O CASO DE UM DESMATE ILEGAL NA AMAZÔNIA ANTECIPADO PELA DETECÇÃO DE FOGO E DA DEGRADAÇÃO FLORESTAL

A CASE OF ILLEGAL CLEARING IN AMAZONIA ANTECIPATED BY THE DETECTION OF FIRES AND FOREST DEGRADATION

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RESUMO

Este trabalho mostra como um desmatamento ilegal de 520 ha na Amazônia detectado no início de 2012 foi o resultado de processos de queima e degradação da floresta iniciados pelo menos oito anos antes. O monitoramento diário de focos de queima em imagens de baixa resolução espacial (1 a 6 km), assim como o de degradação anual da floresta natural em imagens de média resolução (até 30 metros), ambos realizados operacionalmente pelo INPE, registraram a recorrência de ações antrópicas ilegais na área desde 2004. Os resultados mostram que o desmatamento e suas consequências ambientais, como estresse da biodiversidade e emissões atmosféricas, são graduais e não devem ser consideradas como representativas apenas do ano em que o desmate final foi constatado. A área estudada, no oeste do município de Feliz Natal, MT, foi afetada de forma mais intensa pelo fogo antrópico nas estações anomalamente secas de 2004, 2007 e 2010; em particular, na estiagem pronunciada de 2007 o impacto do fogo foi severo em uma área de ~160.000 ha, o que permitiu sua classificação como degradada. Conclui-se que a combinação do monitoramento de focos de queima de vegetação e da degradação florestal por satélites permitem localizar e antecipar em vários anos as tendências de desmatamento ilegal.

Palavras-chave: fogo, floresta, monitoramento, desmatamento, satélites.

ABSTRACT

This paper shows how a 520 ha illegal deforestation in Amazonia detected in early 2012 was the result of burning and forest degradation processes started at least eight years before. The daily monitoring of fires in low spatial resolution satellite images (1 to 6 km), as well as the yearly mapping of degraded forested areas with medium resolution imagery (up to 30 meters), both operationally done by INPE, registered the recurrence of illegal anthropic activities in the area since 2004. The results show that deforestation and its environmental consequences, such as biodiversity stress and atmospheric emissions, occur gradually and should not be considered as representative just of the year in which the complete forest clearing takes place. The area studied, in the southwest of the Feliz Natal County, Mato Groso State, Brazil, was more intensely affected by fire in the anomalous dry seasons of 2004, 2007 and 2010; particularly, in the pronounced drought of 2007, the fire impact was severe in an area of ~160,000 ha, what enabled its classification as a degraded area. The paper concludes that the combined monitoring of vegetation fires and forest degradation using satellites allows the identification and the forecast of illegal deforestation tendencies many years in advance.

Keywords: fire, forest, monitoring, deforestation, satellites.

INTRODUCTION

Among its duties, IBAMA, the Environmental Institute of Brazil, must enforce the deforestation control in the country (IBAMA, 2012a), and one of its tools to locate new forest clearings in Amazonia is DETER - INPE´s monitoring system that processes 250 m resolution daily MODIS imagery from NASA´s AQUA and TERRA satellites (INPE-DETER, 2012). Following a DETER alert in a recent case during May/2012, IBAMA´s agents arrived at a site in the southwest of the Feliz Natal County, Mato Grosso State - see Figure 1 - with an illegal deforestation of 512 ha in progress; two large tractors were apprehended and a fine

of US$1.1 million was given to the land owners - see IBAMA (2012b) for a picture of the place and more details of this event. An important point in this case is that "… the owner extracted all the timber in 2009-2010, and in the sequence, the forest suffered with the fires, and in the current year the clear-cut was done with the tractors dragging a heavy chain", in a free translation from IBAMA (2012b).
In the following text we show that through exiting operational satellite monitoring systems the anthropic degradation of the natural forest in the area recently cut was detected back in 2004 with the occurrence of fires, and that in 2007 and 2010 it suffered a major fire impact. Considering that deforestation, illegal or not, follows the pattern of timber extraction and fire use prior to the final clearing, the tools have been available for many years to identify in real-time the areas subject to unauthorized exploration and the spatial and temporal tendencies of its expansion in the forest.

