EVALUATION OF THE POTENTIALITY OF WFI/CBERS-3 SENSOR DATA FOR LAND USE AND LAND COVER CLASSIFICATION

Avaliação da potencialidade dos dados do Sensor Wfi/Cbers-3 para classificação do uso e cobertura do solo

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ABSTRACT

The high cost involved in the development and launching of optical orbital sensors makes the planning and study of the potential uses of their products necessary before their launch. CBERS-3 satellite is planned to be launched in 2008 and will carry on board, among other sensors, the Wide Field Imager Camera (WFI). Its technical characteristics will benefit users who need moderate spatial and high temporal resolution images. Then, the objective of this work is to simulate and evaluate the potentiality of a WFI/CBERS-3 image for land use and land cover classification in two landscapes with different characteristics. The first site is characterized by intensive agricultural area in São Paulo State located in the Southeast region of Brazil, and the second area is characterized by deforested areas in Mato Grosso State, located in the Amazon region. The simulation of the WFI/CBERS-3 images was made using two ETM+/Landsat-7 scenes. The obtained classification results achieved for both studied sites show that WFI /CBERS-3 images will be a useful source of information for land use and land cover classification.
Key-words: Digital image processing, CBERS-3 satellite, WFI sensor, Image simulation.

RESUMO

Os altos custos envolvidos no desenvolvimento e no lançamento de sensores ópticos orbitais tornam necessário o planejamento e estudo dos potenciais usos dos produtos gerados por tais sensores antes mesmo de seu lançamento. O satélite CBERS-3 tem lançamento previsto para 2008 e irá carregar a bordo, entre outros sensores, a câmera WFI (Wide Field Imager). As características técnicas deste sensor irão beneficiar usuários que necessitam de imagens de resolução espacial moderada e alta resolução temporal. O objetivo deste trabalho é simular e avaliar o potencial das imagens WFI/CBERS-3 para classificação de uso e cobertura da terra em duas regiões com características de paisagens distintas. A primeira região está localizada no estado de São Paulo e é caracterizada por uma atividade agrícola intensa; a segunda região está localizada no estado do Mato Grosso, inserida na Amazônia Legal, e é caracterizada por diversos focos de desflorestamento. A simulação das imagens WFI/CBERS-3 foi feita utilizando duas imagens ETM+/Landsat-7. Os resultados das classificações obtidas para ambos os casos estudados mostraram que as imagens WFI/CBERS-3 serão uma fonte útil de informações para classificação do uso e cobertura da terra.
Palavras chave: Processamento de imagens digitais, satélite CBERS-3, sensor WFI, simulação de imagens.

1. INTRODUCTION

The China-Brazil Earth Resources Satellite (CBERS) program is a partnership in the space technical scientific segment and the first cooperation in this field involving two developing countries in the world, Brazil and China (EPIPHANIO, 2005). The agreement between Brazil and China for a long-term cooperation in Earth observation from space started back in 1988 (EPIPHANIO, 2005). This partnership resulted in the launching of two satellites, the CBERS-1 in 1999 and the CBERS-2 in 2003, which provided for both countries a great opportunity to monitor their vast territories and resulted in the development of innumerous researches in the Earth resources field, boosted by a well succeeded image distribution policy.

The results obtained by CBERS-1 and CBERS-2 were considered an achievement so important by both countries that an agreement for the follow-up of the program was signed. In addition, the CBERS-3 and the CBERS-4 are planned to be launched in 2008 and 2011, respectively. However, another agreement was signed by both countries that resulted in the launch of CBERS-2B in 2007, to avoid an eventual gap of remote sensing data acquisition between the possible end of CBERS-2 and the launch and commissioning of CBERS-3 (EPIPHANIO, 2005).

The launching of CBERS-3 satellite will provide to the satellite image's users interesting alternatives in terms of new sensors. One of the sensors on board of the CBERS-3 will be the Wide Field Imaging Camera (WFI), which will have improved its spatial and spectral resolutions in comparison with the previous WFI sensors on board of the CBERS-1 and CBERS-2 satellites, maintaining however its high temporal resolution of 5 days. A comparison between the general characteristics of the WFI/CBERS-3 and the ETM+/Landsat-7 sensors is presented in Table 1.

