Embrapa Monitoramento por Satélite

I Workshop do Projeto AGSPEC

26 e 27 de Março de 2012

Monitoramento da cana-de-açúcar para fins de sustentabilidade da produção de etanol

Instituto Nacional de Pesquisas Espaciais – INPE
Divisão de Sensoriamento Remoto - DSR
Laboratório de Senssoriamento Remoto em Agricultura e Floresta - LAF

Bernardo Rudorff
bernardo@dsr.inpe.br

The Canasat Project

Monitoring of Sugarcane Crop using Remote Sensing Images

1. **Mapping and Forecasting Cultivated Area;**
2. **Monitoring of Harvest Practice;**
3. **Land Use Conversion Due to Expansion;**
4. **Time-series to Monitor Land Use Change.**

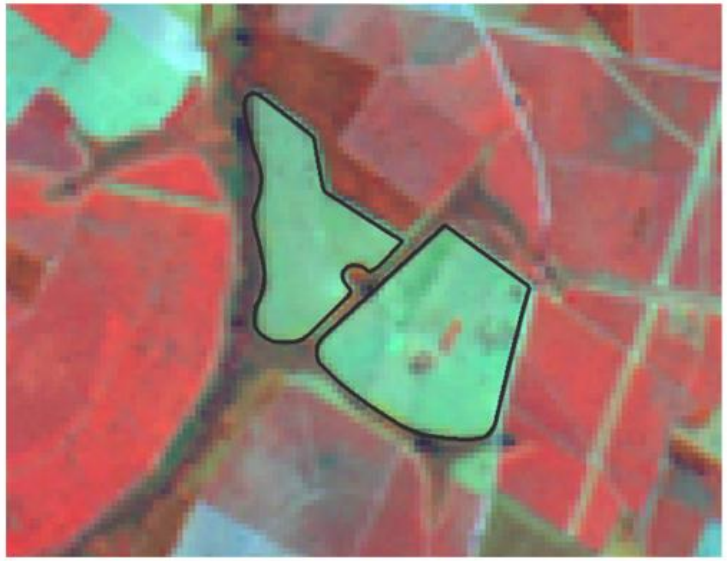
The Canasat Project

Monitoring of Sugarcane Crop using Remote Sensing Images

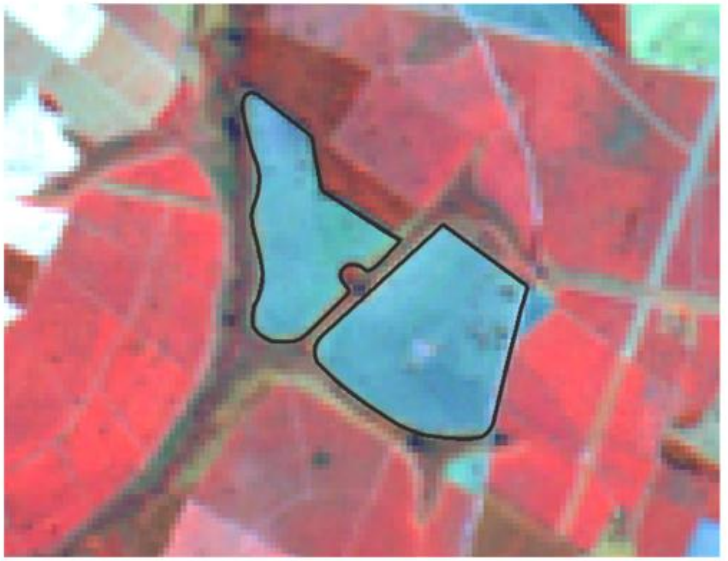
Map and Forecast of Cultivated Area

- **90% of sugarcane in Brazil is cultivated in the South-Central Region;**
- **Cultivated sugarcane land went from 4,3 Mha in 2003 to 8,6 Mha in 2011**

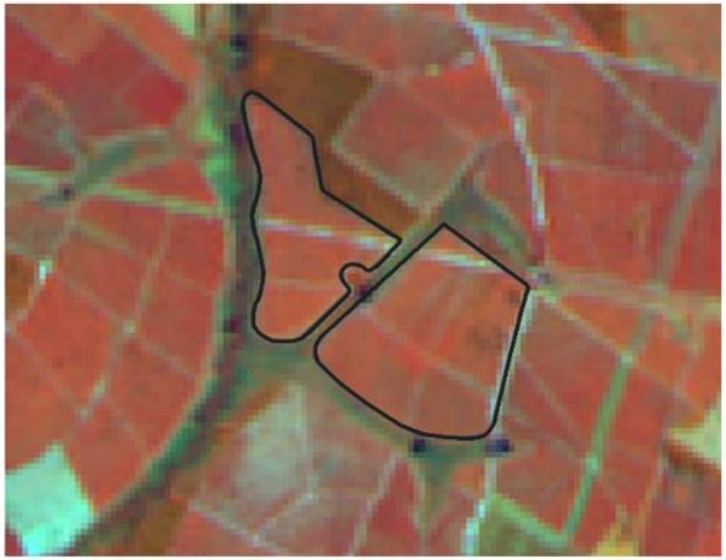
Expansion – new sugarcane plantation



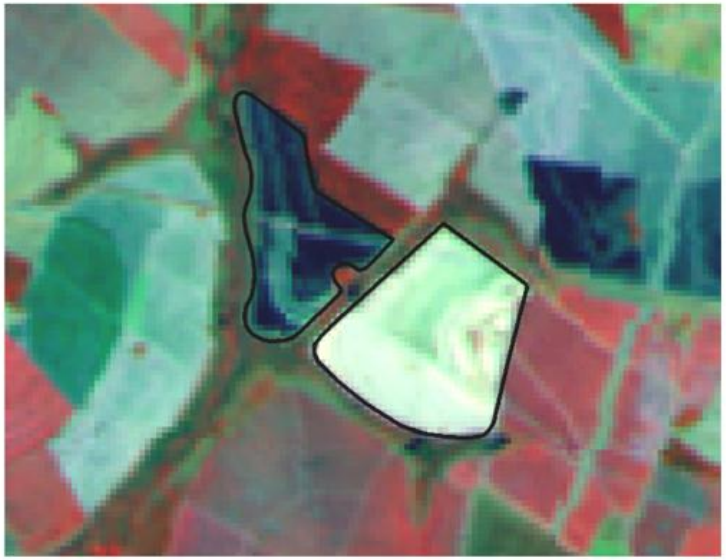
1a) Apr. 24th, 2007



1b) Jun. 11th, 2007

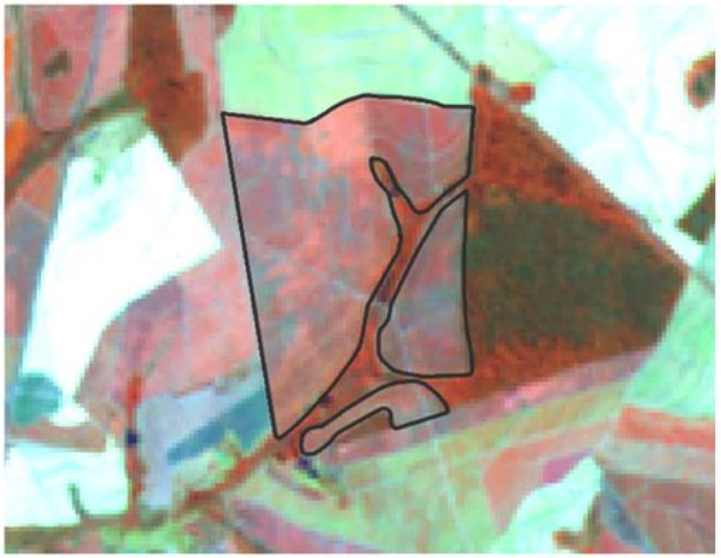


1c) Mar. 25th, 2008

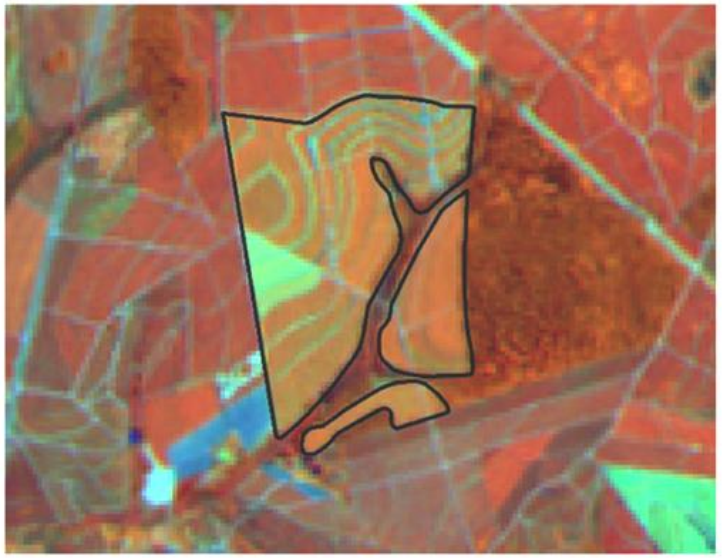


1d) Sep. 17th, 2008

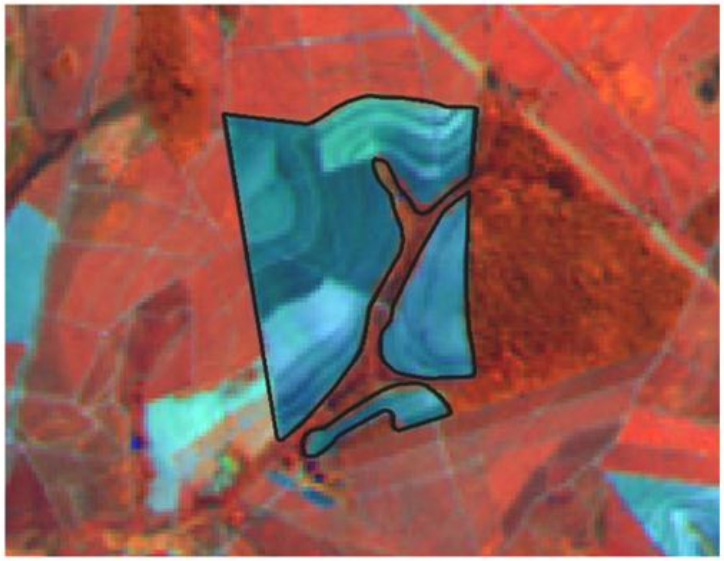
Renewal with crop rotation – 18 months sugarcane plant