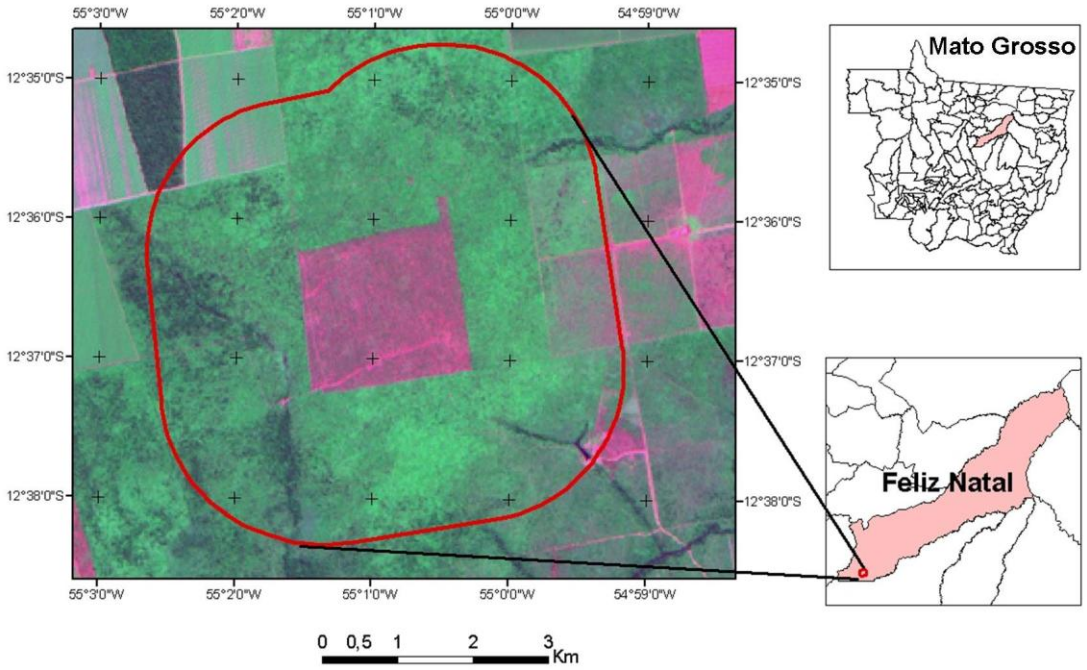


Figure 1. The area of illegal deforestation in the county of Feliz Natal, Mato Grosso State, is indicated by the magenta square with ~2 km x ~2 km in the center of the figure extracted from the 07/May/2012 image of the Indian ResourceSat image, LISS3 sensor, received by INPE; the surrounding polygon includes an additional buffer of 2 km width, where the fire pixels analyzed were located.

Data sources

Vegetation fires were obtained from INPE´s national system and database of fire pixels detected in up to 200 daily images from different polar orbiting and geostationary satellites operationally processed in near real-time (INPE-QUEIMADAS, 2012). The spatial uncertainty in the location of the pixels depends on the image´s pixel size, varying from 1 to 6 km at nadir, and with the geolocation navigation algorithm. In general, 94% of the fires are within 2 km of its actual place (PEREIRA, 2009). Table 1 shows the monthly amounts of fire pixels detected in the polygon that includes the deforestation site with an additional surrounding buffer of 2 km along its border to account for possible fires mis-registered. No fires were detected before 2004 and in 2012, and the months not shown in the table.

Table 1. Number of fire pixels detected in the polygon surrounding the deforestation site.

Month/Year	2004	2005	2006	2007	2008	2009	2010	2011
May	9	1	-	-	2	1	-	-
June	6	-	2	3	-	1	-	3
July	26	-	-	6	-	-	-	-
August	3	5	-	4	-	-	194	-
September	1	16	-	106	-	2	6	-
October	-	8	-	-	3	-	1	-
November	-	-	-	-	3	-	1	-
December	-	-	-	-	-	-	-	-
Total	45	30	2	119	8	4	202	3