TABLE 1 - GENERAL CHARACTERISTICS OF WFI/CBERS-3 AND ETM+/LANDSAT-7 SENSORS. Source: King and Greenstone (1999, p.113), and Selingardi et al. (2003).

	WFI/CBERS-3	**ETM+/Landsat-7**
Spectral bands	0.45 – 0.52 µm 0.52 – 0.59 µm 0.63 – 0.69 µm 0.77 – 0.89 µm	0.45 – 0.52 µm 0.52 – 0.60 µm 0.63 – 0.69 µm 0.76 – 0.90 µm
Swath width	866 km	185 km
Spatial resolution	73 m	30 m
Temporal resolution	5 days	16 days

These spectral and spatial resolution characteristics will be of special interest in works where a constant and accurate monitoring is required. The medium spatial resolution images provided by sensor such as the TM/Landsat-5 or the CCD/CBERS are in mostly of the cases followed by a low temporal resolution, being the ground coverage cycle of 16 days for the TM sensor, and 26 days for the CCD sensor.

Despite the high potential of the use of images provided by orbital sensors in the monitoring of the natural resources, many are the issues concerning the operational use of such images. One of the major problems faced nowadays is the restrictions due to the low availability of cloud free images for some regions.

In the case of agriculture monitoring using remote sensing, during the period of the year when the crops might be observed the possibilities of finding images covered by clouds are very high, making not possible the assessment of the biophysics' parameters of the crops that changes very quickly along a season (DORAISWAMY et al. 2005), turning impracticable in many occasions the use of such images.

One of the alternatives to skirt this problem is to use low or moderate spatial resolution images, as provided by MODIS (Moderate Resolution Imaging Spectroradiometer) sensor, on board of the Terra and Aqua EOS (Earth Observing System) satellites. This sensor provides an excellent alternative for daily images. However, its spatial resolution of 250 meters is not appropriated in regions characterized by small crops areas, where there may be great possibility of intra-pixels mixture carried out by the integration of various spectral responses, which damages the classification performance (FORMAGGIO et al., 2005).

Another situation where the low temporal resolutions regarding the clouds occurrence is an issue related to the monitoring of the deforested areas in the Amazon forest region. ASNER (2001) performed a spatially explicit analysis of cloud cover in the Landsat archive of Brazilian Amazon from 1984 to 1997, concluding that it is possible to assess basic changes in land cover on an annual basis in much of the Brazilian Amazon using Landsat and similar Sun-synchronous, medium spatial resolution instruments, although in some regions like in the state of Amapá, the probability of an observation once per year at 30% cloud cover is close to zero. The same author also concluded that monthly observations of any part of the Amazon basin are highly improbable using TM/Landsat-like optical images.

Therefore many analytical researches are being developed in images of different orbital sensors, in an effort to find the potentialities and disadvantages in the land use and land cover studies, including researches regarding sensors that have not been lunched yet. This kind of information can supply public policies with quantitative and temporal structure in order to plan the best uses of this kind of equipments.

The objective of this work is to simulate a WFI/CBERS-3 image in order to analyze its potential for land use and land cover classification, taking two approaches: the classification of an intensive agriculture area; and the detection of deforested areas in a region of the Brazilian Amazon Forest.

2. METHODS

2.1 Study site and data acquisition

This study was carried out in two study sites: (a) for the objectives of classification in areas of intense agriculture, we chosen the municipality of Ipuã, located in the north part of the São Paulo (SP) State (Figure 1); and (b) for classification of deforested areas, a region located in the city of São Felix do Araguaia, in the northeast part of the Mato Grosso (MT) State (Figure 1) with approximately 360,000 ha was chosen.

The agriculture is the main economical activity in the city of Ipuã, highlighting the cultures of corn, sugar cane and soybean crops. According to the

Brazilian Institute of Geography and Statistics (IBGE), in the 2004 harvest, the city production for the cultures of corn, soybean and sugarcane were 13,470, 39,000 and 2,447,500 tons, respectively.

São Felix do Araguaia municipality is part of the Amazon basin, and is included in a region known as the “arc of deforestation”, characterized by the agriculture boundary expansion with high occurrence of deforested areas. The vegetation cover of the region is characterized by ecological tension between ombrophile forests and seasonal forests. The deforestation patterns in this region according to Miranda (2005) are composed by median and large properties associated to commercial agriculture purposes.

