DROUGHT WATCH IN ARGENTINA USING SATELLITE IMAGERY

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ABSTRACT

NOAA - AVHRR derived indices were use in the main cropping area of Argentina to detect and monitor drought conditions during 1995/96 and 1996/97 crop seasons. Comparisons of the stressed vegetation areas against soil moisture anomalies and precipitation were in good agreement showing the potential of the satellite derived data to determine the area and intensity of droughts.

INTRODUCTION

Droughts are a national problem and early detection of the affected areas in a country and the evolution of the phenomenon is a major concern for the national security and for the actions to take to mitigate the impacts. Droughts affect the economy of the regions, the quality of the ecosystems and also human life. Until substantial improvements in long term predictive capability of droughts occur, early detection and continuous assessments are valuable procedure to call for actions against severe conditions.
In this context, the utility of remote sensing data has already been proved as an efficient and powerful means of environmental monitoring. Because of the characteristics of temporal frequency and spatial resolution, the data adquired by NOAA satellites with AVHRR (Advanced Very High Resolution Radiometer) sensor at present provide the most efficient operational tool for real time assessments. A wide variety of studies, illustrating the utility of AVHRR data for such purposes, have been conducted covering different ecological environments (Lozano-García, et al. 1995; Kogan, 1995a, 1995b; Hobbs, 1995; Liu and Kogan, 1996).This paper presents an analysis of recent droughts in the main cropping area of Argentina and an attempt to validates AVHRR derived indices for drought monitoring in the region.

DATA AND METHODOLOGY

Satellite data in the Global Vegetation Index (GVI) format (7-day composite and 16 by 16 km^2 resolution), were provided by the NOAA/NESDIS Satellite Research Laboratory, in Camp Spring, Maryland (USA). This data were collected from NOAA-14 satellite for South America, from August 1996 to February 1997. The AVHRR has five channels: the visible, near infrared, and three thermal infrared regions of the spectrum. The radiances in the visible and near infrared spectral bands were calibrated following Rao and Chen (1995) and the Normalized Difference Vegetation Index (NDVI) was calculated (Tarpley, *et al.*, 1984; Goward, *et al.*, 1991). The thermal bands measurements were converted to brightness temperature (BT) using a look-up table. The NDVI and BT were smoothed to eliminate high frequency noise from the data.
To monitor weather impacts on vegetation such as drought detection and tracking, the Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI) have shown to be successful (Kogan, 1995a). They are represented by the following equations:

$$VCI = 100*(NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min})$$
$$TCI = 100 * (BT_{max} - BT) / (BT_{max} - BT_{min})$$

where $NDVI_{max}$, $NDVI_{min}$, BT_{max} and BT_{min} are the multi-year maximum and minimum NDVI and BT, respectively for each pixel of the area and each week of the growing season.

The idea of these indices is based on the concept of stratification of ecological potential of an area given by climate, soil, vegetation, and topography and by separation of the short-term weather signal from the long-term ecological signal in the data. The brightness temperatures in AVHRR channels 4 and 5 depend mainly upon the surface temperature, total column atmospheric water vapor and surface-atmosphere temperature gradient (Gutman, et al., 1995). From those channels, only channel 4 data were used since the channel 4 derived temperature is less responsive to water vapor in the atmosphere (Kogan, 1995b). The algorithm for the TCI is similar to the one for the VCI; however, the formula was adapted to represent the

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different response of the vegetation to temperature. That is, high temperatures in the middle of the growing season may indicate unfavorable or drought conditions while lower temperatures may indicate mostly favorable conditions. A combined VCI/T4 index was calculated as (VCI+TCI)/2 for each pixel and week and was used to characterize the 1995/96 and 1996/97 summer crop seasons. The VCI and TCI change from zero for extremely unfavorable conditions to 100 for optimal conditions.

The study covered the pampeana region in Argentina, including the provinces of Buenos Aires, Cordoba, Santa Fe, Entre Rios and La Pampa. Precipitation charts for the region were available from the National Weather Service (NWS) in Argentina and also, soil moisture charts as anomaly of the soil water storage from the normal for the period 1961-95, according to Forte Lay and Aiello (1996).

RESULTS AND DISCUSSION

During the 1996/97 crop summer season, drought occurred in different areas of the pampeana region. Drought extent and severity were outline by precipitation deficits and storage of soil moisture derived from the NWS charts. Late precipitations delayed planting at the starting of the growing season (September/October) 1996 in the provinces of Santa Fe, central and south Cordoba, northeast Buenos Aires, north La Pampa and Entre Rios. Although the area of drought decreased by mid December, the south central part of Cordoba was a center of a region where soil moisture was dryer than normal (Fig. 1). This dryness persisted until the end of February of 1997 and is likely to cause significant crop yield reductions. Drought in the pampeana region was also observed during the 1995/96 crop season and caused a long time depletion of soil moisture. Plant responses to the environment are complex and it is difficult to find in situ measurements or parameters derived from meteorological analysis alone able to characterize drought and the resulting vegetation stress.