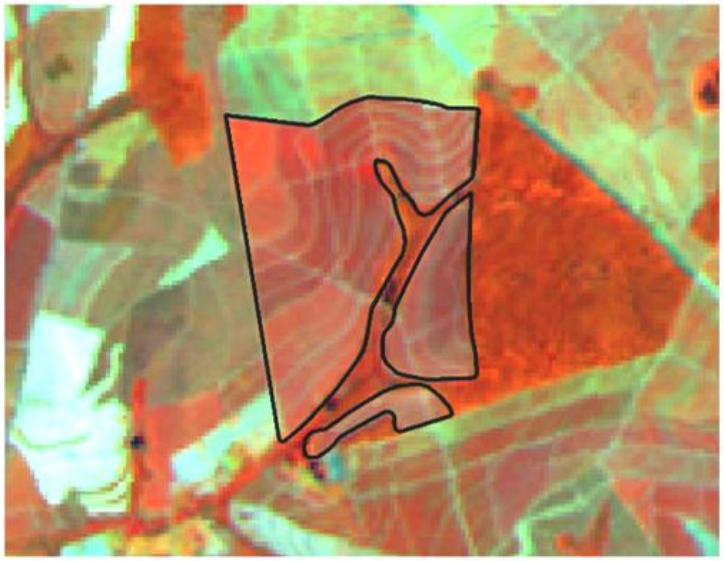
2a) Sep. 15th, 2007



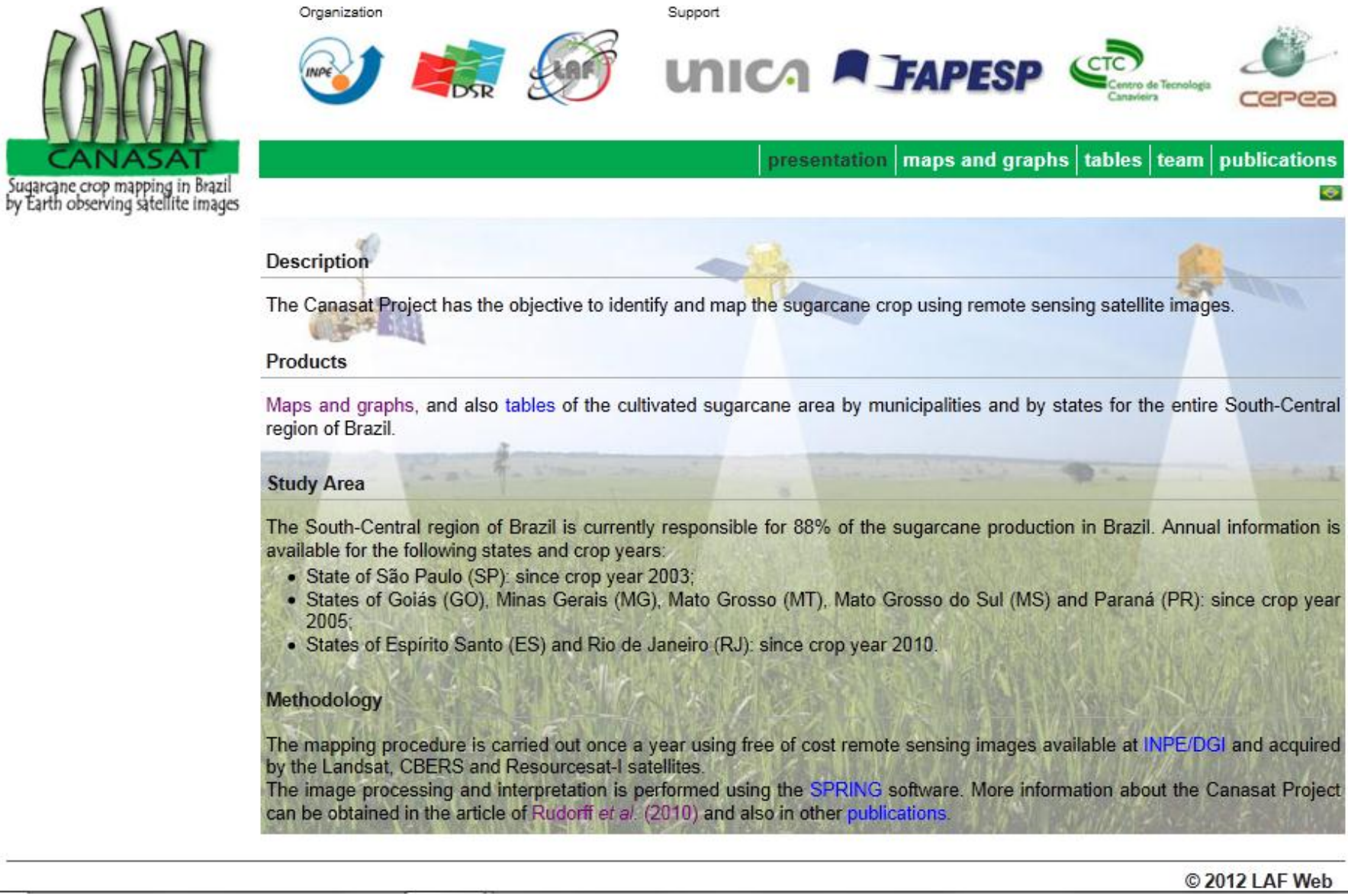
2b) Mar. 25th, 2008



2c) Apr. 26th, 2008



2d) Dec. 06th, 2008



http://www.dsr.inpe.br/laf/canasat/

RUDORFF, B. F. T.; AGUIAR, D. A.; SILVA, W. F.; SUGAWARA, L. M.; ADAMI, M.; MOREIRA, M. A.Studies on the Rapid Expansion of Sugarcane for Ethanol Production in São Paulo State (Brazil) Using Landsat Data. Remote Sensing. 2010; 2(4):1057-1076. doi: <10.3390/rs2041057>

Organization

Support

CANASAT
Sugarcane crop mapping in Brazil by Earth observing satellite images

presentation | maps and graphs | tables | team | publications

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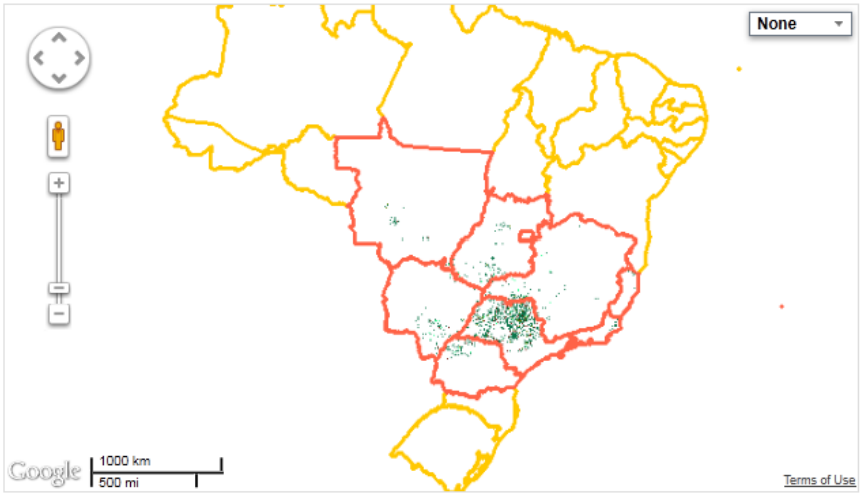


Map layers

- States
- Municipalities

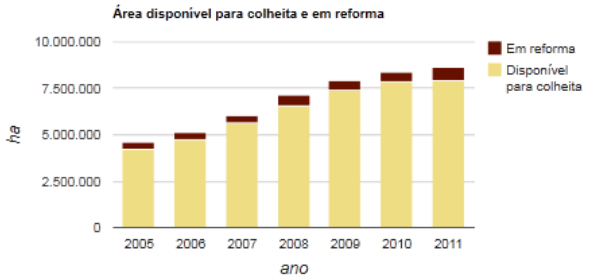
- Crop year 2011
- Crop year 2010
- Crop year 2009
- Crop year 2008
- Crop year 2007
- Crop year 2006
- Crop year 2005
- Crop year 2004
- Crop year 2003

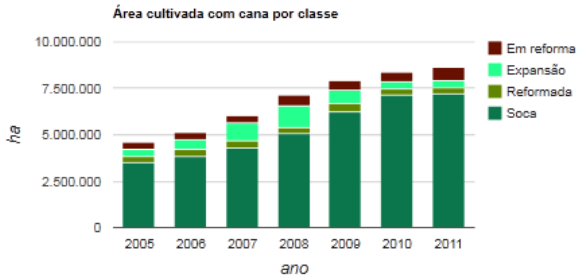
Legenda

- States
- South-Central region
- Sugarcane ratoon
- Sugarcane renovated
- Sugarcane expansion
- Sugarcane under renovation

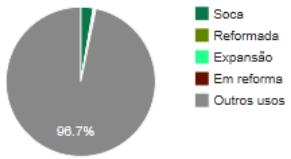
Exhibit data for municipality of [ ] go or for state of South-Central go

Dados da região centro-sul





Uso da terra no ano de 2011



	Disponível para colheita (ha)				Em reforma (ha)	Total cultivado (ha)
	Soca (a)	Reformada (b)	Expansão (c)	Total (a+b+c)		
2005	3514164	296825	407649	4218638	413473	4632111
2006	3828405	371103	529210	4728718	386116	5114834
2007	4300156	355860	1021999	5678015	388457	6066472
2008	5051815	365330	1162115	6579260	576145	7155405
2009	6208844	494907	727948	7431699	475046	7906745
2010	7129287	367486	390931	7887704	460970	8348674
2011	7177449	342108	422995	7942552	717401	8659953

Organization

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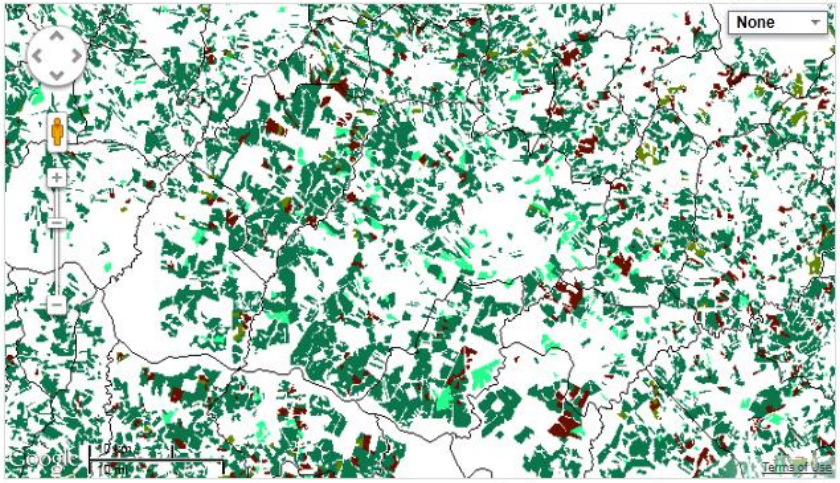
-20.856469, -49.306200



Map layers

- States
- Municipalities

- Crop year 2011
- Crop year 2010
- Crop year 2009
- Crop year 2008
- Crop year 2007
- Crop year 2006
- Crop year 2005
- Crop year 2004
- Crop year 2003

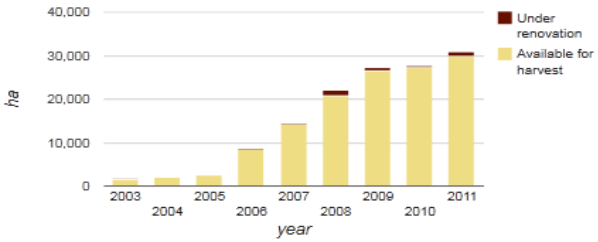
Legenda

- States
- Municipalities
- José Bonifácio - SP
- Sugarcane ratoon
- Sugarcane renovated
- Sugarcane expansion
- Sugarcane under renovation

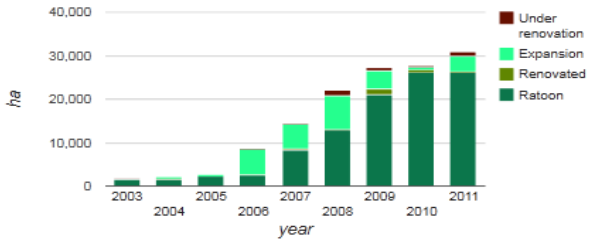
Exhibit data for municipality of José Bonifácio - SP go or for state of SP go

Data from the municipality of José Bonifácio - SP

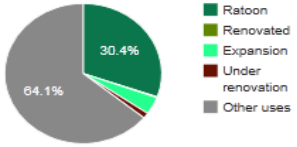
Area available for harvest and under renovation



