Ibi	0.38	0.31	0.31	8
Ilorin	0.38	0.31	0.31	8
Yola	0.36	0.32	0.32	9
Jos	0.36	0.32	0.32	9
Yelwa	0.36	0.32	0.32	9
Zaria	0.36	0.32	0.32	9
Maiduguri	0.36	0.32	0.32	9
Kano	0.36	0.32	0.32	9
Unguru	0.36	0.32	0.32	9
Sokoto	0.36	0.32	0.32	9

Table 7: Steady State Transition Probabilities of Late, Normal and Early Cessation of the rains in Nigeria

Station	Steady State Probabilities of Characteristics of Cessation			Time taken to attain Statistical Equilibrium (Years)
	Late	Normal	Early	
Port-Harcourt	0.29	0.38	0.33	7
Lagos	0.29	0.38	0.33	7
Enugu	0.29	0.38	0.33	7
Ondo	0.29	0.38	0.33	7
Yandev	0.29	0.38	0.33	7
Lokoja	0.29	0.38	0.33	7
Ibi	0.29	0.38	0.33	7
Ilorin	0.29	0.38	0.33	7
Yola	0.29	0.38	0.33	7
Jos	0.29	0.38	0.33	7
Yelwa	0.25	0.39	0.36	6
Zaria	0.25	0.39	0.36	6
Maiduguri	0.25	0.39	0.36	6
Kano	0.25	0.39	0.36	6
Unguru	0.25	0.39	0.36	6
Sokoto	0.25	0.39	0.36	6

In particular, manipulations of crop varieties for growth as well as efficient management and conservation of water supply for agriculture is imperative. For instance, when there is late onset of the rains at a location and there exists the probability of early cessation of the rains in that season, it is necessary to manipulate crop varieties by planting early maturing cultivars or manipulating the course of irrigation. However, where construction of earth dam for irrigation purpose is not feasible, the crops and cropping pattern can be adjusted. This involves choosing the most economically viable crops for the different seasonal moisture distribution patterns. In other words, we require a selection of cultivars with appropriate phenologies that synchronize the crop's growth cycle with the period of effective water availability.

However, we also observed that economically viable strategy within the context of climate variability and change requires not only the analysis of the pattern and duration of effective water availability, but also water adequacy determined according to crop water requirement satisfaction indices during the critical phenological stages.

7.5 Rainfall Adequacy for Some Major Food Crops in Nigeria

Mr. Vice - Chancellor, Sir, there is no doubt that careful processing and analysis of rainfall can enable us to know the potential of rainfall for increased food crop production in this country. In a study carried out in the upper and lower Niger River Basin Authority Area of Nigeria, Bello (1987) showed that this is possible if we relate actual water availability during the rainy season to crop water requirement during the phenological stages, rather than relating crop growth cycle alone to the length of the rainy season. The results show that crops that were found to have marginal production potential when analyzed in terms of length of the rainy season (Fig. 11) showed improved potential (Fig. 12) in the case of the analysis that related actual water availability during the rainy season to the crops moisture requirement/consumptive water use. It follows, therefore, that relating actual water availability to crop water requirement during the different phenological stages is an efficient method of water resources management for crop growth and production. For instance, it is evident in Figure 12 that little irrigation or conservation tillage when irrigation is not practicable will improve further the potentials of these crops in the basin area. Furthermore, double cropping of early maturing cultivars of some of these crops might be feasible in a given season.

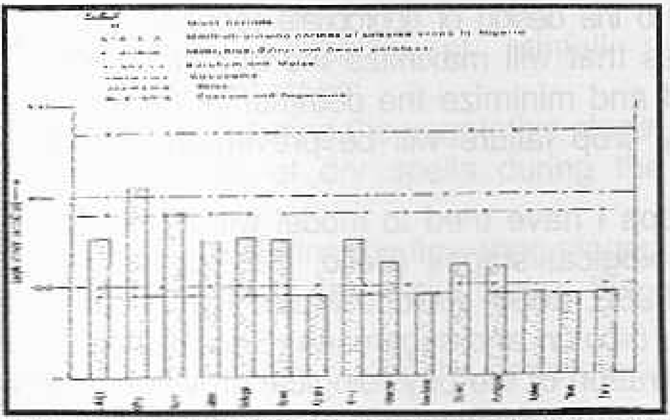


Fig.11: Relating length of the rainy season to the length of crop growth cycle in the Niger River Basin Development Authority Area.,

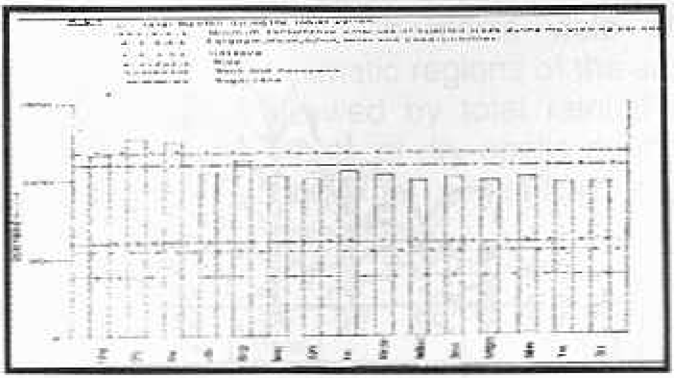


Figure 12: Relating Actual Water Availability during the Rainy Season to Crops Water Requirements during the Phenological stages in the Niger River Basin Development Authority Area, Nigeria.

