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Analysis of MODIS leaf area index product over soybean areas in Rio Grande do Sul State, Brazil

Rodrigo Rizzi [1]
Bernardo Friedrich Theodor Rudorff [1]
Yosio Edemir Shimabukuro [1]

[1] Instituto Nacional de Pesquisas Espaciais - INPE
Caixa Postal 515 - 12201-970 - São José dos Campos - SP, Brasil
{rizzi, bernardo, yosio}@dsr.inpe.br

Abstract. In this paper we have investigated the relationship between the occurrence of *255 standard fill value* pixels in *Collection 4 MODIS LAI* product (MOD15A2) and the soybean areas in Rio Grande do Sul State, Brazil. Time series of 8-day composite LAI product images and 16-day composite NDVI images were referenced to a soybean map produced over Landsat images in order to analyze the influence of soybean areas in the occurrence of *255 standard fill values* pixels as well as in the LAI algorithms performance, throughout the crop season. Besides, a biome classification map (MOD12Q1 Landcover product) was also analyzed to verify whether the occurrence of those pixels is related to a biome-type misclassification. The results indicate that the *Standard fill value* 255 retrievals in *Collection 4 LAI* product are closely related to the soybean areas and their occurrence appears not to be directly related to an eventual misclassification in biome map input. Therefore, the Collection 4 MOD15A2 product is not suitable to monitor LAI seasonal changes over soybean areas.

Key words: remote sensing, MODIS, soybean, leaf area index, sensoriamento remoto, soja, índice de área foliar.

1. Introduction

Leaf Area Index (LAI) is defined as one sided green leaf area per unit ground area, which is an important input parameter in crop yield models to monitor crop growth conditions and to improve yield estimation. However, for country or regional-scale models, LAI data must be collected over a long period of time and should represent every region of the terrestrial surface (Wang et al., 2004). In this context, remote sensing is an appropriate technique for cyclical and relatively low-cost vegetation monitoring over large areas.

Since late February of 2000 the Earth Observing System (EOS) team has produced the *Collection 4 LAI* data derived from MODerate resolution Imaging Spectroradiometer (MODIS) instrument, onboard of the TERRA platform. The MODIS LAI products are produced at a 1 km spatial resolution, composited over an 8-day interval and distributed free of charge from the EROS Data Center Distributed Active Archive Center (EDC DAAC). The globe is tiled for production and distribution purposes into 36 tiles along the east-west axis, and 18 tiles along the north-south axis, each approximately 1200 x 1200 km (Myneni at al., 2002). Each tile contains LAI, FPAR (Fraction of absorbed Photosynthetically Active Radiation) and two quality assessment variable data sets (FparLai_QC and FparExtra_QC), which contain information about retrieval status such as overall quality of input data, cloud condition and algorithm used to produce the retrievals for each pixel (Wang et al., 2004)

The algorithm to estimate LAI exploits the spectral information content of MODIS daily aggregated surface reflectance data (MODAGAGG product) up to 7 spectral bands (centered at 648, 858, 470, 555, 1240, 1640 and 2130 nm) and their corresponding sun-view geometry. Currently, only Red (648 nm) and Near-Infrared (NIR) (858 nm) bands are used due to high uncertainties in the other bands (Wang et al., 2001). Another input to generate the *Collection 4 LAI* data is a global biome map (MOD12Q1 Landcover Product) based on a 1 year MODIS data set stratified into six canopy architectural types. The six biomes are grasses and cereal crops, shrubs, broadleaf crops, savannas, broadleaf forests, and needleleaf forests (Knyazikhin et al., 1998b) (**Figure 2**). LAI retrievals are performed by a look-up-table (LUT) technique which uses an inversion of the three-dimensional Radiative Transfer (RT) model. The algorithm compares observed and modeled canopy reflectances for a group of canopy structures and soil patterns that represent a range of expected natural conditions (Myneni, 2003). In case of a main algorithm failure, poor quality data are retrieved by a back-up algorithm which uses empirical relationship between LAI and Normalized Difference Vegetation Index (NDVI) to retrieve LAI values based on a LUT approach as well. Two key factors impact the retrievals: a) uncertainties in input data and b) uncertainties in the RT algorithm (Tan et al., 2004). *Collection 4 LAI* product currently has a provisional validation status, that is, quality control testing is undergoing to achieve "validated" status (Tan et al. 2004; Yang et al., 2004). The theoretical basis and implementation of the algorithms can be found in Knyazikhin at al. (1998a; 1998b; 1999).