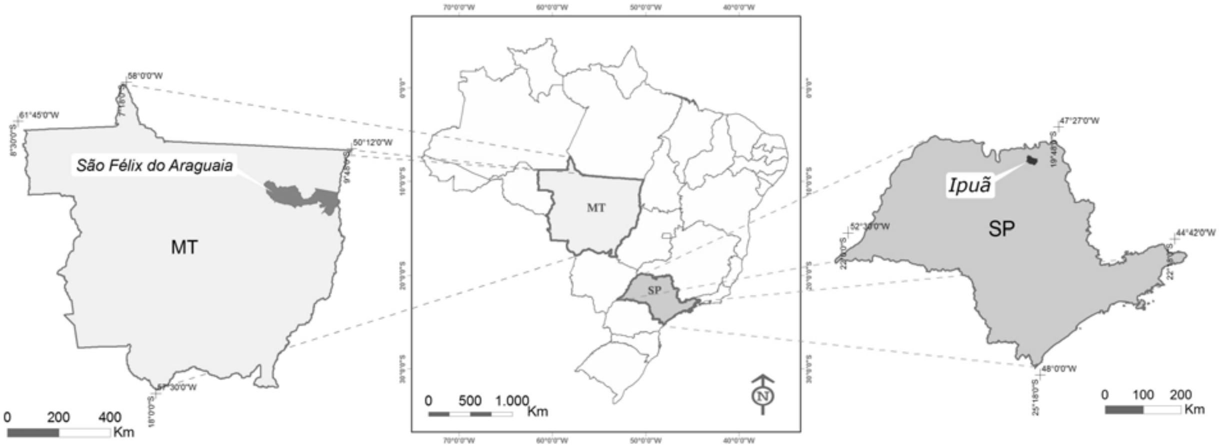

Fig. 1- Location of Ipuã (SP) and São Felix do Araguaia (MT) municipalities.

The image simulation for each of these sites was made with the estimation of the sensor’s Point Spread Function (PSF), which according to Bensebaa (2005) is in general the most common way to evaluate the performance of an imaging sensor.

The WFI/CBERS-3 simulated images were generated by the degradation of two ETM+/Landsat 7 images (Table 2).

TABLE 2 - ETM+/LANDSAT 7 IMAGES USED FOR THE SIMULATION PURPOSE.

Path	Row	Region of interest	Date (mm/dd/yyyy)
225	68	Ipuã	05/19/2003
220	74	S. F. do Araguaia	01/05/2002

2.2 WFI/CBERS-3 image simulation

Two steps were carried out in order to degradate the ETM+ images: application of PSF digital convolution filters, following the methodology proposed by BANON (1990); and the resampling of the filtered images, using the nearest-neighbor technique in order to achieve the original theoretical geometrical scale of the WFI/CBERS-3 sensor.

In order to calculate the digital convolution filters it is necessary to have all the spatial resolution characteristics of both sensors, such as the Instantaneous Field of View (IFOV) and the Effective IFOV (EIFOV).

The characteristics of the WFI/CBERS-3 sensor were obtained from its project documents and from laboratory tests reports (SELINGARDI et al., 2003). These characteristics are showed in Table 3.

TABLE 3 - GEOMETRIC SPECIFICATIONS OF ETM+ AND WFI SENSORS. Source: Boggione (2003) (ETM+), Selingardi et al. (2003) (WFI)

	ETM+ (m)		**WFI/CBERS-3 (m)**	
	Row	Column	Row	Column
IFOV	30	30	73	73
EIFOV (Blue)	35.35	31.25	111	108
EIFOV (Green)	36.15	33.10	104	99
EIFOV (Red)	37.40	33.42	113	105
EIFOV (NIR)	39.16	34.74	128	114

The evaluation of the potentiality of this sensor to classify land use and land cover in intensive agriculture areas, both, the simulated WFI image and the ETM+ image from the municipality of Ipuã, were classified using two supervised classification algorithms: a maximum likelihood classification algorithm (MAXVER); and an algorithm based on the Bhattacharya distance (Bhattacharya). A pixel classifier, as MAXVER, only employs the average and the variance of the digital number, whereas a segment classifier, as the Bhattacharya, can employ besides spectral average and variances, parameters which describe shapes, sizes and the segment context (BELAID et al., 1992). The software SPRING 4.3 was used to classify the images.

