Table 5
The overall accuracy of our algorithm was assessed by comparing our automated crop detection techniques preformed on the wavelet-smoothed EVI time series to the input EVI time-series data (non-smoothed MODIS cropping patterns detected by the user or MODIS) and the farm history from Fazenda Santa Lordes

Reference data	Overall Accuracy	K_{hat}
MODIS	88.5%	92.1%
Fazenda	94.0%	85.7%

Overall accuracy is the percent of points accurately identified in a class out of the total number of points sampled. K_{hat} values are also high for all wavelet powers.

in that remotely-sensed class. The K_{hat} statistic comes from KAPPA analysis for discrete multivariate accuracy assessment. K_{hat} incorporates information from the misclassifications recorded in the error matrix and gives a slightly different accuracy assessment than overall accuracy does. K_{hat} would equal zero if the classifications results were completely random. (Jensen, 1996).

For the raw EVI reference test case, we calculated overall accuracy by comparing the user-detected reference classes to the automated detection of classes from the wavelet-smoothed time series. We used one hundred test points per class. The test points were evenly distributed by year (20 test pixels per year per class) for the not cropland and unclassified classes since there was negligible change in the size of these classes over time. We weighted test points for single and double crop classes by the relative abundance in that year. We randomly located the test points for each year and class using a random sample. We then compared the wavelet-smoothed time-series crop detection results to the raw EVI input data (reference test information) that was subjected to the same criteria to create four classes. For the random test points across the entire scene, we use omission and commission errors to understand our accuracy within the classes as well as overall accuracy and the K_{hat} value.

We also used reference data (known cropping patterns) for Fazenda Santa Lordes to calculate omission and commission errors over the farm. We verify our results to an independent data source. One limitation to this method is the size of the fazenda. While this is a large fazenda, occupying 25 km^2, we are limited to a relatively small sample size (100 pixels) for statistical analysis.

Extensification and intensification are two measures of the extent of row crop agriculture. Extensification, or the increase in total row-crop agricultural area, is measured as the annual increase from one growing season to the next. Each year the area of extensification is calculated as the areas detected as row crops that were not previously detected. Intensification of row crops describes the change from a single to double cropping pattern from one year to the next. The concepts and metrics of extensification and intensification allow us to explain the patterns of agricultural development.

3. Results

3.1. Agricultural extensification

Cropland in the study area increased from 6255 km^2 in the 2001 growing season to 9535 km^2 in the 2005 growing season, as calculated from cropland detection based on annual standard deviation (Table 2). This represents a 34% increase in row-crop agriculture to cover a total area of 24% of the study area. Increases in land cover of row crops were largely at the edges of existing croplands (Fig. 7).

3.2. Detection of cropping patterns

Statistical analysis of detection errors shows overall good results from the wavelet-smoothed time series. The error matrix shows that majority of pixels considered unclassified (more than two crops detected) were actually false-detections of double crops (Table 3). For the purpose of tabulating single and double cropping patterns, we considered double crops to be all pixels with two or more maximums, although this may introduce more error. From the error matrix results we can asses our accuracy (Table 4A). The omission and commission errors (Table 4B) are derived from the error matrix for each classification (Not row crops, 'Not RC', includes native vegetation and pastures; Single cropping patterns; and double cropping patterns). All omission errors are less than 10%, except for Single crops, which have a producer's accuracy of 77.0%. User's accuracy is above 84.0% for all classes analyzed (Table 4B). The wavelet-smoothed time series gives us an

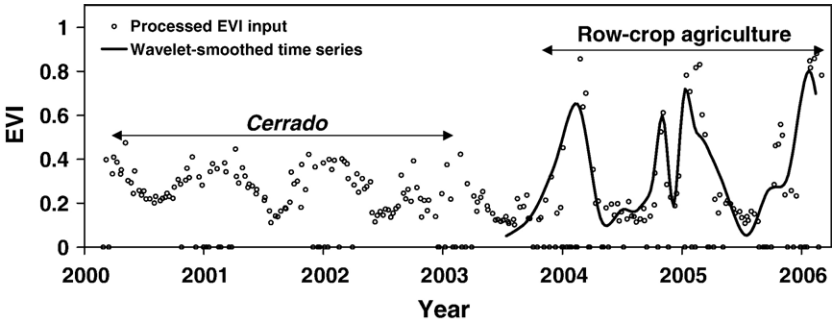

Fig. 8. A field site at Fazenda Santa. Lordes is represented in this time series. The EVI daily time series (2000–2006) after processing for clouds and extremely noisy pixels is plotted with small circles. The solid line shows the 90% power wavelet-smoothed time series. Land cover is converted from *cerrado* to row-crop agriculture in the middle of 2003. In 2004, a single rice crop was grown. In 2005, two soybean crops were grown.