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IDENTIFICATION AND MAPPING OF FOREST DEGRADATION PATTERNS ON THE BRAZILIAN AMAZON BASED ON AWiFS SENSOR IMAGE

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ABSTRACT: The Near Real Time Deforestation Detection System (DETER) was developed by the National Institute for Space Research as an MODIS based alert system to support surveillance and control of deforestation, integrating the plan for prevention and control of deforestation in the Amazon and has been responsible for a fast and systematic deforestation survey since May 2004 in the Brazilian. In the last decade there was a reduction in the size of the deforestation patches. This reduction causes a major limitation to DETER mapping capabilities due to its reduced spatial resolution. This study aims to map and identify forest degradation patterns using the Advanced Wide Field Sensor (AWiFS) onboard of Resourcesat-I satellite testing its suitability to map and monitor deforestation in the Amazon rainforest. It was possible to identify the presence of six forest degradation patterns, within a mapped area of 2757.3 ha as clear cut, 7620.91 ha for moderate degradation, 9295.42 ha as high degradation, 31.7810,38 ha as burnt scar, 9300.22 ha for regular selective cut and 928.77 ha for conventional selective cut. The highest percentage of mapped area (~ 91%) is associated with the burnt scar class. This result indicates that the AWiFS sensor with moderate spatial resolution, can be used in the monitoring and surveillance of the Brazilian Amazon, providing support for conservation measures.

1. INTRODUCTION

The Brazilian Amazon has large biogeographic heterogeneity and had its human occupation processes resulting in a huge variety of spatial patterns that may be associated with different actors, history and types of occupation (Alves, 2002; Fearnside, 2008). It is estimated that in 1990 the rainforests covered and area between 11.5 and 12.4 million km² (Achard et al., 2002). The Brazilian Legal Amazon (BLA), has approximately 5 million km ², represents about 30% of the rainforests being the largest contiguous rainforest in the planet and home a vast biodiversity (Foley et al., 2007). Its deforestation is a global environmental problem (Fearnside, 2008).

The use of the digital image processing techniques and remote sensing products has been an important tool to a better understanding of the complex Amazonian anthropic process, allowing the identification of a several types of degradation, deforestation, land use and land cover patterns.

To assess deforestation, the National Institute for Space Research (INPE), through the Satellite Monitoring System of the Brazilian Amazon Forest (PRODES), has estimated since 1988 the annual rates of gross deforestation in AML (Câmara et al., 2006).

Despite the critical importance of the PRODES project in forest monitoring and public policy design, it suffers from a relatively long delay between satellite observation and data consolidation. Hence the historical series and annual deforestation rates produced do not allow for a timely identification of areas in the initial or intermediate stages of degradation neither for the establishment of efficient preventive actions to control or reverse the deforestation process.

For this reason the Near Real Time Deforestation Detection System (DETER) was developed by the National Institute for Space Research (INPE) as an alert system to support surveillance and control of deforestation, integrating the Plan for Prevention and Control of Deforestation in the Amazon (PPCDAM). This system has been responsible for a fast and systematic deforestation survey since May 2004. Based on MODIS data from Terra/Aqua satellites, its spatial resolution is 250m (Anderson et al., 2005; INPE, 2013) and maps both clear cut and forest degradation areas (INPE, 2008).

In the last decade PRODES historical series indicate a reduction of size on clear cut patches (Rosa et al., 2012) this reduction adheres to DETER a major limitation on deforestation mapping, since it is not possible to detect areas smaller than 25 ha and there is little efficacy detecting areas between 25 to 100 ha (Escada et al, 2011)

Thus, this study aims to map and identify forest degradation patterns using the Advanced Wide Field Sensor (AWiFS) onboard of Resourcesat-I satellite testing its suitability to map and monitor deforestation in the Amazon rainforest.

2. METHODS

The Indian program of Earth Observation Satellites (IRS) provides images in various resolutions (temporal, spatial, spectral and radiometric) enabling a variety of applications, especially for environmental studies. The

AWiFS sensor onboard of Resourcesat-1satellite, due to its characteristics are promising for the improvement of techniques and existing systems of forest monitoring, especially for the mapping of areas smaller than 25 ha (Diniz et al., 2013 .) These characteristics are shown in Table 1.

