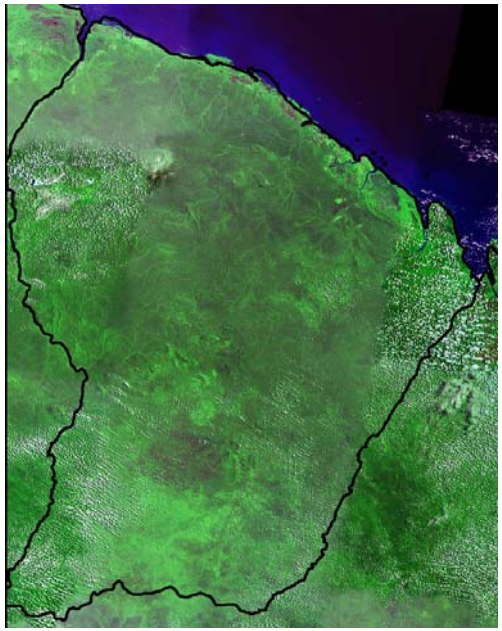
# MONITORING LAND USE AND LAND USE CHANGES IN FRENCH GUIANA BY OPTICAL REMOTE SENSING





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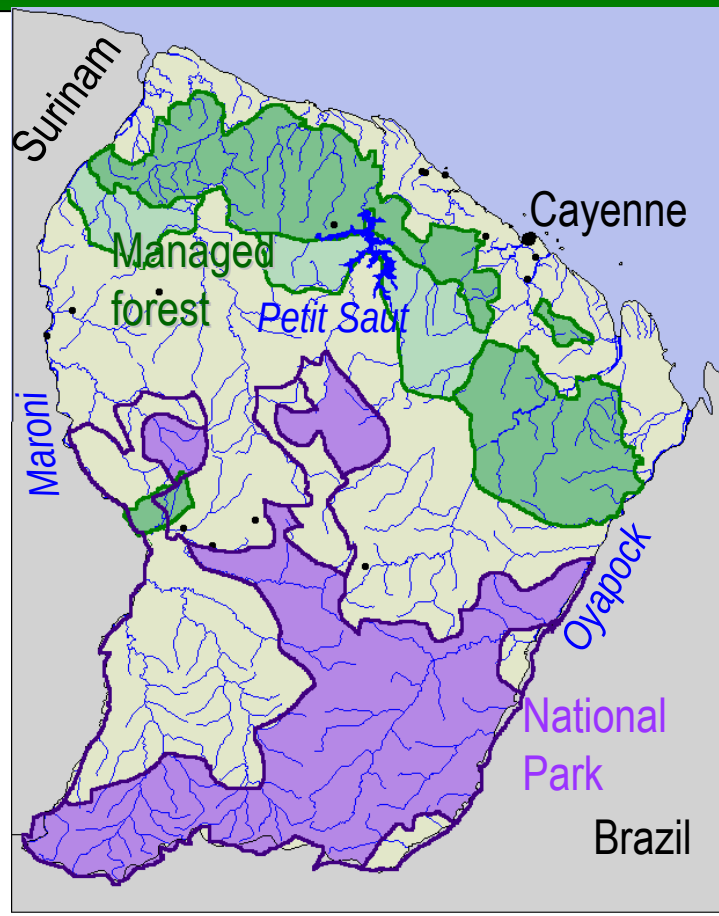
# Context : French Guiana

- French overseas “Department” ~84 000 km²
- Human activity concentrated in a narrow coastal strip and along main rivers
- French Guiana forest
  - *~80 000 km² of tropical forest.*
    *~ 95% of the total territory*
    *~ 1/3 of total French forest (including mainland)*
- Deforestation causes in French Guiana
  - Traditional shifting cultivation:
    Small individual areas (0.3 to 1 ha)
  - Extension of modern agriculture
  - Gold mining: Small individual areas - Legal or illegal –
    About 12 000 ha since 1990 - Along streams and rivers
  - Petit Saut dam: Hydroelectricity – reservoir about 30 000 ha, Dam filling in 1994