Cultivated sugarcane area by class



Soil use in the year of 2011



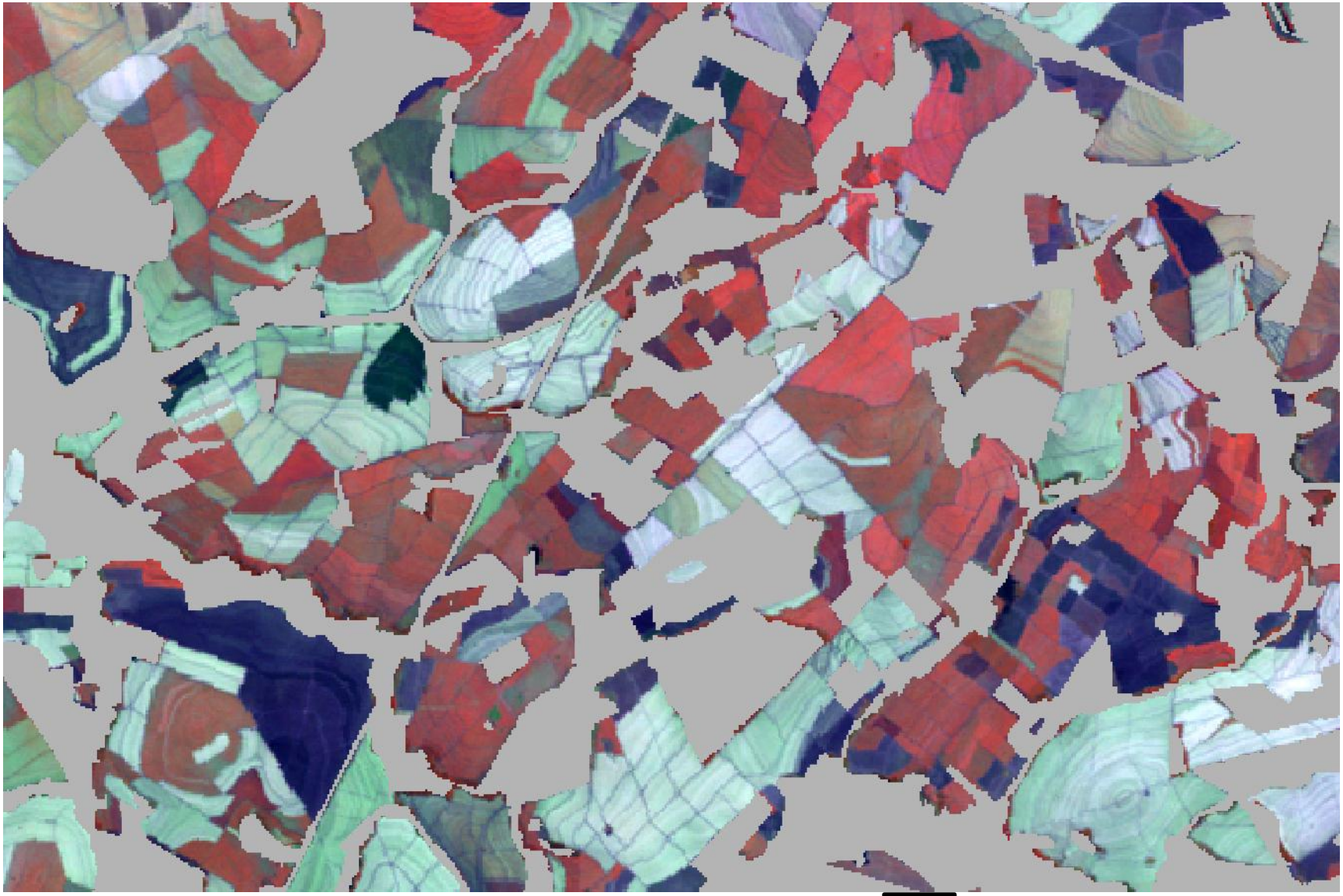
	Total available sugarcane for harvest (ha)				Under renovation (ha)	Total cultivated (ha)
	Ratoon (a)	Renovated (b)	Expansion (c)	Total (a+b+c)		
2003	1645	0	0	1645	73	1718
2004	1626	132	352	2110	0	2110
2005	2238	0	464	2702	14	2716
2006	2567	14	5922	8503	126	8629
2007	8363	123	5688	14174	118	14292
2008	12915	118	7774	20807	1219	22026
2009	21023	1239	4218	26480	760	27240
2010	26145	641	594	27380	248	27628
2011	26156	176	3480	29812	1086	30898

Monitoring of Sugarcane Harvest Practice

Green Harvest

Pre-Harvest Burning

Green harvest and Pre-harvest burning

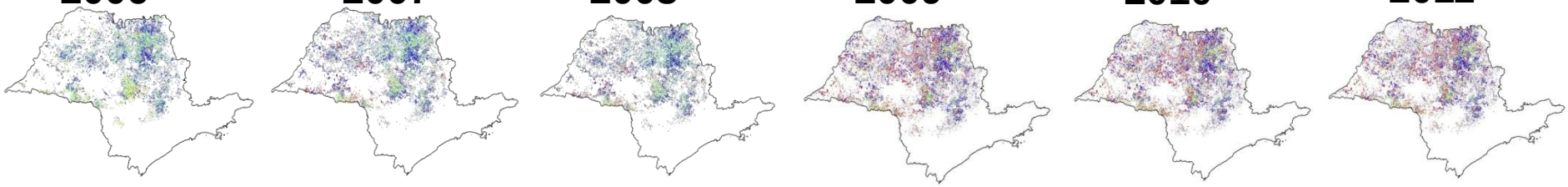


Landsat-5 18 August 2011 Other than sugarcane

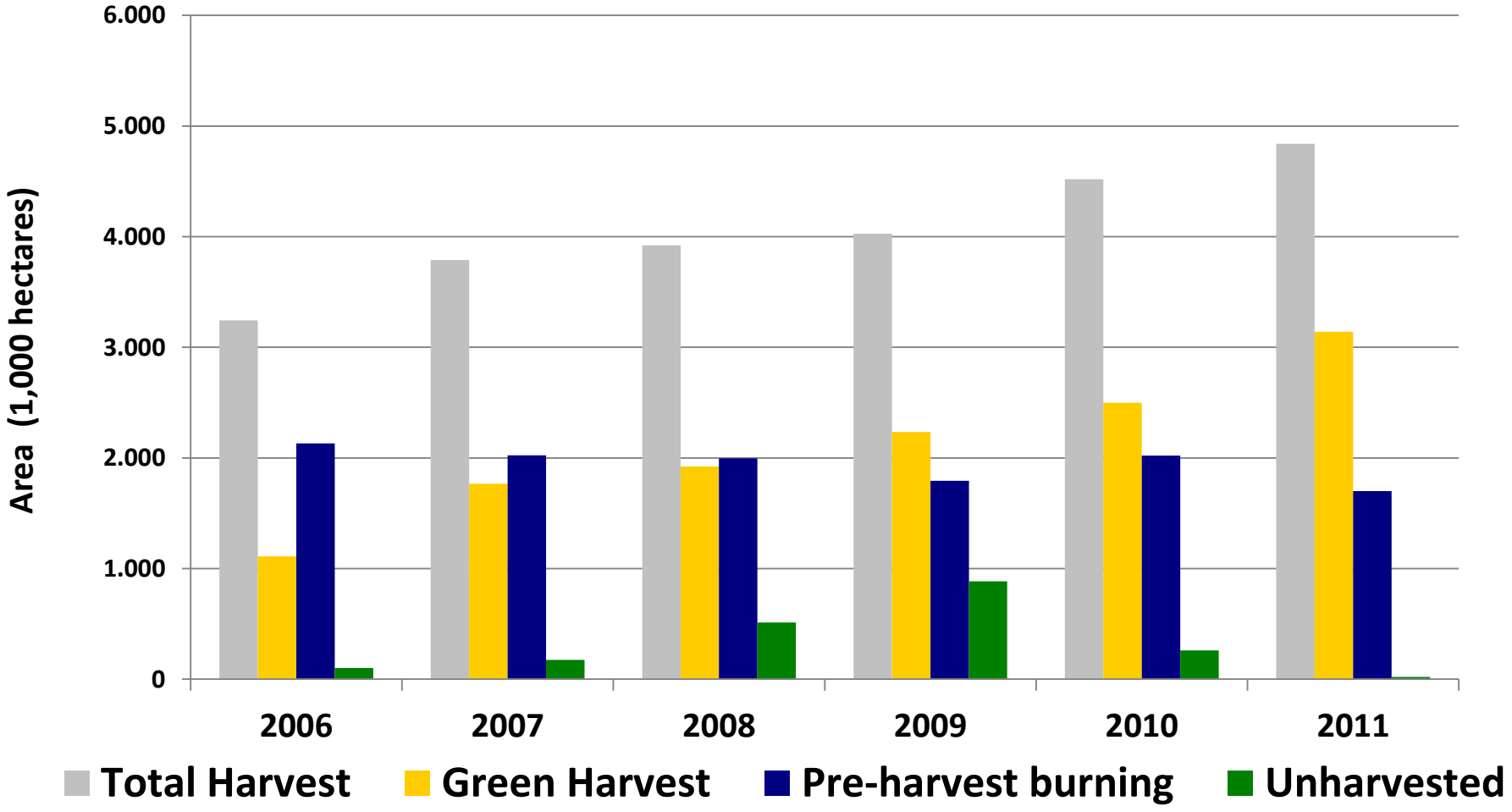
Percentage of Sugarcane by Harvest Type

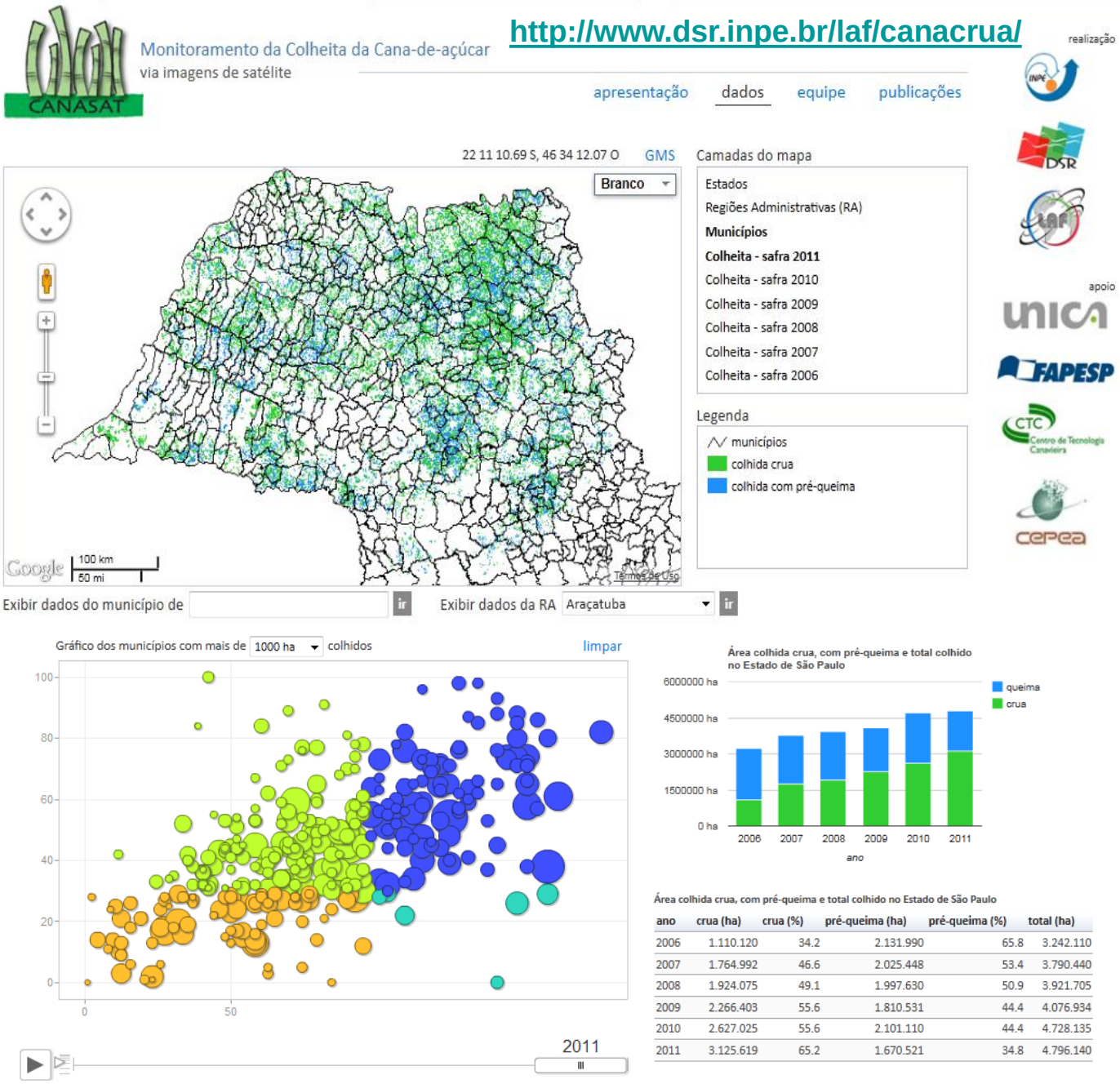
Harvest Season	Green harvest	Pre-harvest Burning
2006	34.2	65.8
2007	46.6	53.4
2008	49.1	50.9
2009	55.5	44.5
2010	55.6	44.4
2011	64.8	35.2

