Tropical management Forest Observatory
March 24th – 28th, Macapa, Brazil

Spatial and temporal characterization of tropical forests using remotely sensed data

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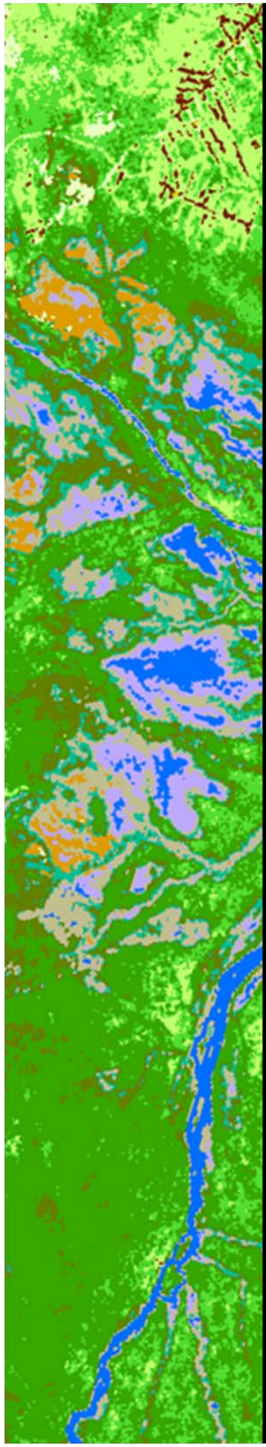


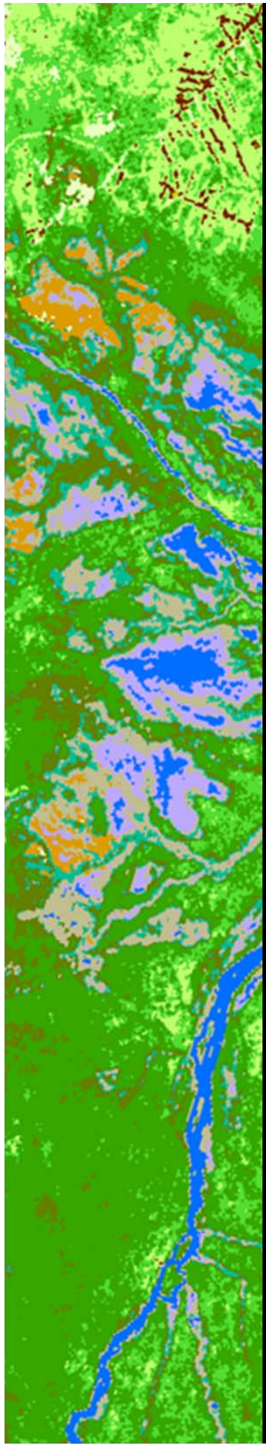
Context

Optical remote sensing is used in different manners in the context of tropical forests monitoring:

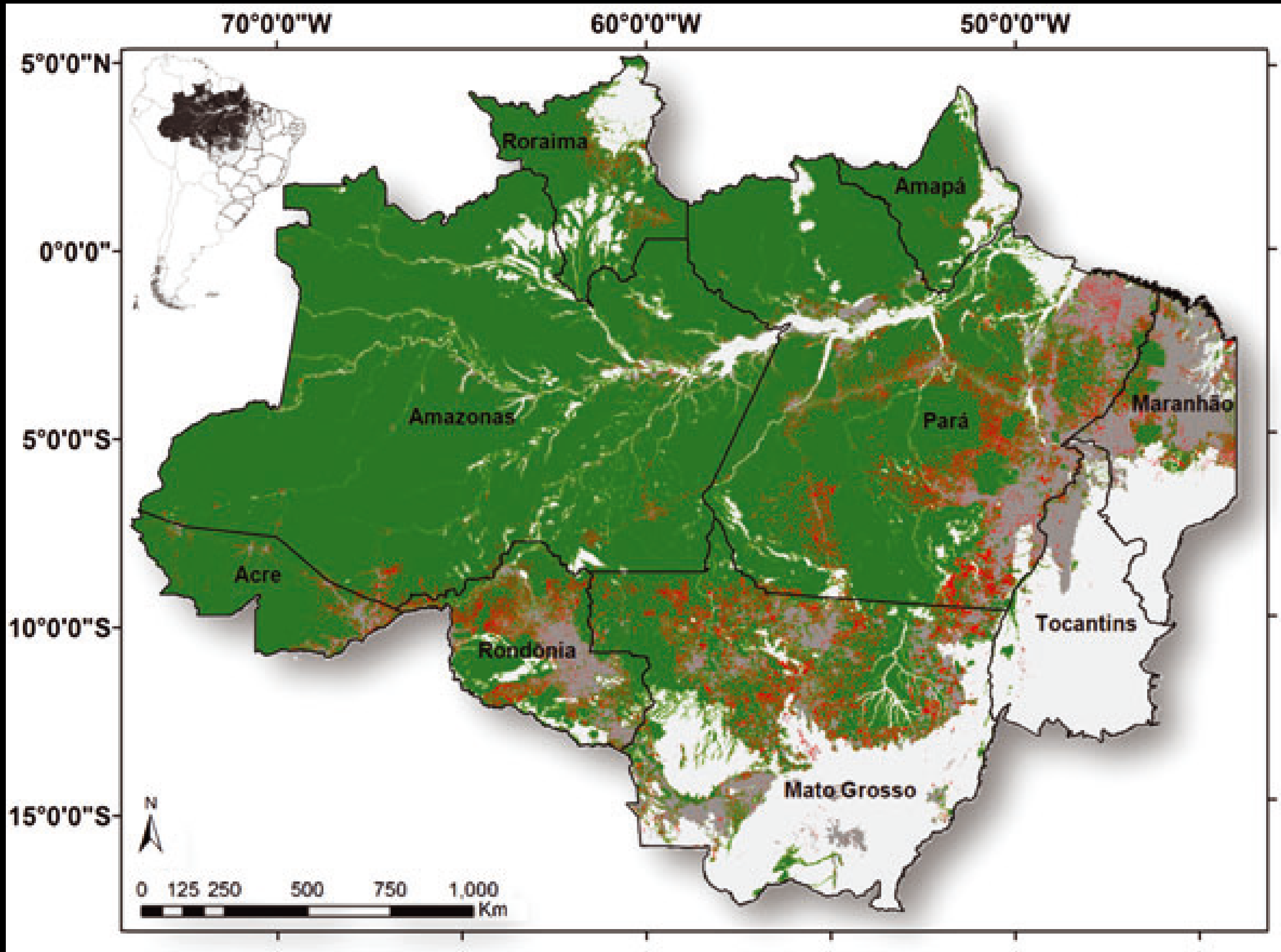
Land-cover characterization (forest types)
Measuring deforestation (change detection)
Estimation of degradation (under development)

Objectives of this presentation are:

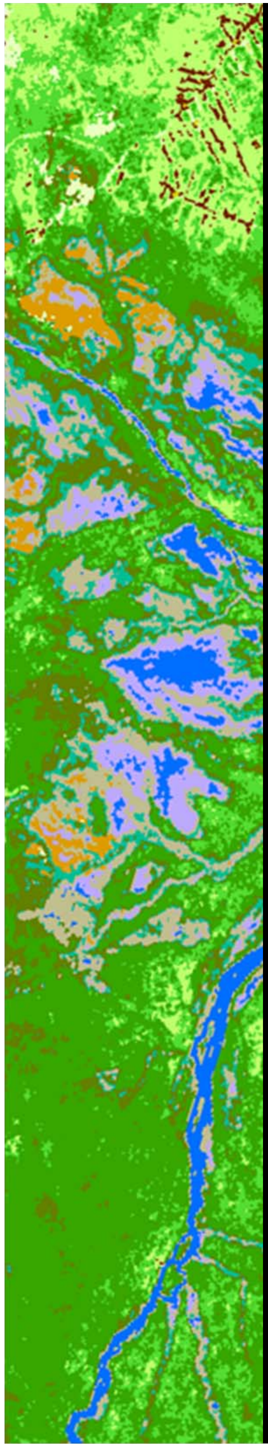
(1) show the potential of optical remote sensing for land cover characterization in space and time;
(2) check the deforestation information already available;
(3) make a review of what is done in terms of degradation;
(4) present perspectives in the scaling-up workflow we develop.



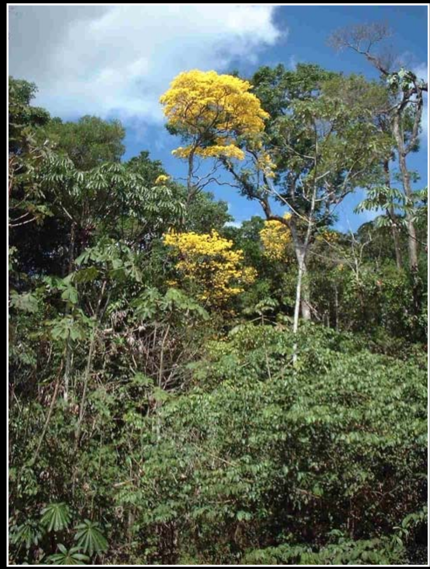
At global scale : a green leaf



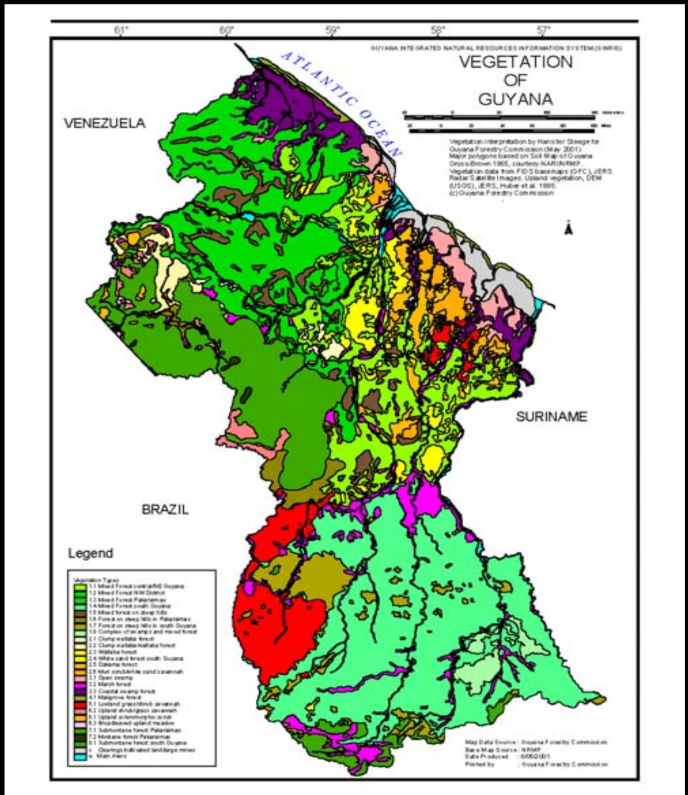
Map showing in green the undisturbed forest area, in red the deforested area from 2000 to 2010, in dark grey the deforested area prior to 2000 and in light grey non-forested areas.
The deforestation data are from the INPE/PRODES (2010*b*) project. Inset: a map of South America highlighting the Amazon biome within the boundaries of the Brazilian Legal Amazonia. Black lines indicates the political boundaries of Amazonian states. Aragao et al., 2014



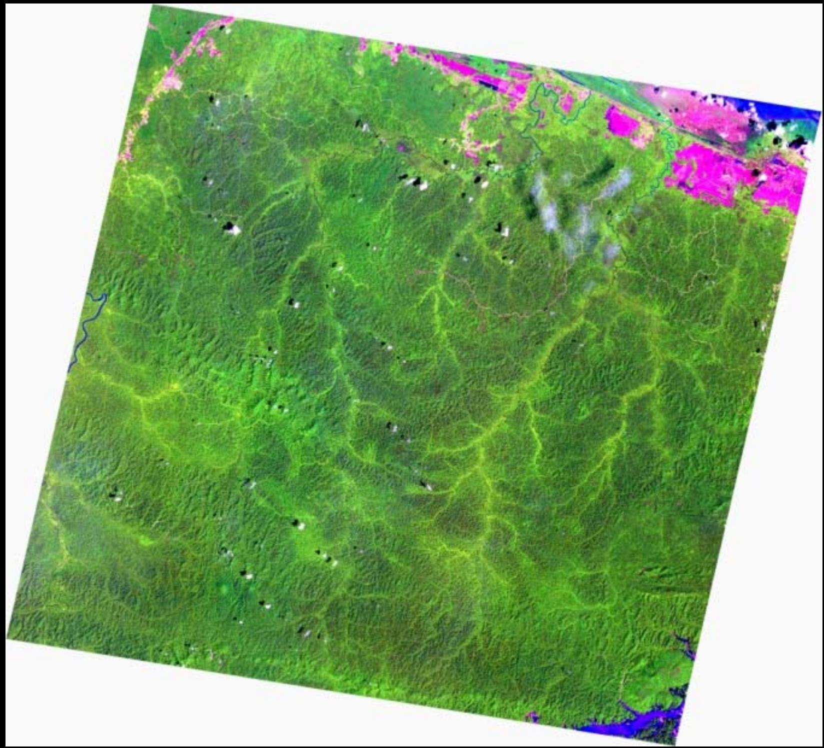
At local scale : multiple complexity

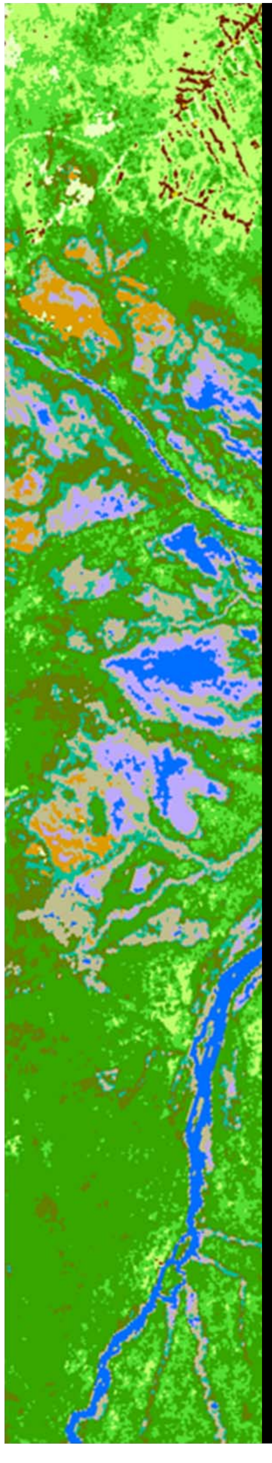


Behind the green layer of the global maps, there are various tropical forest types

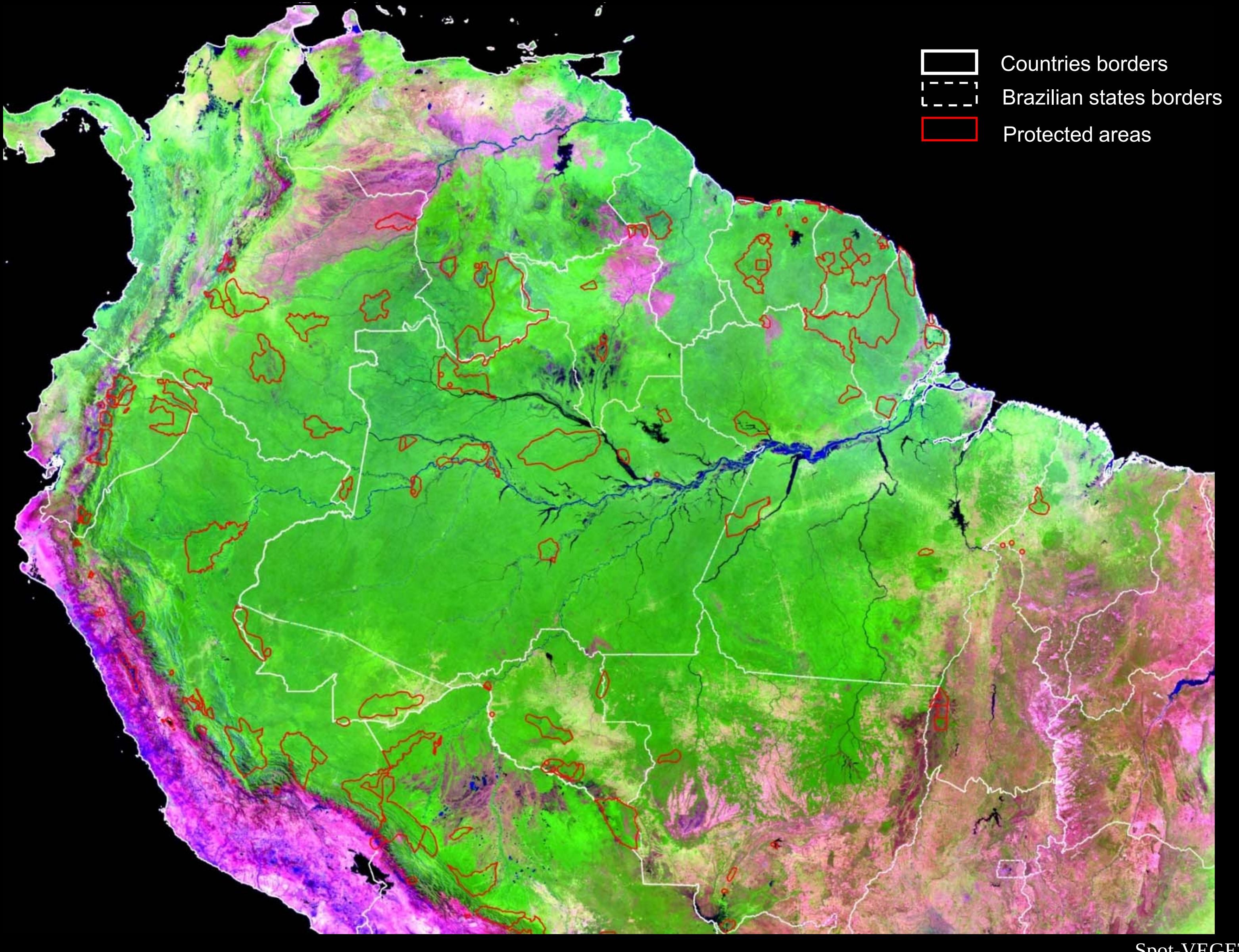


Ter Steege, 2001



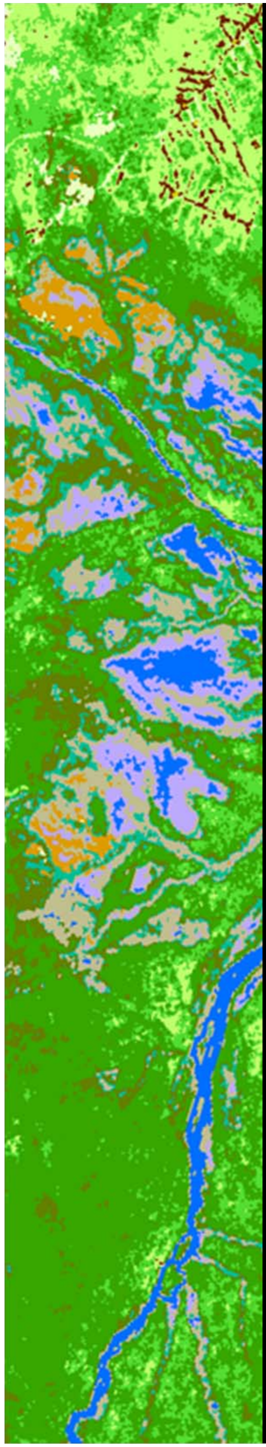


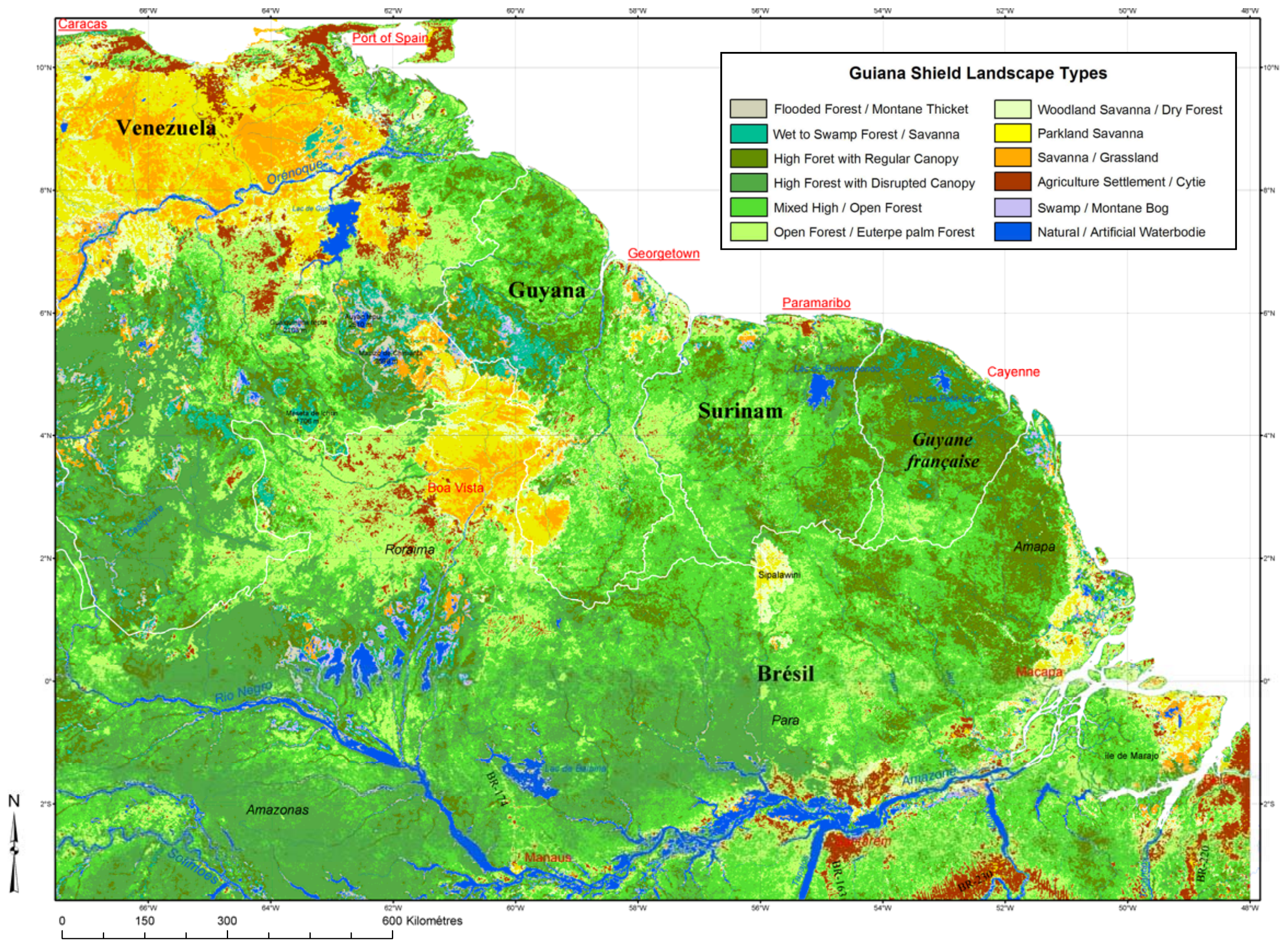
Spatial patterns on annual synthesis SPOT/VGT data