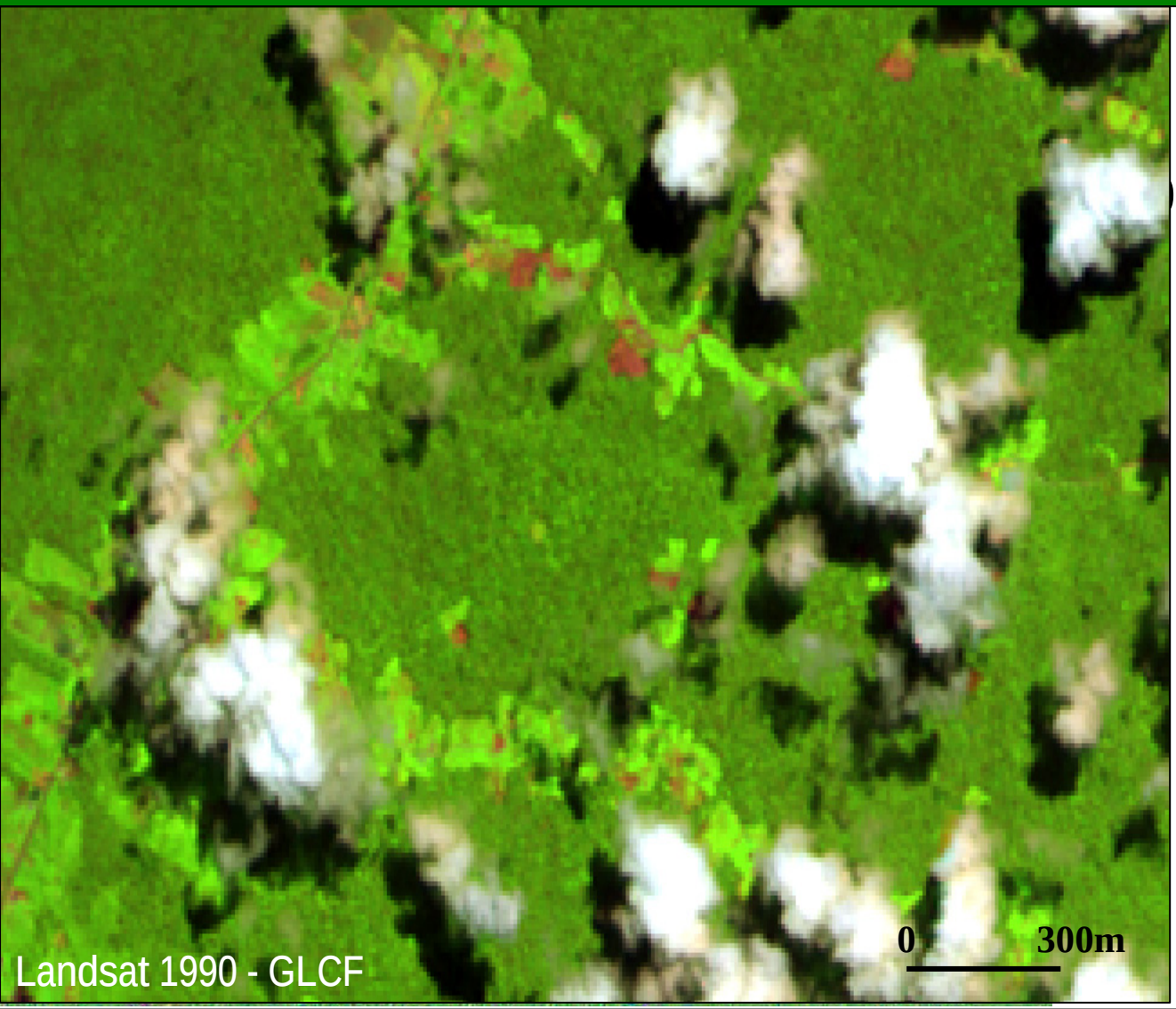


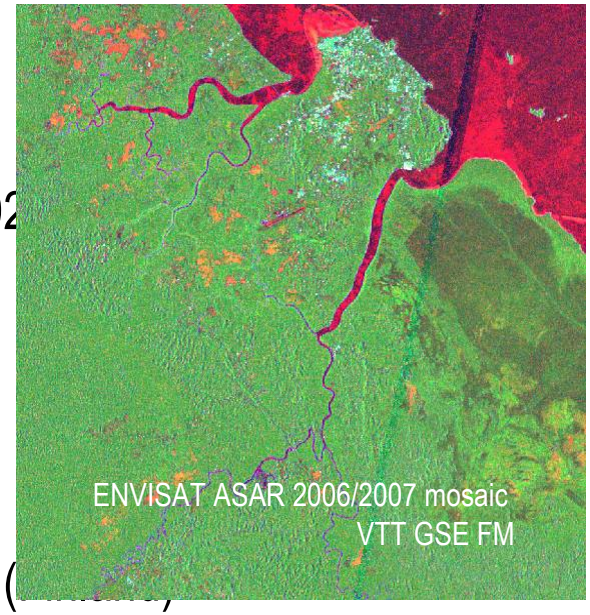

➢Limited deforestation concerning small parcels :
a challenge for monitoring

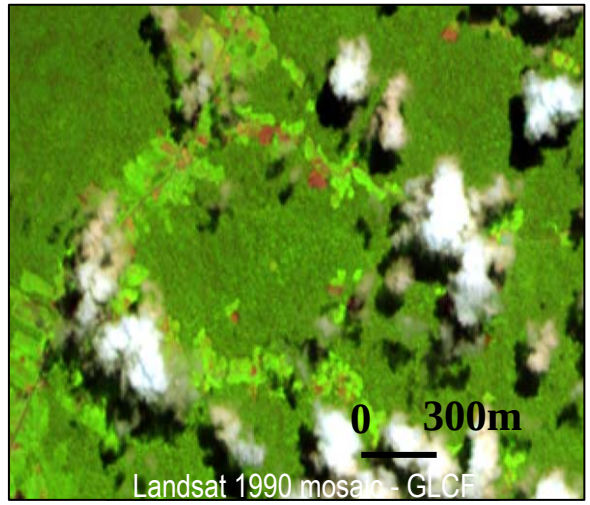
# French Guyana and Kyoto protocol

- Reporting on GHG emission and sinks in LUCF Sector
  - Article 3.3 : Aforestation /deforestation/reforestation since 1990
  - Article 3.4 : Forest management
  - Has to be carried out on the whole national territory, including overseas departments
- Specific constraints in French Guiana
  - France is the only Annex 1 country with tropical forests
  - No preexisting systematic and exhaustive land use survey
    - Very recent and partial Land use inventory from the Ministry of agriculture (TERUTI LUCAS)
    - French NFI permanent inventory of forest resources is limited to mainland France
  - Impossibility to carry out a systematic ground based survey
  - No exhaustive Aerial photography mission
  - Important cloud cover

# Use of Satellite imagery



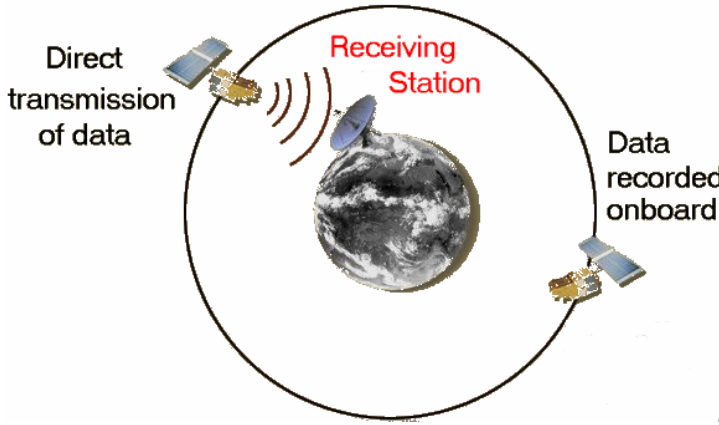



# SEAS-Guyane

- Multiple partner Project leaded by IRD
- Technologic platform for acquisition and processing of High resolution satellite data (SPOT et ENVISAT)
  - 2005: Installation of a new SPOT/ ENVISAT Ground Receiving Station in Cayenne

