Agronomy and hydrology with Sentinel-2 type time series

Towards spatial characterization of crop productivity and its impacts on water and nutrient cycle at the catchment scale.

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Research objectives:

Interactions between agricultural practices...

... and water resources at catchment scales

What is the classical approach?
Research objectives:

Interactions between agricultural practices...

Crop transpiration
Irrigation practices
Fertilization (N, P, K)

Water bodies:
- Volumes
- Uses
- N Contaminant

Crops:
- Yield
- Biomass
- N export

... and water resources at catchment scales

Distributed agro-hydrological model
Main limitation to this approach ... 
... no spatial calibration
Research objectives:

Main limitation to this approach ...
... no spatial calibration

Can we benefit from sentinel-2 time series ...
... in Agro-hydrological studies?

Black box calibration
Discharge and Nitrogen fluxes
First step model setup: TNT2

**Spatial Input data:**
- Agricultural practices
- Land Use
- Soil parameters map
- Topography and drainage network
- Meteo variables

**TNT2 model:**
Topography Nitrogen Transfer and Transformation

*Beaujouan et al., 2002)*

**Crop model**
- Leaf Area Index
- Biomass
- N uptake

**Distributed Hydrological Model TNT**
- Evapotranspiration
- Discharge
- Nitrogen fluxes

*Brison et al., 1998, 2001)*

**N, W stress**
**Method**

Formosat-2 (Sentinel-2) times series → Leaf Area Index → Agro-hydrological model

Spatial calibration?

- **BV-NNET** (Biophysical Variable Neural NETwork)
- **TNT2** (Topography Nitrogen Transfer and Transformation)

Green leaf area per unit ground surface area

\[ \text{LAI} = \text{leaf area} / \text{ground area}, \text{m}^2 / \text{m}^2 \]
Study area

Regional Spatial Observatory:

- Systematic high resolution images acquisition
  - Formosat-2 since 2006
  - SPOT since 2002
  - SPOT4(take5)

- Ground measurements (Vegetation, Climate, hydrology...)

Crop land

Vineyard

Pasture/Forest

Pyrenees Mountains

Save River
Experimental catchment area

Formosat-2 ground coverage

10 km

Experimental catchment area

10 km

Sentinel 2 type acquisition of images

Acquisition dates
Data: LAI time series

Formosat-2 derived Leaf Area Index map (July, 12th 2009) 8m resolution

Experimental catchment area

Sunflower

Harvested winter wheat

Claverie et al., 2012, 2013
Data: soil and hydrology

Experimental catchment area

Since 1985
Discharge
Nitrogen fluxes

Meteo station

Hydrology and hydrochemistry data

Agro-hydrological models to simulate Water and Nitrogen cycle under agricultural uses

Ferrant et al., 2011, 2012, 2013
Spatial Input data:

Need of crop rotation
Spatial Input data:

- Need of crop rotation

Land cover from Formosat-2 classification:

- 2006
- 2007
- 2008
- 2009
- 2010
Formosat-2 derived LAI maps
8*8 m resolution

Claverie et al., 2012, 2013
F-2 time series VS TNT2 LAI:

**Observed** LAI Formosat-2

Formosat-2 derived LAI maps
8*8 m resolution  *Claverie et al., 2012, 2013*

**Simulated** LAI TNT2

Apr.

Jul.

Nov.
F-2 time series VS TNT2 LAI:

Time shift between observations and simulations \(\rightarrow\) **re-set seeding date** at the **crop field level**

LAI observed Formosat-2

LAI model TNT-2

Seeding date = generally unknown

\(\rightarrow\) Used as input parameter
Continuous value of LAI obtained by fitting a double logistic equation parameters:

- **Pixel** ➔ local soil crop conditions
- **Crop field** ➔ seeding date/ fertilization level

\[
LAI = Kn + \frac{(Kx - Kn)}{1 + \exp[-a \times (\Sigma T - Ti)]} - \frac{(Kx - Kn)}{1 + \exp[-b \times (\Sigma T - Tf)]}
\]
How to use F2 LAI profile?

Optimization process

Iteration 1

Continuous LAI at the crop field level
How to use F2 LAI profile?

Optimization process

Iteration 2

Continuous LAI at the crop field level
How to use F2 LAI profile?

Optimization process

Iteration $n$

Continuous LAI at the crop field level
Results: Effect on crop cover

Average LAI simulated for all winter wheat crops
Results: Effect on crop cover

LAI optimization using LAI maps:
- Increase of LAI estimates
- Increase of biomass estimates
- Increase N uptake by 10%
Results: Effect at the catchment level

- Low impact on hydrology
  - 1 à 2 mm/y; 1% of annual discharge

- Significant nitrogen fluxes decrease:
  Better agreement with measurements (from 11 to 9: observed 7 kgN/ha/y)
  - 11% of annual fluxes decrease

LAI optimization using LAI maps:
- Increase of LAI estimates
- Increase of biomass estimates
- Increase N uptake by 10%
- Increase of wheat yield

Strong Wheat yield influence (increase 20%)
need validation

Realistic decrease of nitrogen fluxes in river
Perspectives: Soil crop situations

12-Sep-2006

Satellite OBSERVATION of LAI  TNT2 model SIMULATION of LAI

Only optimized on time shift at crop field level

Next challenges:
• Re-setting soil parameters
  ✓ Depth
  ✓ Porosity
  ✓ Drainage

• RS crop productivity
  ✓ W stress
  ✓ N stress
Perspectives: Soil crop situations

Ortho photo IGN 31/12/2006  VS max of interpolated LAI from Sentinel-2 type time series

First growth stage of the winter wheat ➔ delay of emergence

➔ Impact the final crop growth
Importance of sentinel-2 time series for:

- Input parameter re-setting
- Catching crop growth variability
- Understanding the spatial processes involved
- Strong influence on Nitrogen cycle

Questions are welcome!