

PRELIMINARY ANALYSIS OF DROUGHT IN 2012 IN SEMI-ARID OF ALAGOAS USING INDICES OF VEGETATION THROUGH SENSOR MODIS

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Abstract

During the year of 2012 was observed one of the most intense droughts of the last years in the Northeast of Brazil. This fact has encouraged some analytic studies using orbital sensors as example the current research. The goals of this research was to calculate and analyze the Vegetation Condition Index (VCI) to the Countryside of Alagoas in view of an analysis of the drought that happened in 2012 in comparison with the last 11 years utilizing orbital images of Normalized Difference Indices Vegetation (NDVI). The dates were obtained with *EMBRAPA Informática Agropecuária*. The results were exposed in thematic maps and spreadsheet that highlighted areas with the smallest and largest vegetation condition index and the period of occurrence as well.

Keywords - Remote Sensing, NDVI, VCI.

Introduction

There is a lack of meteorological data for the area of Alagoas State. In order to overcome that, the monitoring of adverse phenomena such as cyclone, flooding, and droughts is commonly made through satellite data of high temporal resolution and global coverage, which gives a good measure of the biophysical parameters. Thus, the analysis

through satellite images is the most effective way to evaluate the earth-surface system.

It is of paramount importance previous knowledge of these parameters to reduce its impact and possible definitions of mitigation strategies of its effects.

The NDVI (Normalized Difference Vegetation Index) is the index most used in the satellite data processing, according to Da Costa

et al (2009), Dos Santos (2012), Ideiao et al (2008), Matos et al (2013), Novas (2008), and Santiago et al (2013). It explores the spectral properties of the surface of plants, which absorb light in the visible wavelength by interaction with the chlorophyll. The healthy, turgid leaves use that energy to make photosynthesis and reflect it in the near infrared. That index can be used to either evaluate the radiation involved in the photosynthesis process, or as an estimate of seasonal and annual changes associated with a species (LIU, 2003 apud NOVAS, 2008; STÖCKLI and VIDALE, 2004; STÖCKLI, 2005).

The surface reflectances in the near infrared is located between 0.8 μ m and 1.1 μ m. In the visible, it is between 0.6 μ m and 0.7 μ m (the red color) (ASRAR *et al.*, 1984).

The NDVI values varies from -1 to +1. Negative values indicate water surface or high humidity, whereas positive values are associated with continental regions. Dense area covered by plants means larger NDVI (DOS SANTOS, 2012).

Kogan (1995a, 1995b), Covele, (2011), and Sá (2008) analysis concluded that NDVI is influenced by both the ecological and climatical components.

It is difficult to measure the climatical component because it is changed by the ecological component. Therefore, whenever NDVI is applied, in order to analyse the impact of the weather over the vegetation, the components have to be separated.

The estimate of the impact of the weather over the vegetation is possible if the variety related to the contribution of the geographic sources is separated from the ecological component.

The ecological component is mainly governed by environmental changes such as climate, soil, topography, and species of vegetation, which determines the amount and distribution of the vegetation on the earth surface. The NDVI climatical component is controlled by weather parameters like rain, temperature, wind, that shows both the state of the vegetation and its life period in the annual cycle. The climatical component is overlaid the ecological component. That is clearly seen from the better response of the vegetation in time periods when climate is favorable, which stimulate the use of ecological sources. (COVELE, 2011; SÁ, 2008; KOGAN, 1995a, 1995b, 1997; SINGH *et al.*, 2003).

The maximum and minimum NDVI values calculated to a specific period and area, which include extreme events of climatic variability, may be used as a criterion to evaluate the amount of ecological sources or the ecosystem capacity of the region. Works like Kogan (1995a, 1995b, 1997) and later, Covele, (2011) on droughts in USA and others countries, introduced the Vegetation Condition Index (VCI) and Temperature Vegetation Condition Index (TCI), that indicate the impact of climatic changes on the vegetation through AVHRR data (NDVI and channel 4). The VCI measures the weather

component (ecological component) and it is more related to the quantity of humidity (KOGAN, 2001).