2.3 Image evaluation

For the Ipuã study site, the analysis of the results were made by the comparison between the thematic maps generated by the classifications, as well as the evaluation of its accuracy – inclusion an omission errors, and kappa index - , by means of comparison with a ground reference map of the region for the same date, produced by LUIS (2003). This reference map, originally with 23 classes, was regrouped into 9 classes in order to evaluate the classification algorithms utilized.

In the deforested areas detection case, the classification of the simulated WFI image was made following the methodology used by the Project for the Monitoring of Deforested Areas in the Amazon Region (PRODES) (INPE, 2006). This methodology uses the linear spectral mixing model to estimate the vegetation, shade and soil fractions of the image, followed by the segmentation of the soil or shade fraction image, that is afterwards treated by a non-supervised region classification algorithm (ISOSEG) based on the Mahalanobis distance as a measure of the similarity of the classes (BINS et al., 1993). The next step was to label the classes generated by the classification algorithm, and some image editions were made to adjust the classes. Once the objective of this work was to evaluate the performance of the classification using the simulated image, no editions were made within the classification maps.

3. RESULTS AND DISCUSSION

The digital filters calculated using the methodology proposed by BANON (1990) are displayed in Figure 2.

N=2 Green Band			N=3 Blue Band		
0.10756	0.12788	0.10756	0.068965	0.12988	0.068965
0.098465	0.11707	0.098465	0.11958	0.22521	0.11958
0.10756	0.12788	0.10756	0.068965	0.12988	0.068965

N=3 Red Band			N=4 NIR Band		
0.067013	0.10008	0.067013	0.061044	0.09194	0.061044
0.15223	0.22734	0.15223	0.16313	0.24569	0.16313
0.067013	0.10008	0.067013	0.061044	0.09194	0.061044

Fig. 2- PSF digital filters calculated for all spectral bands analyzed. N=number of times that the filters must be applied to the image.

3.1 Classification of intensive agriculture region

In Figure 3 a part of the original ETM+ image and the simulated WFI image are presented, where it is possible to observe the degradation of the spatial resolution in the simulated image. The resulted classification for both sensor's images, according to Figure 4, show that more predominant classes as sugarcane and soybean suffered little influence of the degradation. In both classifications, cultures segments with no well defined delimitations, as pasture and straw, presented higher differences of localization when simulated for the WFI.

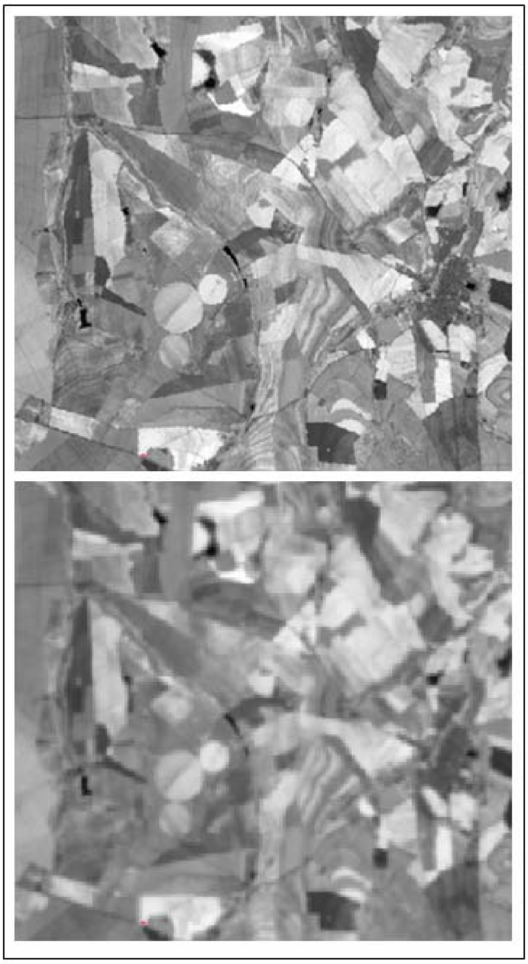

Fig. 3 - The near infrared band images of ETM+ (above) and the simulated WFI (below).

