

Open Source Big Earth Observation Data Analytics

www.esensing.org

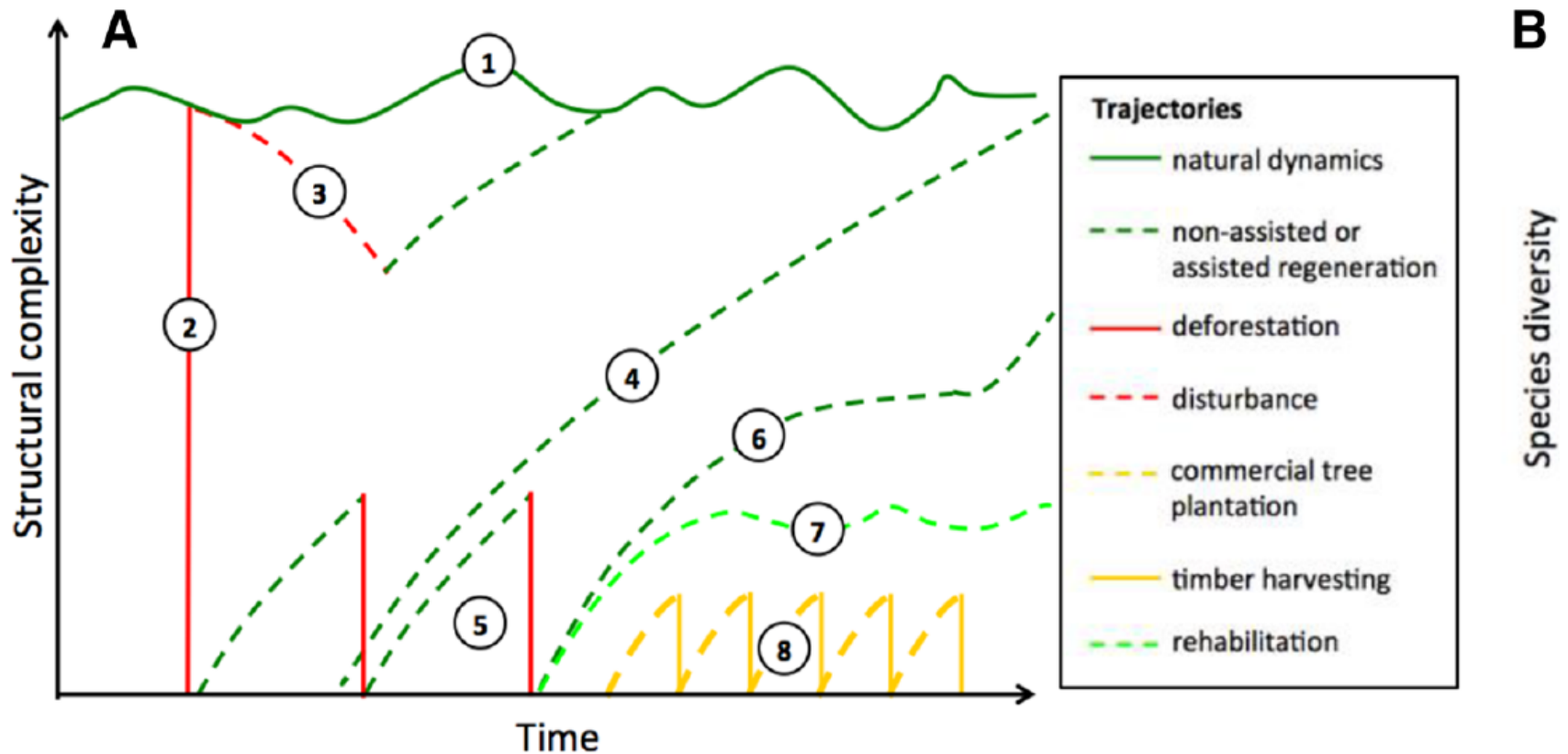
Presented by: Lúbia Vinhas

The background of the slide is a composite image of a natural landscape. It features tall grasses in the foreground, a body of water in the middle ground, and a green hillside in the background. The image is overlaid with a semi-transparent white banner that contains the title text.

ESTRATÉGIA DO PROGRAMA

**DE MONITORAMENTO AMBIENTAL DOS
BIOMAS BRASILEIROS**

Distinguishing forests by temporal evolution



Distinguishing forests by temporal evolution

C



1
an old-growth forest remnant included in a protected area



2
a deforested land for soybean cultivation in the Amazon



3
forest fires and regeneration after disturbance



4
natural regeneration and future return to a pre-disturbance state



5
a shifting cultivation fallow cultivated with cassava



6
restoration plantation in a cropland, some years after deforestation

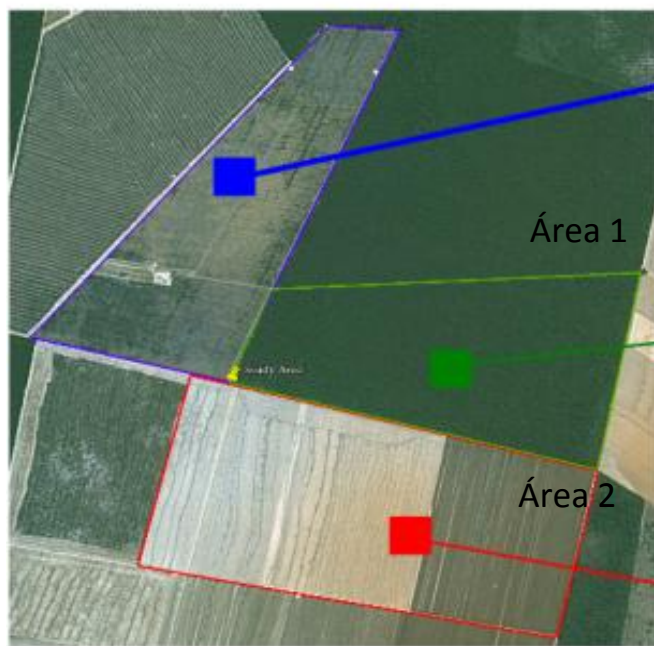


7
shaded coffee cultivated in agroforestry system



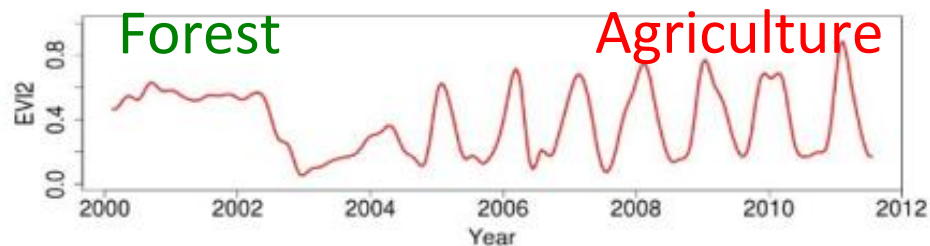
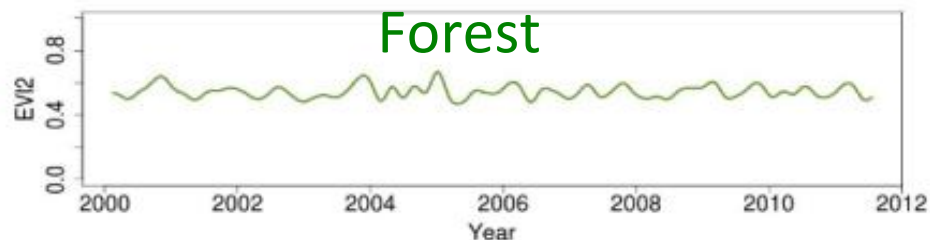
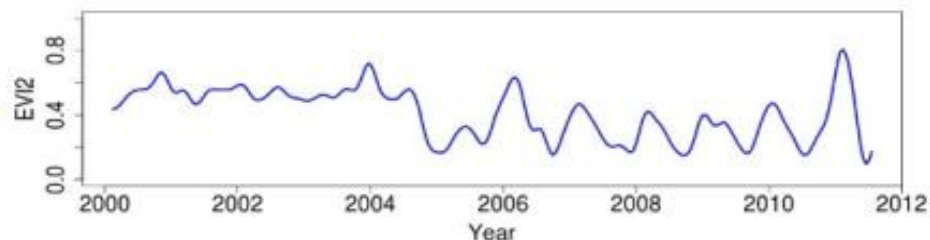
8
commercial pine tree plantation with dense understory

Land trajectories



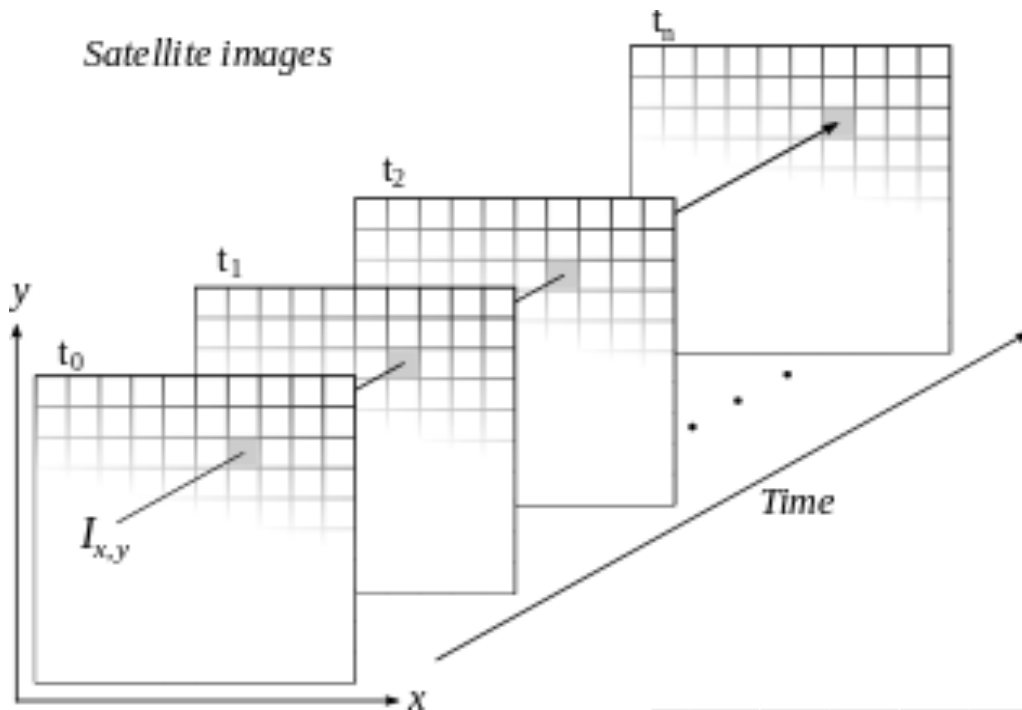
Área 3

Forest Pasture Agric



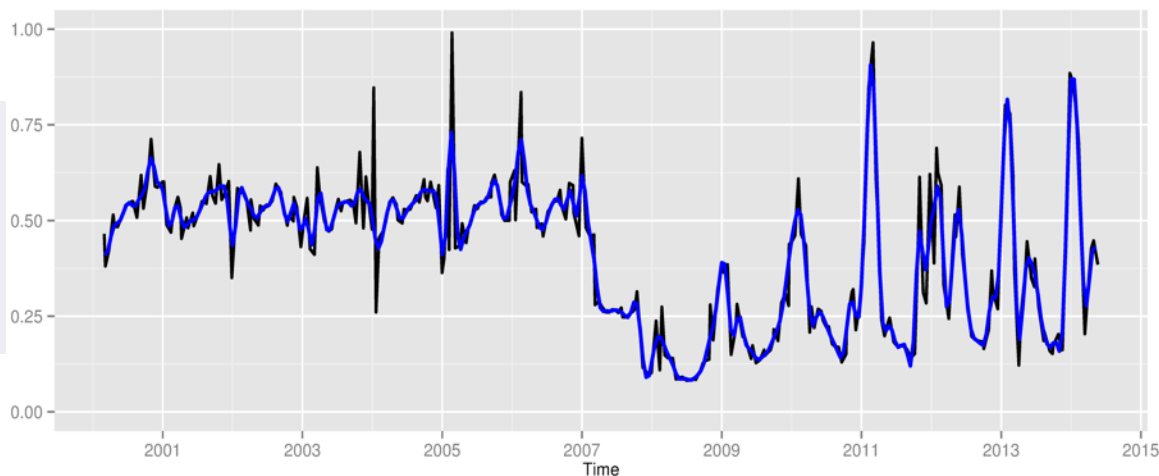
“The transformations of land cover due to actions of land use”

Space first-time later or time first-space later?



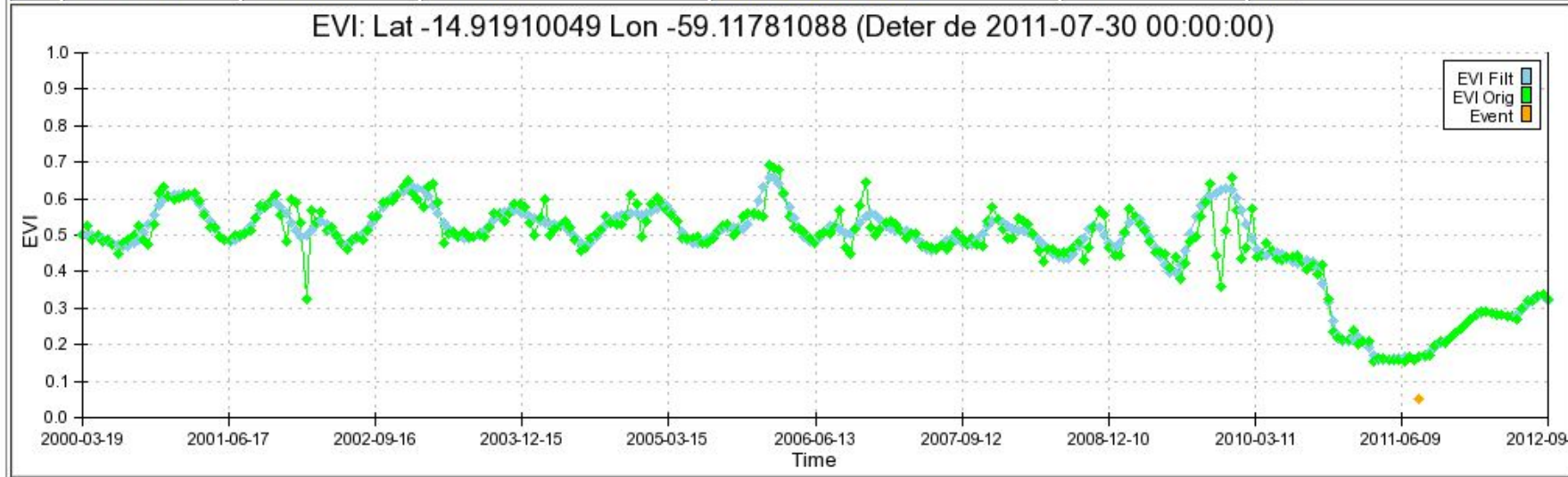
Space first: classify images separately
Compare results in time

Time first: classify time series separately
Join results to get maps



The transition from natural to managed land as seen by remote sensing

Nr	Lat	Long	Mes/Ano Deter	Município/UF	Area km2	Classe Avaliacao
3	-14.91910049	-59.11781088	JULHO/2011	Pontes e Lacerda/MT	2.64	Corte_raso