Bands	Resolutions				Swath
	Spectral (mm)	Spatial (m)	Temporal	Radiometric	
Green	0.52 - 0.59	56	5 days	10 bits	740 km
Red	0.62 – 0.68				
NIR	0.77 – 0.86				
SWIR	1.55 - 1.70				

Table 1. AWiFS sensor characteristics.

In this research one AWiFS image was used, path / row 325/084, quadrant C, date 04/04/2013, in the state of Mato Grosso located in the Brazilian Legal Amazon (Figure 1).

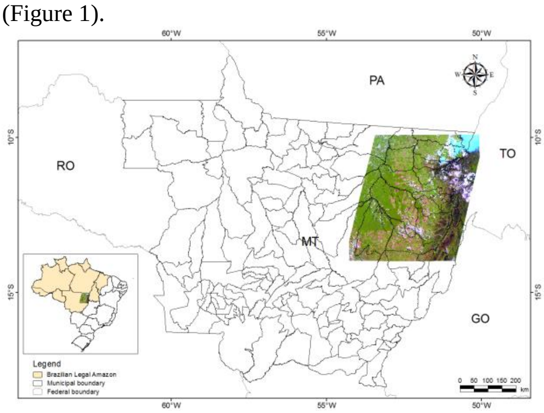


Figure 1. Study area location.

This image was incorporated into a PostgreSQL database, version 8.4, structured by TerraAmazon version 4.4.1, based on TerraLib technology, which was been developed by INPE to systematize the database structure for the satellite monitoring of the Brazilian Amazon Forest.

After database creation, color composite is proceeded on 5R4G3B channels. Then geometric correction is performed based on image to image process, having GLS2005 product as reference (Tucker et al., 2004). Twenty five (25) reference points were used, spatially well distributed and RMSE of 0.58, which represents 32 meters average error.

Over the correted image, the Linear Spectral Mixture Model (Shimabukuro and Smith, 1991) is applied to obtain the fraction images (vegetation, soil and shade). This process is performed to highlight the mapping features. A vector mask containing PRODES classes of hydrography, not forest and deforestation, also called PRODES mask, was used to prevent the mapping of targets prior to the year of 2013. Thus this study mapped only recent clearings that were outside of the PRODES mask.

According to INPE (2008) six patterns of forest degradation were identified: (1) Clear-cut, predominantly exposed soil without forest cover. (2) Medium degradation, predominance of forest cover with patches of bare soil, indicating presence of store yards and small canopy gaps. (3) High degradation corresponds to the presence of larger canopy gaps leading to huge soil exposure, secondary vegetation and / or large brunt areas with some remnant forest fragments. (4) Burnt scars, usually presents concentric arcs interspersed with vegetation or bare soil (windrows). (5) Regular selective logging, follows regular geometrical pattern of logging, in most cases due to the existence of a management plan, the main paths for timber transport are clearly detected, secondary paths are parallel to one another and well distribute, as it is, the distribution of the store yards. (6) Conventional selective logging, store yards are larger than regular, both primary and secondary paths are not regularly connected generating and unusual geometric pattern. On Table 2, the interpretation key is showed for each of thematic classes as well as their characteristics when observed on color composite composition 5 (R), 4 (G) and 3 (B) and on soil fraction.

