An approach to orbital image classification for the assessment of potato plantation areas

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XI Brazil-Japan International Workshop. IFSP-Caraguatatuba; Universidade Estadual de Campinas; Gifu University; Tokyo University of Agriculture and Technology. Caraguatatuba [SP], Brasil. 11/09/2013. [Conpadre n.16/2013].

Abstract

In the city of Bueno Brandão, South of Minas Gerais State, Brazil, the Watershed of Rio das Antas is located prior to the public water supply and is susceptible to hydro-degradation due to the intensive agricultural activities developed in the area. The potato plantation is the most significant cropping in the city. Because of the possibility of interfering in the preservation areas, mainly the ones surrounding water courses and springs, it is very important to do the assessment of the plantation sites, in order to avoid the risk of water contamination. The procedures adopted by the agro activity farmers generally present the following features: intensive use of agro-chemicals, cropping in places with slopes which are higher than 20%, close to or in permanent preservation areas. The scope of this study was to develop the proper methodology for the assessment of the plantation areas, regarding the short time of procedure, as the period between the plantation and the harvest occurs in six months the furthest. These areas vary year in year out, as the plantation sites often change due to the land degradation. Because of that, geotechnologies are recommended to detect the plantation areas by the use of satellite images and accurate data processing. Considering the availability of LANDSAT medium resolution images, methods for their appropriate classification were approached to provide effective target detection.

Keywords

Pixel-based Classification, OBIA, Assessment of Plantations, Preservation Area Interference, Water Contamination Risk.

Introduction

According to IBGE (2007), the agricultural activities with the most number of producers in Bueno Brandão, MG, are the potato and coffee plantations. However, the intensive use of agricultural defensive chemicals, the elevate frequency of planting, the presence of land disproved of vegetation protection and the plantation in preservation areas, made the potato cropping highly responsible for potentializing the risk of water contamination in the Sub-basin of Antas River. However, prior determining the sites with a major risk of contamination, it is necessary to develop an effective methodology for detecting plantation areas, which is the main scope of this study.

On one hand, the potato plantation must be held in dry sunny places, with a reasonable availability of water for irrigation. On the other hand, the area must present easy drainage features, as the plant does not tolerate water excess. Because of that, Bueno Brandão has been the ideal place for this culture along history. It represents a mountainous area with an abundant amount of water.

For the correction of soil, fertilizers are generally applied before and after plantation. In Bueno Brandão, as most of the areas used for plantation have a declivity higher than 20%, there should be adopted soil conservation methods, minimizing the superficial flow of water, which carries all materials disposed on the land to the rivers, as there is mostly no natural vegetation protecting them. In spite of that, traditional and non-conservationist methods are commonly applied in environmentally fragile areas of plantation.

In that area, the most common agricultural model is the traditional one, despite the predominant steep soles of the region. It may cause degradation to the water resources due to the use of excessive and inadequate chemicals, mainly because of: trespassing preservation areas around springs and water courses and destroying the vegetation covering riparian forests. So the detection of plantation areas is important to monitor land cover and avoid the risk of water contamination in the region. For the methodology applied, it was important to consider that, the preparation of the land commonly occurs between August and September, making it more appropriate to visualize bare soil areas by the use of orbital images, and accurate techniques to provide the target detection.

Materials and Methods

The city of Bueno Brandão is located in the south of Minas Gerais State, in the micro region of Alta Mantiqueira. The highest altitude is 1,719m and the lowest is 840m, with S 22º26’27” latitude and W 46º21’03” longitude, of W 45ºcentral meridian and fuse 23. The region has rivers with a low discharge volume, among which are the rivers called Antas, Cascavel and Cachoeirinha. The local topography is mountainous in 70% of the area, with the presence of many waterfalls. The municipal area is 355.23 sq-km, comprehending the watershed of Rio das Antas. It is located prior to public distribution and has the area of 50.22 km², with latitudes between S 22º31’38” and S 22º24’15” and longitudes between W 46º22’13” and W 46º13’56” geographical coordinates, as it is illustrated in Figure 1.

The mountainous condition of the area might be represented by different classes of slope (VIEIRA, 1988). They describe the natural limitation to use the land, regarding the agro plantation. The definitions of the six classes are detailed as it follows: Class A) soft slope or practically plan, inferior to 3%; Class B) low slope and slightly hilly, between 3% and 8%;

Class C) moderate slope, between 8% and 20%; Class D) severe slope, between 20% and 25%; Class E) very severe slope, between 45% and 75%; Class F) cliffs, with slopes superior to 75%. In Bueno Brandão, regarding the classes described by Vieira (1988), the corresponding areas of slope in the watershed of Rio das Antas might be observed in Table 1.