The goal of this study is to apply NDVI and VCI to analyze droughts that occurred in semi-arid area of Alagoas, in 2012, by comparison between 2012 and a temporal serie (2003-2014).

Materials and Methods

The Northeast of Brazil is located at the Inter-Tropical Zone of the earth, which is characterized by large quantity of light incidence on the surface, high temperatures in

all seasons, and irregular distribution of the precipitation. Alagoas is marked by different kinds of vegetation, climate, and precipitation distribution. However, this study was focused on the semi-arid zone of Alagoas because of the historical incidence of drought events, which has negative consequences on the economy that is based on cattle.

The semi-arid zone of Alagoas shows tropical climate and typical vegetation, called Caatinga, that is adapted to low humidity of the region (Figure 1, from the MODIS sensor, located between 38.2°W to 36.8°W and 8.9°S to 9.9°S.)

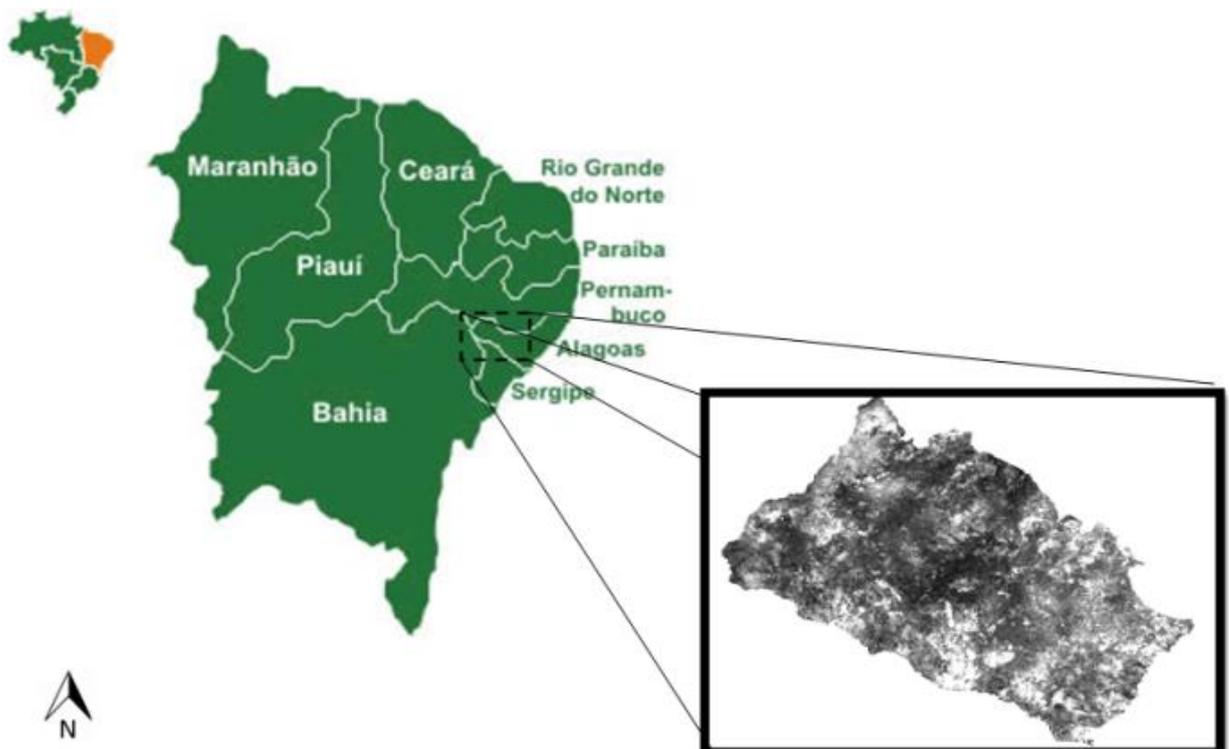


Figure 1 – Study area: semi-arid zone of Alagoas.

The constant amount of clouds over the Northeast of Brazil (NEB) may cause many errors in the estimate of the variables from orbital images (DI PACE, 2004). Thus, it was

chosen the MOD13Q1 product from level 3 of the MODIS sensor, which minimizes cloud effects.

