A methodology for crop rotation and land cover changes - application to southwest region of Toulouse

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Abstract

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

➢ Reforestation, changing land use and best practices can increase carbon sequestration in biomass and soils for a period of several decades, which may constitute a significant contribution to the fight against the greenhouse effect. Deforestation, conversely, can lead to significant levels of CO2 emission.

➢ We propose a specific methodology to evaluate changes 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.

➢ Application: Agricultural area of South-West region of Toulouse,

Introduction

➢Human activities including production mainly by burning fossil carbon, deforestation and agriculture are closely linked to large concentrations of greenhouse gas emissions. In the case of CO2, an alternative is to increase the role of "sinks" that plays temporary vegetation, mainly by increasing the duration of carbon storage in biomass.

➢A mode change of land use directly affects the interactions between the biosphere and the atmosphere.

➢A large amount is fixed annually by crops through photosynthesis.

➢Most of the fixed carbon can be released following harvest.

➢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.

➢The **project objectives** is to create maps of land use changes from satellite images to quantify the carbon flux between soil and atmosphere.

➢ We present land use change maps in the **southwest region of Toulouse**, from FORMOSAT classifications of 2006 - 2009. 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

Unsupersived classification if ground truth are not known (ancient dates) and/or supervised classification (classification contextual algorithm: Iterative Conditional Mode (ICM) markovian model) → robust. Improved by exogenic data (segmentation, GIS, …).

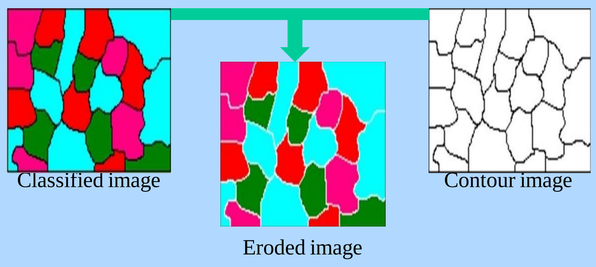
Step 2: Regrouping precise classes in a main theme

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

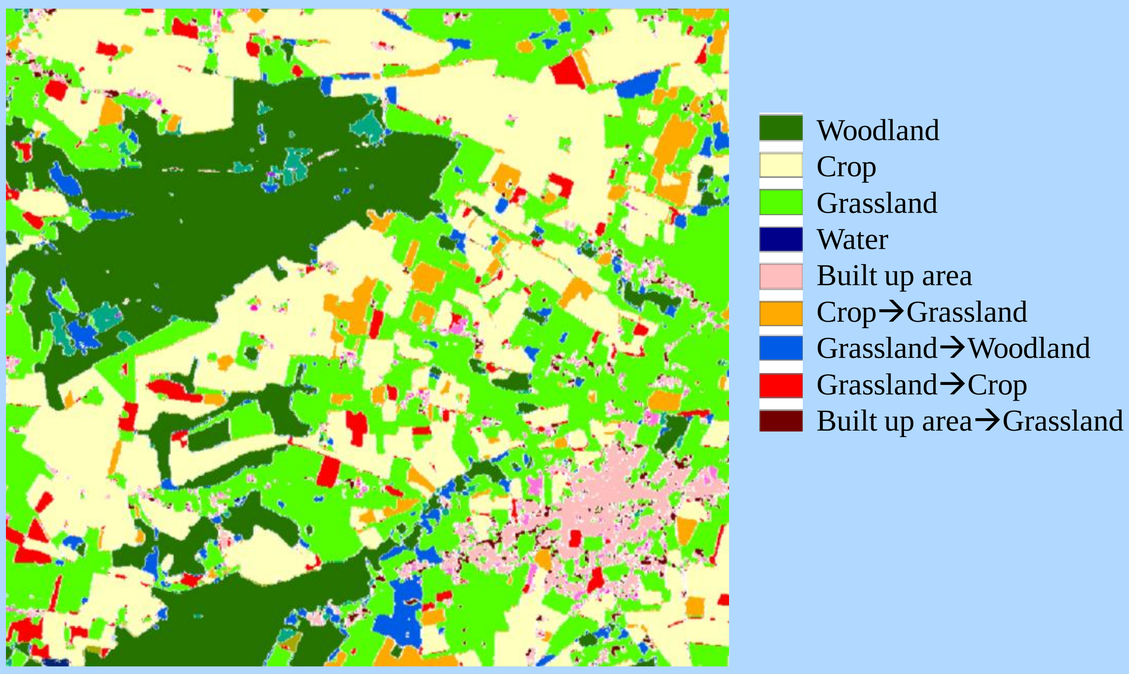
Step 3: Regularization (smoothing) with segmentation; which homogenous regions are affected to the same class.