7.6 Crop-Weather Modeling

I would want to stress further that climate variability and change will persist. Therefore, there is the need to develop operational crop-weather models that will enable us identify the beneficial and detrimental climatic parameters that are significantly critical to the growth and good yield formation of crops during their different phenological stages. This is invaluable to the design of appropriate technological/agronomic techniques that will maximize the beneficial effects on the one hand and minimize the detrimental on the other hand. Ultimately crop failure will be prevented and good yields obtained.

Some crops I have tried to model within the time scale of the phenological stages (Bello, 1989b; 1993a, b; 1996c; 1997c; 1998b; 2000) include Maize (*Zea mays*), sorghum (*Sorghum bicolor*) and sugarcane (*Saccharum L.*).Figure 13 is an illustration of the physiological growth of maize during five major phenological stages of investigation.

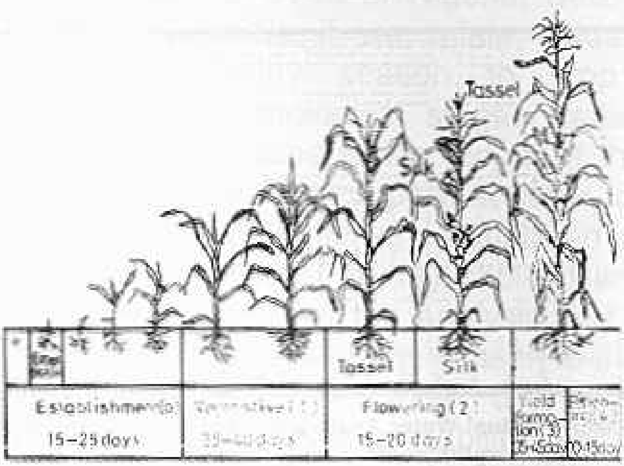


Figure14: Phenological stages of maize

The results in Table 8 show the relationship between maize yield and hydro- meteorological variables for the different phenological stages of maize in the savanna eco-climatic region of Nigeria. The climatic parameters that were found to be significantly correlated with maize yield at a minimum of 95% probability level during the different phenolgical stages of the crop are:

(i) Inter-diurnal variability of rainfall during the establishment stage;
(ii) Evaporation during the vegetative stage;
(iii) Mean length of dry spells during the flowering stage;
(iv) Total rainfall during the flowering stage;
(v) Mean length of dry spells during the grain filling stage; and
(vi) Relative humidity during the flowering stage.

We found out further that inter-diurnal variability of rainfall during the establishment stage accounted for the highest proportion of the variation in maize yield at selected locations in the different climatic regions of the savanna belt of Nigeria. This was followed by total rainfall during the flowering stage, mean length of dry spells during the grain filling, evaporation during the vegetative, and relative humidity during the ripening stage.

Table 8: Relationship between Maize Yield and Hydrometeorogical Variables for Different Phenological Stages of Maize in the Savanna Eco Climatic zones of Nigeria

Phenological Stage	Variables	Level of Significance and Climatic Region	Types of Relationship
ESTABLISHMENT STAGE	TR IVR MLDS E RH	Not significant 95% in humid and moist-sub humid climates; 99% in semi-arid and Dry sub-humid climate 90% in all climate regions Not significant Not significant	Positive Negative Negative Negative Positive
VEGETATIVE STAGE	TR IVR MLDS E RH	Not significant 90% in all climate regions Not significant 95% in all climate regions Not significant	Negative Negative Negative Negative Positive
FLOWERING STAGE	TR IVR MLDS E RH	95% in all climate regions Not significant 90% in humid and moist-sub humid climates 95% in semi-arid and Dry sub-humid climate Not significant	Positive Negative Negative Negative Positive

Table 8 continued

GAIN FILLING STAGE	TR	90% in all climate regions	Positive
	IVR	Not significant	Positive
	MLDS	95% in all climate regions	Negative
	E	Not significant	Negative
	RH	Not significant	Positive
RIPENING STAGE	TR	Not significant	Negative
	IVR	Not significant	Negative
	MLDS	Not significant	Negative
	E	Not significant	Positive
	RH	95% in humid and moist-sub humid climates 90% in semi-arid climate	Negative

TR = Total Rainfall
IVR = Interdiurnal variability of rainfall
MLDS = Mean Length of Dry Spells
E = Evaporation; RH= Relative Humidity

Table 9: Proportion of the Variation in Maize Yield explained by the Critical Hydrometerorlogical indices during the different phenological Stages in the different Climatic Regions of the Savanna Belt of Nigeria.

