Satellite monitoring of desertification
INRIA project-team Clime

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Land degradation: the major cause of desertification

Human activities are the main causes of land degradation:

•Socio-economic pressures: high demand for agricultural surfaces (crops, pastures) for food supply, export.

which in turn set-up biophysical pressures on the environment:

•Unsuited land use/management:

- Deforestation to gain surface for cattle and crops,
- Intensive agriculture, mono-cultivations.

•Inadapted agricultural practices:

- Ovegrazing,
- Intensive irrigation,
- Massive use of fertilizers.

Various aspects of land degradation

•Physical processes: change of soil structure by crusting, compaction, erosion.

•Chemical processes: acidification, alkanisation, salinisation, loss of fertility.

•Biological processes: loss of biodiversity, of biomass.

(erosion of a wheat field, USA; gully erosion, Brazil)

Consequences of land degradation

•Economic: loss of a significant portion of arable lands and of their productivity, threat on food safety (estimated yield loss due to degradation, in Africa: 8%). This loss of productivity can cancel or even overcome the gains due to improved technology and organization.

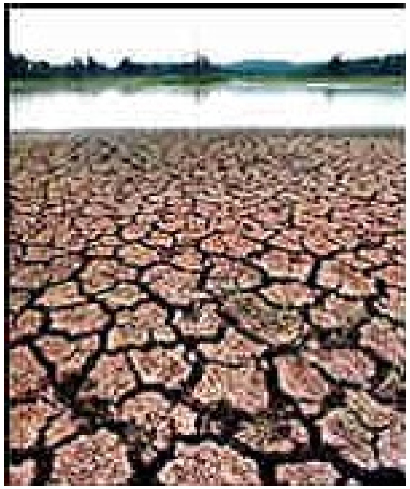
•Consequences:

- On water: water contamination, sedimentation (e.g. high sedimentation of the Yellow River consequence of the Loess plateau deforestation some 1000yrs ago).
- On air: non-vegetated soils are prone to wind erosion, causing episodes of high aerosols load in the air (more frequent and intense sand winds in China)

Consequences of land degradation

•Floodings: compact soils increase surface run-off and decrease ability to capture water -> larger and more frequent floodings downstream.

•Desertification: top of soil removal causes soil sterility and accumulation of sand (illustrations: dry banks of the Yellow river and desertification of Tulufan/Xinjang).



Importance at global scale

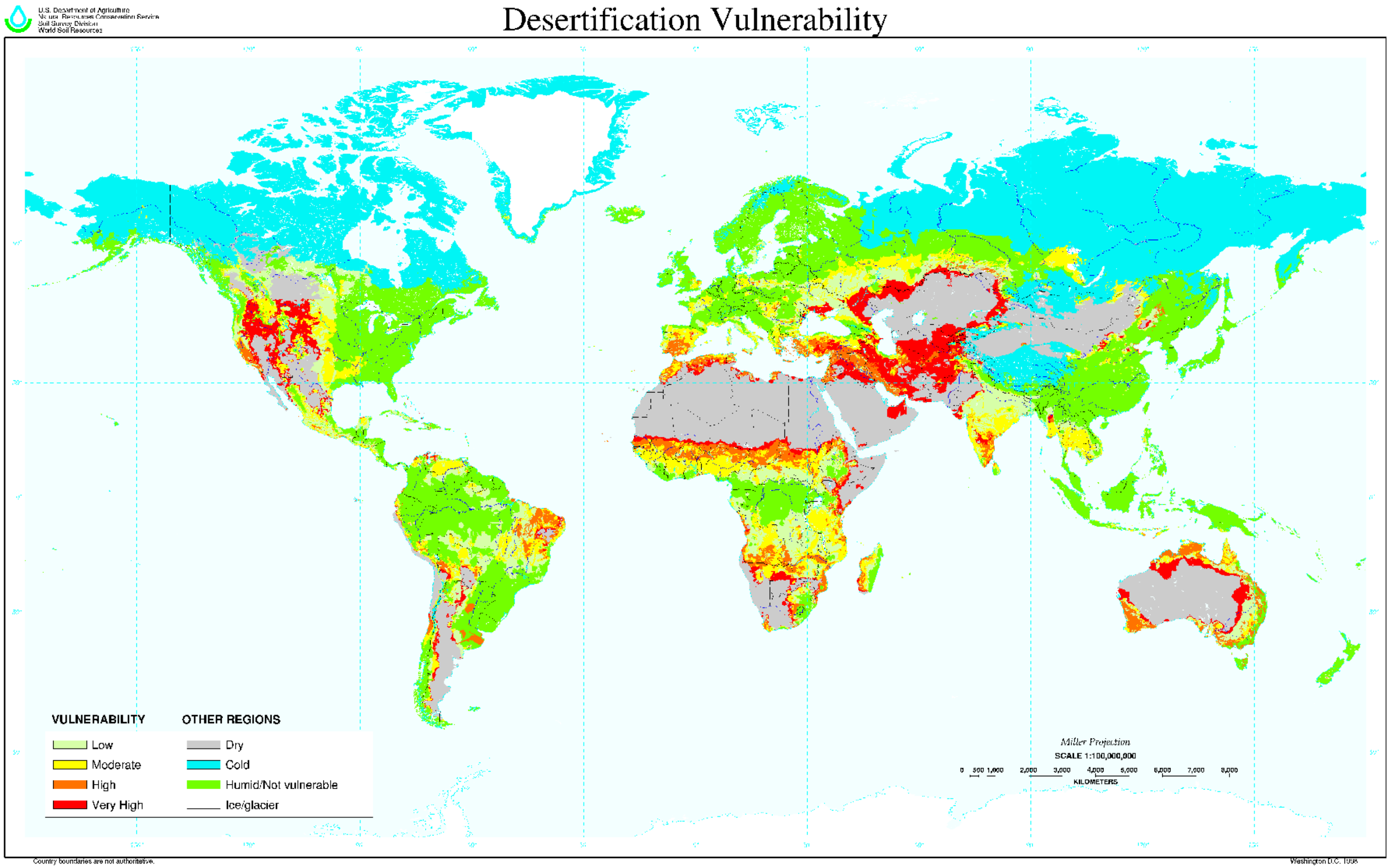
•Land degradation impacts land surface all other the world even outside dry areas.