Three other INPE products were used in the analysis. DETER (INPE-DETER, 2012) provides monthly maps with contours of recent deforestation with at least 25 ha in the Brazilian Amazonia identified in visual analyses of digital MODIS 250 m resolution images; its purpose is to alert control agencies of possible ongoing unlawful forest, and this was the tool that directed the IBAMA enforcement agents to the case herein presented. DETER should not be confounded with PRODES (INPE-PRODES, 2012), which produces Brazil´s formal annual deforestation assessment using medium resolution imagery (up to 30 m). A second product used was DEGRAD (INPE-DEGRAD, 2012), an annual product based on visual interpretation of the PRODES digital images that maps the Amazon forest degradation by causes such as fires and selective logging. The third tool used was the MODIS 250 m resolution 16-day series (INPE-LAF, 2012) for temporal analysis of the EVI vegetation index, starting in 2000 (FREITAS *et al*., 2011). The info layers from DETER, PRODES and DEGRAD are also available in the internet at INPE´s geographical information system for fire pixels (INPE-BDQ, 2012), what allows a combined exam of the forest´s occupation dynamics.

RESULTS AND DISCUSSION

Figure 2 shows the area of interest with the fire detections indicated by the yellow dots in its interior during 2004 (2a), 2007 (2b) and 2010(2c), and in 2012 (2d), prior to the final clearing that is evident in Figure 1. In 2004 the region already had large clearings (magenta color), where most of the fire pixels were detected; some light and dark patterns in the standing forest (green color) and a few scattered fire pixels indicate that degradation was already occurring. 2007 shows many more fires (119) in the polygon comprising the 2012 illegal clearing, as well as in the original forest of the region; the gray and dark-blue areas in the forest corroborate the effect of the fire in the standing trees. This effect was identified by INPE´s DEGRAD as seen in Figure 3a, in which INPE-BDQ shows the fire pixels of 2007 with the contours of the areas considered as degraded by DEGRAD; however, because of the few good quality Landsat-TM available for 2007, the polygons refer to 2008 images and is dated as so. In Figure 3b the 2007 fire pixels are presented with the potential deforestation polygons from DETER´s 2008 analysis, indicating a large portion of the forest in the region as heavily damaged. In 2010 the maximum number of fire pixels occurred (202) with almost all (192) during August, further degrading the forest.