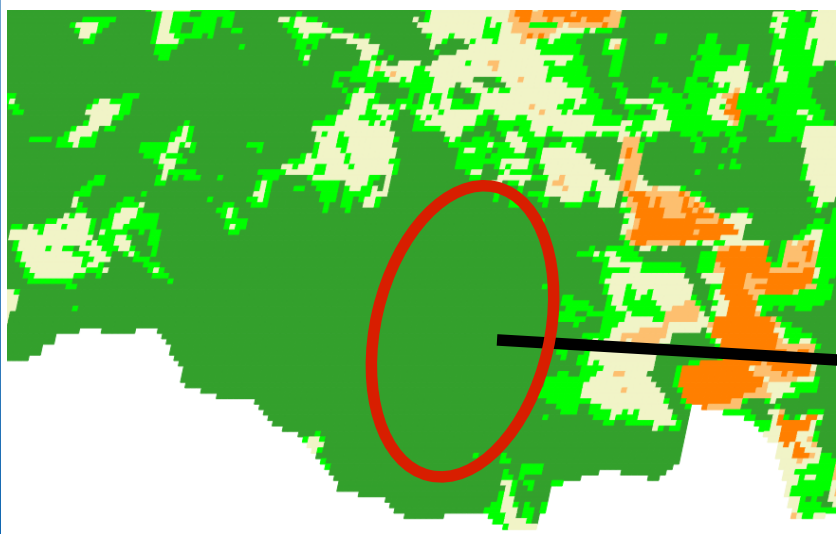
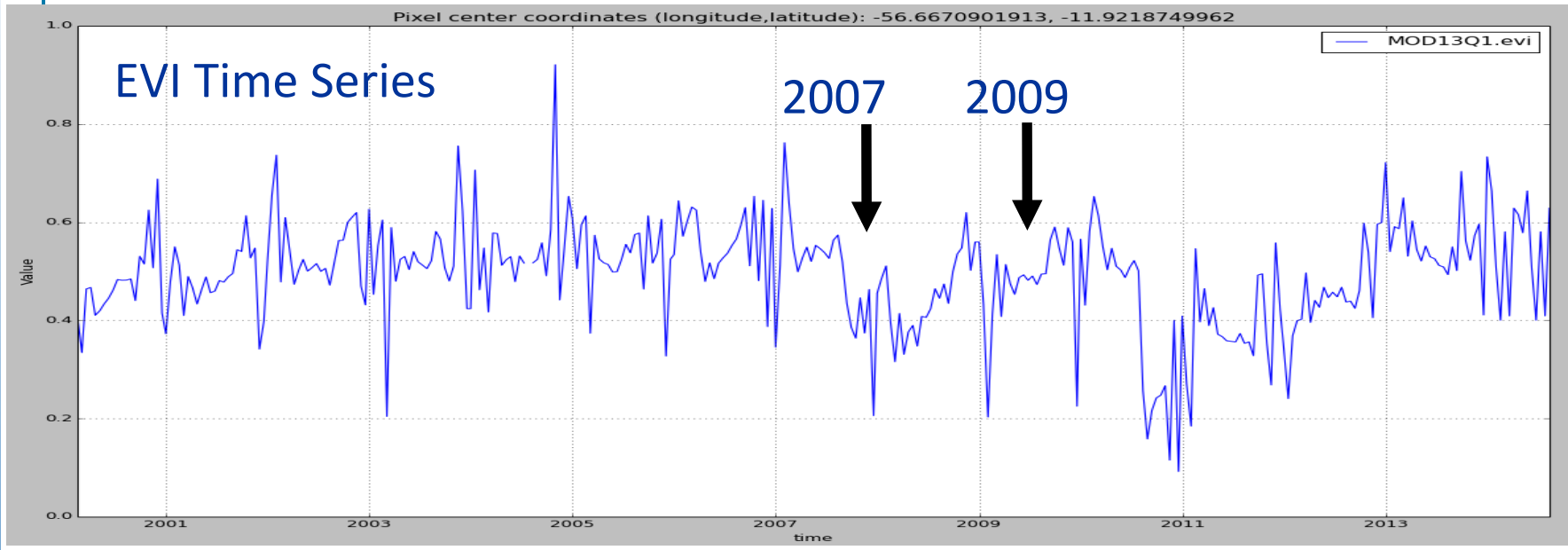
2010



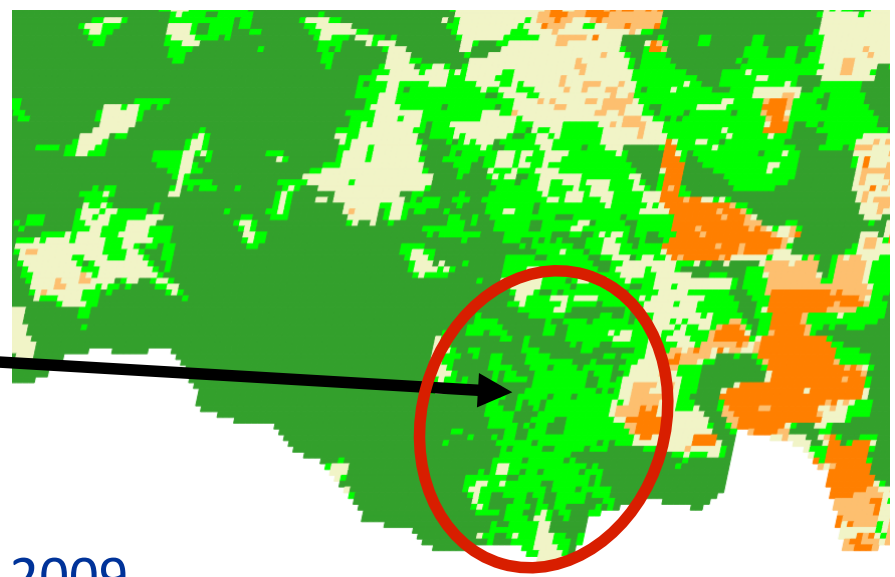
2011



Land trajectories: forest degradation



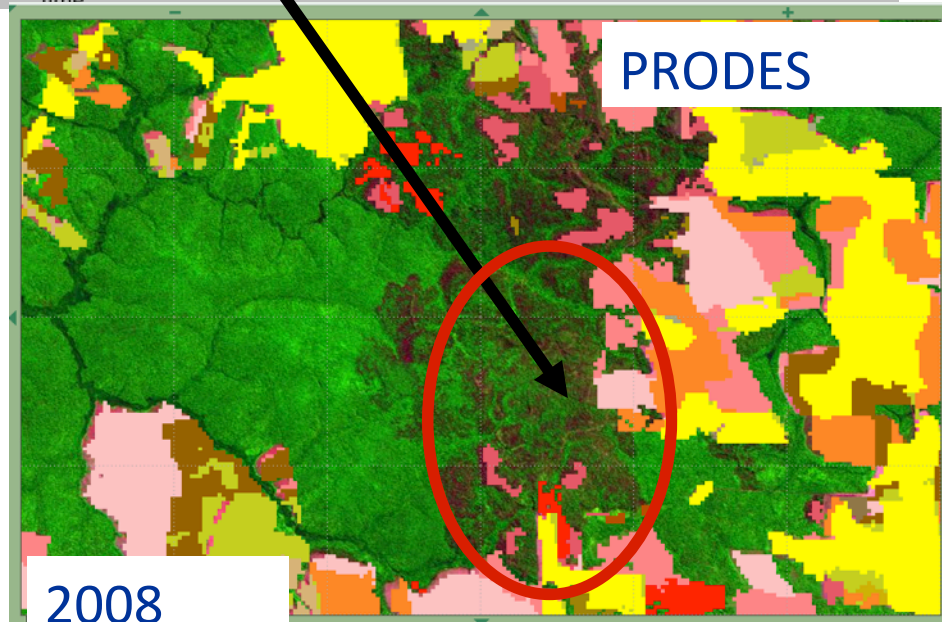
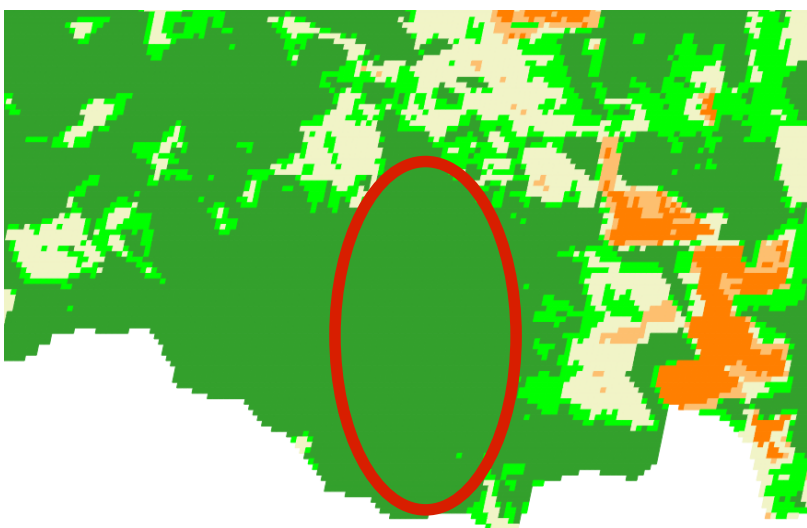
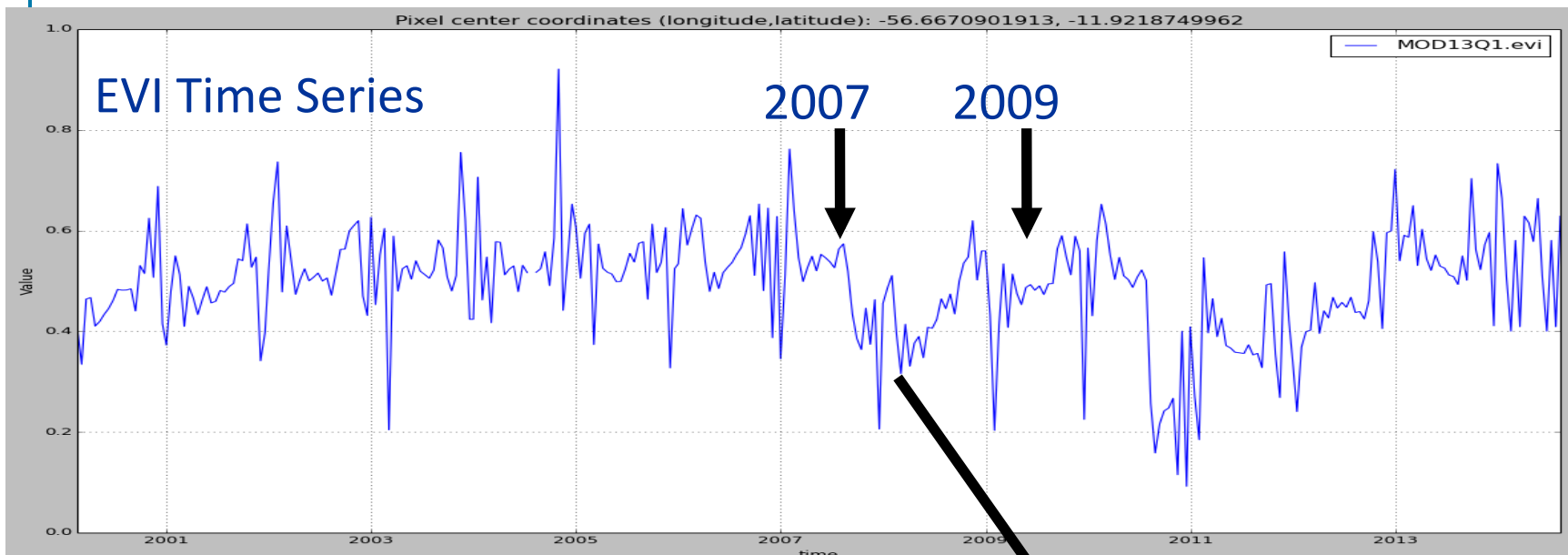
2007



2009

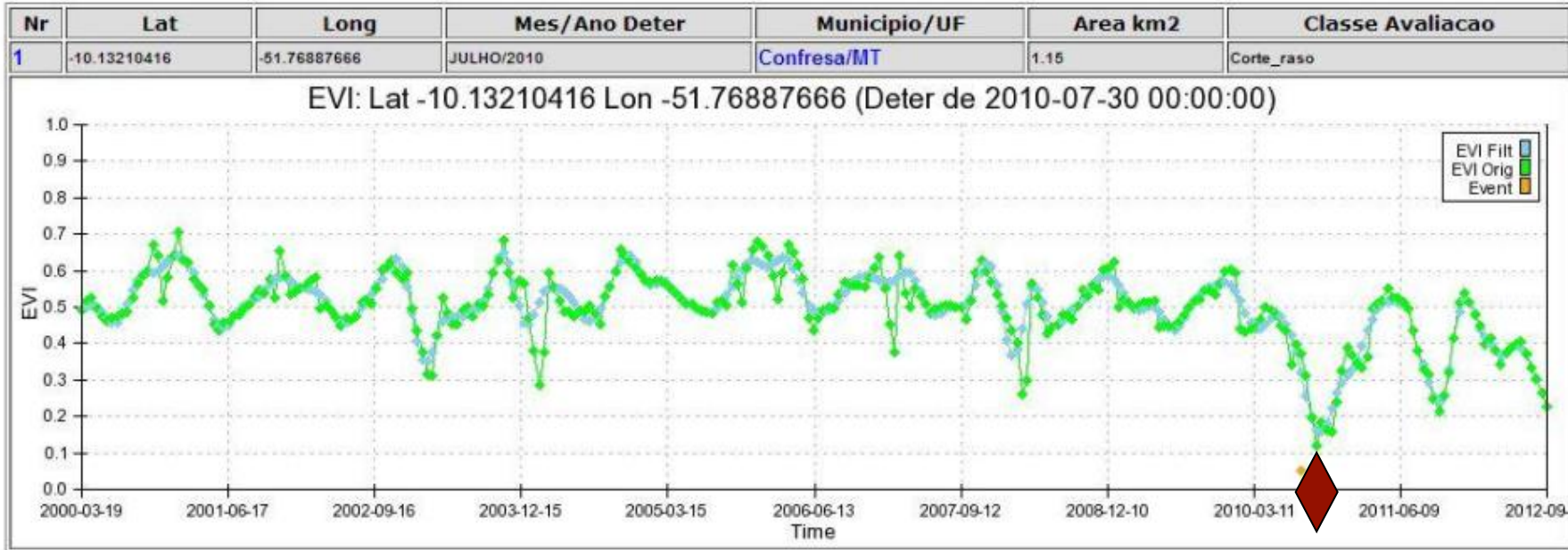


Land trajectories: forest degradation



Land trajectories: deforestation events

images: INPE



2010



2011

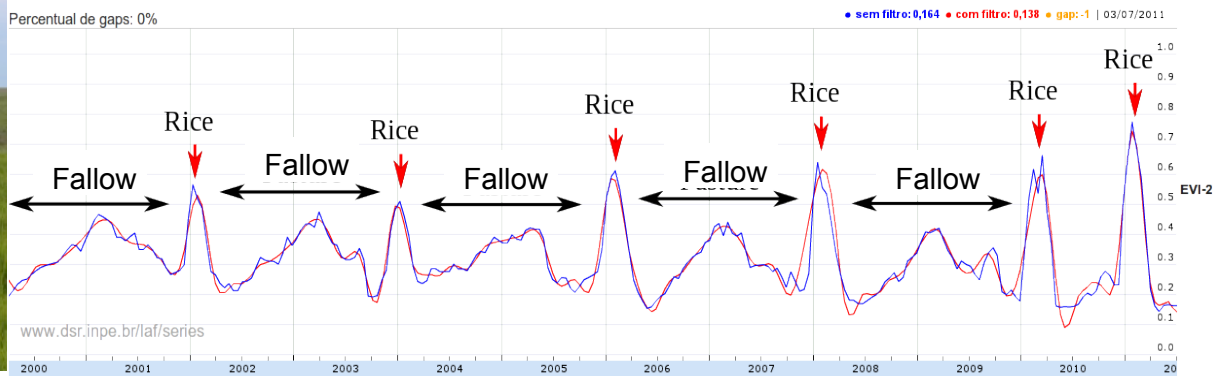


Land trajectories require adequate data



Coordenadas do ponto: (-29.915910, -53.465365)

