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Improved Techniques for Crop Classification using MODIS Imagery

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Abstract

Brazil has become a major player in world soybean markets, second only to the U.S. Brazil Crop area is about 10 million hectares and is now rapidly expanding into the Brazilian savannah (Cerrado) and the Amazonian region where forested area is being converted to cropland. There is a need for accurate updated information on the newly expanded agricultural areas in Brazil and the current total production. The objective of this research was to develop an operational method for assessing soybean crop area that would facilitate developing remote sensing based algorithms for assessing crop yields in major producing areas. The Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Terra satellite offers a good potential for assessing crop area as well as provide opportunity to retrieve crop condition parameters that can be used to assess crop yields. A three-year MODIS data set was acquired for the study and this research describes the methods used for processing the 8-day composite reflectance data from bands 1 and 2 and its use in developing the classification of soybean crop area in four major soybean producing areas in Brazil. The results suggest methods that can be used for operational application of MODIS 250m data for classification as well as potential use in crop yield assessment.

Introduction

The rapid expansion of crop and pasture cultivation into the savanna will have major impact on the environment and has to be balanced with proper management strategies. Mechanization of crop production has resulted in excessive tillage and turning over the soil that enhances soil carbon losses. With favorable climate it is possible to cultivate three crops sequentially in a single year. Since the goal of this research is to monitor agricultural crop growth and development, a good classification of crop area of Brazil is the first critical step. The agricultural crops in Brazil are spread over a very large area and most of the landuse is natural vegetation, and standard classification methods may not be feasible.

A decision tree approach based on metrics derived from multi-temporal remotely sensed imagery may be better suited to handle non-normal, non-homogeneous data sets [1]. Reference [2] used this technique to classify at the global scale using AVHRR data. Recently, reference [3] used multi-temporal NDVI and SAVI indices calculated from AVHRR images to classify the major three types of land cover in the Cerrado. MODIS data was used to develop the best possible classification for crop area in four major soybean crop production provinces. Other researchers have attempted to use MODIS for classifications of crops [4]. Their study areas were relatively small in size and also were the primary crop in the area with no other major crop that would interfere in the classification.

Despite the great efforts to develop the best 8-day MODIS composite reflectance and NDVI products, there are periods when the data values have a much higher or lower value that are outside the seasonal trend. Our analyses suggest that this is due to a combination of errors associated with atmospheric, geometric, and BRDF corrections and registration [5]. To overcome this problem, the data is processed using the Savitzky-Golay technique for smoothing time series data [6].

This paper describes the use of MODIS Terra data at 250 m resolution for classification of crop area in four provinces of Brazil that are the major soybean producing areas. The 8-day composite MODIS data was not usable as available and required to be reprocessed to minimize the effect of cloud cover and other factors that distorted the data. A data filtering technique used to reprocess the data is described. Since the majority of the area in the provinces were natural vegetation (trees, shrubs, rangeland) it was important to develop a crop classification to monitor the crop condition during the growing season. The normalized vegetation index was tracked through the growing season to assess the changes in crop growing condition that is an indication of potential crop yields for the current season in comparison with previous years.

Since its launch many researchers have attempted to use MODIS for classifications. References [4] presented their attempts to use MODIS for classification. In this research, their sample sizes were relatively small and their methodology

was designed for classification of a single crop type, and ignoring MODIS pixels that had multiple land-uses.

Materials and Methods

A. Study area

Total cereal production in Brazil amounts to 122.8 million tones reported by IGBE [7]. The average yields are: maize, 3.0 t/ha; wheat, 1.6 t/ha; rice, 3 t/ha; soybeans 2.7 t/ha. Of those crops, only soybeans have a high average yield level, a yield that is comparable to the world's best. Brazil's 2005-06 soybean crop is estimated at 57.0 million tons, and the harvested soybean area is estimated at 22.1 million hectares [8]. Since the focus of this paper is on soybean crop, we selected the provinces of Mato Grosso, Mato Grosso do Sul, Goias and Parana, which are the major soybean production area to develop classification for the potential crop area. Figure 1 shows the projected soybean producing areas in the various provinces of Brazil developed by the U.S. Department of Agriculture [8].