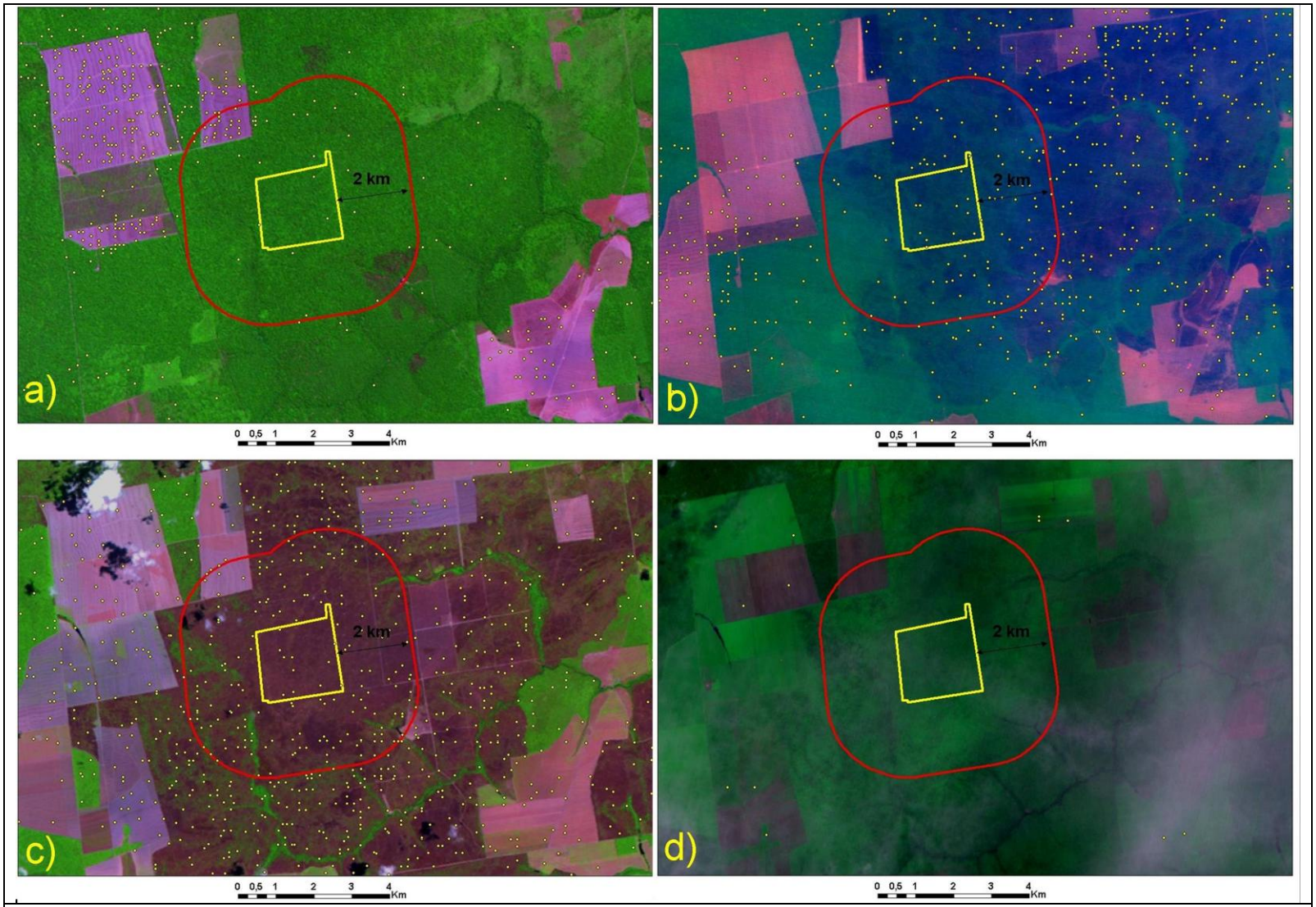


Figure 2. The deforestation site (outlined in yellow) in four years and the associated fire detections (small yellow dots):
2a) 23/Jul/2004, with the first fires detected; 2b) 18/Sept/2007, in a dry year with more fires; 2c) 13/Apr/2010, where the wide-scale effect of the 2007 fire is still present and fires peaked, and; 2d), 13/Apr/2012, prior to the final deforestation shown in Figure 1. The first three images are Landsat-TM, with R5-G4-B3 color & band combination, and the fourth is a RSI-LISS3 with R3-G4-B2.

