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# **Extended-Range Weather Forecasting in Sub-Saharan West Africa: Assessing a Potential Tool for Adapting Food Production to Climate Variability and Climate Change**

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**ABSTRACT** This contribution is designed primarily to bring into focus seasonal weather forecasting as a potential tool for adapting crop production to the variable and changing climate of sub-Saharan West Africa. The contribution is essentially a synthesis of several investigations, the details of which have been provided in the technical report of AIACC Project titled “Climate variability, climate change and food security in sub Saharan West Africa” ([http://www.aiaccproject.org/Final%20Reports/final\\_reports.html](http://www.aiaccproject.org/Final%20Reports/final_reports.html)) The existing climate forecasting capacity in the sub-continent incorporates the activities of national, regional, continental and international forecasting organizations. Some of the choices available to farmers as responses to a fore knowledge of seasonal weather were identified through stakeholder investigation. The current forecasting capacity was assessed and found not to be sufficiently skilful for the needs of agricultural practice. For one thing, the target predictands were not the factors most closely correlated with crop performance and yield. For another, both the spatial and the temporal resolutions of the forecasts were demonstrated to be too coarse to be useful for farm level decision making. Perhaps the most critical inadequacy of the capacity, as revealed through stakeholder investigation, is the near absence of a credible procedure for communicating the forecasts to peasant farmers. As a remedy for the skill inadequacy, this contribution includes two examples of statistical models for the respective prediction of onset and cessation of the rainy season. To enhance the communication of the forecasts with the peasant farmers, the existing agricultural extension channels were recommended. These were to be improved and sustained with appropriate policy and budget provisions.

**Key words:** West Africa, weather forecasting, crop production, adaptation, climate variability, climate change.

## **1. Introduction**

The focus of this contribution is the potential application of seasonal weather forecasting as a basic tool for adapting crop production to the variable and changing climate of sub-Saharan West Africa. Weather forecasts are expected to provide insights into future meteorological conditions for a specified locality or region and over a specified period of time. Depending on the time covered, weather forecasts are classified as short range, medium range, or long range. Short-range forecasts are for parts or the whole of a 24-hour period with a further outlook for another

24 hours. Medium-range forecasts are made for periods covering 2 to 5 days ahead. The long-range forecasts are made for periods longer than 5 days. In the current exercise, our interests lie in the long-range category, which we describe as seasonal or "extended-range" weather forecasts. Adaptation is described as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Adaptation could be anticipatory or reactive, private or public, and autonomous or planned. As an adaptation tool, extended-range weather forecasting is anticipatory, public, and planned. In West Africa, the expected beneficiary in the agricultural sector is the peasant farmer.

Notwithstanding the considerable resources already invested in weather prediction and climate monitoring in Africa, the overarching anxiety among peasant farmers concerns the unpredictable onset and cessation of the rainy season. A foreknowledge of the weather of an upcoming growing season should enable farmers to plan with greater confidence to forestall its negative consequences and exploit its beneficial opportunities. Whatever tool is available to gain such foreknowledge is an adaptation device. Because variability will remain a significant element in any future climate, skillful weather forecasting will also remain a valid adaptation strategy in the context of any projected climate change. Therefore the primary objective of the studies reported in this chapter is to assess extended-range weather forecasting as a potential tool for adapting food production to climate variability and climate change. Specifically, in the contribution, we will attempt to

1. identify the choices presented to farmers as responses to a foreknowledge of seasonal weather;
2. describe the existing capacity for extended-range weather forecasting;

3. assess the skill of the tools currently deployed for extended-range weather forecasting;
4. highlight the inadequacies in the existing weather forecasting capacity;
5. recommend measures for upgrading the skill of the existing capacity; and
6. recommend policy initiatives for ensuring that the forecasts are timely communicated and made useful to peasant farmers.

## **2. Approaches to the Study**

The basic approach of the chapter is the use of Nigeria as a case study for sub-Saharan West Africa. The chief justification for this is that the country truly represents the climatic profile from the very wet to the semiarid ends of the subcontinent. All the indicator vegetation types of the various climate types are present in the country. Thus, northward from the very humid, eastern, coastal locations, through the subhumid Middle Belt, to the margins of the Sahara Desert, the vegetation profile includes Evergreen Rainforests (Koppen's Af), Southern Guinea Savannah (Koppen's Aw), Northern Guinea Savannah (Koppen's Aw), Sudan Savannah (Koppen's BS), and Sahel Savannah (Koppen's BS). Of all the countries in West Africa, Nigeria is alone able to produce the complete range of foodstuffs characteristic of the subcontinent as a whole. Apart from the presence of the major tropical climate and vegetation types, the range of latitude, the varied relief and soils, together with differing peoples with their contrasted methods and crops make this possible (Harrison-Church, 1956).

The contribution is a synthesis of several investigations of climate variability, climate change, and food security in sub-Saharan West Africa, the details of which have been provided in the technical report to the AIACC Project (Adejuwon, 2006). Some of the work, including

Adejuwon (2002, 2005, 2006), Adejuwon and Odekunle (2004, 2005), Odekunle (2003, 2004) and Odekunle et al. (2005), has been published in scholarly journals, in which details of the methods used can be found. However, their findings are integrated to constitute the substance of the current work.

The review of the possible farm operation choices for responding to the forecasts (section 3) is based mainly on the data collected during field surveys. The field surveys were conducted in five major ecological zones in Nigeria, including: rainforest (Atakumosa Local Government Area of Osun state), Southern Guinea savannah (Irepodun Local Government Area of Oyo state), Northern Guinea savannah (Oorelope Local Government area of Oyo state), Sudan savannah (Askira Local Government Area of Bornu state), and Sahel savannah (Konduga Local Government Area of Bornu state). The surveys used questionnaires applied to household heads in 10 communities in each local government area. The questions of interest were designed to extract information regarding householders' perception of the effects of interannual climate variability on crops, animals, and livelihood. Apart from the questionnaires, discussions were held with groups at household and community levels. These discussions were also directed at how the weather affects the lives of the individuals, households, or communities concerned. The topics considered include crops cultivated, farm operations schedules, effects of droughts, hedging strategies to reduce the negative impacts of weather, survival strategies, use of irrigation, use of fertilizer, and use of credit among others.

The assessment of the capacity represented by the major forecasting organizations (section 4) is based on archival sources such as scholarly journals (Folland et al., 1986, 1991; Ward et al,

1990) and broadcasted weather forecasts for the period 1990–2000 (Philippon and Fontaine, 2000; Colman and Richardson, 1996; Colman et al., 1997, 2000). They were also published in *Experimental Long-Lead Forecasts Bulletin*. These provide not only the details of the forecasts but also of the statistical and the dynamic models used as tools for the forecasts. The profile of ACMAD and the other regional weather organizations (section 5.3) is based on information provided at their respective Web sites. The forecasts of the Nigerian Central Forecasting Organization (CFO) (section 5.4), as well as the climate records for the period from 1961 to 1995, were collected from the offices of the Nigerian Meteorological Agency at Oshodi, Lagos state. While collecting the forecasts, information regarding the operations of the Agency and its relationship to the regional and continental forecasting organizations were also collected. The methods used for the assessment of forecasting skills (section 5) are described in detail in Adejuwon and Odekunle (2004). A shorter version is presented in the appropriate section in this contribution. Also, the methods used for the specification of models for the forecast of onset and cessation of the rainy season (section 8) are described in the relevant section of this chapter.