2006 2007 2008 2009 2010 2011



Harvested sugarcane area in São Paulo

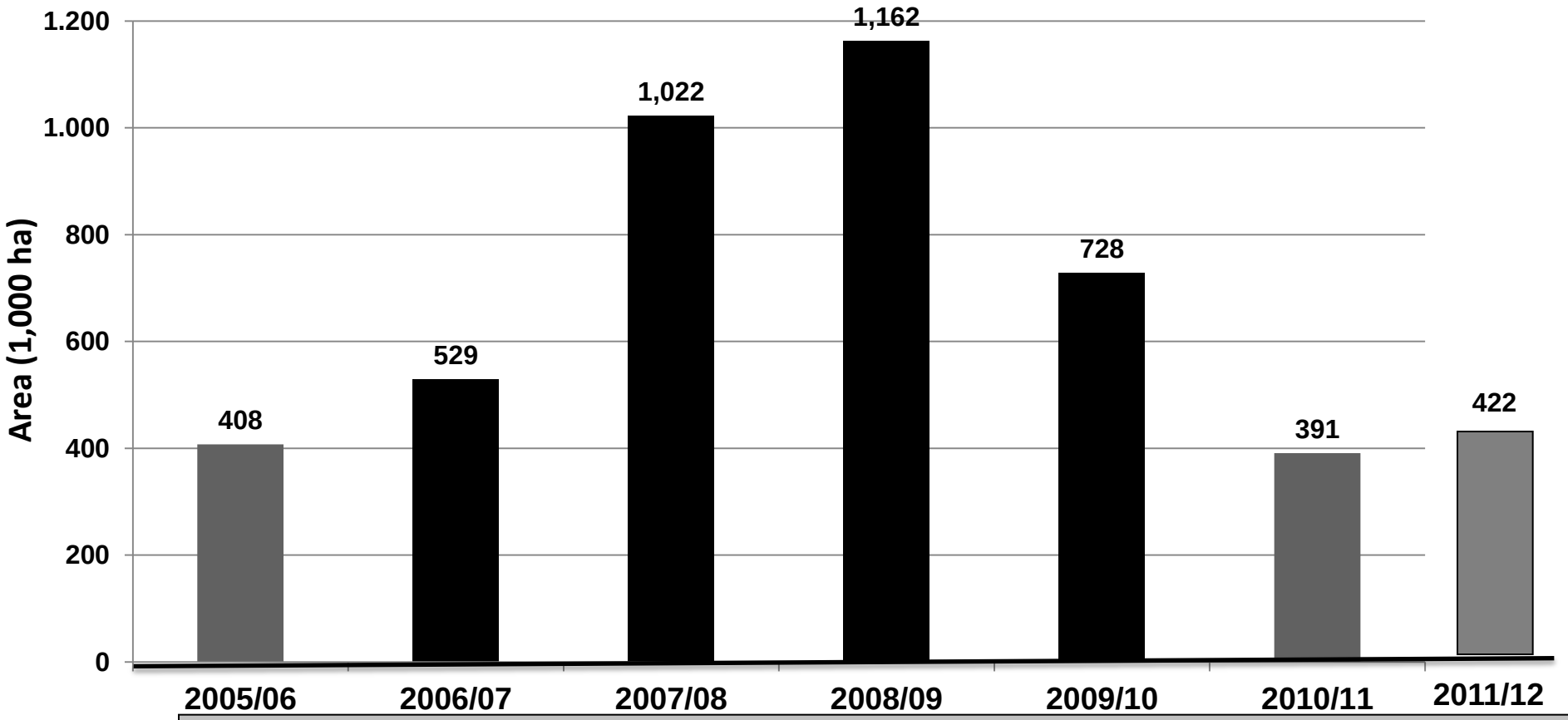




Aguiar, D.A.; Rudorff, B.F.T.; Silva, W.F.; Adami, M.; Mello, M.P. Remote Sensing Images in Support of Environmental Protocol: Monitoring the Sugarcane Harvest in São Paulo State, Brazil. *Remote Sens.* **2011**, *3*, 2682-2703.

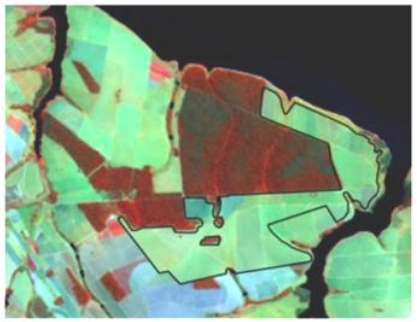
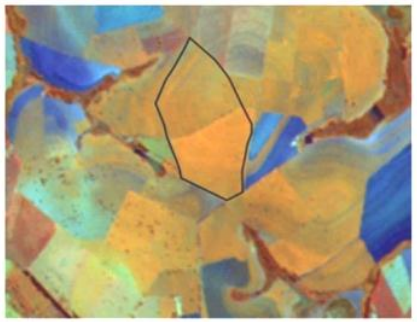
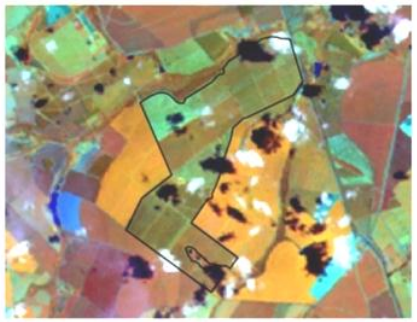
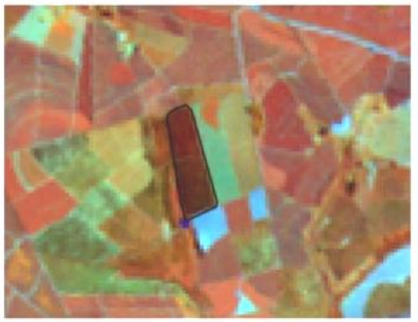
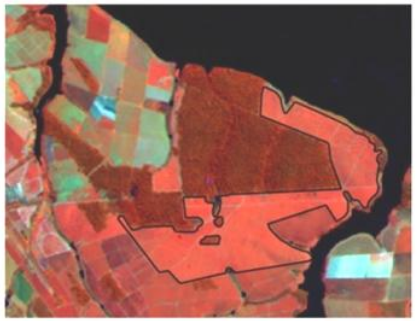
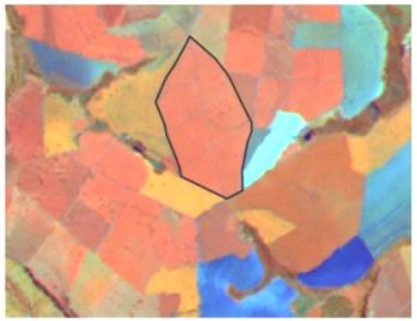
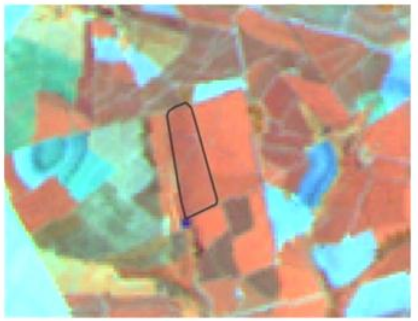
Evaluation of land use conversion due to sugarcane expansion

Expansion of Sugarcane in South-Central Brazil
2005/06 to 2011/12

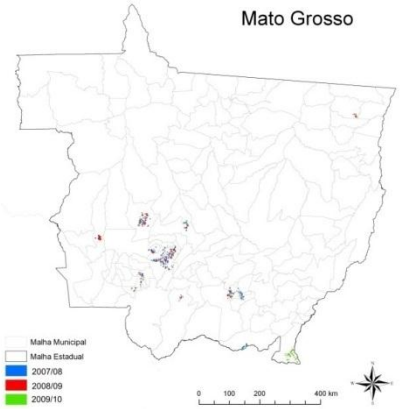


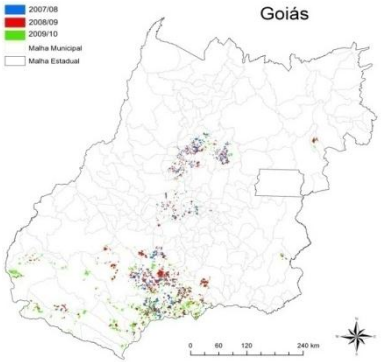
	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12
Relative expansion		8.5%	10.0%	16.4%	15.9%	9.0%	4.7%	4.8%
Cultivated area (1,000 ha)	4,786	5,269	6,221	7,326	8,007	8,341	8,660

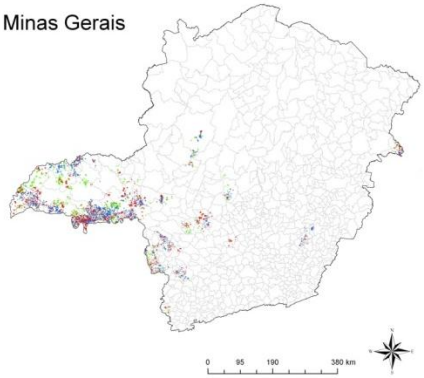
direct Land Use Change

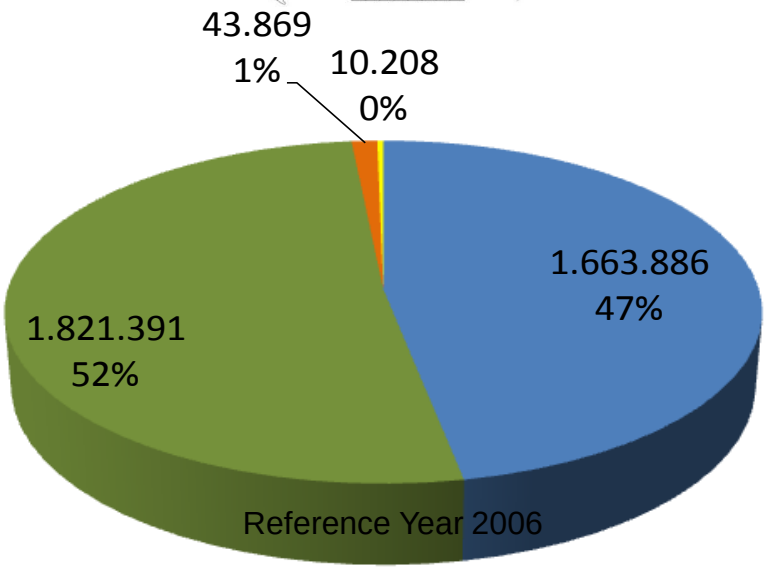
Pasture	Soybean	Citrus	Arboreous Vegetation
			
6a) 12/09/06	7a) 21/04/06	8a) 04/03/06	9a) 21/04/06
			
6b) 26/04/08	7b) 26/04/08	8b) 26/04/08	9b) 26/04/08

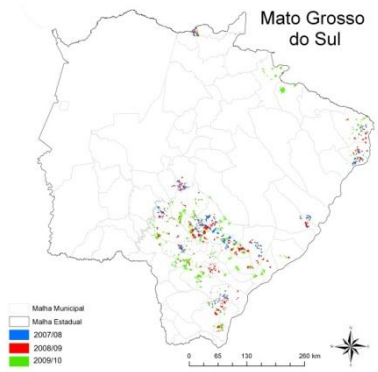
Land use prior to sugarcane expansion over four crop seasons: 2006/07 to 2009/10

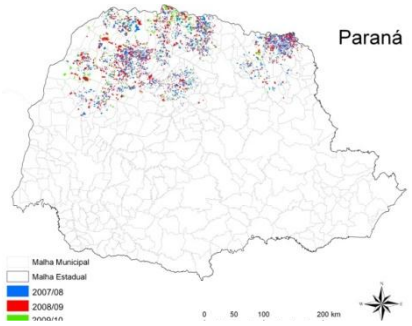


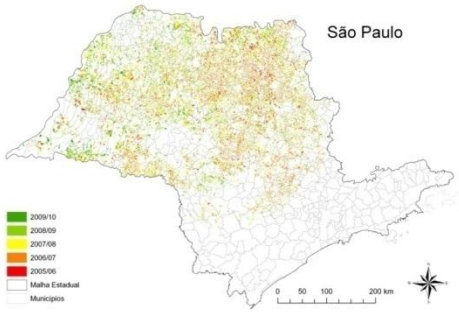












NASSAR, A. M.; RUDORFF, B. F. T.; ANTONIAZZI, L. B.; AGUIAR, D. A.; BACCHI, M. R. P.; ADAMI, M. Prospects of the sugarcane expansion in Brazil: impacts on direct and indirect land use changes (Peter Zuurbier and Jos van de Vooren) Sugarcane ethanol - Contributions to climate change mitigation and the environment. Wageningen: Wageningen Academic Publishers, 2008. p. 63-93. ISBN 9789086860906.