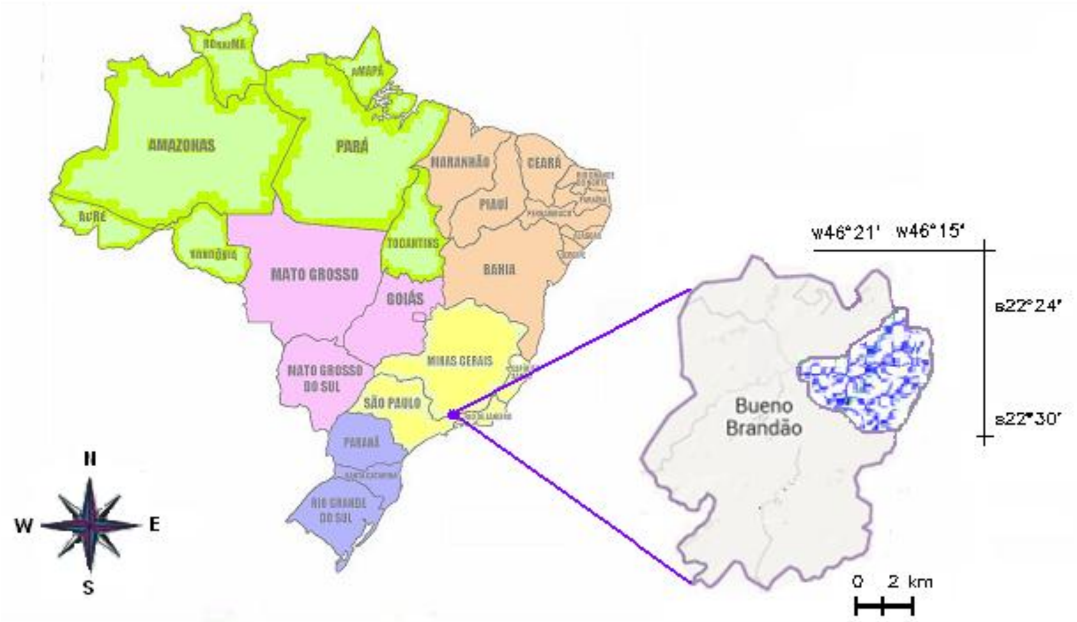

Figure 1. Location of the study area, highlighting the municipality of Bueno Brandão and the watershed of Rio das Antas, in the State of Minas Gerais, Brazil.

Source: elaborated by the authors on the basis of: BOULOMYTIS (2008).

Table 1. Areas of slope in the Watershed of Rio das Antas

Slope (%)	Area (km²)	Percentage of Slope in the Watershed of Rio das Antas (%)
< 3	3,60	7,20
between 3 and 8	3,72	7,40
between 8 and 20	16,88	33,60
>20	26,02	51,80

The soil fertility might be improved through the implementation of innumerous agronomic techniques (FILGUEIRA, 1999). In order to have mechanized operations for the use of these techiniques, the land must have appropriate topography attributes. In high slope areas, besides the high cost of plantation, there is a significant risk for the occurrence of erosion and the operations become much more complex. Nevertheless, the plantation system should depend on the local topography.

In Bueno Brandão, although the topography attributes are incoherent to the mechanized system, it is still predominant for the preparation of the land (56%) (CIB, 2008). According to

Brigante et al. (2003) and Boulomytis (2008), this plantation system is inadequate because of the high slope in the cropping sites and the intensive use of agrochemicals inside or surrounding the preservation areas. It justifies the importance of the study, based on the fact that, even though the area has a natural limitation to the potato agro plantation it is still intensively used for this purpose.

For the study, a LANDSAT TM5 medium resolution image with the following features was used: orbit/point 219/76, bands 3, 4 and 5, from August 16th, 2007, available at the DGI-INPE Home Page (http://www.dgi.inpe.br/siteDgi/index_pt.php). For the registration of the image, the Chart of Brazil – Munhoz and Ouro Fino, in the scale of 1:50.000, was used (IBGE, 1972).

The classification of the area was done by the use of: 1) the SPRING v 5.1.8 software (CÂMARA et. al, 1996), for the pixel-based classification; 2) and, the Definiens Developer® Platform (2006), for the Object-Based Image Analysis (OBIA).