•In arid/semi-arid areas (1/3 of total land surface) it causes desertification: more than 2/3 of Earth's drylands are degraded and threatened by desertification.

- North America: 74% of dry areas are degraded;
- South America, Africa: 73%;
- Asia: 71%;
- Europe: 65%;
- Australia-Pacific: 54% (Dregne & Chou 1994).

•These figures tend to increase as land degradation is a vicious circle, very hard to combat: degraded lands are more prone to wind and water erosion than non-degraded lands.

Vulnerability to desertification (USAD)



Situation in China

•Most critical problem: extension of deserts (3,600 sq.km of grassland taken by the desert every year), causing loss of $50 billions/year to Chinese economy, 24,000 villages abandoned, loss of agricultural land (in China arable land is only 7% of total surface).

•Planned countermeasures give China an unique expertise in fighting desertification:

- the Green Great Wall, a forest belt as long as 4,000km to hold back the Gobi desert (completion expected 2074).
- Change of agricultural practices (terraces, change of land use policy);
- Biological approaches to lower soil vulnerability (biological carpet);
- Cloud seeding.

Need of satellite monitoring

- It is very hard to combat desertification once it has started.
- Monitoring must be performed:
  - For prevention: detection of precursors of desertification:
    - Deforestation,
    - Overgrazing.
  - For recovery: mapping of desert evolution.
- Monitoring must be performed at different spatial scales: local (land parcels) -> regional (catchment) -> national & global,
- and different temporal scales:
  - Short term phenomena (deforestation by tree cut or burning)
  - Progressive transitions (year after year monitoring of vegetation strength to detect erosion)