Sampling procedure to evaluate the dLUC dynamic over the period of 2000 to 2009 for sugarcane expansion from 2006 to 2009 using Landsat and MODIS time series

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Curva: 27019

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Safra: 01/02	Uso:	Pastagem
Safra: 02/03	Uso:	Pastagem
Safra: 03/04	Uso:	Área agrícola
Safra: 04/05	Uso:	Área agrícola
Safra: 05/06	Uso:	Área agrícola
Safra: 06/07	Uso:	Cana-de-açúcar
Safra: 07/08	Uso:	Cana-de-açúcar
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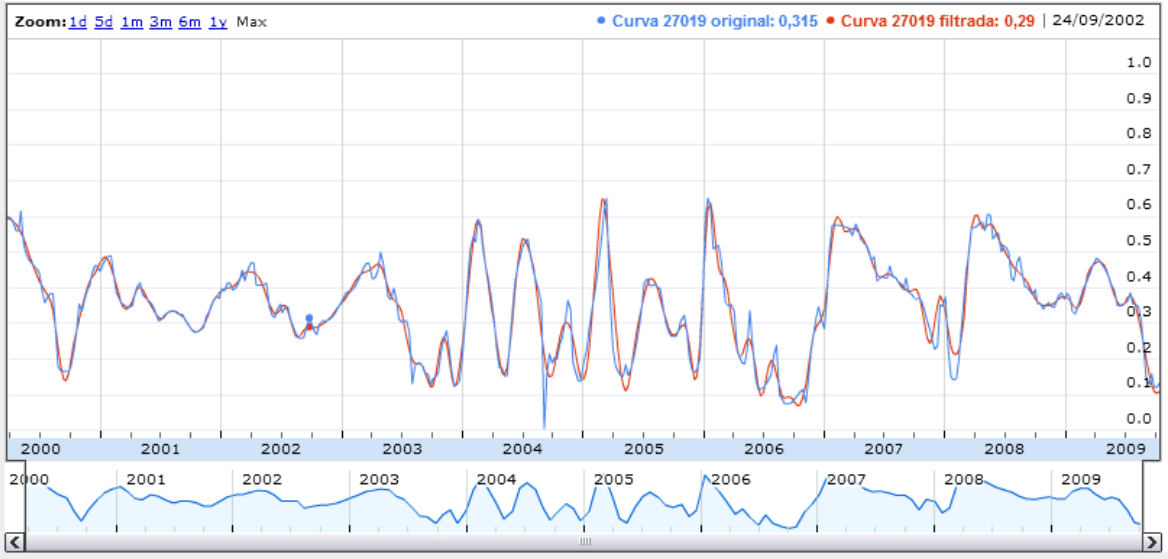

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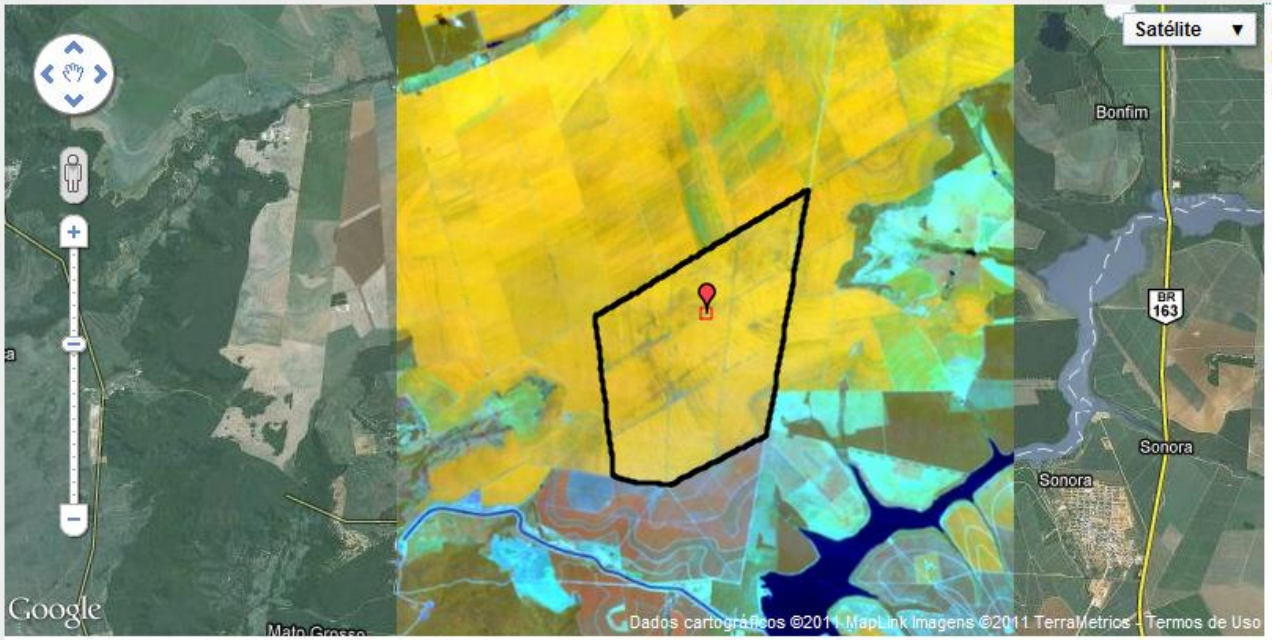

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Curva: 6019

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Safra: 02/03	Uso:	Área agrícola
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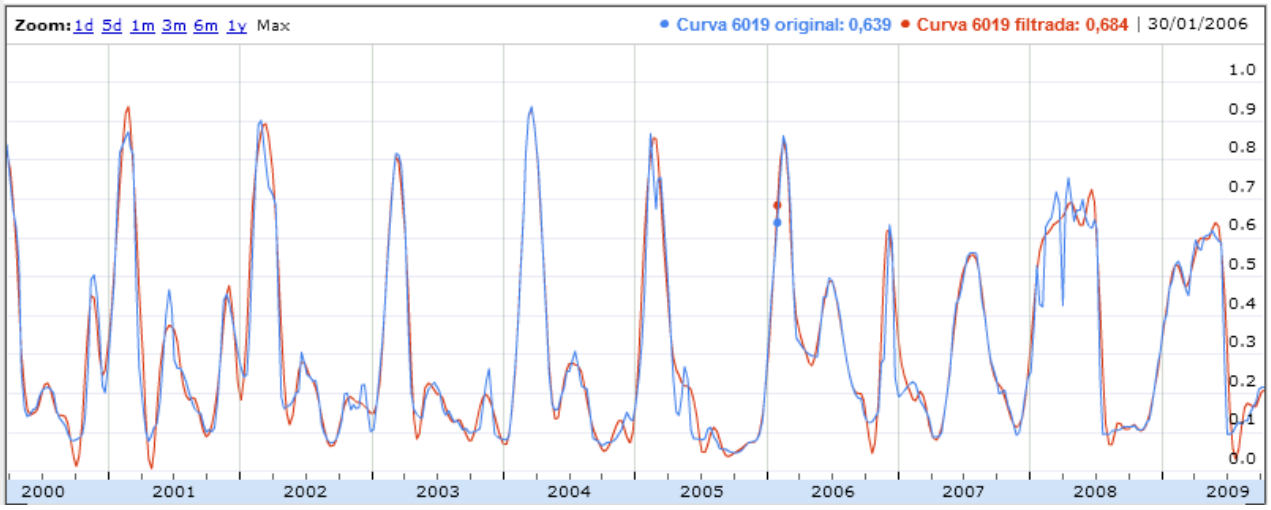
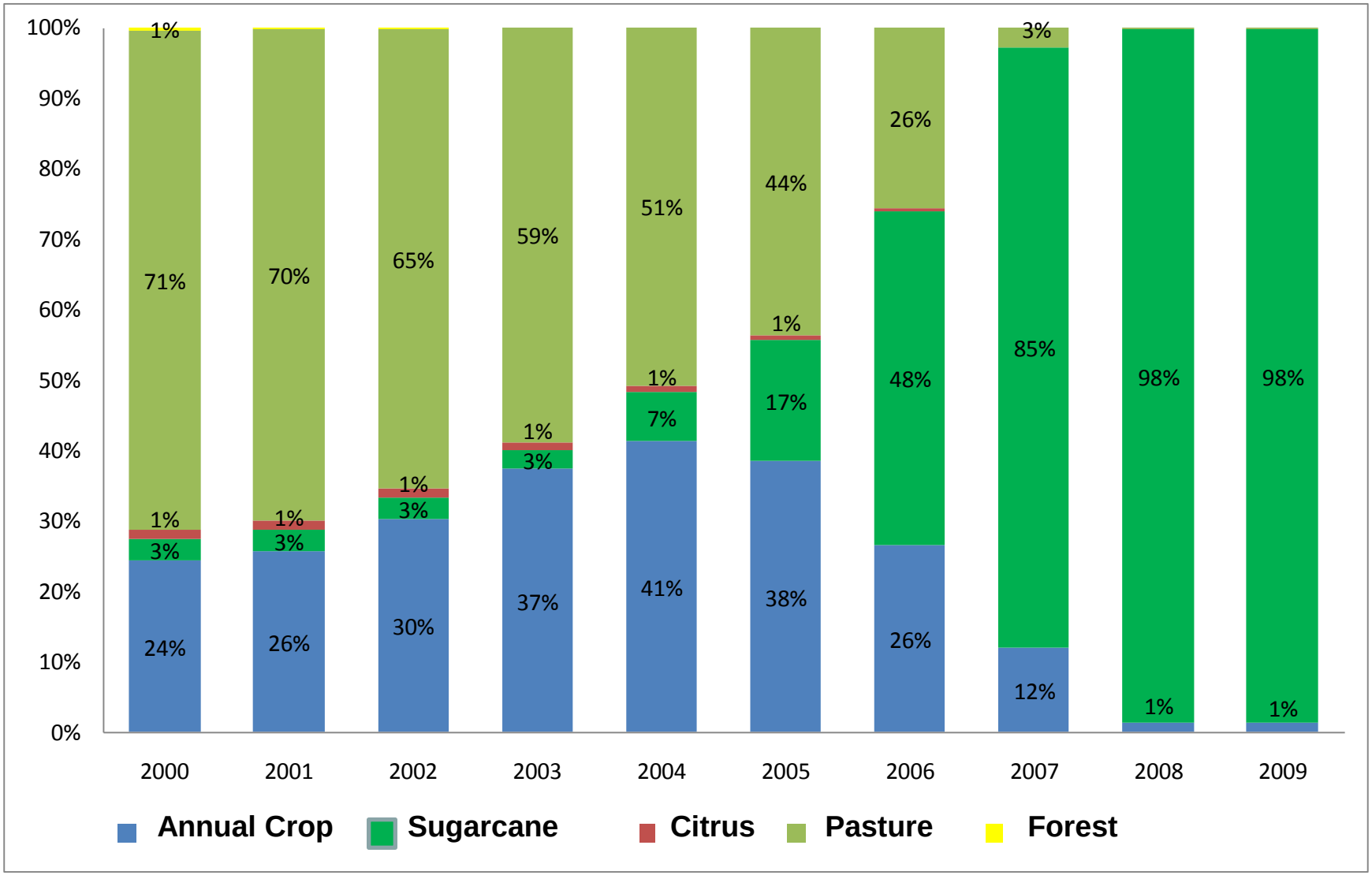


Land Use Change Dynamic from 2000 to 2009 for Sugarcane Expansion during 2006 to 2009



Adami, M.; Rudorff, B.; Freitas, R.; Aguiar, D.; Sugawara, L.; Mello, M. Remote Sensing Time Series to Evaluate Direct Land Use Change of Recent Expanded Sugarcane Crop in Brazil. In *Proceedings of the 1st World Sustain. Forum*, 1-30 November 2011; Sciforum Electronic Conferences Series, 2011.

