Estimation of carbon emission and storage with RS image classification from LUCC application to southwest region of Toulouse

Antoine Masse, Danielle Ducrot, Eric Ceschia

CESBIO - Centre d'Etudes Spatiales de la Biosphère,
18, avenue Edouard Belin, bpi 2801, F-31401 Toulouse cedex 9.
Phone: +33(0) 561 558 531
e-mail: antoine.masse@cesbio.cnes.fr, Danielle.Ducrot@cesbio.cnes.fr

Introduction

➢ **Land use /cover change (LUCC)** can provide an estimate of carbon emission and storage.

➢Deforestation and agriculture are closely linked to large concentrations of greenhouse gas emissions. In the case of CO_2, an alternative is to increase the role of "sinks" that plays temporary vegetation, mainly by increasing the duration of carbon storage in biomass.

➢Action by anthropogenic reforestation, land use change and good agricultural practices can increase carbon sequestration in biomass and soils for periods of several decades, which may constitute a significant contribution to the fight against the greenhouse effect

- A mode change of land use directly affect Biosphere – Atmosphere interactions.
- A large amount is fixed annually by crops through photosynthesis.
- Most of the fixed carbon can be released following harvest.

➢We propose a specific **methodology to evaluate change** in landscape based on **satellite image classification** involving unsupervised and supervised approaches.

- The different steps of the process are essential to avoid false changes and to quantify land cover change with a high degree of accuracy.
- Various statistical results are given: **changes** or no changes, types of changes, and **crop rotations** over several years

➢**land use change maps are created to quantify the carbon flux between soil and atmosphere.**

➢ We present **Toulouse southwest region** LUC maps from 2006 – 2009 FORMOSAT classifications This study was conducted in two parts:

- Changes in land use between 2006 and 2009.
- Crop rotations are given for 4 years (year per year 2006-2009).

Change detection

The process consists in fuzzy contextual **classifications of satellite images,** the most accurate possible; **regrouping** classes of the same theme; **smoothing classification; eroding** contours without taking "mixels" into account; **comparing** the classified images at different dates to **provide** statistics and image changes.

Context : Rural area

Step 1: Unsupervised and/or supervised classification

Unsupervised classification if ground truths are not known (old dates) and/or supervised classification (classification contextual algorithm: Iterative Conditional Mode (ICM) Markovian model, improved by exogenic data (segmentation, GIS, …) if necessary → robust method

Step 2: Regrouping precise classes in a main theme

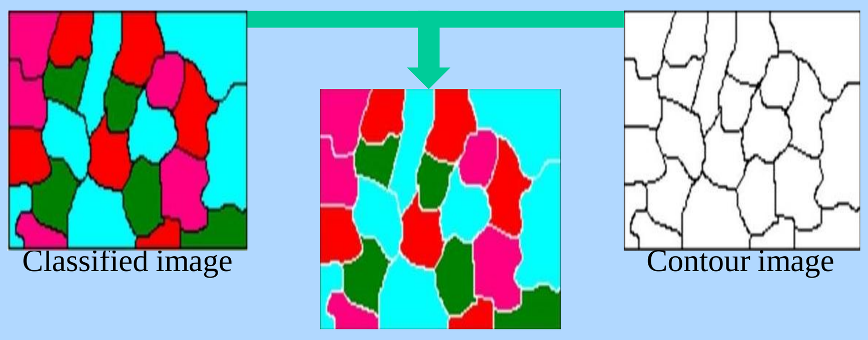
- Woodland: Hardwood, Pinewood, Eucalyptus, Poplar.
- Water: Lake, Gravel
- Built up area/mineral surfaces: Dense urban area, Industrial built, Dispersed settlement, Roads, Bare soil
- Grassland: Temporary meadow, Permanent pasture, Fallow field, Wasteland, Lawn
- Crops: Wheat, Rapeseed, Barley, Corn, Sunflower, Sorghum, Soybean, Peas, Hemp

Step 3: Regularization (smoothing) with segmentation; which homogenous regions are affected to the same class (close to oriented object classification).