Moreover, *Collection 4 LAI* product specifies a set of *fill values* assigned to the LAI fields in the case of non-vegetated or non-computed pixels, as shown in **Table 1**. The *255 standard fill value* is used to represent pixels outside projection which results from the reprojection process or in case the range of input surface reflectance variability exceeds the threshold allowed by the LUTs.

Table 1. Description of the fill values in *Collection 4 MOD15A2 LAI* product.

249	Unclassified
250	Urban, built-up class
251	Permanent wetlands, marshes
252	Perennial snow, ice, tundra
253	Barren, desert, or very sparsely vegetated
254	Water (ocean or inland)
255	Standard fill value, for non-computed pixels or pixels outside projection

From a visual analysis it was observed that the *255 standard fill value* pixels in *Collection 4 MODIS LAI* product (MOD15A2) and soybean areas were coincident. Therefore, we investigated in this paper the relationship between the occurrence of those pixels and soybean planted areas in Rio Grande do Sul State, Brazil.

2. Material and Methods

The study was conducted in the state of Rio Grande do Sul, located in the southern portion of Brazil, limited by geographical coordinates W 50^o 40' to 56^o 20' and S 27^o 03' to S 30^o 13' corresponding to tiles h13v11-12 in an area of about 117,628 km^2 that comprises more than 90% of the state soybean production. The soybean crop season goes from early November (sowing) to early April (harvest) and for the majority of the soybean areas, the maximum growth stage occurs in mid February. The soybean area mapping (**Figure 1**) was carried out in a previous study (Rizzi, 2004) using both digital and visual classification over multitemporal Landsat images at two critical growth stages (early February and early March) during the crop season of 2000/01.

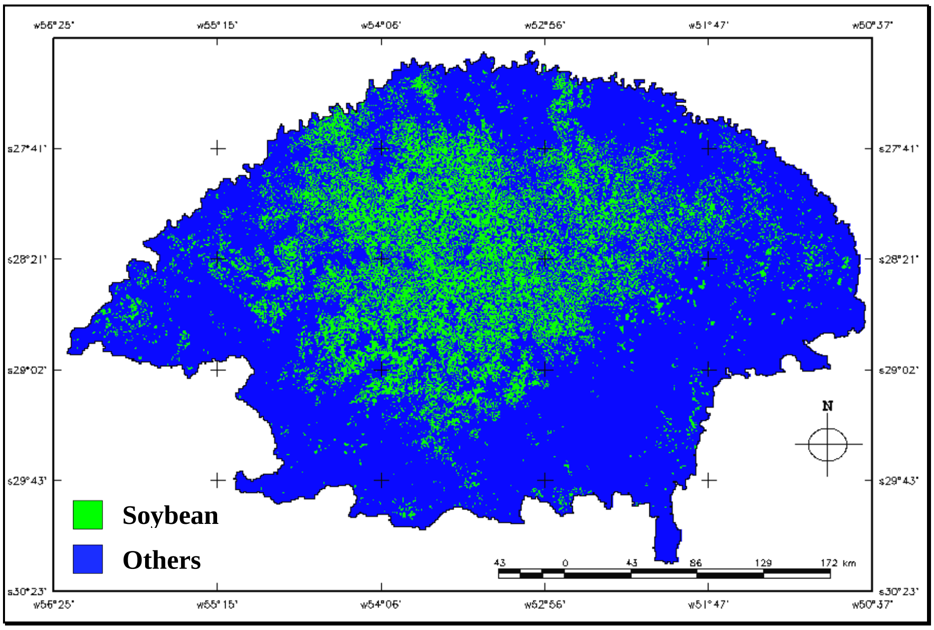

Figure 1: Thematic map of soybean areas mapped over multitemporal Landsat images (Rizzi, 2004).

Time series of 8-day composite MODIS LAI product images (MOD15A2) and 16-day composite MODIS NDVI images (MOD13Q1 collection 4) were acquired at EDC DAAC data gateway to cover the entire soybean growing season (from early November, 2000 to early April, 2001). Our primary objective was to analyze the influence of soybean areas in the occurrence of *255 standard fill value* pixels as well as in the LAI algorithms performance. Thus, 1km LAI and FparLai_QC pixels were referenced to the soybean map and grouped in relation to its soybean percentage, in a 10% interval, to determine the number of *255 standard fill value* pixels and the number of pixels retrieved by each algorithm per 10% interval in every LAI image. In order to establish the soybean spectral behavior during the crop season, NDVI images were linked with the soybean map (**Figure 1**) and their seasonal profile averaged over all soybean areas. Finally, a biome classification map (MOD12Q1 landcover product) (**Figure 2**) was also acquired and referenced with the soybean map to determine the number of pixels in each biome type per 10% interval to verify if the occurrence of those pixels is related to a *landcover* biome-type misclassification.