Thematic Project FAPESP/BIOEN

Process 2008/56252-0

Environmental and Socioeconomic Impacts Associated with the Production and Consumption of Sugarcane Ethanol in South Central Brazil

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Work packages

1) Temporal-spatial evaluation of sugarcane crop based on remote sensing images

2) Temporal-spatial analysis of sugarcane albedo and spectral reflectance

3) Spatial dynamic modelling to generate scenarios for sugarcane crop expansion

4) Temporal-spatial evaluation of inland aquatic system's eutrophication in response to sugarcane expansion using remote sensing images

5) Assessing the regional weather, climate and air chemistry composition impacts of the ethanol sugarcane production in South Central Brazil

6) Characterization of the atmospheric chemistry composition changes and its impacts associated with sugarcane plantation and ethanol and bioelectricity plants in South Central Brazil

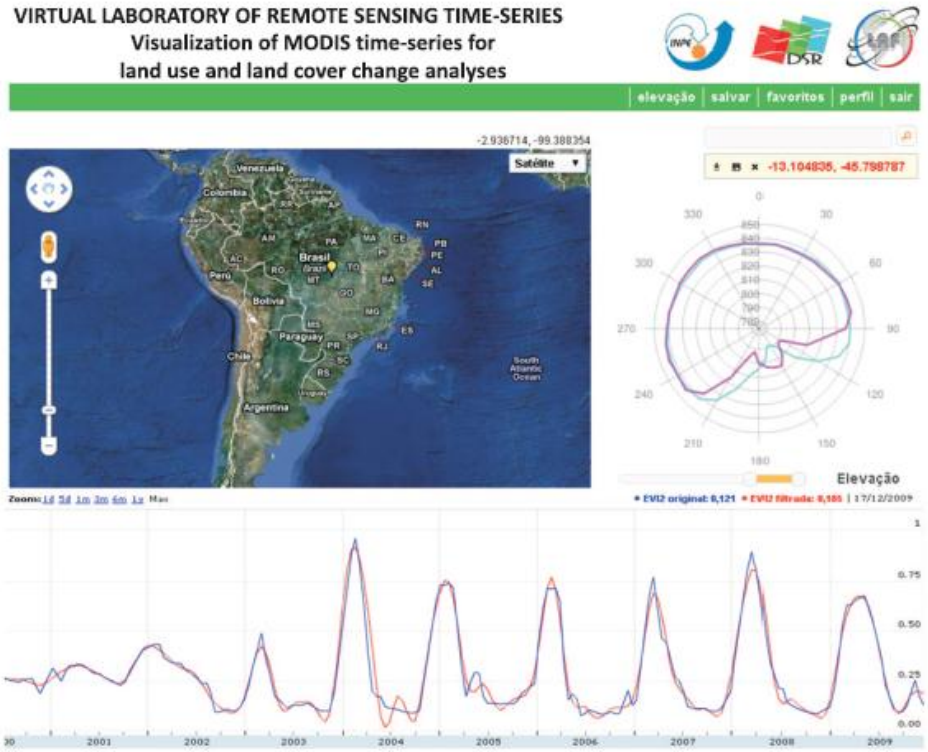
7) The impacts of Brazilian biofuel program on human health

8) Social-economic impacts of the expansion of sugarcane activity in the São Paulo State

January 2011/December 2014

Virtual Laboratory of Remote Sensing Time-Series

www.dsr.inpe.br/laf/series



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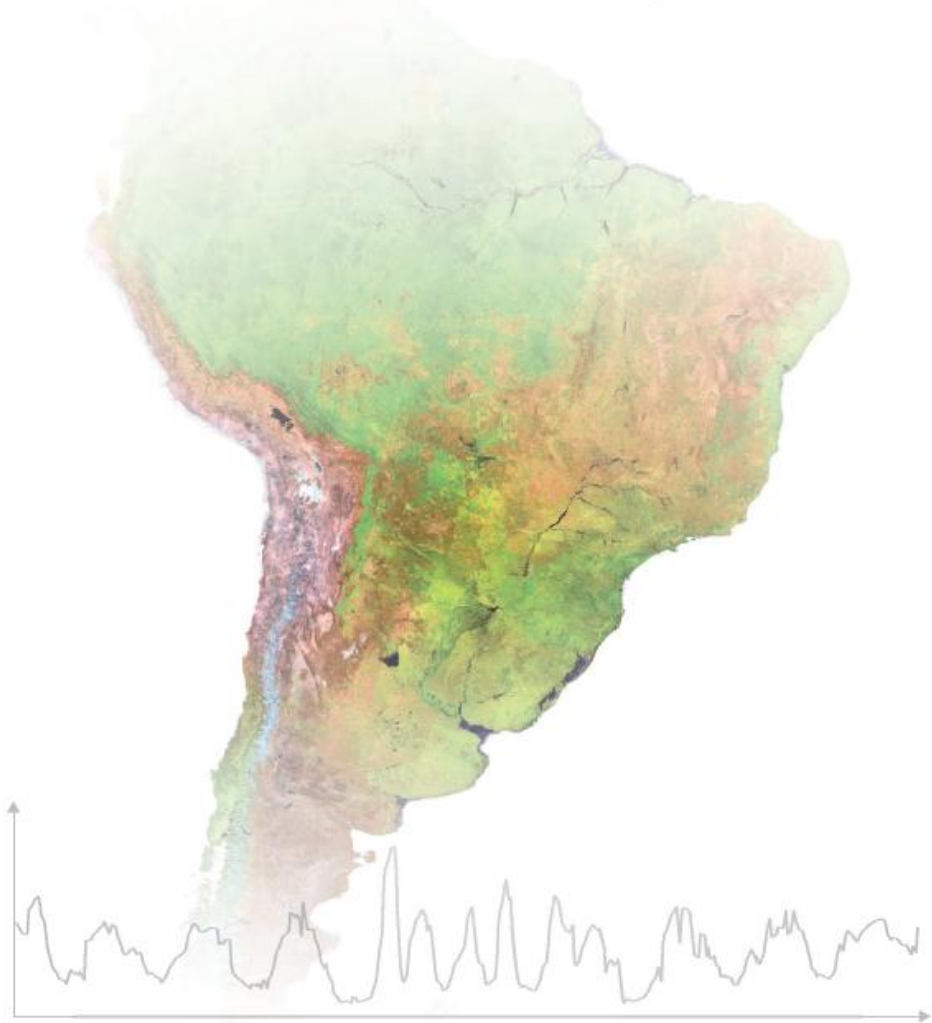
Visualization of MODIS time-series for

land use and land cover change analyses



Visualization of time-series from the MODIS sensor

Time-series of MODIS[1] images are available for instant visualization, for every pixel, over the South American continent, since the year 2000.

A web tool was developed for instantaneous visualization of MODIS time-series within the concept of a virtual laboratory[2] to support land use and land cover change (LULCC) analyses based on a more than 10 years history of daily MODIS data acquisition.

Each curve of the time-series represents the variation over time of the vegetation index (EVI2) for a user's selected pixel on the virtual globe of Google Maps.

The time-series were constructed based on filtered vegetation index (EVI2) of the MOD13Q1 product (collection 5, 16 days composite at spatial resolution of 250 m) available at NASA (https://wist.echo.nasa.gov)[2].

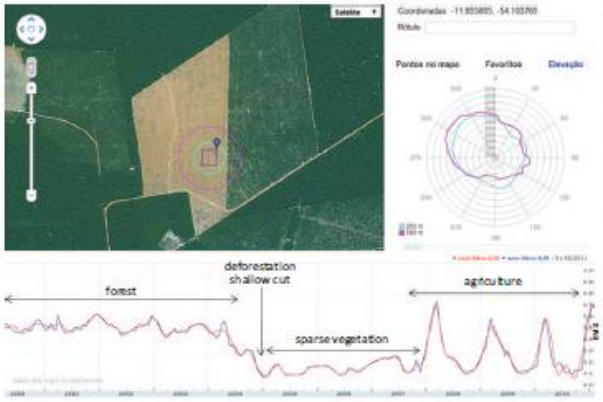
With a minimum of technical knowledge about vegetation dynamics it is possible to retrieve the land use and land cover change history for a given pixel. The figures presented next provide interpreted examples of the land use and land cover change based on the temporal variation of the vegetation index.

The instantaneous visualization of the time-series can be accessed at

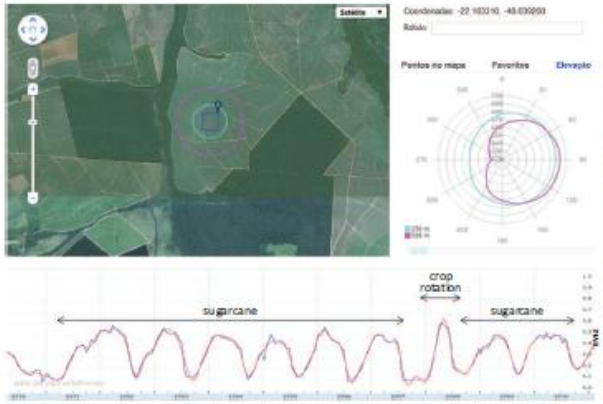
www.dsr.inpe.br/laf/series

[1]Images are from the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor on board of NASA's Terra platform. More information about the sensor can be obtained in: Rudorff, B. F. T., Shimabukuro, Y. E., Ceballos, J. C. O sensor MODIS e suas aplicações ambientais no Brasil (The MODIS sensor and its environmental applications in Brazil). São José dos Campos, SP. Parêntese, 2007, v.1. 425p.

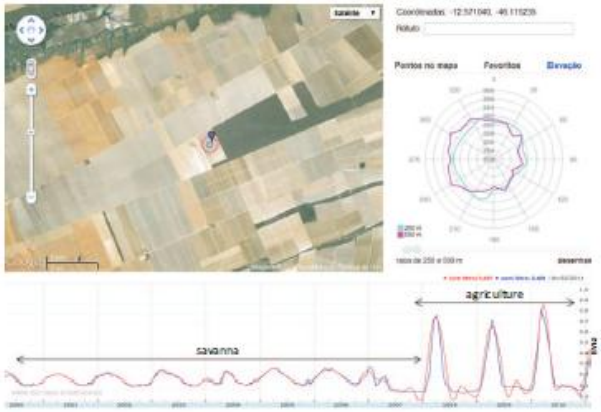
[2]A detailed description about the Virtual Laboratory of Remote Sensing Time-Series and the data filtering procedure can be found in: Freitas, R.M., Arai, E., Adami, M., Ferreira, A. S., Sato, F. Y., Shimabukuro, Y.E., Rosa, R. R., Anderson, L. O., Rudorff, B. F. T. Virtual laboratory of remote sensing time series: visualization of MODIS EVI2 data set over South America, Journal of Computational Interdisciplinary Sciences (JCIS), PACIS, v. 2-1, 2011 (http://epacis.org/jcis.php).



The time-series graph shown in this figure refers to the pixel (blue balloon) in Google Maps. Analyzing this time-series it can be noticed the land presented a forest cover until 2004 when it began to be deforested. After deforestation the land remained with sparse vegetation as indicated by the low EVI2 values. By the end of 2007 a summer crop was planted reaching its maximum development in the beginning of 2008 followed by an abrupt decrease of EVI2 values in response to senescence and crop harvest. The same dynamic can be observed for the following crop year.



