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ANALYSIS OF AGRICULTURAL RISK BASED ON THE INFORMATION OF CLIMATE, SOIL AND CROP CONDITIONS*

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ABSTRACT

The prediction of crop success based on the analysis of long term climate data was attempted by using a computer simulation approach. The 5 day-rainfall amounts at different probability levels were analyzed by using an incomplete gamma distribution statistical package. A simple water balance model was programmed to estimate the field water balance through the year.

The combinations of different soil water storage capacities with different crop water requirements allow one to predict the probabilities of crop success under different soil environments for different crops. The fitting of the available soil water with the crop water use throughout the year provide the information of sowing time, harvest time and possible dry spells. It helps the farmers to have a better crop planting. With knowing the local soil water storage capacity and the crops intended for planting, one can easily tell the sowing time and the crop success probability from the output of this model. Furthermore, the model analysis provides the simple criteria for crop zoning while the water requirement of desired crop and soil water storage capacity are obtained. The zoning of important crops may also provide a better crop rotation system based on the appropriate soil and water managements.

INTRODUCTION

In the regions of semi-arid tropics, the erratic distribution of rainfall is often the main constraint of crop production. The traditional operation of rainfed agriculture at the semi-arid tropics in the northeast Brazil has three distinctive features. First is a trial-error method of planting. The farmers keep planting the seeds on the ground whenever the soil receives enough moist until the seedlings survive from the unexpected dry spells. Second, the farmers put as many different crops as possible on the very same piece of land. The farmers expect to harvest some high value crops if it is a good rainfall year or the drought resistant crops if it is a dry year. It provides a certain amount of insurance against crop failure. The third feature is that fertilizers and crop protection chemicals are not been used. Whenever the soil fertility is exhausted, they simply move on to the other land.

As a result of these farm practices, the rainfed agriculture in the semi-arid tropics is often characterized as low production, high erosion, and high risk of crop failure. In order to promote and stabilize crop productions in this rainfed agriculture land, we have to integrate our efforts on solving the production factors such as genetics, fertility, soil and water management, crop protection and management plus the consideration of social economical impacts. Nonetheless, the immediate effort probably will be concentrated on providing the farmers the information for better crop planning with less risk of crop failure based on the computer simulation approach with the analysis of the system of soil-plant-atmospheric continuum.

In order to provide the farmers the information of crop planning for better water management, one has to seek a simple approach to arrive at a reasonable approximation of field water balance based on long term climate data (Bernardo, 1974; Liu, 1977). The simulation model is developed to suit this purpose even without the information of local soil water storage capacity and local growth crop water requirements. It is the advantage of the simulation technique that the model simply assume a wide range of soil water storage capacity to cover the different soil types and soil depth, and a wide range of crop water use through a growth cycle. The farmers can obtain the information of the proper sowing time and the risk of crop failure against drought while they know the soil conditions in their field and what crop they are going to plant. This simple model hopefully will provide the useful information for farmers' immediate need in crop planning such as cropping systems and soil and water managements for the optimum yield of rainfed crops.

The detailed work of the water balance models in a cropping or a non cropping field has been studied intensively (Ritchie, 1972; van Bavel, 1966 and Hillel, 1971). The models do provide reasonable predicton of the field water balance. While the application of the models to other field conditions, many input parameters have to be obtained from the particular field for a particular crop before the model can be suitably applied. Most models require the daily rainfall data in order to have an accurate amount of water been put into a water balance equation. It does create some difficulty in the prediction of crop success before planting since there is often a great variation of daily rainfall from year to year. Hence the long term rainfall data as the input were used in our model. The rainfall inputs were classified as 13 classes depending on the 13 levels of probability obtained from the incomplete gamma distribution analysis. From the comparison of water balance at a crop field with certain soil-crop information, one can obtain at a certain level of rainfall amount for growing the crop. The perçentage of crop risk then is obtained from the probability level of the incomplete gamma distribution analysis.