The Antenna


The receiving area



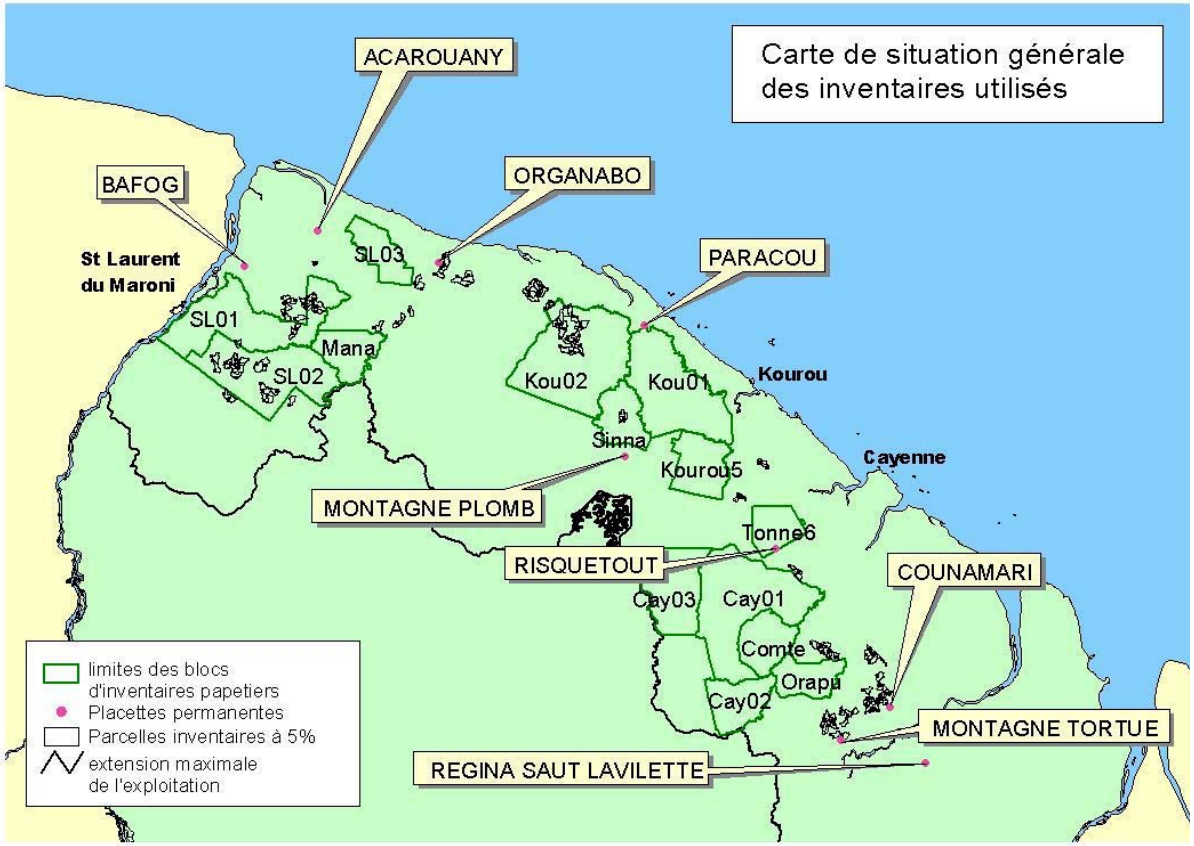

➢Dramatic Increase of SPOT image acquisition capacities over the region

# Objectives of the project

- In 2006 the French Ministry of agriculture put in charge the NFI of designing and testing a new LUCC inventory for French Guiana
- Objectives of the project
  - To produce a first global cloudless SPOT mosaic over French Guiana for year 2006
  - To test a first LUCC inventory for the 1990-2006 period
  - To define the inventory methods and process for the commitment period 2008/2012
- Methods
  - Statistical inventory ≠ wall to wall mapping
  - On the basis of stratified sample points
  - By visual photo-interpretation of the 2006 SPOT and 1990 GLCF Landsat Mosaic
- To be combined with emission factors
  - Dendrometric expertise carried out in 2005 by ONF, CNRS and CIRAD
  - From existing inventory data and experimental protocols
  - ➢ One global of Volume per hectare for French Guiana forest 350 t/ha
    Above and below ground dry biomass – soil biomass

# Emission factors

- ONF / CIRAD/ CNRS Dendrometric expertise
  - Dispositifs



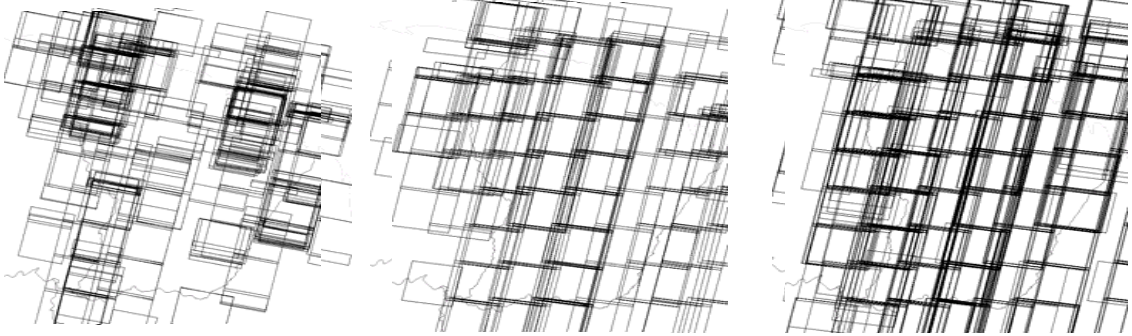

- Biomasse épigée totale des arbres de plus de 10cm
  > Volume sur écorce, densité, facteurs d'expansion
  > Terre ferme 350 T/ha ± 25
  > Marécages 290 T/ha ± 30

- Autres compartiments - étude bibliographique :
  > Biomasse épigée vivante autre que les arbres > 10 cm : 15 à 30 T/ha ;
  > Biomasse épigée morte (litière et bois mort) : 20 à 40 T/ha ;
  > Matière organique du sol : 75 à 100 TC/ha

