ANALYSIS OF NOAA/AVHRR MULTITEMPORAL IMAGES, CLIMATE CONDITIONS AND CULTIVATED LAND OF SUGARCANE FIELDS APPLIED TO AGRICULTURAL MONITORING

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ABSTRACT

The purpose of this work is to assess the sugarcane yield variation in regional scale through NDVI images from a low resolution spatial satellite. We have used Principal Component Analysis (PCA) and Cluster Analysis to correlate sugarcane cultivated land with multitemporal NDVI images also verifying the influence of climate conditions to them. According to both techniques (PCA and clustering), clusters for different set of variables are distinct only when cultivated land was included in the dataset. On the contrary, climate variables determine the clustering formation. Exploring multitemporal images from high resolution satellites through data mining techniques, such as cluster analysis, is a valuable way to improve crops monitoring specially at a time when it becomes increasingly important to understand the impact of climate change on agriculture.

Index Terms— Clustering, PCA, time series, low spatial resolution, NDVI

1. INTRODUCTION

The NOAA/AVHRR is a meteorological satellite whose technical characteristics allow its use in vegetation studies, such as: high temporal resolution, low spatial resolution and global coverage that increases the availability of images with low cloud cover and low satellite viewing angle. Thus, there is a great volume of NOAA/AVHRR multitemporal images that can be used in agriculture to improve crops monitoring throughout the crop season, in particular agriculture crops that are cultivated in large extensions, such as the sugarcane.

Brazil is the largest sugarcane producer in the World, contributing with 35% of global production, followed by India, Thailand and Australia. The main derivatives of sugarcane, such as sugar and ethanol, are important to Brazilian economy, attending to the national and international markets. In fact, sugarcane is strategic to the Country since it is the main source of renewable energy used to replace fossil fuels and reduce the emission of greenhouse gases [1].

In Brazil, the phenological cycles of sugarcane have two different lengths: 12 months (called "plant cane") and 18 months (called "ratoon cane"). This difference in both cycles is not evident in low spatial resolution images then increasing the spectral mixture in the pixels. However, this spectral mixture that occurs in some pixels does not disturb the images analysis of agricultural crops cultivated in large and contiguous areas, such as sugarcane. Thus, NOAA/AVHRR has been used to estimate sugarcane productivity [2] and to assess the influence of climate conditions in sugarcane growing [3].

This paper presents a principal component analysis and cluster analysis to verify the relationship of multitemporal NDVI images, climate variables and cultivated land official data to assess the sugarcane yield variation in regional scale. NDVI images were calculated using NOAA/AVHRR satellite of eight sugarcane crop seasons. Clusters were similar when data of cultivated land were used with NDVI and climate data and were different when that variable was not included in the analysis. Clusters are only distinct when the cultivated land is not included in the dataset. The principal component analysis showed that the principal component 2 (PC2) with different variables only when the precipitation distribution was dissimilar of the Climatological Normal. In the other years, PC2 is composed of variables maximum temperature and cultivated land. These set of analysis contribute to better understand the sugarcane development and expansion.

2. MATERIAL AND METHODS

The study area is composed of 16 cities located in the São Paulo state (Figure 1), which is the main sugarcane producing region in Brazil. São Paulo state is located in Southeastern Brazil (54° 00' to 43° 30' W and 25° 30' to 19° 30' S). NDVI multitemporal images were obtained from NOAA-16 and NOAA-17 satellites from April 2001 to March 2009.