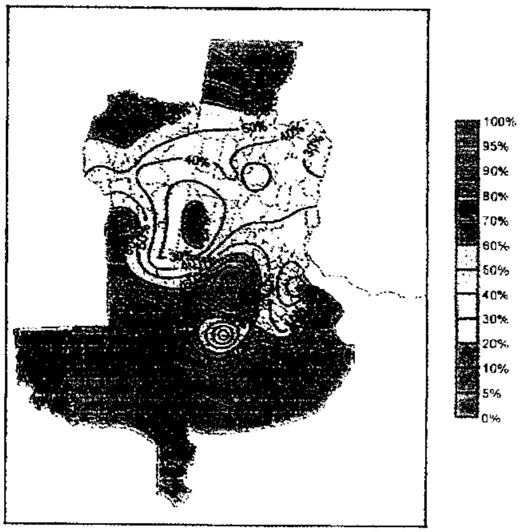

Fig. 1. Departure of soil moisture from normal in the pampeana region on December 16, 1996 (<5:much drier than normal; 40 - 60: around normal;>95: much wetter than normal).

Fig. 2. VCI/T4-derived vegetation condition during the second week of December (wk 24) (red: below 30 %; green: 31% to 70%; blue: above 70%)

Drought conditions were analyzed by the VCI/T4 index which characterizes vegetation health in response to the weather conditions. Comparison of the images of VCI/T4 with soil water storage anomalies showed a coincidence of drought area with ground measurements. Unfortunately, sparced ground observations make it difficult to compare area affected by drought with satellite observations. To facilitate the comparison, VCI/T4 numerical values were aggregated for three large categories, below 30%, 31% to 70% and, above 70% (Fig. 2). Satellite indices provided more accurate information on drought extent, severity, and impacts compared to ground observations. Example of a water stressed area is shown in the figure in southwest and northwest BuenosAires, southeast Cordoba, south Santa Fe and north La Pampa provinces. Images of VCI/T4 show the dinamics of the drought-affected areas in mid February of 1996/97 in comparison with 1995/96 (Fig. 3).

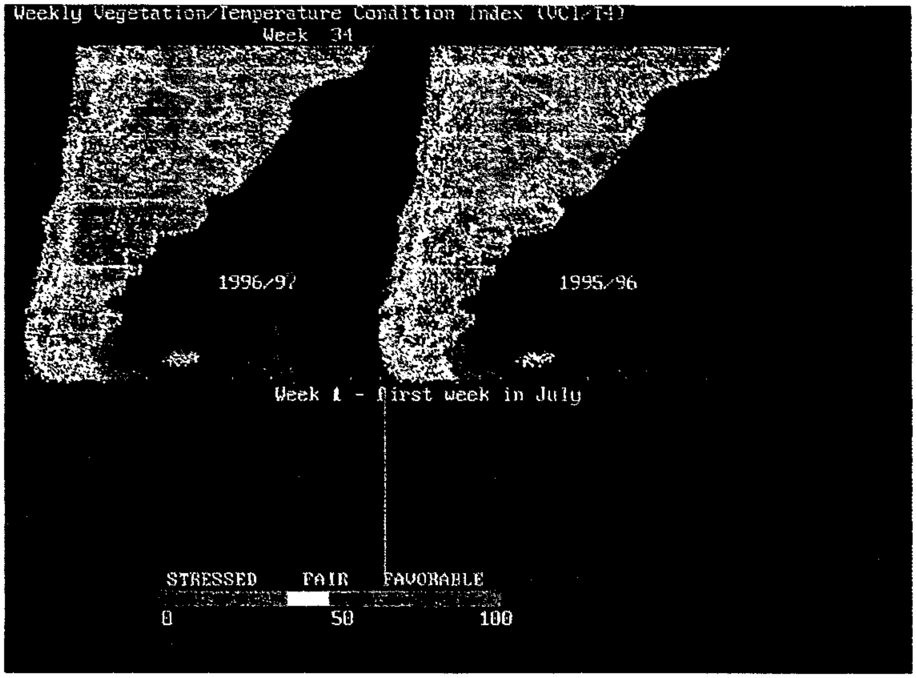

Fig. 3. Comparison of the vegetation condition during the third week of February for the 1995/96 and 1996/97 crop seasons, respectively.

At the end of the growing season of 1996/97 droughts were still observed in southeast Cordoba, central Santa Fe, and southern Entre Rios. The remaining pampeana region vegetation condition was favorable. During 1995/96 season, vegetation was under severe water stress as satellite data showed. Results of the analysis demonstrated that the VCI and TCI can be used for practical purposes of drought monitoring and tracking.

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