12.C.5 AGROMETEOROLOGICAL FORECAST AND WARNING SYSTEM FOR SÃO PAULO STATE, BRAZIL

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1. INTRODUCTION

The State of São Paulo comprises an area of 248.600 km^2, and is located between the coordinates 44°10'44'' and 53°7'42'' longitude west and 19°46'24'' and 25° 18'12'' latitude south. Its altitude varies from sea level to regions with elevation close to 2.000m situated in the "***Serras do Mar and da Mantiqueira".*** Its topographic characteristics as part of the State follow the Atlantic Ocean, and both mountain chains close to the coast form a large temperature diversity and availability of water resources, with annual temperatures varying from 14 to 23° C and total annual rainfall ranging from 1200 to 2500 mm.

These distinct climatic situations, with water deficits and water surplus periods clearly defined allow a very diversified and highly technical agricultural exploitation. The agribusiness is very profitable and based on perennial crops such as: coffee, citrus, sugar cane, pastures, as well as annual crops such as: corn, wheat, barley and horticulture. On the other hand, the climatic differences allow the cultivation of tropical fruit such as banana, mango and pineapple and subtropical or mediterranean climate fruits such as figs, grapes ,apples and peaches. This high agricultural diversity and the value of agribusiness are intimately related to the technologies generated in the Agricultural Research Institutes and undoubtedly we can claim that much of this development is due to the more than 115 years of research and technologies developed by the Instituto Agronômico de Campinas, providing the technologies for adapting and agricultural exploitation of the distinct edaphoclimatic regions in the State.

Even with its high degree of development, agriculture in the State of São Paulo is frequently affected by climate variability such as : frost, drought, flooding. The intensity, frequency and evaluation of these events are very distinct, and the effect of these meteorological adversities on agriculture and society depend on an agile and reliable monitoring system of the agroenvironmental variables.

The Agriculture and Supply Department through the ***Instituto Agronômico de Campinas*** operates a network of meteorological stations with about 116 data collection locations in the State. The largest part of these meteorological stations has contributed with over 60 years of observation, and Campinas alone has historic data series dating from 1890.

The meteorological data collected in this network offer support to statewide agricultural development plans, water resources, research, agricultural zoning, agribusiness activities, among others.

2. AGROMETEOROLOGY FORECAST AND WARNING SYSTEM

The interactions between the meteorological factors, crop development and the various agricultural activities are very dynamic and demand continuous surveillance and monitoring.

Aware of this, the Agriculture and Supply Departament through the Instituto Agronômico de Campinas (IAC) started in 1988 an Operational Advisory System based on agrometeorological information aiming to offer support to agricultural activities. The counseling and agrometeorological analyses are conducted by the Integrated Center for Agrometeorological Information (CIIAGRO) (Brunini et al, 1996). It is an operational framework that provides agrometeorological information to farmers and extension services regarding the type of soil, crop development, agricultural practice, pest management, irrigation requirements, climatic risks (frost, drought, dry spell), stored water in the soil, water balance, crop yield, and weather forecast. It is based on a network of 116 weather stations.

The basic objectives of the agrometeorological information system can

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be summarized as: a)supply agrometeorological information to the agribusiness to help in the decision process for agricultural practices; b)support public strategies for food production and civil defense; c) drought preparadness and mitigation.

Currently, the procedure for the elaboration of these reports consists in the gathering and analyses of daily air temperature and rainfall data. These parameters are collected twice a week, typed into a computer and by means of specific software, the water balance and agrometeorological analyses of the 116 locations in the State of São Paulo are prepared. This considers the types of soil, crops and growing season (Brunini et al, 1998). The potential evapotranspiration is estimated according to the Camargo & Camargo equation (1983) and the water balances are performed based on the Thornthwaite & Mather – 1955 methodology, and also on the ratio between ETR/ETP and the available water in the soil.

Agrometeorological bulletins bring the meteorological informations, the counseling and the agrometeorological warning referring to the following parameters and agricultural activities(Table 1)

a)Crop calendar, soil tillage, crop sowing and harvesting;**b)**Application of agricultural chemical products;**c**)Irrigation management and crop water requirements; **d**)Frost and other adverse phenomena;**e)**Meteorological Data;**f**)Soil water balance and crop development**;g**)Weather forecast for the next 72 hours and its effects on agriculture;**h)**Drought indices and rainfall anomaly

Based on the information presented in the agrometeorological bulletin, agroclimatic maps are produced as in the example presented in figure 1. In this case only the water availability in the soil, and its effect on crop development are discussed.