Climatical stage	Interdiurnal Variability of Rainfall During the Establishment Stage (%)	Evaporation during the vegetative Stage (%)	Mean Length of Dry Spells During the Flowering Stage (%)	Total rainfall during the Flowering Stage (%)	Mean Length of Dry Spells During the Grain Filling Stage (%)	Relative Humidity During the Ripening Stage (%)	All Elements Combined (%) R^2
HUMID							
Yandev	45.2	3.0	1.6	11.5	6.8	2.5	70.6
MOIST SUBHUMID							
Markurdi	47.1	2.4	1.8	11.0	7.2	2.0	71.5
Lokoja	45.8	4.4	3.1	12.5	7.8	2.3	75.9
Kabba	47.2	2.5	1.4	11.3	6.5	1.9	70.8
Ilorin	47.9	2.4	1.0	13.1	7.0	2.0	73.4
Badeggi	56.4	2.0	1.1	10.5	6.4	1.2	77.6
Mokwa	56.2	2.5	1.0	11.	5.9	1.0	77.9
Minna	54.3	2.0	1.3	10.1	6.1	1.1	74.9
Jos	44.8	4.1	1.0	12.2	6.2	2.0	70.3
DRY SUBHUMID							
Yola	64.3	2.1	1.4	9.5	3.2	0.6	81.1
New Bussa	65.2	2.6	2.5	7.4	4.3	0.6	82.6
Yelwa	65.8	2.4	2.2	6.8	3.7	0.5	81.4
Bauchi	54.9	4.5	2.3	8.5	5.7	1.0	76.9
Kontagora	56.7	4.7	3.1	8.8	7.2	1.	81.5
Kaduna	57.9	4.2	2.0	8.2	6.8	1.0	80.1
Zaria	57.4	4.4	3.1	8.6	7.1	0.9	81.5
Gusau	66.1	4.1	2.0	7.5	4.8	0.5	87.4
Potiskum	67.9	5.0	2.3	7.0	5.7	0.8	88.7
Kano	70.1	5.2	2.0	7.2	5.6	0.6	90.7
SEMI-ARID							
Maiduguri	72.3	5.3	2.2	7.4	5.2	0.4	92.8
Katsina	70.5	4.9	2.6	6.9	5.8	0.6	91.2
Sokoto	67.7	4.5	2.1	7.1	6.0	1.0	88.4

In another study on climate-maize yield relationship, we found out that high inter-diurnal variability of rainfall during the establishment stage in conjunction with evaporation and air temperature during the vegetative and grain filling stages proved significant in reducing the final maize yield. This implies that supplemental water supply or mulching will be required if rainfall distribution is poor during the establishment stage. Also conservation tillage will be required to check the rate of evaporation.
In a similar study on the effects of moisture and thermal climatic variables on cane sugar yield at Bacita, Nigeria (Bello, 1996c), the phenological stages of investigation are the establishment, vegetative/ stalk elongation and ripening stage. The results of the stepwise multiple regression models are presented in Tables 10, 11 and 12, respectively.

In each equation in Tables 10-12; Y = cane sugar yield, X_1 = actual water availability (AWA), X_2 = pan evaporation, X_3 = relative humidity, X_4 = air temperature, X_5 = soil temperature at 30cm and X_6 = hours of sunshine.

Results (Table 10) show that actual water availability (AWA, X1) during the establishment stage is the most critical climatic parameter for physiological development of sugar cane.

Table 10: Stepwise multiple linear regressions as applied to cane yield and climatic variables during the establishment stage.

Step	Regression Equation	Variable added to the equation	Cumulative co-efficient of determination (R^2)	Increase in R^2 due to variable added	Level of significance (P)
1.	$Y = 8.2004 - 0.1839 X_1$	X_1	0.52	—	P<0.01*
2.	$Y = 2.7848 - 0.1817 X_1 + 0.7357 X_6$	X_6	0.69	0.17	P<0.01*
3.	$Y = 10.0901 - 0.1683 X_1 - 0.2746 X_4 + 0.8377 X_6$	X_4	0.72	0.03	P<0.025*
4.	$Y = 26.7689 - 0.1837 X_1 - 0.0975 X_3 - 0.6710 X_4 + 1.0471 X_6$	X_3	0.74	0.02	P<0.05*
5.	$Y = 27.4421 - 0.1470 X_1 + 0.1542 X_2 - 0.0966 X_3 - 0.7097 X_4 + 0.9655 X_6$	X_2	0.75	0.01	NS
6.	$Y = 28.4269 - 0.1418 X_1 + 0.1536 X_2 - 0.0990 X_3 - 0.6582 X_4 - 0.0595 X_5 - 0.9005 X_6$	X_5	0.75	0.00	NS

* = Significant , NS = Not significant

We observed a significant negative influence of AWA on the crop at this stage. The implication is that water supply in excess of evaporative demand of the plant environment vis-à-vis plant water requirement at this stage will adversely affect root development, sprouting of the stem cuttings , formation of cane stalk and the ultimate sucrose content. Furthermore excess water supply at this stage can lead to concentration of reduced iron, manganese and toxic sulphides which have adverse effects on the yield formation of sugar. It follows therefore that relatively low soil moisture tension is required at this stage for final yield of high quality juice. We recommended that application of irrigation water at this stage should be guided by the crop's consumptive use of water so as to avoid excess water supply that may result in the production of green matter at the expense of sucrose accumulation.