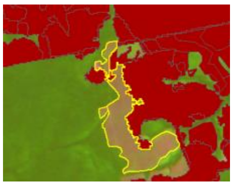
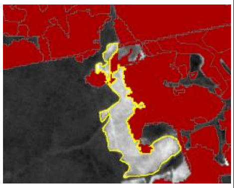
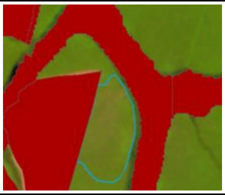
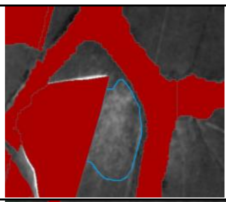
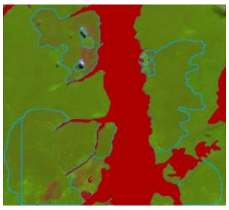
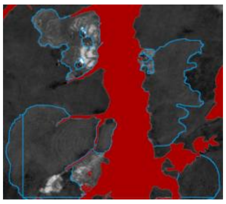
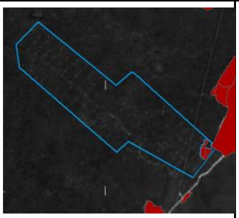
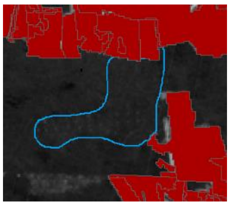
CLASS	COLOR COMPSITION	SOIL FRACTION	INTERPRETATION KEY ON COLOR COMPSITION 5(R) 4(G) 3(B)	INTERPRETATIO N KEY ON SOIL FRACTION
Clear Cut			Magenta tonality, or very light green (dimmed). Regular shape, smooth texture, well-defined boundaries between polygon (bare soil) and the forest matrix.	Light gray tonality. Regular shape, smooth texture, well-defined boundaries between polygon (bare soil) and the forest matrix.
Moderate Degradation			Green and magenta tones mixed but predominance of green, related to the presence of forest patches (bare soil) and secondary vegetation.	Dark gray tonality indicating predominance of forest cover associated with light gray spots (bare soil).
High Degradation			Green and magenta tones are mixed but predominantly magenta, related to the presence of gaps, bare soil and secondary vegetation.	Predominance of light gray tones associated with the presence of clearings, secondary vegetation and bare soil.
Burnt Scars			Predominance of light gray tones associated with the presence of clearings, secondary vegetation and bare soil.	Predominance of gray tonality lighter than the matrix, with smooth texture and circular pattern, in combination with dark areas that represents forest patterns.
Regular Selective Logging			Predominance of green tonality and pattern of forest, with presence of small circular magenta features (points),with well-defined geometric pattern.	Predominance of dark gray tonality with presence of small lighter and circular features, medium density and frequency, geometric pattern well defined.
Convetional Selective Logging			Predominance of dark green tonality with minimal presence of light green and / or magenta tones.	Predominance of dark gray tonality with presence of light gray dots, irregularly distributed, associated with lack of management plan.
PRODES Mask	Clear cut		Degradation	

Tabela 2. Key interpretation of mapped classes.

3. RESULTS AND DICUSSION

On Table 3 shows the results of the present study mapped area as well as the representation of each class. This table can be observed that class comprises Shallow Cut 2757.33 ha, equivalent to 0.79% of the mapped area AWiFS.

Table 3 presents the results in absolute and percentage terms of each mapped class. It can be seen that the Clear Cut class comprises 2757.33 ha, equivalent to 0.79% of AWiFS mapped area. For the classes Moderate and High Degradation, an area of 7620.91 ha and 9295.42 ha were mapped, corresponding to 2.19% and 2.67% respectively. As Burnt Scar 31.7810,38 ha was mapped corresponding to 91.40% of the total mapped area. Finally the classes Regular and Conventional Selective Logging reached 9300.22 ha and 928.77 ha which represents 2.67% and 0.26% respectively. These data are indicative that fire occurrence is the largest causing agent of forest degradation in the study area. It also points that AWiFS sensor provides useful data for mapping forest degradation in its various levels.

Class	Área (ha)	Área (%)
Clear Cut	2.757,33	0,79
Moderate Degradation	7.620,91	2,19
High Degradation	9.295,42	2,67
Burn Scars	31.7810,38	91,40
Regular Selective Logging	9.300,22	2,68
Conventional Slective Logging	928,77	0,27
Total	347.713,03	100

Tabela 3. Total mapped area per class.