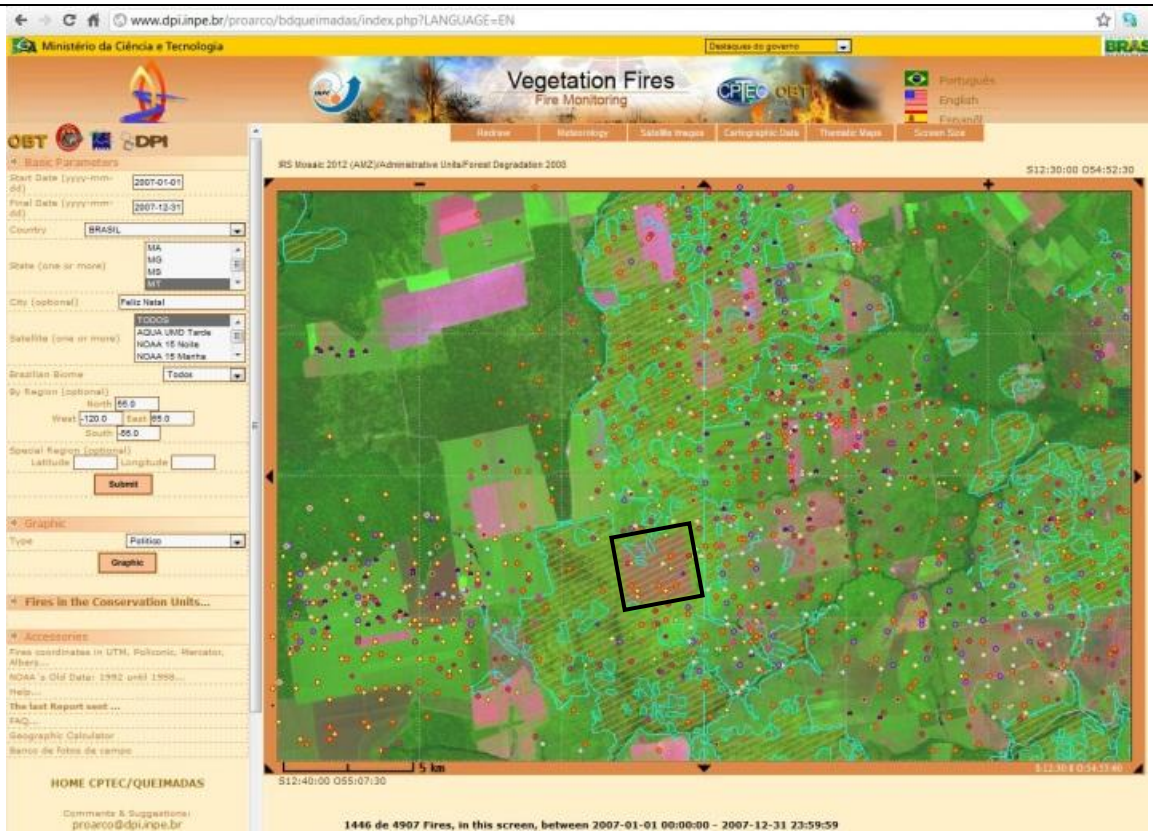


Figure 3a. INPE´s fire system BDQ showing the fire pixels of 2007 (colored dots) and the contours of the 2007 degraded areas from DEGRAD, with the RSI image of 13/April/2012 as background; the illegal deforestation plot is in the black square.

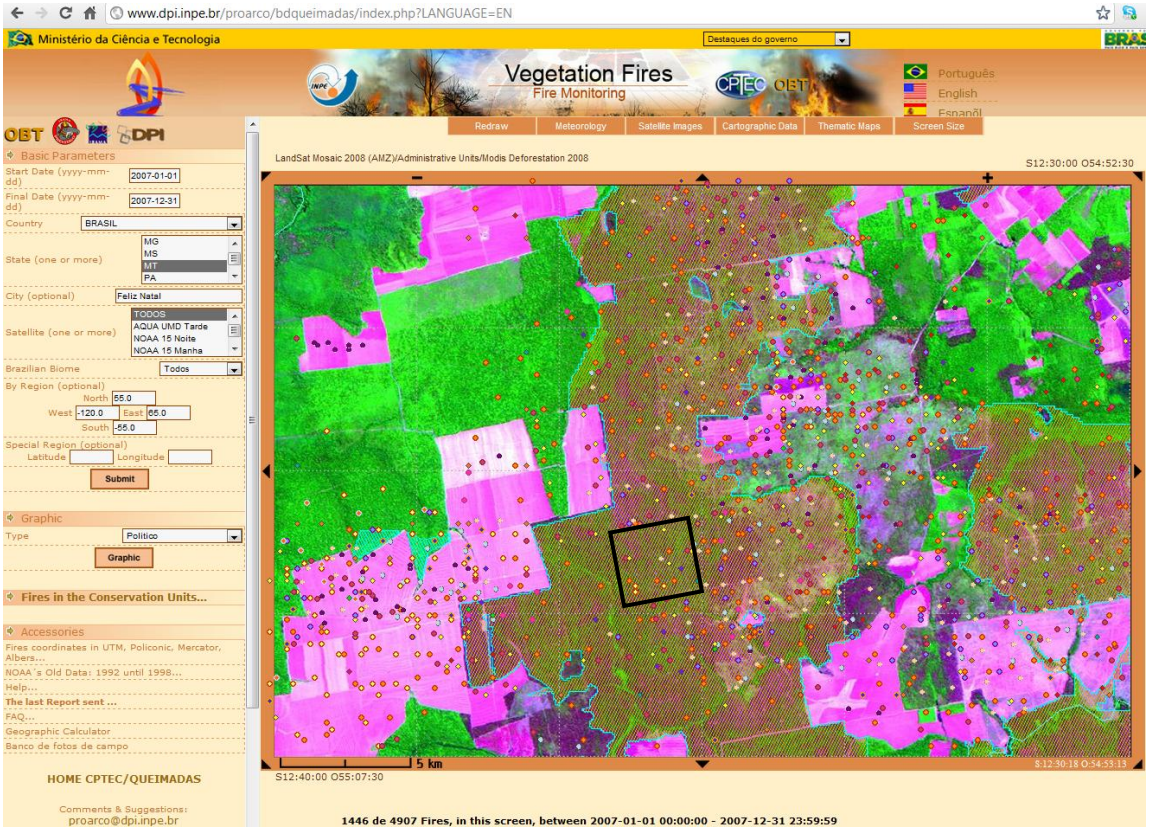


Figure 3b. INPE´s fire system BDQ showing the fire pixels of 2007 (colored dots) and the contours of the 2008 potential deforestation, with a Landsat-TM image of 2008 as background; the illegal deforestation plot took place in the black square.