For the prediction of cane sugar yield, the regression equation:
$Y = 26.7689 - 0.1837\ X_1 - 0.00975\ X_3 - 0.6710\ X_4 + 1.0471\ X_6$ (equation on step 4 of the model in Table 10) appeared as the most appropriate equation for predicting sugar cane yield during the establishment stage.

During the vegetative/stem elongation stage of cane sugar sunshine(X6) is the most critical climatic parameter for stalk growth and sucrose accumulation (Table 11). We found out that sunshine had a significant positive effect on sucrose accumulation.

Table11: Multiple linear regressions as applied to cane yield and climatic variables during the vegetative / stalk elongation stage.

Step	Regression equation	Variable added to the equation	Cumulative co-efficient of determination(R^2)	Increase in R^2 due to variable added	Level of significance (P)
1.	$Y = -10.4214 + 2.3571\ X_6$	X_6	0.51	—	P<0.01*
2.	$Y = 12.0948 + 0.0796\ X_1 + 2.4358\ X_6$	X_1	0.72	0.21	P<0.025*
3	$Y = -9.3899 + 0.0959\ X_1 - 1.0369\ X_2 + 2.8593\ X_6$	X_2	0.75	0.03	P<0.05*
4	$Y = -19.004 + 0.1111\ X_1 - 1.0344\ X_2 + 0.2716_5 + 3.201\ X_6$	X_5	0.75	0.01	NS

Table 11 continued

5	$Y = -15.5421 + 0.0998 X_1 - 1.0666 X_2 - 0.9569 X_4 + 0.8582 X_5 + 3.8712 X_7$	X_4	0.77	0.01	NS
6	$Y = -15.5610 + 0.0996 X_1 - 1.0679 X_2 + 0.0003 X_3 - 0.9563 X_4 + 0.8580 X_5 + 3.8709 X_6$	X_3	0.77	0.00	NS

* = Significant NS = Not significant

The fact is that since the reflection co-efficient of sugar cane is highest during the vegetative stage, long hours of sunshine will be needed for the formative processes of the plant to occur at a high rate. Similarly, the significant positive effect of AWA implies that moisture stress at this stage is detrimental to sucrose accumulation. This observation agrees with the results of a number of other studies (Ashton 1956, Chang 1961, Thompson and Wood 1967, Oliver 1972). It was observed that water deficiency led to an increase in the ratio of root to stem while the leaf became thicker and its area reduced.
The consequence of this physiological adaptation was a reduction in the quantity and quality of sucrose content.

In general, the equation: $Y = -9.3899 + 0.0959 X_1 - 1.0369 X_2 + 2.8593 X_6$ (step 3 in Table 11) appeared as the best model for predicting the sucrose content of sugar cane during the vegetative / stalk elongation stage.

At ripening or dry-off stage(Table 12) the significant negative effects of temperature and humidity(X4) is an indication that high temperature and humidity may encourage cane attack by bacterial (gumming) and fungal (red rot) diseases and consequently lowers the sucrose content and quality.

Table 12: Stepwise multiple linear regressions as applied to cane yield and climatic variables during the ripening stage

Step	Regression equation	Variable added to the equation	Cumulative co-efficient of determination (R^2)	Increase in R^2 due to variable added	Level of significance (P)
1.	$Y = 25.0821 - 0.6195 X_4$	X_4	0.42	—	$P<0.025^*$
2.	$Y = 26.2091 - 0.2583 X_2 - 0.5930 X_4$	X_2	0.54	0.12	$P<0.05^*$
3.	$Y = 42.2531 - 0.2891 X_2 - 0.1212 X_3 - 0.8509 X_4$	X_3	0.62	0.08	$P<0.05^*$
4.	$Y = 51.8763 - 0.3764 X_2 - 0.1550 X_3 - 0.7640 X_4 - 0.2782 X_5$	X_5	0.67	0.05	$P<0.05^*$
5.	$Y = 48.6831 - 0.3907 X_2 - 0.1551 X_3 - 0.7508 X_4 - 0.2451 X_5 + 0.2367 X_6$	X_6	0.68	0.01	NS
6.	$Y = 45.1442 - 0.0483 X_1 - 0.3873 X_2 - 0.1308 X_3 - 0.6727 X_4 - 0.2815 X_5 + 0.3809 X_6$	X_1	0.68	0.00	NS