The total of 100 land use and cover samples were collected in the field with a GPS (Global Position System) receptor (30 samples of potato plantation sites) and with the ©2010 Google Earth – Image©2012 Geoeye (20 water courses, 30 other-plantation areas and 20 forest areas).

The methodology of the study had the purpose of detecting the potato plantation areas by the use of the most effective procedure. Thus, two techniques were approached and compared: the pixel-based classification; the OBIA. The reason for achieving the image in this period of the year (August to September) is that there is bare soil and lack of vegetation in the potato plantation sites, making it visually easier to identify this cluster.

Regarding the pixel-based classification technique, for the segmentation, three processes were done: 10x10, 10x15 e 10x20 (10 tons of gray per region of 10, 15 or 20 pixels). After analyzing the most appropriate result, the segmentation of 10x10 pixels was selected, in order to gather the cluster with fewer cells and more similar tons of gray. This procedure promoted a better pixel-based classification afterwards. The classifier used was Bhattacharyya, with a limier of acceptation of 99%.

Samples were used for training the classification algorithm, based on the distribution of probability in each class. They contemplated 10 samples of each kind. It was possible to identify an area of representative and homogeneous sampling, including the variability of gray levels for each class (CÂMARA et al., 1996).

The OBIA was also based on the segmentation and classification steps (BOULOMYTIS and ALVES, 2012). In this study, at the first step, objects were created in different scales, according to the criteria of shape, color and homogeneity, all connected. At the second step, the objects became related by the definition of a class hierarchy and semantic information. In the image, an object represents an entity which might be individualized by the class attributes and properties of the original data. The segmentation is a fundamental step in this process, responsible for generating spectrally homogeneous segments which represent the inherent dimensions concerning the objects contained in the images (BLASCHKE, 2010).

The spatial features of an object in the image are defined by aspects of texture, context information and geometric attributes. A set of attributes characterizing spatial relationships of objects in a given scale are used in addition to their spectral characteristics. It is increasingly recognized that the spatial information associated with objects, particularly the characteristics of context attributes, that make up the relational can be explained when the pixels are

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grouped into objects (BURNETT and BLASCHKE, 2003). As it may be observed in Table 2, the attributes used were spectral and relational. It was not possible to use shape attributes due to the lack or regularity and reduced dimensions of potato plantation sites, besides the presence of slopes in the same region where they are located.

Table 2. Attributes and attribute types used for the OBIA classification technique

Class	Attributes	Attributes types
Water bodies	NDWI	spectral
Forest	NDVI	spectral
Potato plantations	NDVI	spectral
	maximum difference	spectral
Other plantations	not potato plantation	relational
	not Forest	relational

One of the best known vegetation indices used in this study is the Normalized Difference Vegetation Index (NDVI), calculated from the ratio among images of red and infrared bands and the sum of these bands (Equation 1). The NDVI is based on the spectral response behavior of vegetation, using information from satellite images and are destined to characterize the biophysical and biochemical processes of such areas, besides identifying areas with vegetation cover (NASA, 2011).

$$NDVI = \frac{\text{Near IR} - \text{Red}}{\text{Near IR} + \text{Red}} \quad \textbf{(1)}$$

The Normalized Difference Water Index (NDWI) is derived using similar principles compared to the NDVI, but the green band is used instead of the red one (Equation 2). NDWI enhance the water spectral information, maximizing some features, such as: the typical reflectance of water features by using green wavelengths, the low reflectance of NIR by water features and the high reflectance of NIR by terrestrial vegetation and soil features. The outcomes from this index are positive values for water features and zero or negative values for soil and terrestrial vegetation (MCFEETERS, 1996).

$$NDWI = \frac{\text{Green} - \text{Near IR}}{\text{Green} + \text{Near IR}} \quad \textbf{(2)}$$

In the OBIA process, a data bank was created in the Definiens Developer® Platform (2006), containing the Landsat TM5 image and the surrounding limit of the watershed. Based on previous researches (ALVES et al, 2010; ALVES et al., 2009), and considering the characteristics of the used data and the purpose of the classification, parameters of scale, shape and color were defined for the segmentation. Initially, two levels of segmentation were created (Figure 2).