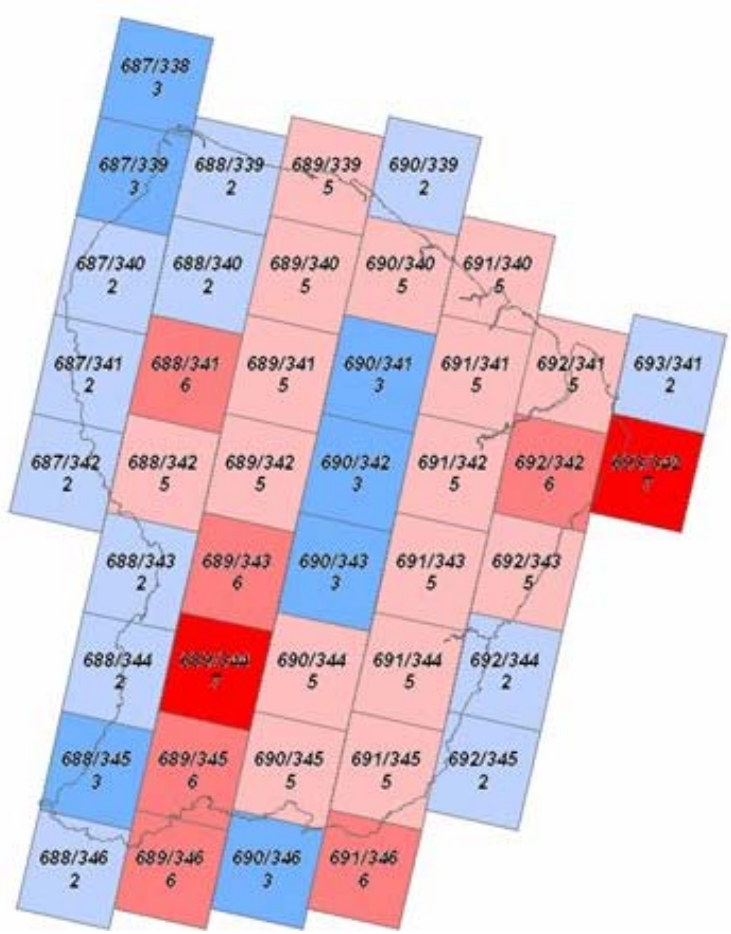
# Satellite Data : SPOT 2006

- Several thousands SPOT scenes acquired at the Cayenne Ground station during 2006

SPOT 5 SPOT 4 SPOT 2



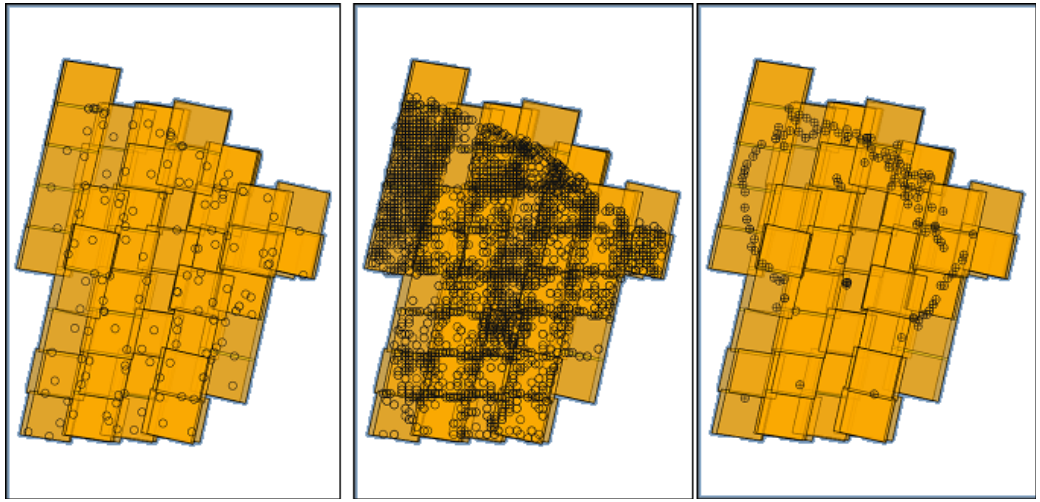
Cloud cover < 75 %




- Selection of 2 to 7 images per frame (depending on the cloud coverage)
  - –65 SPOT 2 20m multispectral
  - –63 SPOT 4 20m multispectral
  - –47 SPOT 5 10m multispectral
  - –Mean acquisition date : September 2006

# SPOT Image processing

- SPOT Images Orthorectification
  - All 175 selected images processed in one spatiotriangulation block
  - 134 GCPs from The National Geographic institute IGN ; more than 4500 tie points



148 manual tie points

4460 automatic tie points

134 IGN Ground control Points

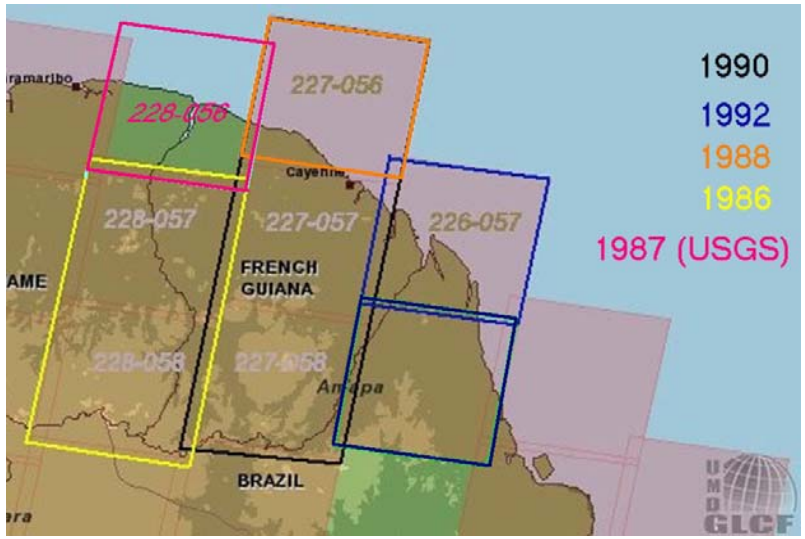
IGN GCPs measurements

  - 20 m resolution resampling with use of SRTM 2000 Digital Terrain Model (90 m resol.)

➢0.15 to 0.2 pixels residual errors (~ 2 to 3 meters geometric accuracy)

# Satellite Data : LANDSAT 1990

- 7 Images from Global Landcover Facility (GLCF – Uni. Maryland)
- + 1 image USGS
- All Images around 1990
  - From 1986 to 1992
  - 62% of the territory covered by 1990 images
  - Mean acquisition date October 1989




- Landsat images georeferenced again using SPOT orthos as references
  - 24 to 49 tie points between each Landsat scene and the corresponding SPOT images
  - Bilinear model between Landsat Coordinates and SPOT Coordinates