* = Significant NS = Not significant

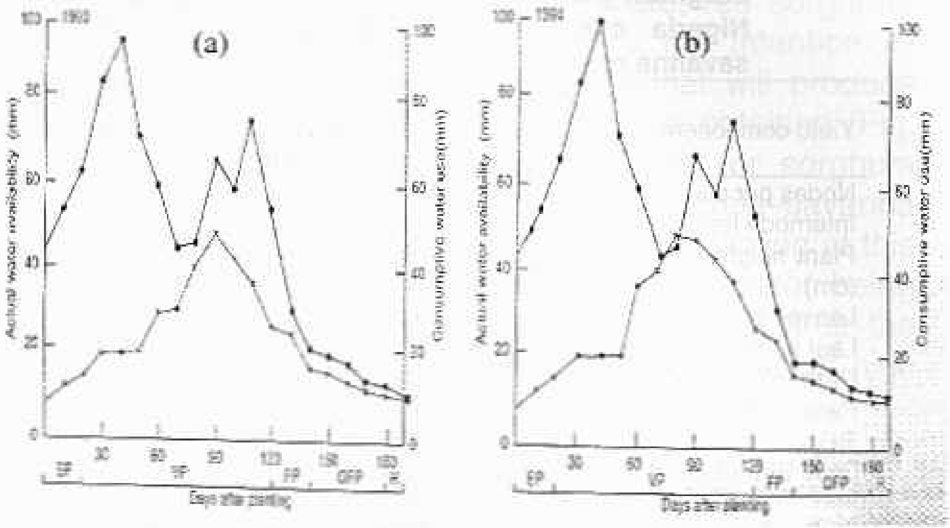
Therefore, to maintain a high quality sucrose yield, the growth of sugar cane should be so scheduled such that the ripening stage does not coincide with the period of high temperature, evaporation and humidity. Also during the ripening stage, the negative correlation shown by AWA agrees with the findings of Jackson (1977) that some levels of moisture stress at ripening stage is more beneficial than wet conditions. In particular wet conditions during the late ripening/ early harvesting period could impede burning, cutting and transportation to the mills.

We found out generally that the model that best predicts the sucrose content of sugar during the ripening stage as shown in step 4 of Table 12 is:

$$Y = 51.8763 - 0.3764 X_2 - 0.1550 X_3 - 0.7640 X_4 - 0.2782 X_5$$

Mr. Vice - Chancellor, Sir, the results of my field experimental research work on crop-weather modeling carried out at locations in the Forest-Savanna transition zone of Nigeria that were all published in International Journal of Experimental Agriculture in Great Britain and the Journal of Agricultural Meteorology in the Netherlands gave me great joy in my research endeavour.

Apart from work done on maize, rice, yam and industrial sugarcane, the results of work done on sorghum (*Sorghum bicolor*) are as summarized in Figures 14 and 15. Specific contribution of the field experiment on sorghum in Abeokuta north and environ is that we were able to confirm the climatic potential of the area for sorghum production; contrary to previous report (House, 1985) that the area falls outside the type of savanna ecological unit for the cultivation of the crop. In actual fact, total rainfall (1107mm) recorded at the study site appeared to be supra-optimal for it falls outside the range of optimum rainfall (500-1000) reported for sorghum growth in the savanna region (Kowal and Knabe, 1972; Kassam and Kowal,1973; House 1985). But we were able to carry out field experiment on sorghum-rainfall model (Figure 14) by manipulating the cropping pattern and synchronizing actual water availability from rainfall during the phenological stages with the crop's water requirements, such that, available moisture during the moisture sensitive period was not in excess of the optimum for sorghum production.



Figures 14 a and b: Relationship between actual water availability (AWA) and consumptive water use (ET_{crop}) by sorghum the crop's phonological periods in the forest savannah transition zone of Nigeria in 1993 and 1994 (• AWA, -x- ET_{crop}, phenological periods)

Results in Table 13 confirm further the agro-climatic potential of the forest-savanna transition zone for sorghum cultivation; the yield components obtained appeared encouraging.

Table 13: Some yield components (mean values for 1994) of sorghum grown in the forest-savanna transition zone of Nigeria compared with a location in the Guinea savanna region

Yield component	Location	
	Forest-savanna transition zone	Guinea savanna Region*
Nodes per plant	25	15
Internode length (cm)	12	17
Plant height (ground to flag leaf, (cm)	300	255
Leaves per plant at flowering	25	15
Leaf blade (length x breadth (cm)	110 x 10	100 x 10
Days to panicle initiation (d)	120	100
Panicle length (cm)	50	55
Days to flowering (d)	135	120
Days to grains maturity(d)	170	145
Grain yield (kg ha $^{-1}$)	950	1015

**Value for Guinea Savanna Region were obtained from Kwara Agricultural Development Project Headquarters, Ilorin (8° 29'N, 4° 35' E).*

The yield components of sorghum grown in the forest-savanna transition zone (Table 13), however, showed retarded inflorescence development and lower ultimate yield than that in the guinea savanna. We observed that this trend could be attributed to higher amount of rainfall, in other words, higher ratio of actual water availability to consumptive water use by the crop, which caused sporadic and prolonged vegetative growth of sorghum (Figs. 14 a and b) and led to a delay in panicle initiation and flowering (Table 13), and lower ultimate yield in the transition zone than in the savanna region.

In order to improve on the yield of sorghum in the forest-savanna transition zone another field experiment was attempted by varying planting date using two late maturing Guinea genotypes of Sorghum (the Janare, red sorghum) and Farin Dawa (white sorghum) with the intention of determining the optimum planting dates that will produce substantial higher sorghum yield. The result obtained (Fig. 15) shows that the optimum planting date for sorghum cultivars, Janare and Farin Dawa in the forest–savanna transition zone of Nigeria was 10-12th June. Planting at this time produced the highest grain yield and the reason being that the cropping calendar was scheduled such that the later part of vegetative period avoided the period of high Actual Water Availability (AWA).

In particular, the planting around the period of June 10-12 amounted to a delay in planting by 51 days (51d) after the onset of the rains, and this led to a reduced plant height at panicle initiation (PI), but there was observable increase in grains yield (Figs. 15a and b).