Comparing the MAXVER classification of the ETM+ and WFI images (Figure 4), it is verified a soybean area lost in detriment mainly to pasture and corn crop areas, computing more than 2000 ha (16.25 %). There was a gain of 4000 ha for the sugar cane areas, especially on forest areas. The corn presented increment of 27% of its area, spreading itself also on forest areas. A reduction in the bare soil and straw areas was also observed, although not presenting great displacement in the space.

In the *Bhattacharya* classification, in it turns, when comparing the results of both images the sugarcane also gain area, however in a subtle way. The soybean, as observed in the MAXVER classification loses around 4000 ha in area in the WFI classification. The corn area was practically unchanged comparing both classifications, but the straw area increased 45% taking place mainly of the sugarcane of the ETM+ classification.

The corn, pasture and bare soil were better classified using the MAXVER algorithm, although the more fragmented segments, as forest areas, straw, urban areas and rivers were more efficiently classified by the *Battacharya* algorithm.

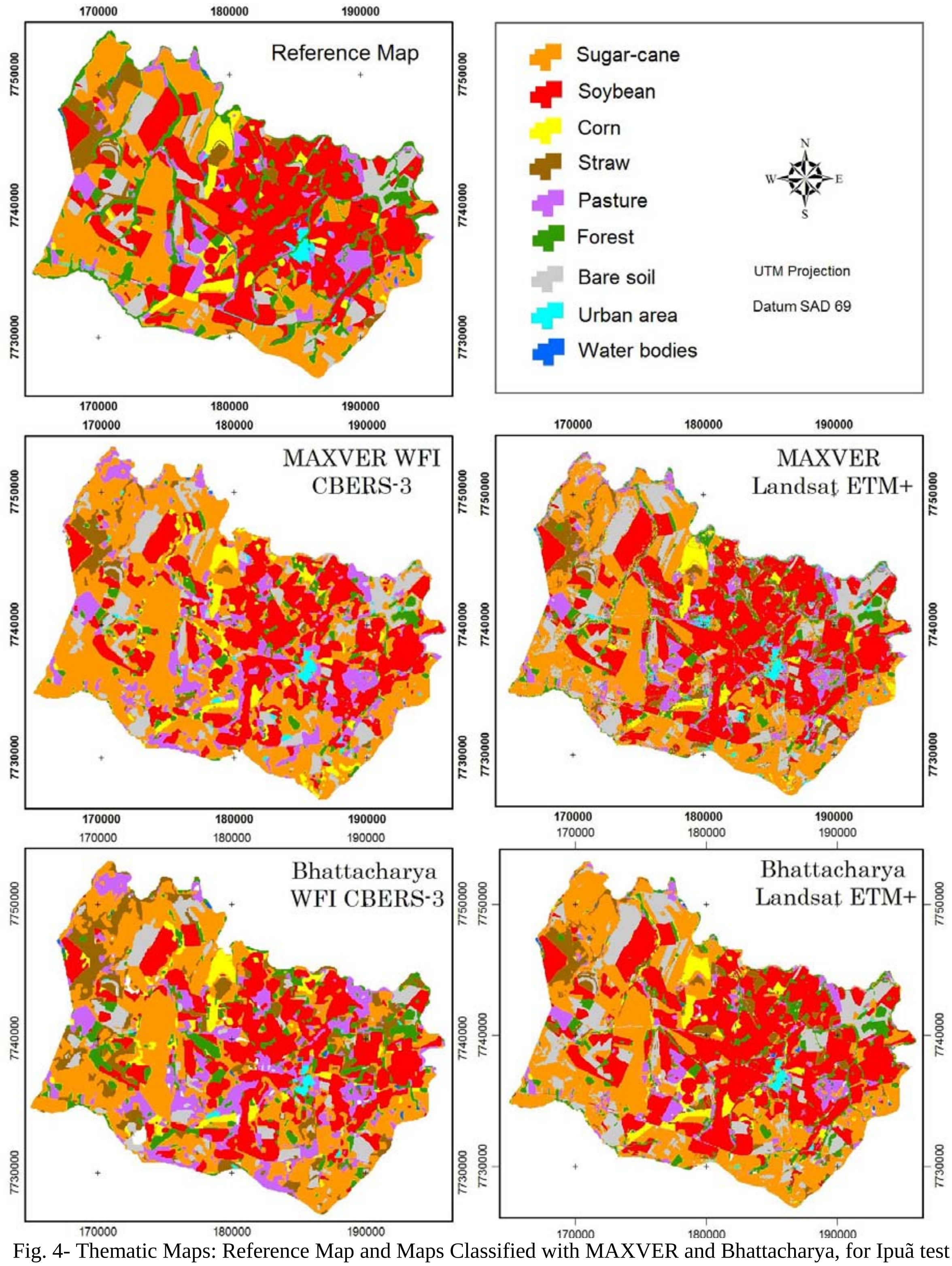

Fig. 4- Thematic Maps: Reference Map and Maps Classified with MAXVER and Bhattacharya, for Ipuã test site.

TABLE 4 - ACCURACY FOR BOTH CLASSIFICATIONS OF THE SIMULATED IMAGE, FOR EACH CLASS, WHEN COMPARING WITH THE REFERENCE MAP.

Accuracy (%): WFI x Reference Map		
Classes	MAXVER	BHATTACHARYA
Sugar Cane	84.75	72.38
Soybean	70.64	65.67
Corn	56.71	51.55
Forest	25.33	36.12
Straw	41.70	71.19
Pasture	65.21	61.62
Bare Soil	73.64	48.99
Water bodies	2.67	3.12
