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Using MODIS to detect cropping frequency variation in mechanized agriculture in Amazonia

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Abstract. Policy makers concerned with managing rapidly developing agriculture on the Amazon frontier currently have no Basin-wide spatial and temporal information on exactly when and how soybean and other mechanized annual cropping have developed in the region. To address this, we present a preliminary evaluation of the use of Moderate Resolution Imaging Spectroradiometer (MODIS) 250 m vegetation index (VI) time-series data to detect cropping frequency in two municipalities, Vilhena, Rondônia, and Santarém, Pará.

Key-words: Land-use and land-cover change, MODIS, agricultural intensification, EVI, agriculture, soybeans, Brazil

1. Introduction

This paper offers a method to map and analyze land-use intensity levels in mechanized farming (single cropping vs. double cropping). Moderate Resolution Imaging Spectroradiometer (MODIS) allows for the detection of subtle changes in land cover using continuous surface attributes at seasonal and inter-annual scales at a moderate spatial resolution. Our results, comparing two geographically disparate municipalities, point out the challenges of developing a Basin-wide monitoring program for tracking the development of mechanized annual cropping.

2. Methods

A time series of MODIS 250-m Enhanced Vegetation Index (EVI) data spanning from 14-Sep-02 to 13-Sep-05 (Vilhena) and 3-Dec-03 to 15-Oct-06 (Santarém) was assembled for the tiles corresponding to each municipality. Data (collection 4) from both Terra (MOD13Q1) and Aqua (MYD13Q1) platforms were obtained. A maximum value compositing technique was employed on a pixel-by-pixel, composite period basis to produce Terra-Aqua merged EVI time series data sets. For each pixel in a given composite period, the maximum VI value between the Terra (morning overpass) and Aqua (afternoon overpass) observations was retained in the merged VI time series to produce relatively cloud-free data. The stacked time series of EVI images was then reprojected from the sinusoidal projection to the geographic projection (WGS84). The native 234-m spatial resolution of the MODIS VI data was retained during resampling in order to maximize the spatial acuity of the imagery. However, the data are still referred to as MODIS 250-m data to be consistent with the existing literature. Lastly, the Vilhena and Santarém growing regions were subset for analysis from the time series of EVI images.

In situ data were collected in the municipality of Vilhena, Rondônia, Brazil, in July and August 2005, and in June 2006 in Santarém, Pará. The timing and type of cropping practices of farmers engaged in mechanized annual cropping were recorded for individual field sites since 2003 and 2004 in Vilhena and Santarém, respectively. The field-level information was integrated into a GIS as specific polygons with attribute data, which were used to aid in the classification and accuracy assessment of the MODIS time-series data. For data analysis, the "natural" crop year for each municipality was determined through consideration of crop cycles typical of the areas, in conjunction with visual examination of time series MODIS EVI from the sampled field sites. For Vilhena, the crop year begins in September (MODIS period 17: Julian days 257-272, Sep 14 - Sep 29). For Santarém, the crop year begins in December (MODIS period 22: Julian days 337-352, Dec 3 - Dec 18). Our focus is solely on cropland, so VI values from the first three and the last three MODIS periods were excluded since fields are largely idle during those times.

3. Results

Figure 1 illustrates the difference between the cropping practices within and between the sites. We determined that approximately 75-80% accuracy can be expected when using elementary classification methods to separate cropland that is single crop from cropland that is double crop. This accuracy is comparable to that achieved by Wardlow (2006) in the U.S. Central Great Plains using similar MODIS VI time series information.

4. Discussion

This study provides a test of methods to detect, map, and track the dynamics of mechanized agriculture in the Amazon using MODIS. The two cases are near the extreme ends of the so-called "arc of deforestation" in Amazonia. Vilhena, at 12°42'S, 60°04'W, is located in the southwest Amazon Basin, a region at the humid tropical forest/savanna transition. Santarém, 1,200 km away to the north and east of Vilhena, at approximately 2°25'S, 54°43'W, is situated well within the humid tropical forest biome. Good accuracies were achieved in single vs. double crop detection in our two cases, suggesting such detection should be possible in other areas. Any future Basin-wide monitoring system, however, will be complicated by variability in phenology, agricultural calendar, and MODIS data quality across the Basin. Results indicate the usefulness of MODIS data in Basin-wide studies of agricultural intensification, albeit with many caveats and concerns. The Santarém sample distribution is

highly skewed toward single crop (nearly 88% of the sample area), suggesting a higher overall classification accuracy can be achieved by trivially classifying everything as single crop rather than applying the elementary classification methods that were examined. Detecting cropping frequencies is expected to be the simplest task in our research agenda, yet errors were still present. One common error involved misclassifying some double-cropped sites as single-cropped sites. It is possible that some double crop sites did not receive adequate investment and management by farmers, leading to a depressed second peak in the VI values. Our study only examined croplands, and future work will have to determine differences in VI time-series for pasture, forest, and secondary forest as well. Morton *et al.* (2006) had difficulty distinguishing between pasture and single-cropped lands in Mato Grosso. More research will tell whether other useful information can be extracted from MODIS and other multi-temporal data such as crop type and yield (Wardlow and Egbert, 2002; Wardlow *et al*., 2005, Wardlow *et al.,* 2006).

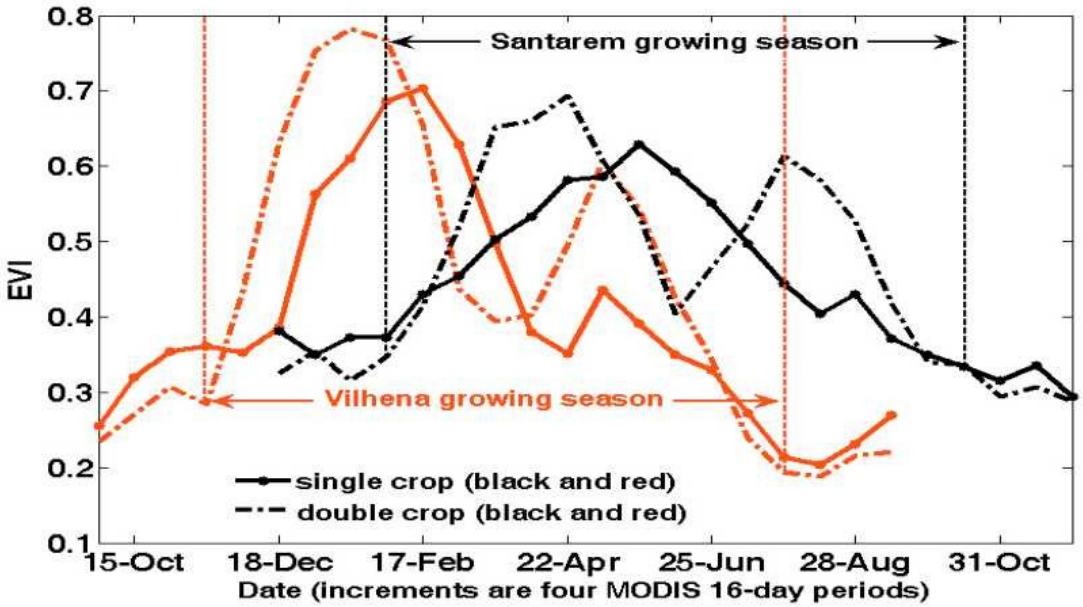

Figure 1. Mean EVI time-series from Vilhena (single crop: 48 fields/1429 pixels; double crop: 34 fields/1677 pixels) and Santarém (single crop: 151 fields/1968 pixels; double crop: 28 fields/271 pixels).¶

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