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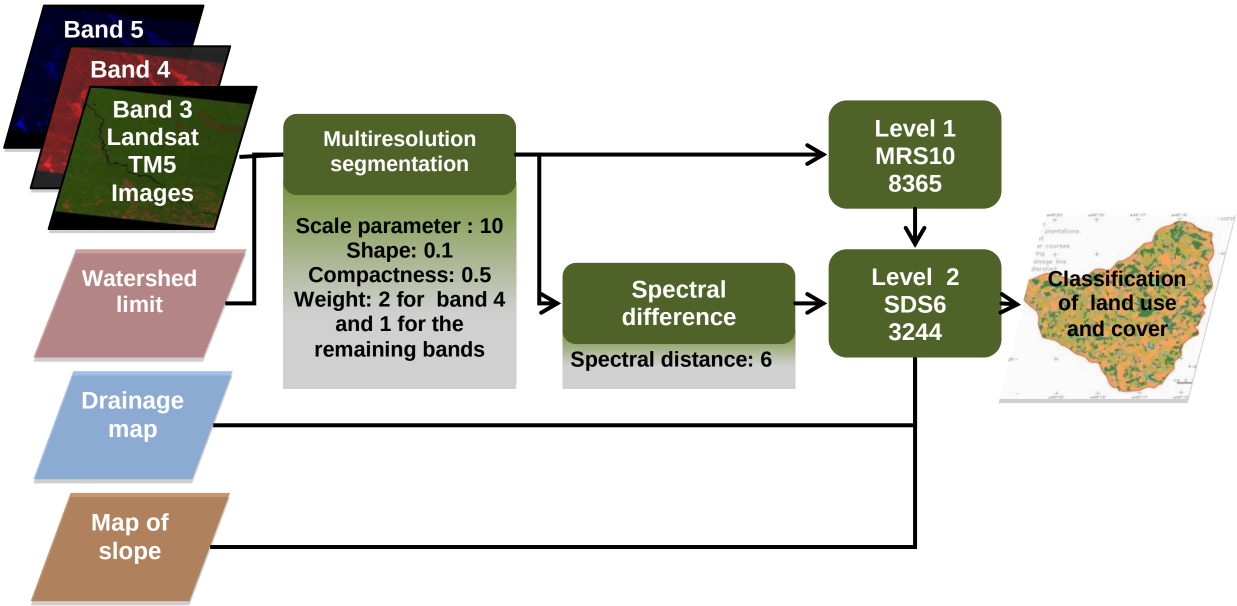

Figure 2. Flowchart of OBIA classification showing the levels of segmentation and parameters used in this research.

Source: elaborated by the authors.

For the validation issue, the samples which had not been used in the supervisioned classification were later processed (20 potato plantation areas, 10 water courses, 20 other-plantation areas and 10 forest areas). By the use of the Kappa index (CONGALTON and GREEN, 2009), a confusion matrix of the classification was done and the Z test processed for both of the techniques.

Results and Discussion

The main thematic classes attributed to the study area were: *Potato Plantation, Other plantation, Water course, Forest and Spring*, as it is shown at Figure 3. The percentage area of each thematic class is displayed in the diagram of Figure 4.

Even though the region has abundant hydrological resources, the “Water courses” class corresponded only to a little more than 1.2% of the area. It occurred because, from orbital images, there are water courses that may not be detected due to the vegetation which covers them and the mountains surrounding the area. It becomes difficult to obtain the drainage line only by applying traditional classification methods. As it was not the purpose of this research whatsoever, no specific methodology to satisfy this demand was processed.

The vegetation areas corresponding to other kinds of agro plantations and pastures were classified as “Other plantations”. These other kinds of agro plantations, such as coffee and corn, represent a smaller percentage than the potato plantation. Most of the “Other plantations” class is represented by pastures, as the predominant system of managing the cattle in the region is extensive and depends on large areas for feeding the animals. As it was not the scope of the article, there was no aim to classify the pasture individually.