Urban area	23.17	38.55

From the confusion matrix between the reference map and the classifications the inclusion error, omission error, global accuracy and Kappa index values were calculated. The inclusion and the omission error values for all generated classifications are displayed in Figures 5 and 6.

In the graphics of Figures 5 and 6 the classes were displayed in a decreasing order according to the total area the class takes up in the region. In the MAXVER classification a tendency is clearly observed, in the sense that the increasing of the errors with the decreasing of the area that the classes take up. This tendency however was not observed in the *Bhattacharya* classification.

The errors increment observed in the WFI image classifications when compared with the ETM+ classification was higher in more fragmented segments, or in more linear and narrow forms, as was the case of the forest class. However some classes were better classified in the WFI image, as observed with the soybean and bare soil. Table 5 shows the global accuracy and Kappa index values found.

Although the classification of the ETM+ image achieved the same global accuracies in both tested classifications, in the case of the simulated image the MAXVER classification achieved better results than the Bhattacharya. However when analyzing the Kappa indexes, according to the classification proposed by LANDIS & KOCH (1977) the accuracy obtained by both the simulated WFI image classification is considered “moderated”, and the original image classifications as “good”.

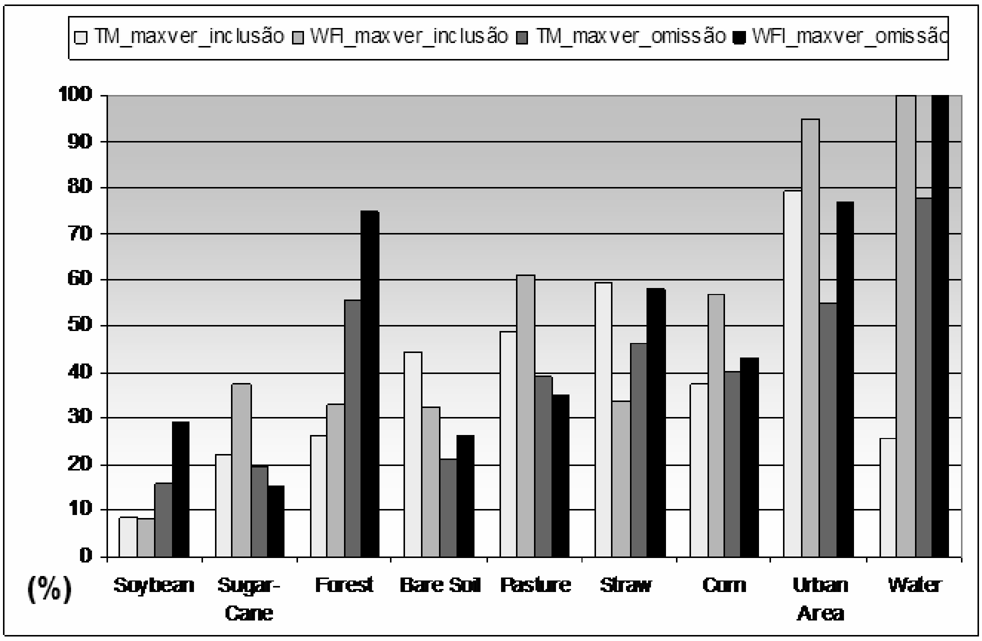

Fig. 5 - MAXVER classification Inclusion and Omission errors.