The MOD13Q1 product gives both NDVI data and Enhanced Vegetation Index (EVI) data, in a 250m spatial resolution. It consists of a mosaic of images from daily observations of bidirectional reflectances during 16 days. The observations coincide with the beginning of the monthly calendar with Sinusoidal projection (SILVA, 2004 apud MATOS et al, 2013). For example, for the first image of the year it is considerable the daily images between 1st and 16th Jan.

The Mosaic that generates MOD13Q1 product is made in order to: minimize in effect of the clouds, so the indexes are obtained with better spatial resolution; make the geometry of acquiring and illumination uniform; assure the data quality and efficiency, and so on (LATORRE et al., 2007 apud MATOS et al., 2013).

The *EMBRAPA, Informática Agropecuária*, has begun development of MODIS Product Bank in the Brazilian Base of the State to gather and get available images, which are ready to be used; in other words, it does not require a complementary processing.

The MODIS Product Bank processes MOD13Q1 products in many steps, one of them includes the generation of tile mosaic (spatial cropping) which cover national territory, and the cartographic reprojection that converts sinusoidal in geographic (datum WGS-84) in a GeoTIFF output format (Esquerdo et al, 2011). NDVI images related to MOD13Q1 product from *EMBRAPA* were collected to the area of Alagoas State for the

period between 2003 to 2014, available at <http://www.modis.cnpqia.embrapa.br/geonetw/ork/srv/pt/main.home>.

The images were cut out through shapefiles (archives in spatial vector format) highlighting the semi-arid zone of Alagoas. Shapefiles are available at the FTP address of the Brazilian Institute of Geography and Statistics (IBGE): <ftp://geofpt.ibge.gov.br/mapas/escolares/mudos/municipios/>.

The NDVI that comes from the MOD13Q1 product is given by the following expression (Allen et al. 2002):

$$IVDN = \frac{\rho_{IV} - \rho_V}{\rho_{IV} + \rho_V} \quad (1)$$

Where ρ_{IV} e ρ_V are near infrared and visible reflectances, respectively.

The VCI, according Kogan (1990), is calculated from the difference between maximum and minimum NDVI (Equation 2). It represents the NDVI percentile of its maximum amplitude in each place. In this paper, it was applied to the images collected to the 2012 year.

$$VCI = \frac{IVDN_j - IVDN_{min}}{IVDN_{max} + IVDN_{min}} \quad (2)$$

In the Equation 2 *VCI* is the index referred to period *j*, which in this paper was 11 years; $NDVI_{max}$ and $NDVI_{min}$ are maximum and minimum values of NDVI during that period.

In order to get $NDVI_{min}$ it was calculated the average of the first percentile of each NDVI image. The results were gathered to make a final average (of all images), which

represents the lower NDVI value for the region and time period analyzed. In the same way was calculated the $NDVI_{max}$, but taking the last percentile of each image to obtain the average.

The VCI was obtained for each image through $NDVI_{max}$ and $NDVI_{min}$. Then, the critical areas was identified and the results were presented following a division in 5 classes: Very low (0-20%), Low (20-40%), Intermediate (40-60%), High (60-80%), Very high (80-100%) (COVELE, 2011).

For the sake of to make easier the interpretation of the results, fake color was

applied in the images through *Erdas Imagine* 9.2 software.

Results and Discussion

$NDVI_{min}$ and $NDVI_{max}$ were, respectively, 0.11387 and 0.85444, as it would be expected for a semi-arid area. Those NDVI values restricted VCI maximum value to 76.48074. Therefore, the highest class that can be reached by VCI values for the semi-arid area of Alagoas, based on 11 years of study (2003-2014) is "High". The results for VCI can be seen in Figure 2:

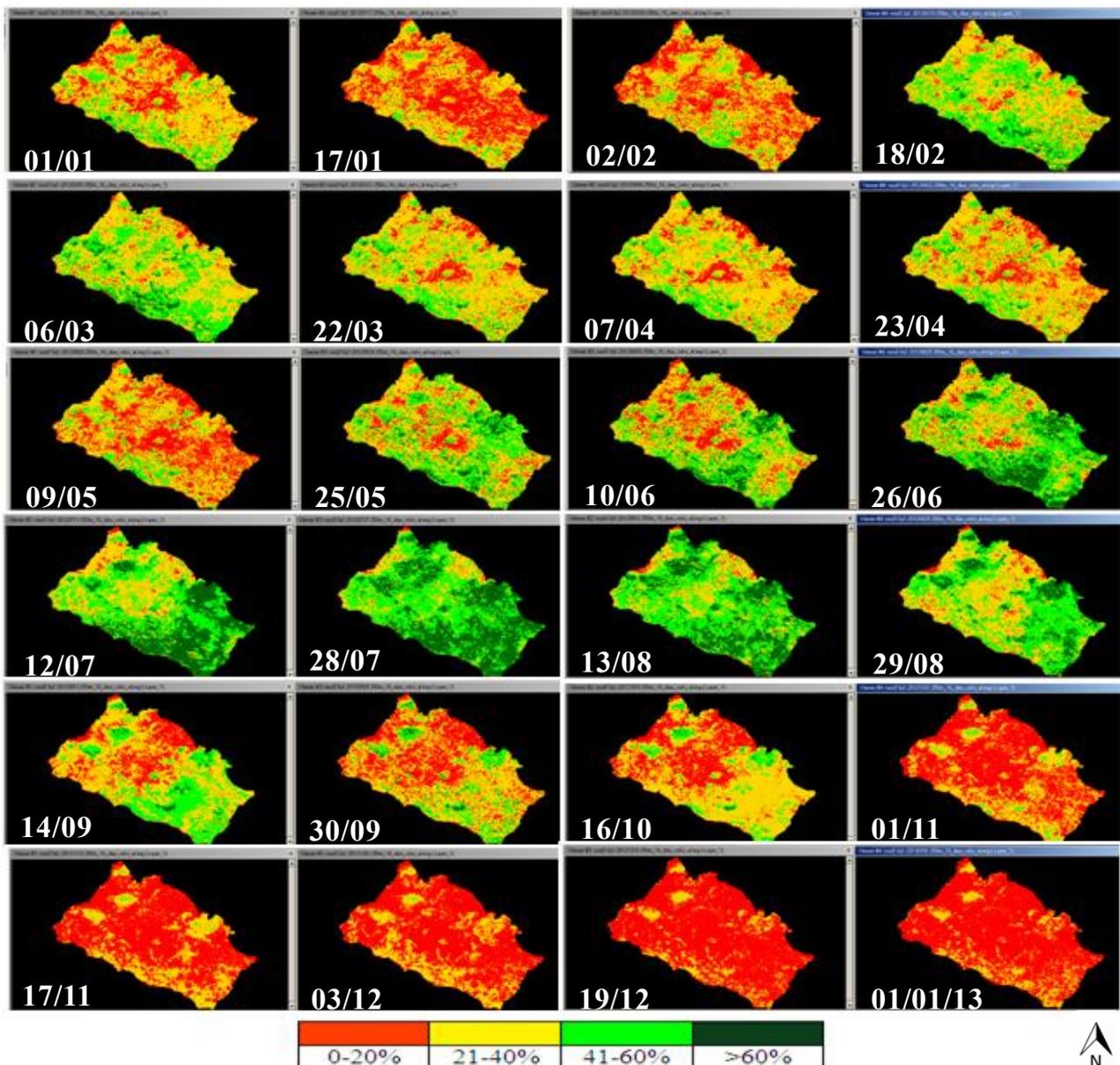


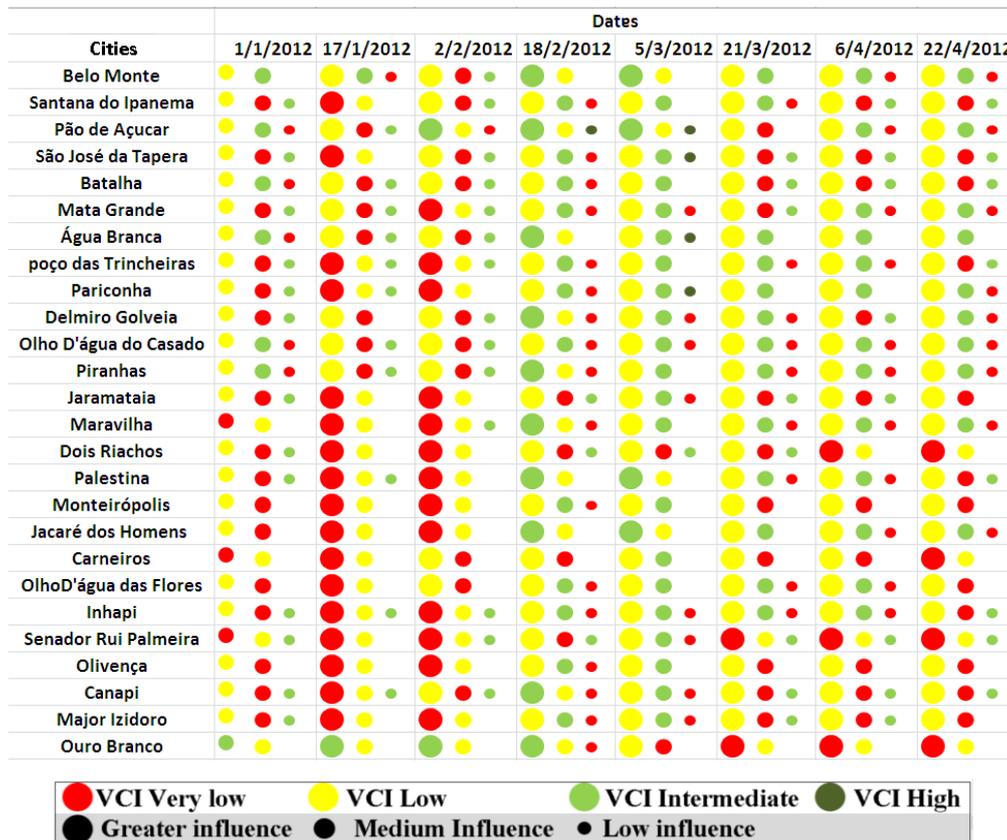
Figure 2: VCI values for the semi-arid area of Alagoas in 2012.

As seen in figure 2, VCI is lower in the period between the beginning and the end of the year, so, from November to February of the following year. Those are the 4 months of droughts in that area, according to Molion and Bernardo, 2000. In the other hand, the images where VCI is highest, is between July and

August, which are among the four months of high humidity in that area (MOLION and BERNARDO, 2000).

The Tables 1, 2, and 3 was created to see the VCI intensity for each city individually. The circles represents VCI measure from higher to lower values. Colors preserved same meaning as the legend in figure 2.

Table 1. VCI intensity for the cities at the semi-arid zone of Alagoas, from Jan. 1st to Apr. 22nd, 2012.



According to Table 1 (as in Figure 2), VCI, which is sensible to humidity, shows low intensity in almost all cities in the second image. In addition, it is seen that its distribution is irregular in the first images. It is easy to see how heterogeneous is its behavior since for two nearby areas, for example, Major Izidoro and Batalha, the first one indicates values higher than the other one.

Table 2 shows a period in which persists big changes of VCI between cities during that period. However, high and homogeneous VCI values were predominant

between July and August, which a rainy months. Belo Monte, Santana do Ipanema, and Pão de Açúcar are examples of cities for which VCI was classified as High in those months.

In Table 3 was observed more homogeneous indexes considering both the geographic and spatial distribution. Again, the VCI values were very low, especially between October and December. It is seen that Ouro Branco indicated the lowest index among the cities. The highest values in 2012 were find at Belo Monte, Santana do Ipanema, and Pão de Açúcar.

Table 2 - VCI intensity for the cities at the semi-arid zone of Alagoas, from May. 8th to Aug. 28th, 2012.