It is, therefore, recommended that as long as the thermal factors are adequate any late maturing of high-yielding sorghum cultivar with about 150-180 days from planting to maturity, can be planted around 10-12th June in any given year in the forest-savanna transition zone with a high probability of obtaining a satisfactory grain yield.

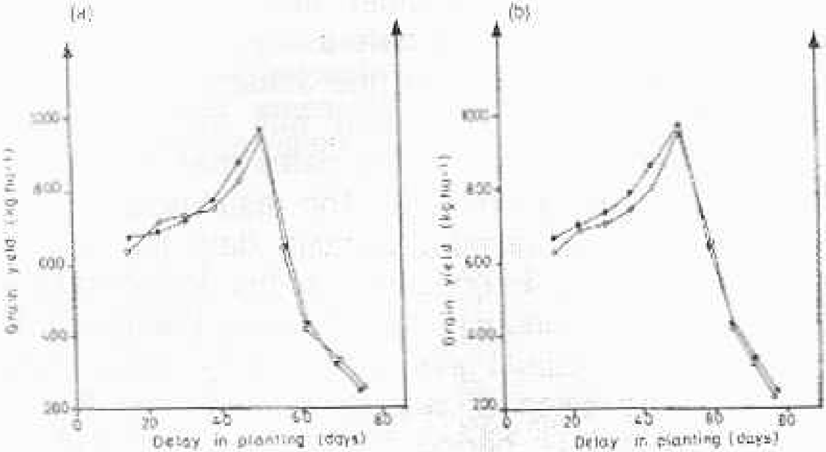


Figure 15 a and b: Grain yield (kg ha^{-1}) of two sorghum cultivars, Janare (•) and Farin Dawa (○), as influenced by delay in planting (days) after the onset of the rains in (a) 1995 and (b) 1996 cropping seasons.

However, in a year with late onset of the rains the required delay in planting might be less than 51 days, but planting should not be done earlier than 4th June. This is to avoid a situation whereby sorghum matures during a humid period which could encourage head moulds and render the grain unfit for human consumption. On the other hand if the onset of the rains is early, and is particularly earlier than 20th April, the delay in planting might necessarily exceed 51 days, but in this case, planting should not be delayed beyond 20th June. This schedule is to ensure that the adverse effect of high AWA are avoided or minimized, while at the same time, precautions are taken against possible shortfall in the duration of the rains, particularly, if such an early onset is marred by an abnormally early or abrupt cessation. In a situation where the onset of the rains is extremely late such that incidence of drought is imminent and the duration of the rains might possibly fall short of 150 days, then cultivars with phenologies that synchronize perfectly with the pattern of actual water availability should be selected.

There is no doubt that the cultivation of mixtures of sorghum and maize with certain legumes is feasible in the area since soil and thermal factors are not constraints while the duration of the rains is appreciably longer than elsewhere in the savanna region of Nigeria (Olaniran, 1983; Bello, 1996b).The advantages of such mixed cropping have also been reported. (Olasantan, 1985; Olasantan and Bello, 2004; Bello and Olasantan, 2004).

8.0 CONCLUSION AND RECOMMENDATIONS

Before going into conclusion, I wish to state that in my contribution to knowledge in this noble field, it is not unto us but to God be the Glory for what He has made possible, and according to Apostle Paul (II Corinthians 3:5), I submit with humility that I am not adequate to claim anything as coming from me, my adequacy is from God.

Mr. Vice - Chancellor, Sir, we have examined the genesis and trends of perturbations in the plant environment since the first generation on earth and have seen clearly that man is the cause of the mounting threats to his food security. Since the beginning of last decade it was evident that human -induced climate variability and change had already put considerable stress on food production and availability. Presently, there is a global food crisis referred to as 'silent tsunami' and this time around Nigeria is not left out. It is disheartening that despite the known consequences of deforestation, we still clear and burn off thousands of hectares of land in each ecological region of Nigeria every year.

Mr. Vice - Chancellor, Sir, My Lord Spiritual and temporal, and distinguished audience, I can not play God at all, but in the light of the evidence before us, there is no doubt that our plant environment is in peril; more so because man-environment interaction is a continuum and increasing population vis-à-vis needs for survival will continue to trigger off more complexities. Therefore, climate will continue to vary and change and man will continue to battle with water and food insecurity.

In Nigeria, the battle with food insecurity may not be a lost one if we can develop objective ecological rehabilitation policy and at the same time make good use of available climatic resources. Such resources can be used in conjunction with crop and soil characteristics to investigate, on a regular basis, the agro-climatic potential of our agro-ecological zones and come up with current versions of agro climatological atlas containing agro climatic land use classification of Nigeria for various food crops. I, therefore, wish to advocate for the establishment of National Agrometeorological Research Centre (NARC) to be saddled with the above and many other responsibilities.