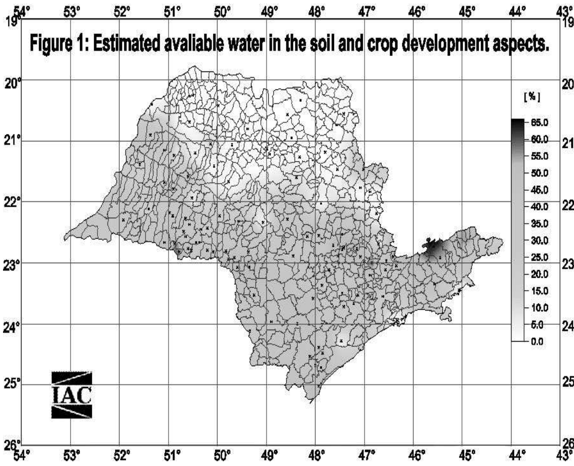
Figure 1: Estimated avaliable water in the soil and crop development aspects.

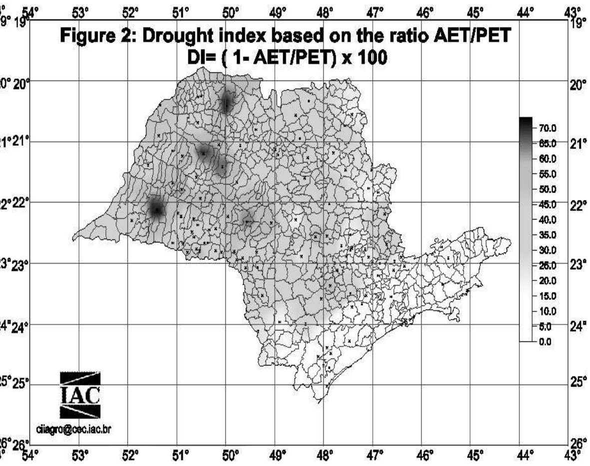
Figure 2: Drought index based on the ratio AET/PET DI= (1- AET/PET) x 100

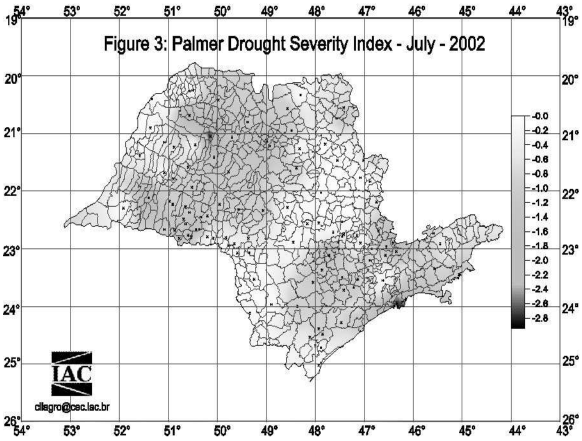
Figure 3: Palmer Drought Severity Index - July - 2002

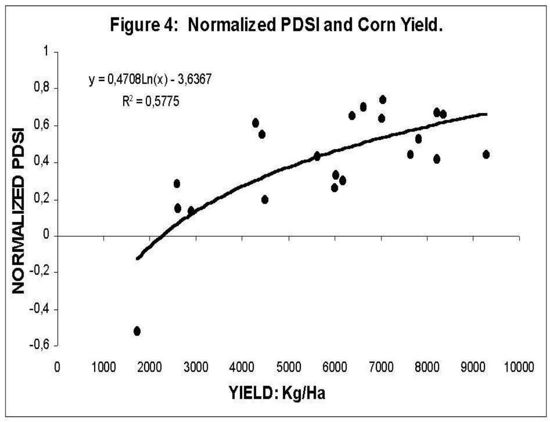

Figure 4: Normalized PDSI and Corn Yield.

It is worth pointing out that the agrometeorological bulletins and the warning forecast are issued twice a week and divulged through Newspapers, TV, Internet and Fax and can be accessed at the following website: www.iac.br/ciiagro. These bulletins are forwarded to Universities, Technical Assistance Services Agricultural Schools, State Secretariats, Civil Defense, Water Resources Department, Farmers and Agricultural Cooperatives. Currently more than 10,000 persons have weekly access to these agrometeorological bulletins.

3. DROUGHT MONITORING AND PREPARADNESS

Agricultural planning and all correlated activities are directly associated with meteorological elements and their oscillations. Among these elements, the pluviometric precipitation is the most active and restrictive. On the other hand, the use of drought indices depends, in many cases, on :

- availability and continuous reception of meteorological information;
- ultimate purpose or application of the drought index;
- ease in making the index available to the various segments of the productive sector.