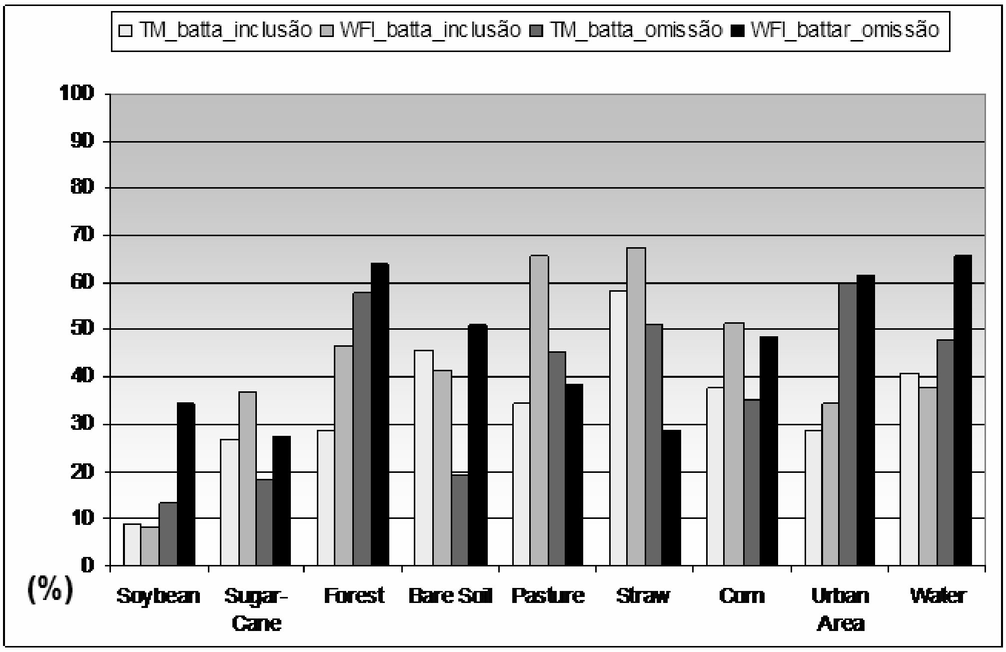

Fig. 6 - *Bhattacharya* classification Inclusion and Omission errors.

TABLE 5 - ETM+ AND SIMULATED WFI CLASSIFICATION GLOBAL ACCURACY AND KAPPA INDEX.

	Global Accuracy(%)	Kappa Index
ETM+(maxver)	73.196	0.6552
WFI(maxver)	66.287	0.5637
ETM+(*Bhatta.)*	73.993	0.6611
WFI(*Bhatta.)*	61.879	0.5164

4.2 Deforested areas detection

In Figure 7 a part of the original ETM+ image and the simulated WFI image are presented. The deforested areas mapping carried through with the simulation of the WFI/CBERS-3 sensor image showed to be coherent with the satellite image used, as showed in Figure 7. There was no need for further verification or image edition, only regarding to some isolated pixels.

The hydrographic network areas were also successfully identified in the simulated image. The deforested areas were sub-estimated by the simulated sensor classification when compared with the PRODES mapping (Figure 8).

Therefore, using the simulated WFI image a total deforested area of 124242 ha was obtained, while the PRODES computations for the same region was 148910 ha. However it is believed that these sub-estimations obtained using the simulated images are mainly due to regrowth areas and selective logging, which are hardly detected by automatic classification algorithms, but can be easily identified by an image interpreter, taking into account that the PRODES final results are obtained after an image edition made by an experienced interpreter.