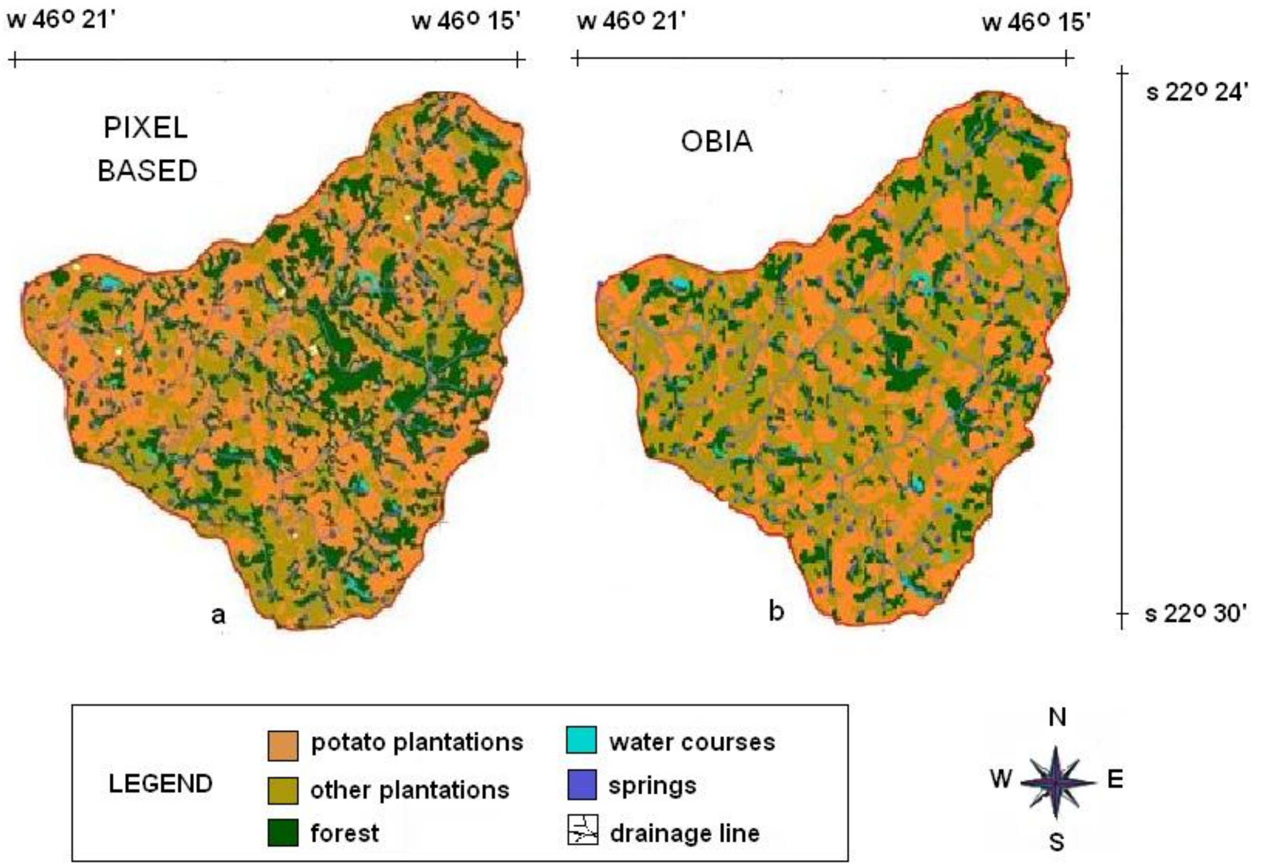

Figure 3. Classification of land use and cover of the Watershed of Rio das Antas, Bueno Brandão, MG, Brazil, using both of the approaches: Pixel-based Classification (a) and OBIA (b).

Source: elaborated by the authors.

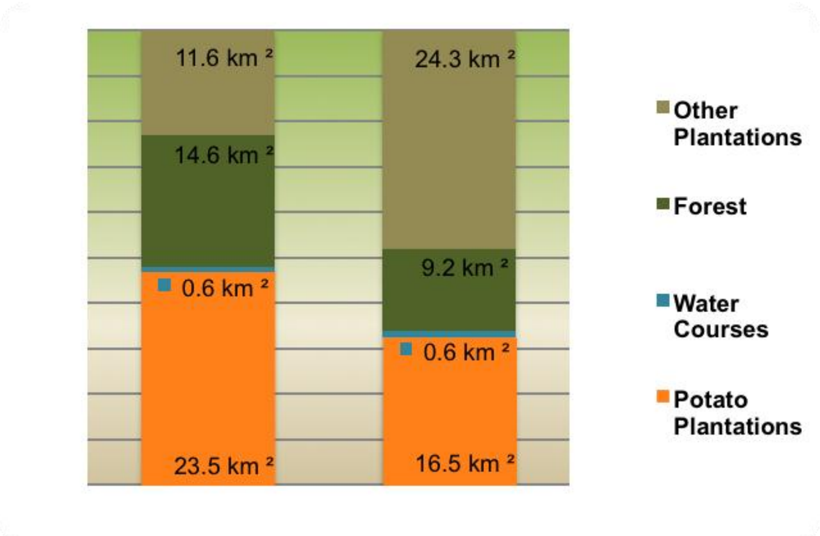

Figure 4. Area Percentage in each one of the classes obtained in both of the classification processes: Pixel-based Classification and OBIA.