  ➢ Geometric accuracy from 19 to 27 meters

# Stratification

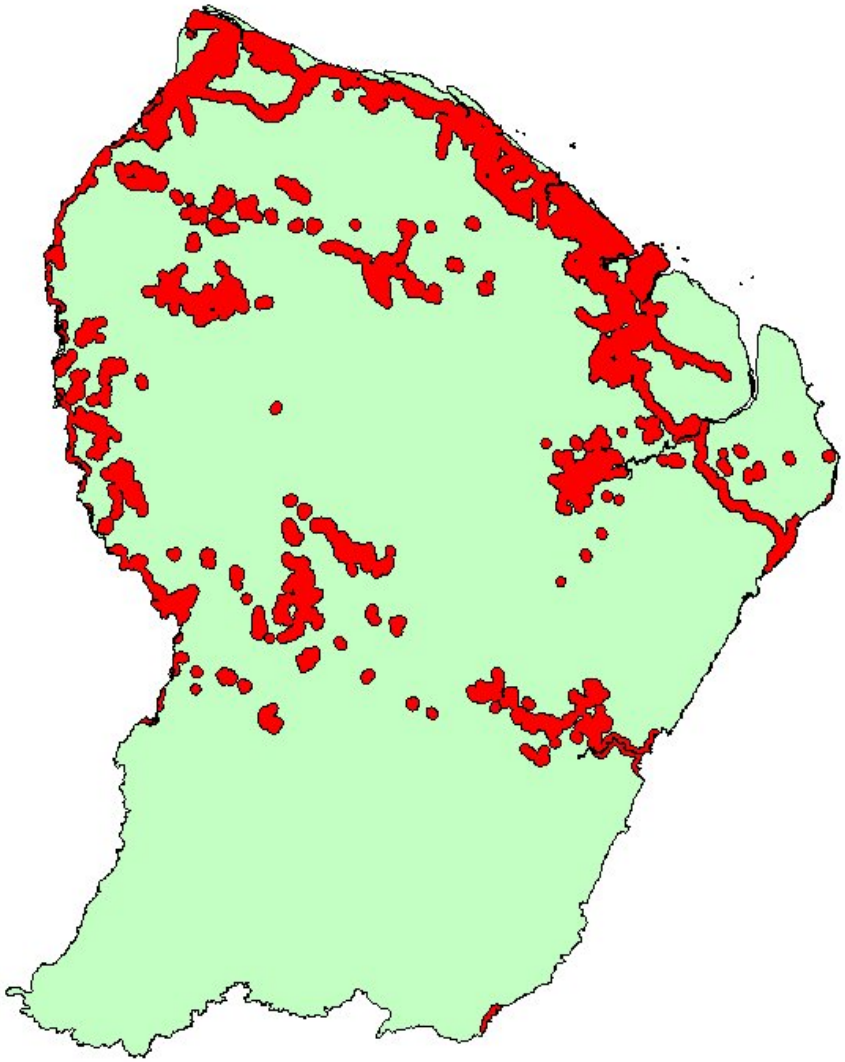
- Objective
  - Optimize the photo-interpretation by focusing on the areas with actual land use changes
  - Improve the accuracy of the estimates

➢ Very critical in the French Guiana context

  - Small changes concentrated in some areas

- Definition of 3 strata from existing information and data
  - Stratum R (Reinforced sampling) = all areas with a high pressure of human activity on the forest
  - Stratum P (Petit Saut) = large area around Petit Saut reservoir
  - Stratum N (Normal sampling) = forest or natural areas that do not suffer from human disturbance : all what is not in strata R or P

# Definition of the strata



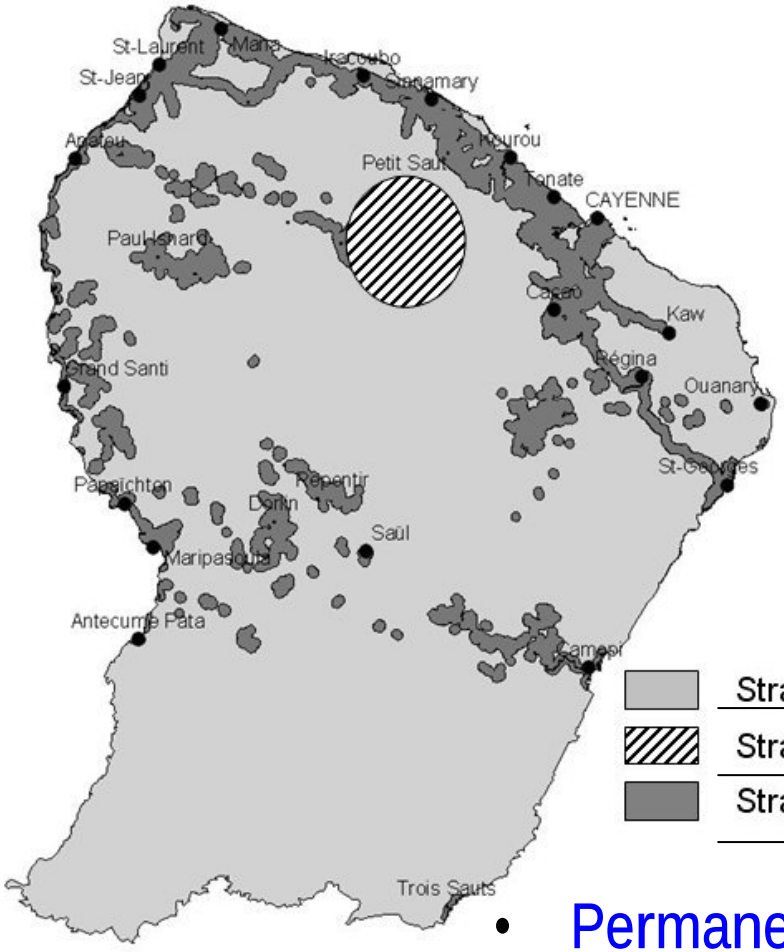
- ONF GIS analysis on existing information
  - Roads
  - Agriculture
  - Human settlements
  - Cities
  - Urban areas
  - Gold mining
  - Maroni villages
  - Camopi & 3 Sauts Villages

2km Buffer

→ Strata R definition

# Sampling design

- Localization of the 3 strata



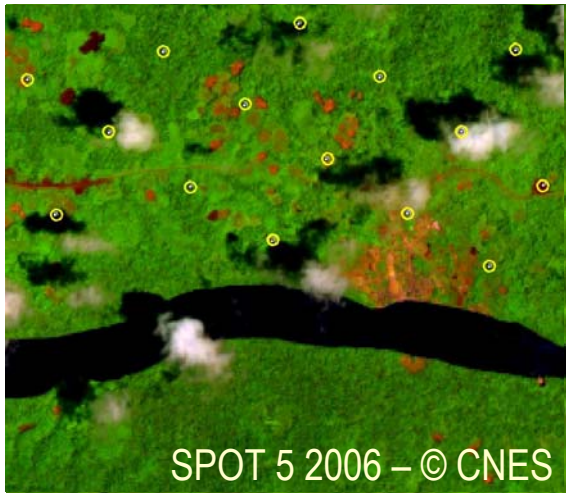

- Systematic/random grid
  - Square grid - 932 m between points
  - Random origin and inclination
- Sample definition
  - Strata R : All Grid points
  - Strata P : All Grid points
  - Strata N : sub-sample 1 point out of 9

| | Total Area | Sampling type | Sample size | Sample points distance |
|---|---|---|---|---|
| Stratum N | 7 021 597 | Normal | 973 | 8388 |
| Stratum P | 212 641 | Reinforced | 2453 | 932 |
| Stratum R | 1 162 273 | Reinforced | 13360 | 932 |