Spot-VEGETATIO

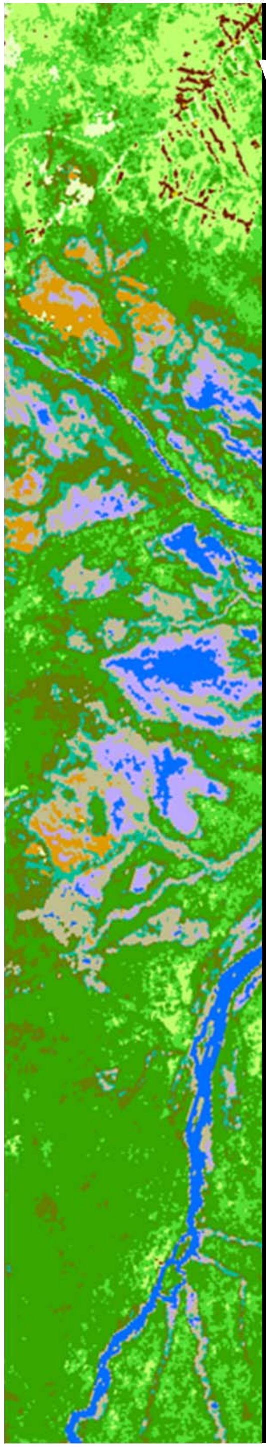
Land use mapping using SPOT/VGT time series data

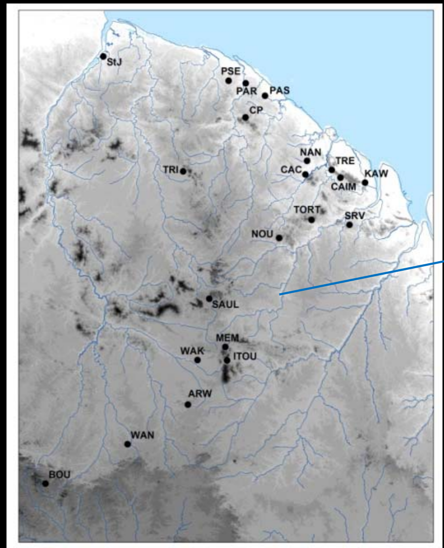


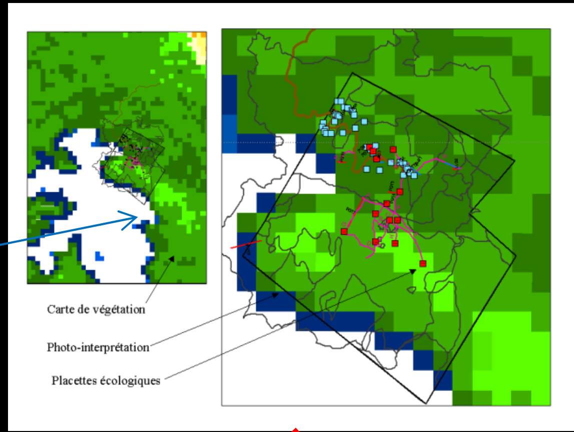


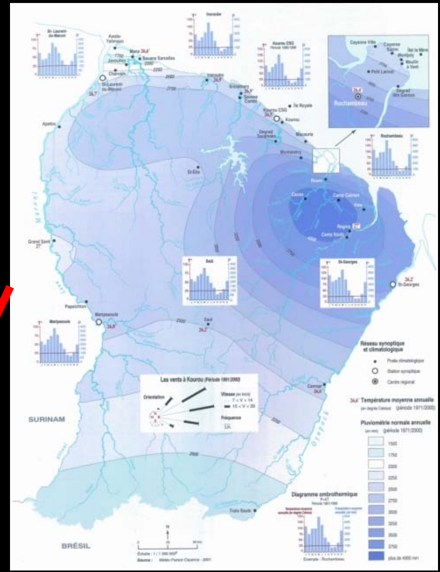
Gond, *et al.*, 2011

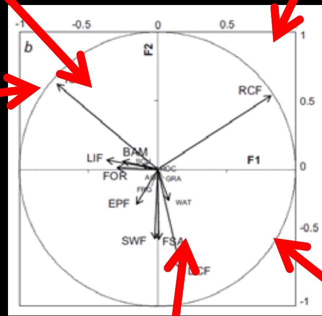
Validation: statistics with environnemental parameters

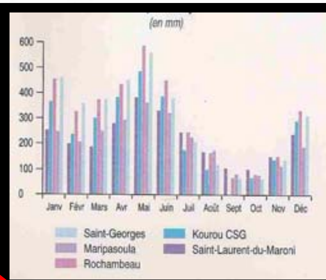


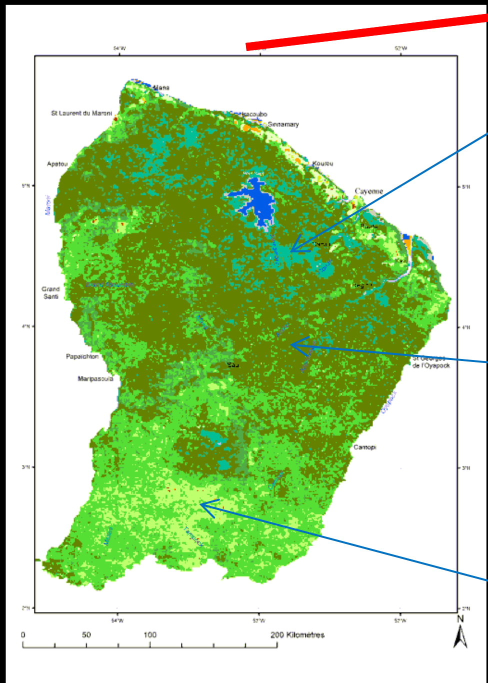


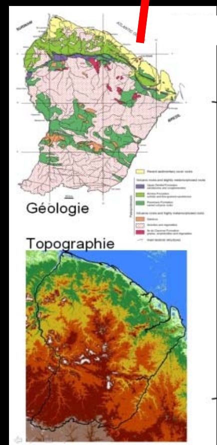


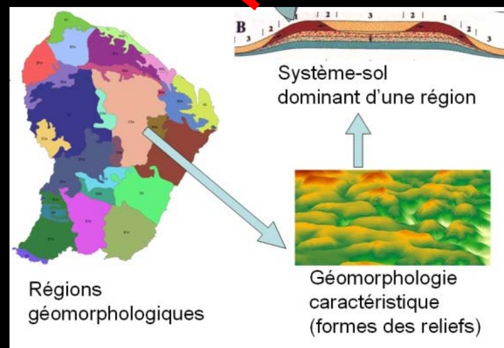




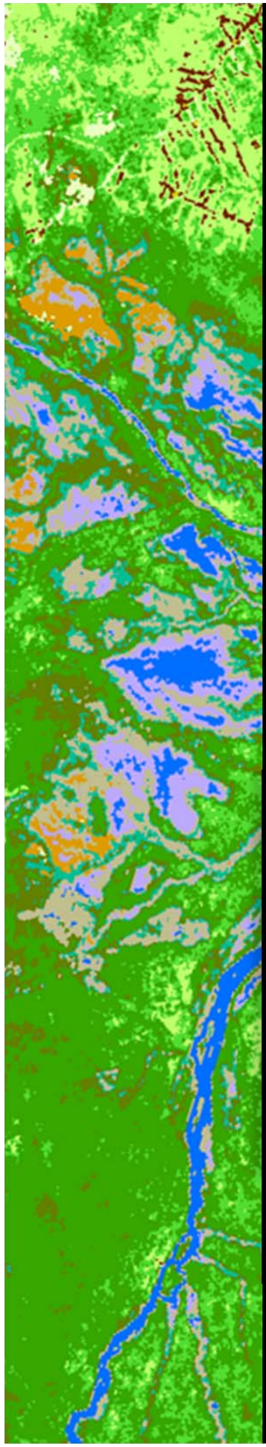




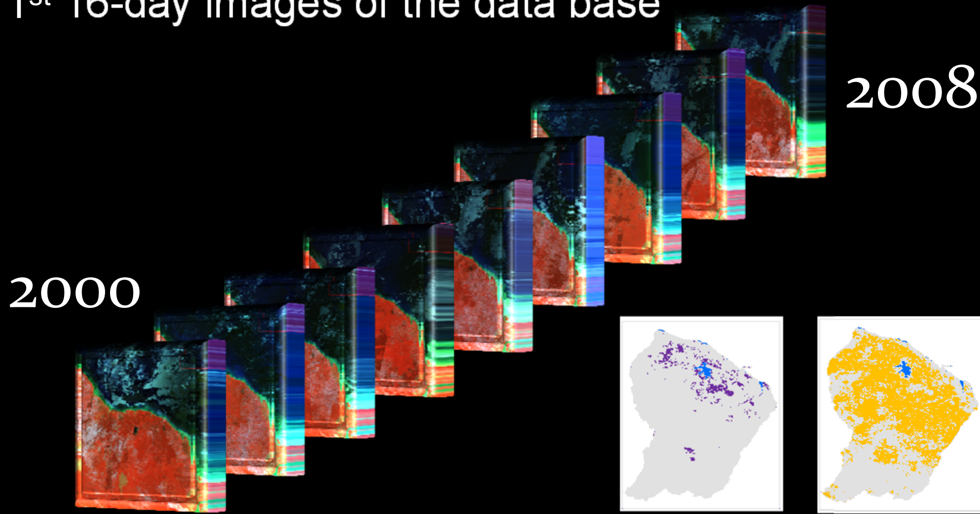


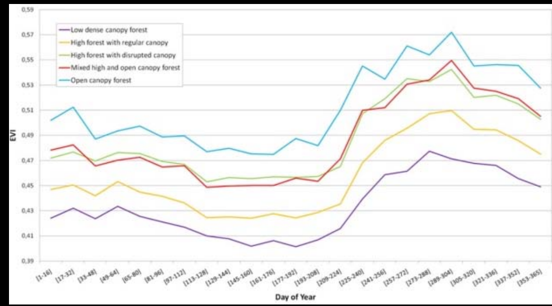


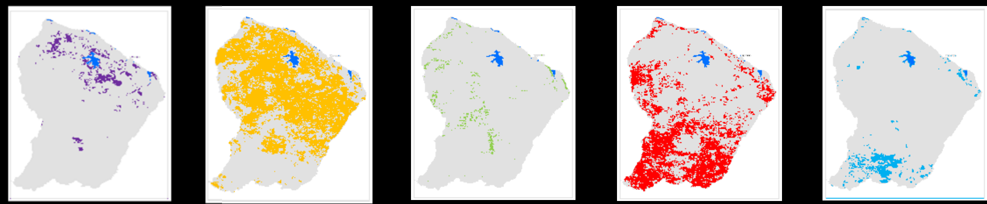
Phenology analysis using MODIS data time series

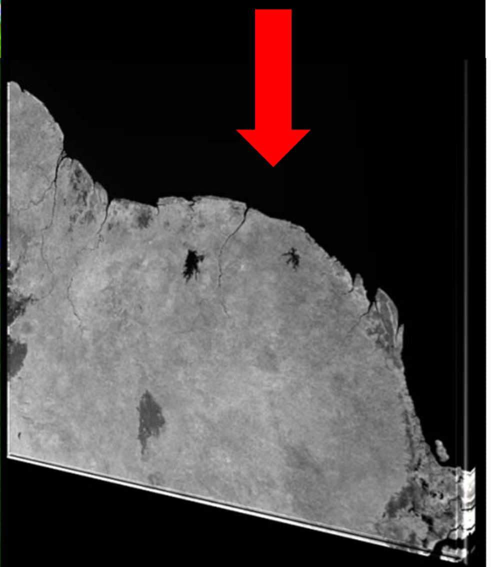


1st 16-day images of the data base

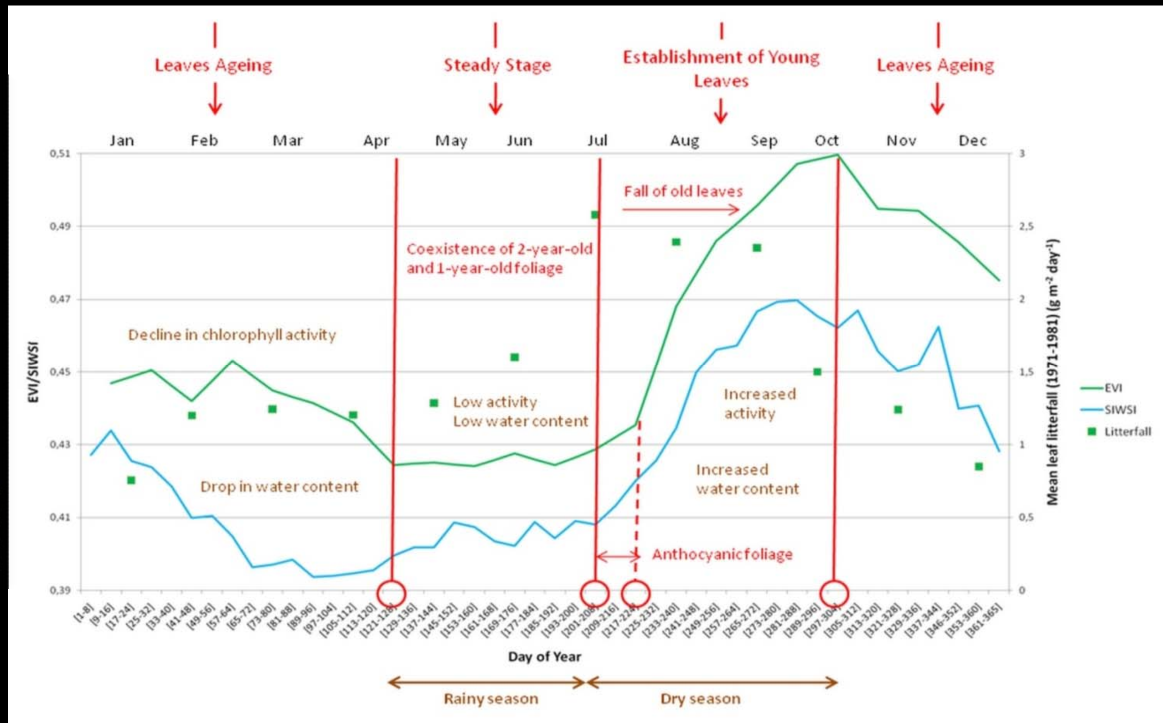


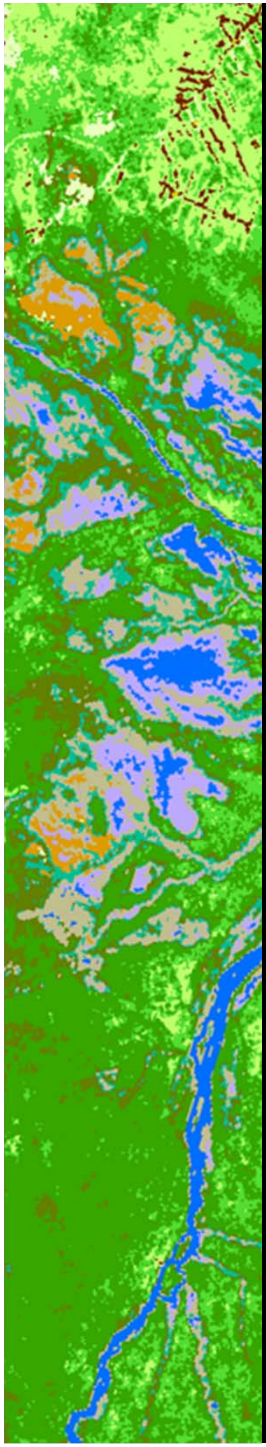




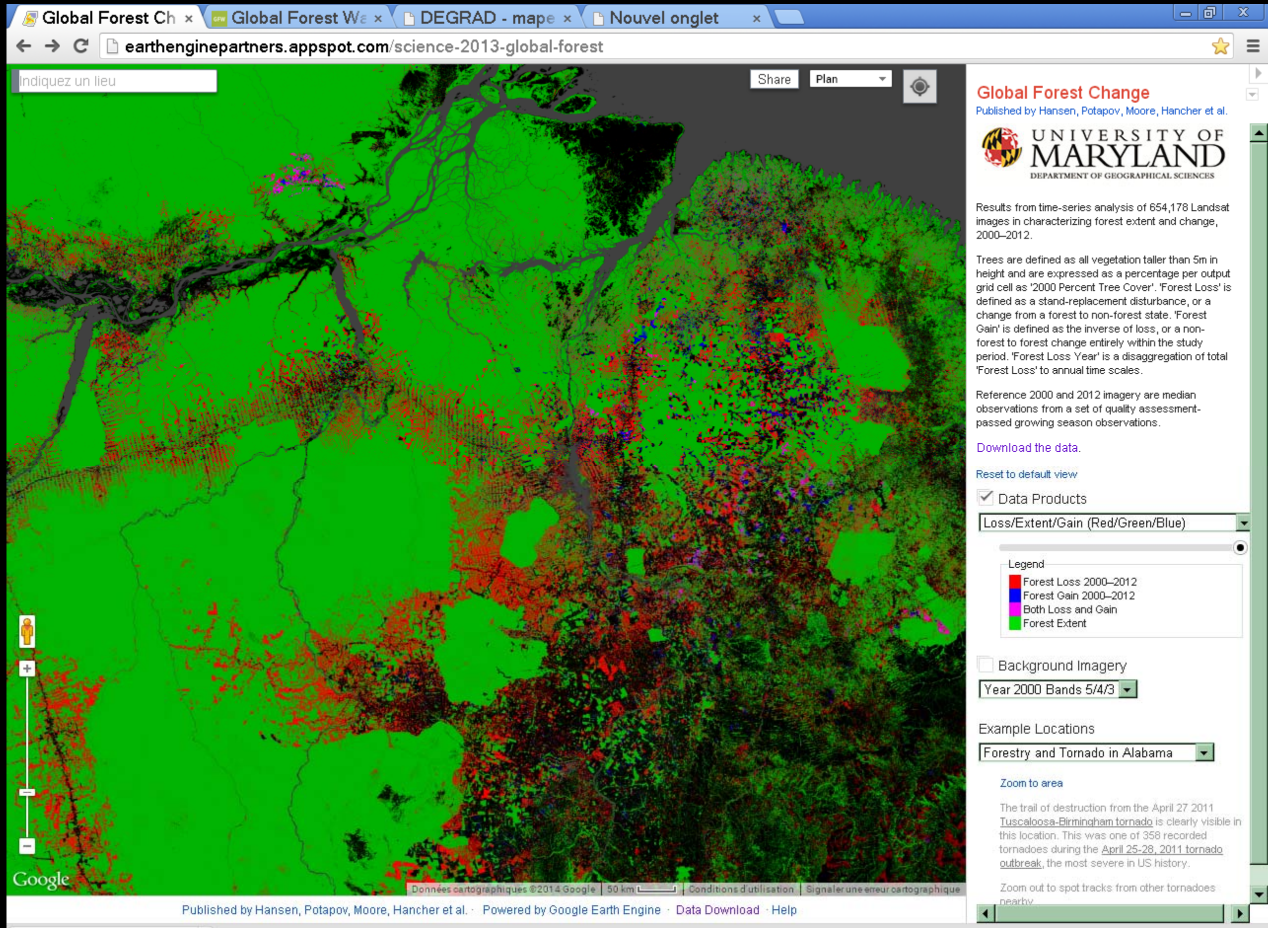


Annual synthesis on 23 EVI 16-day periods





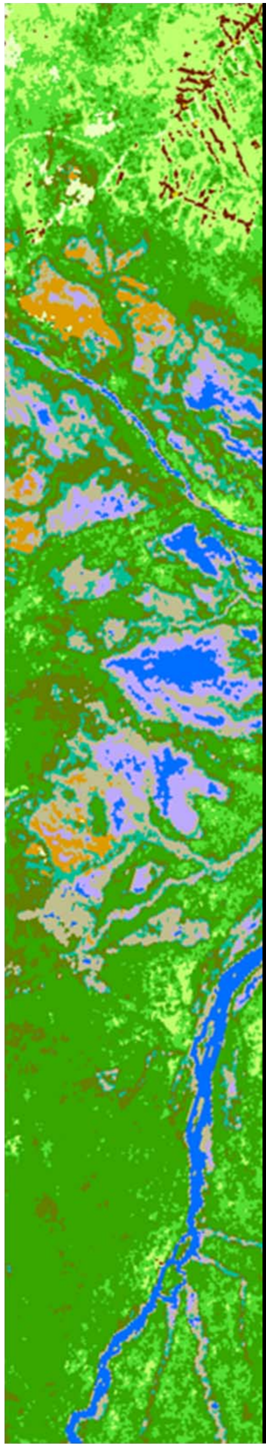
Global Forest Change (Hansen et al.,)