However, I wish to stress at this point that the production of crops suitable for local and regional climatic conditions can no longer remain a matter of pure empiricism. A good understanding of the interaction of climatic complex with the physiological process of the crop and the farming system in an area must be vigorously pursued. It is strongly recommended that any strategy designed to promote

sustainability of agricultural production in a highly variable and changing climate should begin with the traditional farmers who have been operating specific farming systems. Our Scientists could also learn from the experience of our illiterate farmers.
However, with some patience in listening to the farmers, scientists will be in a better position to tap their indigenous technical knowledge of the environment and therefore use scientific knowledge to make indigenous farming systems more sustainable. Such participatory research will make farmers to feel for their environment and exploit it to meet their needs in a sustainable way. In addition, there is the need to strengthen resource conservation by regulating livestock grazing, fuel wood and charcoal exploitation, bush burning and earth quarrying.

Mr. Vice – Chancellor, Sir, and distinguished audience, it is clear to everybody that this country is blessed with abundant agricultural resources. But it is unfortunate that we have relegated the sustainable development of these resources in to the background. We have thrown the mainstay of the economy of Nigerian people in to the abyss and watch our endowed wealth to waste away before our eyes. The good vegetation and the type of farmlands we used to see along major routes in the early seventies have disappeared. Worse still wet lands are running out and fertile farmlands are diminishing in Nigeria. Since the last two years prices of basic food items kept on skyrocketing. Many families in Nigeria today have been forced to change their eating habits. There is no doubt that low birth weights among new born babies in recent times is connected to

inadequacy of the required diet among the child- bearing women in the rural and urban areas.
If meaningful action is not taken urgently it might take this country many years to pedal out the problems emanating from the present food crisis. Therefore, the adaptation of strategies to make food security more robust is expedient. Such strategies, among others include:

- Control and prevention of land degradation and desertification;
- Mitigation of the effect of drought and other metorological hazards;
- Preservation and restoration of wetlands and estuaries;
- Better fisheries stock assessment and management;
- Production of new crop varieties;
- Adaptation of new crops to changing conditions;
- More efficient soil and land management;
- The use of minimum and reduced tillage technologies;
- Changes in the seasonal cropping calendar;
- Improved seasonal climate prediction; and
- Improved adaptation of food production systems to current climate variability.

It is imperative that Nigerian Meteorological Agency (NIMET) broadens her collaboration to include all the Nigerian Universities of Agriculture and others offering courses related to climatology and meteorology. This will facilitate meaningful joint research in crop- weather modeling and agro hydrology.

There is the need to improve on environmental monitoring in this country so as to be able to assess accurately the impact of future climate change on the managed and unmanaged ecosystems. Therefore, it is crucial to monitor climate at the micro and synoptic scales. To do this effectively, we need to improve on the existing method of climate monitoring by taking advantage of recent development in automatic weather observing system which has made it easy to record the occurrence of extreme events on routine basis. The Federal Government can assist to set up automatic weather observing stations in the Universities of Agriculture in this country.

I wish to stress at this point that government should adequately fund Teaching and Research in our universities. Government should not totally shift the responsibility of education of Nigerian people to the private sectors, who may not be able to acquire and sustain high quality human resources required for a university training that will produce graduates who can find their feet anywhere in the world.

The rapid growth in the number of universities in this country appears as a threat to the standard of education and quality of Nigerian University graduates in the near future. Already, there is paucity of academic staff in many of these new universities and the few available academic staff are overstretched in an effort to teach the set curricula and attain high standards.

The National Universities Commission (NUC) is doing very well to ensure quality through accreditation exercise. But to what extent can this continue in view of political climate in Nigeria vis-à-vis uncertainty of the tenure of good leadership? In any case, we appeal to government to make adequate funds available to meet the growing teaching and research needs of both the old and new universities. Furthermore, Teachers in the primary and secondary schools should be encouraged and be paid well regularly because they constitute the bedrock and foundation of any successful educational attainment anywhere in the world.

10.0 ACKNOWLEDGEMENTS

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I thank God for other members of my family, particularly, Chief Oloba Ogunniyi, Chief Asanlu Balogun, Aremu Adebijo, Ayando Olukotun (Baba Morolayo), Chief Aro Malomo, David Aremu Adeniyi, Karimu Ifalola, Buremo Babatunde and Jonathan Awodo Adeniyi (alias esami yahayaha) all of blessed memory for their contributions. May their humble souls rest in peace, Amen.

I thank God for ECWA family and ECWA President Rev Anthony Omolewu Farinto, and his wife who have been my very wonderful family friend. God bless you and all the Ministers, Elders and Fellowships in ECWA for their prayers. I acknowledge the Late Secretary General of WMO, Professor Emeritus G.O.P Obasi of blessed memory, the Nigeria Meteorological Agency (NIMET) and the World Meteorological Organization (WMO) for supporting some of these research studies and my membership of the World Commission for Agrometeorology.

I thank God for all my Teachers from the primary school to the University. Limited time and space given to me has not allowed me to mention every one of them. But I wish to place on record my sincere gratitude to some of them, particularly, Professors O. J. Olaniran, J.S. Ogunsanya, A.O. Adedibu, and Dr Wole Ameyan, in the University of Ilorin and Professors J.S. Oguntoyinbo, J.O. Ayoade, C.O. Ikporukpo, J. A. Ayeni and O.A. Afolayan of the University of Ibadan. In particular, I thank God for Professor O.J. Olaniran, who introduced me into research in theoretical and applied climatology (Agroclimatology). He also taught me humility, patience, the need to always extend a helping hand to others, and thoroughness.