- Permanent sampling : same sample in 1990 and 2006

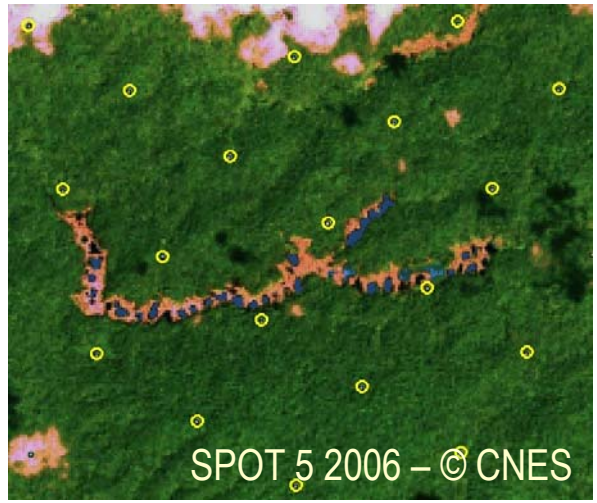
Good estimation of Land Use areas AND Land Use Changes

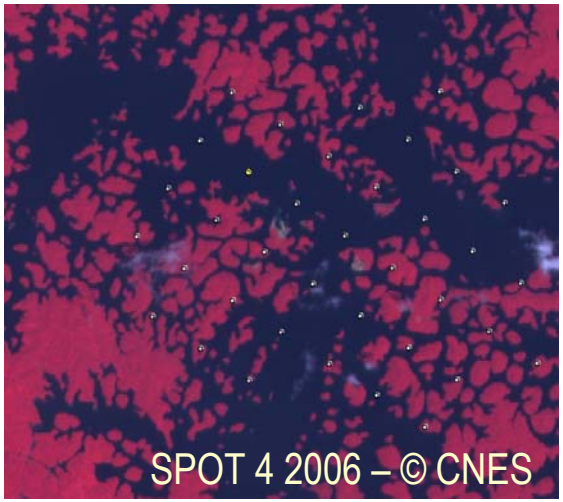
# Photo interpretation




Shifting Cultivation

Gold mining




Petit Saut Reservoir

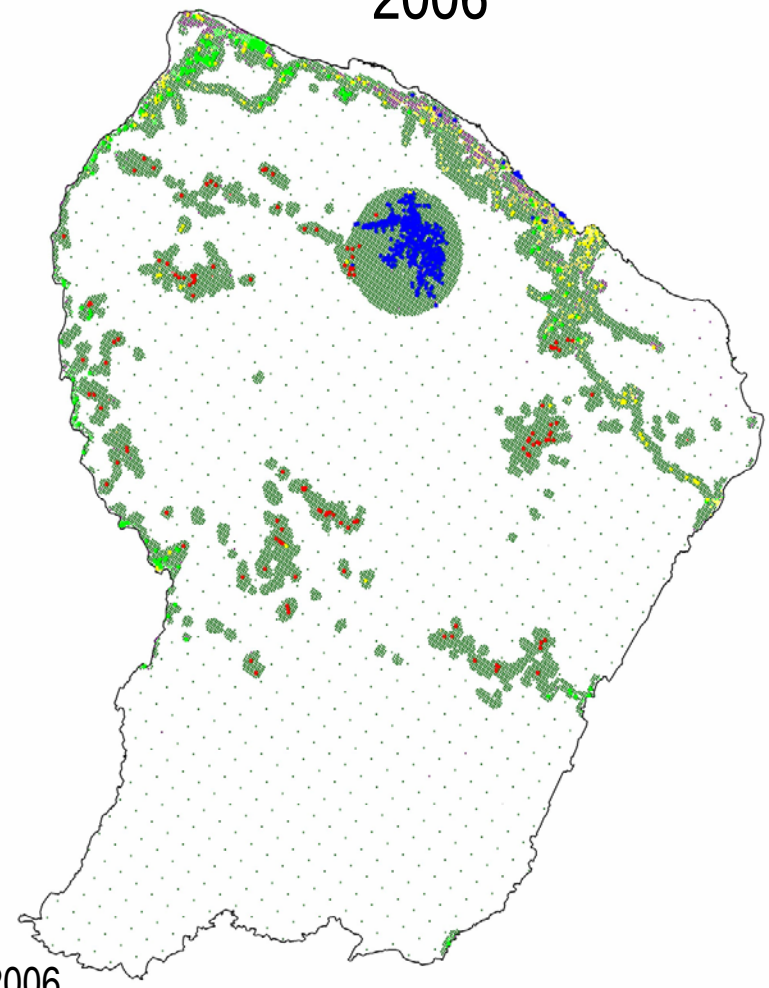
Agriculture extension

# Photo interpretation

## Land Use categories

- Forest
  - Mangroves
  - Other forests
- Settlements
  - Gold mining
  - other Settlements
- Cropland
- Grassland
- Wetlands
  - Water
  - Other wetlands
- Other lands

2006



- Sample plot with land use conversion from forest to other land use between 1990 and 2006
- Sample plot without land use change between 1990 and 2006 – or with an other type of land use conversion

# Statistical estimations

- Land use area estimation from Land use proportion in each strata

Area estimate

$$S_{ij} = P_{ij} \times S_j$$

Variance

$$V_{ij} = (S_j)^2 \times \frac{P_{ij} \times (1 - P_{ij})}{n_j}$$

Stand. dev.