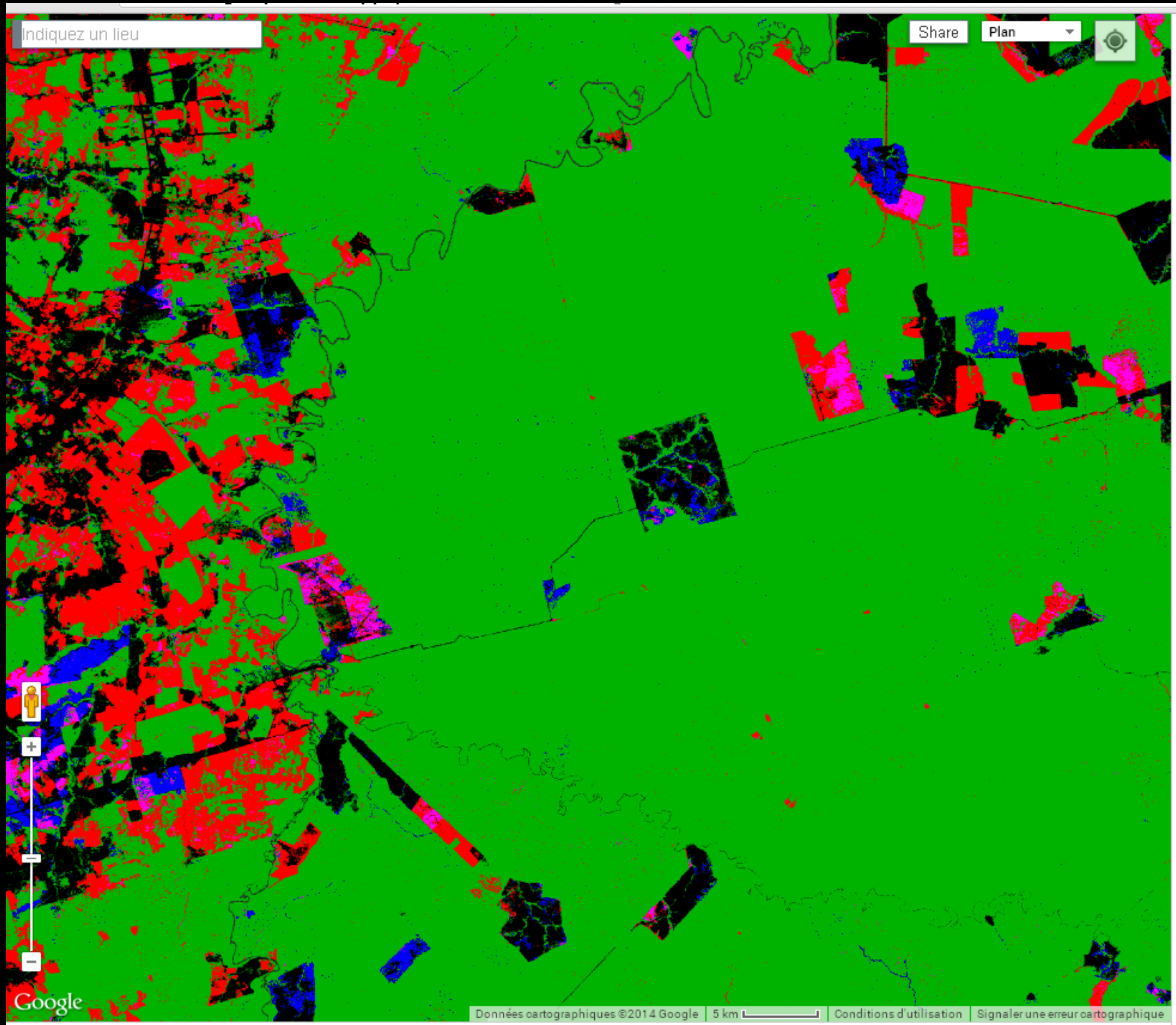


654,178 LANDSAT 7 ETM+ images from 2000-2012
Forest loss (red), forest extent (green), forest gain (blue)
Option for forest lost by year (0 to 12) and tree cover (% in 2000)
10x10   at 30m resolution, median (filter QA) for bands 3,4,5 and 7 (TOA)

http://earthenginepartners.appspot.com/science-2013-global-forest

Global Forest Change: locally (CIKEL)

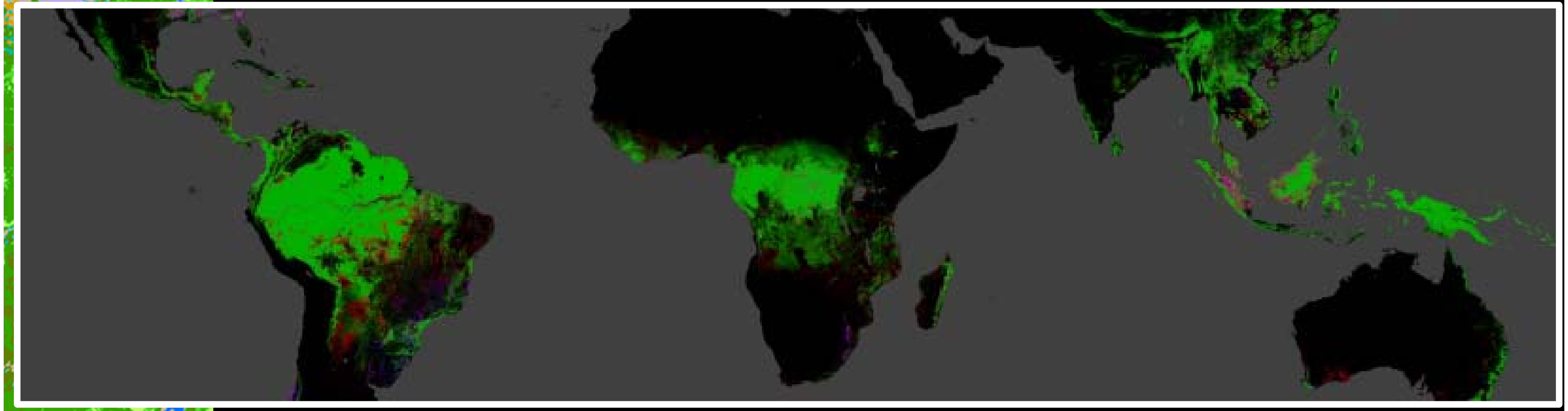


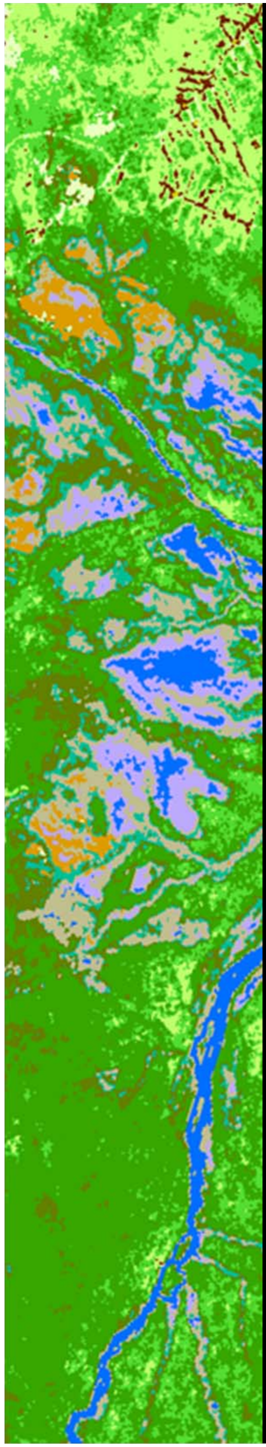


More deforestation than degradation

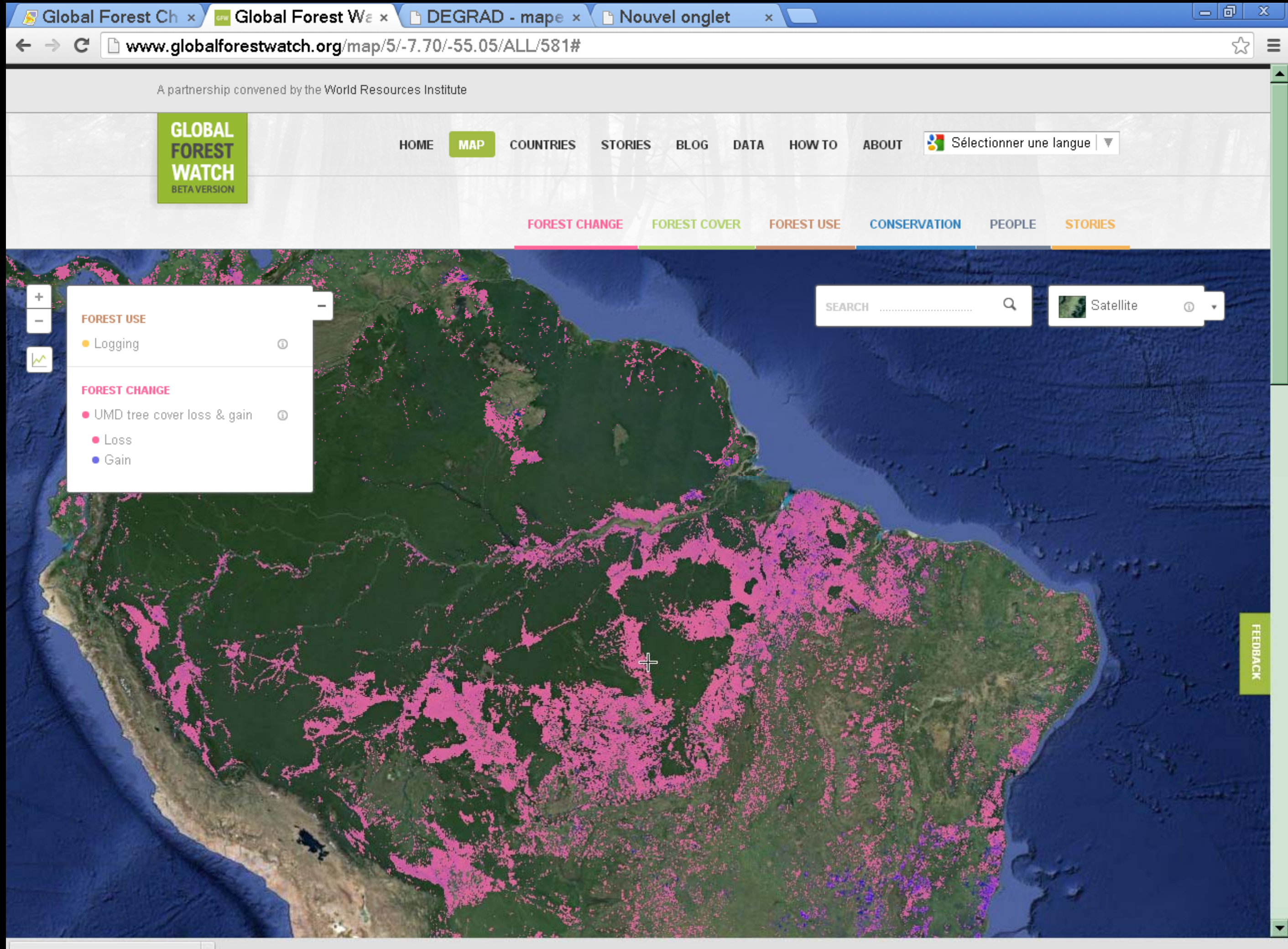
Global Forest Change

It is really global and pan-tropical



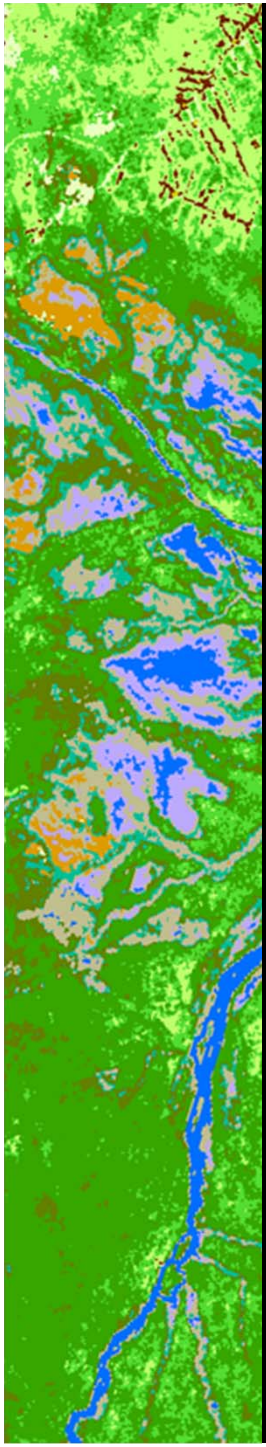


Global Forest Watch



Compile several sources of information:

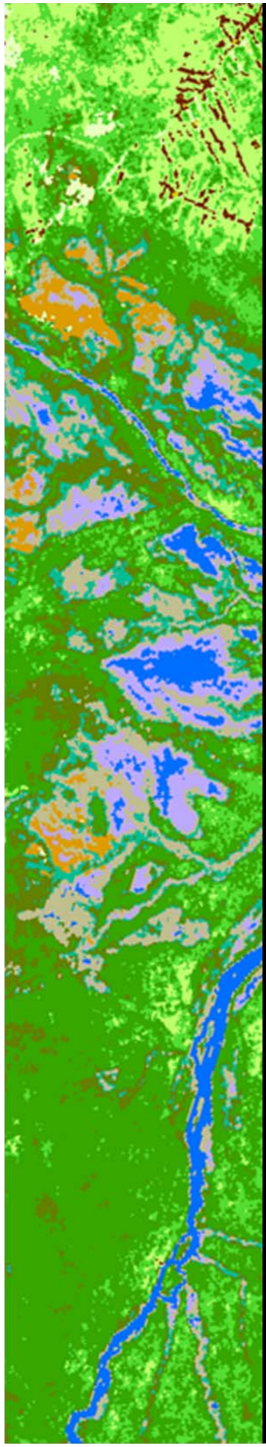
- UMD (Hansen et al.,), FORMA alert, IMAZON, etc.

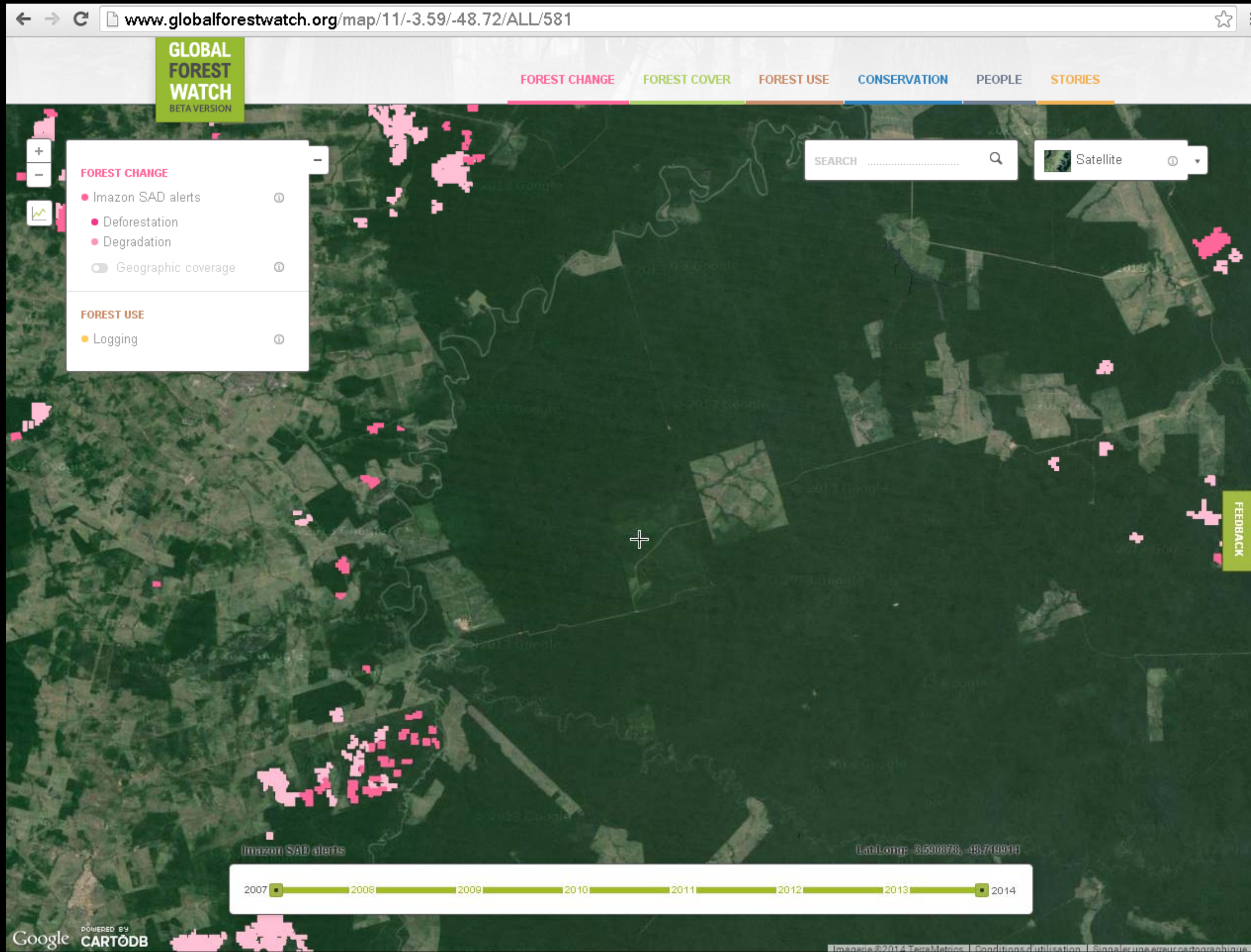


Global Forest Watch: FORMA alert on CIKEL

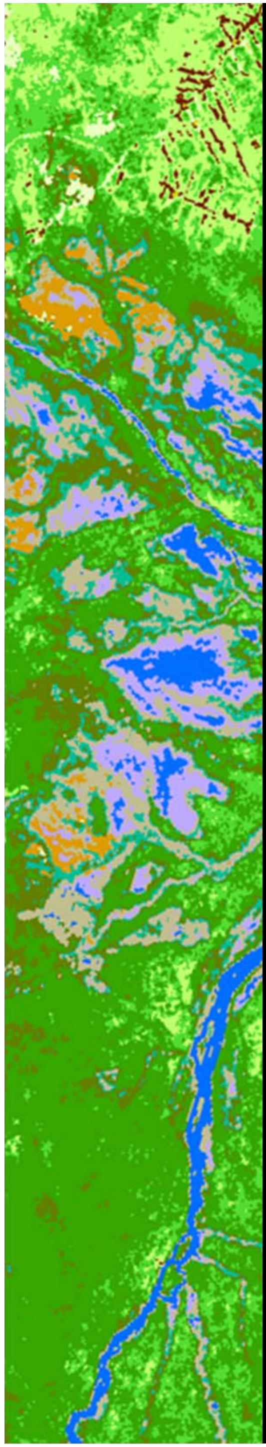
Humid tropical forest biome (WWF), Monthly alert since Jan. 2006
MODIS 500m

Global Forest Watch: IMAZON on CIKEL

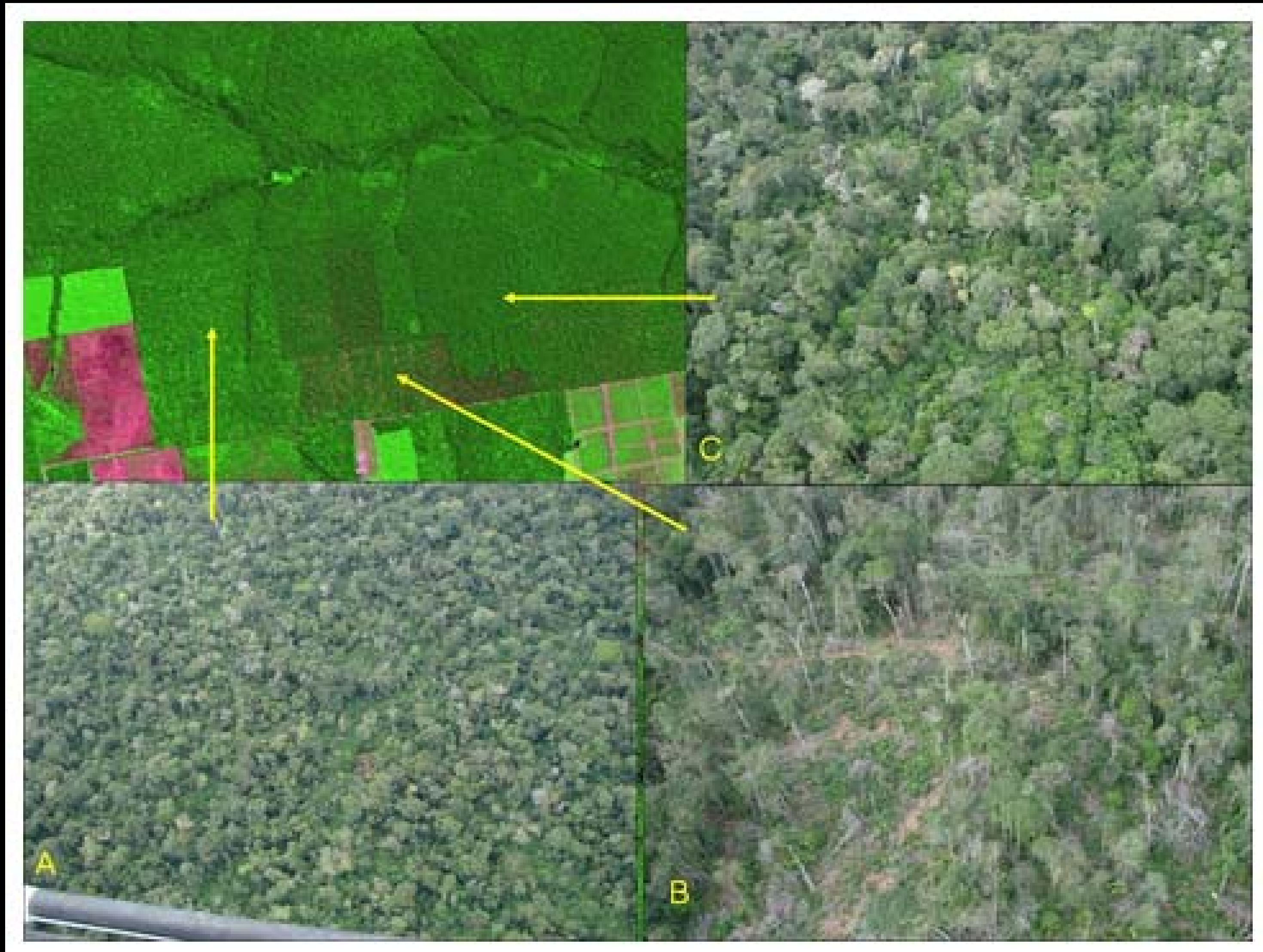




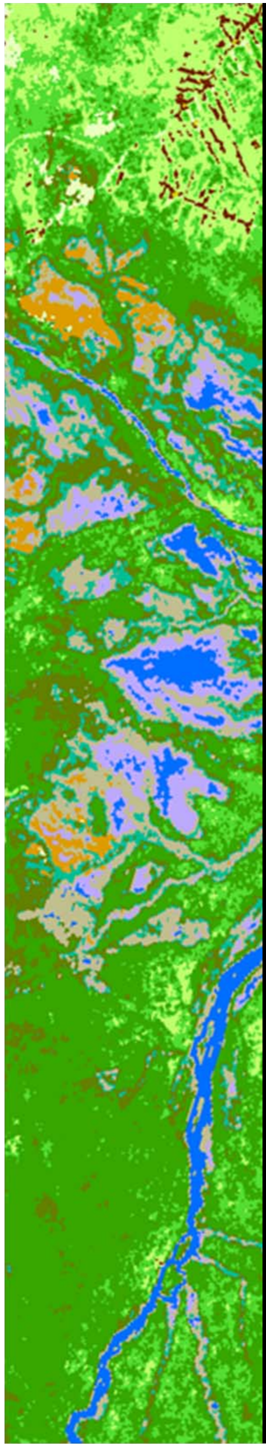
Amazonia legal, Forest Transparency bulletin, Monthly alert since Jan. 2007
MODIS 250m and validation LANDSAT and CBERS