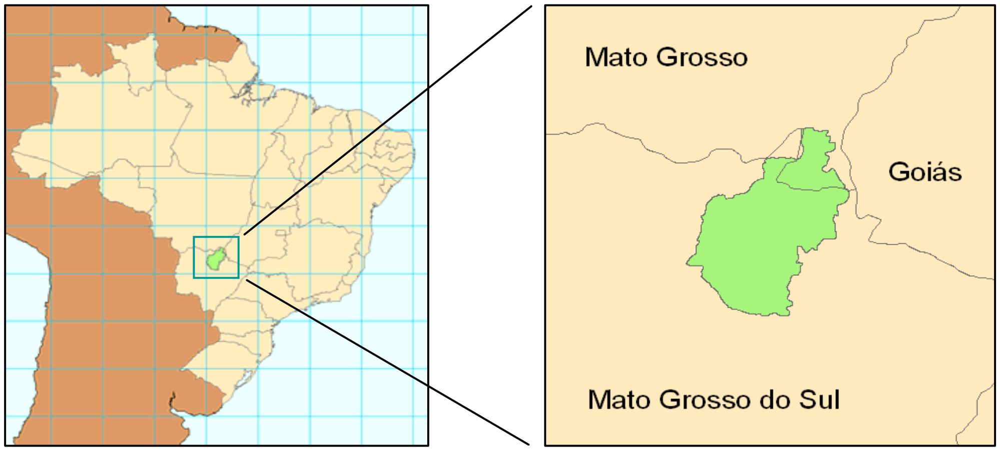
Approach developed by Clime

- •Problem to be solved: monitoring degradation over large areas at low cost.
- •Low resolution data is required for monitoring large areas. To monitor vegetation, use of:
  - AVHRR: 1km, daily vegetation indices;
  - MODIS: 250m, daily vegetation indices.
- •Monitoring is formulated as analyzing time-series of vegetation indices (temporal profiles):
  - To what types of land use correspond different temporal profiles?
  - What mathematical tools to represent and interpret temporal profiles?
- •To answer these questions, training is required:
  - Performed on well documented sites;
  - Based on fusion with high resolution data (Landsat, Spot, completed with field data)

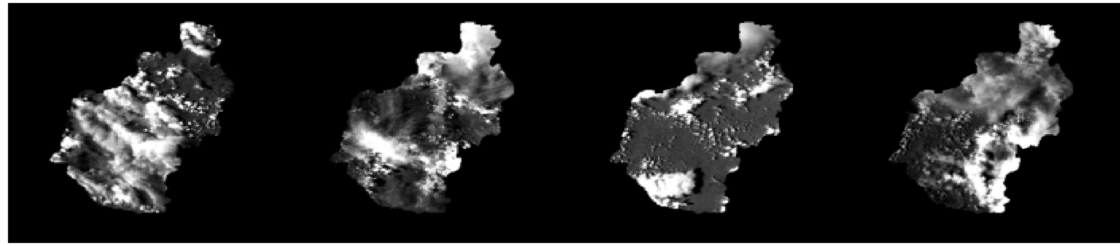
Illustration: deforestation detection in Brazil

•Training area: high Taquari basin (28,000 sq.km), in the Pantanal area (UNESCO world reserve of biodiversity), threatened by erosion and siltation.

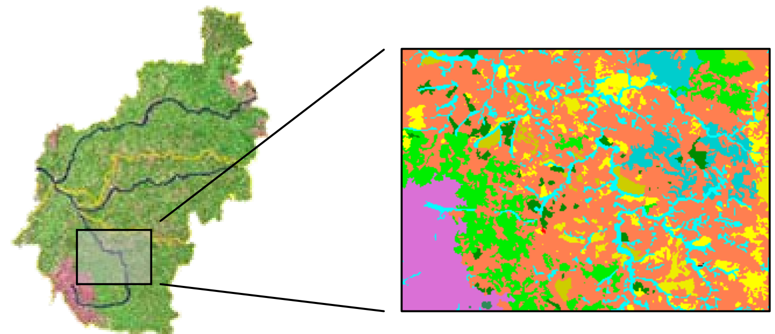
•Training area representative of dry forest-savannas, in view of monitoring the Rio de la Plata basin (3,000,000 sq.km)