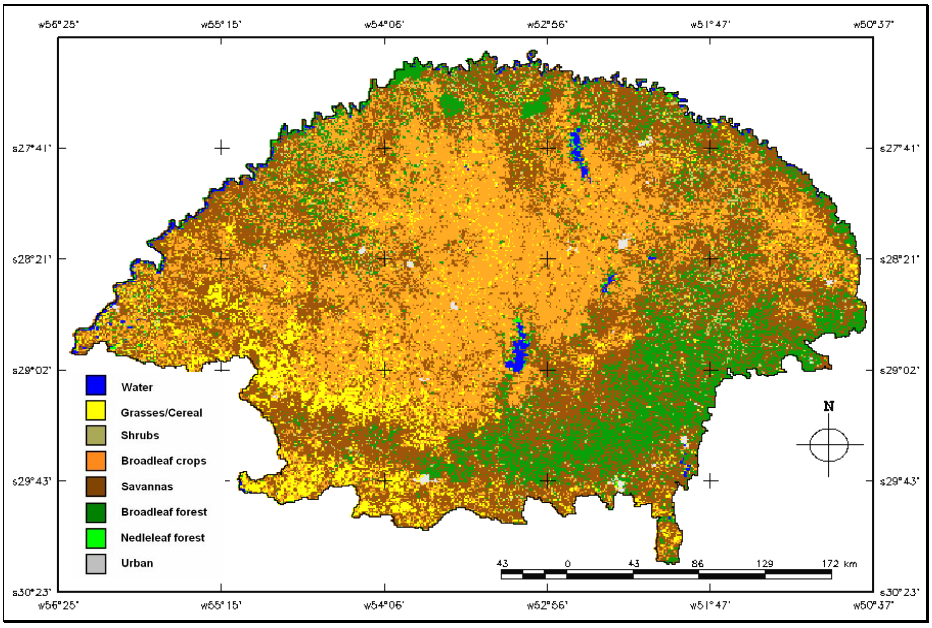

Figure 2: 1 km six-biome *landcover* map (MOD12Q1) used by the *Collection 4 MODIS LAI* algorithms.

3. Results

Figure 3 shows the relative frequency of *Standard fill value 255* pixels (%) in each 1km LAI image in relation to the percentage of soybean in the pixel plus the averaged soybean NDVI temporal profile throughout the crop season. Note that NDVI data appear to be valid inasmuch as its averaged seasonal profile indicates a close consistency with the soybean growing season. Low NDVI values were found in early and late soybean season (from November to early December and from late March to April, respectively), while high NDVI values were found during the middle of soybean season (between late January and early March). Nonetheless, the relative frequency of *Standard fill value 255* pixels shows an increasing trend in mid January and decreases rapidly in mid March for every 10% interval. It is also noticeable that the maximum relative frequency of those pixels occurs in late February, mainly for pixels with high soybean percentage (above 60%), when the soybean plants reach their maximum growth stage (NDVI close to 0.9). For instance, the LAI composite image from day 57th to 65th (late February) has about 75% of its pixels with 100% of soybean represented by *Standard fill value 255* retrievals. Furthermore, the frequency of those retrievals increases as the percentage of soybean in the pixel increases. Therefore, those results reinforce the evidence that the occurrence of *Standard fill value 255* retrievals is closely related to the presence of soybean areas.