### **3. Operational Choices in Responding to Variable Weather**

#### **3.1 Farm operations timing and the variable weather**

Farmers, whether in the humid or semi-arid zones, realize the need to time farm operations to correspond with specific weather patterns. The dry season is used to prepare the land for cultivation. The bush could be cleared entirely by the use of fire. In most cases, the bush is first cleared by slashing before fire is applied. If the rains come too early, preparation operations could be adversely affected. It is, therefore, necessary to know when the rains are going to start. However, the main anxiety about the onset of the rainy season concerns the planting date.

Farmers like to sow their crops as early as possible. The earlier the crops are sown, the earlier the food products will be made available to end the annually occurring period of food deficiency. Moreover, farmers who get their crops early to the market are likely to enjoy better prices. It has been demonstrated that yields of crops planted earlier during the rainy season are higher than those planted later (Adejuwon, 2002; Fakorede, 1985). This is explained as the gains from early season nitrogen flush from farm residues of the previous season. Also, incident solar radiation levels are highest during this period before the heavy rains come, and the clouds reduce the amount of sunlight available for photosynthesis. All of these factors explain why farmers are anxious about when the rains will come.

Sometimes, there are false starts of the rainy season and farmers rush to plant their crops. This can result in disaster, as the seedlings may be completely lost. Replanting could be expensive if the seeds have to be purchased. If replanting seeds are sourced from the farmers' stores, they could deplete food needed by the household during the period of low food supply. The amount of resources wasted in this way could be considerable when the crop concerned is yam. The yam seed is cut from the same tuber used as food, and could be up to 25% of production. The farmers would, therefore, benefit considerably from a foreknowledge of the onset of the rainy season.

Crop yield response to rainfall variability was investigated in the semiarid zone of Nigeria (Adejuwon, 2005). June rainfall turned out to be a more powerful predictor of crop yield than any of the other monthly rainfall variables. This is explained by the fact that June is the month of the onset of the rainy season. Low or insufficient June rainfall implies a delayed onset and a rainy season not long enough for the needs of most crops.

Crops such as cow peas or late maize are planted so that they could be ready for harvesting after the rains have ceased. A late cessation of the rains means that the crops would be harvested

under wet conditions, and much of the crop could be lost to molds and other pests and diseases. On the other hand, if the rains cease too early, the entire crop could fail due to inadequate moisture. There is a system of yam production practiced at the drier margins of the rain forest zone, which requires the seeds to be planted at the end of the rainy season, just before the rains cease. The seed remains dormant for the whole period of the dry season. As soon as the rains come during the following year, yam vines shoot up and harvestable tubers are produced two or three months ahead of the normal yam harvest season. New yam produced in this way commands very high prices, as they are preferred to the old yam, which would by then be losing its taste. The critical weather requirement of this system is that at least one heavy downpour must fall on the planted seeds before the dormancy period. In the absence of this, as much as 50% of the crop could be lost. Thus the farmers can also benefit considerably from a foreknowledge of when the rains would cease.

In the study of crop yield response to rainfall variability (Adejuwon, 2005), September rainfall also served as a powerful predictor of yield. September is the month of cessation of the rainy season. Low or inadequate rain in September is evidence that the season is truncated before it could provide adequate moisture for crops during the critical phases of grain filling.

The length of the rainy season and the amount of rain that falls during the peak rainfall period are also watched with anxiety by farmers. Palm fruits are harvested by climbing the tree to cut the fruit. This is a very hazardous operation, especially during the rainy season when the trunks are slippery. Fewer climbers are available during the rainy season, and for this reason, palm products such as palm oil, are in short supply and expensive. The fruits are left to waste and the longer the

rainy season the greater the loss. Also, during the rainy season, rural roads become impassable and crops like cassava are unable to reach the market.

Heavy tropical rainstorms can make all of the difference between a good harvest and crop failure. Farmers complain that such storms could cause a heavy loss to flowers before they become fruits. Cow peas are an example of crops that could be damaged in this way. Heavy rainfall reduces the number of pods per stand of cocoa, while it increases the degree of infestation by the black pod disease (Thoroid, 1952; Adejuwon, 1962). Years with heavy rainfall, therefore, usually correspond to years with low yields of the crop. Moreover, cocoa harvested at the height of the rainy season has low grades and may not be able to make the export market. This is due to the prevailing heavy clouds and the little sunlight available for drying the produce. A prolonged little dry spell midway into the rainy season is a blessing to cocoa farmers.

A minimum amount of rainfall during the dry season is needed for the establishment phase of tree crops. Cocoa is usually planted as seeds or seedlings during the rainy season. The new crop plants will die during the first dry season if no rain falls or if there is a spell of desiccating harmattan winds from the Sahara. Thus in the forest zone farmers meet with varying successes in developing a new plot to the crop, depending on how much rain falls during the first dry season after planting (Adejuwon, 1962). Farmers' needs from the weather forecaster, includes statements on whether or not the dry season will be completely dry.

### **3.2 Coping without the benefits of weather forecasts**

It needs to be noted that the peasant farmers are not altogether helpless in the absence of weather forecast information. Traditional agricultural practices include a number of no-regret options designed to mitigate the negative consequences of unfavourable weather, applicable each year, whether or not the weather turns out to be unfavorable. One good example of such practices is the storage of water and the use of shallow wells to extend the period of adequate water supply at the end of the rainy season. Such practices will help to cushion the impacts of abrupt termination of the rainy season. Mulching is another practice, which helps to protect seedlings against dry spells during the earlier parts of the growing season. The use of wetlands, whether extensive floodplains or local valley bottoms, is part of traditional agricultural practice. Wherever such lands are available, they help to reduce the impacts of the milder droughts on peasant communities.

As of now, farmers use a number of hedging strategies while expecting the worst of weather and hoping for the best. Such strategies include multiple cropping, relay cropping and intercropping. These are recognizable features of traditional farming practices evolved over time all over the country and are designed to make one crop serve as an insurance against the failure of another. In the case of multiple cropping, crops that occupy different ecological niches are planted together on the same plot. For example, maize may be planted with melon. While maize is a standing crop, melon is a creeper. In the case of relay cropping, several crops are planted in succession on the same plot to make use of different parts of the growing season. For example, in the Guinea Savannah Zone of South western Nigeria, maize is planted in April, harvested in July; sorghum is planted in June and harvested in November. In the case of intercropping, some crops are

planted at low density among the major crop, which is planted on every heap. For example, maize could be planted at low density on a farm plot primarily meant for yam production.