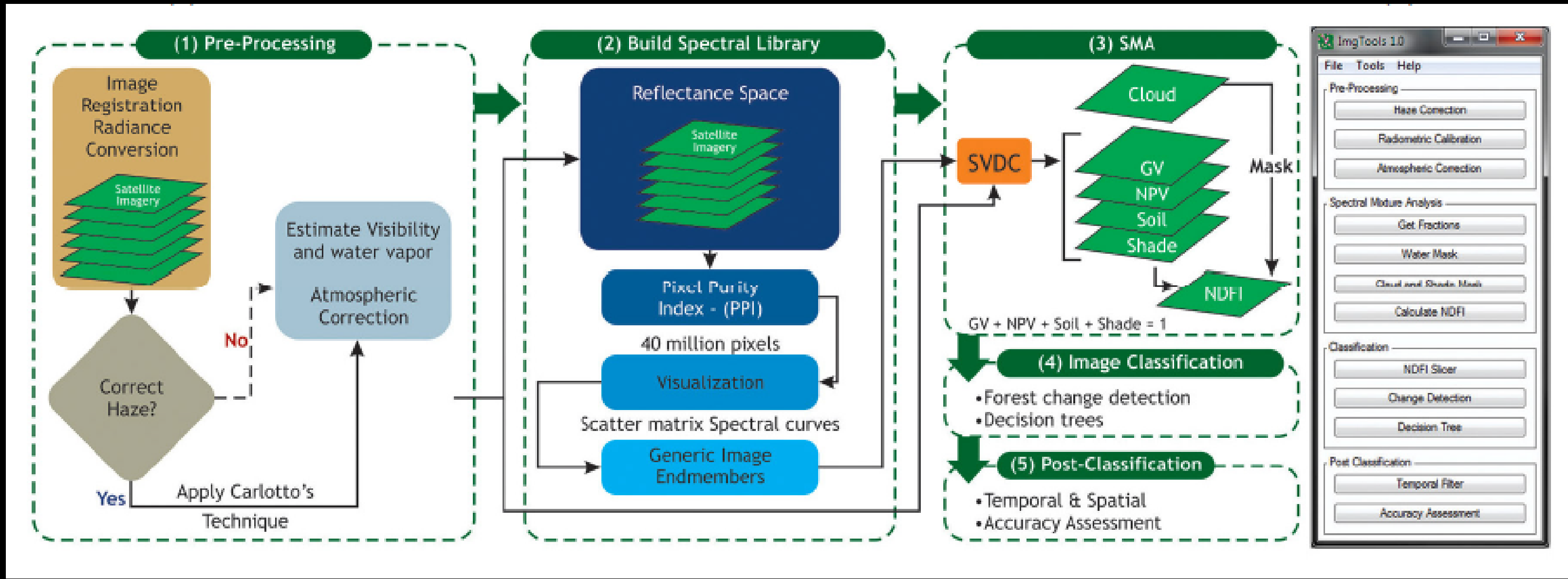
Gradient of forest degradation (INPE)



A figura acima mostra os padrões de degradação florestal por extração de madeira observados em imagens realçadas. A) Degradação de intensidade moderada, área em regeneração após exploração madeireira, pátios ainda evidentes; B) Degradação de intensidade alta, exploração madeireira ativa, grande proporção de solo exposto; C) Degradação de intensidade leve, evidência de abertura de estradas de acesso.



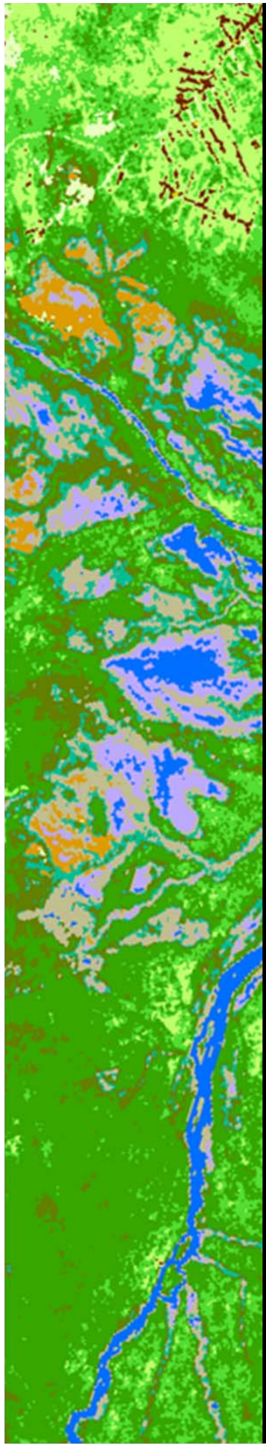
Forest degradation detection (Souza et al.,)



Flow of the image processing procedures as implemented with an ImgTools conceptual framework (**a**) including:

1) pre-processing,
2) spectral endmember library development,
3) Spectral Mixture Analysis (SMA);
4) Image Classification, and
5) Post-Classification processing and assessment.

Souza, C., Jr.; Siqueira, J.V. ImgTools: A Software for Optical Remotely Sensed Data Analysis. In Proceeding of Anais XVI Simpósio Brasileiro de Sensoriamento Remoto, Foz do Iguaçu, PR, Brazil, 13–18 April 2013; pp. 1571–1578.



Spectral Mixture Analysis (Souza et al.,)

$$R_n = \sum_{i=1}^{n} F_i \, R_{i,b} + \varepsilon_b$$

SMA equation

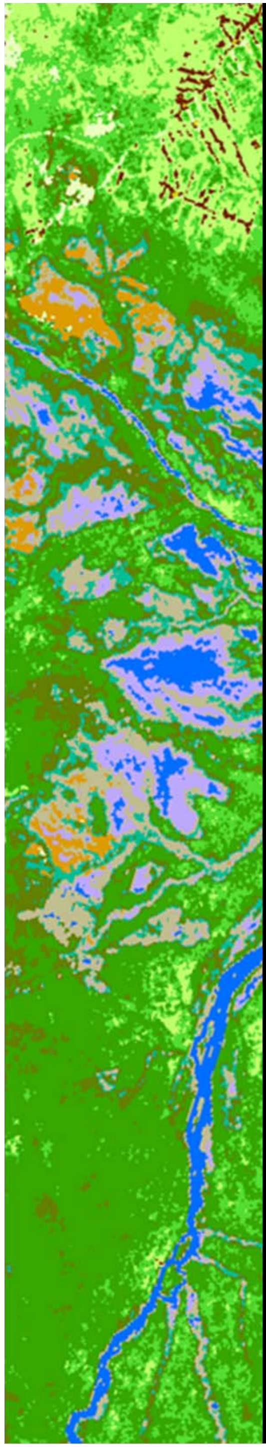
$$\text{NDFI} = \frac{\text{GV}_{\text{Shade}} - (\text{NPV} + \text{Soil})}{\text{GV}_{\text{Shade}} + \text{NPV} + \text{Soil}}$$

$$\text{GV}_{\text{Shade}} = \frac{\text{GV}}{100 - \text{Shade}}$$

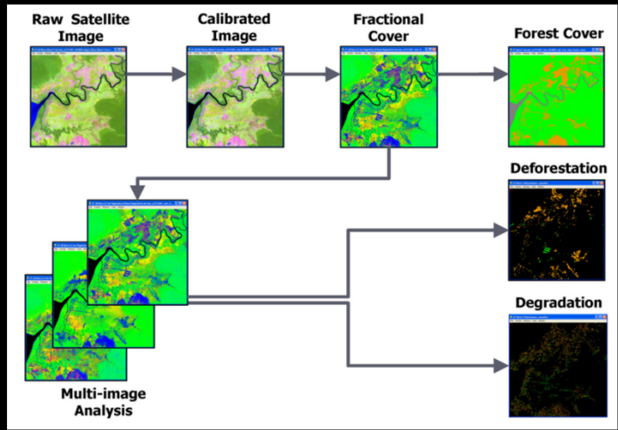
GV=Green Vegetation
NPV: Non-Photosynthetic Vegetation
Soil and shade

When NDFI is close to
1 = forest; 0 = degradation; -1 = bare soil

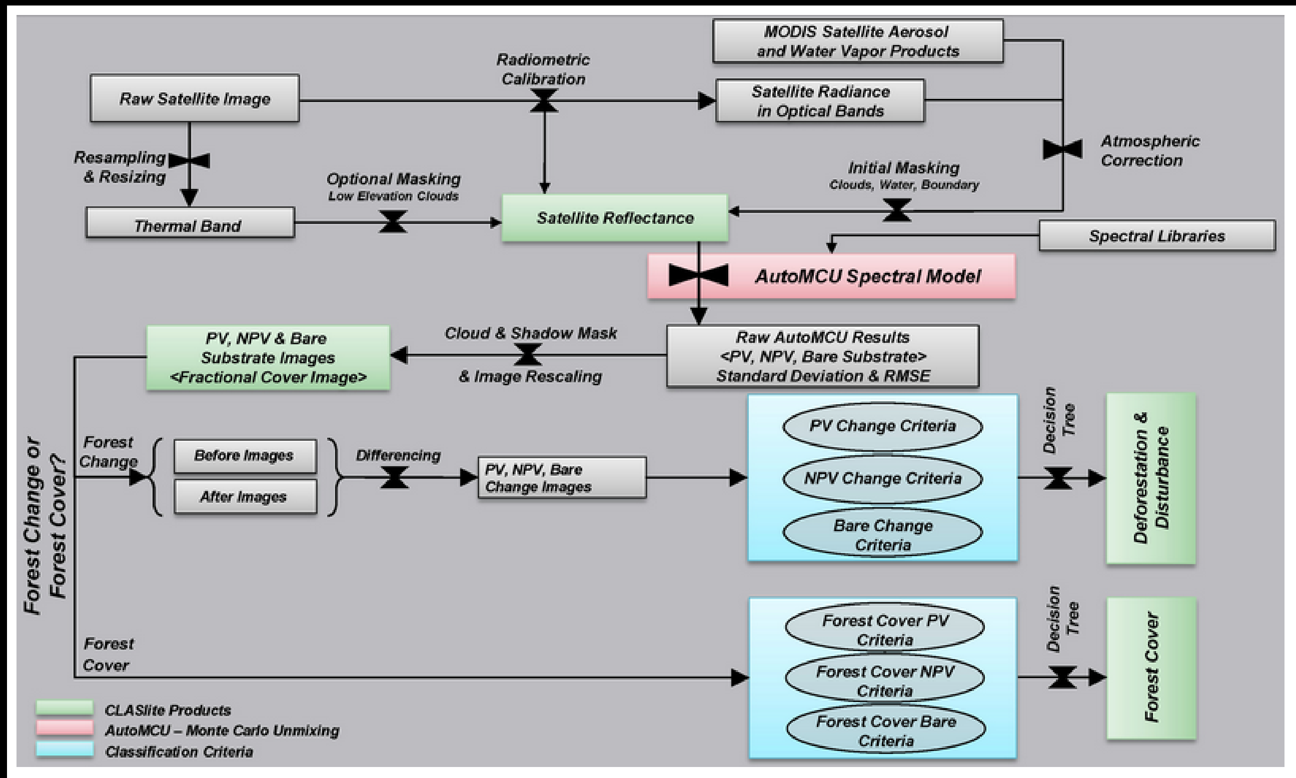
Souza Jr, C. M., J. V. Siqueira, M. H. Sales, A. V. Fonseca, J. G. Ribeiro, I. Numata, M. A. Cochrane, et al. 2013. Ten-year Landsat classification of deforestation and forest degradation in the brazilian amazon. Remote Sensing 5:5493-513.



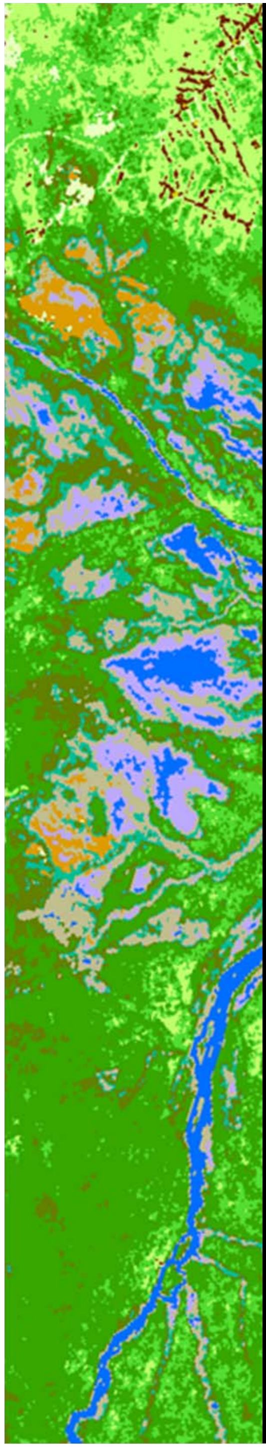
Forest degradation detection (Asner et al.,)



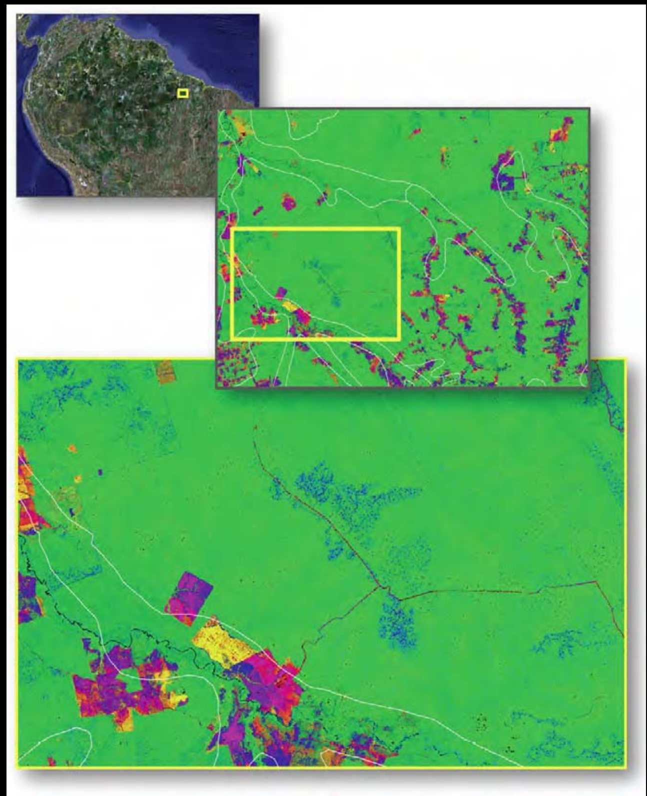
Similar system using unmixed pixel modelling with forest cover estimation



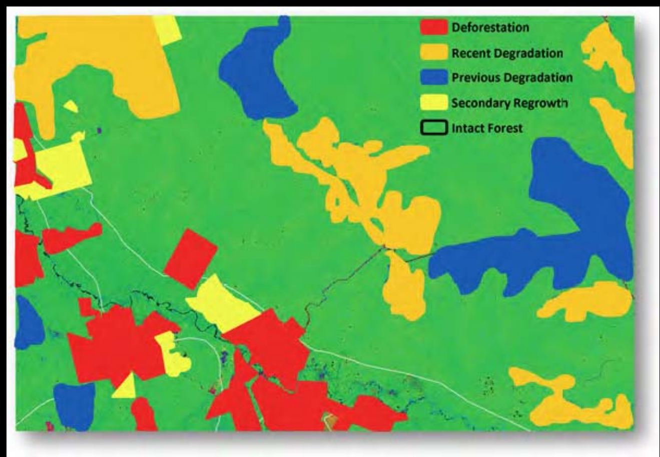
http://claslite.carnegiescience.edu/en/index.html

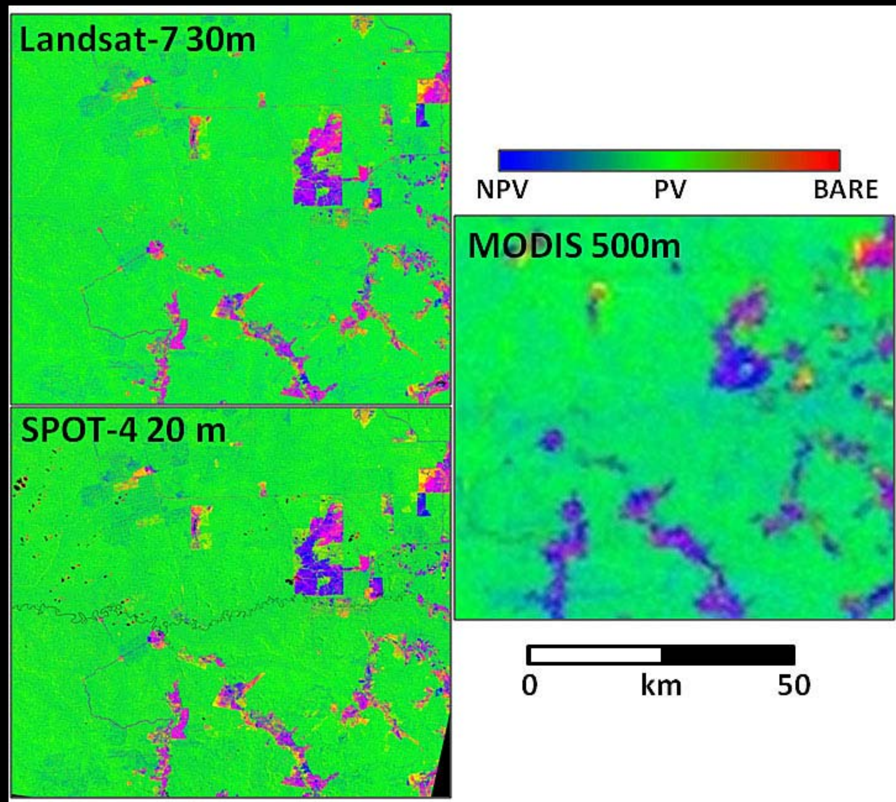


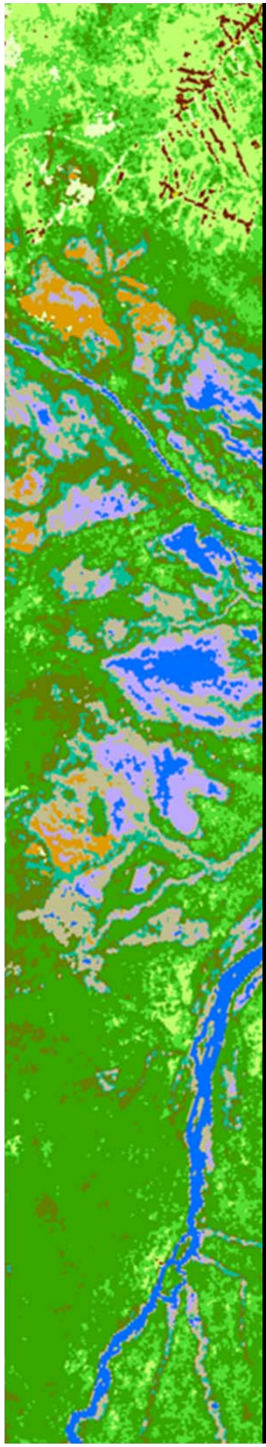
CLASlite (Asner et al.,)



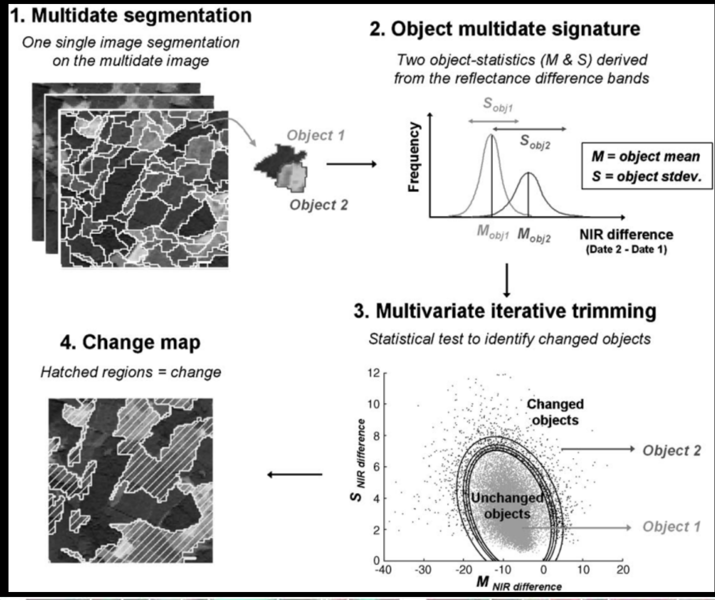
CLASlite image results for an 1500 km2 region.
(0–100%) canopy cover of live/forest vegetation, dead or senescent vegetation, and bare soils
Recently deforested, burned areas are red-magenta;
forest regrowth is green ;
soils is yellow;
selective logging is blue ;
intact forest is dark green.