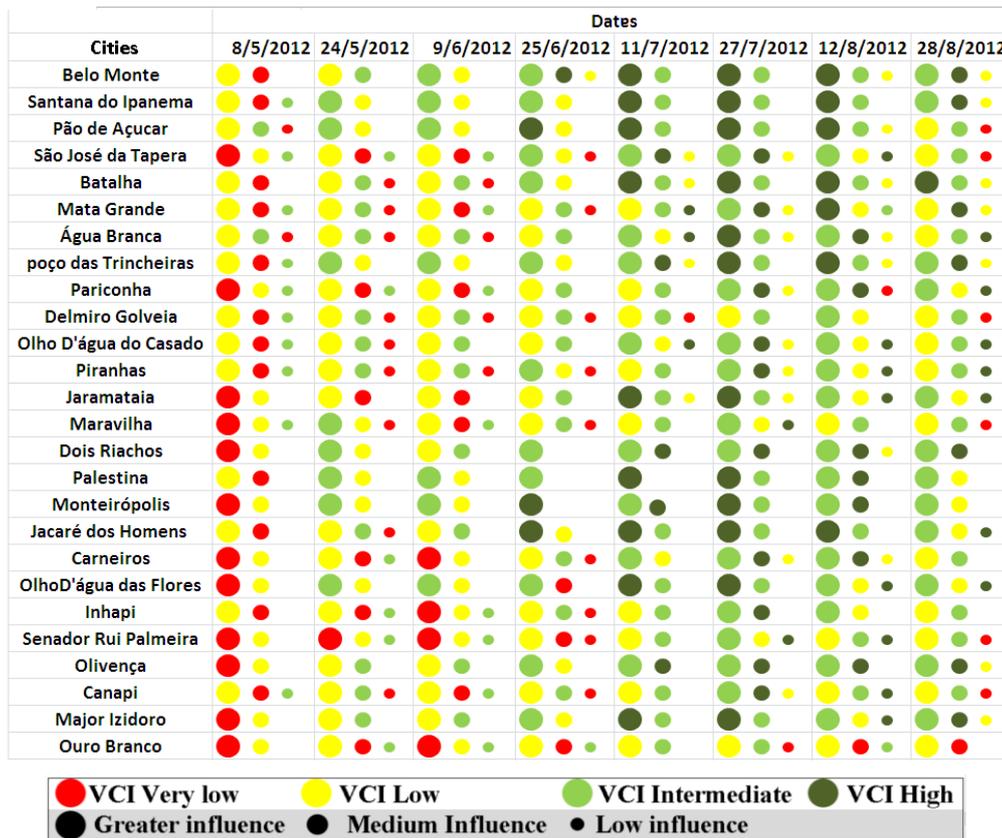
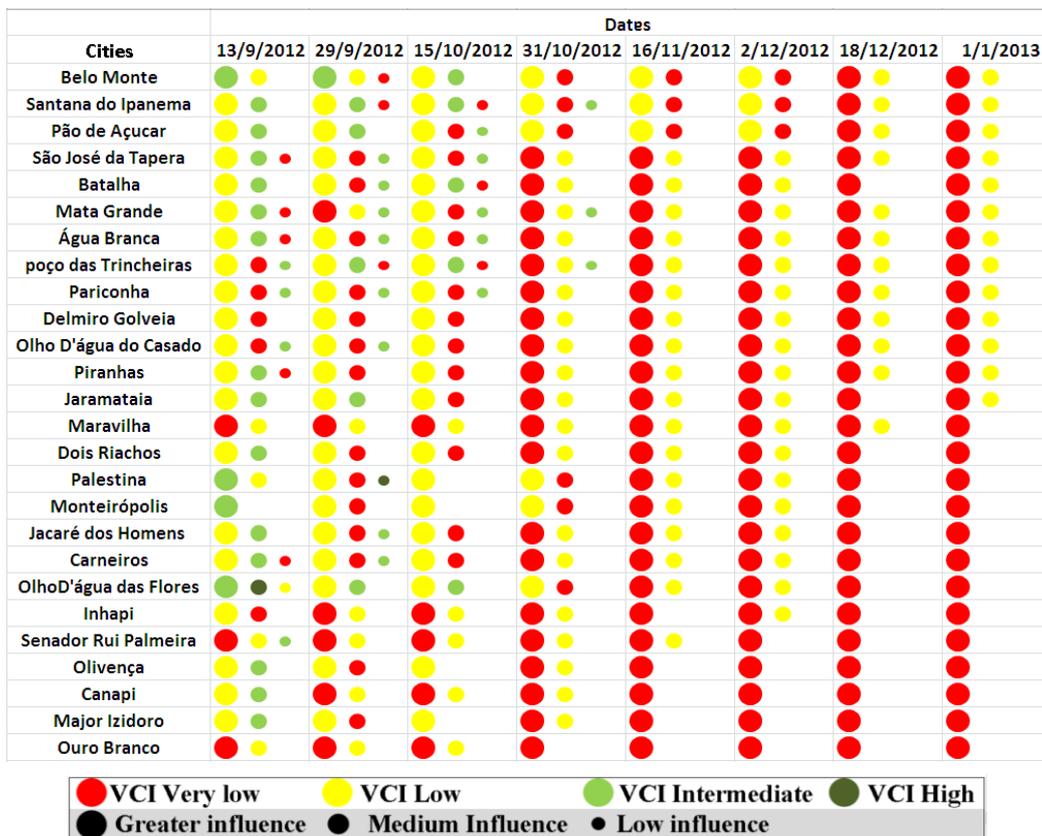