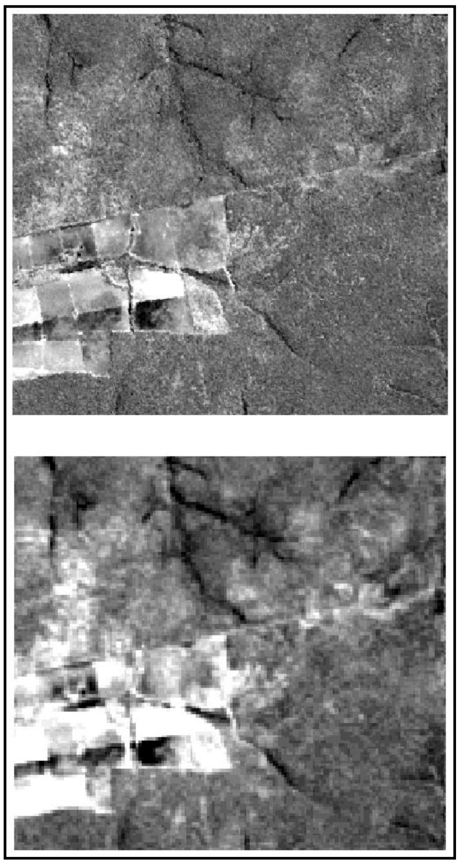

Fig. 7 - The near infrared band images of ETM+ (above) and the simulated WFI (below).

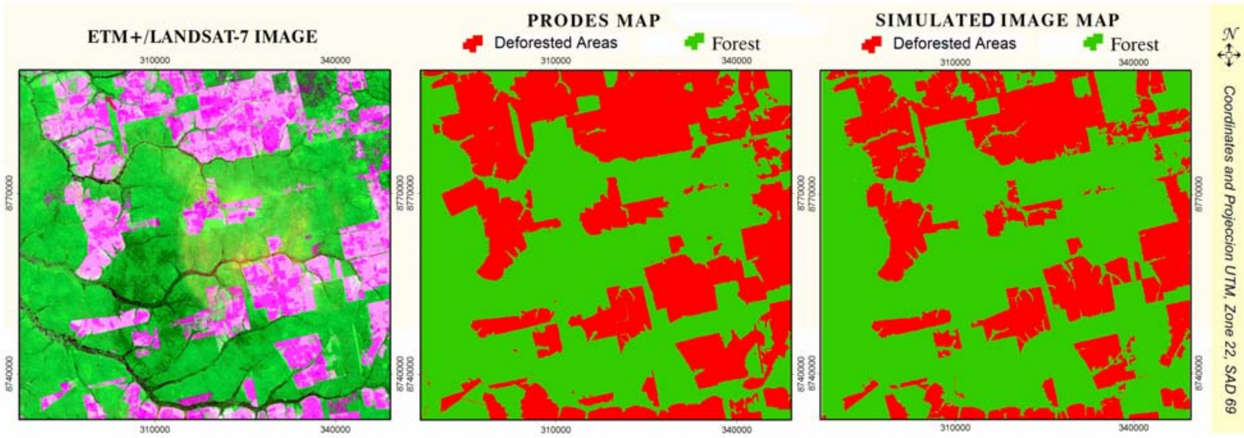

Fig. 8 - ETM+/Landsat-7 Image (left); PRODES Map (center); simulated image map (right).

4. CONCLUSIONS

The classification of the simulated WFI/CBERS-3 image was able to identify in an efficient way the main agriculture crops in the studied area: soybean, sugarcane and corn. For pasture and straw areas, satisfactory results were achieved. The degradation of the image spatial resolution caused classification errors mainly in areas with fragmented aspects, linear or with low spatial resolution limitations should be taken into account.

The deforested areas detection using the simulated WFI/CBERS-3 image was satisfactory and coherent with the PRODES data, when analyzing a deforestation pattern of median and large agriculture properties, confirming therefore, the potential for the use of this sensor's images in the studied conditions. However other researches must be taken in order to evaluate the performance of such images in the detection of areas with different deforestation patterns.

The classification algorithm used in the analysis exerts an important role in the results obtained. For example the MAXVER algorithm showed to be more susceptible to errors as the classes' areas decreases; however it obtained at the end a better global accuracy.

Therefore this simulation indicate that the WFI/CBERS-3 images will be qualified for land use classification in agriculture areas, although its spectral definition, as occurred with the forest, water bodies and urban area classes.

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