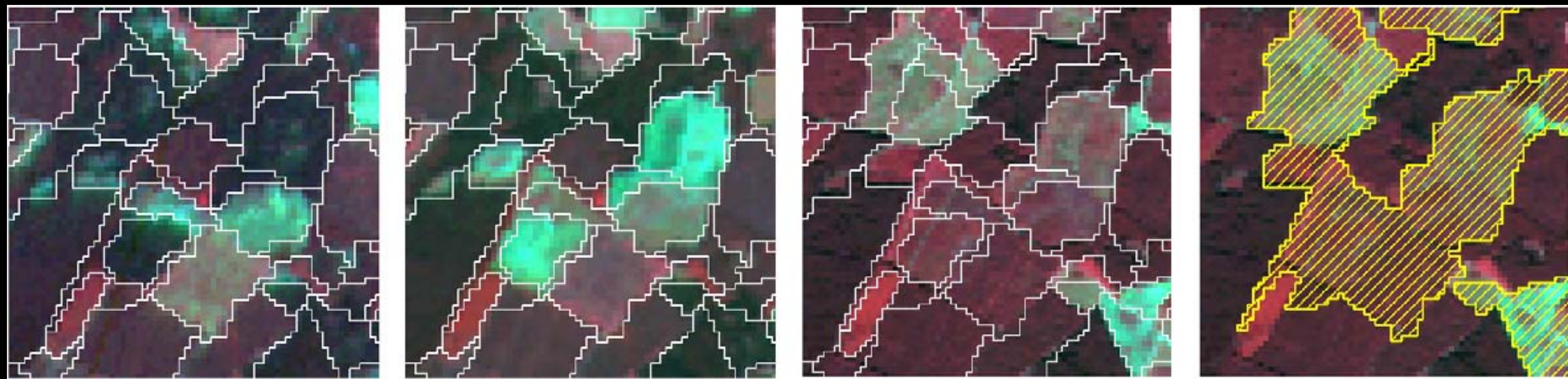




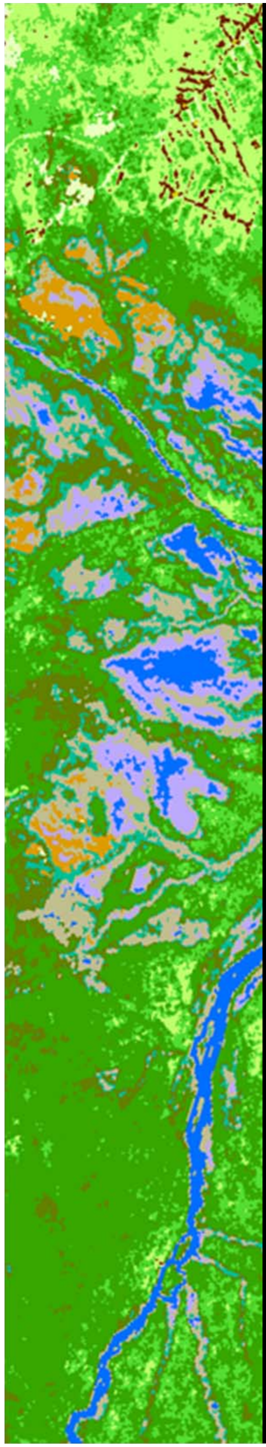
Oriented Object base model (Desclée et al.,)



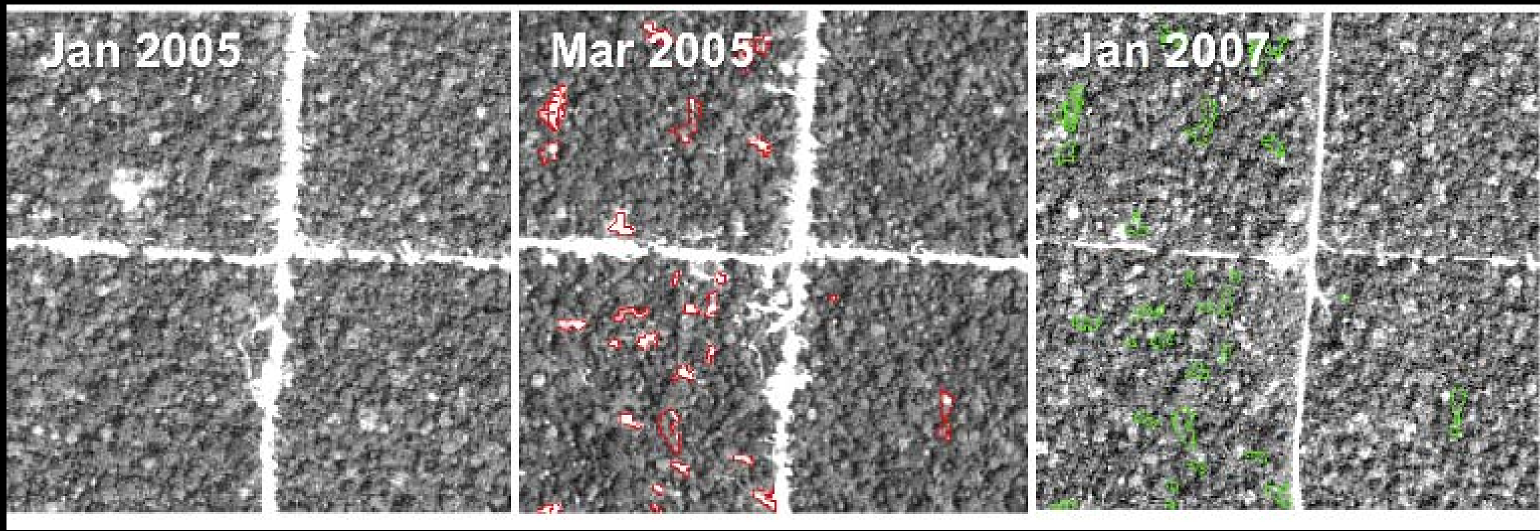
- Multiple date
- Oriented object classification
- Change detection



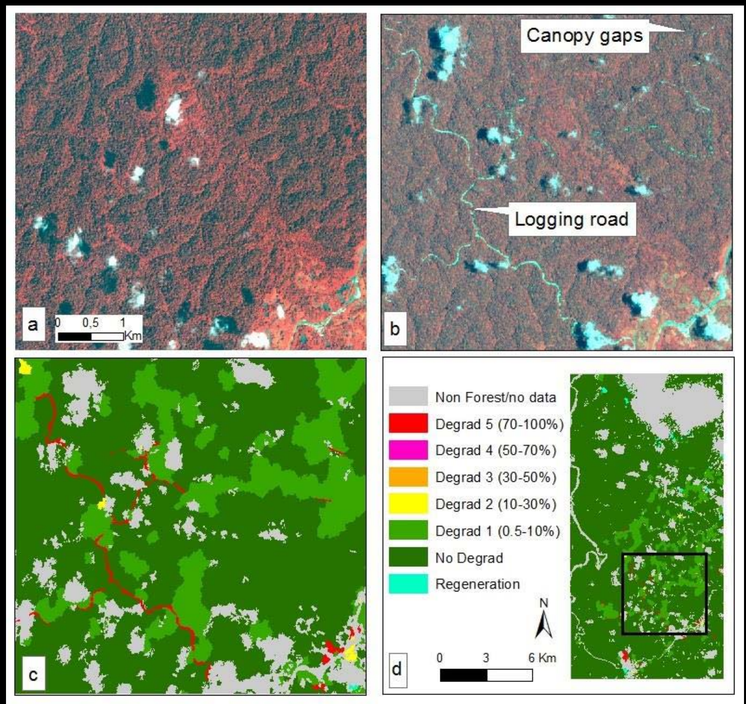
False color composite subsets (RGB=NIR–Red–Green) of each image of the SPOT time series (1992–1995–2003) overlaid by the multidate segmentation result.
Bright objects are clear-cuts while regions in reddish grey are regenerating areas.
The hatched regions on the change map correspond to detected changed objects by the OB-Reflectance method



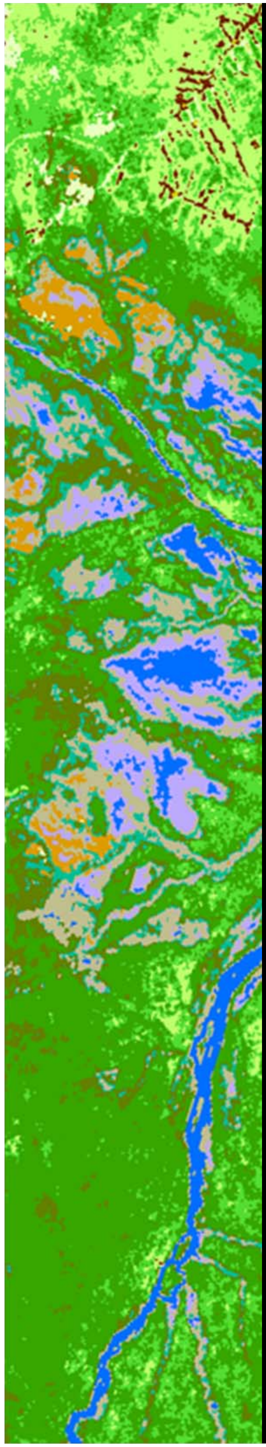
Very High Resolution images



Logging gap monitoring 2005-2007 with SPOT (2,5m). 7% of the surface is impacted (with 60% of gaps and 40% of road).



Quickbird images 2010 and 2012.
The degradation map (in c) shows the percentage area difference of small patches of bare soil for the period 2010-2012,
d) the whole 20x10km study area with black box indicating the location of the figures a, b and c (Source : REDDiness).



Combined approach (Cirad-ONF)

Development of tools to measure the degradation of harvested tropical forests:
(1) road network monitoring and (2) canopy gaps detection

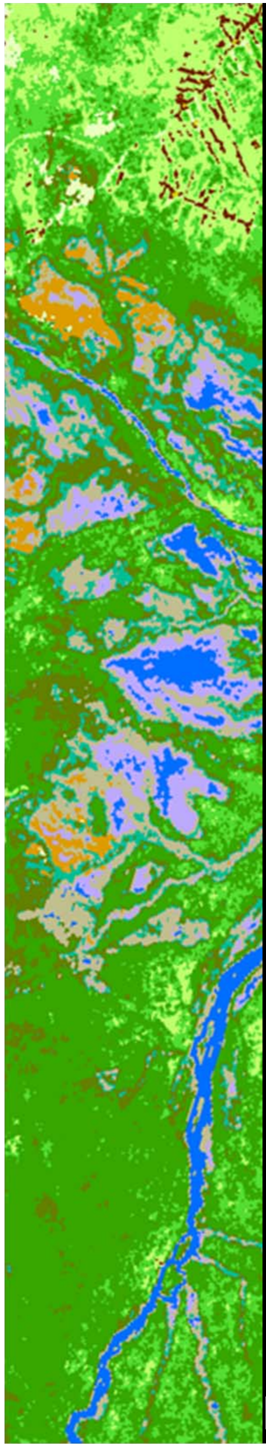
Outcome:
These tools have to facilitate the post-harvesting control

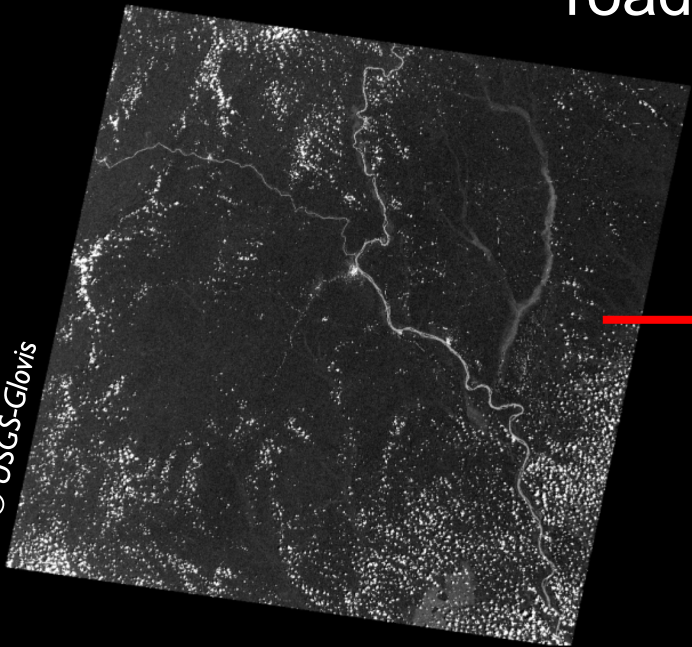
Harvesting

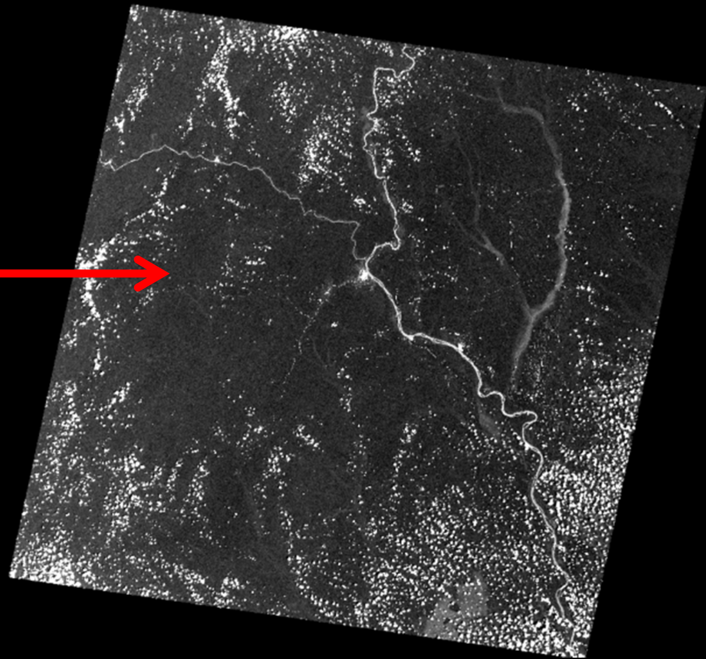
Log yard

Tracks and roads

road network monitoring







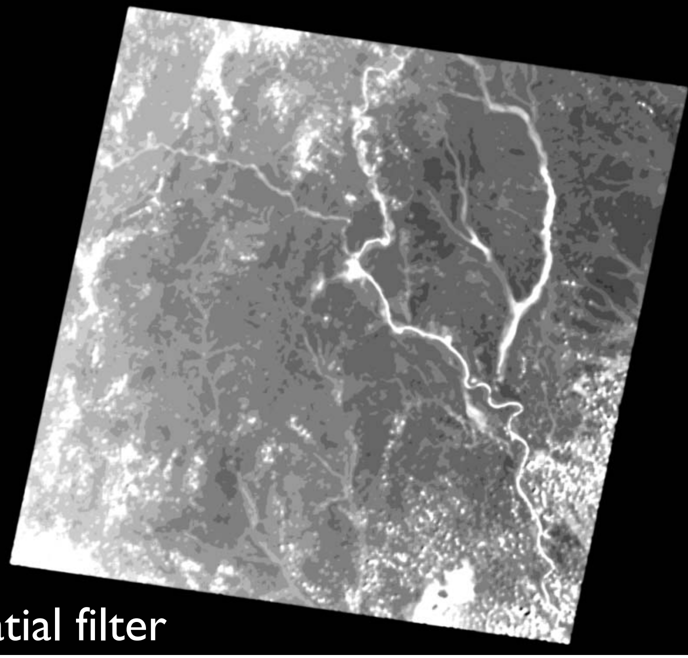
1 - Radiometric calibration

2 - Spectral indices processing

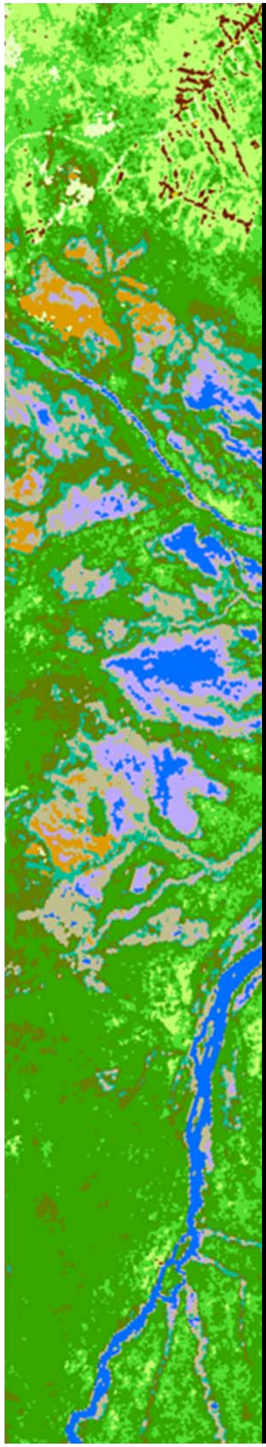
NDVI = (NIR – Red) / (NIR + Red)

GR = (Green – Red) / (Green + Red)

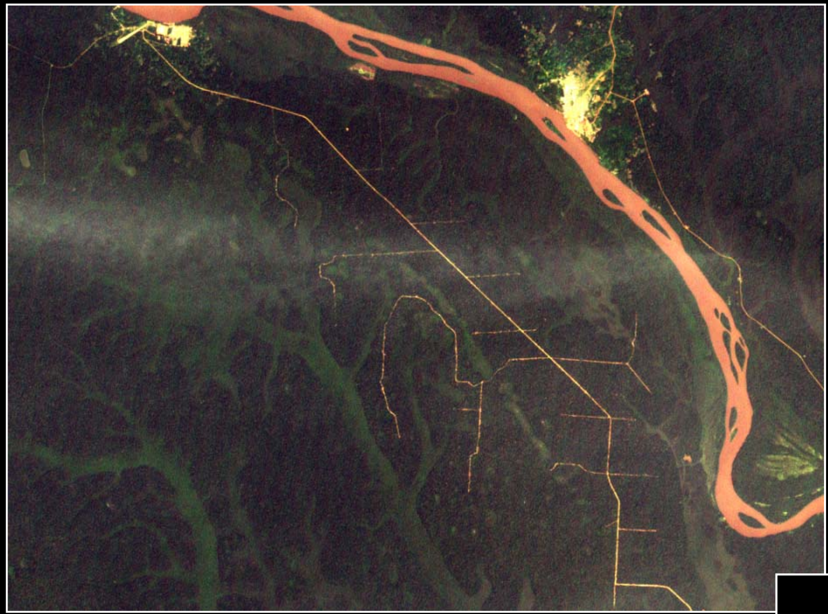
NDVI + GR



Local contrast improved by the median spatial filter

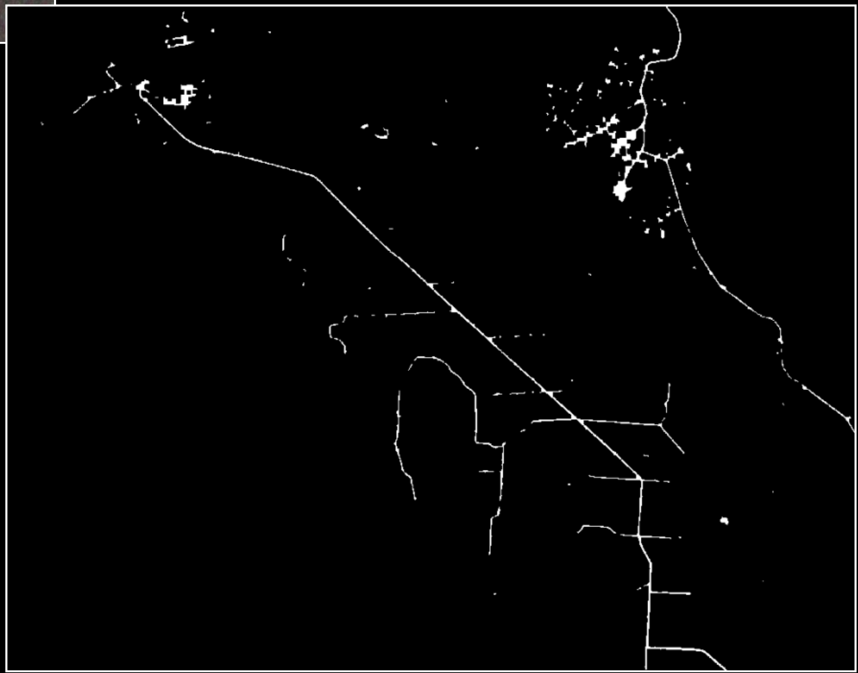


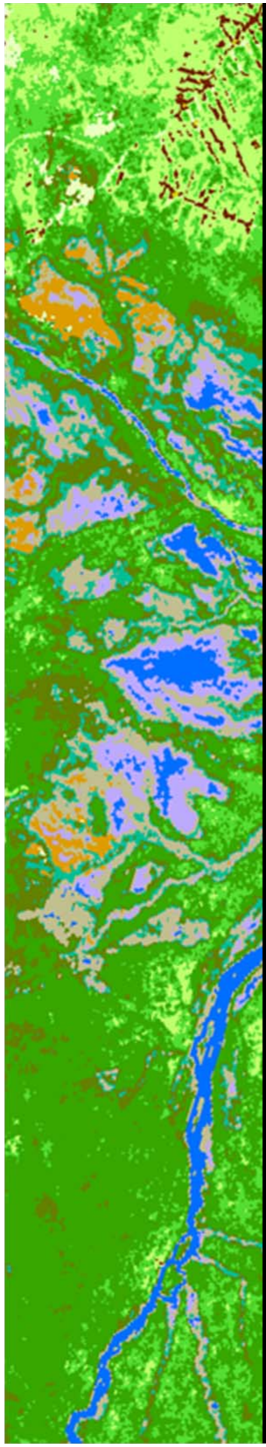
Processing



3 – Bare soil identification
using Red, GR, NDVI+GR channels

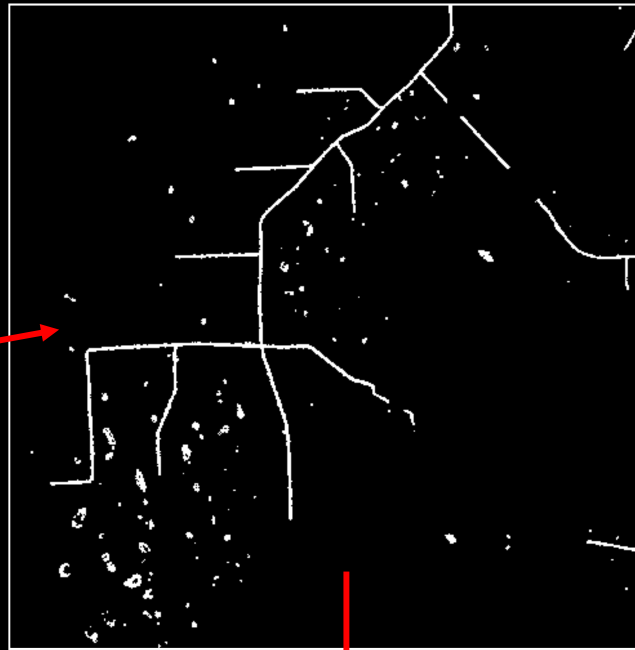
4 - Cloud and water masking
using Blue and SWIR channels