In the forest zone, tree food crops are maintained as insurance against the failure of field crops. In normal years, the fruits of the tree crops are not harvested. However, during the years of inadequate rainfall when the yields of the field crops are not able to sustain the peasants' livelihood, they fall back on the tree crops whose food products are considered to be of less quality. Also, cocoyam, planted under cocoa, is treated as a weed during normal years. However, whenever the major food crops fail, it becomes a dependable source of food.

There are also measures for damage control as soon as it is realized that an abnormally dry season is in the offing. One of such measures is replanting with crops with shorter growing seasons or that are more tolerant of arid conditions. Water yam with a maturity period of 3 months could be planted to replace white yam, whose maturity period lasts seven months; millet, with a maturity period of two months, could be planted to replace sorghum, which takes six months to mature.

### **3.3 Decisions that might benefit from forecast information**

In a typical tropical region like West Africa, rainfall is the principal controlling element of crop productivity (Nieuwolt, 1982, Stern and Coe, 1982). The crop plants are sensitive to the moisture situation both during their growth, development, and especially as they reach maturity. This is reflected in a definite soil and atmospheric moisture range, in which field preparations are

expected to commence and also in which such farm operations as sowing, thinning; transplanting, weeding, irrigation, insecticide, and fertilizer applications, as well as harvesting, are scheduled to take place. Thus as seasonal weather changes from one year to the other, the most suitable crops, cropping systems, and operations schedules also change. The need thus arises to choose from a range of options.

As an adaptation strategy, extended-range weather forecasting represents an early warning system that could be used at farm-level decision-making. A foreknowledge of seasonal weather affords the farmer the opportunity to make decisions that could enhance the productivity of his farm and maximize returns on his inputs of land labor and capital. Among others, the *ex-ante* decisions that might benefit from a foreknowledge of seasonal weather include:

1. timing of farm operations, e.g., land preparation, tillage, planting, transplanting, thinning, weeding, irrigation, harvesting, application of insecticides, herbicides, fungicides, and fertilizer;
2. type of tillage, depth of planting, density of planting;
3. choice of crops and crop varieties;
4. whether or not to adopt water conserving practices and which type to adopt;
5. how much water to store and use for irrigation;
6. mode of irrigation (flooding or sprinkler);
7. how much fertilizer, pesticide, herbicide, and fungicide to apply;
8. mode of application of the various inputs;
9. whether or not to use fertilizer, herbicides, or pesticides;

10. choice of site, e.g., cultivation of fadama (poorly drained) soils during years of drought and deep loamy soils during years of heavy rainfall;
11. choice of farming systems, e.g., single or multicropping or inter cropping;
12. how much credit to secure; and
13. proportion of production to store or sell.

#### **4. Existing Capacity for Extended-Range Weather Forecasting**

##### **4.1 Externally based weather forecasting organizations**

Because of lack of the necessary tools, both human and instrumental, West Africa depends, to a very large extent, on organizations based in Europe and North America for its operational weather forecasting capacity. Three organizations, including National Oceanic and Atmospheric Administration (NOAA; USA), Met Office (United Kingdom), and Centre de Recherche de Climatologie of France (of the Centre National de la Recherche Scientifique (CNRS)) routinely make forecasts directed at the West African subcontinent.

###### *4.1.1 Met Office Forecasts*

The Met Office has been engaged in experimental forecasts of seasonal rainfall in the Sahel (region 1) since 1986. Since 1992, the organization has extended the coverage of its forecasts to a slightly redefined Sahel (region 2, 15 W to 37.5 E and 12.5 N to 17.5 N). The new areas covered also include an area south of the Sahel (region 3, 7.5 W to 33.75 E, 10 N to 12.5 N) and another area extending to the coast of the Gulf of Guinea (region 4, approximately 7.5 W to

7.5 E, 5 N to 10 N). The forecasts are based on ocean and atmospheric information available in early May (Colman et al., 1996, 1997; Graham and Clark, 2000). The forecasts are for June, July, August, and September or July, August, and September.

The statistical forecasting methods used are the multiple linear regression and discriminant analysis. Predictors include indices of March and April sea surface temperature anomaly patterns, which are represented by eigenvectors. The same predictors are used by both forecasting methods. They were selected using statistical forecast hindcasts and global circulation model simulation experiments. The predictors for regions 1, 2, and 3 include a global SSTA pattern showing opposing signs north and south of the equator, a global pattern with strong weights in the tropical South Atlantic, and a global pattern showing ENSO-related variability and regional patterns for the South Atlantic. The one predictor used for the Guinea Coastal region (region 4) is a South Atlantic pattern with strong weights in the Gulf of Guinea (Colman et al., 2000).

Both the Stepwise Linear Regression and the Linear Discriminant techniques are based on Folland et al (1991). The analyses were carried out on seasonally averaged  $10^0 \times 10^0$  square SSTA data and the mean seasonal rainfall for a training period of at least 30 years. The results, given for the four regions defined by longitude and latitude mainly, give boundaries for five rainfall predictor categories as percentages of mean rainfall for the training period. In the case of the Linear Discriminant Model, the predictors also consist of five categories. Using archival data, the category boundaries were defined so that each category, known as quint, is equiprobable in the training period (Folland et al., 1986). The forecasts were given, relative to the mean of the

training period as very dry, dry, average, wet, and very wet. Attempts are now being made to forecast seasonal weather using multiple model configurations (Graham et al, 2000). It is expected that a higher skill level would be attained with a combination of dynamic models than with single model forecasts.

#### *4.1.2 CNRS—France forecasts*

Two complementary statistical tools are applied by The Centre de Recherche de Climatologie of France in forecasting rainfall in West Africa (Philippon and Fontaine, 2000). The tools, consisting of the Multiple Linear Regression Analysis and the Linear Discriminant Analysis have been adapted from Folland et al (1991). However, the predictor composition is quite different. Also different is the procedure for their computation and selection. In order to make the forecasts available before the beginning of the growing season, only information available by the end of April is employed. The predictors (June to September cumulated rainfall) refer to the entire West African subcontinent (17.5 N–5 N; 17.5 W–17.5 E) and use 2.5 latitude and 3.75 longitude grid box rainfall database. The predictors also consist, on the one hand, of a regional Sahel index computed over the zone extending from 10 N to 17.5 N and from 15 W to 15 E. On the other hand, they consist of 41 local indexes covering the whole of West Africa. Thus each block in the  $2.5 \times 3.75$  grid has its own forecast results. The data utilized include a set of 27 potential and tropical (30 N–30 S) sea surface temperature (SST) indexes analyzed on a  $5 \times 5$  grid. There is also another set of data of 50 potential regional (25 W–15 E; 25 N–5 S) atmospheric indexes describing near-surface humidity, moist static energy, and geopotential values.

### *4.1.3 NOAA forecasts*

An African Desk has been established at the Climate Prediction Centre, National Oceanic and Atmospheric Administration (Silver Spring, MD, USA). The African Desk has been experimenting with African seasonal forecasting in collaboration with the Climate Prediction Centre (CPC). Efforts have so far been limited to statistical methods. In 1996, 1997, and 1999, Canonical Correlation Analysis (CCA) was employed to produce experimental forecasts for rainfall anomalies for July, August, and September in the Sahel (Thiaw and Barnston, 1996, 1997, and 1999). Sahel, in these forecasts, was defined as lying within 10 N–25 N and 20 W–45 E.