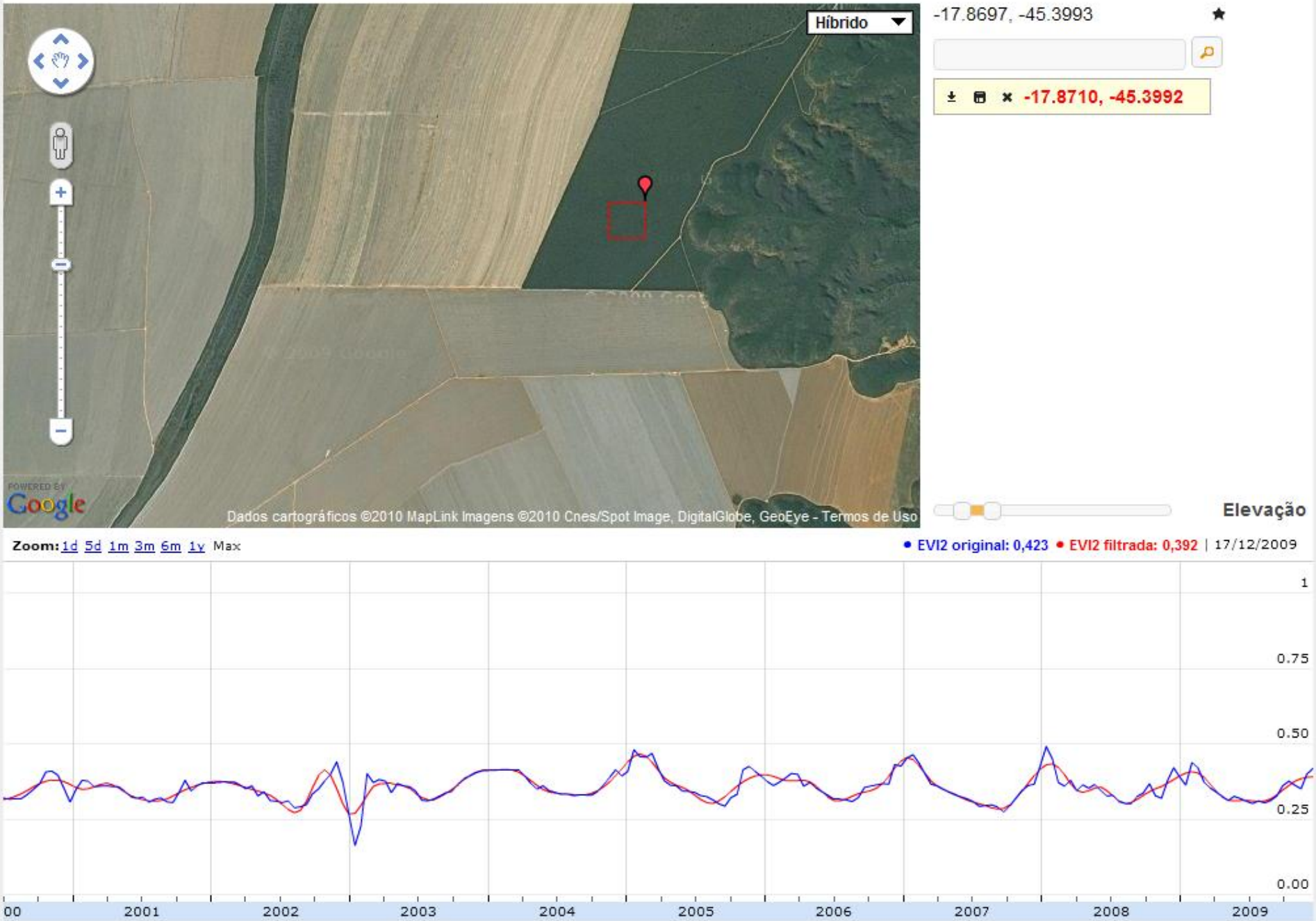
With some knowledge about the sugarcane crop growth cycle one can observe that the pixel (blue balloon in figure next) is from a sugarcane field planted in the beginning of 2001 that grew for a period of about 18 months prior to harvest in mid 2002. During the following five years the field was harvested every year after a growing period of 12 months each year. In 2007, crop rotation was performed with an annual crop (leguminous) followed by a new sugarcane crop. More information on this field can be obtained using the coordinates of the pixel in the Canasat website at:
http://www.dsr.inpe.br/laf/canasat/



The time-series graph for the pixel (blue balloon) in this figure is from a field within an agricultural region located at the frontier of the Savanna in western Bahia state, Brazil. The region was originally covered by savanna and was gradually converted to intense agricultural land use. This region is characterized by large soybean, corn, cotton and coffee plantations. Considering the shape of the time-series graph one can assume that after 2007 the field was cultivated with a summer crop, possibly soybean or corn. This kind of information is relevant for certification purposes of agricultural crops.