Table 4 shows the polygons per class and grouped by size ranges. For clear cut class most of the polygons mapped (46) were between the range >= 50 and <100 representing approximately 70% of the polygons in this class, however the range >= 100 grouped eight polygons representing approximately 65 % of the mapped area. The present study confirms the results obtained by Rudorff et al. (2011) that grouped PRODES deforestation polygons and found that approximately 60% of the clear cut polygons were larger than 100 ha. However, Rosa et al. (2012) and Diniz et al. (2013), indicate that most of the recent deforestation are represented by areas smaller than 50 h. This is an indication that the size of the polygons mapped is related to the geographical position of the image. In this case, the average size of polygons clear cut was 42.68 ha.

The average polygon size for scar burnt class was 1018.71. Most of the polygons mapped (204 polygons) are >= 100 ha, corresponding to an area of 31.5528,80 ha and represent about 99% of the burnt area.

For Conventional Selective Logging and Regular Selective Logging the greatest amount of polygons are in the range >= 100 ha. Three (3) polygons mapped as Conventional Selective Logging belonged to the range >= 100 ha, representing an area of 800.14 ha, accounting for nearly 90% of the class area. For the Regular Selective Logging class 12 polygons were mapped corresponding to an area of 9247.17 ha and positioned in the stratum >= 100, which represents over 99% of the class area. There are indications that the class Conventional Selective Logging is related to illegal practice of timber exploitation, while the Regular Selective Logging is most probably related to regulated logging following the rules established on a management plan. This difference of area between these two patterns is probably related to effectiveness of the deforestation control.

Finally for Moderate and High Degradation classes, most of the polygons are located in the >= 100 ha rage. Twenty nine (29) polygons of High Degradation were identified, corresponding to 7861.59 ha of area. In this same stratum Moderate Degradation identified to 22 polygons and an area of 6312.01 ha. Souza Jr. et al. (2003) associates degradation processes with the removal of trees, whether selective or not, within or without the use of fire.

Class	**Range (ha)**	**Area (ha)**	**Nº Pol**	**% Pol**	**% Area**
Clear cut	<25	279.09	8	11.94	9.76
	>=25; <50	315.93	5	7.46	11.05
	>=50;<100	391.40	46	68.66	13.68
	>=100	1873.30	8	11.94	65.51
Sub Total		**2,859.73**	**67**	**12.62**	**0.82**
Burnt scars	<25	572.42	76	24.36	0.18
	>=25; <50	600.66	17	5.44	0.19
	>=50;<100	1137.14	15	4.81	0.36
	>=100	315528.80	204	65.38	99.27
Sub Total		**317,839.00**	**312**	**58.76**	**91.37**
Conventional selective logging	>=25; <50	43.52	1	0.20	4.68
	>=50; <100	85.10	1	0.20	9.16
	>=100	800.14	3	0.60	86.16
Sub Total		**928.76**	**5**	**0.94**	**0.27**
Regular selective logging	<25	13.46	1	7.14	0.14
	>=25; <50	39.58	1	7.14	0.43
	>=100	9247.17	12	85.71	99.43
Sub Total		**9,300.21**	**14**	**2.64**	**2.67**
High degradation	<25	259.85	28	35.44	2.8
	>=25; <50	423.19	11	13.92	4.54
	>=50; <100	766.60	11	13.92	8.23
	>=100	7861.59	29	36.71	84.43
Sub Total		**9,311.23**	**79**	**14.88**	**2.68**
Medium degradation	<25	100.86	10	18.52	1.32
	>=25; <50	279.52	8	14.81	3.67
	>=50; <100	929.66	14	25.93	12.19
	>=100	6312.01	22	40.74	82.82
Sub Total		**7,622.05**	**54**	**10.17**	**2.19**
Total		**347,860.98**	**531**	**100**	**100**

Table 4. AWiFS detections qualified and quantified by class and size ranges.

The spatial distribution of classes can be observed in Figure 2. It is easy to note the most of the burnt area mapped are located inside of indigenous land boundaries.

