DROUGHT EARLY WARNING SYSTEM FOR CROP PRODUCTION

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Abstract. A new drought early warning system similar to the system developed by NOAA/NESDIS is suggested for implantation in Brazil. The proposed drought early warning system is based on three subsystems: agroclimatic index, satellite assessment and crop yield forecast subsystems. Each subsystem contains several well developed assessment tools, derived from various data sources. Assessment tools produced by the drought early warning system include: NOAA satellite products such as vegetation index and vegetation condition index maps; vegetation index time-series and color-coded images; agroclimatic indices such as crop water use maps; crop risk index tables and maps; and crop yield forecast models including agrometeorological models, crop growth models and vegetation index models. Short and long term weather forecast information should be incorporated in producing an assessment report. A geographic information system, which analyzes various data sources by overlaying, integrating and cross-checking between different assessment tools for consistency and convergence of information, should be used to produce a synthesized quantitative report.

Introduction

In the past few years, Brazilian annual total grain production have reached around seventy million tons. But some years dropped to as low as fifty million tons due to mainly the drastic nature of tropical rainfall variability. Since agriculture production is one of the most important Brazilian economy resources, the timely information of annual grain production will certainly avoid an economic disorder caused by frequent drought events. Hence, the development of new technology on crop yield prediction is urgently needed. Recent fast advance in using NOAA AVHRR data on large area crop drought early warning (Hutchinson, 1991), as well as yield forecasting (Maselli, et al 1992) shows that the timely forecasting of climatic impacts on food production through remote sensed daTA on an operational basis is feasible.

Various crop risk early warning systems have been established recently in Brazil. All these systems still do not fully explore the use of remote sensing data collected by satellite. A new Drought Early Warning System similar to the system developed by NOAA/NESDIS (Sakamoto and Steyaert, 1987) is thus suggested for implantation in Brazil.

System Description

The proposed drought early warning system is based on three subsystems: (1) agroclimatical indices, (2) satellite images, and (3) crop yield forecasts . As indicated in Figure 1, each subsystem contains several well developed assessment tools. These assessment tools are derived from various data sources collected for each subsystem. Assessment tools produced by the drought early warning system would include: NOAA AVHRR products such as weekly Normalized Difference Index (NDVI) and Vegetation Condition Index (VCI) images; agroclimatical indices maps such as crop water use and crop drought risk maps; and crop yield forecast models including statistical-agroclimatical models, plant process models and vegetation index models.

Agroclimatic Subsystem

An appropriate threshold for assessment potential climatic impacts is determined by analysis of the agroclimatical indices. There are several useful agroclimatic indices can be applied including: Water Balance Index (WBI) and Crop Yield Index (CYI) based on crop yield response to water use (Doorenbos and Kassam, 1979); Yield Moisture Index (YMI) based on crop weighted monthly cumulative rainfall amount (Sakamoto et al, 1984); and Crop Risk Index (CRI) based on the analyses of rainfall probability and weighting on yield response to crop water use (Liu et al, 1987). These crop risk indices, derived from historical data, are used in conjunction with episodic or ancillary information, such as insect attacks and floods. A reliable and timely rainfall data base is essential to derive these agroclimatical indices.

Satellite Assessment Subsystem

Meteorological radar and geostational satellite may be used to analysis cloud patters and hence to estimate rainfall amount. Also NOAA polar orbiting satellites provide daily Advance Very High Resolution Radiometers (AVHRR) data with a spatial resolution of 1.1 km x 1.1 km. Selected 1.1 km data are recorded and called as Local Area Coverage (LAC). The LAC data also are sampled internally to obtain 4 km resolution data, called Global Area Coverage (GAC). The standard NOAA/NESDIS AVHRR data in the Global Vegetation Index (GVI) is with a resolution of 16 km which is sampled from an array of GAC data (Kidwell,1991). The choice of LAC, GAC, or GVI data depends on the objectives, cost, hardware requirements, and the timetable imposed for a functional operational system.

Vegetation index images such as weekly maximum value composite NDVI and CVI image maps will be produced to monitor the crop growth conditions. Multi-temporal comparison of NDVI and VCI profiles provides an useful tool to analysis the crop green conditions at different phenological stages under different geographic conditions.

Figure 2 shows an example of annual drought area dynamics delineated by NDVI and VCI images (Liu and Kogan, 1993) which can be applied to monitor crop growth condition. NDVI drought pattern monitors the seasonal evolution of drought area under different geographical features (Fig. b); while VCI monitors the severity of drought occurrence for a specific region (Fig. 1d).

Crop Yield Forecast Subsystem

There are several alternatives for estimating crop yield. These include: crop conditions as observed in the field; statistical-agroclimatical models based on historical climate and crop data; plant process models based on the simulation of crop growth and development under certain climatic and crop genetic conditions; and satellite derived vegetation index models.