Source: elaborated by the authors.

According to IBGE (2007), in 2006 the production of potato in Bueno Brandão was in 10.20 km^2, which would represent less than half of the classified area using pixel based classification. In OBIA classification (16.5 km^2), the area of the potato crop was less overestimated, than the pixel-based classification (23.5 km^2), compared to the IBGE estimation. One of the main reasons for the occurrence of this pattern was probably because of the spectral similarity to the other bare soil areas, which did not correspond to potato plantations. As there was not a different attribute to distinguish them, they were classified the same way.

In the OBIA classification the first level of segmentation, MRS10, generated a high level of separability and detailing, allowing the separation of small objects. The higher weight given to band 4 was used to highlight the vegetation response in the near infrared, distinguishing the vegetation areas (forest and other plantations), which presented bare soil.

The algorithm *spectral difference segmentation* was used to assemble contiguous objects with similar spectral characteristics. In this case, the used parameter considered up to 6 levels of gray. Thus, the small objects generated in the MRS10 level were preserved, as well as the ones which represented small potato plantations. This algorithm allowed the reduction of objects. As a result, there was a reduction of the processing time of the classification, minimizing the internal details of non-desirable thematic classes. In the SDS6 level, the final classification was finally done.

For the validation process the confusion matrix was generated after crossing the samples with the reference map and both of the applied techniques. The results may be seen on Table 3.

Table 3. Global Accuracy, Kappa index and Z tests obtained for the classification using both techniques.

<table>
<tr><th>Classification Method</th><th>Global Accuracy</th><th>Kappa index</th><th>Z test (α=5%)</th><th>Comparative Z test (α=5%)</th></tr>
<tr><td>Pixel Based</td><td>0.62</td><td>0.47</td><td>5.19</td><td rowspan="2">- 1.97</td></tr>
<tr><td>OBIA</td><td>0.78</td><td>0.70</td><td>9.47</td></tr>
</table>

The classification with the pixel-based approach obtained a theme map in which the global accuracy and Kappa indexes (K) have been respectively 62% and 0.47. The value found for Kappa coefficient was acceptable but close to poor (K<0.40), based on Congalton and Green (2009). It showed the lack of conformity of the classification compared to the reference map. The Z test applied for the image classifications indicated that the null hypothesis, considering the classifications to be similar to a random classification, was negated, since the Kappa values were significantly higher than zero, for the significance level of 5%.

The OBIA classification obtained a theme map in which the global accuracy and Kappa indexes have been respectively 78% and 0.70. The value found for Kappa coefficient was acceptable (0.4<K<0.8), based on Congalton and Green (2009). The classification was more proper when compared with the reference map. It was confirmed by the Z test in which there is an agreement between the classifications and the reference image, for the adopted level of significance (α=5%). The result of it for the pixel-based classification was 9.47. The Z test was also applied in a comparative way to verify the results of the two methods. The result obtained, at a significance level of 5%, confirms that the Kappa value of the traditional method (pixel-based classification) is significantly lower the one obtained by the second method, OBIA.

Conclusions

The validation process showed that the approach using OBIA was more accurate, as it also considered relational attributes, beyond others.

It is important to notice that the methodology using the pixel-based classification might be applied only when the image is in the proper period, while the farmers are preparing the land and there are bare soil areas.

In case the potato crops are growing and flourishing, the OBIA might also be a more appropriate technique, because besides the spectral and texture attributes, relational attributes may be used, considering the same classes in different dates, such as, the object attributes, the relationship between classes, the global relationship and the logic operators (that may occur at the same class hierarchy level or at higher or lower ones).

Finally, this methodology proved to be very useful for the assessment of potato plantation areas prior to the actual plantation, when the producers are still preparing the land. In case it is in an environmentally fragile area, this methodology may be applied by the responsible technical departments of governmental agencies as an aid to monitor the specific locations of plantations. Even it the application of agricultural rotation systems occurs every year, this methodology might be helpful, as long as updated orbital imagery is obtained and imported to the data bank for the desired classification process.

Acknowledgements

We would like to acknowledge CAPES for supporting the research and INPE for providing part of the necessary data and infrastructure.

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