Percentual de gaps: 0%

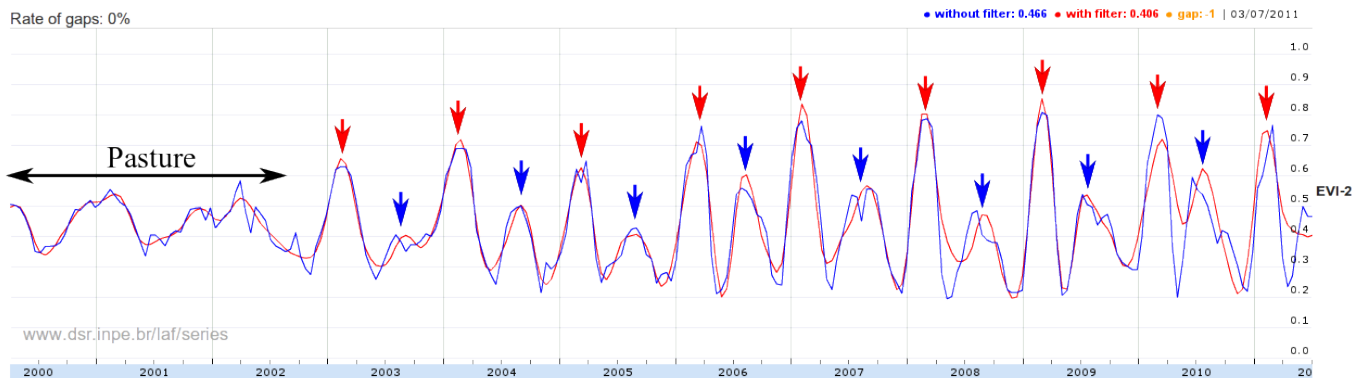


→ Soybean
→ Ryegrass



Point coordinates: (-29.668960, -54.008655) Municipality: Santa Maria - RS

Rate of gaps: 0%



Tropical forest: stable signal + low seasonal change



-17.8697, -45.3993
-17.8710, -45.3992

One sample per year (PRODES)

graphics: LAF/INPE





Double-cropping: soybeans + corn



-17.7948, -45.4173

± [icon] × -17.7946, -45.4351

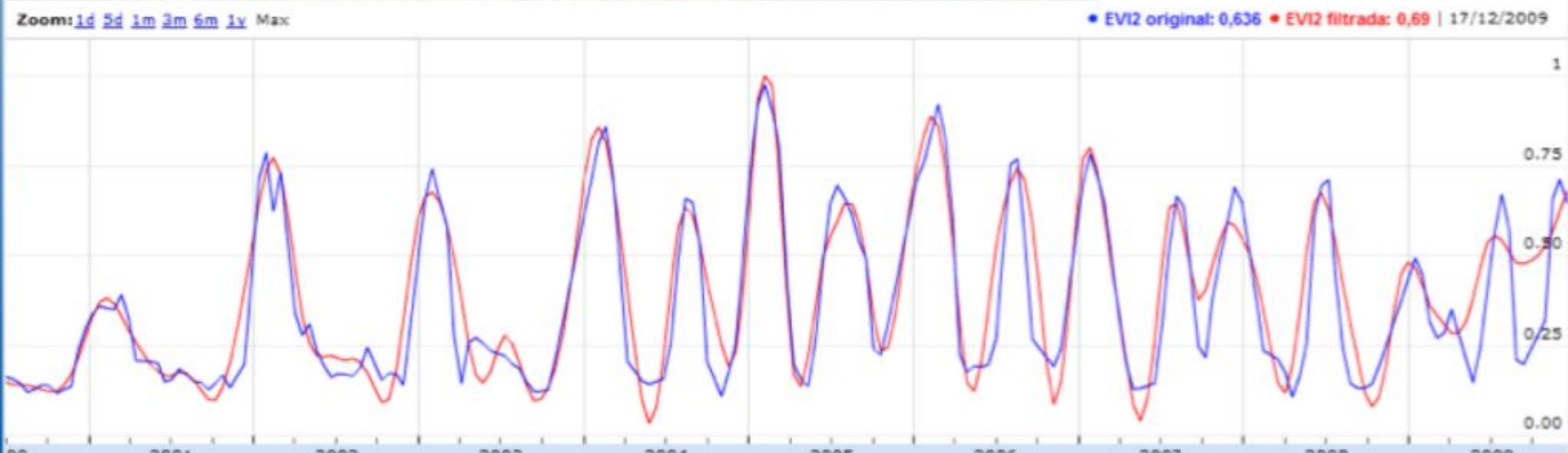
± [icon] × **-17.7969, -45.4171**

Two samples per month (?)

graphics: LAF/INPE

Elevação

• EVI2 original: 0,636 • EVI2 filtrada: 0,69 | 17/12/2009



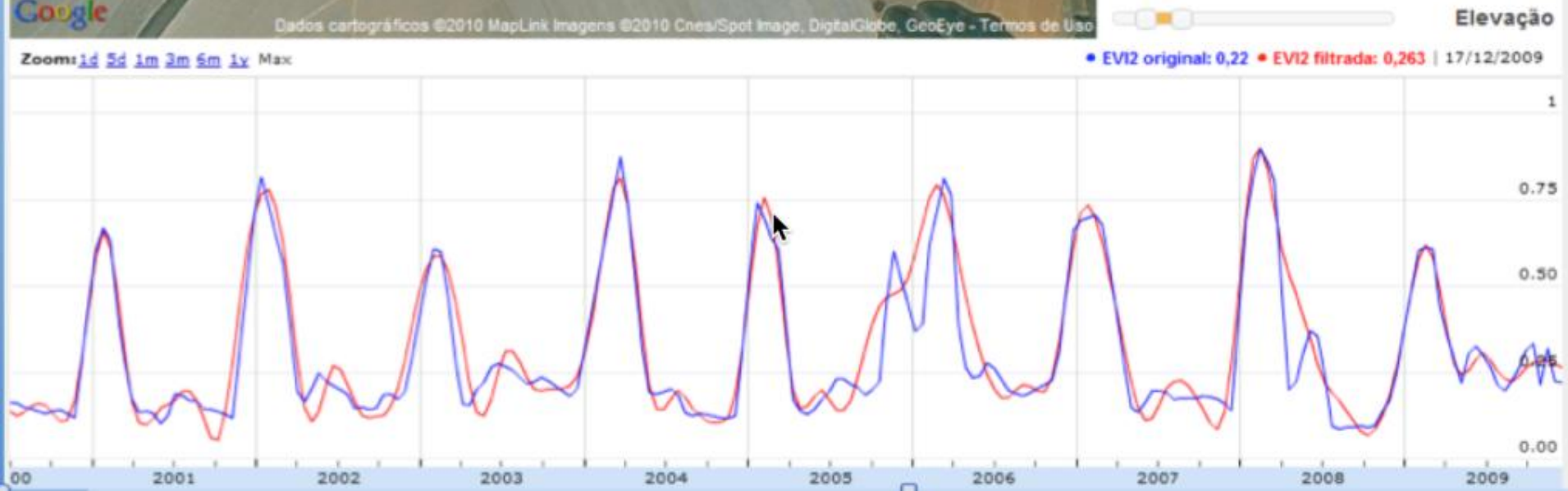
Single-crop grain production: soybeans



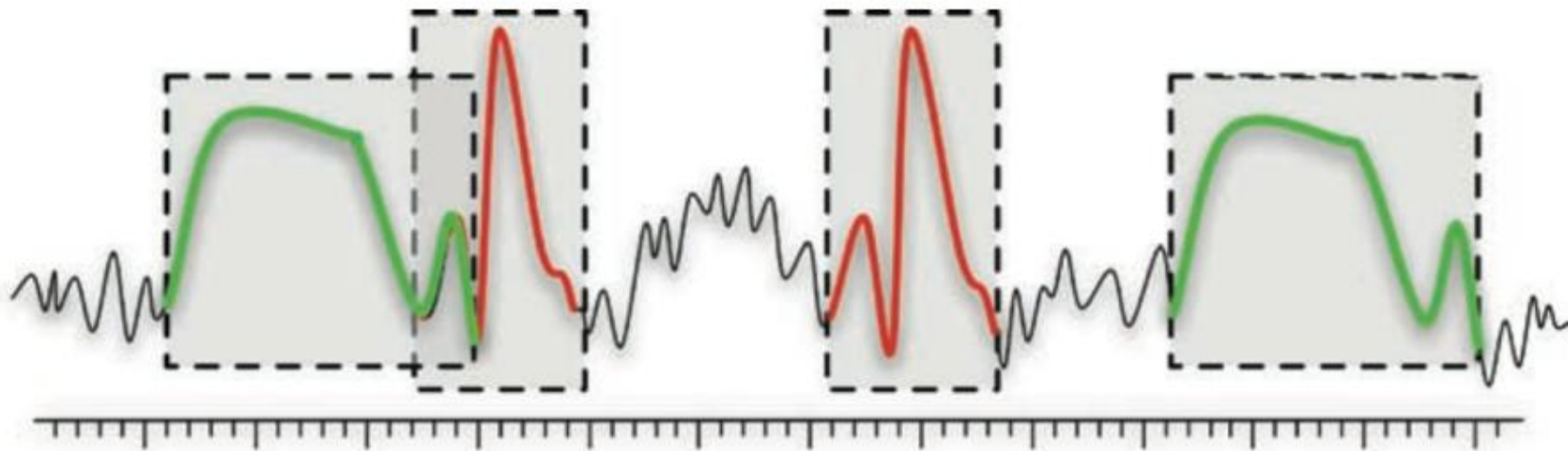
-17.8697, -45.4105
± × -17.8710, -45.3992
± × **-17.8710, -45.4104**

One sample per month (?)

graphics: LAF/INPE

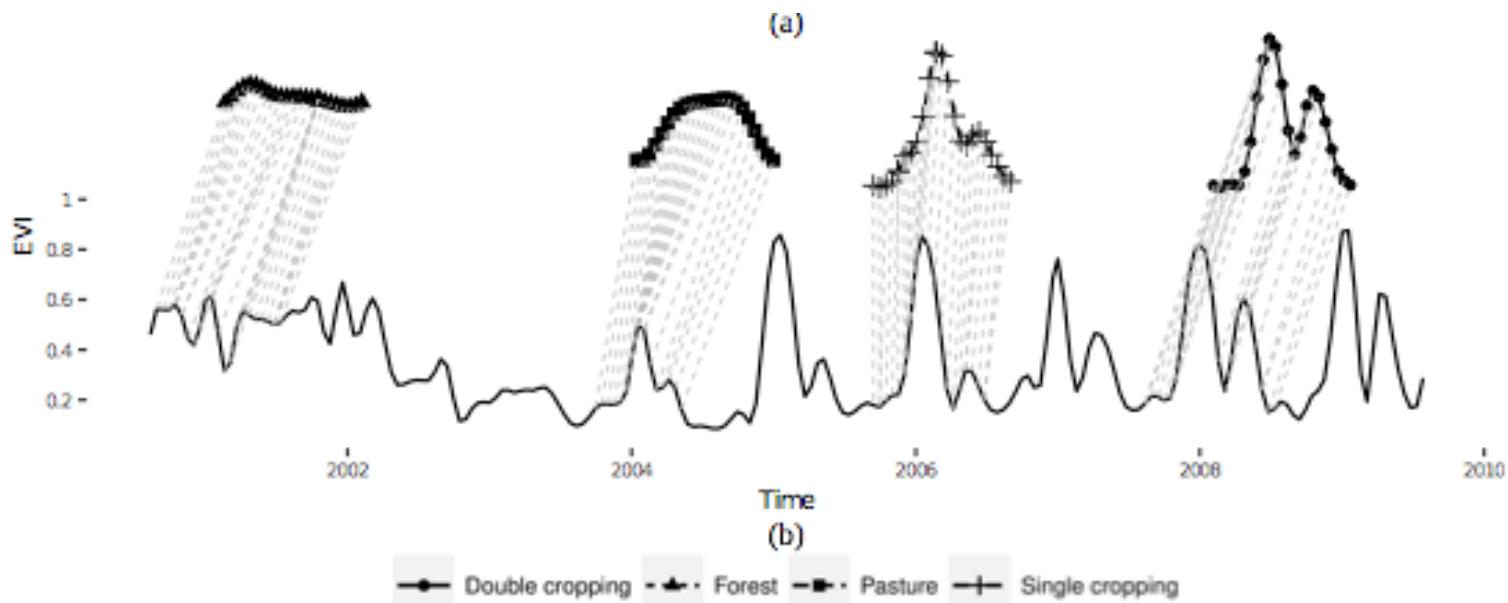


Time series mining: pattern matching



Finding subsequences in a time series
High computational complexity
Patterns are idealized, data is noisy

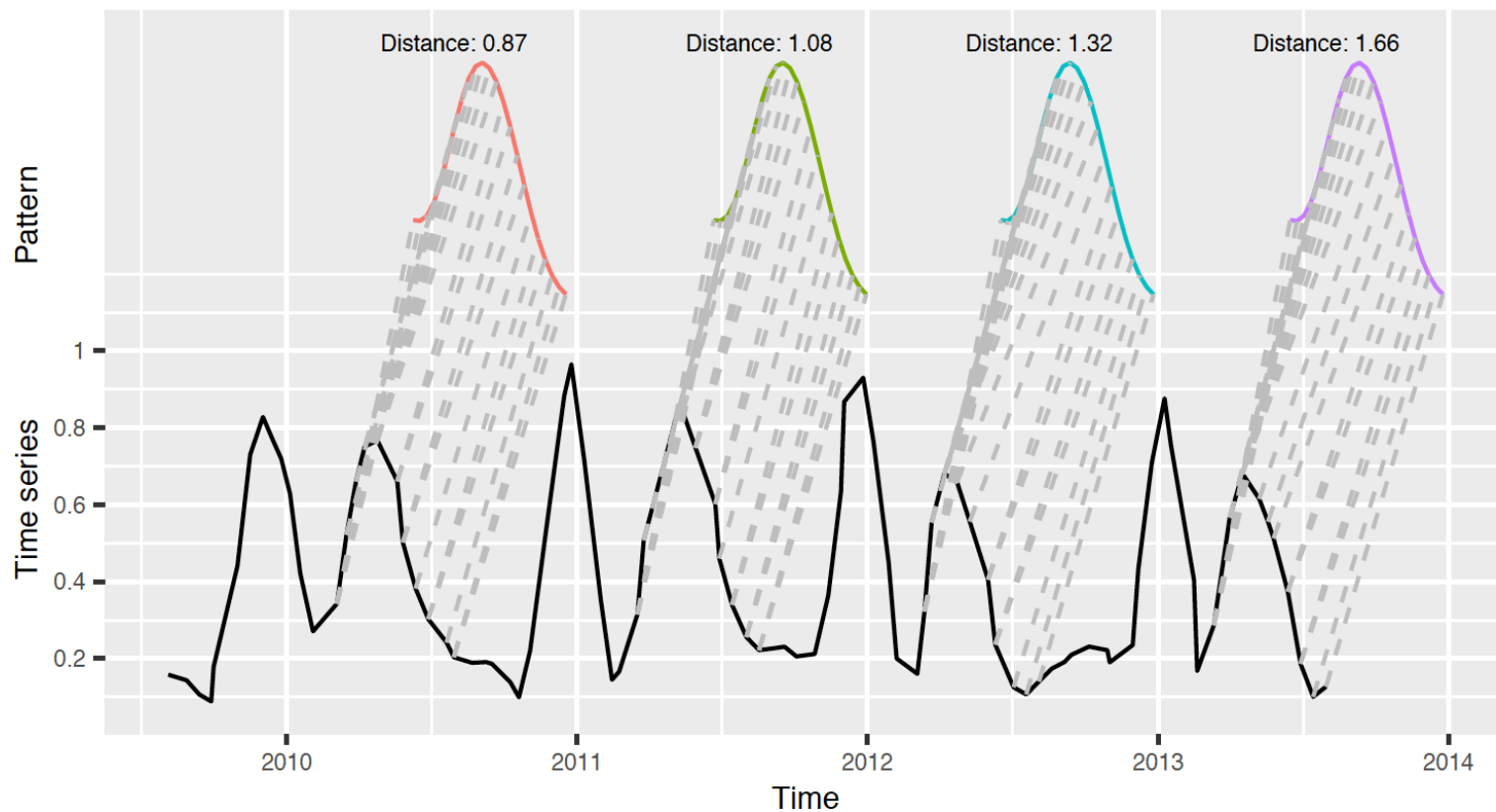
How to match land use patterns in a remote sensing time series?