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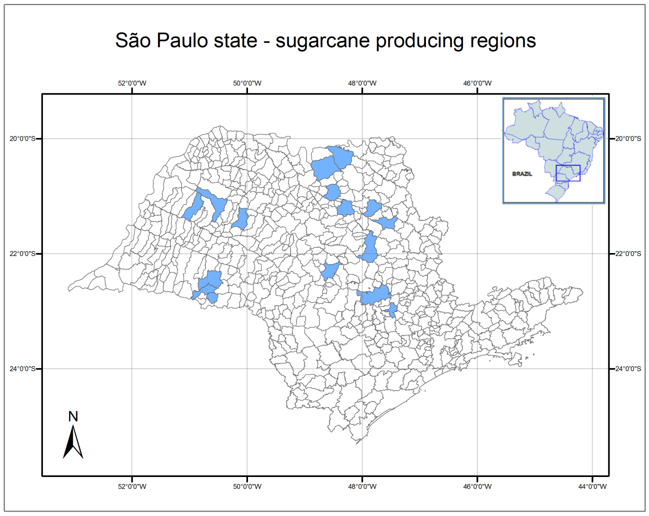

Fig. 1. Map with 16 cities of São Paulo state used in the cluster analysis.

We have used the NAVPRO system [4] to preprocess AVHRR images, specially geometric correction. NAVPRO performs all steps of preprocessing automatically, such as format conversion, radiometric calibration, geometric correction (precise georeferencing) and NDVI generation. The NDVI calculation was based on daily NOAA/AVHRR images, removing pixels with solar zenith angle greater than 70° and satellite viewing angles greater than 42°. The effects of shadows, aerosols and water vapor were minimized by the use of the Maximum Value Composite (MVC), based on monthly NDVI images.

NDVI temporal profiles for each city were defined by fusing monthly NDVI values of sugarcane fields extracted using geographical coordinates (latitude and longitude) provided by the CANASAT/INPE Project (www.canasat.inpe.br). We have generated eight time series for each crop season (from April to March). We also extracted the maximum NDVI value for each time series corresponding to one crop season.

We have used PCA as a first step to reduce the dimensionality of datasets [5]. Thereafter, we have used the K-Means clustering method [6] to assess all time series (NDVI, climate variables and cultivated land) of the 16 cities, using the Minitab 14 software (www.minitab.com). Cultivated land was obtained from the official government source (IBGE - www.ibge.gov.br). We also used precipitation, maximum temperature, minimum temperature and maximum NDVI. The cluster analysis was performed combining the variables in three different sets:

#1. cultivated land, maximum NDVI, precipitation, maximum and minimum temperatures;

#2. cultivated land and maximum NDVI;

#3. maximum NDVI, precipitation, maximum and minimum temperatures.

The number of clusters was defined empirically equal to three. The ARCGIS software (www.esri.com) was used to visualize the spatial distribution of each cluster for all cities and crop seasons analyzed. In addition, we have applied principal component analysis to complement the study on the relationship of multitemporal NDVI images, cultivated land and climate.

3. RESULTS

Figures 2A, 2B, and 2C show the results for Set #1 (cultivated land, maximum NDVI, precipitation, maximum and minimum temperatures) while Figures 2D, 2E and 2F have the maps of Set #2 for three crop seasons (from 2005/2006 to 2007/2008). Figure 3 shows the Climatological Normal of São Paulo state for the period 1960-1990 and the precipitation distribution of the study area in 2005, 2007 and 2008.

The use of Sets #1 and #2 gave the same pattern of clustering, being the cultivated land the variable responsible for the definition of clusters. The cultivated land decreases from Cluster #1 (blue) to Cluster #3 (green) in the majority of crop seasons as it can be seen in Table 1.

Cluster	01/ 02	02/ 03	03/ 04	04/ 05	05/ 06	06/ 07	07/ 08	08/ 09
1	6	9	4	4	7	6	5	6
2	5	3	4	5	5	6	6	4
3	5	4	8	7	4	4	5	6

Table 1. Number of sugarcane producing regions in each grouping class of #Set1

Set #3 gave another clustering since the cultivated land was not used. In this case, clusters were defined mainly by the multitemporal values of precipitation and maximum NDVI.

Table 2 presents the number of regions by cluster in all crop seasons studied. As it can be seen in Table 2, the distribution of clusters changes in the period from 2004/2005 to 2006/2007 being influenced by climate variables since cultivated land is not included in the dataset.