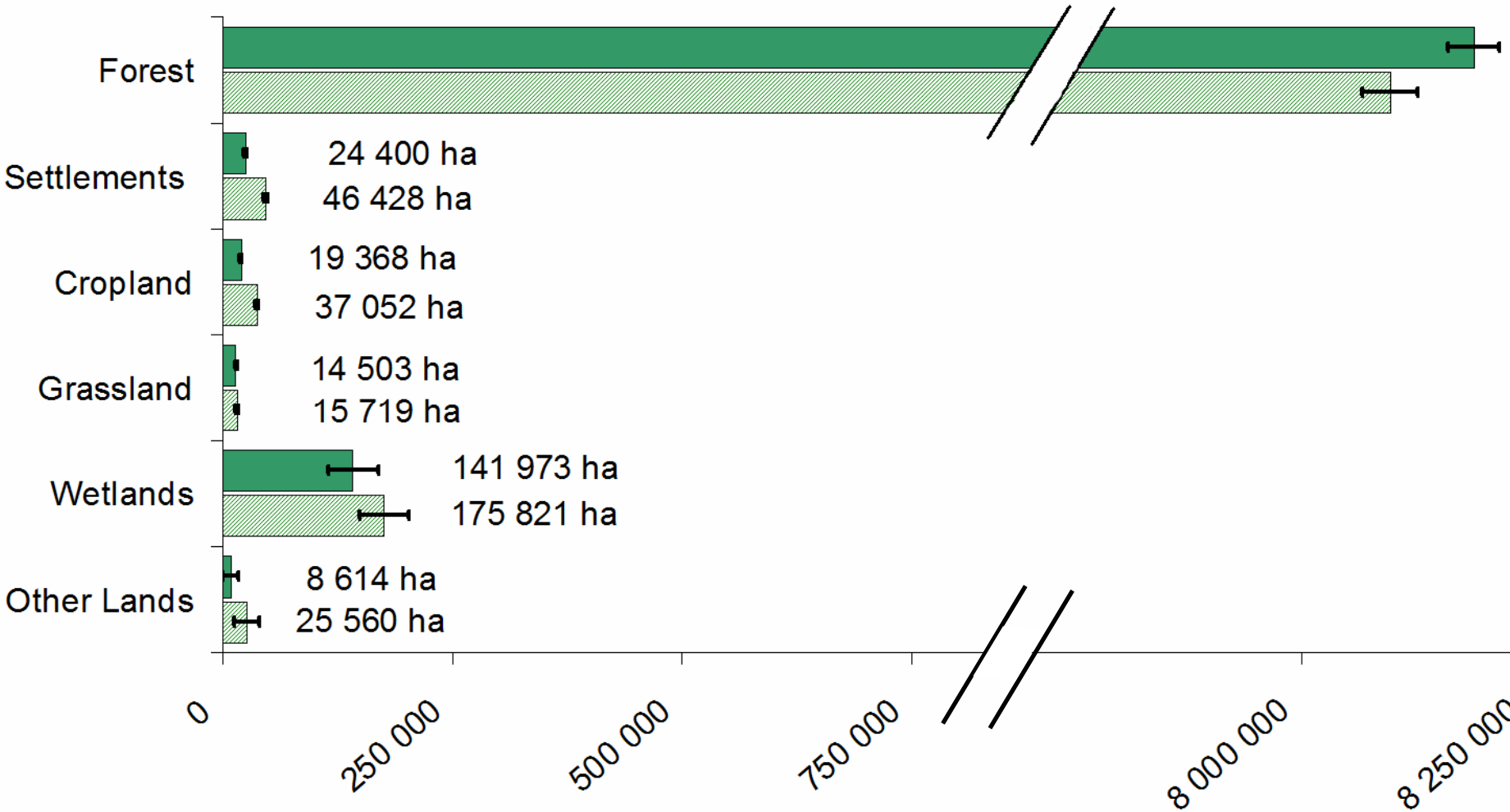
$$\sigma_{ij} = \sqrt{V_{ij}}$$

Standard error of the estimate

- Land use conversion areas estimated from Land use conversion proportions in each strata : Same formulas
  - Estimates + Precision of estimates

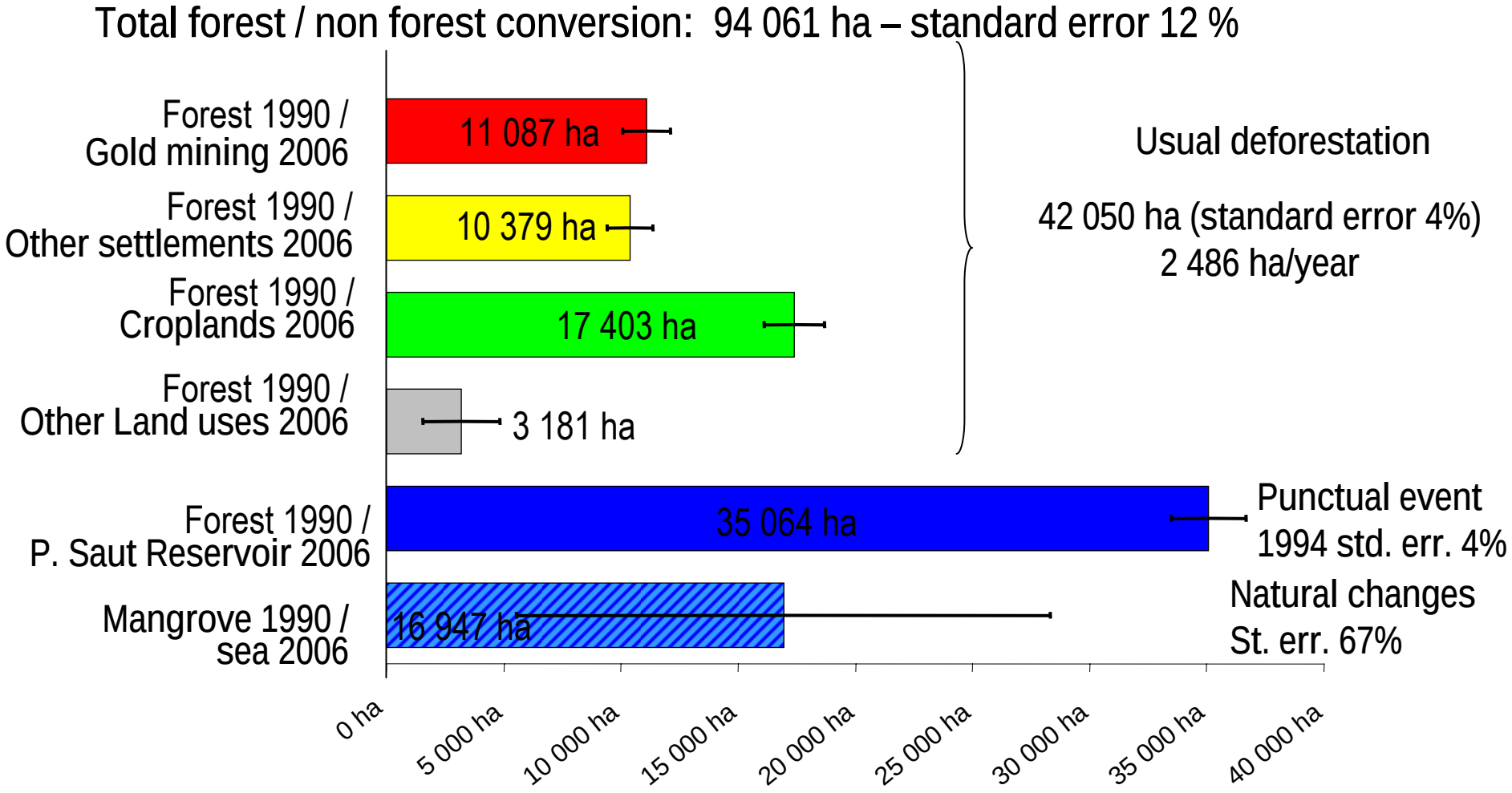
- Sample used = All points without clouds in 1990 And 2006.
  15744 points on 16786