A good match needs shape similarity and temporal coherence



Data mining for remote sensing time series



Finding alignments of short templates in a long time series considering the agricultural calendar



MODIS x Time-weighted DTW

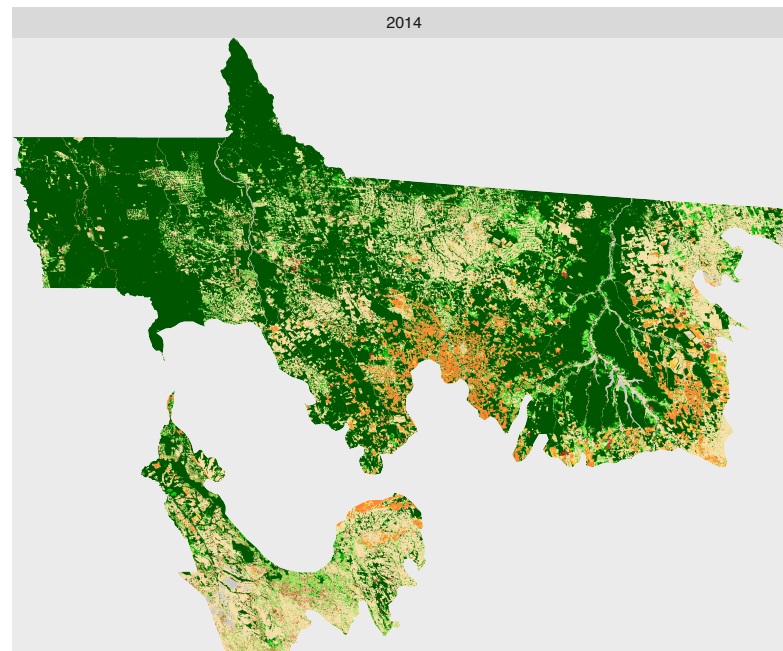
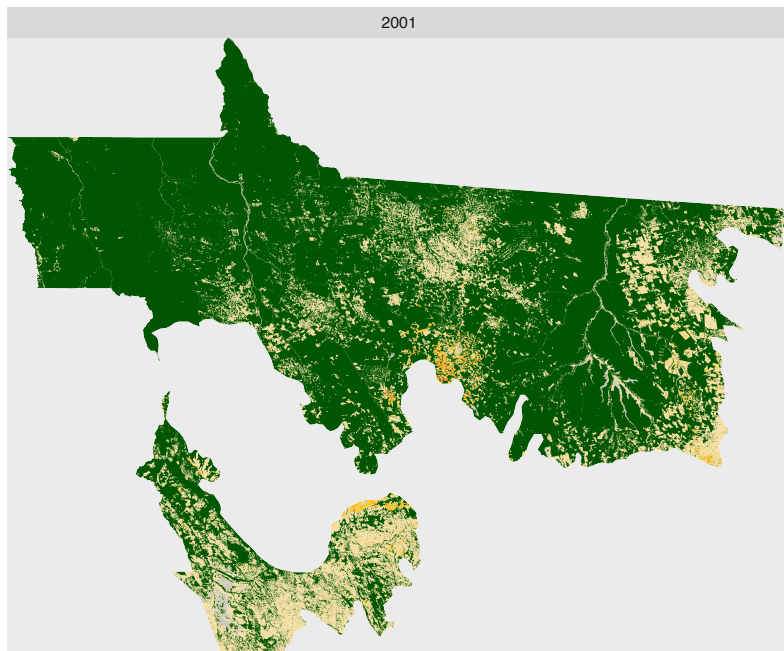
Class	User (%)		Producer (%)	
	MODIS	TWDTW	MODIS	TWDTW
Forest	87.23	94.00	77.36	88.68
Pastureland	67.71	88.41	85.53	85.80
Cropland	89.33	92.00	75.28	96.73

Producer's accuracy: fraction of correctly classified pixels compared to all pixels of that ground truth class

User's accuracy (reliability): fraction of correctly classified pixels of a class compared to all pixels classified as being that class



Land use change trajectories in the Amazonian biome of Mato Grosso state (2001-2014)

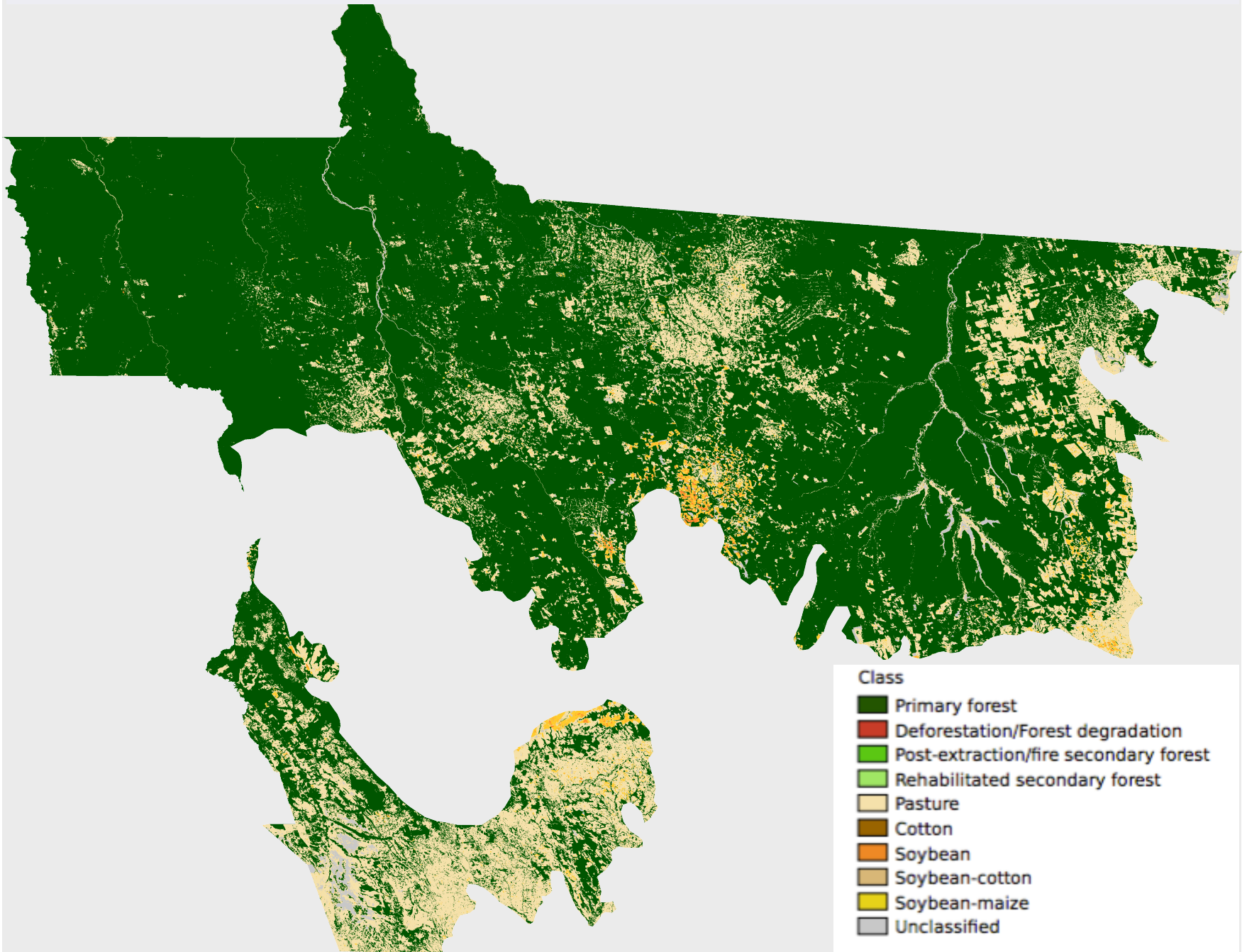


Class

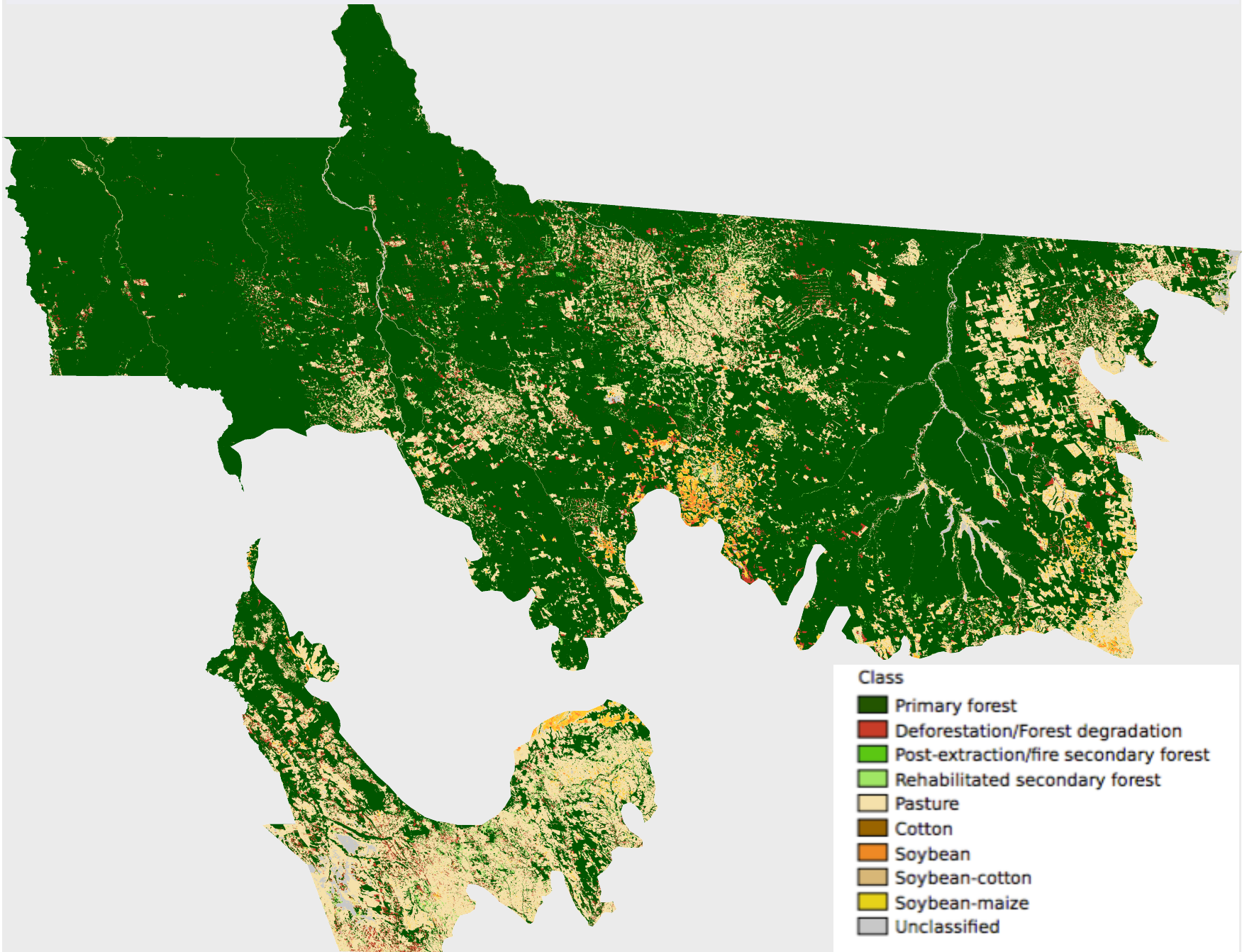
- Primary forest
- Deforestation/Forest degradation
- Post-extraction/fire secondary forest
- Rehabilitated secondary forest
- Pasture
- Cotton
- Soybean
- Soybean-cotton
- Soybean-maize
- Unclassified

33 million time series

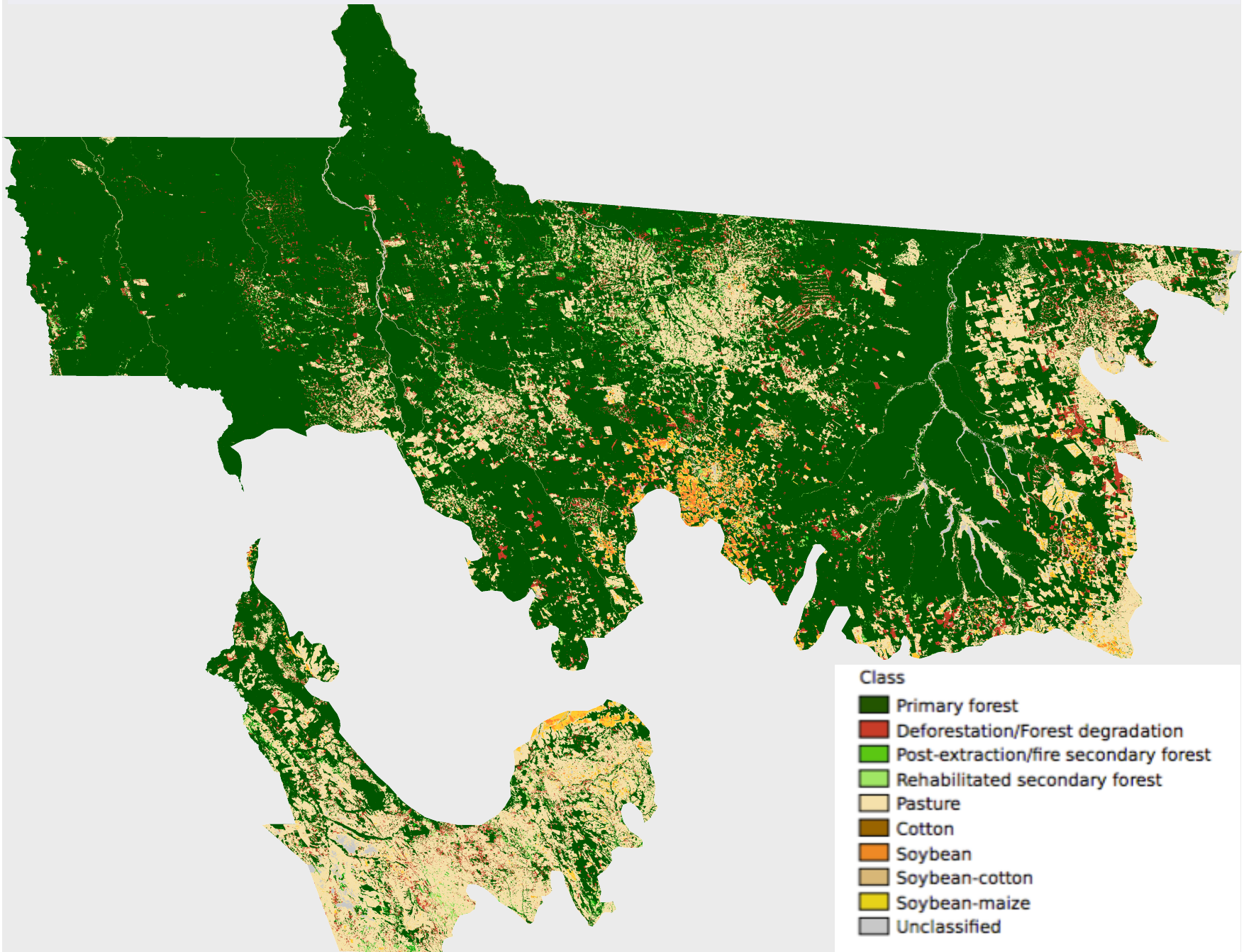
Mato Grosso – Amazonia biome (2001)