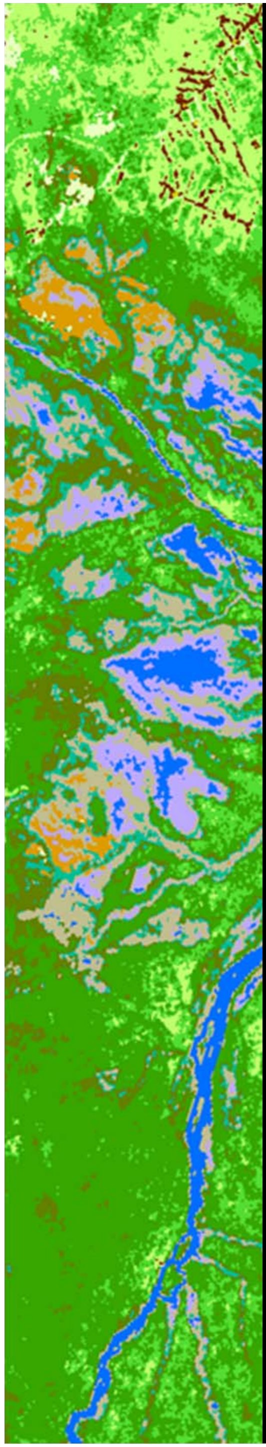


Processing

5 - morphological filter

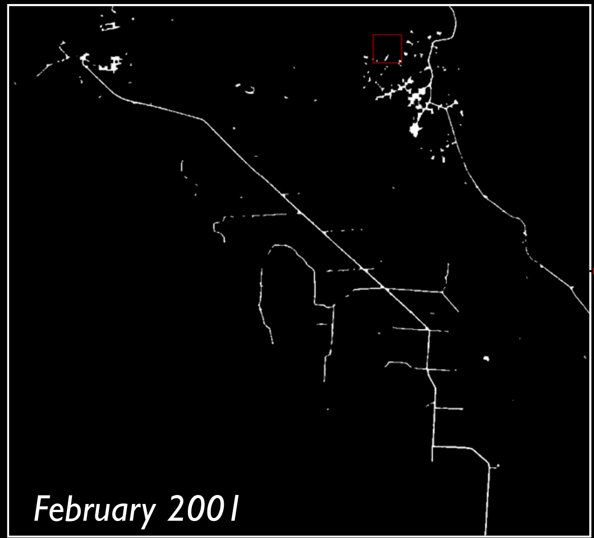


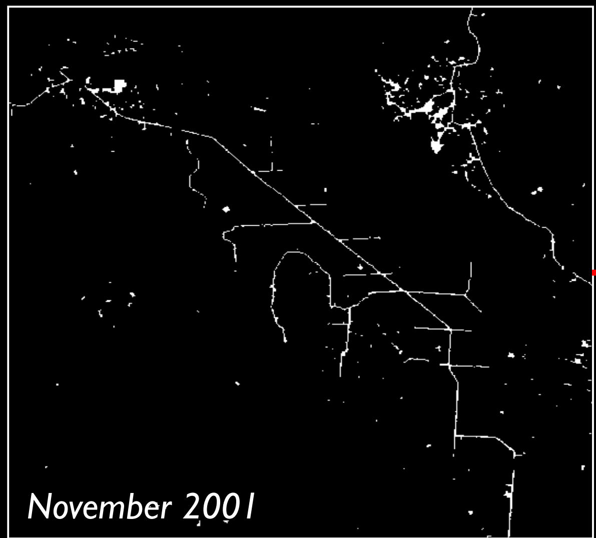
50 pixels size with an elongation rate of 3

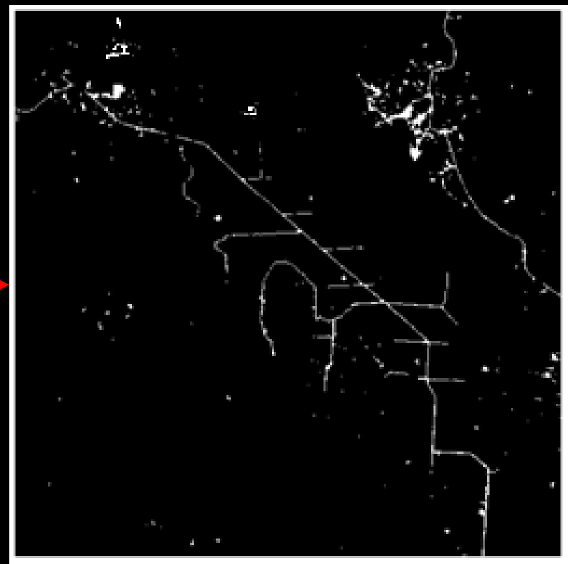


Processing

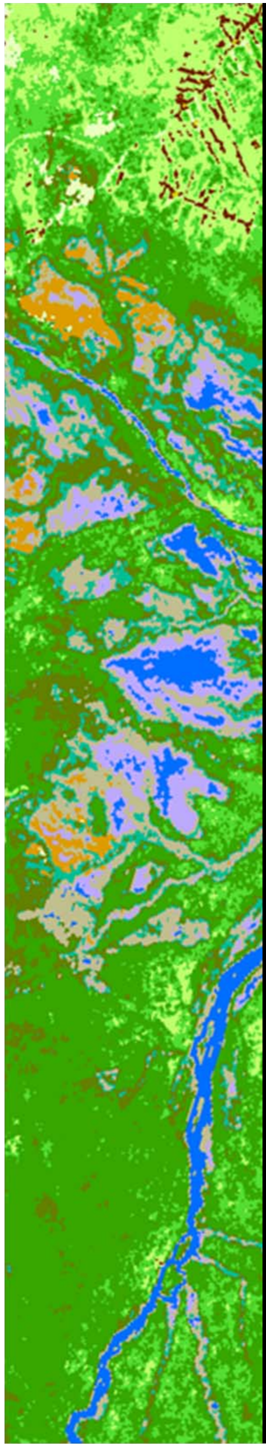
6 – Yearly synthesis





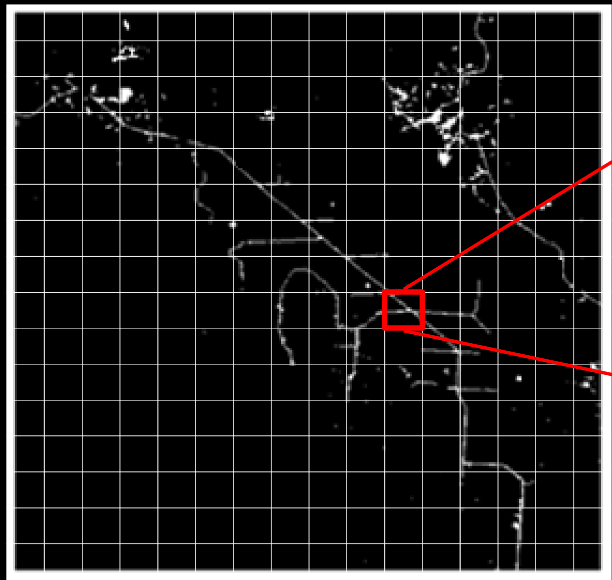


Annual bare soil mapping in 2001

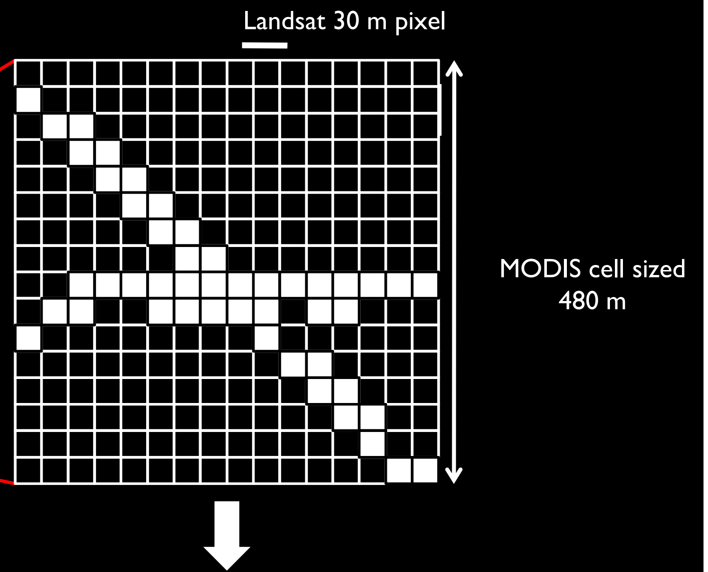


Processing

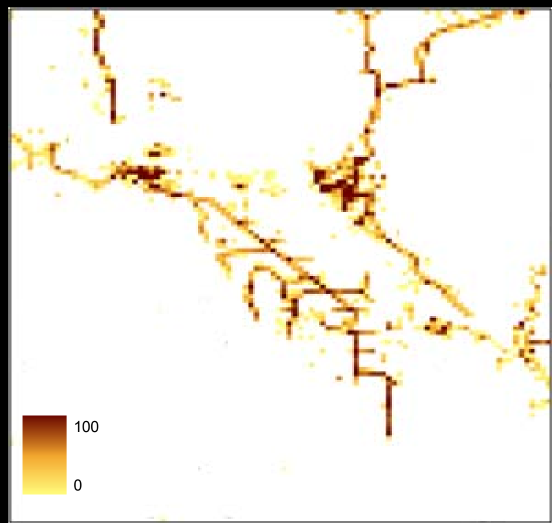
7 – Spatial synthesis



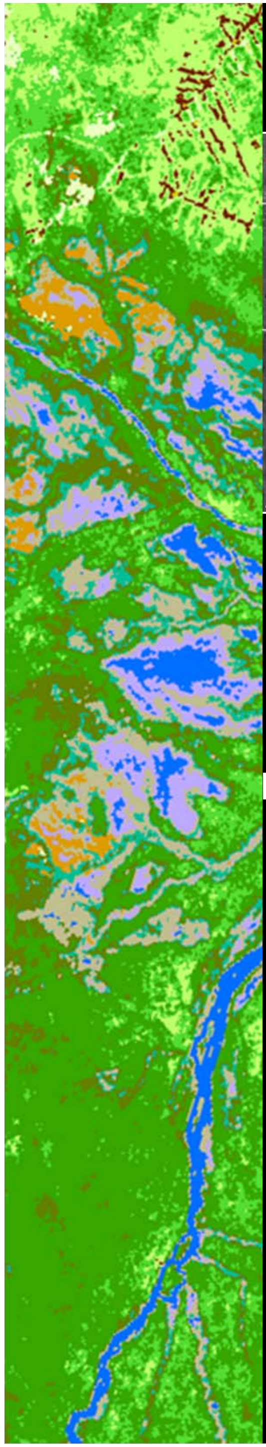
Annual bare soil mapping in 2001



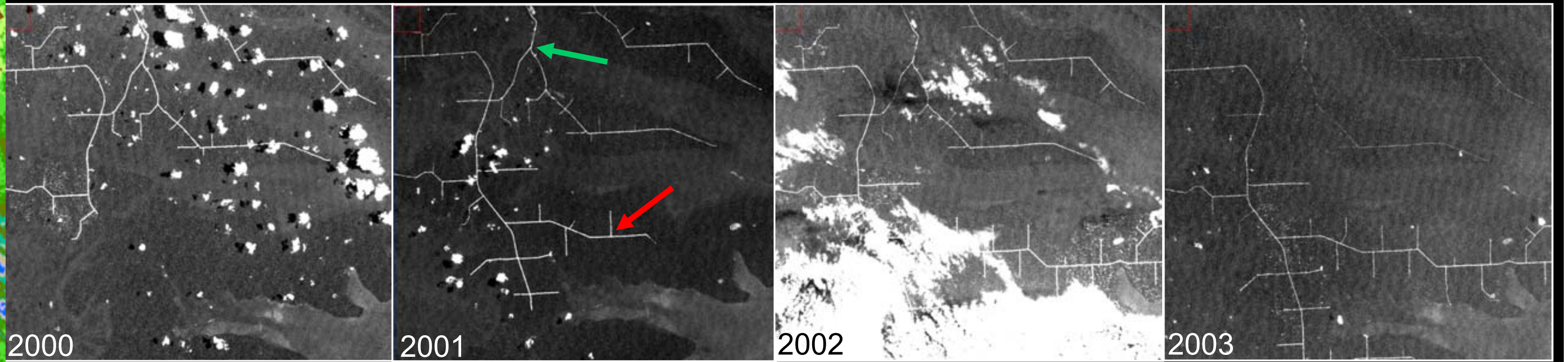
47 bare soil pixels detected
on a surface of 256 pixels
= 18% of bare soil



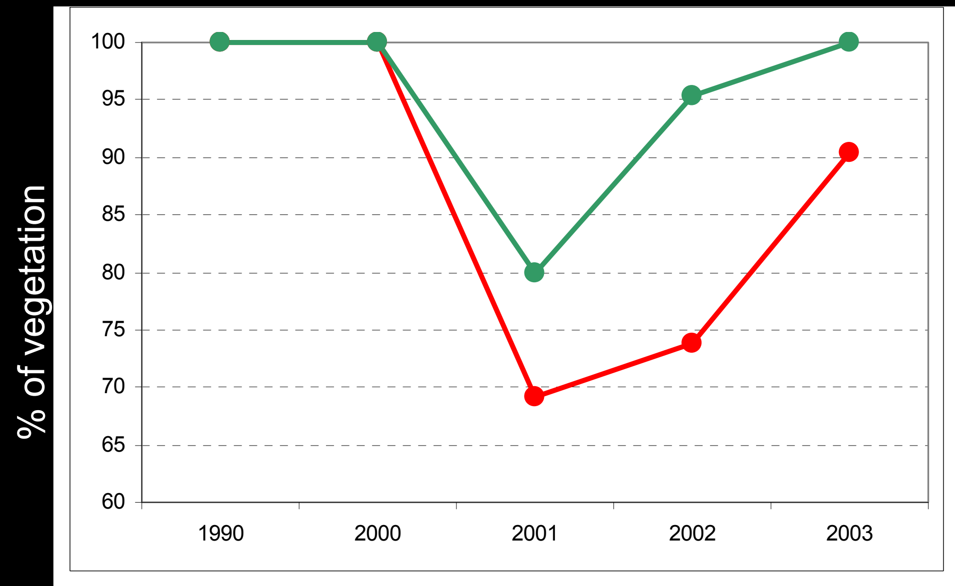
Spatial indication of bare soil in 2001



Cell monitoring

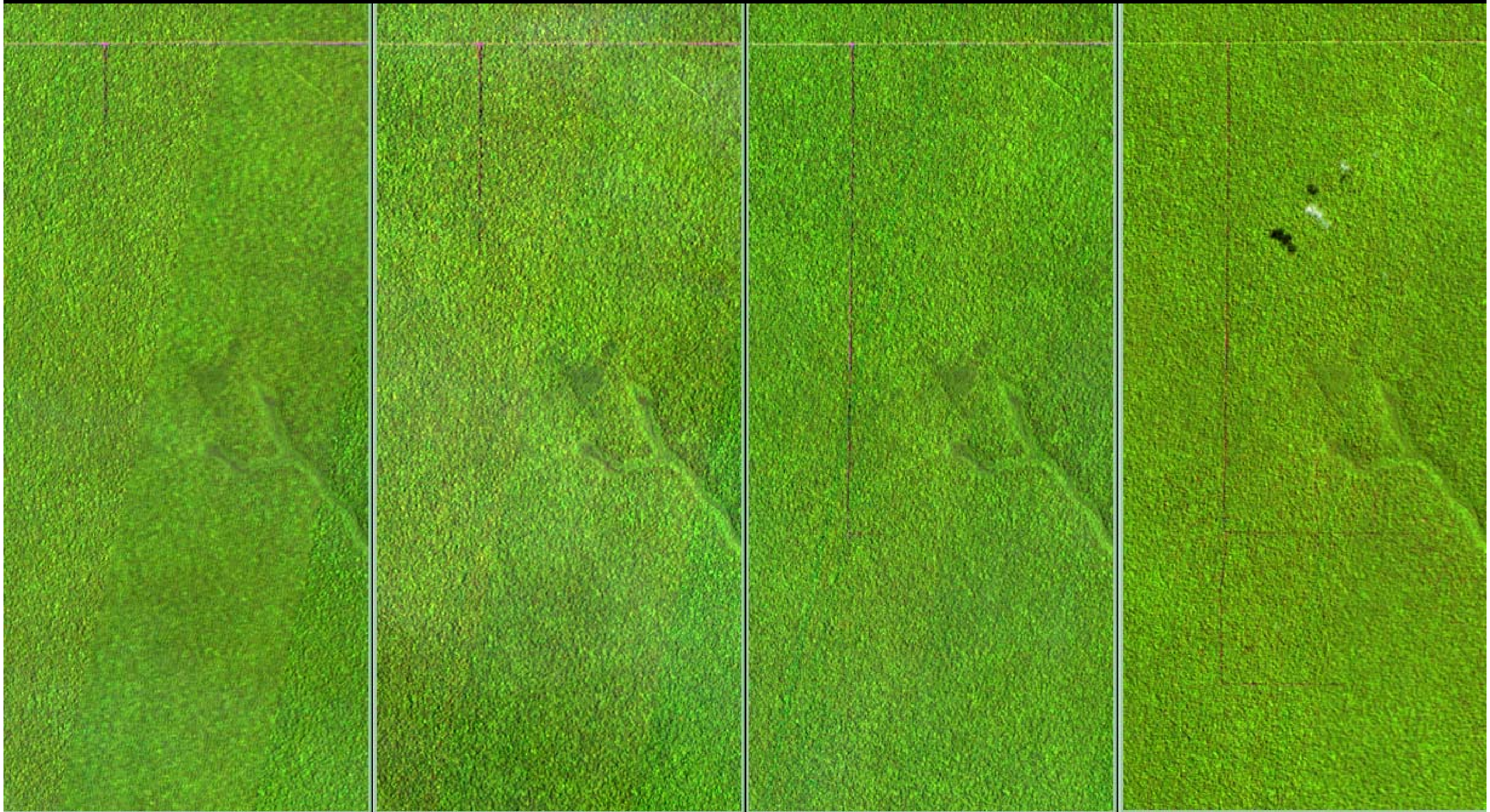


Bare soil index 0% 31% 26% 10%



Bare soil index decreasing 2/3 in 2 years

Monitoring logging activities using Sentinel 2 (perspective)