CCA consists of a regression procedure that forecasts a multivariate predictand field from a multivariate predictor field. Originally, Barnston designed the CCA tool for extended weather forecasting in the USA (Thiaw and Barnston, 1999). In its basic pattern, four consecutive 3-month predictor periods are followed by a lead time, and then a single three-month predictor, or target period. So far, the experiments confirm that the global SSTA field is the best predictor. This is also the view shared by the European and African forecasting teams. Additional fields could enhance forecast skill. However, the data do not extend far enough into the past (minimum of 25 years for an adequate training period). The candidate additional fields include upper air geopotential heat, tropical low level wind, and outgoing long-wave radiation. For 1999, Sahel rainfall forecasts, the predictor data were the global SSTA field over the four 3-month periods of June to August, 1998; September to November, 1998; December to February 1998–1999; and March to May, 1999. On the basis of data from 1955 to 1996, the CCA is used to model linearly,

the relationship between the previous year's SST anomaly evolution and the target year's July–September rainfall anomaly. Using the model developed the 1999 July–September rainfall anomaly was projected from the previous year's quarterly SST anomalies.

## **4.2 African and West African forecasting organizations**

### *4.2.1 Role of ACMAD*

The organization charged with the responsibility for gathering, collating, and disseminating weather forecast information in Africa is The Africa Centre for Meteorological Applications for Development (ACMAD; URL: <http://www.acmad.ne>). ACMAD was created in 1987 by the Conference of Ministers of the United Nations Economic Commission for Africa and the World Meteorological Organisation. ACMAD was started in 1992 in Niamey, Niger Republic. The center represents the joint efforts of the African Meteorological Community to meet the challenge of weather prediction for the continent. The strategy is for the center to lead both in training personnel for capacity building within the continent and operational activities, such as the issuance of products.

In the execution of its action programs, ACMAD operates in synergy and in a network with international partners, partner institutions, and focal points. The international partners include CNRS (France), United Kingdom Met Office, and United States NOAA, among others. These organizations provide the primary weather information to be collated and transmitted to the end users within the various African countries. The partner institutions have specific sector and regional responsibilities that require weather and climate information. Among such institutions

are AGRHYMET and ICRISAT. The interests of ICRISAT lie in agricultural development in semi-arid tropics. The concern of AGRHYMET is for agriculture and hydrology in the Sahel region of West Africa. These organizations in one way or the other are expected to help in broadcasting information to sector end users. To reciprocate, they could also use the Web site of ACMAD to advertise their products for the benefit of their stakeholders. The primary focal points are the National Meteorological Services of 53 African countries. Focal points for ACMAD have also been established within the operational structure of subregional economic groupings, such as the Economic Community of West African States and South Africa Development Community. The focal points are the primary recipients of the products emanating from ACMAD, meant for end users in agriculture, energy, water resources, and other sectors within the various countries.

The data reception at ACMAD is achieved via a unique African Meteorological Environmental Diagnostic Integrated System (AMEDIS). The AMEDIS is a system for receiving, processing, and broadcasting meteorological information. It also consists of the display units, SYNERGIE and MESSIR-VISION. SYNERGIE is a (software suitable for universal applications) forecaster tool for an easy and efficient access to a wide range of observed and predicted meteorological data. It is versatile and adaptable to specific situations and also further developments. The MESSIR-VISION is comparatively less expensive and is operational on a PC.

The operational products of the Numerical Weather Prediction Unit within ACMAD include the daily Meteorological Bulletin for national meteorological services and the daily continent-wide 24-hour public significant weather forecasts. These products give relatively accurate forecasts

that, however, do not go far enough into the future for our purpose. The numerical weather production unit of ACMAD also issues 5-day guidance bulletins on specific days of the week (i.e., Monday, Wednesday, and Friday). On the other days, namely, Tuesday and Thursday, the unit issues 3-day guidance bulletins to monitor and follow up the previous day's 5-day guidance bulletin. The terms "guidance" and "forecast" are understood in the context that ACMAD issues weather guidance to African National Meteorological Services, which have the responsibility to issue the weather forecasts for the specific countries or subregions. The conventional network of surface and upper air observations within ACMAD's area of responsibility is generally too poor to make longer-term relevant numerical forecasting feasible.

However, ACMAD, through its *African Climate Watch* page (URL: <http://www.acmad.ne>), advertises two relevant products for short-term, medium-term, and seasonal weather prediction: "El Nino/La Nina Update on Impact over Africa" and "Rainfall Onset over West Africa". The former gives early-warning type of forecasts extending over three to nine months. However, this is a very new product that has yet to be tested. The other product predicts the onset of the rainy season within three to six weeks (Omotosho, 1990). However, the predictions are confirmed only within three weeks.

ACMAD is thus not yet qualified to conclusively interpret the "upcoming significant weather" predictions from the model products. Weather forecasting consists of complex and interactive processes on various scales of motion, even smaller than considered on the GCMS (General Circulation Models). The degree of importance of the smaller-scale circulation varies from one subregion to the other and from one season to the other. Concrete ideas may be formulated only

through local knowledge, research, and/or evaluation of model performances. Therefore, extended-range weather forecasting remains the responsibility of the National or Subregional Services.

#### *4.2.2 Role of PRESAO*

Suggestions leading to the inauguration of PRESAO (First West African Forum on Climate Variability and Its Applications in Early Warning Systems for Food Security) were made at the Cotonou Workshop on “Climate Variability Prediction, Water Resource and Agricultural Productivity: Food Security in Tropical Sub-Saharan Africa” (Fleming et al., 1997). Working Group I of the Workshop strongly recommended the organization of a West African Climate Prediction Forum designed to pool expertise in the subcontinent for the purpose of weather prediction. Both producers and users of predictions were to be assembled for two-way interactions designed to optimize 1) use of 1998 prediction information and 2) design of predictions produced for subsequent years. ACMAD was charged with the responsibility for organizing the forum by constituting an organizing committee to choose the venue, invite participants, and arrange funding with the help of the START Secretariat. Pilot project needs were to be identified during the first meeting of the forum scheduled for 1998. During the subsequent 12 months, the goals of improving 1) the prediction information available in 1999 and 2) the ability of the agricultural and water resources sectors to use that prediction information were to be pursued. The PRESAO forecast map appears on the Web page of ACMAD and is meant to be accessed and downscaled by the National Meteorological Services. Such maps have since been produced and published.