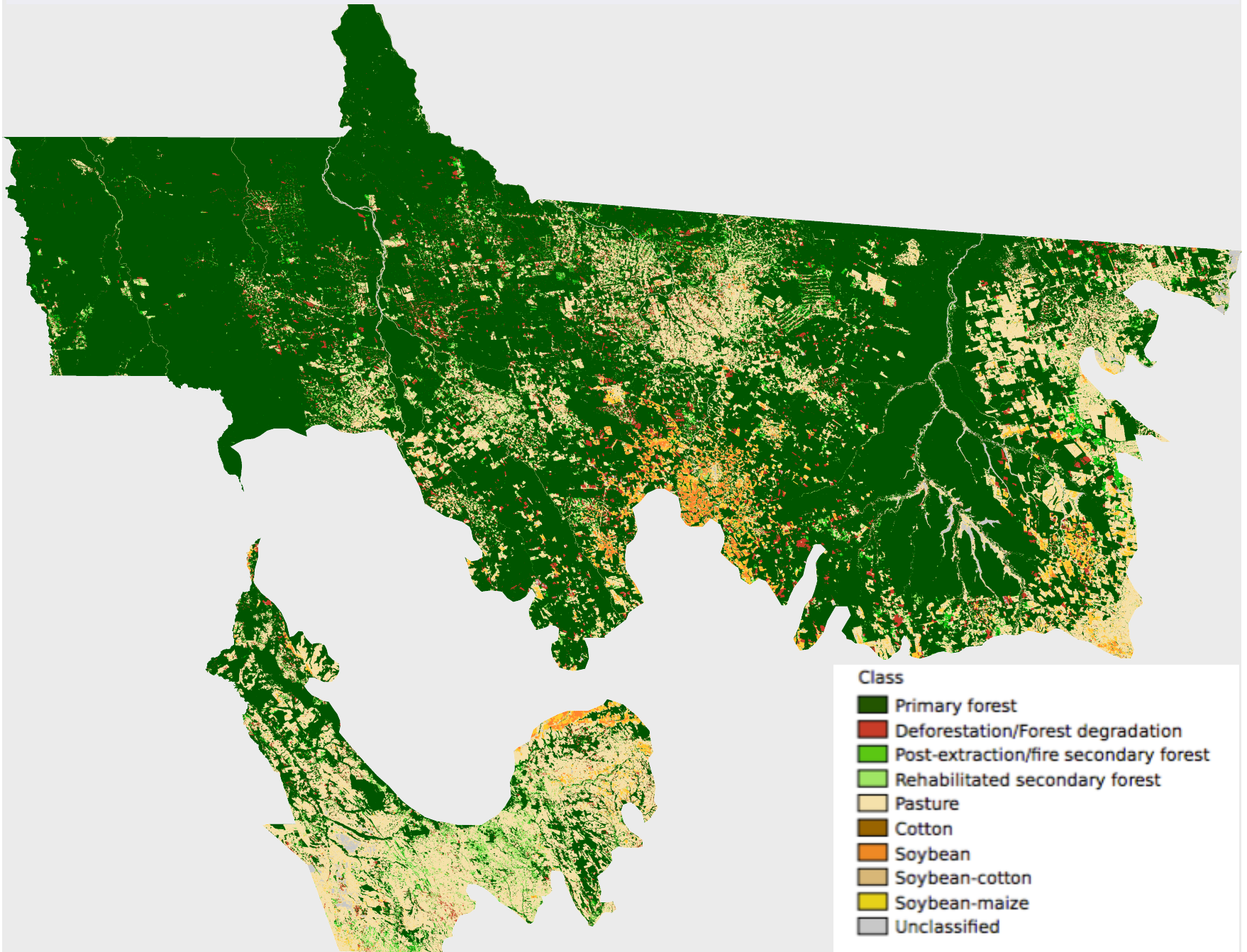
Mato Grosso – Amazonia biome (2002)



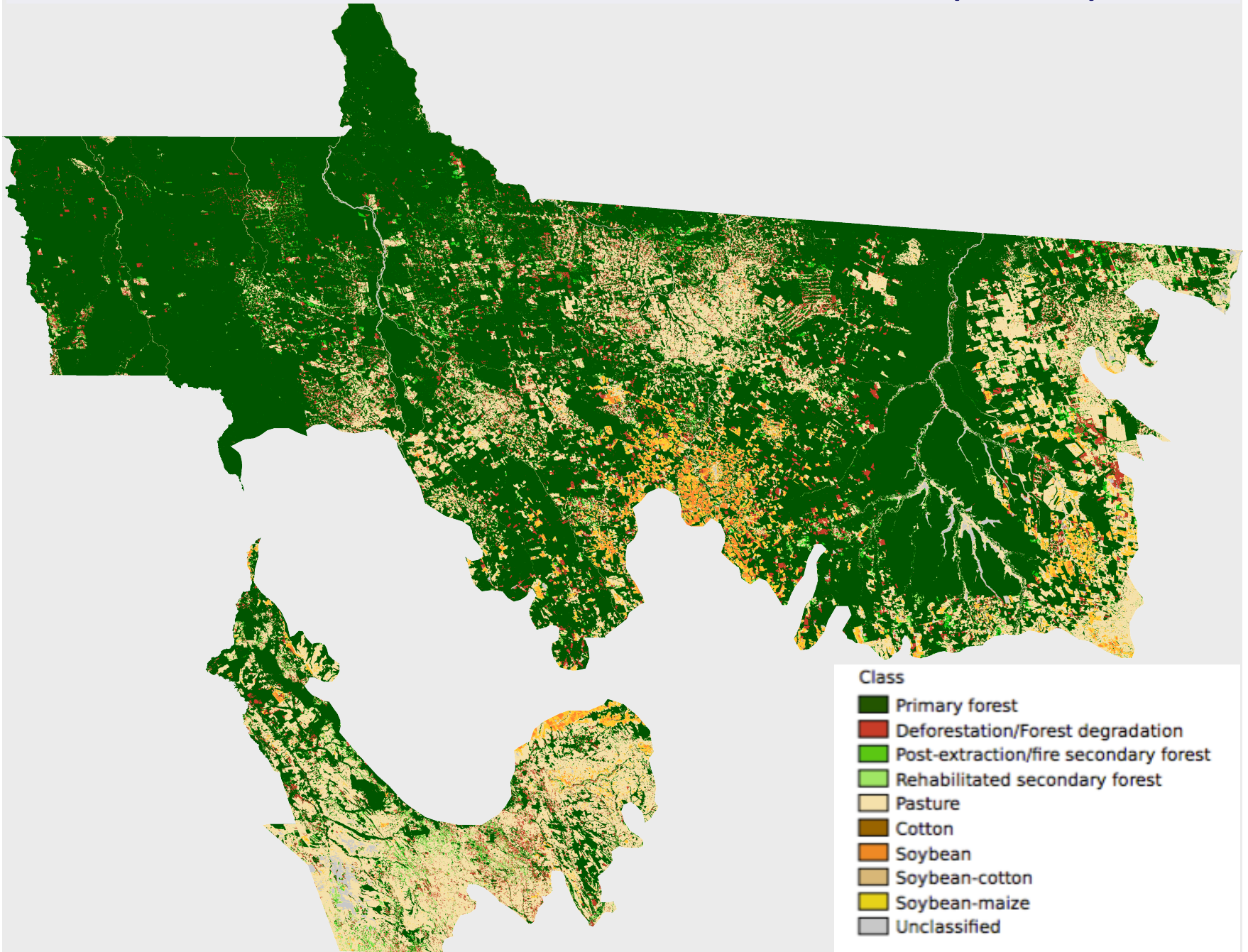
Mato Grosso – Amazonia biome (2003)



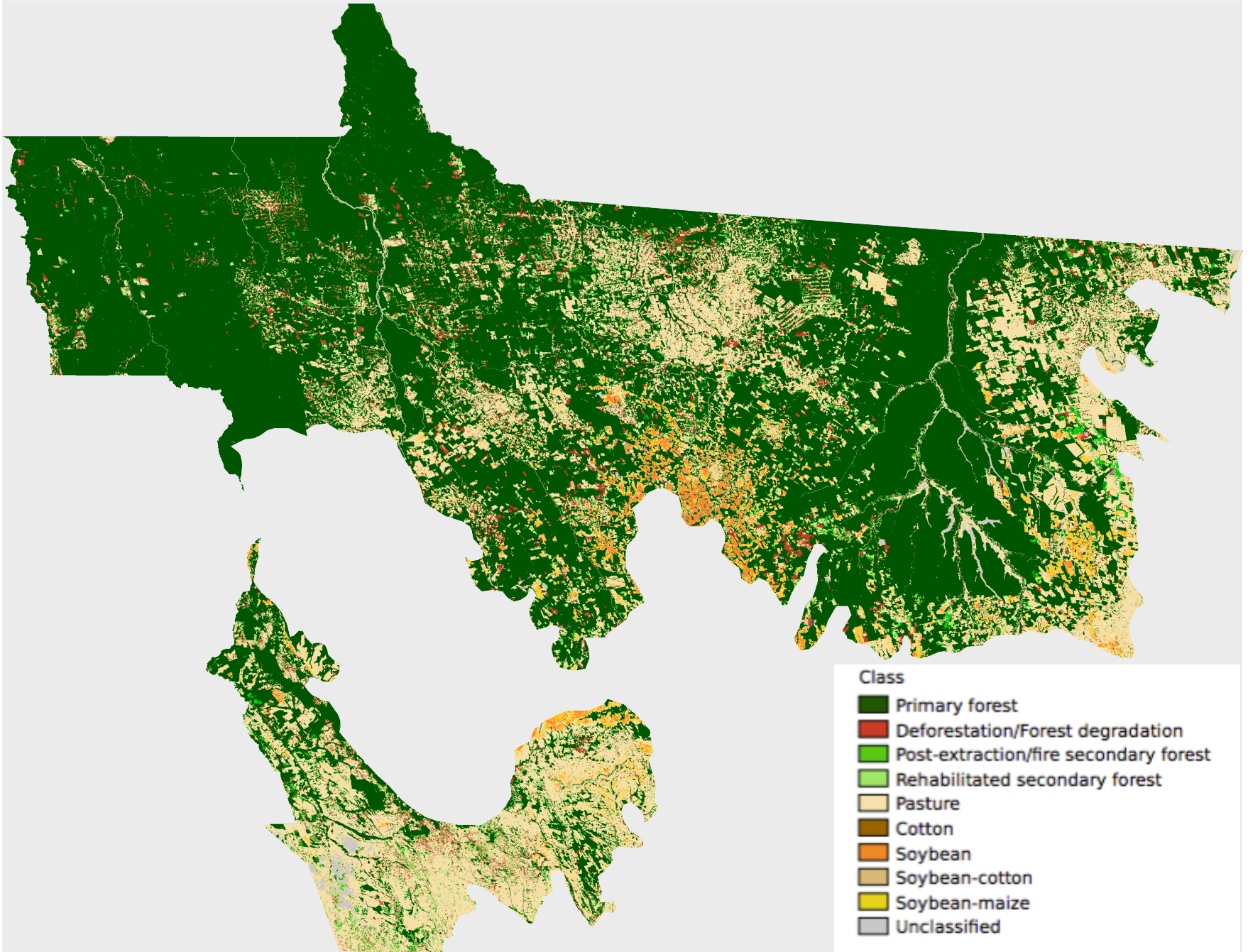
Mato Grosso – Amazonia biome (2004)



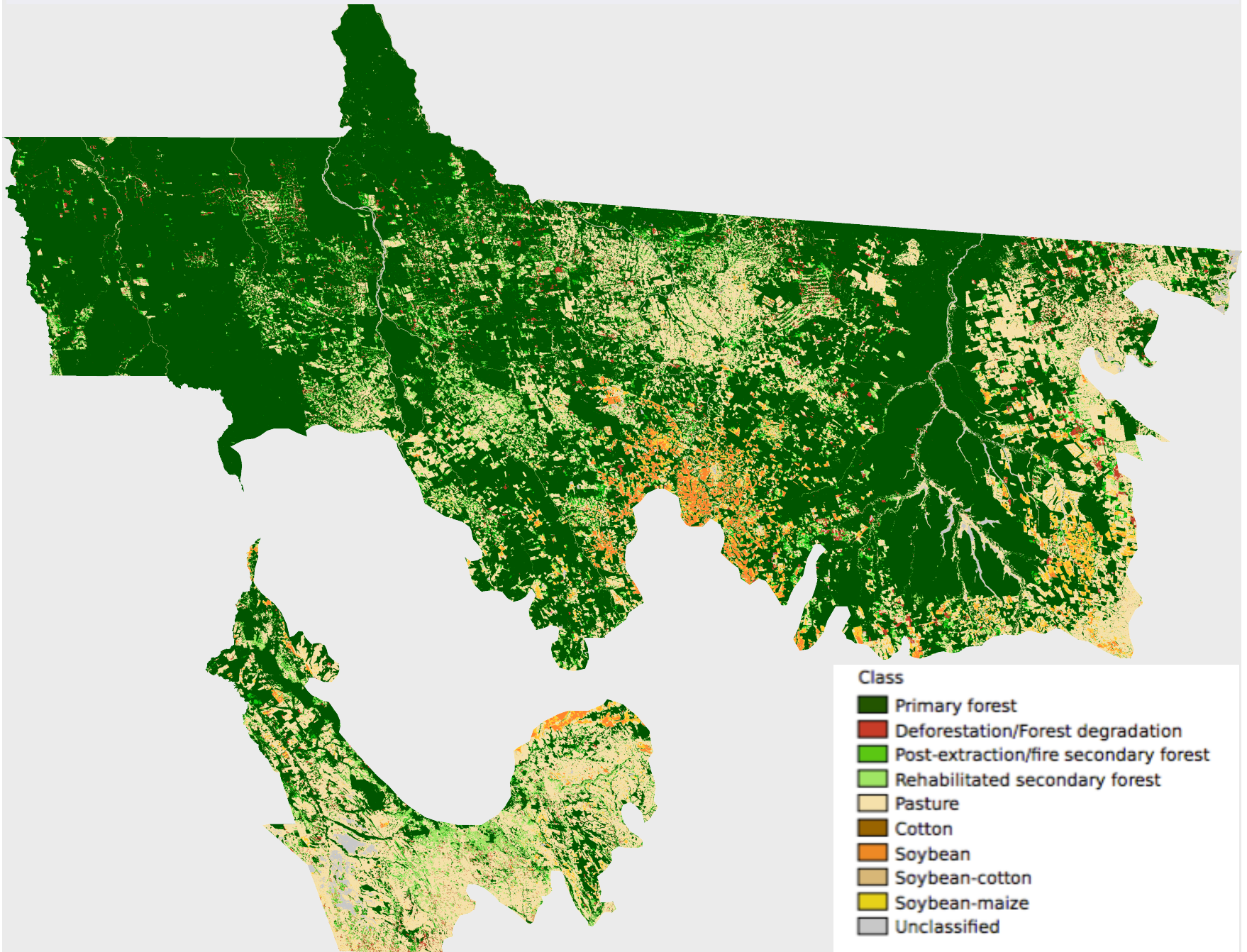
Mato Grosso – Amazonia biome (2005)