Statistical-agroclimatical models have been applied to crop yield forecasting with significant success in the seventies (McGuigg, 1975). However, the model will frequently fail to estimate the crop yield under such extreme events not recorded in the historic data used for building the model. Plant process models possess high precision once the model has been calibrated successfully (Hodges, et al 1987) but require a fair amount of daily meteorological data input. Satellite derived vegetation index models include NDVI (LIU, et al 1992) and VCI model. Although both models are still under their developing and testing stages (Maselli et al 1992, Liu and Kogan, 1993), these models possess high potential on large scale crop yield forecasting.

Liu (et al, 1992), compared three models constructed for estimating maize yield in the microregion of Ribeirão Preto, São Paulo. They found that the plant growth model had better estimate with a mean error of 3.3%, the statistical model with 6.5%, and the satellite NDVI model with 11.8%. Although the satellite model had a larger error, it had a better spatial information where other models had only limited point source data.

Each alternative has its advantage and disadvantage. All models have to be constructed and used to estimate different crop yields. Hence a reliable forecast of crop yield may be issued while the estimates of most models have converged to the same prediction. The real-tine, operational collection of various sources of information about crop conditions, environmental variations, weather development, ecological balance, and production estimates from various organizations may also help to cross-check the conclusions obtained from the three models.

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Figure 1. Structure of the Drought Early Warning System (DEWS)

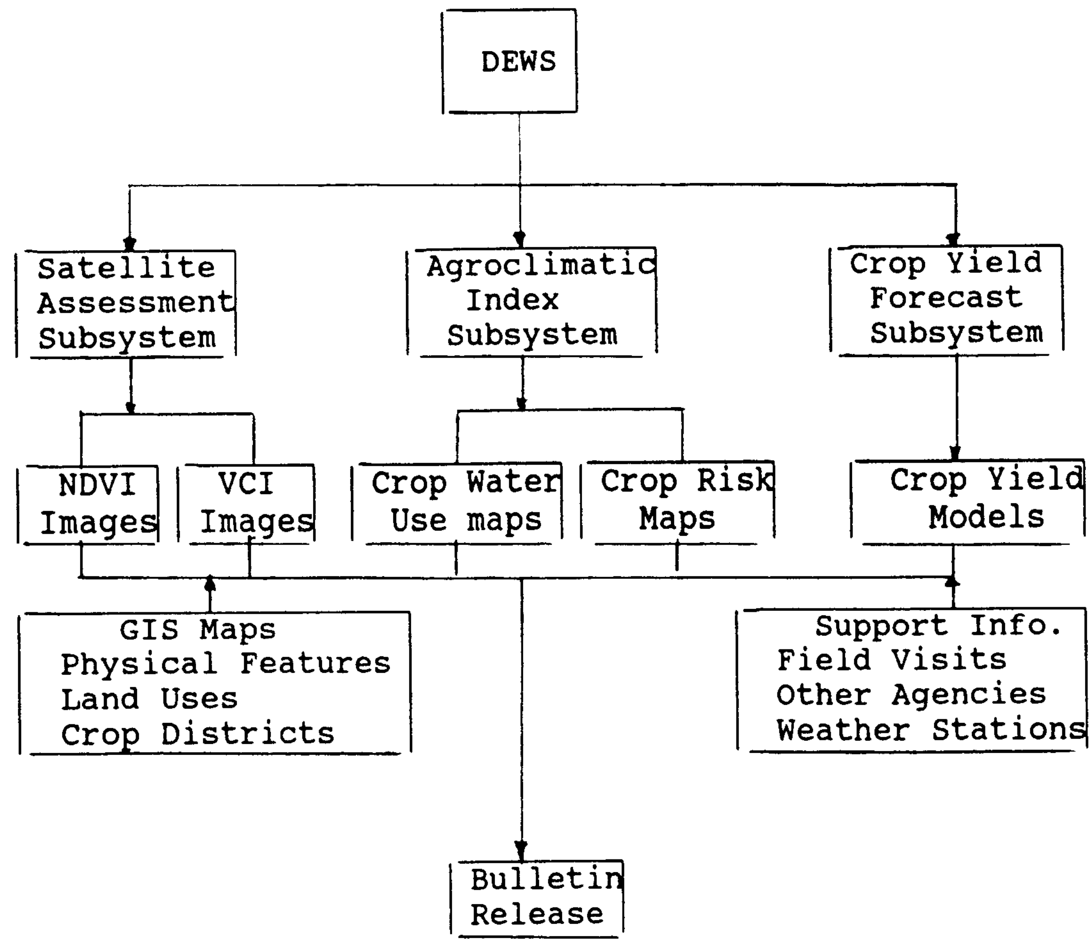

Fig. 2 - Drought area dynamics of South America Continent for the rainy season of 1986/1987.