### **4.3 National meteorological services: the case of Nigeria**

The former Department of Meteorological Services in the Nigerian Federal Ministry of Civil Aviation became the Nigerian Meteorological Agency (NIMET) in 2002. It is thus, now an independent organization, established by an Act of Parliament. Within NIMET, there is the Nigerian Central Climate Forecasting Office (CFO), which holds the responsibility for short-term and extended-range weather forecasts. Ahead of each cropping season, CFO issues a bulletin on weather outlook for the season. CFO bases its forecasts on analogue, statistical, and dynamic methods. In addition to forecasts downscaled from European and American forecasting organizations. While making its local forecasts, CFO makes use of SSTA data of  $2^{\circ} \times 2^{\circ}$  resolution (Toure, 2000), compared with SSTA data on a resolution of  $5^{\circ} \times 5^{\circ}$  employed by CNRS (Philippon and Fontaine, 2000) and the  $10^{\circ} \times 10^{\circ}$  grid SSTA data used by the Met Office (Colman et. al., 2000).

For its own local forecasts, CFO makes use of the current trend of weather, the pressure systems, the position of the Intertropical Zone of Convergence (ITCZ), and global SSTA. For example, the outlook for 1997 was based on data collected for the month of February of that year. It was noted that the pressure values for the "Azores High" were higher than normal, that pressure values for the "St. Helena High" were higher than normal, that the position of the ITCZ was along latitude  $7.5^{\circ}\text{N}$ , the same position as it was during the previous year (1996), that the sea surface temperature anomalies for the South Atlantic were below normal; and that the SSTA for the Pacific Ocean were also below normal, but warming up. Considering the SSTA over the South Atlantic, the outlook was for below normal rainfall over the southern states for the early season and normal for the late season. According to the outlook, predictions of SSTA over the

Pacific Ocean by the CPC (NOAA, USA) indicated that rains over the northern states from June to September would tend to be less than normal. CFO also makes forecasts of the dates of the first rains (which is not the same thing as the date of onset of the rainy season as defined by Ilesanmi (1972a). Very often, the first rains represent only a false start.

## **5. Assessing the Skill of the Existing Capacity**

### **5.1 Forecasts assessed**

The forecasts assessed have been prepared by various meteorological organizations, including: MO (Met Office–United Kingdom), Centre de Recherche de Climatologie, 21000 Dijon–France (CNRS), NOAA (USA) and the CFO (Nigeria). The forecasts of the international organizations were obtained from articles published in *Experimental Long-Lead Forecasts Bulletin*. The forecasts of the Nigerian CFO were obtained directly from their offices in Lagos, Nigeria.

The stations selected to test the forecasting skills of the various tools include Benin City, Lagos, Ibadan, Ilorin, Enugu, Minna, Jos, Kaduna, Lokoja, Maiduguri, and Kano, all located within Nigeria (Fig. 1). The stations have been selected to represent the various climatic and ecological zones between the Gulf of Guinea in the south and Sahara Desert in the north (Fig. 2). Their selection is also based on the availability of rainfall data from 1961 to 2000. The forecasts assessed were for the five years from 1996 to 2000.

### **5.2 Methodology of forecast skill assessment**

The scheme used here for the assessment of forecast skill was first described in detail in Adejuwon and Odekunle (2004). Skillful forecasts are those that are subsequently confirmed by observations. High skills are demonstrated when forecasts are very close to observations, whereas low skills are recorded when the two are substantially different. One practical problem in assessing the skills is the fact that observations and forecasts are not presented in the same units of measurement. Observations are usually presented on an interval scale with the amounts of rainfall given in millimeters. On the other hand, forecasts are stated using ordinal categories. The most common are quint categories varying from very wet, to wet, average, dry, and very wet. Determination of what is very wet, wet, etc. in this exercise was based on the records from 1961 to 1995. Rainfall values for each year, whether annual, seasonal, or monthly, were arranged in descending order of magnitude and divided into five groups. The resulting highest quint consists of the values for the seven wettest years and the lowest those of the seven driest years. The years with rainfall values falling within the range in the highest quint are classified as very wet, while years with values falling within the range of rainfall in the lowest quint are classified as very dry. Other years are similarly classified as wet, average, or dry.

Sometimes, tercile categories are used by simply forecasting near normal, above normal, or below normal. Determination of what is above normal, near normal, or below normal was also based on the records from 1961 to 1995. Rainfall values for each year, whether annual, seasonal, or monthly were arranged in descending order of magnitude and divided into three groups. The resulting highest tercile (above normal) consists of the twelve wettest years and the lowest (below normal) those of the twelve driest years. The eleven middle years define the near-normal range. The quint and the tercile limits provide the framework for converting both observations

and forecasts to the same units of measurement (Adejuwon and Odekunle 2004). In assessing the skills of forecasts, the same criteria were used to classify observations (OBS) as were used for the forecast categories (CA). Where observations and forecasts fell within the same category, skill was assessed as high. Where there was a one-category difference, as, for example, observation was very wet and forecast was average, skill was assessed as moderate. In situations of more than one category disparity between observation and forecasts, the skill was assessed as low. Tables 1a and 1b provide the framework for the assessment of the skills of the forecasts.

### **5.3 Results and discussion**

The skill of the forecasts for June, July, August, and September annual rainfall totals, as determined in the analysis is 26% "high", 45% "moderate", and 29% "low". There is thus considerable room for improvement. The results ranked NOAA and CFO ahead of CNRS and MO in weather forecasting skill over West Africa (Table 2). A careful look at the background of the methods of data collection and analysis appears to explain the relative successes of the forecasting organizations. Virtually, all of the forecasting organizations made use of the SSTA as a predictor among others. However, a noticeable difference in the nature of the sea surface temperature data used by various organizations is with respect to the spatial resolution. Although CFO and NOAA made use of SSTA data of  $2^{\circ} \times 2^{\circ}$  resolution (Tourre, 2000), CNRS used seasonally averaged  $5^{\circ} \times 5^{\circ}$  grid SSTA data (Philippon and Fontaine, 2000), and U.K. MO used seasonally averaged  $10^{\circ} \times 10^{\circ}$  square SSTA data (Colman et al., 2000). It thus appears that the finer the SSTA resolution, the better the forecasting skill.

The number of predictor variables used in the forecast models also seems to have played a role in determining the level of skill. Although MO, whose tools seem to be less skilful than the others, made use of SSTA data alone in the construction of their prediction models, other forecasting centers made use of additional rainfall formation-related factors. For instance: CFO which came first, on the basis of having the smallest "low skill" score, made additional use of synoptic data, including current weather, pressure systems, equivalent potential temperature, and the position of the ITCZ. NOAA that came first, on the basis of the highest "high skill" score made additional use of upper air geopotential heat, tropical low level wind, and outgoing long-wave radiation (Thiaw and Barnston, 1999). CNRS, which was third, used additional factors, such as geopotential indexes, describing near surface humidity and moist static energy values (Philippon and Fontaine, 2000). Note that ITCZ is one major factor not used by CNRS in the construction of their prediction model. This study thus shows that the more predictor variables used in the construction of a forecast model the better the skill of forecast attained.