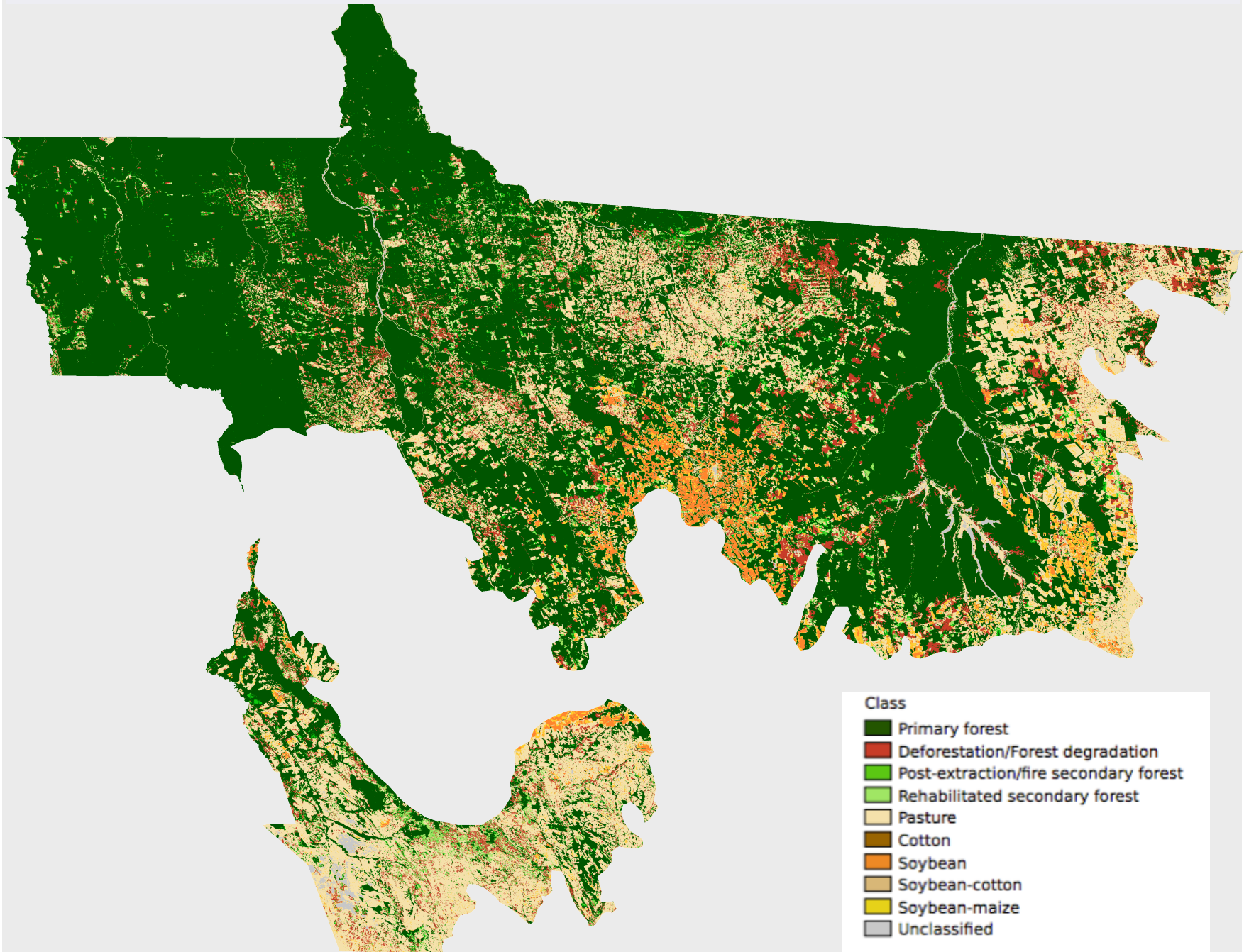
Mato Grosso – Amazonia biome (2006)



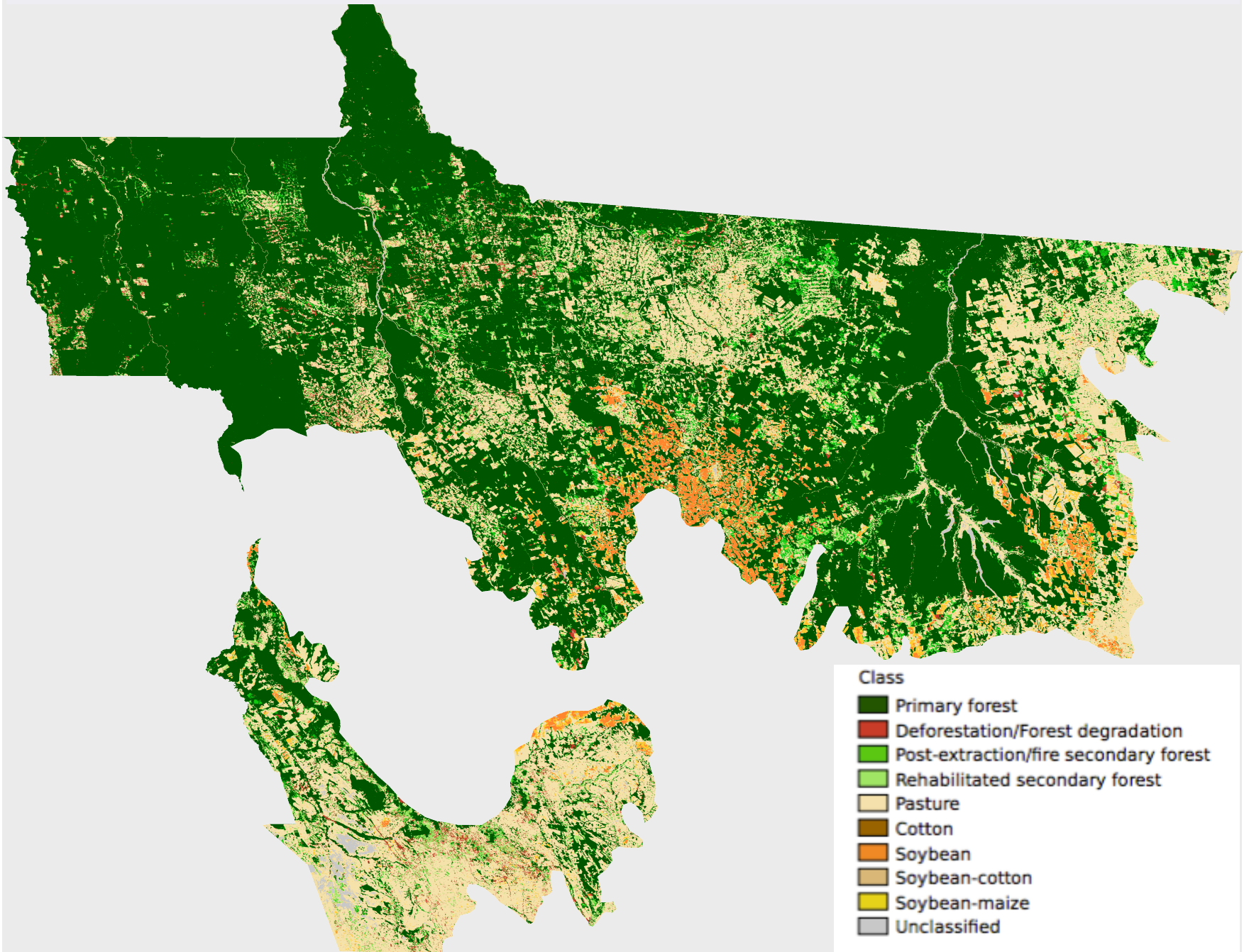
Mato Grosso – Amazonia biome (2007)



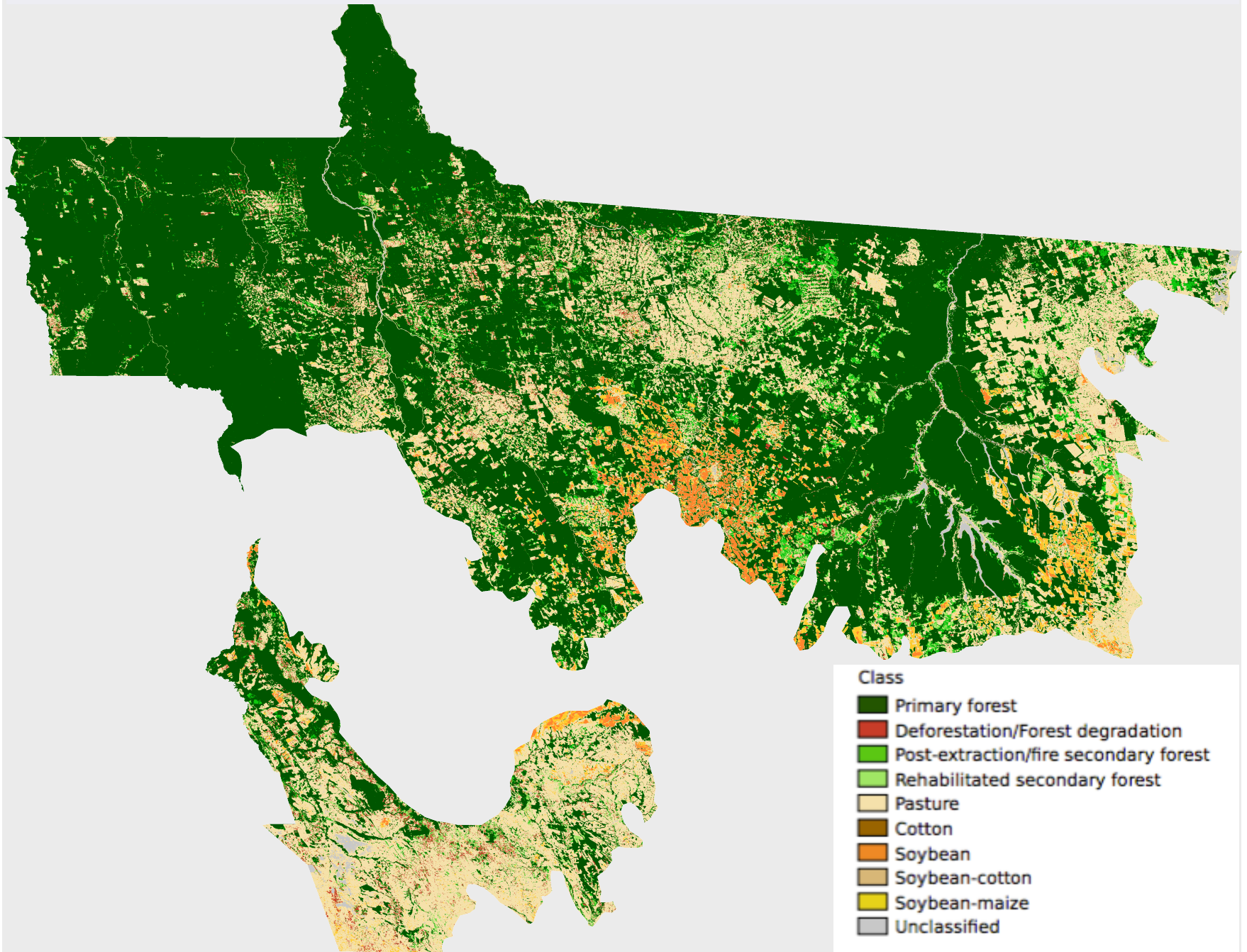
Mato Grosso – Amazonia biome (2008)



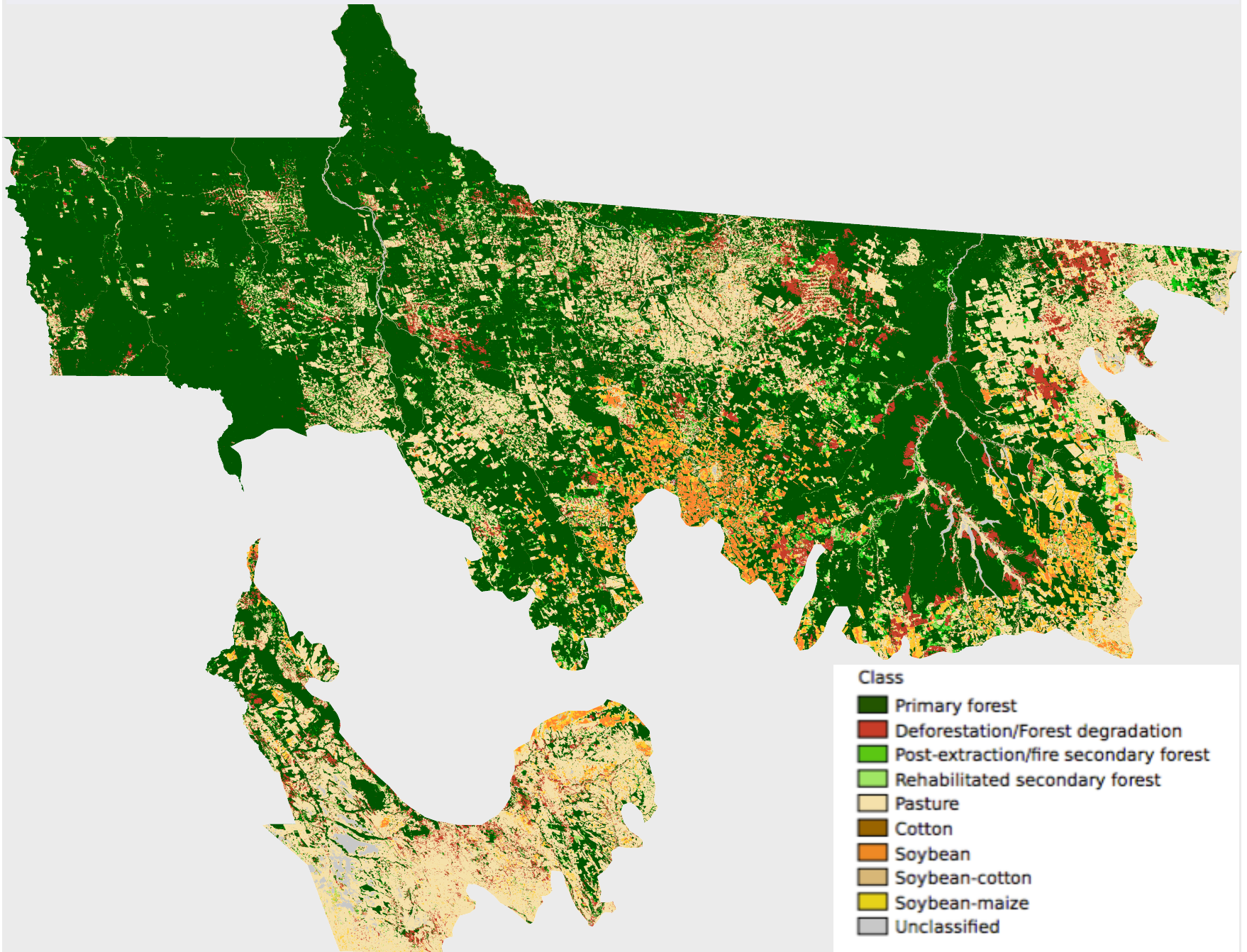
Mato Grosso – Amazonia biome (2009)