Training



•One year of MODIS data

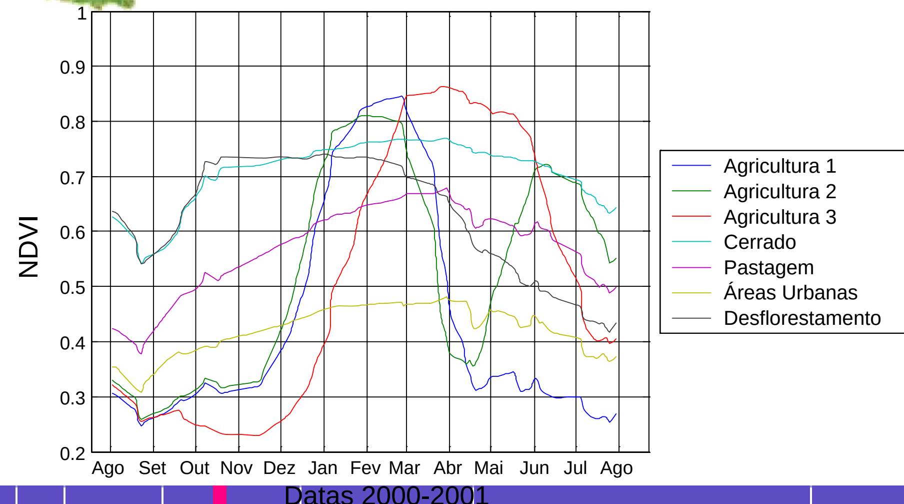


•Classification of a Landsat images in 14 land uses

Split of agricultural classes

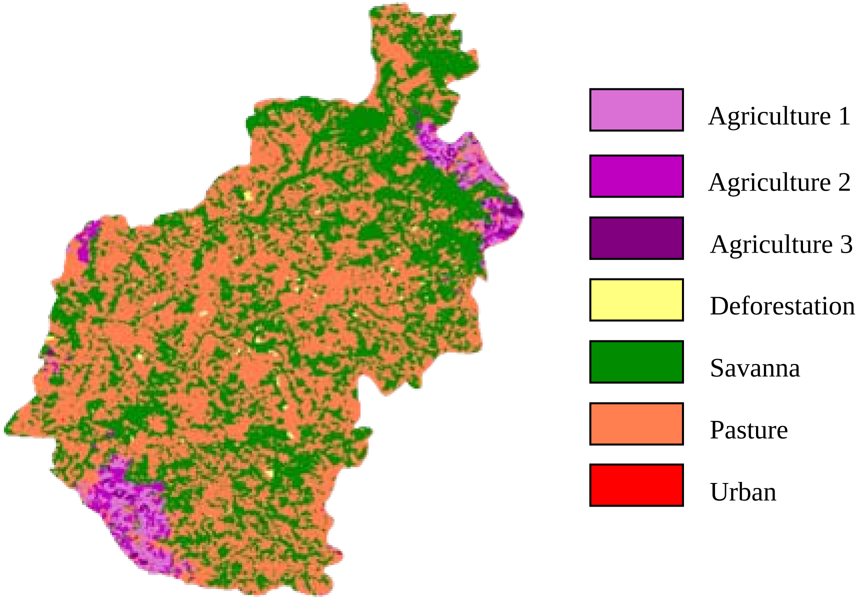
Merge of wooded classes

•7 different land use classes detected with MODIS data, and their mean profile

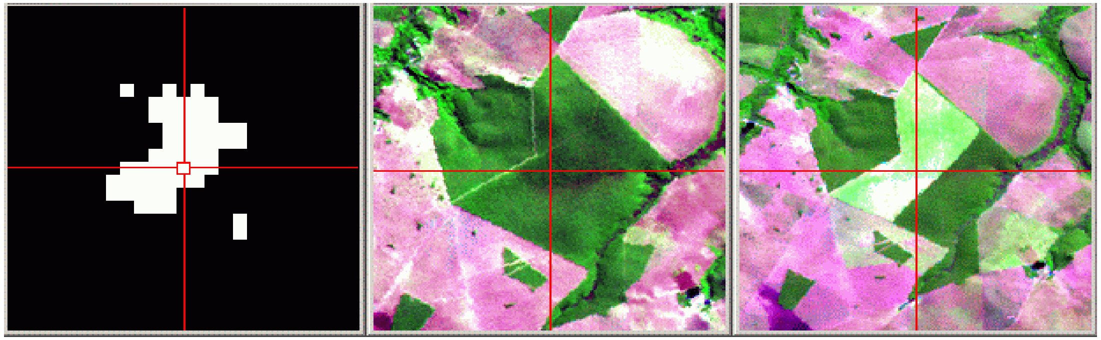


Deforestation detection

•The observed temporal profiles are analyzed to perform a low resolution classification:

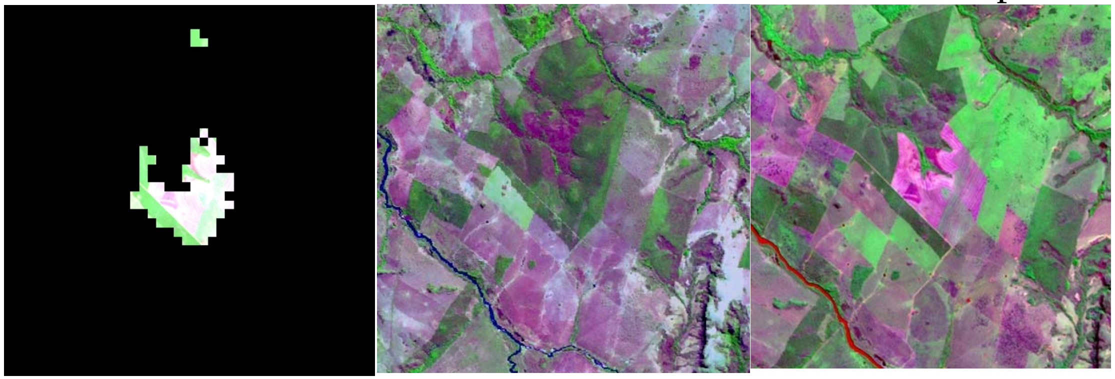


Validation



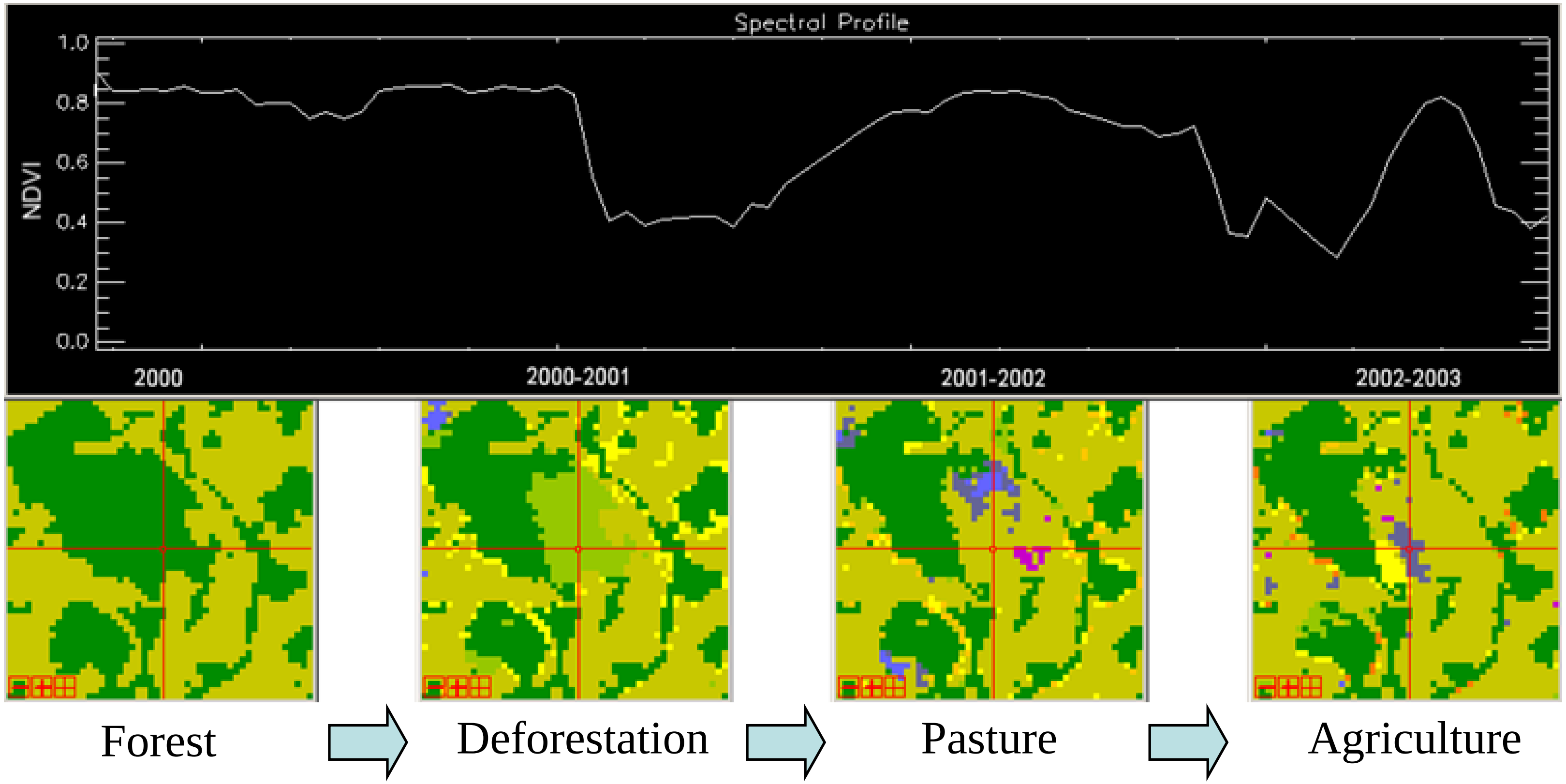
6,25 km

Déforestation LANDSAT avant LANDSAT après



Deforestation and land use monitoring

•Multi-annual analysis of observed temporal profiles, example:



Conclusions & perspectives

•Expertise gained on deforestation and land use change monitoring over large areas through project with Brazil.

•Ongoing work on:

- Process automation,
- Multi-annual robustness.

•Perspectives on desertification:

- Deforestation and land use changes considered as precursors of desertification: allow to take countermeasures in advance.
- Direct desertification monitoring. Need to devise a methodology to monitor progressive changes occurring on several years/decades: vegetation removal due to overgrazing/erosion, top of soil removal.
- Set-up of an international partnership on desertification.