Municipality of Buritizeiro, Minas Gerais, Brazil

www.dsr.inpe.br/laf/series/



Laboratório de Agricultura e Floresta do INPE

Gráficos de séries temporais MODIS

Sair

-17.8697, -45.4105

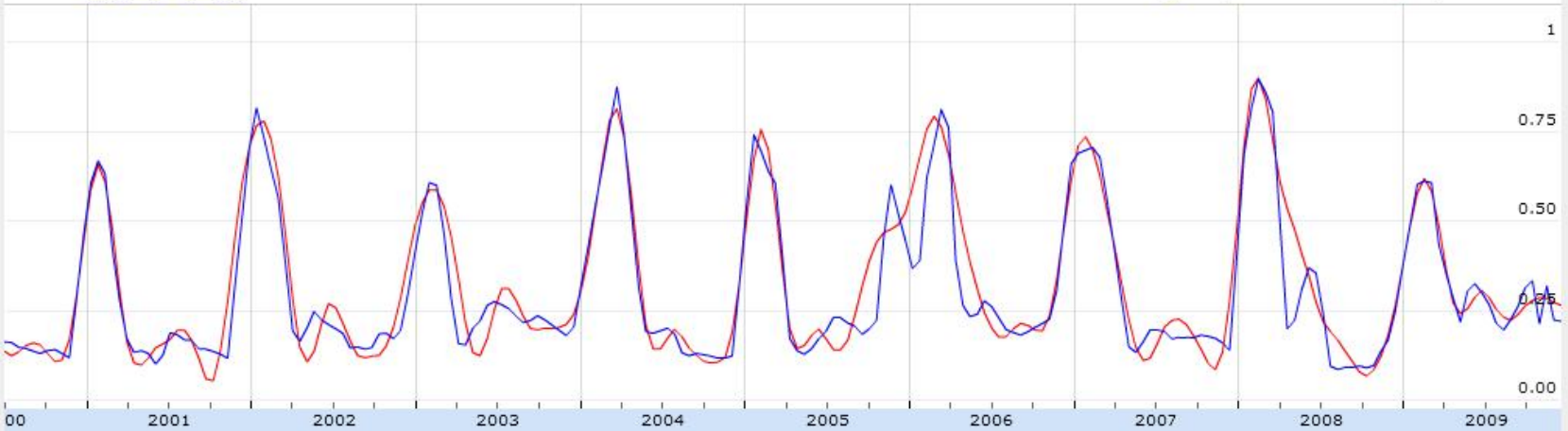
-17.8710, -45.3992

-17.8710, -45.4104

Elevação

Zoom: 1d 5d 1m 3m 6m 1y Max

• EVI2 original: 0,22 • EVI2 filtrada: 0,263 | 17/12/2009



Laboratório de Agricultura e Floresta do INPE

Gráficos de séries temporais MODIS

Sair

-17.8767, -45.4016

-17.8710, -45.3992

-17.8710, -45.4104

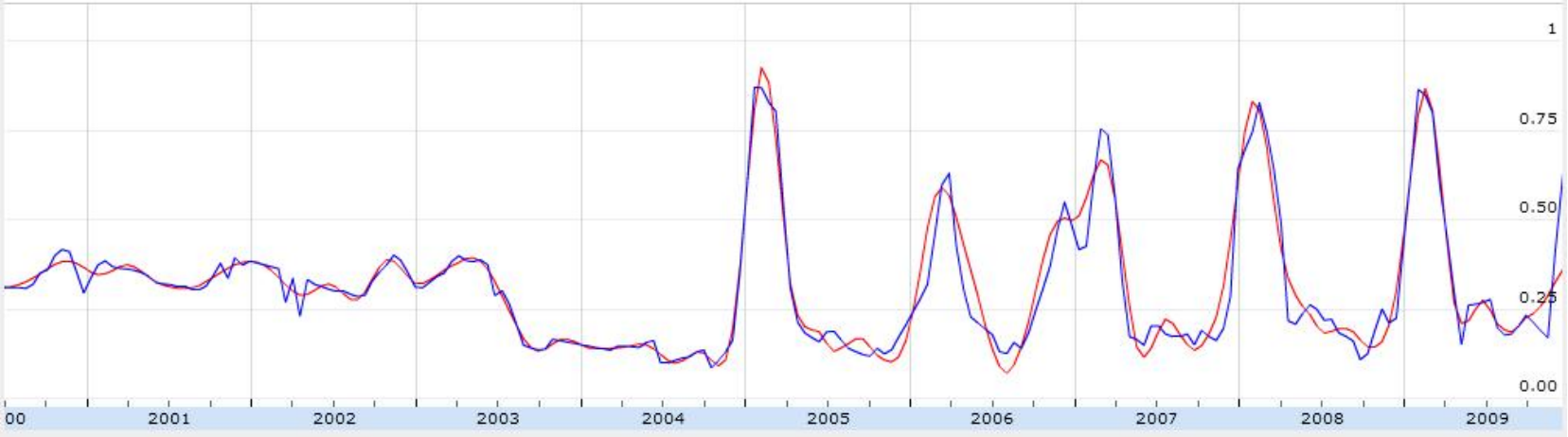
-17.8777, -45.4014

Ex. de Cana
-22.407711, -50.790675

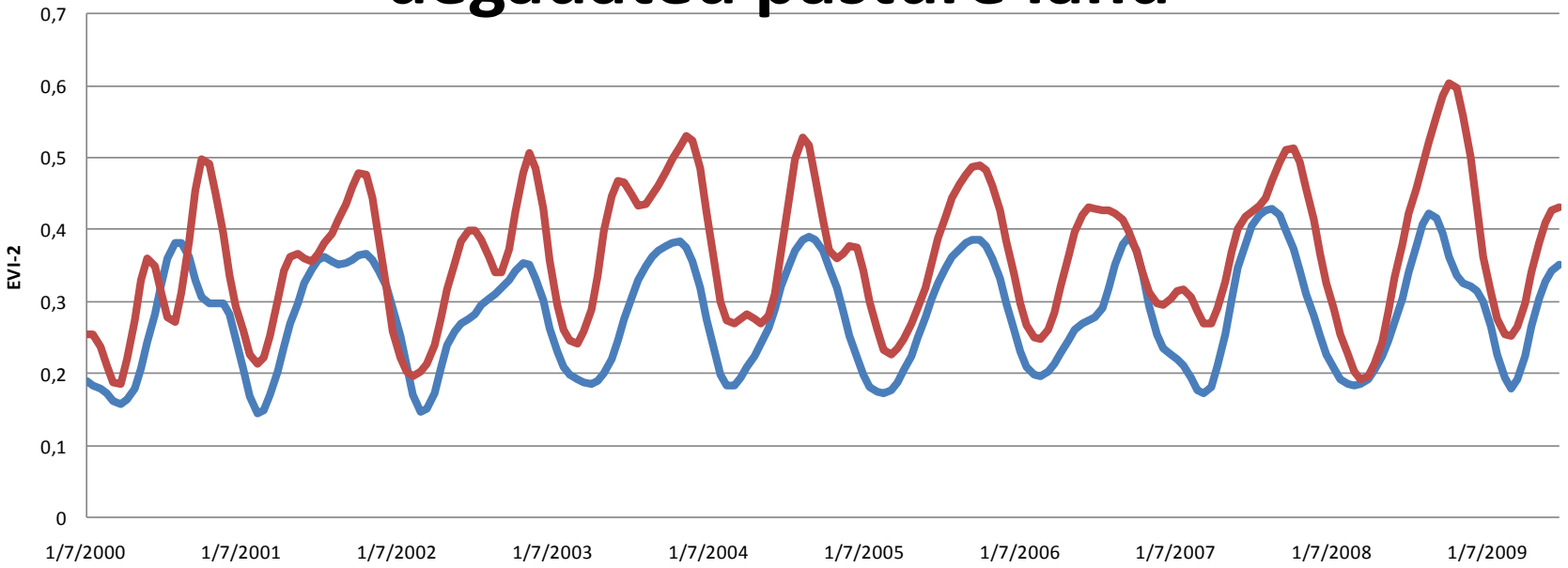
Elevação

Zoom: 1d 5d 1m 3m 6m 1y Max

• EVI2 original: 0,654 • EVI2 filtrada: 0,365 | 17/12/2009



MODIS time-series to evaluate degadated pasture land

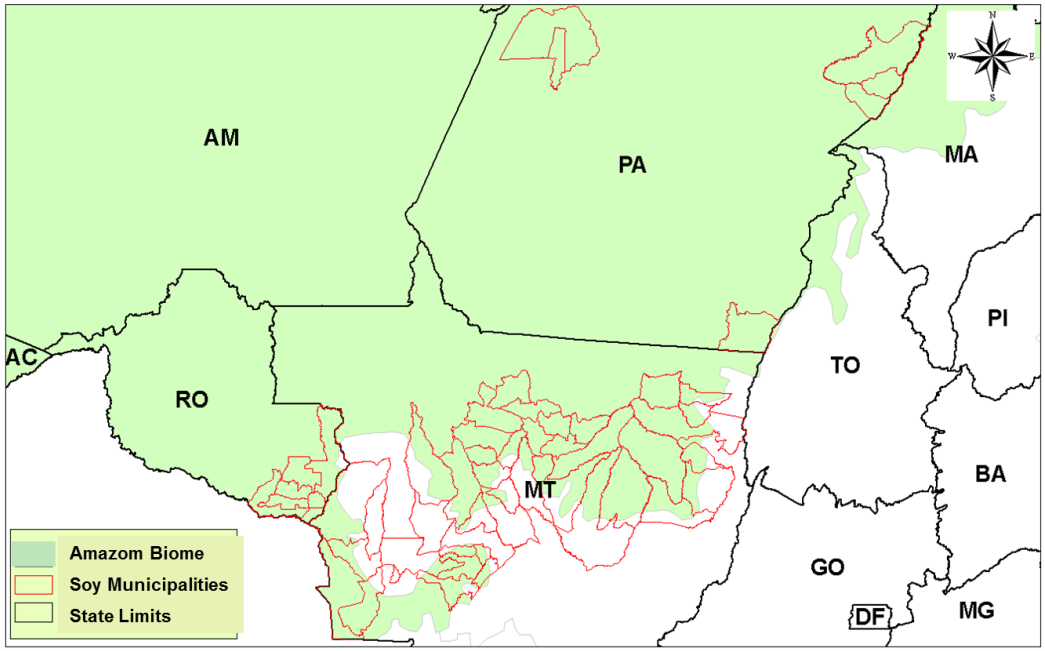


SOY MORATORIUM

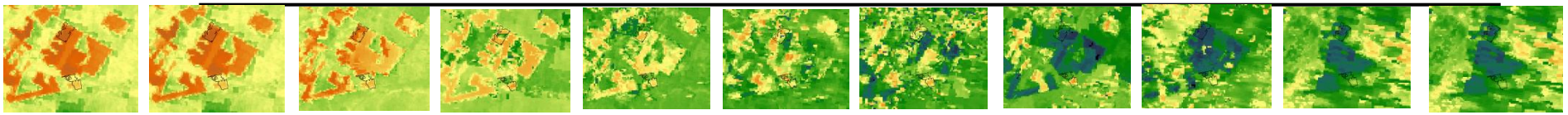
MONITORING SOY PLANTATION IN THE AMAZON BIOME IN DEFORESTED FIELDS AFTER 24TH JULY 2006

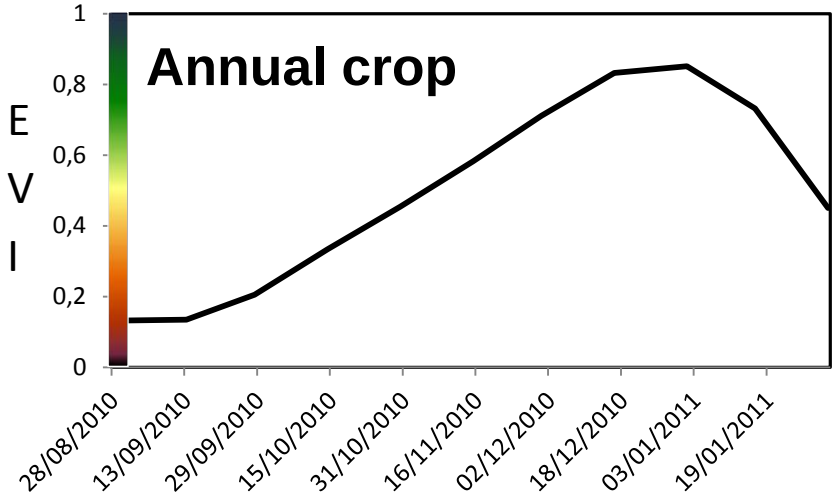
Soybean in the Amazon biome

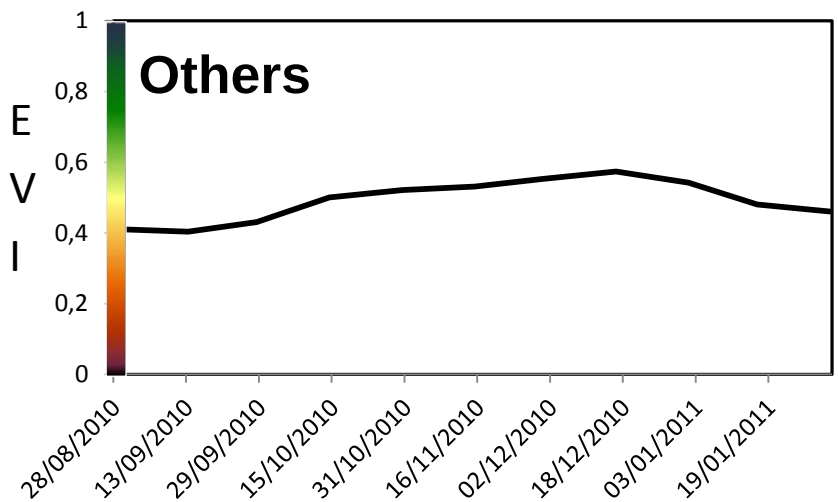
- Brazilian Amazon biome (4.2 Mkm^2) has 553 municipalities;
- 7.5% of Brazilian soybean is produced in the Amazon biome (1.9 Mha) and concentrated in 53 municipalities;
- Deforestation in the Legal Amazon from 2007 to 2010 was 39,026 km^2;
- Deforestation in soy municipalities from 2007 to 2010 was 4,862 km^2 (12.5%);



Monitoring Deforested Fields through Satellite Images





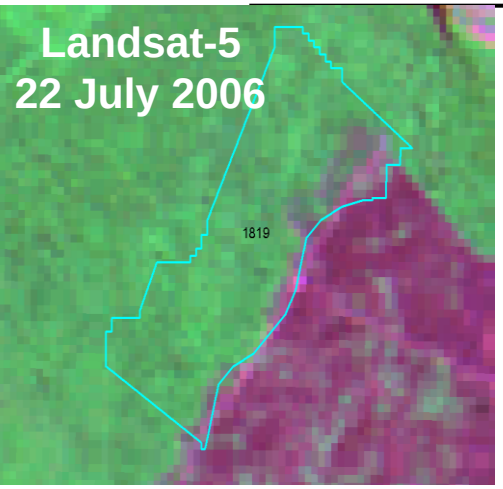


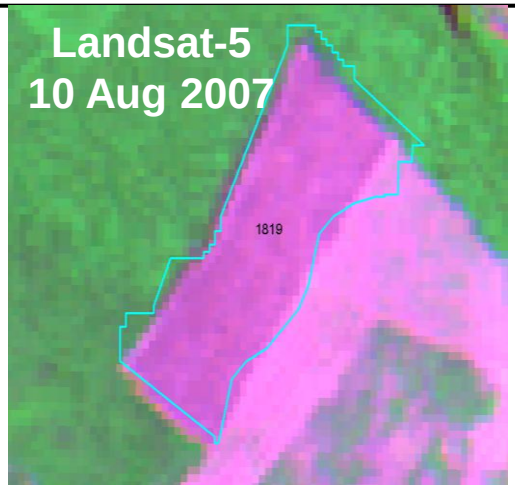
- **In the 4th year (2010/11) of the Soy Moratorium 11,698 ha were identified as soybean in recent deforestations;**
- **This soybean area corresponds to: 0.3% of the deforestation in the Legal Amazon since the beginning of the Moratorium; 2.4% of the deforestation of soy producing municipalities (3.1% of deforestation > 25 ha); and 0.6% of the soybean area of the Amazon Biome.**

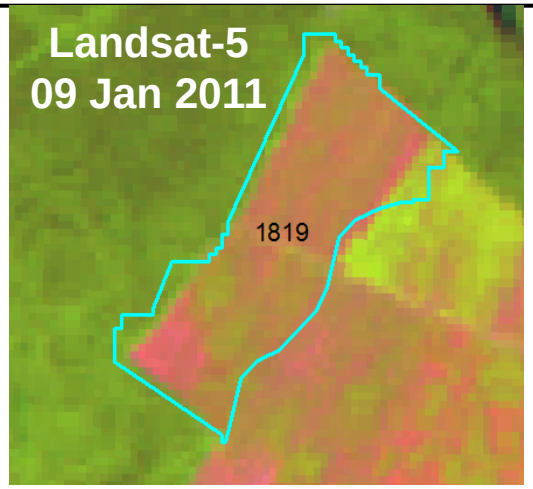
Rudorff, B.F.T.; Adami, M.; Aguiar, D.A.; Moreira, M.A.; Mello, M.P.; Fabiani, L.; Amaral, D.F.; Pires, B.M. The Soy Moratorium in the Amazon Biome Monitored by Remote Sensing Images. *Remote Sens.* **2011**, *3*, 185-202.

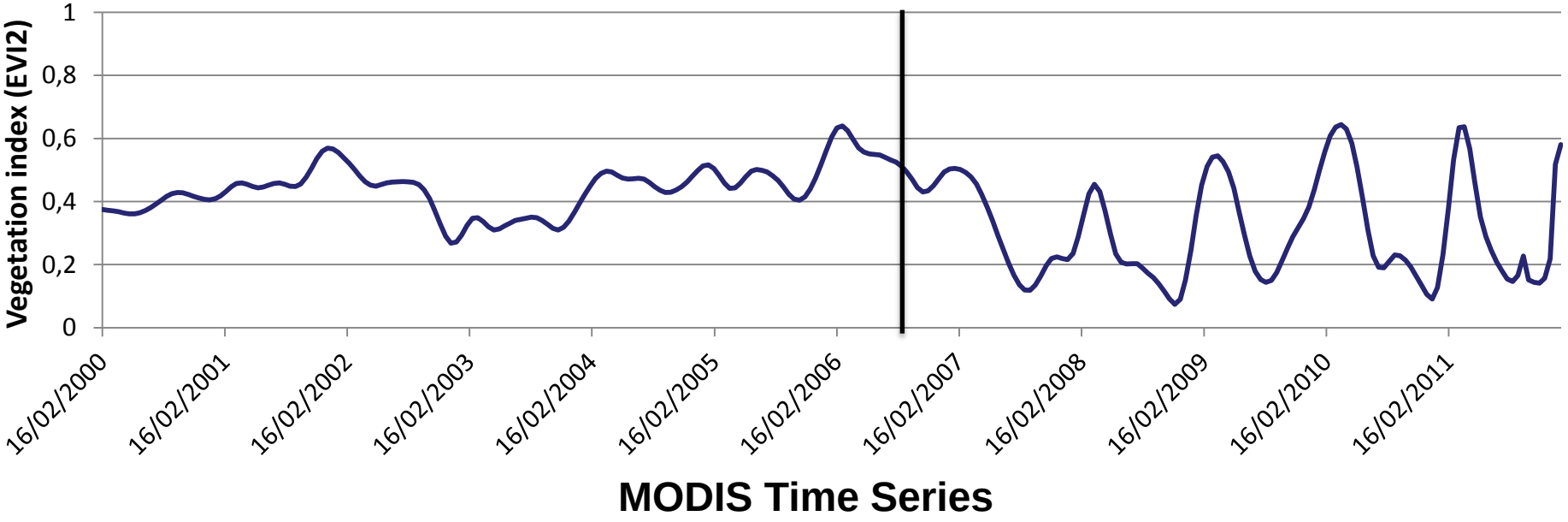
Rudorff, B.; Adami, M.; Risso, J.; Aguiar, D.; Pires, B.; Amaral, D.; Fabiani, L.; Cecarelli, I. Remote Sensing Images to Detect Soy Plantations in the Amazon Biome – the Soy Moratorium Initiative. In *Proceedings of the 1st World Sustain. Forum*, 1-30 November 2011; Sciforum Electronic Conferences Series, 2011.

PRODES deforested field that was contested by the farmer









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