Step 4 : Contour erosion

➢ classification contours

➢ to compare classified images (2006 to 2009) it is necessary to eliminate "mixels" (mixed pixels on border of classes). They correspond to false changes, and imply errors change in statistics



Classified image

Contour image

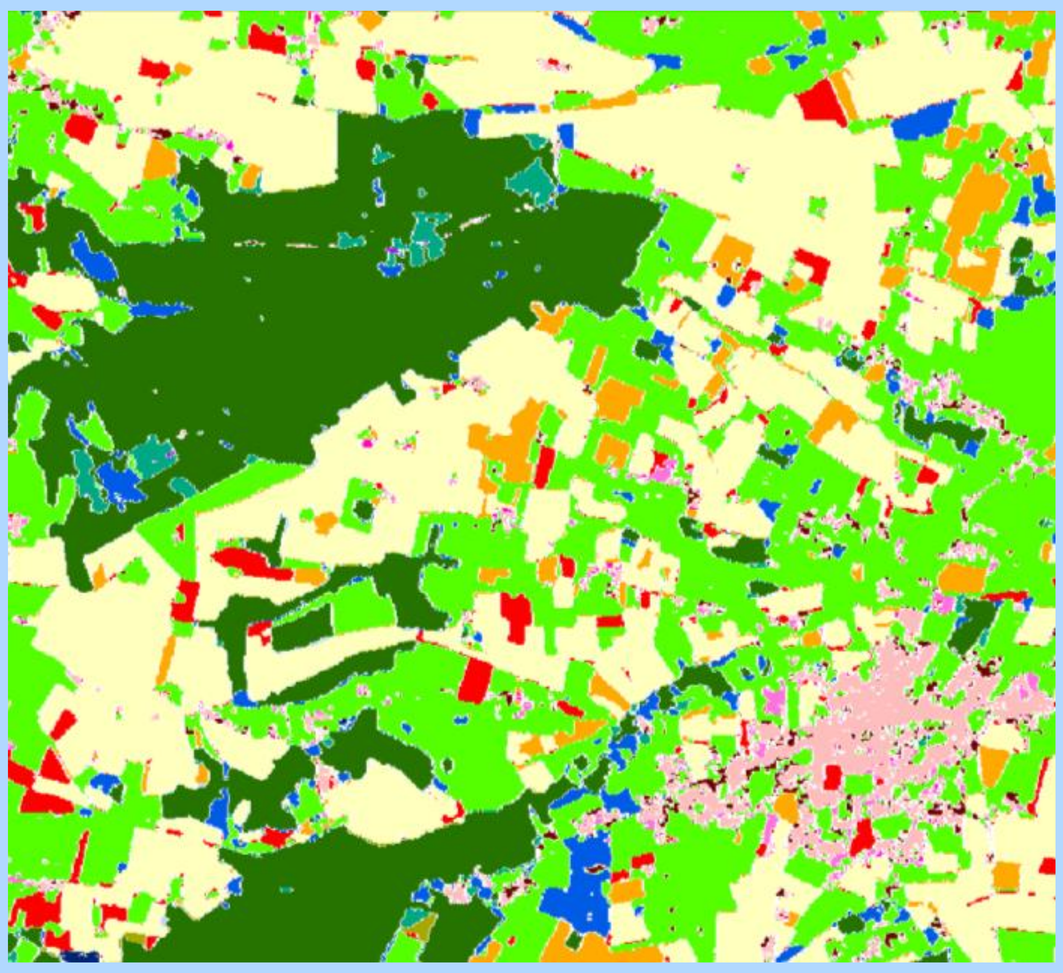
Eroded image

Step 5 : Classified images comparison

➢ **creation** of change classes and **change maps**

➢ Comparison of classified images from change matrices: change-classes are created.