The study clearly demonstrates regional disparities in the skills of the forecasting tools (Table 3). The prediction skill is generally higher for southern coastal locations than for the northern continental locations. It is well known that the Atlantic Ocean is the major, if not the only, source of moisture into the West Africa subcontinent. The moisture is brought to the land areas by the southwesterly winds moving in after the northward migrating ITCZ. The characteristics of the southwesterly winds, which bring the moisture to the continent, are, in turn, determined by the nature of the sea surface temperature of the Gulf of Guinea (Adedokun, 1978). It is thus logical that the conditions of the southwesterly winds, as determined by the SSTA and its associated ITCZ, would be least modified near the coast. As the ITCZ advances and the southerly winds

progress further inland, their thermodynamic transformations become more pronounced. The changes in the nature of southwesterly winds and other rainfall-associated factors are thus a function of space and time. Thus, the space connection between rainfall over the land and the activities over the Atlantic Ocean weakens with distance between a location over the land and the sea. It is, therefore, not surprising that a prediction model based on SSTA is more skillful in the south, near the ocean, than in the interior of the continent.

## **6. Inadequacies in the Existing Capacity**

A number of inadequacies follow the trail of the forecasts as they were made from 1996 to 2000. First, the skill was not sufficiently high, and there was no evidence to the effect that it was improving (Adejuwon and Odekunle, 2004). Second, the forecasts were directed at the total rainfall amount, whereas the more relevant determinants of crop yield were neglected. As noted by Odekunle and Gbuyiro (2003), all of the recent studies on rainfall predictability in West Africa, including those from the Department of Meteorology, University of Oklahoma (Norman, OK, USA) (Berte and Ward, 1998), Nigerian Central Forecasting Office, (Omotosho et al 2000), Centre de Recherche de Climatologie, 21000 Dijon-France (Philippon and Fontaine, 2000), UK Meteorological Office, Bracknell, United Kingdom (Colman et al, 2000), Gbuyiro et al (2002), and Wilson (2002), were directed to rainfall amounts only. The number of rain days, which is a measure of rainfall effectiveness, was hardly ever included. The same total amount of rainfall is expected to benefit crops more coming as drizzle over several days than when it comes in one heavy downpour (Odekunle and Gbuyiuro, 2003). Other important parameters of rainfall that were not considered as predictandts are the rainfalls of onset and retreat periods. These are of

paramount importance in the subregion because they affect regional economies (Walter, 1967; Olaniran, 1983; Adejuwon et al., 1990). A failure in early establishment of rainfall onset, for example, usually indicates a drought in the early part of the rainy season as noted earlier in section 4.

Third, as noted by Odekunle et al. (2005), the forecasting tools currently deployed are regional in approach and general in perspective. Models developed at such coarse spatial scales often fail at individual farm-level sites. Within the same zone, in respect of which the forecasts are usually made, a wet season in one station may be a dry season in another (Adejuwon et al., 1990). The disparities in forecasting skills between stations lying in the same ecological zones, as demonstrated in Table 2, are probably a result of such intrazonal variability.

Fourth and the most serious inadequacy of the existing capacity is the absence of an effective means of communicating the forecasts with any end user in the agricultural sector. During stakeholder field surveys conducted in all ecological zones, from the rainforest belt in the south to the Sahel savannah zone in the north, in 50 village communities, not a single respondent affirmed receiving either directly or indirectly, weather-related information from the Meteorological Services (Adejuwon, 2005). Extension personnel routinely advise the farmers in their charge on the timing of their farming activities. It turned out that such advice is based, not on weather information received from the Meteorological Services, but on their knowledge of the climate of the area.

## **7. Measures for upgrading the forecasting effectiveness**

New attempts are being made to generate extended-range weather forecasting models in Nigeria (Odekunle, 2004, Odekunle et al 2005, Odekunle and Gbuyiro, 2003, Odekunle et al, 2005, Odekunle, 2006 and Adejuwon and Odekunle, 2006). The models, which are yet to be incorporated into the seasonal weather forecasting programmes of the country, are designed to improve the skills, credibility and applicability of the existing capacity at the local level. For example, Odekunle et al (2005) examined the rainfall onset and retreat dates between 1962 and 1996 in Nigeria, and generated models for their prediction. The study adopted a composite of rainfall-promoting factors namely, sea surface temperature of the tropical Atlantic Ocean, land-sea thermal contrast between some selected locations in Nigeria and the tropical Atlantic Ocean, surface location of the Inter-tropical Convergence Zone and the land surface temperature in selected locations. Rainfall and temperature data were collected from Ikeja, Benin, Ibadan, Ilorin, Kaduna and Kano, in Nigeria. Cumulative percentage mean rainfall was employed to generate the rainfall onset and retreat dates series, while the method of stepwise multiple regression analysis was used to construct the required prediction models.

The results obtained showed that the hypothesized rainfall-promoting factors are efficient in predicting rainfall onset and retreat dates. The results also indicated that all the areas of the tropical Atlantic Ocean, from the Gulf of Guinea, through St Helena and Ascension Island, up to the Benguela Current region, influence the inter-annual variability in the rainfall onset and retreat dates of the country. The results have also demonstrated that the most important factors affecting inter-annual variability in rainfall onset and retreat dates in Nigeria are the SST of the Atlantic ocean (from the Gulf of Guinea, through St. Helena and Ascension Island, up to the Benguela current region) and the land=sea thermal contrast between selected stations in the

country and the various SST locations. The land surface temperature and the surface location of ITCZ are somewhat less important. Both the statistical “goodness of fit” (using both the  $R^2$  and  $a$  values) and the actual “goodness of fit” (by comparing the observed rainfall onset and retreat dates with the predicted values using 1962–1969 and 1995–1996 data) of the models obtained in this study tend to support the reliability of the models for predicting rainfall onset and retreat dates in Nigeria.

The pattern of the results obtained is not unexpected because studies have demonstrated that SST anomalies are a significant cause of inter-annual variability in tropical rainfall characteristics (Adedokun, 1978; Folland et al., 1991; Colman et al., 2000). Also, the land-sea thermal contrast factor, through its effect on both the strength of southwesterlies and the frequency of easterly shear, has long been recognized as a prime factor of inter-annual rainfall variability in the sub-region (Carlson, 1969; Adedokun, 1978; Folland et al., 1991). The nature of the influence is such that increased land-sea thermal contrast (high temperature gradient) enhances the convergence strength around the ITCZ, which in turn increases the frequency of easterly shear and thus more precipitation (Carlson, 1969; Adedokun, 1978). It is the wind shear that promotes frequent squalls, disturbance lines and most convection and overturning that constitute the ITCZ band of rainfall (see for example, Riehl et al., 1974; Moncrieff and Miller, 1976; Nicholson and Chervin, 1983).

#### **8. Measures for communicating forecasts to end users**

Also, for upgrading the weather-forecasting capacity, the forecasts should be issued and forwarded with the assurance that they will be received in good time and used by farmers for

planning the next set of farm operations. Each national forecasting organization should have within it an Agricultural Meteorology Department, which should bear the responsibility to prepare the forecasts in a form that could be effectively communicated to end users.