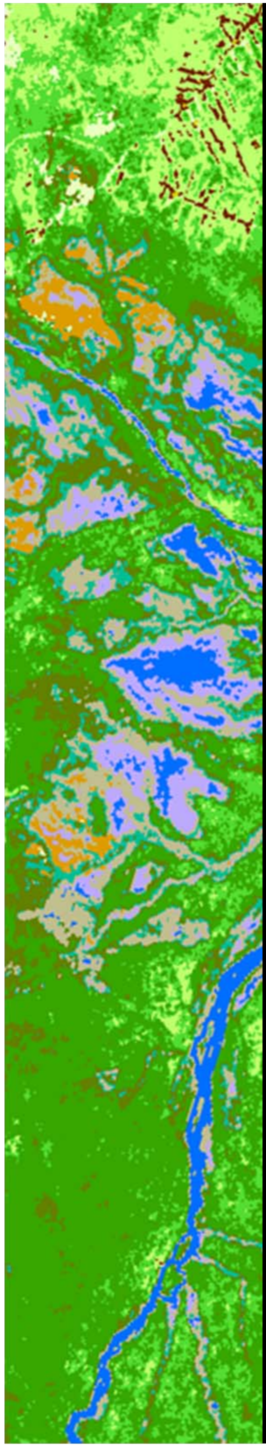


March 4th | April 3rd | April 13th | June 2nd

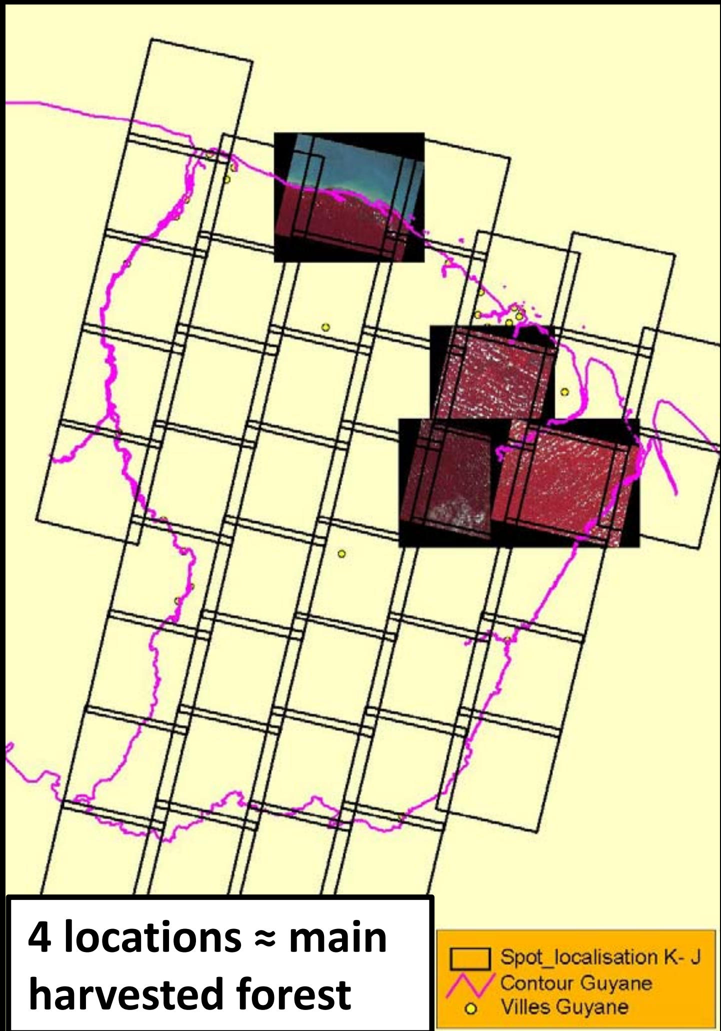
30 days | 10 days | 50 days

Opening | Logging

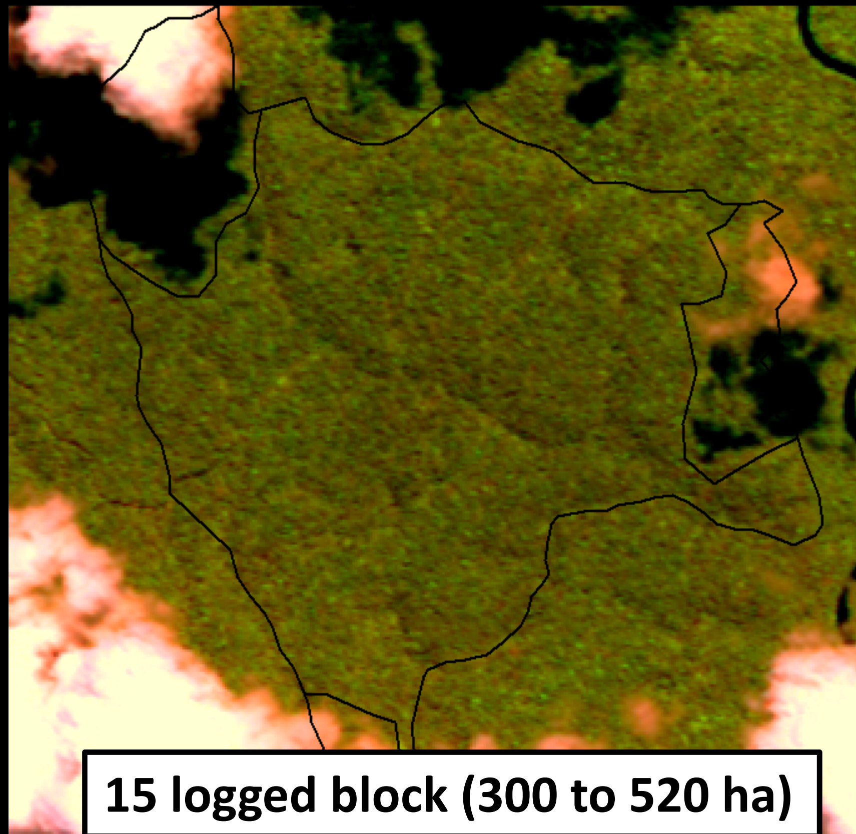
Location: North Congo
Spot-4 (Take-5) experiment

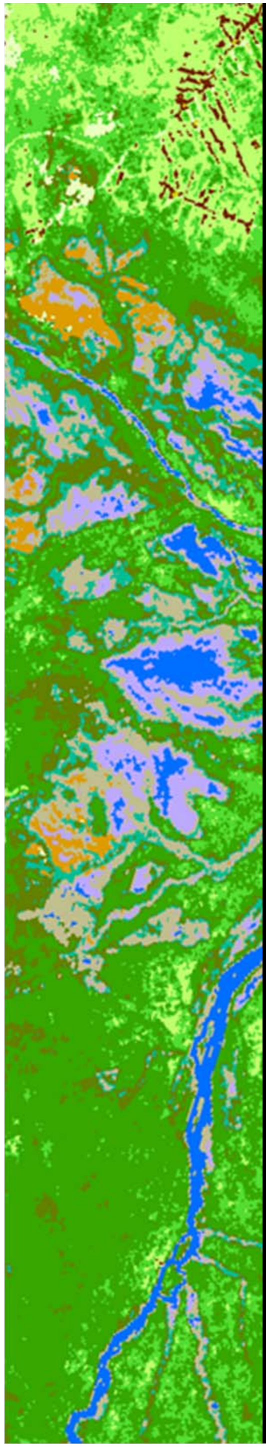


canopy gaps detection



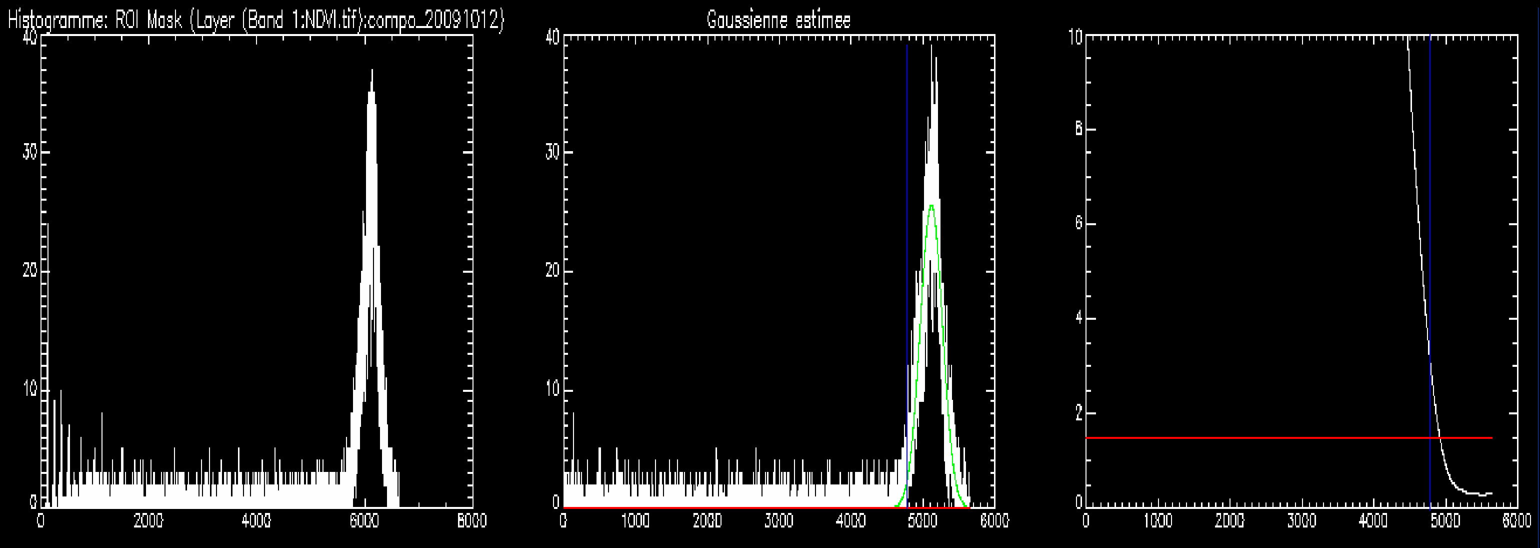
Medium spatial resolution optical satellite images produced by SPOT 5 and 4 (10 and 20 meters)





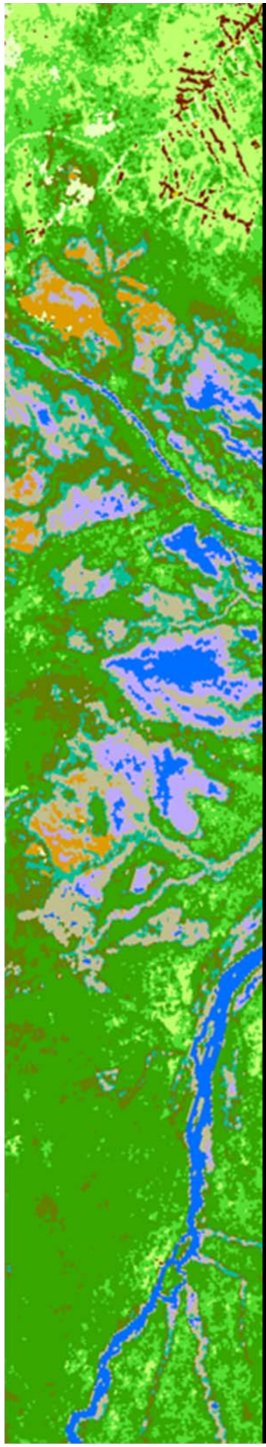
Remote sensing process

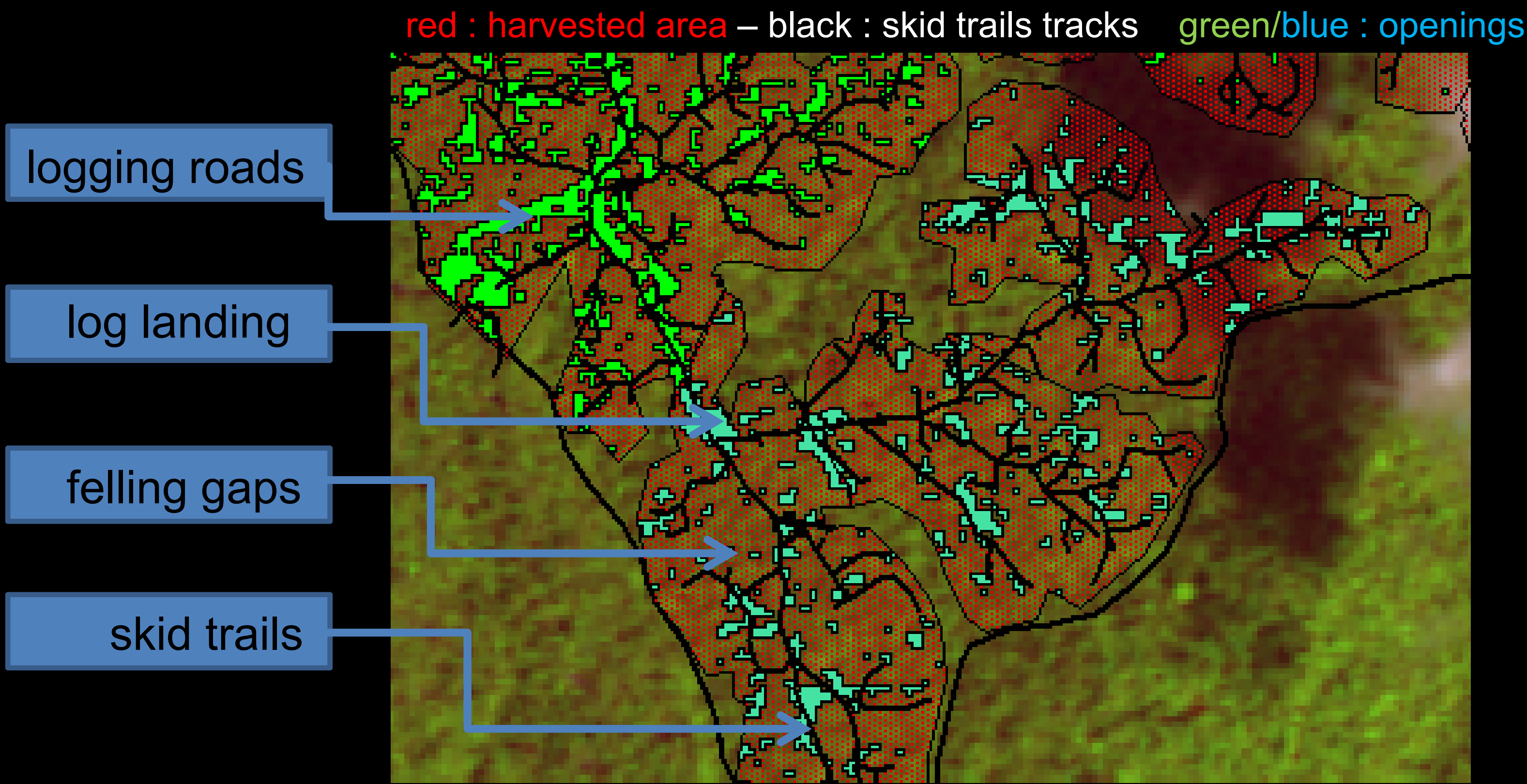
- Filter : Canopy (majority) vs. gap (minority) – all others objects are manually eliminated (clouds, shadows, water, etc…)
- Using 2 index NDVI (photosynthetic activity) and NDWI (moist content)
- Modeling a Gaussian distribution (least squares method) = detect a divergence threshold – significant difference between G function and effective histogram



Pixels values histogram → Gaussian function estimation → K divergence threshold

Results : impacts map

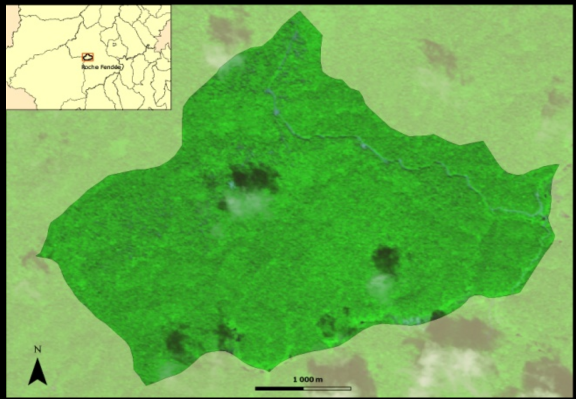




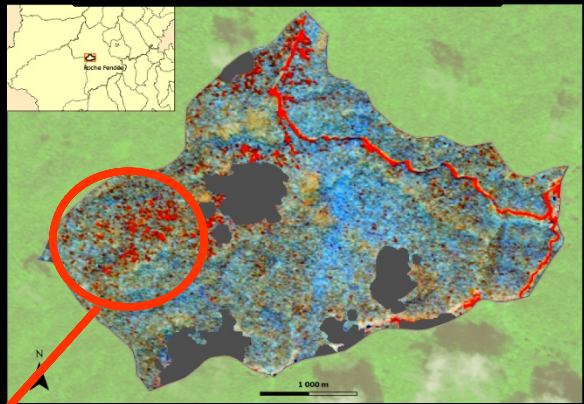
- Visible during 6 months to one year
- For a two years long logging operation – complete impacts can be mapped from the cumulative information collected on at least 6 images

Monitoring logging activities : logging impacts

SPOT-5, RFE-65 plot
November 7th, 2010



Multi-index color composite
(NDVI, NDWI and MIR)

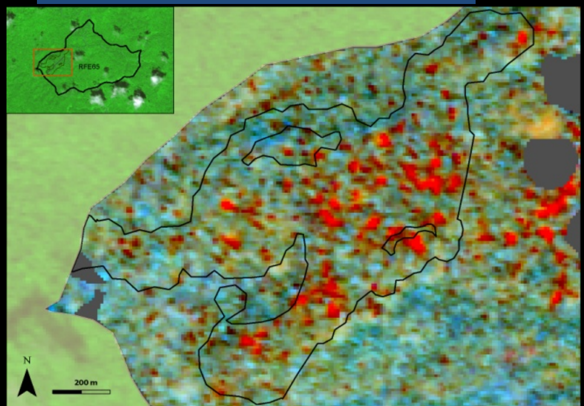


In French Guiana, 10.000 ha are exploited per year

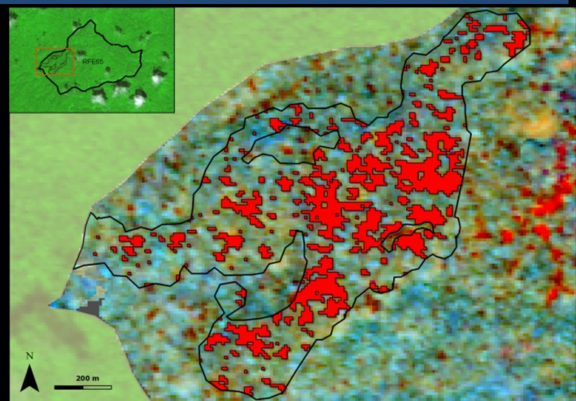
Thanks to the SEAS reception station these areas are regularly monitored using SPOT-5 (10m)

Development of a Timber Quality Index within the certification framework (PEFC and FSC)

Production Unit (78ha)



Impacted areas digitalization



From Spot / Sentinel-2

20,8ha impacted (26,6%)

From logger

308 trees for 1550 m^3

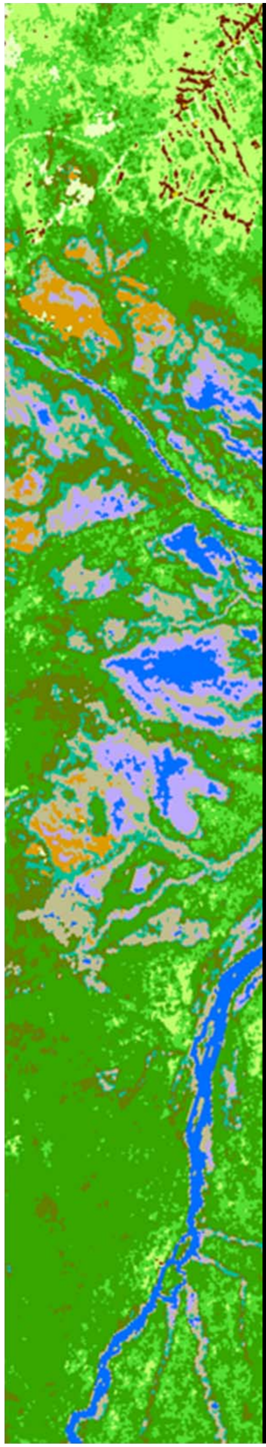
Timber statistics

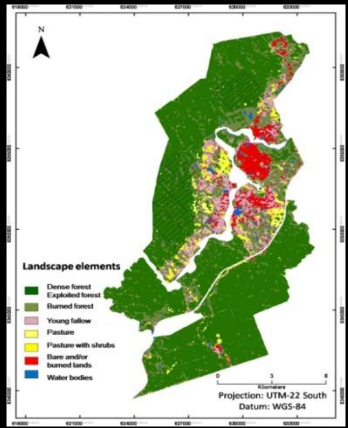
3,9 trees/ha and 19,8 m^3/ha (5m^3/tree)

Timber Quality index

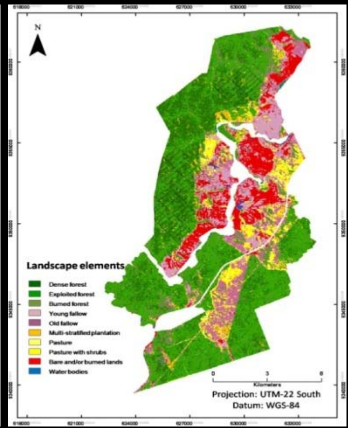
675m² impacted per tree
134m² impacted per m^3