The study can also be extended to obtain a detailed agroclimatological zoning for certain regional important crops. The agroclimatological zoning will provide an important information for a regional farming systems development (Dillon, 1978). A set of cropping system and management for optimum yields on rainfed land then can be developed and utilized.

METHODS

Data of rainfall were grouped into a 5-day interval' through Julian year. Each month was divided into 6 periods of 5-day interval. The month with 31 days have a period of 6 days at the end of the month. In February, the last period contained either 4 or 3 days depending on the leap year or not. Hence, a year was divided into 72 periods. These presigned periods were used as the time scale throughout the analysis.

The occurrences of certain periods of rainfall were treated as mutually independent random variables with an incomplete gamma distribution. A computer program of incomplete gamma distribution of rainfall analysis is available at the World Meteorological Organization. This program was employed to calculate the cumulated rainfall of 5-day interval at twelve probability levels (95%, 90%, 80%, 75%, 70%, 60%, 50%, 40%, 35%, 25%, 10% and 5%).

$$ASW(N+1) = ASW(N) + PPT(N+1) - AET(N+1) - ROFF(N+1) \ldots \quad (1)$$

According to the simple water balance equation (eq. 1), the net soil water storage (ASW(N+1) at the end of each period can be estimated by the sum of ASW(N) at the end of the previous period and the amount of rainfall (PPT(N+1)) received in this period, substracting the soil water losses due to evaporation or actual evaportranspiration (AET(N+1)) and runoff (ROFF(N+1)).

The ROFF term is defined as the amount of water exceeds a certain maximum soil water capacity (MWA) within a certain period of rainfall.

The term of AET(N+1) was estimated by two equations at two stages of field conditions - cropping and non cropping time (Ritchie, 1972).

The cumulative evaporation equation (Black et al., 1969) was used to estimate the evaporation from the bare soil during non cropping time; while the actual evapotranspiration was estimated as a function of soil water status, crop stages, and evaporative demand during cropping period.

$$AET(N+1) = CRH * KCROP * SOIL * PET$$

Where CRH = monthly mean relative humidity, expressed as

$$CRH = 1.1 - 0.002 * RH(\%)$$

KCROP = Crop water requirement coefficient, expressed as the ratio of AET to PET which varies with the growth stages (Doorenbos, 1977).

SOIL = soil water content coefficient, expressed as

SOIL = $\log_e (SWA+1)/\log_e(MWA + 1)$, (Pierce(1958); Bernardo, 1975).

PET = potential evapotranspiration, as a function of extraterrestal radiation, temperature, relative humidity and sun angle (Hargreaves, 1974).

Crop water requirements are often described by the KCROP which are ratios of AET to PET at different growth stages.

The KCROP were estimated by 3 approximate curves for 3 duration crops through the growth stages (Doorenbos, 1977).

With the comparision of available soil water and crop water use through the growth season, a reasonable success of crop yield can be expected if the available soil water storage curves is above crop water use curve.

The sowing time for the long duration crop will be selected at the begining of the rainy season with a rainfall greater than 10 mm. For medium and short duration crops the sowing time, will delay 5 periods and 8 periods respectively in order to fit the peak crop water use with the peak rainfall amount. In examining the rainfall distribution obtained from the incomplete gamma distribution analysis, one can easily select the sowing time for obtaining the best water use, easer land preparation, dryer periods for harvesting time, etc.

SAMPLE ANALYSIS

Weather data at the Bebedouro Experimental Station have been on the records only 15 years. Due to some missing data, 13 years of data were used for this analysis.

Computer program and outputs of mean rainfall, potential evapotranspiration, probabilities of rainfall, surface runoff and water balance were listed on the appendix.

From the result of crop risk analysis, in the Bebedouroro region, the cropping success is about only 10% (Fig. 1). It indicates that the farmer in this region can only expect to harvest the crop with reasonable productivity once every 10 years. For agriculture development, it is nearly infeasible to grow dry land crops. Hence the dry land agricultural activities in this region are concentrated on goat production. Even the cattles are difficult to raise because of the 4 to 5 months of dry season (Fig. 2) which all the native available vegetation are in dormancy or dry out.