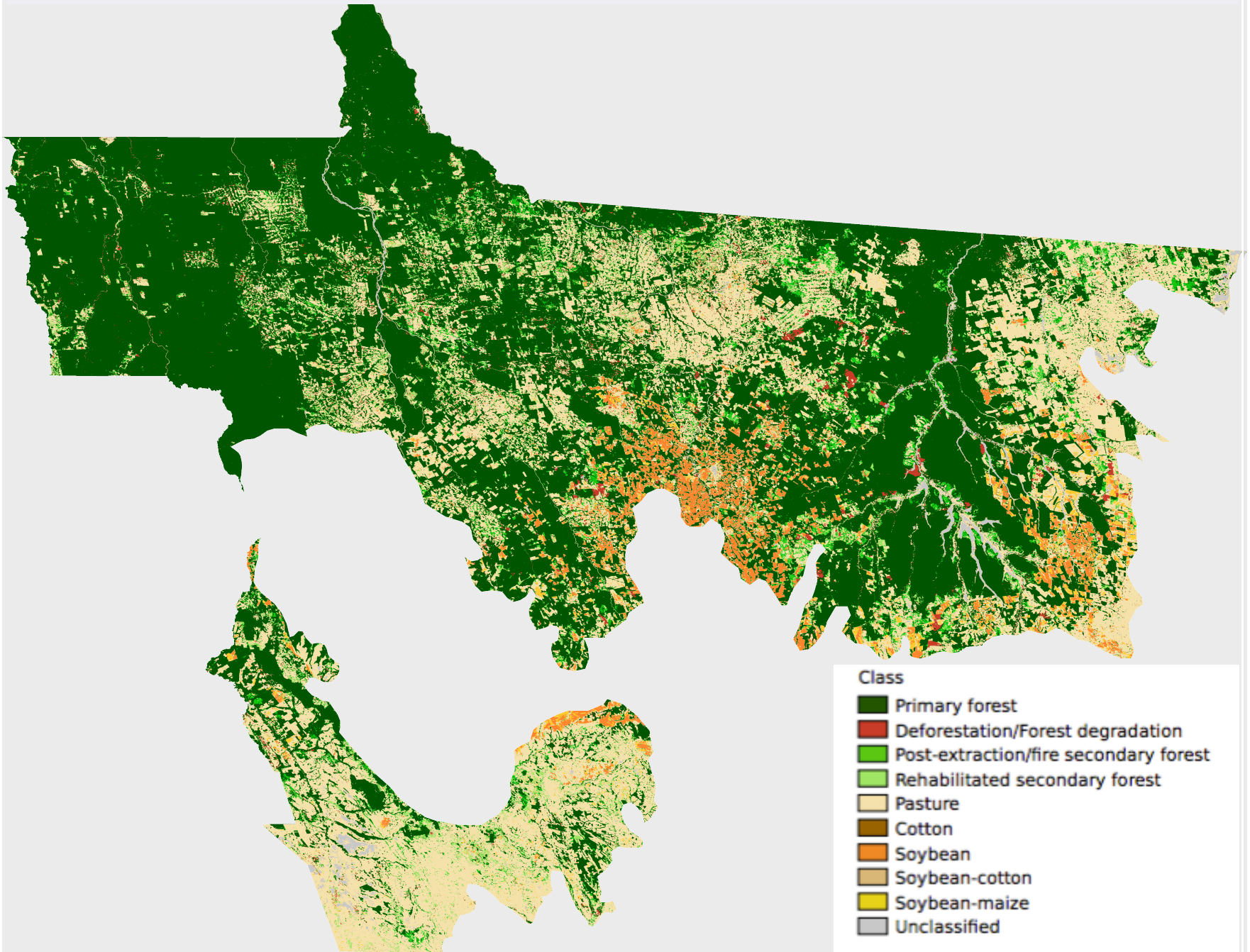
Mato Grosso – Amazonia biome (2010)



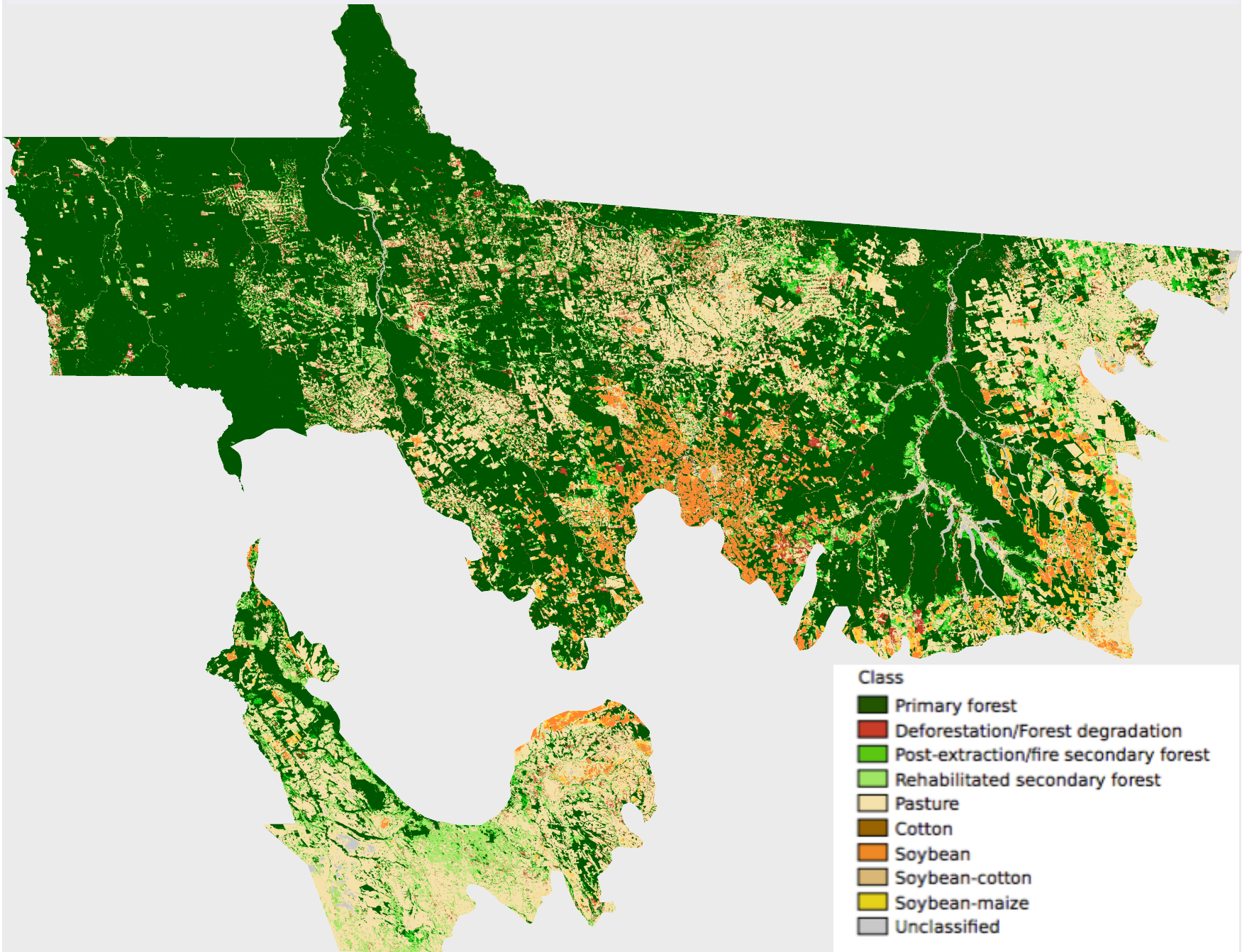
Mato Grosso – Amazonia biome (2011)



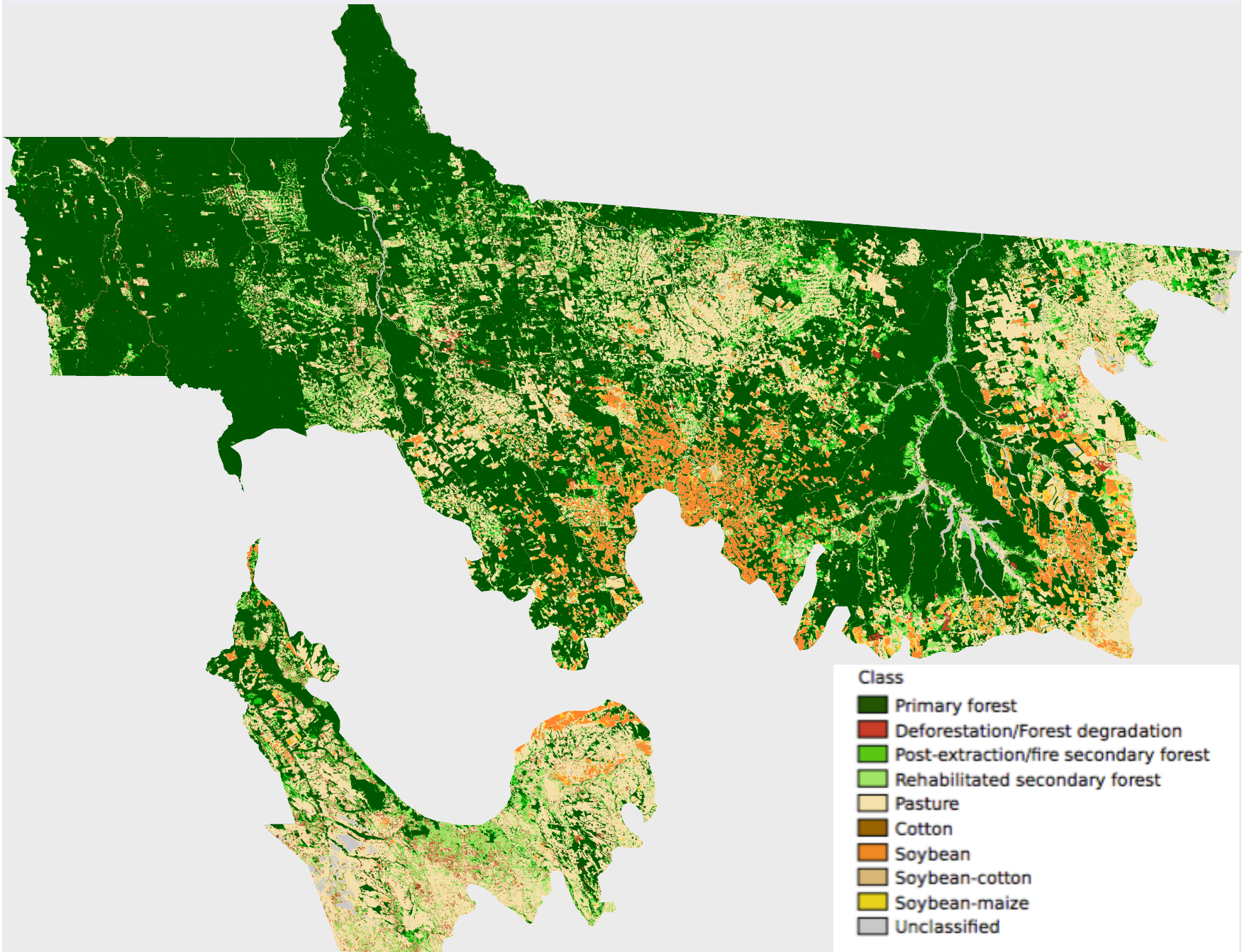
Mato Grosso – Amazonia biome (2012)



Mato Grosso – Amazonia biome (2013)

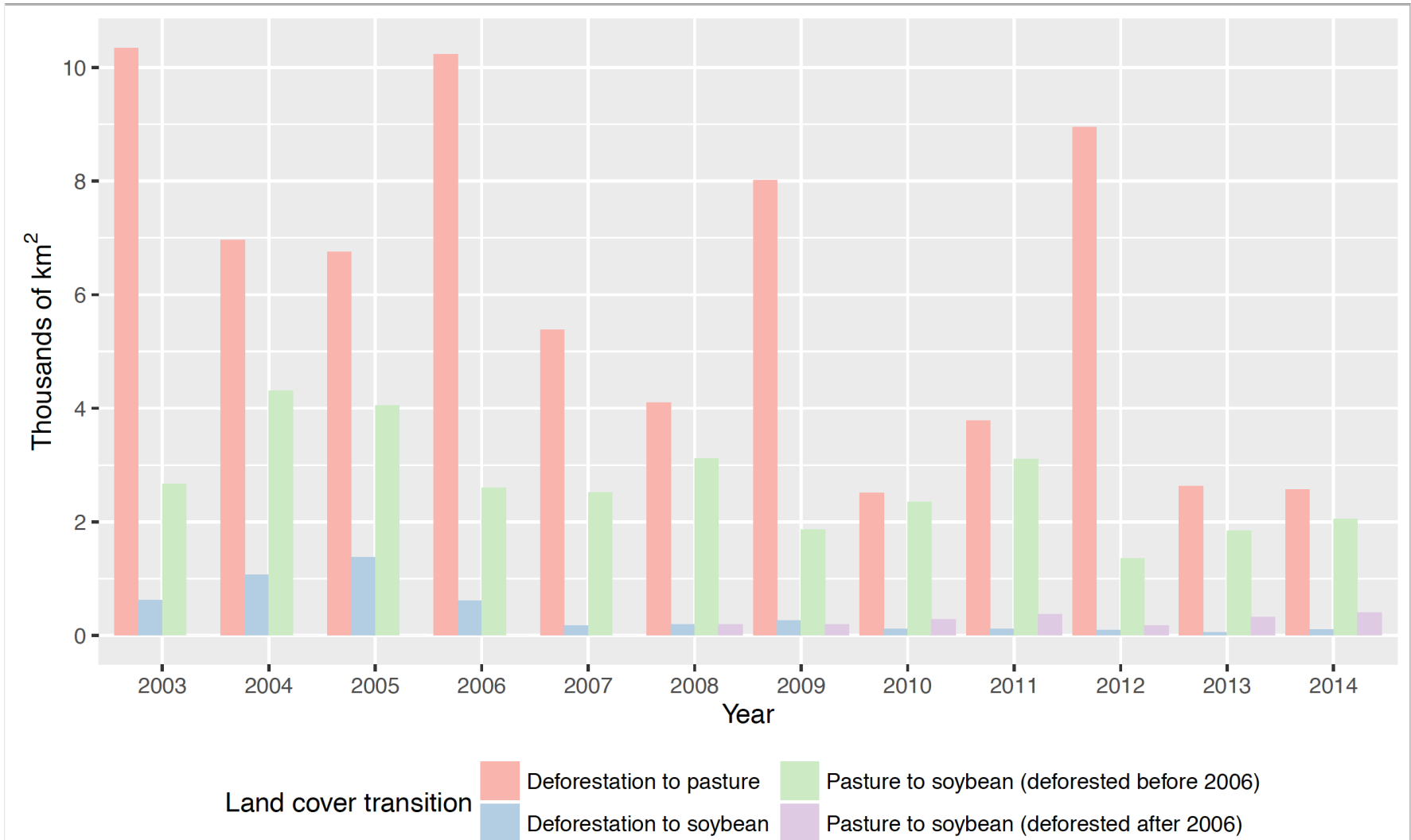


Mato Grosso – Amazonia biome (2014)





Using events to understand land transitions





Interval temporal logic (Allen)

Thirteen basic relations

Allen's thirteen basic relations are illustrated in Table 1. This table shows all the possible relations that two definite intervals can have. Each one is defined graphically by a diagram relating two definite intervals *a* and *b*, with time running \rightarrow from left to right. For example, the first diagram shows that "*a* precedes *b*" means that *a* ends before *b* begins, with a gap separating them; the second shows that "*a* meets *b*" means that *b* ends when *a* begins.

precedes	meets	overlaps	finished by	contains	starts	equals	started by	during	finishes	overlap- ped by	met by	preceded by
p	m	o	F	D	s	e	S	d	f	O	M	P

Table 1. Allen's thirteen basic relations

$$\text{holds}(p, t) \equiv \forall t' (\text{in}(t', t) \Rightarrow \text{holds}(p, t'))$$

$$(\text{occur}(e, t) \wedge \text{in}(t', t)) \Rightarrow \neg \text{occur}(e, t')$$



Rules of interval temporal logic

Which forest areas have been replaced by soybeans?