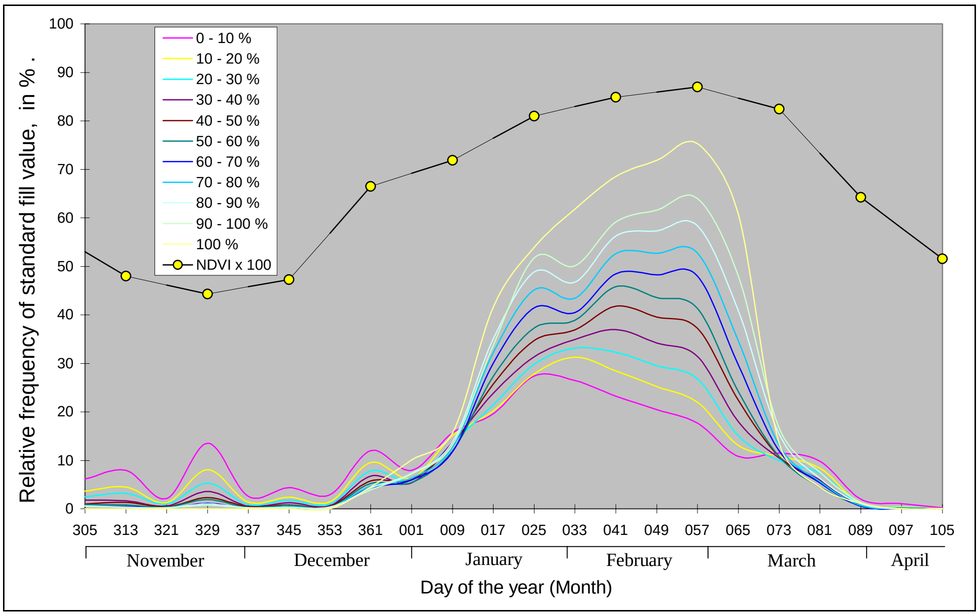

Figure 3: Relative frequency of *Standard fill value 255* pixels (%) in relation to the percentage of soybean in the pixel plus the averaged soybean NDVI temporal behavior.

The relative frequency of pixels retrieved by each algorithm is separately shown in **Figure 4** for each pixel soybean percentage in a 10% interval. Note that the highest relative frequency of *No Data* pixels (when both main and back-up algorithms could not retrieve a valid LAI value) occurs during the mid soybean season (between mid January and mid March) and increases as the percentage of soybean in the pixel increases. Nevertheless, during this period, main algorithm retrievals decrease while back-up algorithm retrievals increase as the percentage of soybean in the pixel increases. On the other hand, the frequency of main algorithm retrievals is significantly higher and overwhelms other retrievals in early and late soybean season (from November to mid December and from late March to April, respectively). This dominance is also higher as the percentage of soybean in the pixel increases, mainly during the early season. Those results suggest that the presence of soybean areas also impacts the algorithms performance in retrieving LAI values.