➢ **For example** :91.13% of Woodland in 2006 has not changed



Step 6 : Crop rotation,

comparison of N classifications in N years and obtaining of change matrices → **rotation maps**.

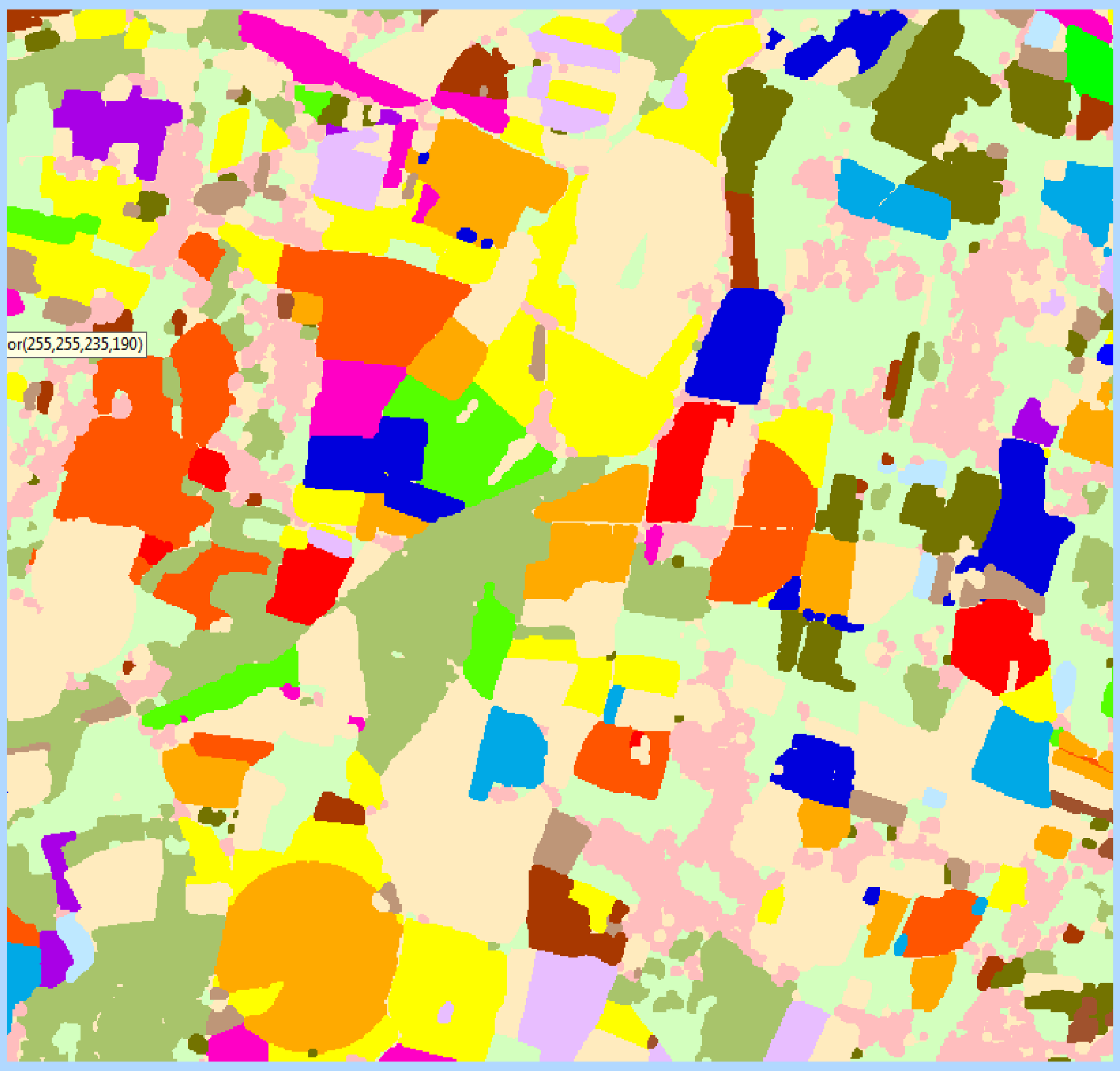
The following table gives the pixel number (area percentage of no change or annual, biannual rotations …)