One of the most practical methods for quantifying a drought index is through the confrontation between the source and the sink, which in this case can be specified by precipitation (P) and the Potential Evapotranspiration (PET).

For Brazil, the Integrated Center of Agrometeorological Information (CIIAGRO) uses, the following criteria for the routine evaluation of the drought conditions and crop development:

a) Absence of stress conditions
$P \leq PET$ and $W/Wx \geq 0.60$

b) Moderate stress conditions
$P \leq PET$ and
$0.40 \leq W/Wx < 0.60$

c) Dry conditions
$P < PET$ and
$0 < W/Wx < 0,40$

d) Extremely dry conditions
$P = 0$ and $W/WX = 0$

where:

W= total water availability in the soil
Wx= maximum water availability in the soil
P = Accumulated Rainfall
PET = Potential Evapotranspiration

Considering that crop responses to drought may vary considerably depending on their phenological stage and actual evapotranspiration (AET), a drought index (DI) based on the ration AET/PET is currently been used, and it is defined as:

$$DI = 1 - (AET/PET)$$

Actual and potential evapotranspiration are calculated in a 10-day period considering maximum water holding capacity of the soil as 125 mm.

These conditions are evaluated weekly in a routine process for 116 locations in the state of São Paulo, generating drought intensity maps for the State as presented in figure 2.

3.1. PALMER DROUGHT SEVERITY INDEX (PDSI)

One of the most employed and world renowned methods for drought quantification is the Palmer Drought Severity Index (PDSI) (Palmer, 1965).

Currently the Integrated Center of Agrometeorological Information (CIIAGRO) has been developing studies and applications for the PDSI for the entire State of São Paulo, making it available through web site access.

PDSI is determined as:

$$PDSI_i = 0{,}897 PDSI_{i-1} + (z/3)$$
$$z = (Pi - \overline{P}i)Ki$$

The normalization value for K_i was determined experimentally by Palmer (1965) using 9 locations in the USA. For the State of São Paulo (Brunini et al. 2002) working with parameters from 93 separate locations determined that the K_i would be equal to:

$$Ki = \frac{21{,}14K'}{\sum_{1}^{12} DK'}$$

Making the estimation of the PDSI more accurate.

A sequential analysis of the PDSI of 3 contrasting periods, that is, in extremely dry years like 1963/1964, 2000/2001 and very humid years such as 1982/1983 was conducted for the locations of Tatui and Campinas, considering a period for analysis from 1932 to 2001,for Tatui and from 1890 to 2001 for Campinas It was observed that the PDSI allows a continuous monitoring of drought conditions indicating precipitation anomalies with a PDSI smaller than -3 (drought) or higher than 4 indicating excessively moist conditions in the State such as in the 1982/1983 period.

PDSI are monthly available for São Paulo as indicated in figure 3.

It must be noted the most of PDSI studies refers to monthly analysis of the water balance parameters. This does not always yield satisfactory results when evaluating the impact of a drought on an annual crop, making it interesting to have this analysis carried out at least every 10-day period.

An analysis of the drought conditions as indicated by the PDSI at a decadal level and the productivity of the corn crop is presented for the period from 1992 to 1994 for the location of Votuporanga – SP.

Note that with 60% chance the PDSI can account for the reduction in this crops yield, which is very good in terms of agricultural planning (Figure 4).

In this case the normalization of the PDSI value was defined. It was observed that between -0.2 and 0.2 there would be no effect on the crop and the normalized index values for PDSI are calculated by:

$$\overline{PDSI} = \left(\frac{PDSI - 0.2}{PDSI}\right)$$

3.2. STANDARDIZED PRECIPITATION INDEX (SPI)

The Standardized Precipitation Index (SPI) was developed to evaluate the precipitation anomalies for a given location, comparing these anomalies within predetermined time intervals (McKee et al. 1993).

In Latin America this index has been used recently to monitor and quantify the dry periods (Seiler & Bressan 2000, Brunini et al 2000, 2001).

The Integrated Center of Agrometeorological Information (CIIAGRO) is currently developing a routine methodology for the evaluation of the SPI for the entire state of São Paulo based on meteorological information gathered in 116 locations. The SPI parameters showed a perfect adjustment for the evaluation of drought periods in this State in critical years such as 1963 and 2000/2001, either when considering monthly totals (SPI-1) or for semesters (SPI-6) or annual analysis (SPI-12) (Brunini et al. 2001). The SPI analysis, the monthly (SPI-1), quartely (SPI-3) values are presented in figure 5 and figure 6 for June 2002.