First, the forecasts must be credible (Patt and Gwato, 2002). Where previous forecasts were perceived as incorrect, the tendency would be for subsequent ones to be ignored. Credibility is primarily determined by the level of skill. It is also a function the difference between what was promised by the forecasts and what was realized. At their best, forecasts are probabilistic. By couching forecasts in deterministic language, skill will invariably be perceived as low whenever there is an incorrect forecast. On the other hand, a probabilistic forecast is accorded a benefit of the doubt with infrequent incorrect forecasts. Considerable efforts, therefore, need to be put into how the forecasts are interpreted before they are transmitted. It is not always easy to find a simple expression to convey the concept of probability, especially in a nonmathematical context, in which peasant farmers operate. Another requirement for a credible forecast is that it must be presented at a spatial resolution or scale with which individuals can identify. As indicated in section 7, forecasts are made for extensive zones, within which there could be considerable differences in the actual weather observed. CFO divides Nigeria into five zones and makes its forecasts for each zone. In order to achieve a high skill level for each zone, the skill levels for the localities within the zone, with which the farmers are familiar, have been compromised.

Second, the forecasts must be presented in simple, easily understandable language. Forecasts need to be presented in the local languages. Where forecasts are rendered in strange and confusing language, users will either not incorporate them or they will do so in a way that is

counterproductive (Patt and Gwato, 2002). The forecaster cannot be expected to be experts in all the local languages. However, leaving the translation entirely in the hands of local, agricultural extension personnel may introduce considerable angles of distortion. Sometimes, to make the forecasts believable, doses of exaggeration are introduced. Apart from this, technical terminologies in English language may not have local language equivalents. Hence, there is the need for the forecasters to work repetitively with users or the intermediary conveyers of forecasts to be able to arrive at an appropriate forecasting language for each locality.

Third, the department should also bear the responsibility to issue forecasts early enough to be useful in planning the following season's operations. Planting normally starts as soon as the rainy season is established. The decision as to what farm operations to adopt for the season, therefore, must have been made before then. While the rainy season may come as late as June in the semiarid zone, it could come as early as February in the humid, coastal zone. Weather forecasts made in April or May are practically useless to half of the farming community in Nigeria. The expected end users will hence not be in a position to make use of them.

Fourth, the forecasts must include information that could cause decisions based on tradition or climate-based timing of the farm operational schedule of activities to be altered. If forecasts do not contain enough new information to alter specific decisions, the expected users will not organize their activities in response to them (Patt and Gwato, 2002). As indicated in section 4.2, the peasant farmers are not altogether helpless in the absence of weather forecast information. Traditional agricultural practices include a number of no-regret options designed to mitigate the negative consequences of unfavourable weather, applicable each year, whether or not the

weather turns out to be unfavourable. These must have covered a considerable proportion of the risks posed by interannual climate variability. One way of providing the type of information that could offer credible choices is to indicate the changes in crop yield that could be expected given the forecast in question. The Agricultural Meteorology department of NIMET must be equipped in terms of personnel to issue such forecasts.

Even though, there is an Agricultural Meteorology Department within NIMET, it appears that the organization is not explicitly charged with activities that could expedite the transmission of the forecasts. Its extended-range weather forecasts are consigned to the archives as soon as they are made. Either by amendment to the Act establishing the Agency or to the relevant statute or regulations, the responsibility of NIMET in this regard should be clearly stated. The Agro Met Department should be strengthened and charged with the responsibility of translating the forecasts into forms that could be understood and relevant to the needs of farmers. The government at the federal level should also accommodate budgetary provisions for communicating the forecasts to the agricultural extension services.

A related problem concerns the channel of communicating the forecasts with the farmers. Our suggestion is that the existing administrative structure should be adopted. Just as ACMAD recognizes the National Meteorological Services as the focal points within each member country for the dissemination of its products, NIMET should identify focal points close to the farmers for purposes of passing on weather forecast information to them. Because NIMET is a federal agency, the logical location of such focal points is within the administrative structure of the states. However, this will tend to prolong the line of communication and reduce its efficiency.

Therefore, we are suggesting the Local Government Administration (LGA) as the location of NIMET focal points. The precedent for this is the direct transfer of LGA component of the federally generated revenue to the local governments without passing through the states. There are more than 700 LGAs in the country. Each LGA is structured to have a Department of Agriculture, whose political head is the Supervisory Councillor for Agriculture. There are also within such departments technical staff with qualifications comparable to those of a holder of Higher National Diploma (obtained after four years postsecondary with one-year sandwiched industrial training). Focal points established within such departments will be close enough to the farmers and are likely to guarantee effective and efficient transmission of forecasts. The LGA represents government at the grass roots, while the technical staffs in the agricultural department are expected to operate among the rural populace, especially among the farmers. They speak the same language as the farmers and are well placed to ensure that vital weather information get to the farmers within a few days.

As part of the bottom-up approach, we are suggesting that the forecasts should be based on the existing 28 synoptic weather stations in the country. On the average, each station will be expected to represent the weather of an area with the size of 30,000 square kilometers. This, it is hoped will enhance the skill of the forecasts, as they could be accessed from each farm site. This means that 28 weather forecast pamphlets will be produced to cover the country. Thus, it is the forecasts for the weather station closest to each focal point that will be sent to the farmers who need it. However, communication should not just be one-way. There should be opportunities for feedback from the consumers of the forecasts. Such could be in the form of specific requests for forecasts or in the form of complaints about the level of skills demonstrated by the forecasts.

## 9. Conclusions

Extended-range weather forecasting in West Africa has been recognized as a basic step for creating an early warning system. This is in view of the fact that no comprehensive adaptation plan could be made to forestall the negative consequences of climate variability and climate change without gaining insights into future meteorological conditions of each locality. With this understanding, the skill of the existing capacity for extended-range weather forecasting was assessed. The study noted a number of inadequacies in both the prediction skill and the usefulness of the forecasts to the end users. The prediction skill seems inadequate because of the high percentage of the “moderate skill” and low percentage of the “high skill” categories obtained in its assessment. Inadequacies in terms of the usefulness to the end users include; 1) lack of forecasts on rainfall characteristics such as onset, cessation, length of the growing season and rain-days; 2) lack of forecasts for specific localities instead of extensive zones; and 3) lack of forecasts for coastal and middle belts of West Africa by some of the forecasting organizations. As an example of what could be done to make up for the inadequacies, prediction models were generated for the relevant rainfall characteristics, including onset and cessation dates of the rainy season. In other published works, we have also generated prediction models for the length of the rainy season, the length of the "safe" period and the number of rain days (Odekunle and Gbuyiro, 2003; Odekunle, 2004). The models generated represent an improvement on the existing weather forecasting tools, as they could be used to make forecasts for specific locations (i.e., the weather stations), and for all the zones from the coast to the Sahel. The section of the study concluded

that rainfall characteristics of the region could be reliably predicted, using the rainfall engendering factors of SST and land/sea thermal contrast alone.

Apart from improving the skills of the forecasts, suggestions were made for removing the constraints at present attendant on effective forecast communication with the peasant farmers. There were constraints posed by inadequate or lack of credibility, late publication of forecasts, cognitive deficiencies, and absence of clear choices associated with specific forecasts. Suggestions were also made to adopt the existing agricultural extension channels for communicating the forecasts. This requires the close cooperation between forecasters and extension personnel to ensure that forecasts are rendered in forms and languages understood by the farmers.