	CLASSIFICATION 2009				
CLASSIFICATION 2006	Wood	Crop	Grassland	Water	Mineral Surfaces/built
Wood	**91.13**	0.21	8.62	0.01	0.04
Crop	0.05	**91.19**	8.38	0.00	0.37
Grassland	6.24	12.59	**79.56**	0.00	1.60
Water	0.84	1.63	0.68	**89.88**	6.96
Mineral Surfaces/built	0.27	0.74	6.11	0.06	**92.82**

Arrouays D. *et al, "Contribution à la lutte contre l'effet de serre : stocker du carbone dans les sols agricoles de France ?", INRA, 2002*

Masse A., Ducrot D., Ceschia E., Marais-Sicre C ,"A methodology for the detection of land cover changes – Application to the Toulouse south western region", SPIE, Sept 2010..

West. T, Badaruv, Brandt C, Schuh A., Ogle S.M, : Regional upteke and release of cropcarbon in the USA Biogeoscience, 8, 2037-2046,2011.



Results

- **Monoculture** is mainly **Corn**; it covers **7.7**% of the territory, others are negligible
- Main rotation: Wheat and Sunflower: biannual rotation (20% of eroded surface with 5.1% Wheat-Sunflower)
- Rotation with 4 crops is negligible

Step 7 : LCLU and changes in soil Carbon

Maps of Land use change for the main classes (forest, croplands and pastures) were used to estimate changes in Soil Organic Carbon (SOC) by applying a simple model based on regional observations (Arrouays et al. 2002). For forests and pastures, we assumed that SOC content were stable.

For croplands, **carbon budgets** ($gC.m^{-2}$) of crop rotations were calculated by as follow:

$$C_{budget} = NPP + Rh + C_{exported\_t\_harvest} + (C_{\_input\_as\_organic\_fertilization})$$

Regional yield statistics were computed to estimate Net Primary Production (NPP) and crop carbon balance by using a similar methodology as proposed by West et al. (2010).

Yield was converted in $gC.m^{-2}$ by using crop specific C contents. Crop specific harvest index was used to estimate aboveground NPP from yield. A constant root/shoot ratio of 0.15 for all crops was used to convert aboveground NPP into total NPP.

$\boldsymbol{C_{\_exported\_at\_harvest}}$ *was* estimated by using yield regional statistics,