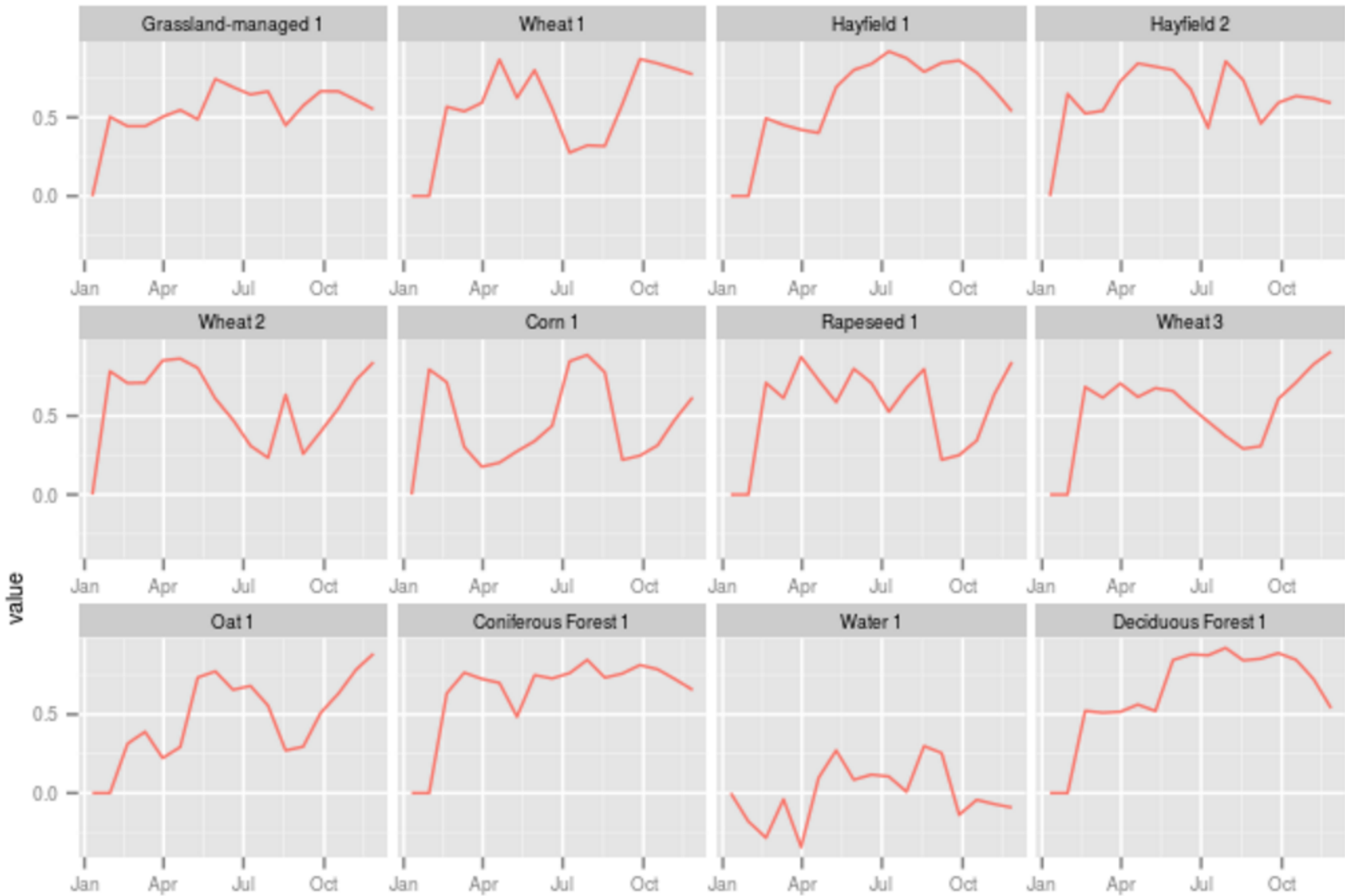
$$\forall s \in S, \text{occur}(s, \text{"defor"}, t \downarrow 1) \cap (\text{meets}(t \downarrow 1, t \downarrow 2)) \cap \text{occur}(s, \text{"soy"}, t \downarrow 2)$$

Which forest areas have been replaced by pasture and then turned into soybeans?

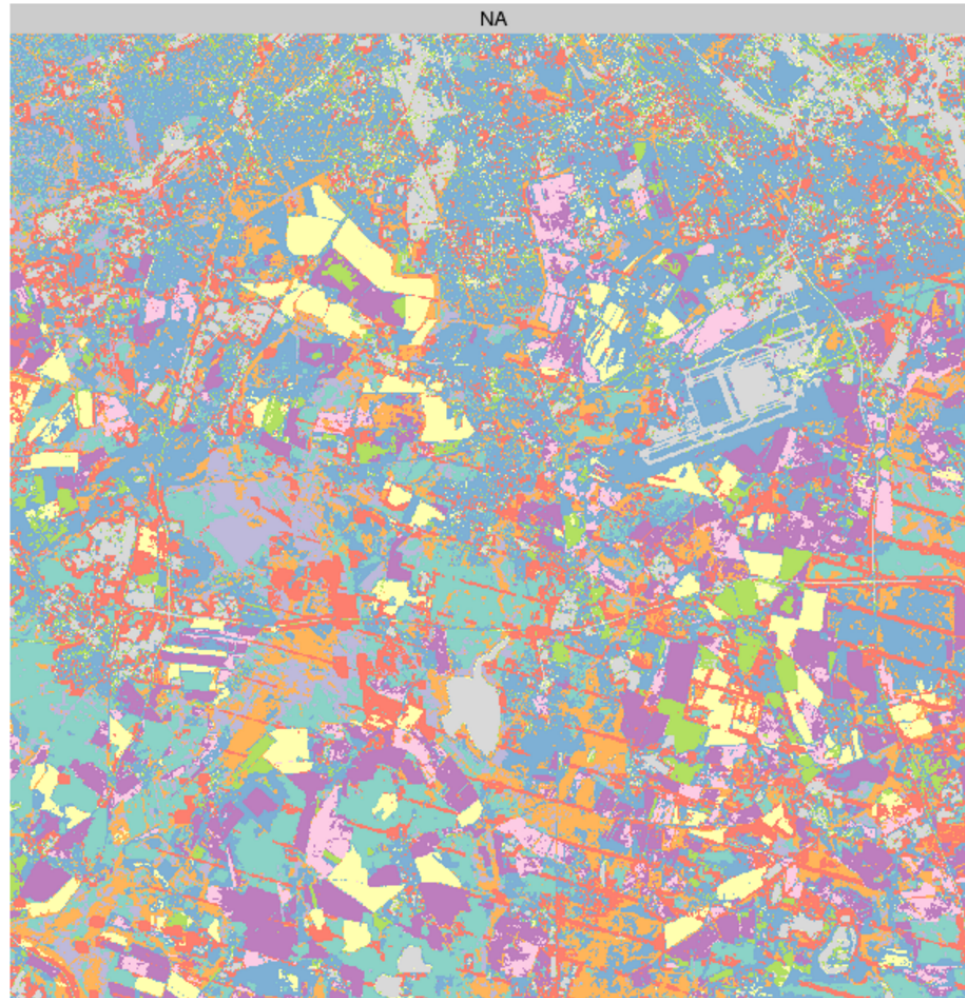
$$\forall s \in S, \text{occur}(s, \text{"defor"}, t \downarrow 1) \cap (\text{meets}(t \downarrow 1, t \downarrow 2)) \cap \text{occur}(s, \text{"pasture"}, t \downarrow 2) \cap (\text{precedes}(t \downarrow 1, t \downarrow 3)) \cap \text{occur}(s, \text{"soy"}, t \downarrow 3)$$



Middle-resolution time series (LANDSAT-8 + Sentinel-2A)



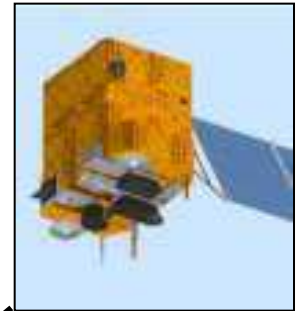
Classificação resultante (mid-resolution)



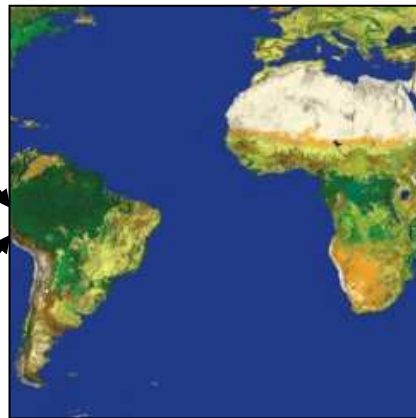
ous Forest Corn Deciduous Forest Grassland Grassland-managed Hayfield Oat Rapeseed



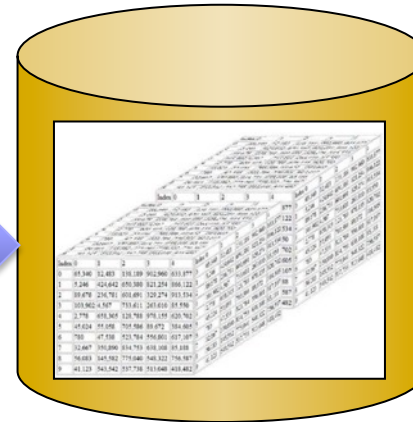
Open source and open data = knowledge sharing



New insights into land use change



R: New data analysis methods



SciDB: array database for big scientific data

Free satellite imagery

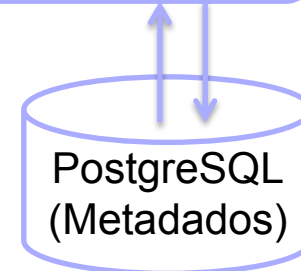
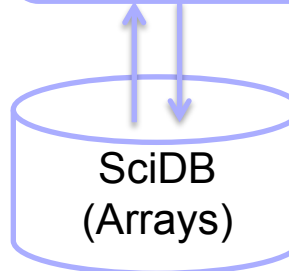
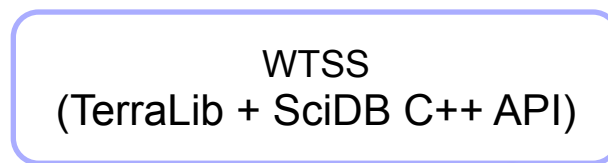
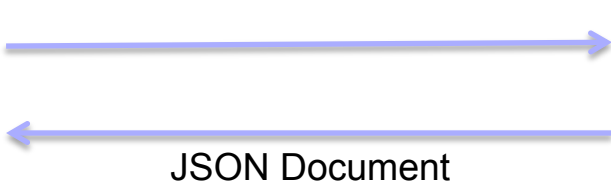


Big EO data analytics: the new frontier on Earth observation



WTSS Client

http://www.dpi.inpe.br/wtss/time_series?
coverage=MOD09Q1,attributes=red,nir&
longitude=-54,latitude=-12&start=2000-02-18&end=2000-03-05



```
{ "result": {
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                   "values": [ 1004, 1160, 241 ]
                 },
                 { "name": "quality",
                   "values": [ 4842, 3102, 2116 ]
                 }
            ],
  "timeline": [ "2000-02-18", "2000-02-26", "2000-03-05" ],
  "center_coordinates": { "latitude": -11.99, "longitude": -53.99
  }
},
"query": {
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  "attributes": [ "red", "quality" ],
  "latitude": -12,
  "longitude": -54,
  "start": "2000-02-18",
  "end": "2000-03-05"
}
}
```

WTSS – Web Time Series Service: a lightweight service for handling remote sensing imagery as time series



Thesis

- Victor Maus: Land Use / Land Cover change monitoring using remote sensing imagery time series – dtwSat
- Adeline Maciel: Spatiotemporal interval logic for reasoning about land use change using big Earth observation data sets (Março 2017)
- Alber Sanchez: Algorithms for real-time monitoring of deforestation events in big Earth Observation data (March 2018)
- Luiz Fernando Assis: Extraction and analysis of land cover samples for classification of big Earth Observation data (Março 2019)
- Rolf Simões: Land use classification of largescale LANDSAT time series (March 2020)



Articles in Journals

- A Time-Weighted Dynamic Time Warping Method for Land-Use and Land-Cover Mapping, IEEE JSTARS
- dtwSat: Time-Weighted Dynamic Time Warping for remote sensing time series analysis in R, Journal Statistical Software (submitted)
- Long-term land use and land cover change in Brazilian Amazonia using satellite image time series, Remote Sensing (in preparation)
- Spatiotemporal interval logic for reasoning about land use change using big Earth observation data sets, IJGIS (in preparation)



Produção acadêmica: conferencias

- Using dynamic geospatial ontologies to support information extraction from big Earth observation data sets, GIScience 2016 (accepted)
- Big Earth Observation Data Analytics: Matching Requirements to System Architectures, ACM GIS 2016 (submitted)
- Web Services for Big Earth Observation Data, GeoInfo 2016 (submitted)



e-Sensing: project portal

www.esensing.org Pesquisar

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e-sensing: big Earth observation data analytics for LUCC

E-SENSING

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- :: Journal Papers
- :: Presentations
- :: People
- :: Reports
- :: Software
- :: Thesis

E-SENSING: BIG EARTH OBSERVATION DATA ANALYTICS FOR LAND USE AND LAND COVER CHANGE INFORMATION

The **e-sensing** project develops new ways to extract information on land use and land cover change from big Earth Observation data sets, using open Science. Our project is building *a new generation of knowledge platforms for handling big geospatial data*.

The "e-sensing" project is supported by FAPESP (grant 2014/08398-6), under the "e-science" program.

For more information, please see the [project overview](#), the [project proposal](#), or the [project presentation](#).



e-sensing project selects post-doc in geospatial web services

September 2016

PROJECT DEVELOPMENT



Image Processing Division

INSTITUTIONAL SUPPORT



National Institute for Space Research - Brazil

FUNDING ORGANIZATION



São Paulo Research Foundation



e-Sensing - platform portal (prototype)

terra-brasilis.info/test/composer/E-SENSING

Pesquisar

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Procurar por endereço

Camadas Shiny panel

Projeto: E-SENSING Login Sobre

Camadas

Camadas Legenda

- Camadas
 - modisSouthAmerica
 - modisSouthAmerica
 - pontos_interesse
 - pontos_interesse
- Camadas de base
 - Google Satellite
 - Google Hybrid
 - Google Terrain
 - Google Roadmap
 - OpenStreetMap
 - Blank

Camada selecionada: Sem seleção

Shiny panel

Time-Weighted Dynamic Time Warping

Time series

TWDTW dissimilarity measure

Pattern

- Soybean
- Cotton
- Maize

Variable

- ndvi

Close



e-Sensing: reproducibility



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e-sensing

e-Sensing: Big Earth observation data

INPE, São José dos Campos esensin

Repositories

People 0

Filters

Find a repository...

wtss.py

Python Client API for Web Time Series Service

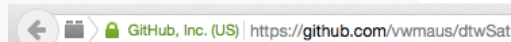
Updated 9 hours ago

wtss.R

R Client API for Web Time Series Service

Updated 4 days ago

wtss.tl



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vwmaus / dtwSat

Code

Issues 0

Pull requests 0

Projects 0

Pulse

Graphs

Time-Weighted Dynamic Time Warping for satellite image time series analysis

149 commits

3 branches

18 releases

Branch: master

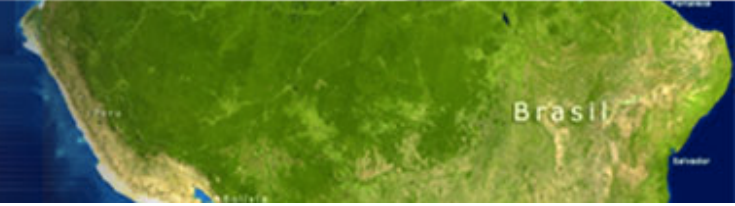
New pull request

Victor Maus Merge branch 'master' of https://github.com/vwmaus/dtwSat

R	Fix Solaris installation errors.
data	Fix big find lowest distance.
figure	Update README
inst	Fix Solaris installation errors.
man	Fix Solaris installation errors.
src	Fix Solaris installation errors.
vignettes	Fix bugs in the examples
.Rbuildignore	Update .Rbuildignore
.directory	Include inquiry bulder



MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS



lubia.vinhas@inpe.br

OBRIGADA. GRAZIE.