Due to the high risk of agriculture production, one has to seek some alternative tecnologies in order to increase and stabilize agriculture productions. Besides the irrigation projects which have been developed by CODEVASF and DNOCS, a suitable farming system can be developed by rainfall water harvesting (Liu, 1978). Therefore, the crop risk analysis is important in crop planning and in the selection of suitable tecnology for agricultural development.

FIG 1. CROP RISK ANALYSIS

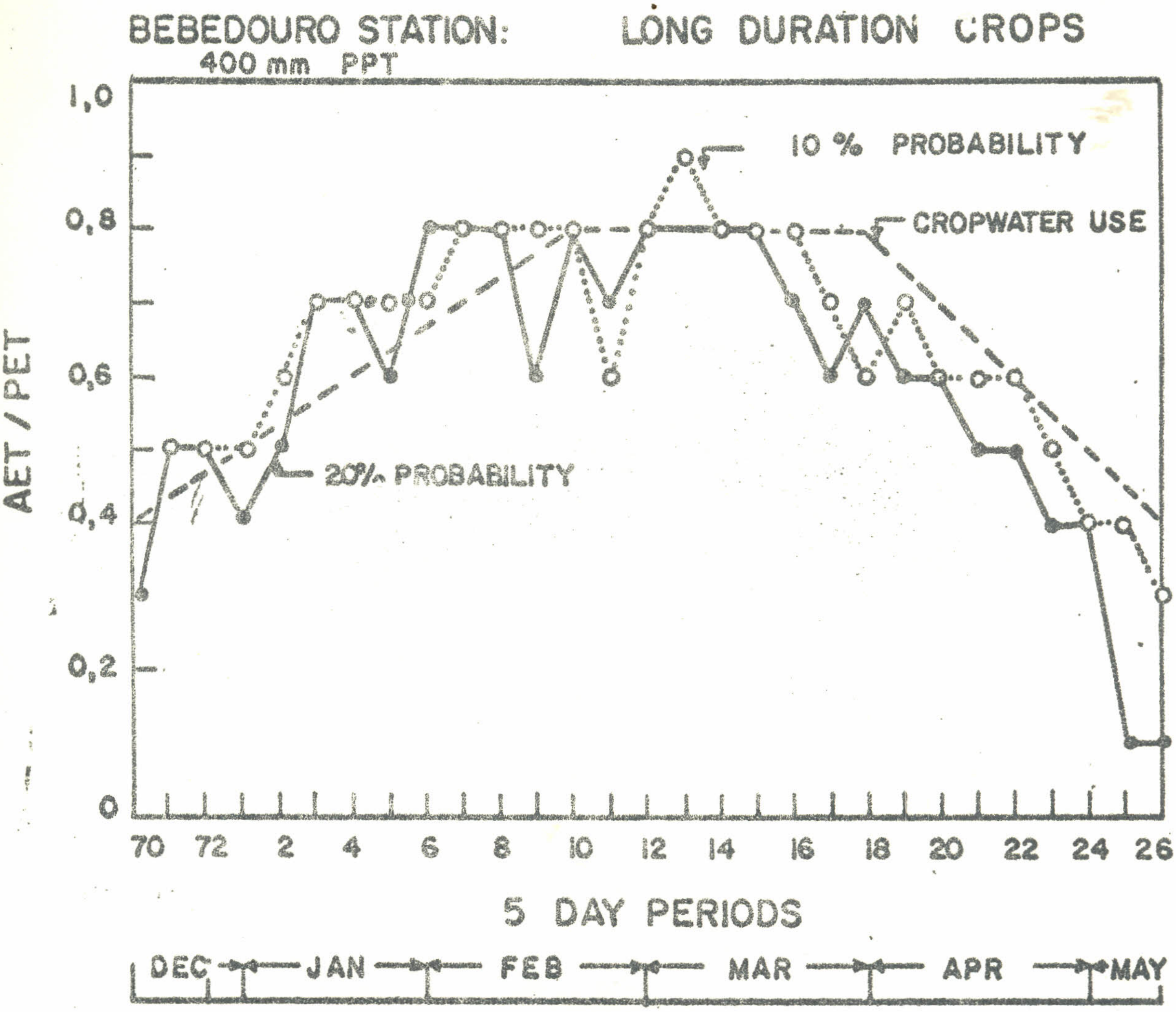
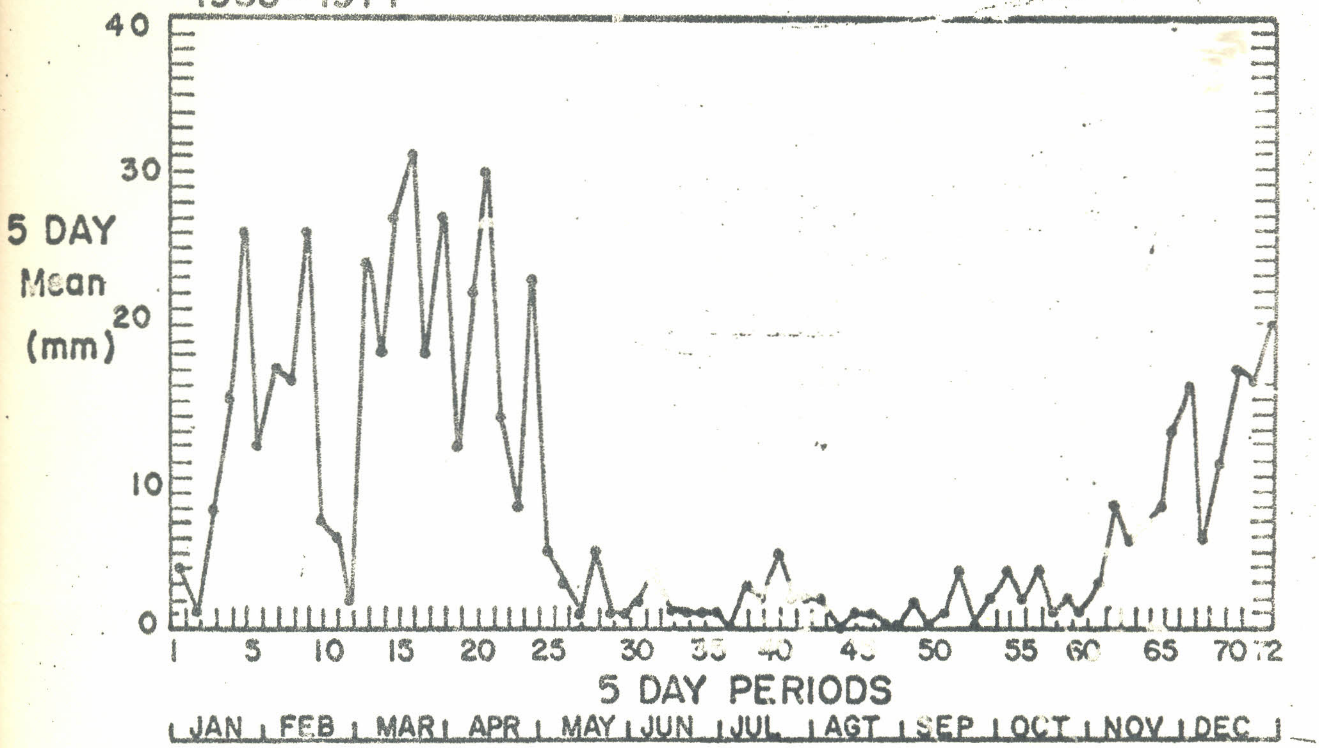


FIG 2. MEAN RAINFALL FOR 5 DAY PERIODS
BEBEDOURO STATION:
1965 - 1977



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APPENDIX

Due to the oversized computer printouts, the listing of computer program and outputs are only provided upon request.