# Results: Land uses 1990 & 2006



# Results

- Analysis forest changes in French Guyana 1990-2006



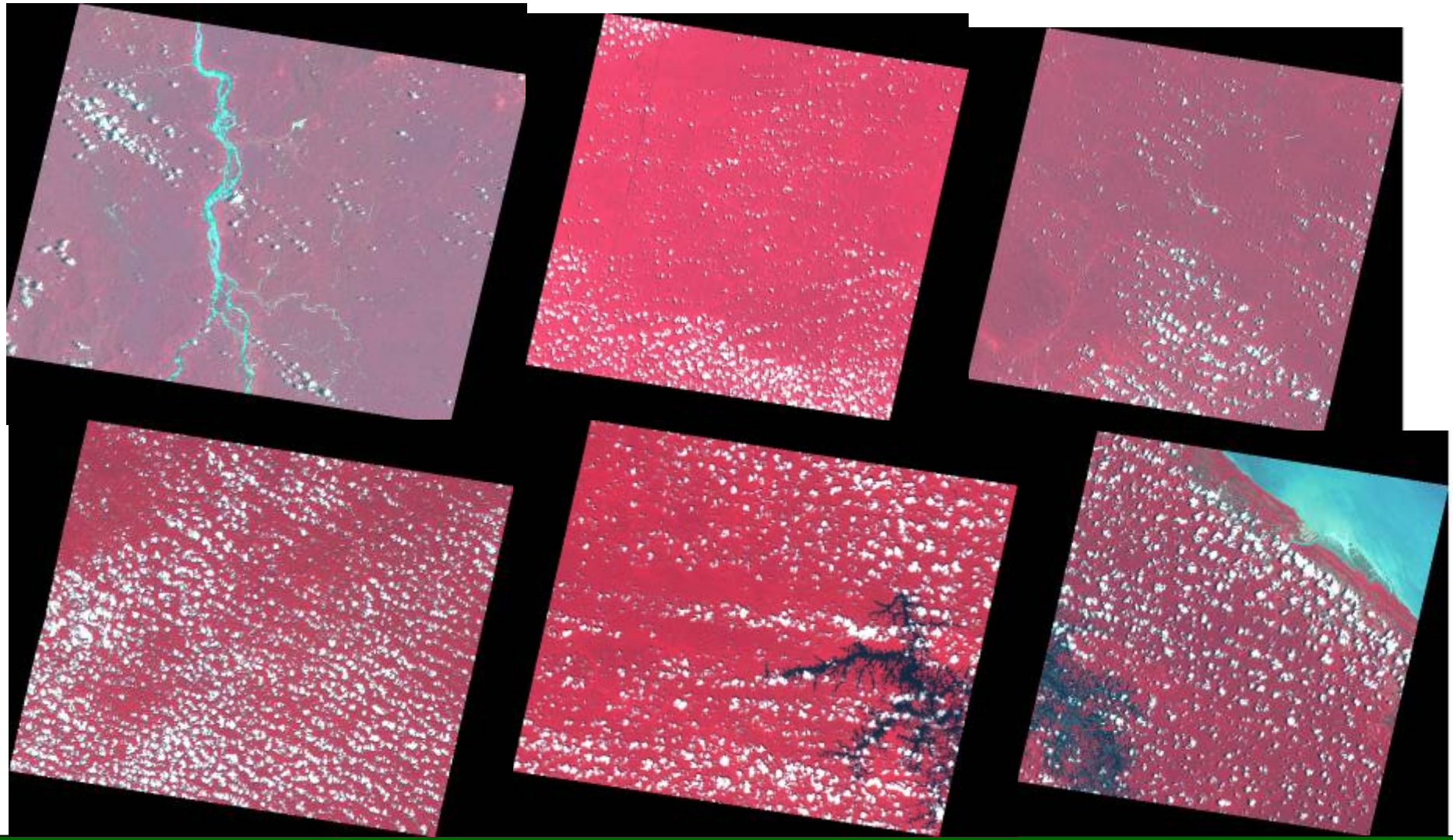
# CONCLUSIONS

- A first Kyoto inventory based on Optical Satellite data
  - Made possible thanks to the new acquisition possibilities at the Cayenne SPOT/ENVISAT receiving station
  - Sampling approach compliant with the 2006 IPCC guidelines and NFI methods
  - 2008 / 2012 period Implementation with minor improvements
- Interest of the method in a REDD regime
  - Efficiency of the method to monitor Deforestation has been demonstrated
  - Possibility to monitor forest degradation? Further investigations needed
    - Use of SPOT 5 data (2.5 to 10 m resolution) or Very High Resolution sensors (< 1m)
    - Combination with radar data (sensitivity to biomass)
    - Combination with field data
  - Key issue: availability of high resolution satellite images around the world
    - SPOT Direct receiving stations: current implantations and new projects
    - Other High resolution optical sensors (DMC constellation, IRS, Future Sentinel II from ESA or Pleiades from CNES)
    - Possibility to combine Low resolution and High resolution satellite imagery in a sampling strategy

# Annex

- SPOT Receiving station Network

# Annex



# Annex