I thank my Dean and colleagues in the College of Environmental Resources Management and, in particular, members of Staff and students in the Department of Water Resources Management and Agrometeorology.

I also express my appreciation to the University Management under the leadership of Professor Oluwafemi Olaiya Balogun, a distinguished scholar and prudent financial manager of the resources of this great University for providing an enabling

environment for the actualization of this Lecture. Please convey my heartfelt appreciation to both staff and students.

Finally, I thank God for giving me Beatrice Bimpelola Ajike Elerineye (nee Balogun) as a wife, a lady of honour and integrity, loving mother, a real virtuous woman , very accommodating, trusting and hardworking. I thank you for your unfailing love and support right from my days as a postgraduate student at the University of Ilorin. Special thanks also go to my children, Ayobami, Ayoola and Ayobanjo; you are all a source of joy to me. May the joy of the Lord Almighty continually be with you, Amen.

I thank you all for coming and for listening and before closing join me to sing this song:

A fope f'Olorun, Lohun ati lokan wa, Eni se hun yanu ,Nu eni ta raiye nyo Gbata wa lo moowo, On na lon toju wa Osi fe bun ife To juwa sibe sii

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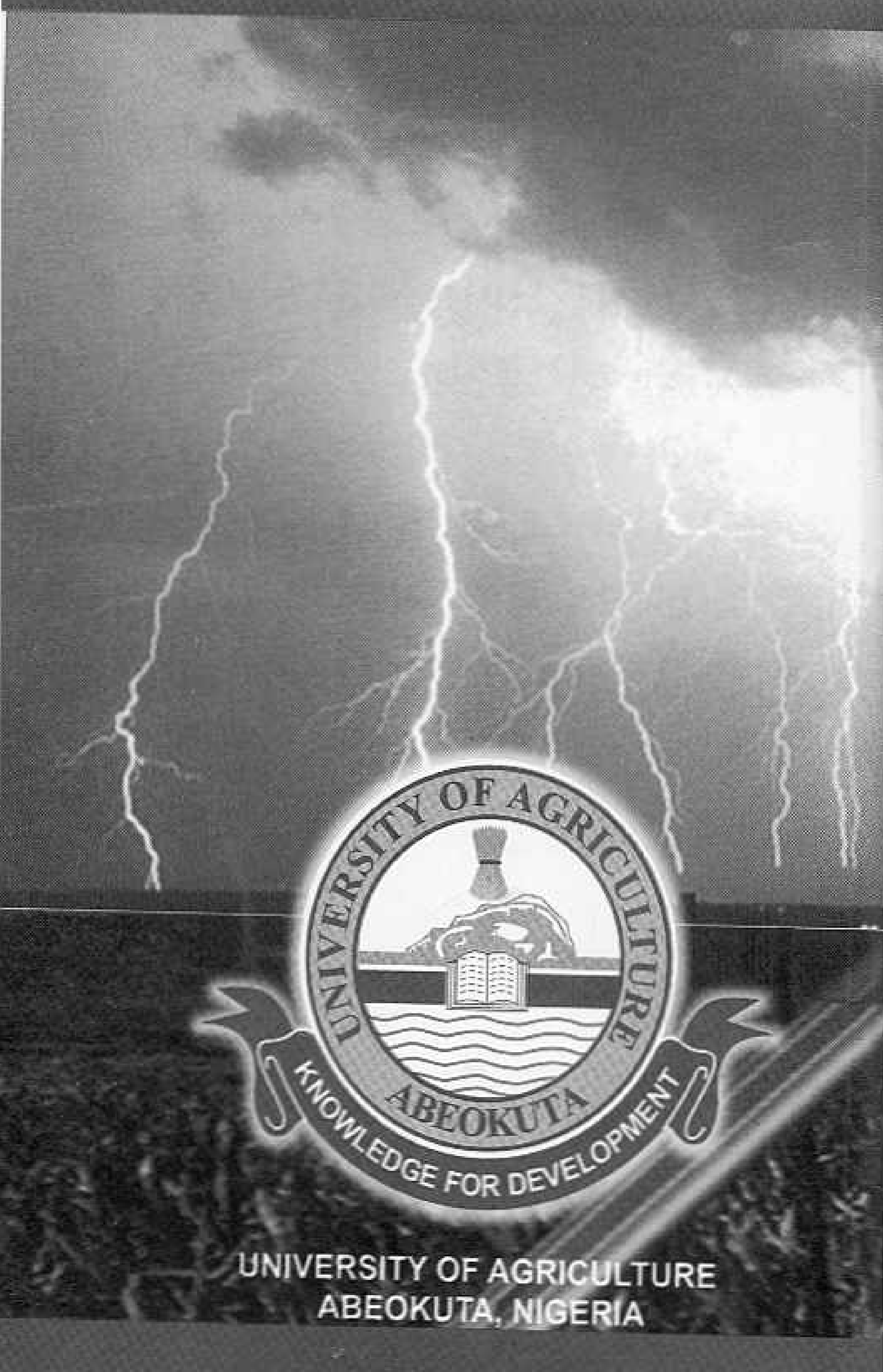
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