2007 had an anomalous dry season in central Brazil, with a deficit of about 100 mm for September in north Mato Grosso (see Figure 4) and with almost no precipitation, following a drought pattern started six months before (INPE-CPTEC, 2012). Under such dry conditions the forest´s understory and decaying wood and leaves become highly flammable (BALCH *et al*, 2008), allowing the propagation of ground fires for weeks in a row, over dozens of kilometers. People behind the deforestation process take advantage of these climate variations to advance their actions, and the abnormal high number of fire pixels in the drier years in the forest corroborates this practice. In this context, this paper´s case is a sample of what has been common practice in the last decades over most of the Amazon forest. No published data seem to exist for the percentage of deforestation which is illegal, but a guess between 80% and 90% is plausible.

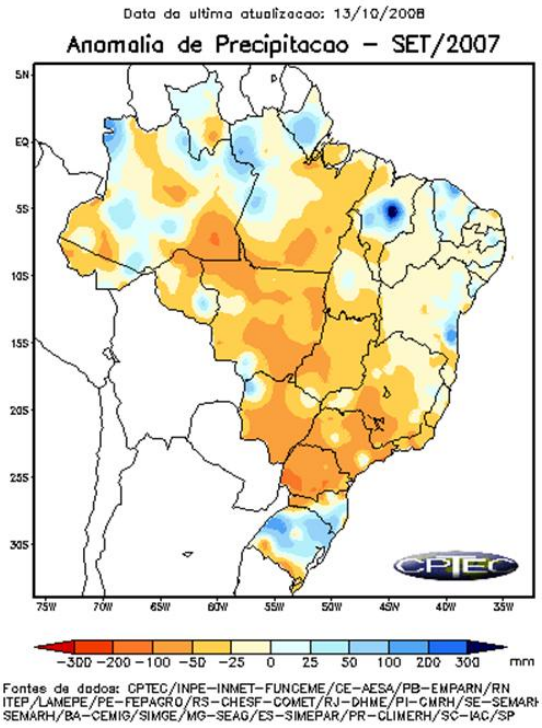


Figure 4. Precipitation anomaly for Brazil, indicating September/2007 as a dry month in north Mato Grosso. (INPE-CPTEC, 2012).

The last set of data used, the 16-day temporal series of MODIS 250 m EVI values since 2010 (INPE-LAF, 2012), confirms 2004, 2007 and 2010 as the only years with a pronounced vegetation stress; the 2012 data is not yet available. Figure 5 shows the EVI temporal variation for one cell (250 m x 250 m) in the deforested plot, being similar to other cells of the plot. The unsmoothed EVI blue curve shows a dip particularly strong at the end of 2007 and 2010, what is interpreted as the effect of the widespread occurrence of anthropic fires in the region.



Figure 5. EVI vegetation index since 2010 from the 16-day temporal series of MODIS 250 m data for the site deforested in May/2012 (INPE-LAF, 2012); the low values at the end of 2004, 2007 and 2010, probably result from the fire effect in degrading the natural forest.

CONCLUSIONS

Illegal forest clearings in the Brazilian Amazon forest during the last decades account for at least some 80% of the total of ~750,000 km^2 of deforestation mapped until the end of 2011 by INPE-PRODES (2012). This value increases substantially when areas of natural forests degraded by selective logging and/or fires are included - an evaluation that remains to be done. In a dynamic process, the extraction of valuable timber and the use of fire, particularly in anomalous dry years, signal the initial steps of a procedure lasting many years, until a final clearing is achieved. Monitoring of fires in satellite images provide a first indication for most of the areas that will be subject to this gradual degradation. As shown in this paper, the identification of critical deforestation areas and their spatial and temporal dynamics, legal or not, becomes feasible when combining existing satellite monitoring tools and products. Enforcement agencies and environmental protection groups can greatly benefit from a more effective use of these freely available data sources.

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