Satellite Remote Sensing and Agrometeorological-Based Early Warning for Food Security for Nigeria

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Abstract

In Nigeria, production of food crops is largely in the hands of millions of small and traditional farmers (subsistence agriculture). This traditional farming system heavily depends on the vagaries of weather condition, amongst other factors. To monitor this condition, there is need for a reliable and effective national early warning system (EWS) for food security. An ideal target for a national EWS would be a method of monitoring crop growth conditions as well as estimating end-of-season crop yields. The methodology would be able to estimate end-of-season crop yield halfway into the growing season and therefore provide an advance warning on the food situation before end of the season. The application of remote sensing in EWS has several advantages, which include a wide and extensive coverage, regular data availability, timely data availability and dissemination, and being cost-effective. This paper describes satellite remote sensing and agrometerological methods for crop yield forecasting for Nigeria. An example of crop yield forecast for millet for the year 2005 planting season in Nigeria is illustrated. Results show excellent prediction capability of the prediction method.

Keywords: *Early warning, Food security, Crop yield forecasting, Remote sensing, Agrometeorology.*

1.0 Introduction

Recent studies indicate that all the climatic zones within Nigeria had experienced drought at one time or another during the past three decades (Akeh et al., 2000). However, the extreme northern zone of Nigeria has the highest number of occurrences of drought years.

A reasonable percentage of agricultural practice in Nigeria is rain-fed. In Nigeria, production of food crops is largely in the hands of millions of small and traditional

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farmers subsistence agriculture. They grow a variety of crops on small parcels of land, sometimes several crops mixed on the same parcel of land, mainly for their own consumption. Production of food crops in the traditional farming sub-sector heavily depends on the vagaries of the weather in addition to availability of inputs and several agronomic and economic factors. In a good season,, there is a bumper harvest while in a poor season, production may go down drastically. In addition, there is now deep global concern for weather and climatic changes caused by global warming and its dynamics and impact on agriculture. There have been, therefore, several calls for national/regional food security systems.

An ideal target for national early warning system for food security would be to develop a methodology for monitoring vegetation crop growth conditions as well as estimating end-of-season crop yields. The methodology would enable us estimate end-of-season crop yield halfway into the growing season and this, if implemented, would give a precise advance warning on the food situation before the end of the season.

Early warning for food security is a relatively new multidisciplinary activity, and comprises an aggregate of methods that have been developed by various researchers, including regional early-warning and food security professionals. These tools and methods, which are in different phases of development, include the crop estimations method, food balance sheet approach, satellite imagery analyses, price analyses, current vulnerability assessments, and rural rapid appraisal method (Chopak, 2002). This research is limited to the application of satellite imagery analysis to early warning for food security issues.

The application of remote sensing in early warning has several advantages which include a wide and extensive coverage, regular data availability, timely data availability and dissemination, as well as cost-effectiveness. Satellite images are often the only information available in near real-time for the arid and semi-arid regions of Africa (Nigeria inclusive), which are often subject to drought and poor crop conditions, and where timely and reliable ground information is often difficult to obtain.

Many national, regional and global early warning for food security systems have been developed in many parts of the world. In Africa alone, three regional systems are worthy of mention. They are the system operated by the Intergovernmental Authority on Development (IGAD), a seven-country regional development organization in East Africa; the system operated by the Southern African Development Community (SADC); and the AGHYMET that covers countries in the Sahel. The SADC Regional Early Warning Unit operates as an integrated project, comprising a Regional Early Warning Unit (REWU), and autonomous National Early Warning Units in each of the ten original SADC member states. There has not been any early warning for food security system for the ECOWAS sub-region. However, most global early warning systems (i.e. Famine Early Warning System Network, (FEWS NET), Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS), Global Information and Early Warning System (GIEWS), also provide information on countries in ECOWAS, including Nigeria.

Factors influencing yield can be categorized as follows (Boken, 2005): (1) abiotec factors, such as soil water, soil fertility, soil texture, soil taxonomy class, and weather; (2) farm management factors, such as soil tillage, soil depth, planting density, sowing date, weeding intensity, manuring rate, crop protection against pest and diseases, harvesting techniques, post-harvest loss, and degree of mechanization; (3) land development factors such as field size, terracing, drainage, and irrigation; (4) socioeconomic factors, such as the distance to market, population pressure, investments, costs of inputs, prices of outputs, education levels, skills, and infrastructure; and (5) catastrophic factors that include warfare, flooding, earthquakes, hailstorms, and frost. Measuring or estimating some of these factors is often not feasible, and the influence of some other factors may be considered insignificant or constant in an economically stable region. It is therefore weather condition alone that affects crop yield most significantly. Various weather parameters such as temperature, precipitation, humidity, solar radiation, cloudiness, and wind velocity affect crop yield, but temperature and precipitation are most significant (Boken, 2005).