Table 3 - VCI intensity for the cities at the semi-arid zone of Alagoas, from Sep. 13rd, 2012 to Jan. 1st, 2013.



From the Meteorological Data Bank to Teaching and Research (BDMEP) (available at

<http://www.inmet.gov.br/projetos/rede/pesquisa/>) data it is clear that the distribution of the

precipitation in 2012 was irregular. It is possible to compare VCI numbers with rainy data, as it was done in table 4 for two cities:

Água Branca (9.28°S and 37.9°W) and Pão de Açúcar (9.75°S and 37.43°W).

Table 4. Precipitation (mm) for each month in 2012 for the cities Água Branca and Pão de Açúcar. Font: BDMEP, 2014.

Date	Água Branca	Pão de Açúcar
	Total Precipitation (mm)	
31/1/2012	0.7	0
31/2/2012		48.1
31/3/2012	9.8	3.6
30/4/2012	6.7	2.1
31/5/2012	49.6	38.5
30/6/2012	57.3	41
31/7/2012	167.8	71
31/8/2012	112.5	0
30/9/2012	29.3	21
31/10/2012	17.9	6.4
30/11/2012	9.2	0
31/12/2012	0.4	0

From the precipitation data, it is seen that in Água Branca and Pão de Açúcar the months of higher amount of precipitation were also periods where VCI was higher. In the first one it happened between July and August; the second one, between June and July. In the same way, the dryer months, which are November and December, indicated lower values of VCI. Unfortunately, precipitation data for February was not available.

Conclusions

VCI has demonstrated to be a satisfactory index to analyze droughts on the semi-arid region of Alagoas. That became clear through the comparison between precipitation data and VCI values, showing that high VCI values are related to high amount

of precipitation. In other words, they are marked by a direct proportional relationship. The precipitation data were also in accordance with the most rainy period of the area.

The Low and Very low indexes were found mainly in the end of one year and the beginning of the following year, and in all cities, but it was especially critical in Canapi, Major Isidoro, and Ouro Branco.

Areas classified as Very low (VCI < 20%) in the end of 2012 suggest that vegetation from semi-arid area of Alagoas was yet injured as a result of the precedent period lack of water resources.

From the results it is not a surprise that 2012 was one of the most dry years of the last decades. That is clear through ICV numbers calculated by the MOD13Q1 product.

It is mandatory to invest on ways in order to decrease the impact on agriculture and cattle because of the negative effects on the economy.

For future studies it is suggested: (1) to make an analysis including the whole NEB area because drought achieved many states entirely; (2) to obtain a larger quantity of images so it can be gotten better values for each index; and (3) To make analysis faster by calculating in an automatic process the ICV data from the images.

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