Step 4 : Contour erosion

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.



Step 5 : Comparison of classified images from **change matrices**: pixel-by-pixel comparison, **creation** of change classes and **change images**.

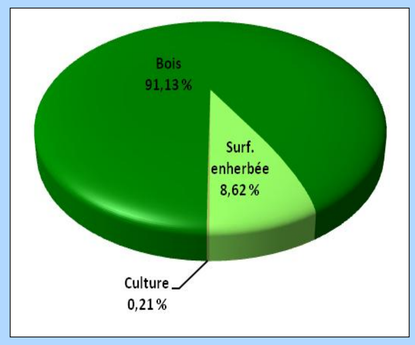


	CLASSIFICATION 2009				
CLASSIFICATION 2006	Wood	Crop	Grassland	Water	Mineral Surfaces/built
Wood	**91.13**	0.21	8.62	0.01	0.04
Crop	0.05	**91.19**	8.38	0.00	0.37
Grassland	6.24	12.59	**79.56**	0.00	1.60
Water	0.84	1.63	0.68	**89.88**	6.96
Mineral Surfaces/built	0.27	0.74	6.11	0.06	**92.82**

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

➢ 91.13% of Woodland in 2006 has not changed.

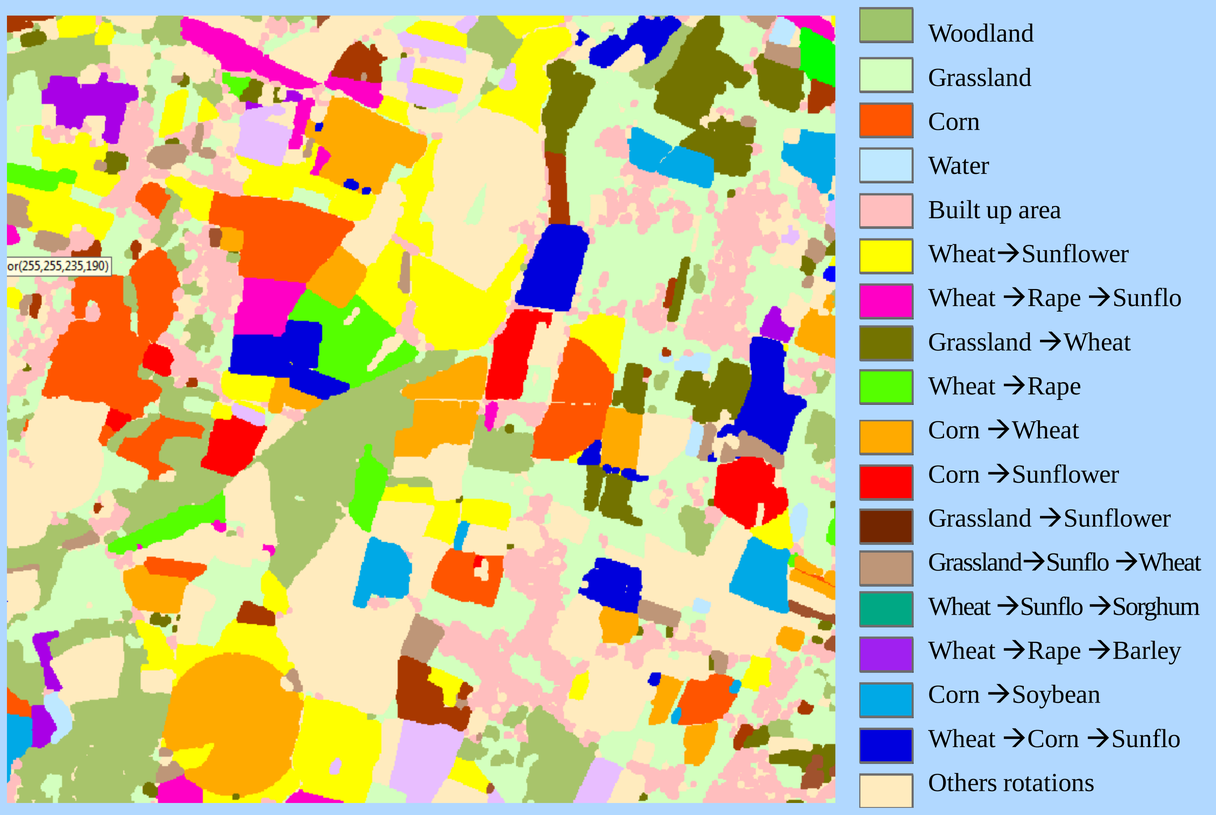
➢ 8.62% switched to Grassland and only 0.21% to Crop.