4. MODERNIZATION OF THE METEOROLOGICAL NETWORK

The recent scenarios established by the IPCC (International Panel for Climatic Changes), describe a sharp increase in overall global temperatures, which leads to an increase in specific extreme meteorological events such as:

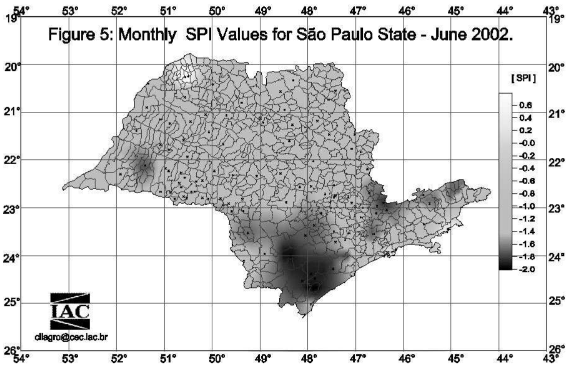

Figure 5: Monthly SPI Values for São Paulo State - June 2002.

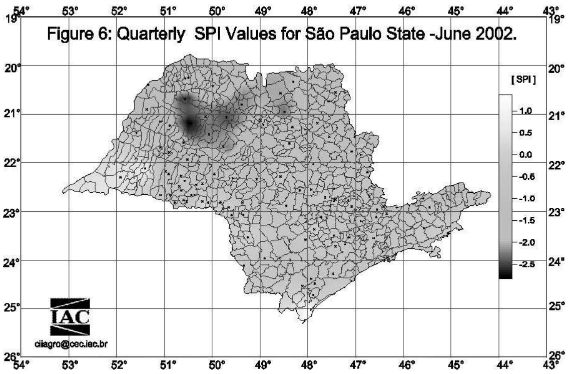

Figure 6: Quarterly SPI Values for São Paulo State -June 2002.

droughts, flooding, frost and hurricanes. In this sense, society must adapt and develop methodologies and strategies to overcome these climatic, meteorological and agronomical adversities, so as to reduce the negative impacts of these abnormalities and its effects on society.

Considering that 70% or more of these extremes and adversities are directly related to meteorological aspects, monitoring these meteorological variables must be continuous, practical and agile, in order to establish strategies and effective and efficient proactive measures.The future projection of the AWSN considers a total of 120 AWS.

The AWS network foresees that all weather stations will have on line access via telephone or radio, or based on a web site design. In this manner the meteorological information could be obtained in whatever time interval deemed necessary, in the event of extremes, or on an hourly basis in regular cases. In order to offer best support to maintenance and managing of the meteorological stations network, the State and the network will be divided into 10 Regional Support Units in such a way that in a 150 km radius performance defects will be immediately corrected.

Table 1– Example of a weekly agrometeorological bulletin for the State of São Paulo-BR

PERIOD ANALIZED: FROM 01/14/2002 a 01/16/2002 -

WATER AVAILABILITY IN THE SOIL AND TIILAGE

The agrometeorological conditions remain favorable for summer crops such as: corn, soy bean, cotton, rice, beans and peanuts and also perennial crops such as citrus, coffee, cotton, sugarcane and pasture. The elevated rainfall indices of the last days were harmful to certain crops, regarding the application of pesticides or sowing .

HARVEST AND PESTICIDE APPLICATION

Conditions remain favorable for the maintenance of agricultural practices in general and specially harvesting.

TECHNICAL COMMENTS

The elevated rainfall indices and low solar radiation recorded in the State of São Paulo for the last few days affected agricultural activities and specific crops such as:

Peanut – affected the crop management, pesticide application, causing an increase in diseases and hindering the harvest in this period.

Cotton – affected the application of pesticides causing a drop in the reproduction organs which may affect final production.

AGROMETEOROLOGICAL SUMMARY

Locality	DI-Days >10 mm	> 0 mm	AWS mm	WDS mm	IR	SM	CH	AS
CAMPINAS	0	0	42	0	NO	FAV	FAV	FAV
MOCOCA	0	0	42	0	NO	FAV	FAV	FAV

WEATHER FORECAST AND AGRICULTURAL PRACTICES

01/17/2002 – sunny and partially cloudy, no forecast of rain, favoring agricultural practices.
01/18/2002 - sunny,no forecast of rain, favoring agricultural practices.
DI – rainfall abnormality; AWS – available water in the soil; WDS - water deficit in the soil; IR – irrigation requirements, SM; CH and AS – soil management; crop harvest and pesticide application respectively.

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