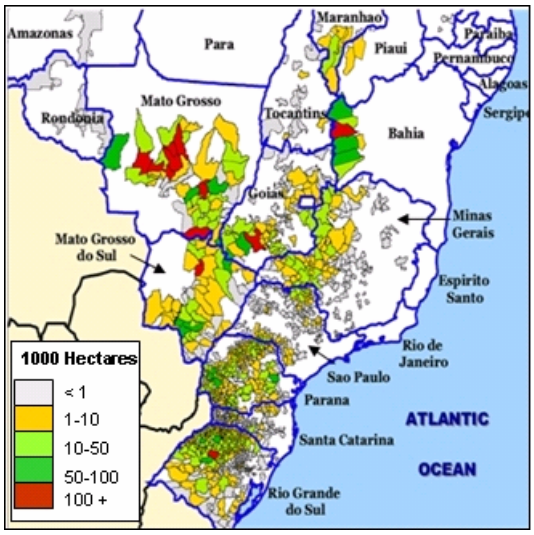

Figure 1. Soybean production area developed by USDA

B. MODIS Data and Processing

The 8-day composite 250 m. resolution MODIS Terra surface reflectance product was acquired through the NASA-DAAC EROS Data Center, Sioux Fall, SD. The images were re-projected from ISIN projection to the Lambert Azimuthal Equal-area projection with central point coordinates of 48 W and 18 S using MODIS re-projection tool. The developed algorithms were in FORTRAN and all images were converted to ASCII format. The images for whole year were used for 2001-02 and 2004-05 years. For the 2005-06 crop seasons the images from day of year (DOY) 249 (2005) to DOY 081 (2006) were used in these analyses.

There were three kinds of errors associated with the standard MODIS data product besides cloud cover – geo-referencing, atmospheric correction and BRDF effect. Because image processing can't fully correct these errors, the 8-day composite images always have patches caused by differences in single day images used. Atmospheric correction errors are partly reduced using a normalize vegetation index such as NDVI. Errors in reflectance caused by atmospheric condition always decreases the NDVI value. To eliminate these decreases, we used multiple steps in Savitzky-Golay filtering method that adapted NDVI profile to develop the upper envelope [6]. The Savitzky-Golay filter was applied to smooth every pixel's time series profile through the entire year. Savitzky-Golay method uses a moving window and in each window noisy values is approximated by polynomial. In this research we used second power polynomial and five point moving window in filtering process.

Data for the entire year was used to eliminate natural vegetation such as trees, shrubs and grasses to focus only on the crop season. The primary period when soybean crop is cultivated is between November and March with a peak in crop growth (NDVI) during mid to late January. Some of the areas have multiple cropping systems and there may be other grain crop besides soybean. The filtered images were used in the soybean classification algorithm. The decision tree developed for classification of soybean area was based on the MODIS NDVI pixel values that satisfied to the following criteria: November NDVI value less that 0.4; January NDVI value higher that 0.8 and in March the NDVI value was less than 0.4. Some other crops may also satisfy to this condition, but for the purpose of using this data for yield prediction these pixels will not adversely influence the outcome. A word of caution is that these are preliminary analyses conducted for a three year period and the results need to be verified when spatial statistics of crop acreage are available. These results are suitable for monitoring crop condition such as drought impact on production and cannot be interpreted for crop estimating acreages.

Results and Discussion

The results presented are preliminary analyses on improved techniques for potential use of MODIS Terra data for crop yield estimation. Published information of spatial data on crop classification is not available for verification and accuracy assessment. The availability of even an approximate crop classification is an important step towards improving crop yield assessment at regional scales.

A. MODIS Data Filtering

NDVI images were calculated from reflectance channel 1 and 2 of 8-day composite images. The soybean crop season is usually between the beginning of November and the end of April, however the data was processed from September 30 to April 7 to include possible shifts in the growing season. The decision tree algorithm described earlier was applied for selecting the potential soybean pixels from filtered NDVI images for 2001-02, 2004-05 and 2005-06 crop season. The Savitzky-Golay filter was applied to smooth NDVI profiles for

each pixel employing 5-point moving window. Figure 2 is an example of the performance of the filtering algorithm applied to a single MODIS pixel.

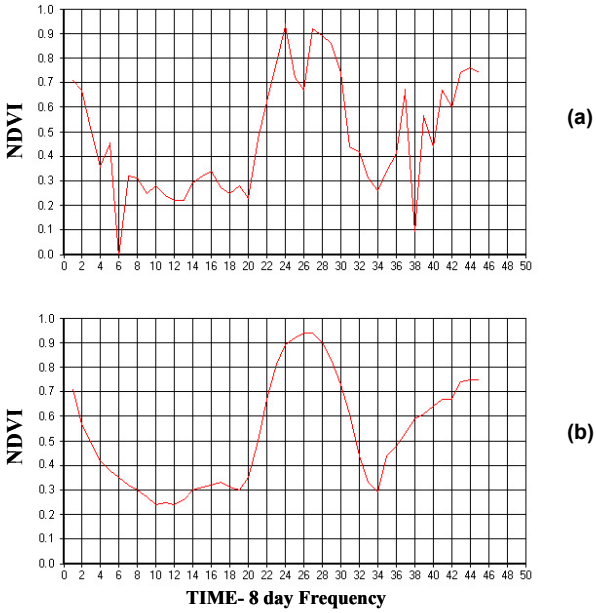

Figure 2. NDVI profile of a sample pixel in its orginal form (a) and after processing with the filter algorithm (b).