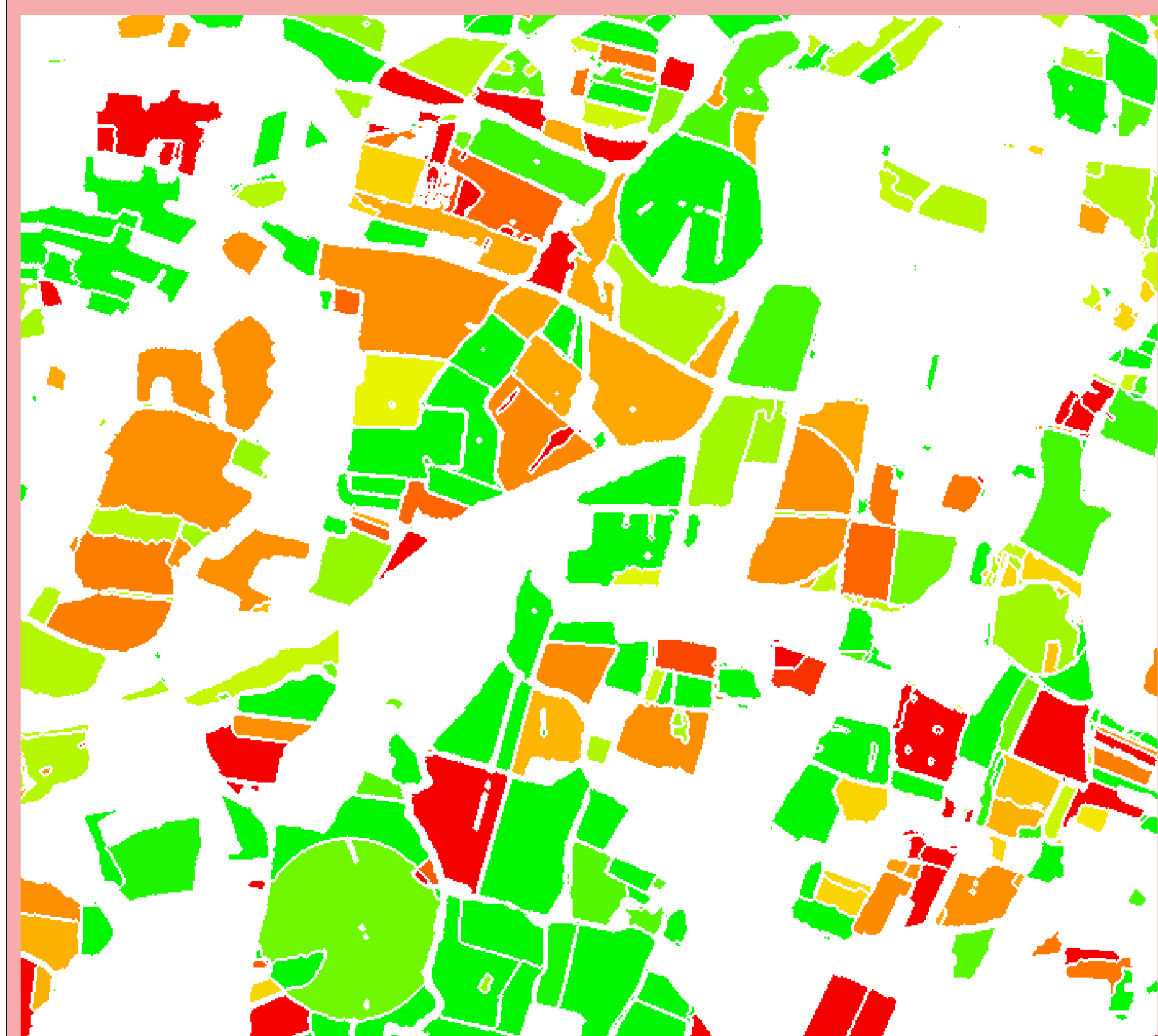
Rh was estimated by considering full or 80% crop residues decomposition (a total or a crop residue decomposition from previous years.

Crop residues were calculated as total *NPP – C_exported_at_harvest*.

Finaly, $\boldsymbol{C_{\_input\_as\_organic\_fertilization}}$ were considered negligible in our area of study.

$\mathbf{C_{\_storage}}$ in the wood was not estimated.

Carbon emission/sequestration map



➢The biggest storage: Wheat-Wheat-Wheat-Wheat → 70 MgCarbon

➢The biggest emission: Corn-Corn-Corn-Corn → 853 MgCarbon

➢Example of rotation:

- wheat-wheat-sunflower-sunflower 1.65 MgCarbon/ha → 93.5 MgCarbon for 56.8 ha
- corn-corn-corn-soybean -0.66 MgCarbon/ha → -32.92 MgCarbon for 49.8 ha

Conclusion

➢ The protocol presented gives accurate change statistics over several years

➢ Every step is important: fuzzy contextual classification, edge erosion, …

➢ Land cover changes from wood, crop, fields are important to evaluate the emission and storage of CO_2, which depend on the nature of the soil and its changes over time.

➢ Absorption does not occur in the same way in wood , in crops and in different kind of crops

➢In the studied area (57,000 ha), we obtain a balanced Carbon Budget → 500 MgCarbon