Cluster	01/ 02	02/ 03	03/ 04	04/ 05	05/ 06	06/ 07	07/ 08	08/ 09
1	7	7	8	3	2	2	6	3
2	1	3	4	7	7	5	7	7
3	8	6	4	6	7	9	3	6

Table 2. Number of sugarcane producing regions in each grouping class of #Set3

This result is confirmed by principal component analysis since in the majority of years the principal component 2 (PC2) has maximum temperature and cultivated land as determinant variables. Only years in which the precipitation distribution was dissimilar of the Climatological Normal (Figure 3), PC2

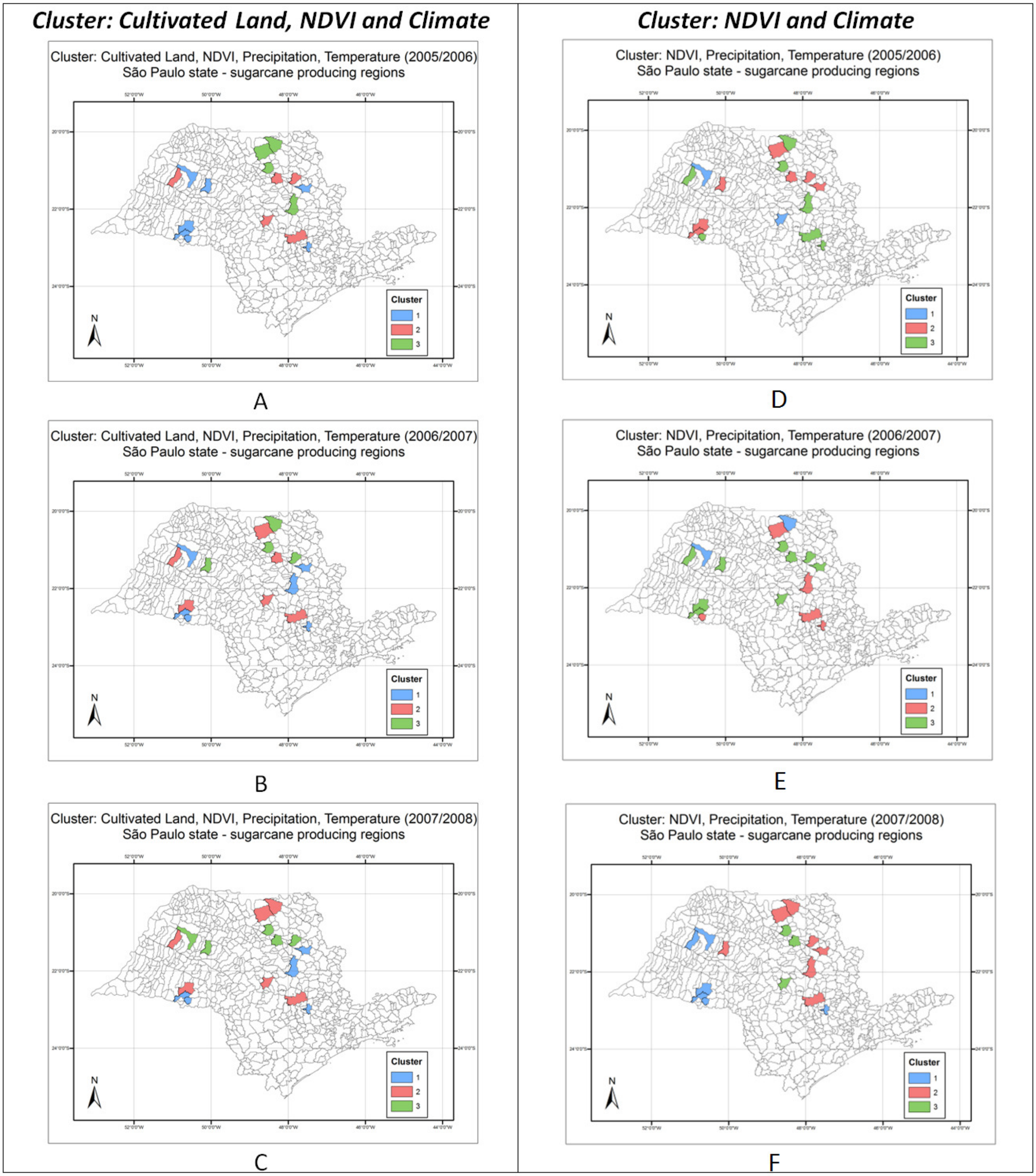

Fig. 2. Maps with clustering based on Sets #1 and #3.

presents other variables, such as NDVI and minimum temperature for 2005/2006, and precipitation and maximum temperature for 2007/2008.

According to [7] NDVI values are influenced by precipi-

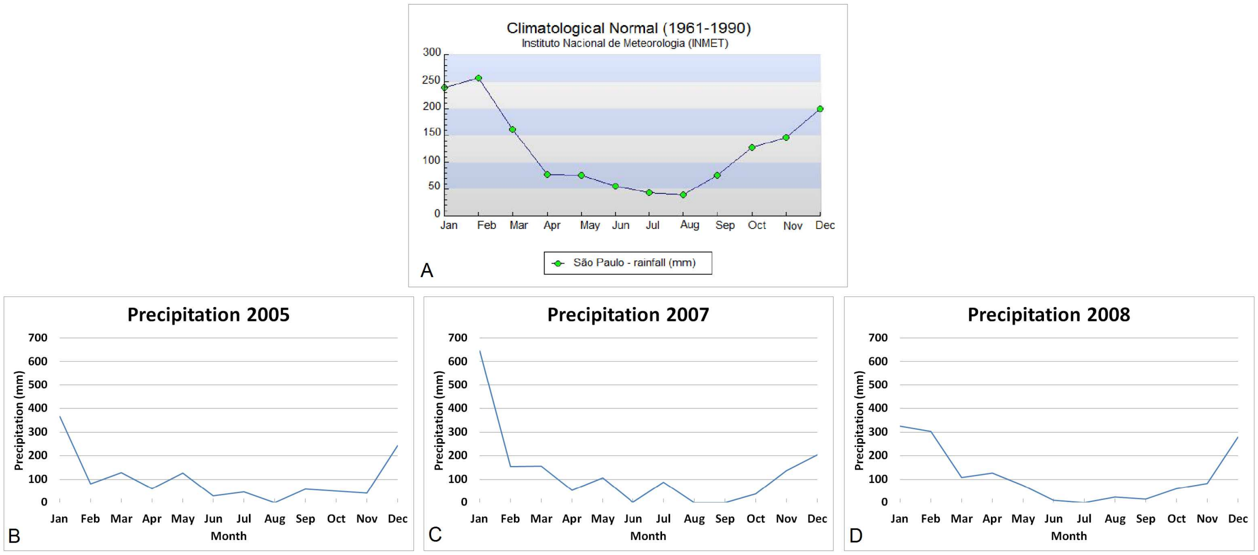

Fig. 3. Graphs of the Climatological Normal of precipitation for São Paulo state (A), precipitation for 2005, 2007 and 2008.

tation after a time lag, what can be observed in Set #3 due to the different grouping compared to the other analyses.

4. CONCLUSIONS

The cluster analysis combined with principal component analysis generated results that can contribute to improve the sugarcane crop monitoring. Technological advances in gathering and processing a large volume of satellite images of low spatial resolution assists the analysis of image series, in order to better visualize the agricultural crops development over time.

In this context, this work showed that it is possible to assess a huge volume of multitemporal images relating them with other variables, such as cultivated area and meteorological time series. The clustering technique highlights changes in the sugarcane crop seasons as well as the relationship between multitemporal images and other time series. The cluster analysis can improve the understanding of the sugarcane development and its expansion to other regions of the Country.

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