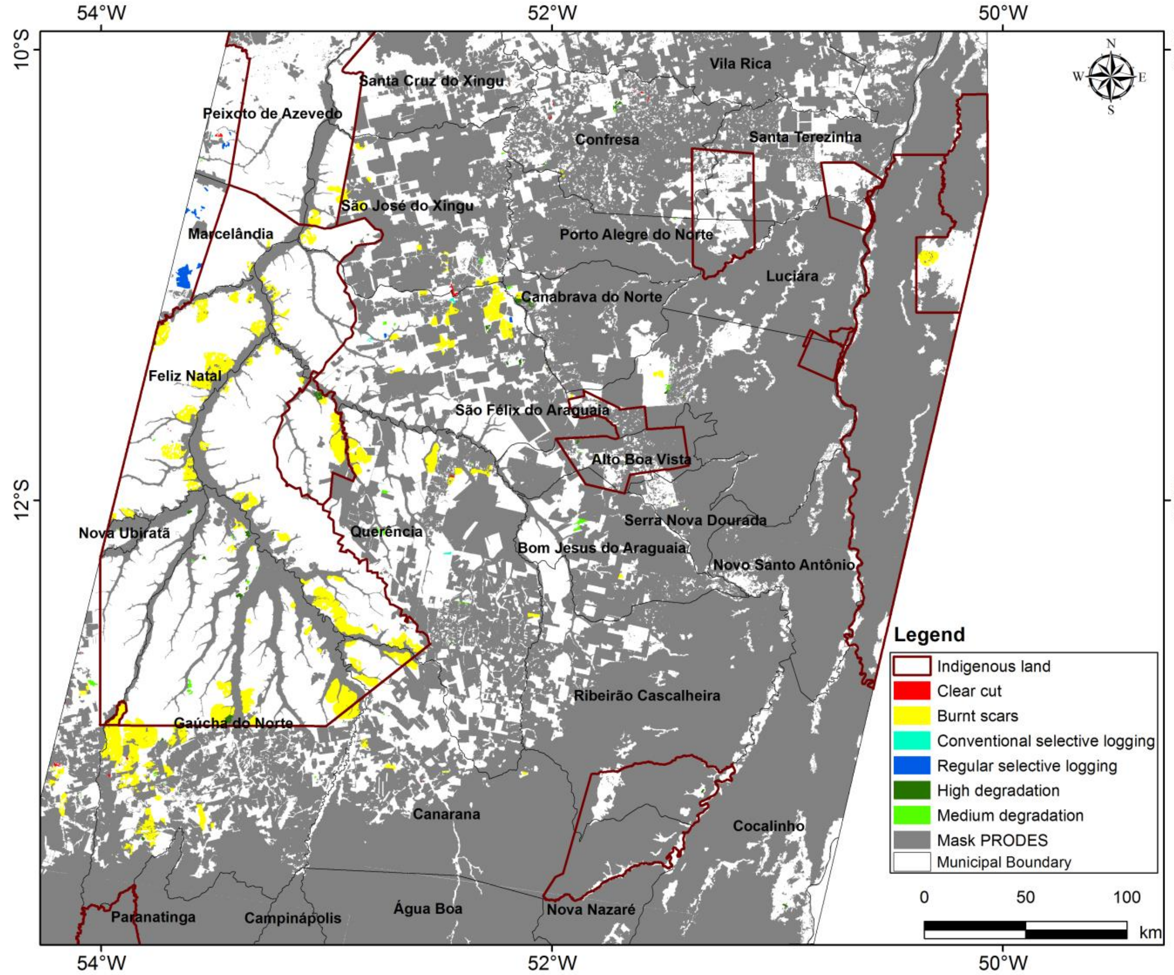


Figura 2. Map of degradation patterns from the image AWiFS.

4. CONCLUSION

Based on the exposed results it was possible to identify the occurrence of six degradation patterns. The area mapped for each class corresponds to 2757.3 ha as Clear Cut, 7620.91 ha as Moderate Degradation, High Degradation reached 9295.42 ha, 31.7810,38 ha to Burnt Scars, 9300.22 ha associate to Regular Selective Logging and 928.77 as Conventional Selective Logging. This paper corroborates with Diniz et al., 2013a, Diniz et al., 2013b, Souza et al., 2011, and indicates that the AWiFS sensor with moderate spatial resolution provides useful data for mapping clear cuts and forest degradation in its various levels and can be used on monitoring and surveillance of tropical forests, providing support for conservation measures.

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