Estimation of biophysical variables and cartography of irrigated surfaces with high temporal and spatial resolution images

Perspective of Sentinel-2 mission

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INTRODUCTION

Remote sensing Data → Biophysical Variables Maps and profiles → Spatialised Biomass, Yield Water needs/supplies

- Green Area Index (GAI)
- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
- Fraction of vegetation cover (FCover)

→ Vegetation status, spatial and temporal, used as input for models

Monitoring agriculture
- Crop scale for cal/val
- Watershed and regional scale
  = decision, management
INTRODUCTION

Remote sensing Data

HRST images

Biophysical Variables Maps and profiles

- Green Area Index (GAI)
- Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
- Fraction of vegetation cover (FCover)

→ Vegetation status, spatial and temporal, used as input for models

Parameterization, calibration

Validation

1

BVnet
Inversion of radiative transfer model

SAFY(E)
Agro-meteo model + land cover maps (irrigated areas)

2

Spatialised Biomass, Yield Water needs/supplies

Monitoring agriculture
- Crop scale for cal/val
- Watershed and regional scale = decision, management

These works were done in the framework of CALVADOVS (TOSCA-CNES) and MAISEO (FUI) projects.
In situ measurements: GAI/FAPAR/FCOVER + Biomass

Processing DHP with Can-Eye software → Estimation of **GAI, FAPAR, FCOVER**
Taking advantage from SPOT4-Take5 to perform an important ground measurement campaign in 2013

- Sunflower, maize and wheat in South-West (CESBIO) 250 DHP measurements in 2013, 50 for biomass + 100 DHPs, ~50 biomass in archives
- Irrigated meadows in South-East (INRA paca) 70 measurements in 2013

→ Large and varied reference dataset

| BIOPHYSICAL VARIABLES : in situ measurements |

Measurements 2006 to 2013
BIOPHYSICAL VARIABLES: with remote sensing data

Estimation of GAI, FAPAR and FCOVER from satellite images
→ BVNET (Biophysical Variable Neural NETwork)
Developed by INRA (EMMAH, Avignon)

Prior distribution of biophysical variables
Sensor and angles

Simulations SAIL/PROSAIL
Radiative transfer model

TOC reflectance

Model inversion
Neural NetWork
→ Learning process

Estimation of GAI, FAPAR and FCOVER
For each pixel

TOC reflectance
Satellite images (N2A)

NNT application
Prior distribution of biophysical variables
Sensor and angles

Work on parameters:
Sensibility of different variables → distributions, class, affected crop, ...
Objective: move toward a single configuration, operational context

<table>
<thead>
<tr>
<th>Variable</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mode</th>
<th>Std</th>
<th>Nb.class</th>
<th>Law</th>
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<td>ALA (°)</td>
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<td>N</td>
<td>1.2</td>
<td>2.2</td>
<td>1.5</td>
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<td>0.3</td>
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<td>Soil properties</td>
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<td>3.5</td>
<td>1.2</td>
<td>2</td>
<td>4</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Input variables distribution for learning database creation

60 images processed for the validation
6 different sensors
2006, 2008, and 2013

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Resolution</th>
<th>Bands used</th>
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<tbody>
<tr>
<td>Formosat2</td>
<td>8m</td>
<td>Green, red, NIR</td>
</tr>
<tr>
<td>SPOT2</td>
<td>20m</td>
<td>Green, red, NIR</td>
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<td>SPOT4</td>
<td>20m</td>
<td>Green, red, NIR, MIR</td>
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<td>SPOT5</td>
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<td>Landsat8</td>
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<td>Landsat7</td>
<td>30m</td>
<td>Green, red, NIR</td>
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BIOPHYSICAL VARIABLES : with remote sensing data

Validation results

Overall good results for later use in models
• Single configuration for all crops and years in South-West
• ALA* parameter changed for irrigated meadows
  *(Average Leaf Angle)

<table>
<thead>
<tr>
<th>Crop</th>
<th>GAI</th>
<th>FAPAR</th>
<th>FCOVER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>26.0</td>
<td>13.2</td>
<td>27.9</td>
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<tr>
<td>Maize</td>
<td>23.3</td>
<td>13.3</td>
<td>18.2</td>
</tr>
<tr>
<td>Soybean</td>
<td>26.4</td>
<td>11.3</td>
<td>9.8</td>
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<tr>
<td>Sunflower</td>
<td>36.9</td>
<td>19.1</td>
<td>21.5</td>
</tr>
<tr>
<td>Irrigated meadows</td>
<td>27.7</td>
<td>10.7</td>
<td>23.7</td>
</tr>
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</table>

Relative error:
GAI : 28%
FAPAR : 14%
FCOVER : 22%
Validation results

Overall good results for later use in models
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  *(Average Leaf Angle)

Perspectives :
• Include BVNET in OTB (processing time gains, OpenSource)
• Further evaluation of BVNET model for correcting sensor effect
• Contribution of MIR for BV estimations
• Crops specific parameters distribution if land cover maps
• Validation in other sites = Sentinel 2 for agriculture
What uses?

Temporal profiles → Model inputs

Maps → Spatialize model output
Cartography of irrigated crops

Work on phenological indicators for the discrimination of irrigated crops
- daily temperature accumulation
- double logistic interpolation

Ex for NDVI accumulation

Double logistic interpolation
Irrigated in blue, not irrigated in green
Preliminary results:

Error < 20% by mid July
• Good perspectives for the discrimination of irrigated crops
• Validation work to continue in 2015
• Automatisation of processing chain
SAFY* : agro-meteorological model
- Limited number of simulated processes and parameters: 13
- Suitable for use of remote sensing data
- daily step

**Input variables:**
- $R_g$ : global radiation
- $T_a$ : air temperature
- Land cover
- GAI profiles

**Output variables:**
- GAI (Green Area Index)
- DAM (Dry Aboveground Mass = biomass)
- Yield

*Simple Algorithm for Yield Estimates; Duchemin et al. (2008)*
BIOMASS ESTIMATION - validation

Preliminary results for biomass estimation
Validation of SAFY model:
• 32% RRMSE for sunflower
• 19% for maize
• 20% for wheat
• Work will continue on calibration and validation
• Efforts for an operational use with limited in-situ data
• Incorporation of water in the model = SAFYE
  → water needs and supplies estimation

First results for calibration of SAFYE on maize:

No irrigation in model

\[
Y = 0.46X + 225.54 \\
R^2 = 0.73 \\
\text{Bias} = -348.6788 \\
\text{RMSE} = 229.2 \\
\text{RRMSE} = 21.4167
\]

Irrigation information

\[
Y = 0.85X + 174.61 \\
R^2 = 0.87 \\
\text{Bias} = 13.3447 \\
\text{RMSE} = 267 \\
\text{RRMSE} = 24.9487
\]
Conclusions and perspectives

Conclusions
• Very good dataset for reference data biophysical variables
• Correct results with BVNET for biophysical variables estimation with remote sensing data
  -> good temporal profile for use as input in models
• Good estimation of biomass, and perspectives for improvement and automatisation with current work
• Promissing results for water needs and supplies estimation with SAFYE

Perspectives
• **BVNET** in OTB
  • continue work to evaluate the interest of BVNet
  → correction sensor effect on multi-sensor series
  → contribution of MIR band
  → specific configuration for each crop
**SAFYE** :
  • continue work on parameters optimization
  • Calibration and validation for water needs and supplies
  • Yield : bad reference data, need new dataset

• Need to continue work on cartography of **irrigated areas** with large dataset, especially SPOT4-Take5 series
Thank you for your attention

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