This paper describes satellite remote sensing and agrometeorological methodology for crop yield forecasting and prediction for Nigeria. An example of crop yield forecast for millet for the year 2005 planting season in Nigeria is illustrated. Section 2 surveys different models for crop yield prediction, and section 3 describes the result of the development of millet crop prediction model for Nigeria. Conclusion is presented in section 4.

2.0 Models

2.1 NDVI Difference Image Model

Remote Sensing-derived NDVI can be exploited for monitoring in a simple and straightforward way. The images of the current 10-day period (or dekad) can be used to compute two difference images. These reveal areas that are greening up or drying down. The second difference is with respect to the average NDVI for the historical period, say, 1981-2006. These reveal areas of anomalous conditions relative to the long-term average. NOAA AVHRR NDVI time series data can be downloaded from the website *http://earlywarning*. cr.usgs. Gov/adds/ datatheme. php

2.2 Rainfall Estimate (RFE) Difference Image Model

Remote Sensing-derived Rainfall Estimate (RFE) can be compiled on a dekadel basis, with each pixel's value representing an estimate of the millimetres of rainfall that have fallen at that location during the 10-day period. Image difference can be applied to them much the same way that it is to the NDVI images. A difference with respect to long-term average shows wet and dry rainfall anomalies. RFE archived data for Africa is produced by the NOAA's Climate Predicting Centre and can be downloaded from the Website http://earlywarning.cr.usgs. Gov/adds/d atatheme. php

2.3 Rainfall and NDVI Combined-Departures (RNCD) Model (Rowland et al., 2005)

A method based on departures of NDVI and RFE data from their respective averages can be used to monitor the annual growing season in an area and make qualitative assessment of harvest prospects up to 4-6 decades in advance. The RNCD is a method based on a combination of NDVI and RFE data into an index that reflects the quality of the growing season conditions, extracted for given administrative units. The growing season is divided into three distinct periods and diagnosed separately for each period. The results of the three periods are combined in a final step to diagnose the whole growing season.

2.4 Agrometeorological Crop Yield Forecasting Methods

Agrometeorological crop yield forecasting methods provide a quantitative estimate of the expected crop yield over a given area, in advance of the harvest and in a way that constitutes an improvement over trends;, provided no extreme conditions occur. In this context, "extreme" stands for conditions, which are statistically infrequent, which involve larger-than-usual energy such as tropical cyclone. WMO include pest outbreak (desert locust) among extreme agrometeorological events. Agrometeorological crop yield forecasting methods can be classified according to many criteria: for instance the type of inputs they require; the scale at which they apply; their capacity to perform correctly under unusual environmental conditions; their cost of development and implementation; their level of analytical and statistical sophistication. In this paper, we would consider two major methods - the regression methods, and the crop simulation methods.

2.4.1 Regression Models

Regression techniques rely on regression equations (linear and non-linear) between crop yield and agrometeorological variables, weather variables, vegetation indices and hybrid combinations of different variables. Some examples of regression method are:

(i) NDVI, SM, ST, and RFE Model (Prasad et al., 2005)

In this model, NDVI, soil moisture (SM), surface temperature (ST), and rainfall estimate (RFE) were used for crop yield assessment and prediction, using the piecewise linear regression method with breakpoint.
The model is given by the equation below.

$$Crop\,Yield = c_1 + (a_1 * NDVI) + (a_2 * SM) + (a_3 * ST) + (a_4 * RFE) \qquad (1)$$

where

NDVI is the Normalized Difference Vegetation Index,
SM is the soil moisture,
ST is the surface temperature, and
RFE is the rainfall estimate.

In this model, NDVI, SM, ST and RFE data are considered major indicators or variables controlling normal crop growth. This approach can be used to predict any shortfall in crop yield using empirical equations. Coefficients used in derived equation largely depend on a pool of historical data.