Step 6 : **Crop rotation**,
comparison of N classifications in N years and obtaining of change matrices.

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

2006 - 2007- 2008 - 2009	Pixel number 2006→ 2007→ 2008→ 2009	area (ha)	Percentage = class pixel number/total pixel number of the eroded image	2006 - 2007- 2008 - 2009	Pixel number 2006→ 2007→ 2008→ 2009	area (ha)	Percentage = class pixel number/total pixel number of the eroded image
monoculture				**Every 3 years:** (main changes)			
Corn-Corn-Corn-Corn	521649	3338,5	**7,799**	Wheat-Wheat-Wheat-Sunflower	85116	544.74	1.273
Wheat-Wheat-Wheat-Wheat	13960	89,3	0,209	Corn-Corn-Corn-Wheat	50577	323.69	0.756
Soybean-Soybean-Soybean-Soybean	144	0,9	0,002	Corn-Corn-Corn-Sunflower	61887	396.08	0.925
Sunflower-Sunflower-Sunflower-Sunflower	3625	23	0,054	Sunflower-Sunflower-Sunflower-Wheat	28427	181.93	0.425
2 crops				Wheat-Wheat-Wheat-Rapeseed	70892	453.71	1.060
Bi-annual (main changes)				Corn-Corn-Corn-Soja	23751	152.01	0.355
Wheat-Sunflower-Wheat-Sunflower	342488	2191,9	**5,12**	Wheat-Wheat-Wheat-Corn	17340	110.98	0.259
Wheat-Rape-Wheat-Rape	70929	453,9	1,06				
Every 2 years				**Rotation**			
Wheat-Wheat-Sunflower-Sunflower	77466	495,78	1,158	**Total 1 crop**	539378	3452,01	8,064
Wheat-Wheat-Rape-Rape	17490	111,94	0,261	**Total 2 crops (biannual)**	467624	2992,78	6,99
Wheat-Wheat-Corn-Corn	9388	60,08	0,14	**Total 2 crops (2 years)**	167212	1070,15	2,5
Corn-Corn-Sunflower-Sunflower	4208	26,93	0,063	**Total 3 crops**	474203	3034,92	7,09



Results

- **Monoculture** is mainly **Corn**; it covers **7.7**% of the territory, the 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 Carbon Storage/Emission**

• Land use change maps for the main classes (forest, croplands and pastures) are used to estimate Soil Organic Carbon (SOC) changes by applying a simple model based on regional observations.

• We estimate soil carbon stocks using a mathematical model (INRA, 2002) from statistics obtained by the land change map.

Examples: -Carbon storage for change: Crop(A) to Grassland(B).

$$Storage = \Delta_{A\to B}\frac{(1-e^{(-kT)})}{T}\ ; T = 2009-2006+1 = 4;\ \Delta_{A\to B} = 25\ Mg.ha^{-1}; k = 0.025\ year^{-1}$$

This change is detected for 2376 ha → 1413 Mg of Carbon is stocked from 2006 to 2009.

-Carbon emission for change: Wheat(A) to Corn(B)
This change is detected for 180 ha → 17.1 Mg of Carbon is released from 2006 to 2009

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

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 CO2, which depend on the nature of the soil and its changes over time.
➢ Wood stores carbon, cutting of a tree will release CO2 into the atmosphere.
➢ Absorption does not occur in the same way in wood , in crops and in different kind of crops
➢ Future work: mapping of carbon exchange

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.