B. Classification of Soybean Area

The results of the filter applied to the study region for the 8-day composite period end February 9, 2002 are shown in Figure 3. The pixels with cloud and data resulting from other contaminations are removed and the image is reconstructed from the filtering algorithm. The filtered MODIS image was then used to develop the classification of soybean crop in the four provinces in the study region. Figure 4 is an example the soybean area classified using the decision tree described earlier. Most of the soybean crop is cultivated in the central and southeastern part of the province as expected.

The MODIS NDVI image processed through the filtering algorithm was then use to develop the NDVI profiles for the three seasons being evaluated. Figure 5 shows the profiles that are the mean NDVI values from crop pixels for each province. A new classification was developed for each of the three years. The data for the 2005-06 season ended in March 6 to enable completion of these analyses. The reported yield [7] for 2001-02 was good year for soybean yields and in the range of 2.72- 3.06 T/Ha compared to the 2004-05 1.84 to 2.91T/Ha which had water deficit conditions in most of the study region. The 2005-06 yields are mixed and expected to be equal to 2004-05 in some provinces and better in others due to variable precipitation in the region.

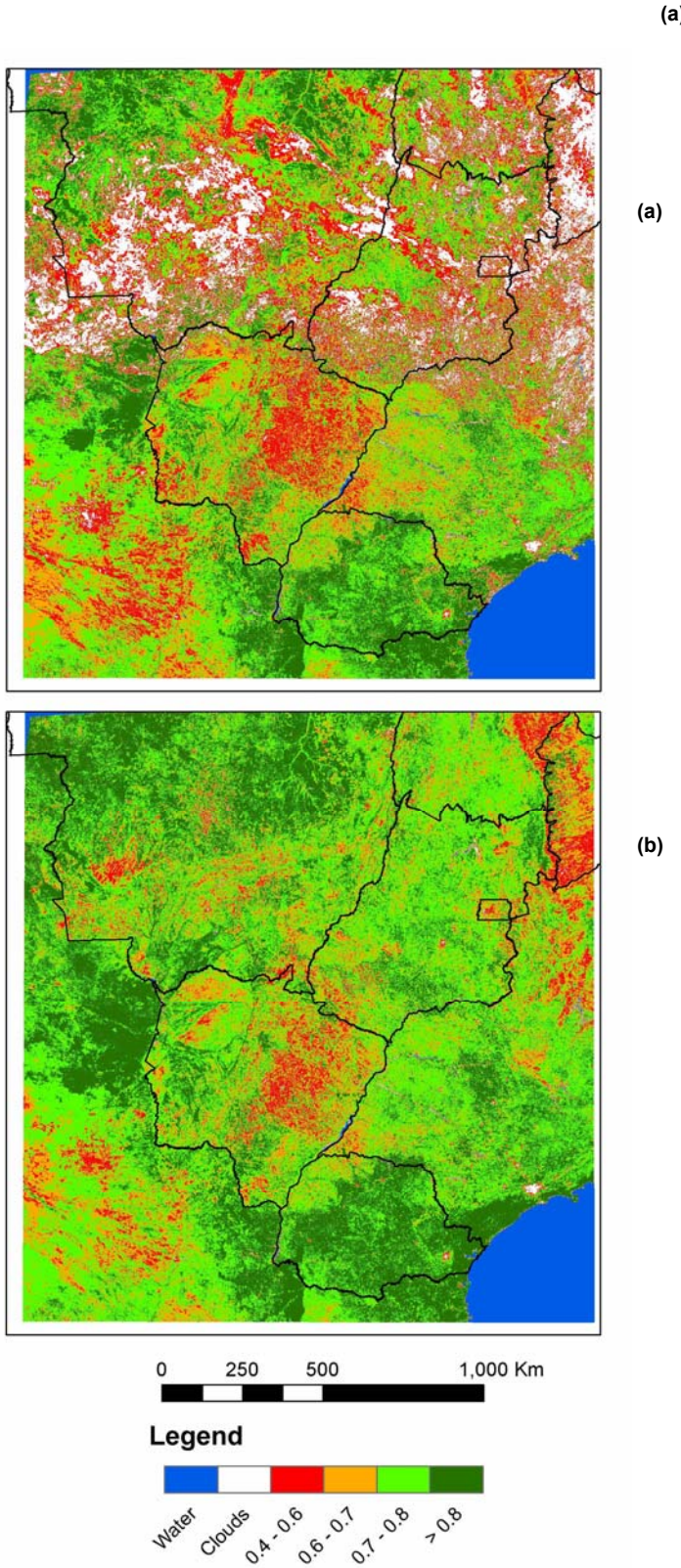

Figure 3. NDVI image of the study region showing the original image (a) and the image processing with the filter (b).

Figure 4. Classification of soybean area for Moto Grosso.

Conclusion

The preliminary analyses shown in this study is to demonstrate two important findings. (1) MODIS imagery can be used for regional classification when screened for data anomalies and contaminations due to clouds and compositing procedures. (2). A decision tree algorithm based on soybean crop phenology was successfully used to classifying the predominant soybean crop cultivated in four provinces in Brazil.

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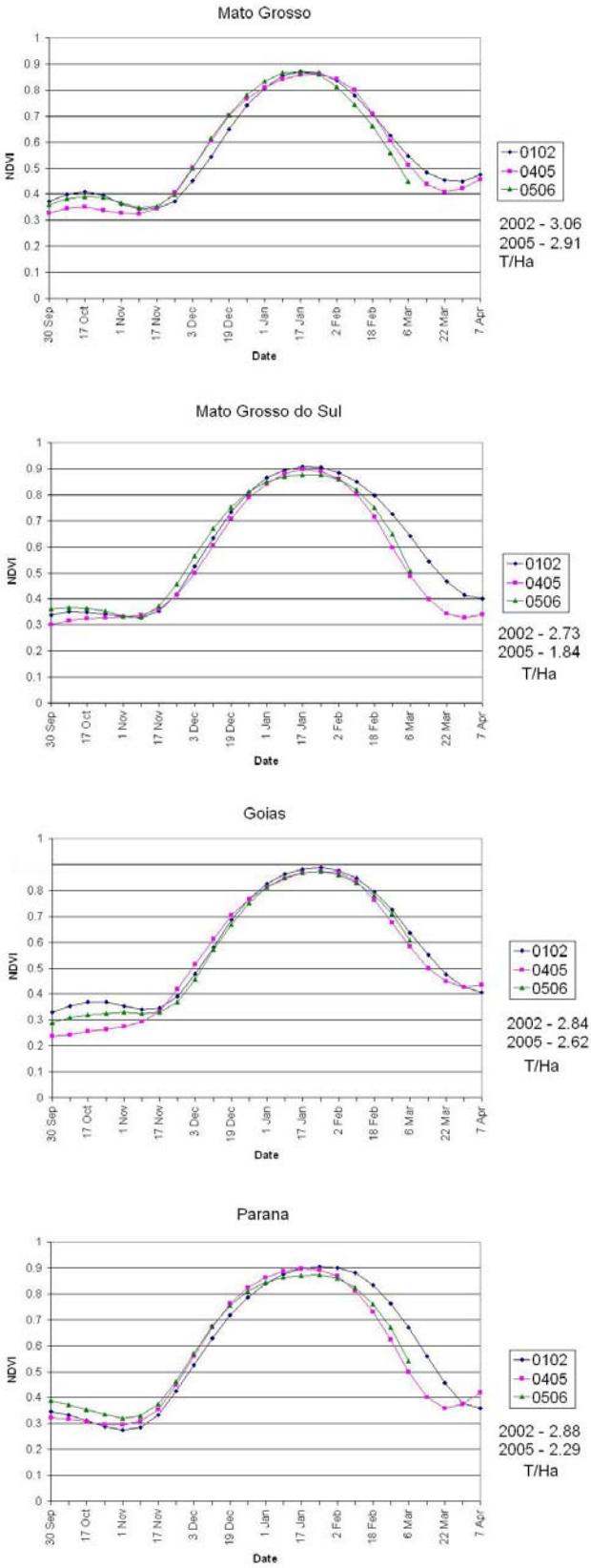

Figure 5. NDVI profile for three crop seasons and mean provincial yields for 2001-02 (0102) and 2004-05 (0405).