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Table 1A. *Skill Assessment of Quint Forecast Categories*

<b>Forecast</b>	<b>Very Wet</b>	<b>Wet</b>	<b>Average</b>	<b>Dry</b>	<b>Very Dry</b>
<b>Observations</b>					
Very Wet	High	Moderate	Low	Low	Low
Wet	Moderate	High	Moderate	Low	Low
Average	Low	Moderate	High	Moderate	Low
Dry	Low	Low	Moderate	High	Moderate
Very Dry	Low	Low	Low	Moderate	High

Table 1B. Skill Assessment of Tercile Forecast Categories

Forecast	Above Normal	Near Normal	Below Normal
Observations			
Above Normal	High	Moderate	Low
Normal	Moderate	High	Moderate
Below Normal	Low	Moderate	High

Table 2. Organizational Skill Performance Assessment of the June, July, August, and September Annual Rainfall Totals

Forecasting Organization	Percentage Contribution of Each Skill Category		
	Skill High	Skill Moderate	Skill Low
MO (all)	21%	44%	35%
NOAA	56%	22%	22%
CNRS	18%	55%	27%
CFO	20%	70%	10%

Table 3. Regional Disparities in the Forecasting Skill

Stations		Percentage Contribution of Each Skill Category		
		Skill High	Skill Moderate	Skill Low
Maiduguri	Sahel	17%	33%	50%
Kano	Sudan	17%	17%	66%
Kaduna	Northern. Guinea	20 %	60%	20%
Minna	Northern. Guinea	25%	25%	50%
Jos	Plateau	17%	50%	33%
Ilorin	Southern. Guinea	17%	83 %	0%
Lokoja	Southern Guinea	50%	25%	25%
Ibadan	Dry Forest	29%	71%	0%
Enugu	Dry Forest	33%	33%	34%
Ikeja	Rain Forest	29%	57%	14%
Benin	Rain Forest	33	67	0%



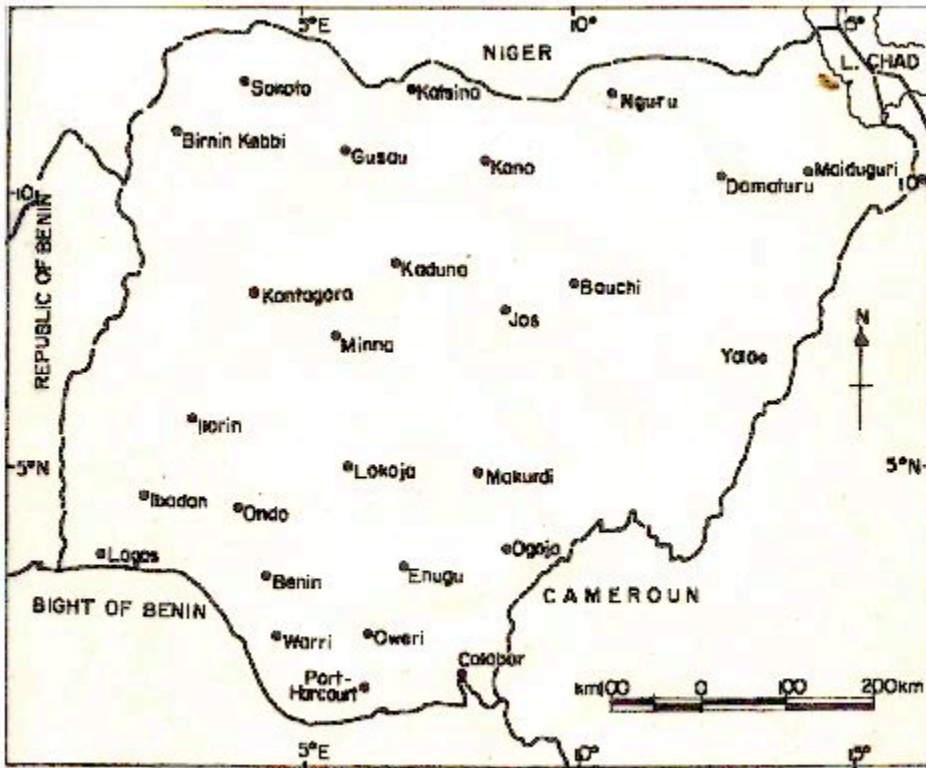


Fig. 1: Nigeria Meteorological stations

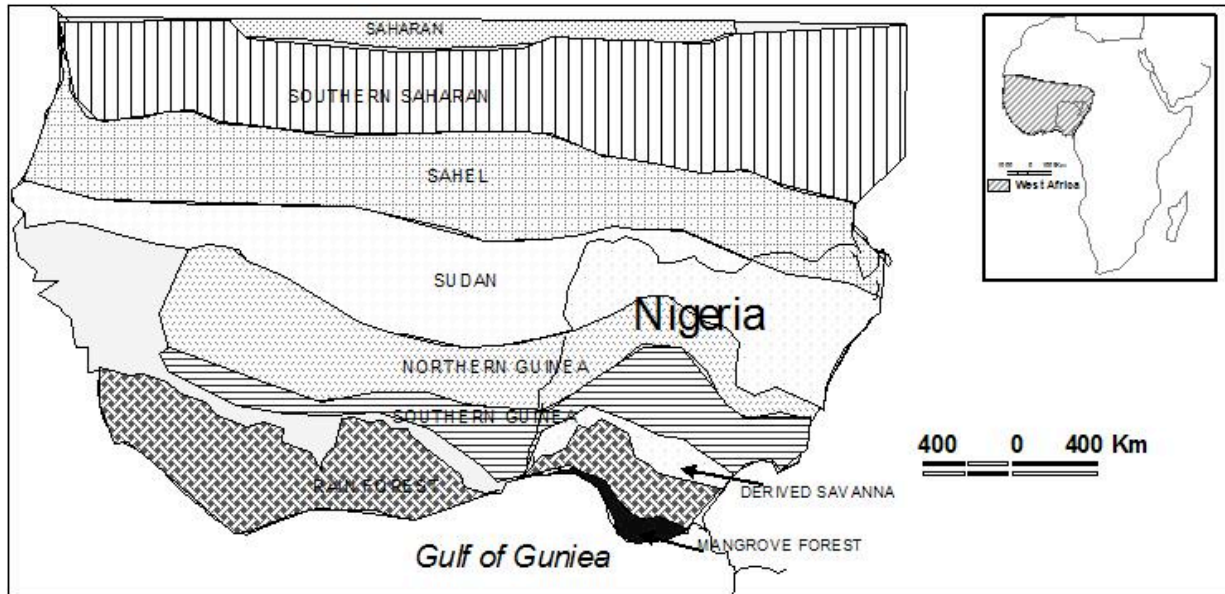


Figure 2. Location of Nigeria and ecological zones of West Africa.