Land cover monitoring: from local to regional scale

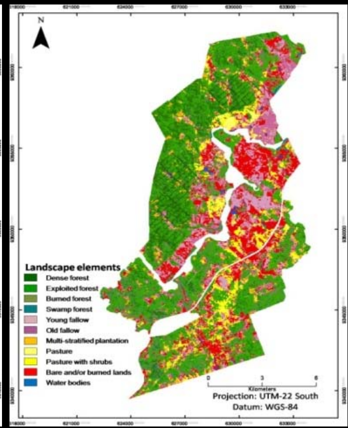




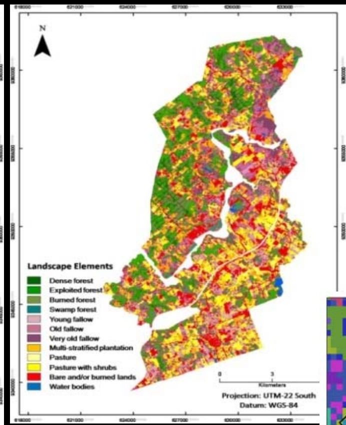
1986



1992

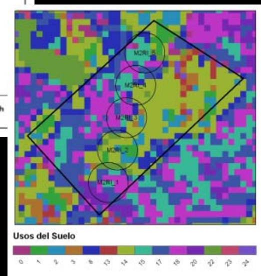


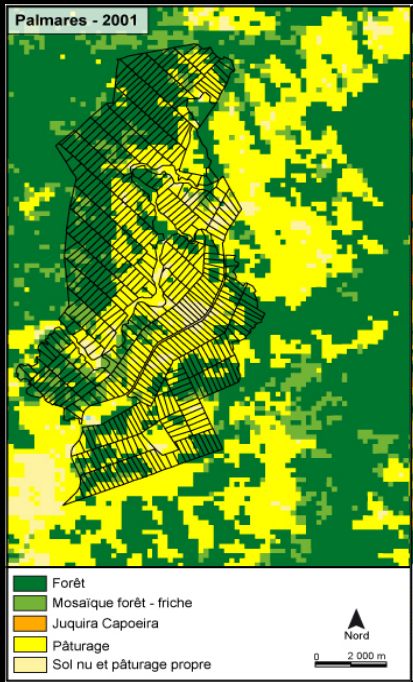
2001

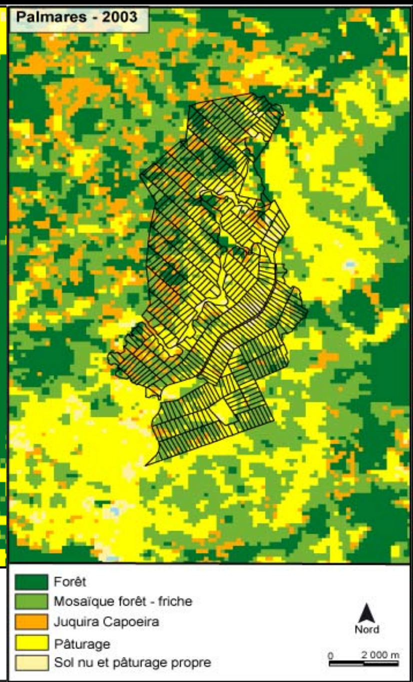


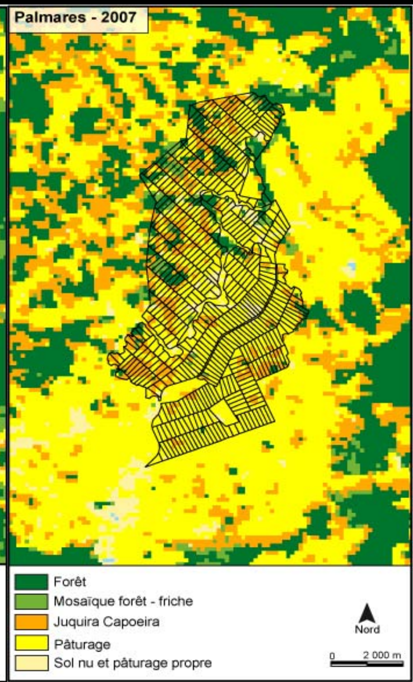
2007

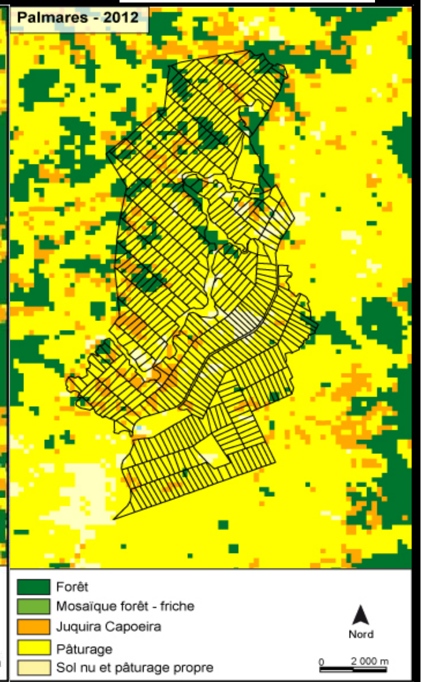
Ecosystem services measurements

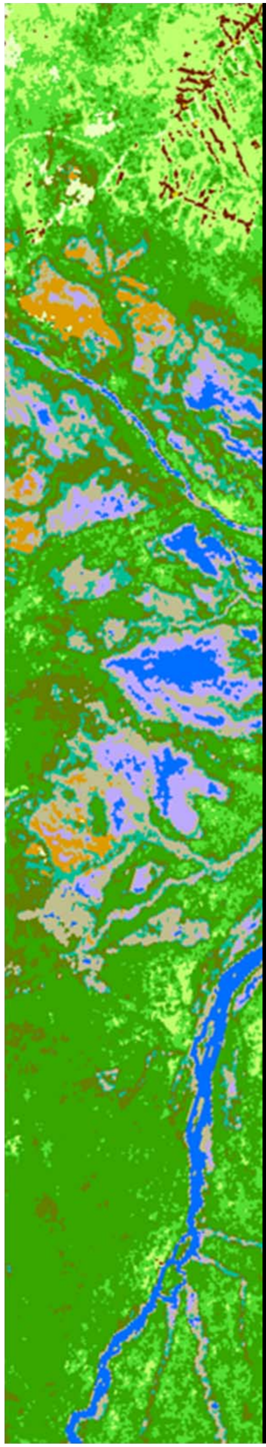




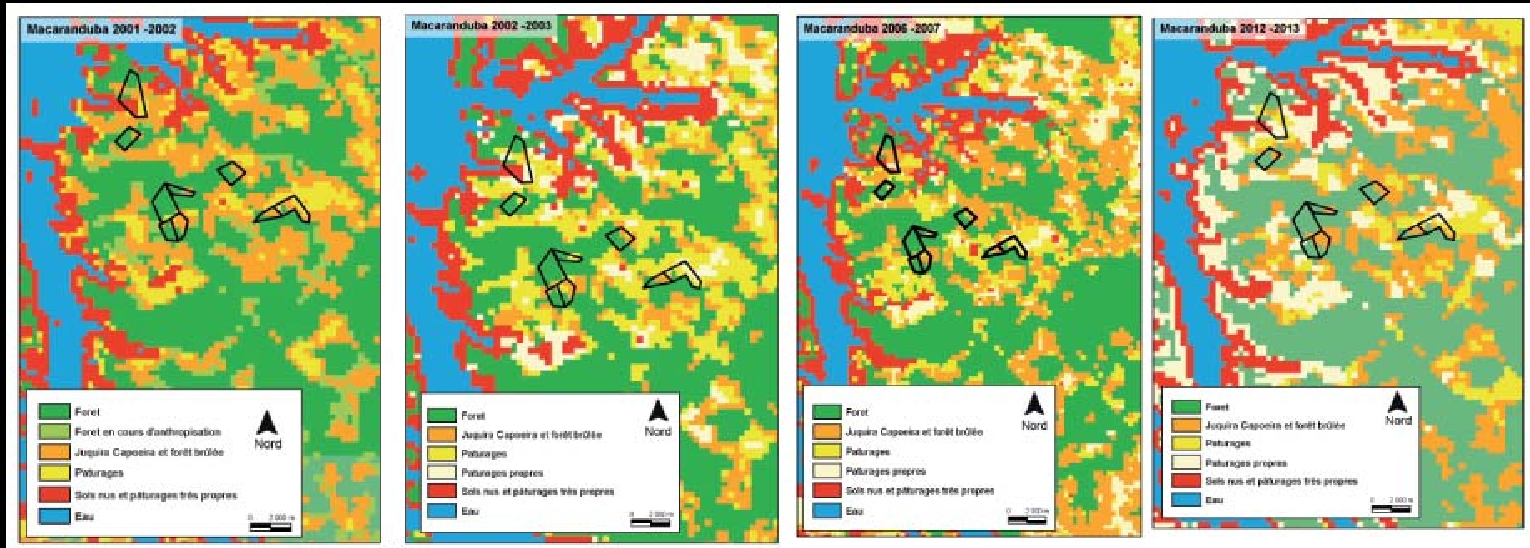




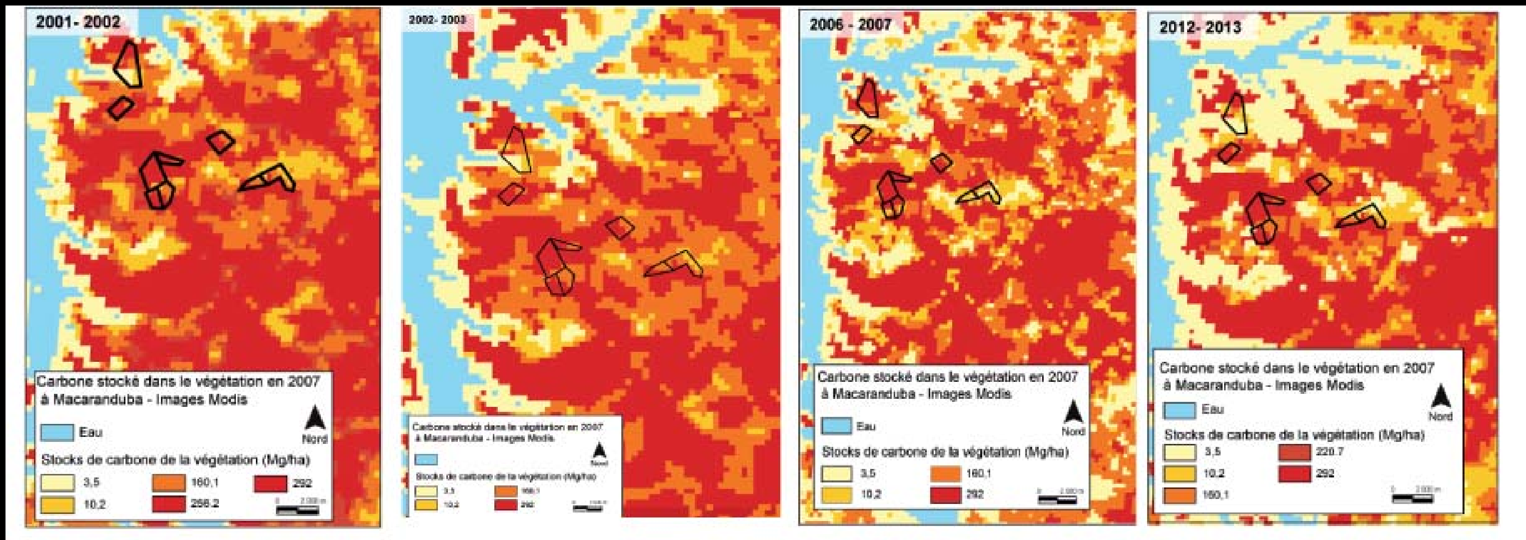




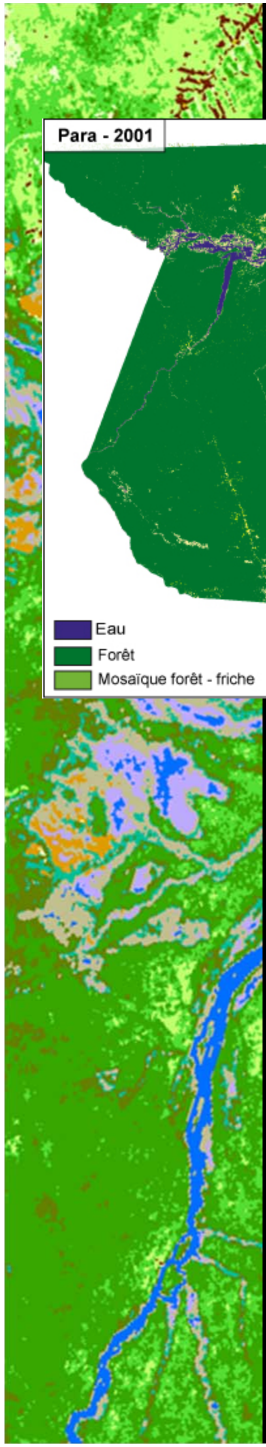
Ecosystems services modeling

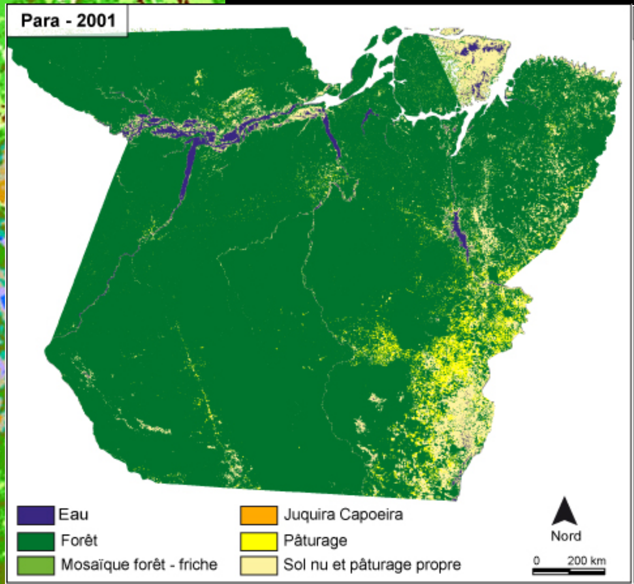


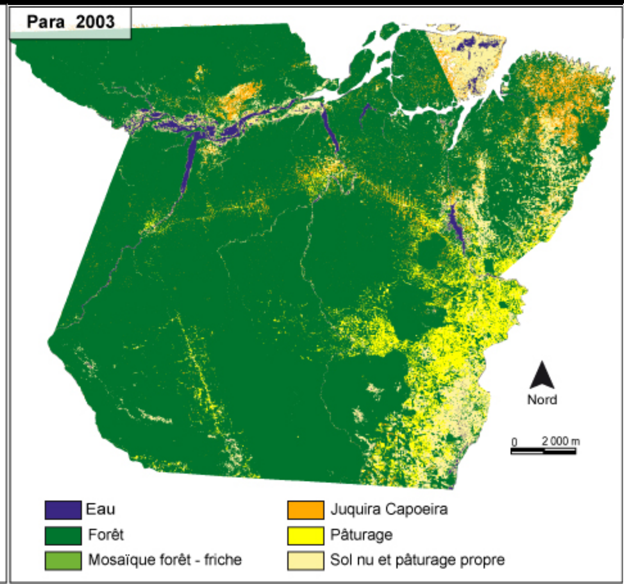
From Land cover to carbon

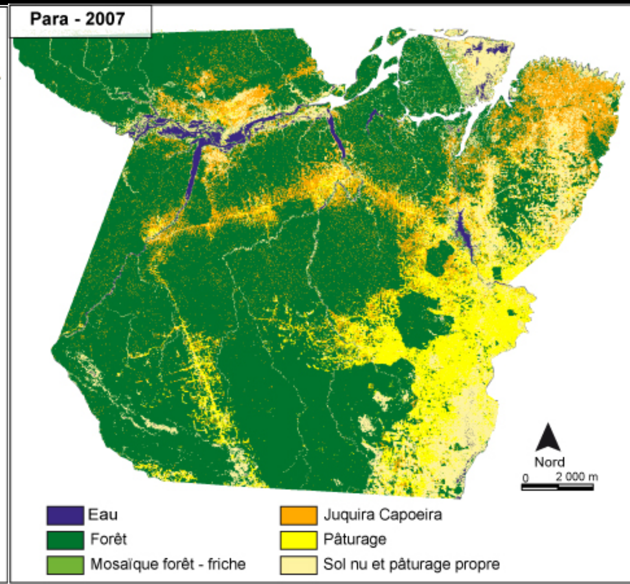


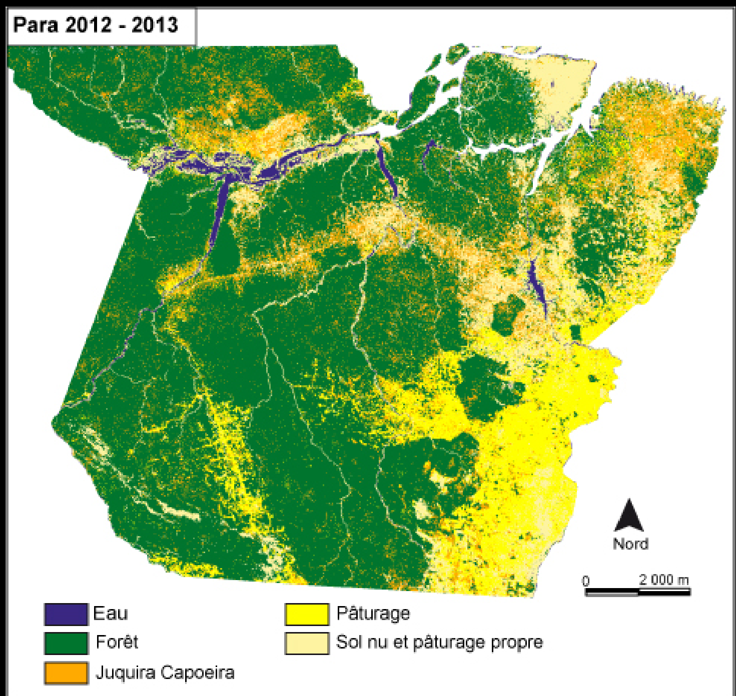
Land cover spatialization to model ecosystems services

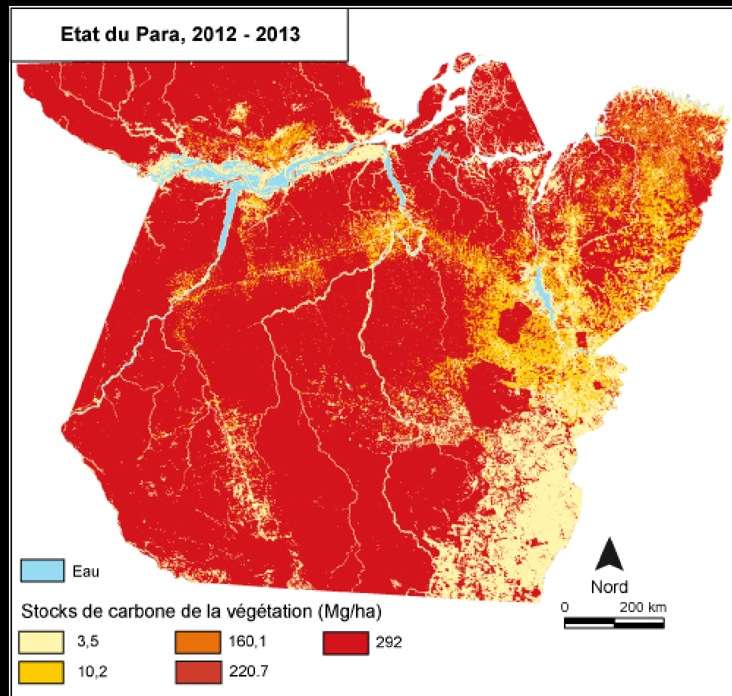


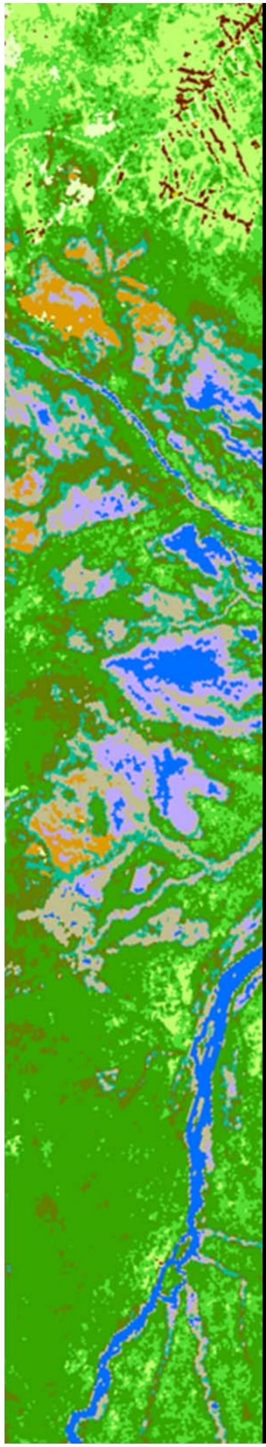












Conclusions and perspectives

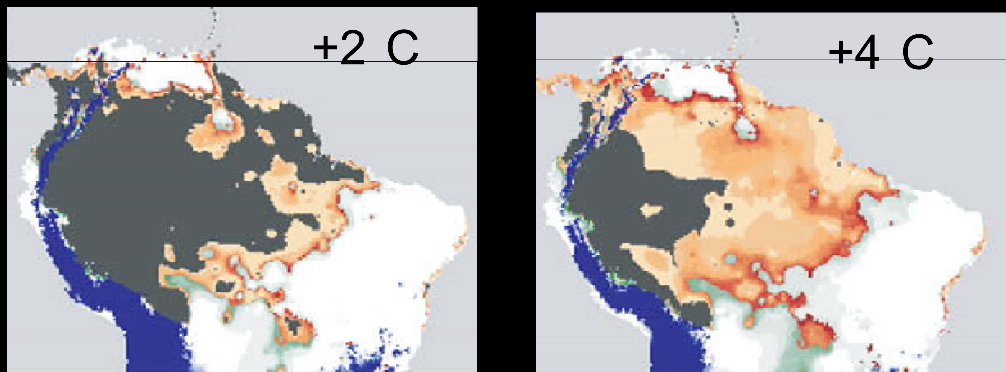
- Remote sensing appears to be a powerful tool for monitoring in space and time

- Scaling-up from local log to regional degradation index evaluation is a challenge

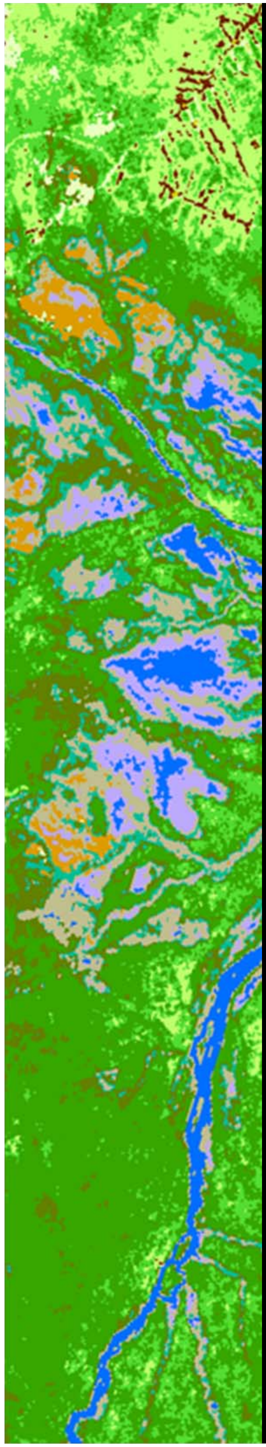
- Improving tropical forest land cover classification is one key

- A second key is to better estimate the forest degradation using low resolution data (MODIS or associated sensors)

- It may be possible to do using MODIS (250m), Proba-V (100m) or Sentienl-2 (10, 20 and 60m)



All this within the climate change context (Zelazowski *et al.*, 2011)



Thanks for your attention