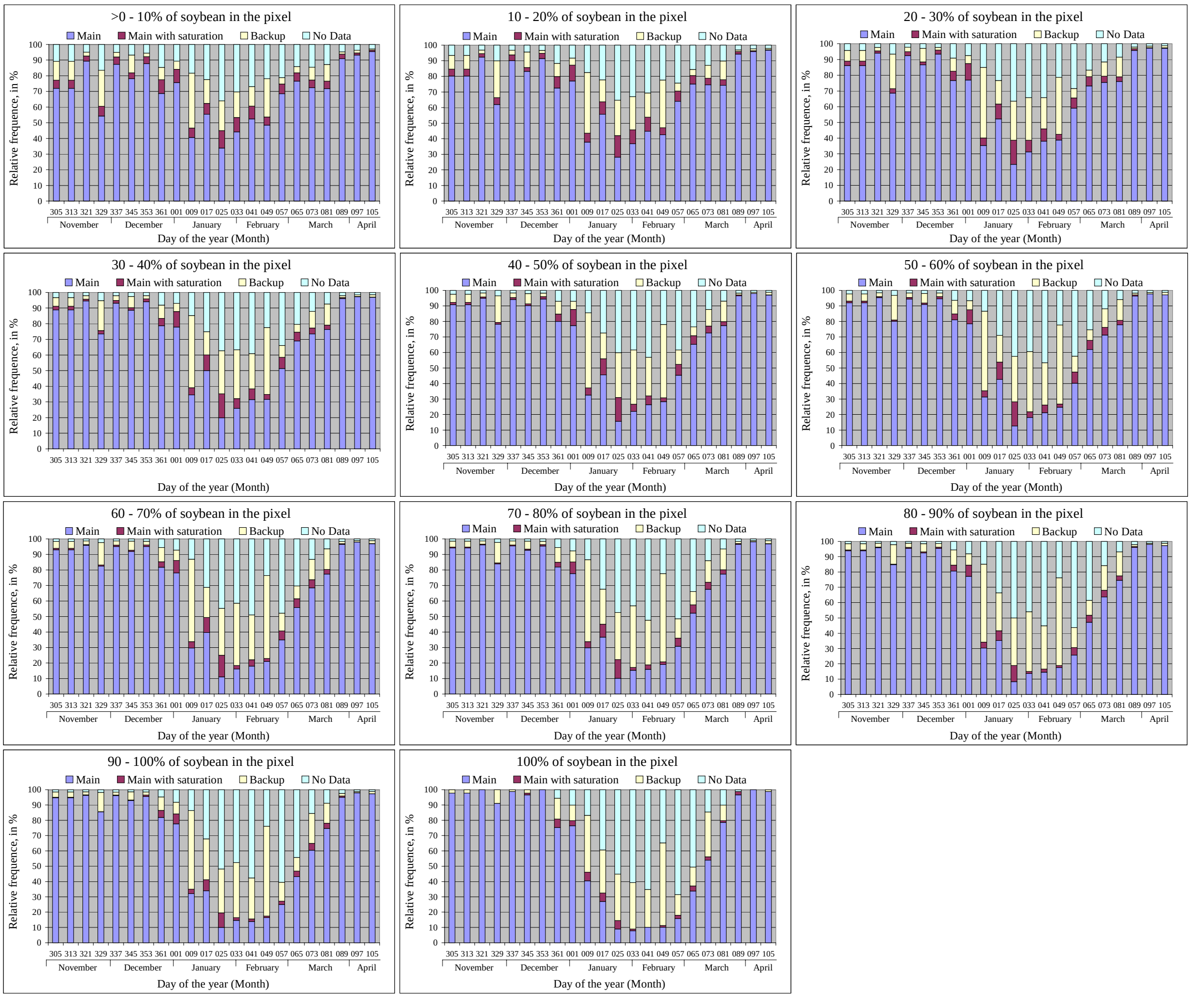

Figure 4: Relative frequency of algorithms (%) in relation to the percentage of soybean percentage in the pixels.

The Relative frequency of biome-type as function of the percentage of soybean in the pixel is presented in **Figure 5**. It is important to point out that the number of *broadleaf* biome-type pixels increases as the percentage of soybean in the pixel increases. Since the soybean can be classified as a *broadleaf* crop, this result indicates that the occurrence of *255 standard fill values* pixels are not directly related to an eventual misclassification in *landcover* input used in those retrievals, although about 27% of pixels with 100% of soybean are represented by *non-broadleaf* biomes in the *landcover* map. Additionally, the *landcover* input shows considerable relative frequency of pixels tagged as *savannah* biome-type (mainly for pixels with low soybean percentage), which is not present in the study area. Most of those areas, which are represented by natural pasture, are being replaced by soybean fields due to increasing demand of soybean in the world's market.

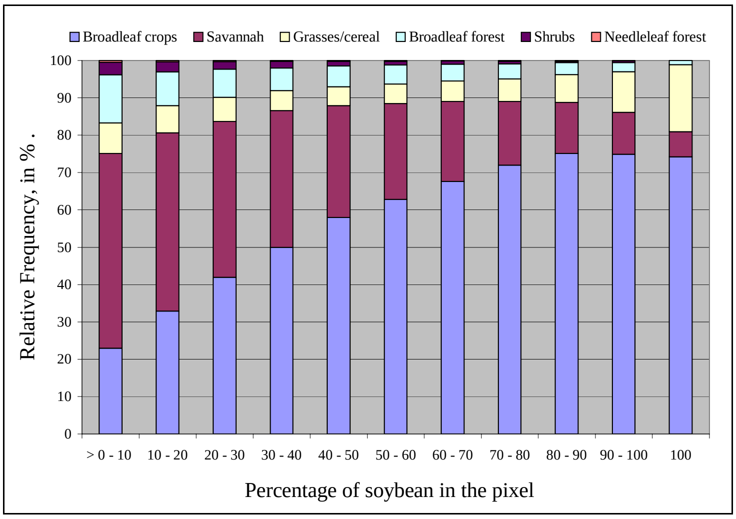

Figure 5: Relative frequency (%) of biome-type by percentage of soybean in the pixel.

4. Conclusion

Since the high relative frequency of *Standard fill value 255* retrievals in *Collection 4 MODIS LAI* product (MOD15A2) occurs for pixels with high soybean percentage, only in a specific period which coincides with the maximum soybean growth stage, the results from our study indicate that those retrievals are closely related to the soybean areas. Besides, their occurrence appears not to be directly related to an eventual misclassification in *landcover* input. Therefore, the Collection 4 MOD15A2 product is not suitable to monitor LAI seasonal changes over soybean areas. Thus, more effort must be focused on validating the product in further studies.

5. References

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