A generic Remote Sensing approach for large-scale Land cover and Land use systems mapping

RSCy - 20th March 2017

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CIRAD - TETIS Research unit
EMBRAPA
INPE
INTRODUCTION

TOSCA AGRIZONE

COMMON SCIENTIFIC OBJECTIVE

Develop methodologies to improve the monitoring *agricultural systems* at a large-scale

GLOBAL CHALLENGE

Increase production in a sustainable way
INTRODUCTION

COMMON SCIENTIFIC OBJECTIVE

Develop methodologies to improve the monitoring of agricultural systems at a large-scale

Explore the potential of RS techniques

- Localization and characterization
- Production
- Agricultural land expansion
- Intensification of management practices
- ...

PROJECT in support of GEOGLAM

PROGRAM in support of GEOABC

TOSCA AGRIZONE
INTRODUCTION

COMMON SCIENTIFIC OBJECTIVE

Develop methodologies to improve the monitoring *agricultural systems* at a large-scale

- Explore the potential of RS techniques
  - Localization and characterization

AGRICULTURAL LAND USE SYSTEMS MAPPING
Land use system mapping involves:

The delineation of relatively homogeneous areas of land, referred to as land units, that are directly linked to a specific type of land use (Driessen & Konijn, 1992; FAO, 1993)
Develop a **multi-level** approach based on **GEOBIA** and **vegetation index time series** analysis for large-scale mapping of agricultural land use systems.
TOCANTINS, Brazil
STUDY SITE

**Area**: 277,621 km²

**Field size**: mostly large (~ 100 ha.)

**Main cropping systems**:  
- Soybean/Cereal double-crop  
- Rice/Soybean double-crop  
- Soybean monoculture  
- Sugarcane monoculture

**Main agricultural practices**:
- Mechanical seeding, fertilization, pesticide application and harvest  
- Dominance of zero-tillage systems

*Landsat 8 2015 mosaic – 30m spatial res.*
MULTI-LEVEL APPROACH

REGIONAL LEVEL

- Delimit homogeneous land units in terms of phenological patterns
- Identification of agricultural land use systems through spatial analysis

FIELD LEVEL

- Annual cropland + Cropping systems classification
REGIONAL LEVEL

Delimit homogeneous land units in terms of phenological patterns
METHODS > Regional level Land units delineation

DATA
MODIS NDVI 16-days composites annual time series
Oct 2014 – Sep 2015
23 composite images
250m spatial resolution

PROCESSING
Principal Component Analysis (PCA)
Radiometric features = PC2 – PC20

RESULT
Multiresolution segmentation
eCognition Developer 9.0
FIELD LEVEL

Annual cropland + Cropping systems classification
DATA
MODIS NDVI annual time series

Landsat 8 mosaic 30m spatial res.

PROCESSING
OBIA + Unsupervised Classification

1
HSR SEGMENTATION (187741 objects)

2
MEDIAN TEMPORAL NDVI PROFILE PER OBJECT (23 composite images)

3
UNSUPERVISED CLASSIFICATION
METHODS > Field Level classification

3 UNSUPERVISED CLASSIFICATION

120 land units

K-means clustering (10 classes per land unit)

Mean temporal NDVI profile per class

K-means Clustering
1200 mean temporal NDVI profiles (10 classes)
RESULTS

NDVI temporal profile analysis of final classes

Mean + SD
Mean
Mean - SD
METHODS > Field Level classification

Soybean single cropping system

Soybean-cereal double cropping system

Rice-Soybean double cropping system
RESULTS

Annual cropland classification

Overall Accuracy = 95.8%
Kappa Index = 0.88

Cropping systems classification

Overall Accuracy = 94.9%
Kappa Index = 0.86

- Soybean single cropping system
- Soybean - Cereal double cropping system
- Rice - Soybean double cropping system
- Other LUS

METHODS > Field Level classification
Identification of agricultural land use systems through spatial analysis
Identification of Agricultural LUS

REGIONAL LEVEL

FIELD LEVEL
Figure 7. The temporal NDVI profiles plots of the of the 22 crop agriculture domain land units. The plots show the mean (solid black curve) and the standard deviation (shaded dark grey curve) of the NDVI pixel values inside the annual agriculture TerraClass mask for each land unit against the day of the year (DOY). A representative land-unit profile for each of the three phenological pattern groups
Agricultural Land Use Systems
State of Tocantins, Brazil, 2015

- Soybean single cropping system
- Soybean / Cereal (Maize, Sorghum, Millet) double cropping system
- Rice / Soybean double cropping system
TERRAClass Amazonia et Cerrado

- **Annual Agriculture ≥ 10%?**
  - Yes → **Crop agriculture domain**
  - No → **Pasture & Rangelands ≥ 30%?**
    - No → **Other land-unit types**
    - Yes → Coexistence land unit

- **Pasture & Rangelands ≥ 30%?**
  - Yes → **Coexistence land unit**
  - No → **Pasture & Rangelands ≥ 60%?**
    - No → **Semi-intensive livestock land unit**
    - Yes → **Intensive livestock land unit**
Figure 8. Map of the main agricultural land-use systems (ALUS) of the Tocantins state in the 2013-2014 growing season.
Reproducibility tests:

- 2016 Tocantins
- Burkina Faso

Landsat 8 PXS
Spatial resolution = 15m
THANK YOU

ACKNOWLEDGEMENTS
EXTRAS
### IN SITU DATA COLLECTION

#### DB LULC – October 2015

<table>
<thead>
<tr>
<th>LULC Class</th>
<th>No. of points TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual cropland</td>
<td>193</td>
</tr>
<tr>
<td>Soybean single cropping</td>
<td>38</td>
</tr>
<tr>
<td>Soybean – Cereal double cropping</td>
<td>133</td>
</tr>
<tr>
<td>Rice- Soybean double cropping</td>
<td>22</td>
</tr>
<tr>
<td>Other LCC</td>
<td>653</td>
</tr>
<tr>
<td>Grassland and meadows</td>
<td>242</td>
</tr>
<tr>
<td>Fallows</td>
<td>28</td>
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<tr>
<td>Perennial crops</td>
<td>67</td>
</tr>
<tr>
<td>Shrubland</td>
<td>128</td>
</tr>
<tr>
<td>Forest</td>
<td>65</td>
</tr>
<tr>
<td>Build-up Surface</td>
<td>30</td>
</tr>
<tr>
<td>Bare soil</td>
<td>12</td>
</tr>
<tr>
<td>Water bodies</td>
<td>15</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>900</strong></td>
</tr>
</tbody>
</table>
## CONFUSION MATRIX

### Annual cropland classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Reference</th>
<th>TOTAL</th>
<th>Producer’s accuracy (%)</th>
<th>User’s accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual cropland</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual cropland</td>
<td>181</td>
<td>26</td>
<td>207</td>
<td>93.78</td>
</tr>
<tr>
<td>Other LCC</td>
<td>12</td>
<td>681</td>
<td>693</td>
<td>96.32</td>
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<tr>
<td>TOTAL</td>
<td>193</td>
<td>707</td>
<td>900</td>
<td><strong>Global accuracy = 95.78%</strong></td>
</tr>
</tbody>
</table>
## Cropping systems classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Reference</th>
<th>TOTAL</th>
<th>Producer’s accuracy (%)</th>
<th>User’s accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean single</td>
<td>35</td>
<td>57</td>
<td>92.11</td>
<td>61.40</td>
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<tr>
<td>Soybean - Cereal</td>
<td>0</td>
<td>128</td>
<td>87.22</td>
<td>90.63</td>
</tr>
<tr>
<td>Rice - Soybean</td>
<td>0</td>
<td>22</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Other LUS</td>
<td>3</td>
<td>681</td>
<td>96.32</td>
<td>98.27</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>38</strong></td>
<td><strong>707</strong></td>
<td><strong>900</strong></td>
<td><strong>Global accuracy = 94.89%</strong></td>
</tr>
</tbody>
</table>

Kappa index = 0.86
## SEGMENTATION PARAMETERS

<table>
<thead>
<tr>
<th>Data</th>
<th>Spatial resolution</th>
<th>Bands (all same weight)</th>
<th>Scale parameter</th>
<th>Color</th>
<th>Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land units</strong></td>
<td>Principal components from NDVI TS</td>
<td>250m</td>
<td>PC2 - PC20</td>
<td>1000</td>
<td>1</td>
</tr>
<tr>
<td><strong>Fields</strong></td>
<td>Landsat 8 mosaic July 2015 (19 Landsat scenes)</td>
<td>30m</td>
<td>B (b2) G (b3) R (b4) NIR (b5) SWIR1 (b6)</td>
<td>110</td>
<td>0.2</td>
</tr>
</tbody>
</table>
### CONFUSION MATRIX

#### Annual cropland classification

<table>
<thead>
<tr>
<th>Prediction</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>181</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>681</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Accuracy**: 0.9578  
**95% CI**: (0.9425, 0.97)  
**No Information Rate**: 0.7856  
**P-Value [Acc > NIR]**: < 2e-16  
**Kappa**: 0.8779  
**Mcnemar’s Test P-Value**: 0.03496  
**Sensitivity**: 0.9378  
**Specificity**: 0.9632  
**Pos Pred Value**: 0.8744  
**Neg Pred Value**: 0.9827  
**Prevalence**: 0.7144  
**Detection Rate**: 0.2011  
**Detection Prevalence**: 0.2300  
**Balanced Accuracy**: 0.9505

#### Cropping systems classification

<table>
<thead>
<tr>
<th>Prediction</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>135</td>
<td>8</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>116</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>9</td>
<td>0</td>
<td>681</td>
</tr>
</tbody>
</table>

**Accuracy**: 0.9489  
**95% CI**: (0.9324, 0.9623)  
**No Information Rate**: 0.7856  
**P-Value [Acc > NIR]**: < 2.2e-16  
**Kappa**: 0.8622  
**Mcnemar’s Test P-Value**: NA

**Statistics by Class:**

<table>
<thead>
<tr>
<th>Class</th>
<th>Class: 1</th>
<th>Class: 2</th>
<th>Class: 3</th>
<th>Class: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.92105</td>
<td>0.8722</td>
<td>1.00000</td>
<td>0.9632</td>
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<tr>
<td>Specificity</td>
<td>0.97448</td>
<td>0.9844</td>
<td>1.00000</td>
<td>0.9378</td>
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<tr>
<td>Pos Pred Value</td>
<td>0.61404</td>
<td>0.9063</td>
<td>1.00000</td>
<td>0.9627</td>
</tr>
<tr>
<td>Neg Pred Value</td>
<td>0.99644</td>
<td>0.9780</td>
<td>1.00000</td>
<td>0.8744</td>
</tr>
<tr>
<td>Prevalence</td>
<td>0.04222</td>
<td>0.1478</td>
<td>0.02444</td>
<td>0.7856</td>
</tr>
<tr>
<td>Detection Rate</td>
<td>0.03889</td>
<td>0.1289</td>
<td>0.02444</td>
<td>0.7567</td>
</tr>
<tr>
<td>Detection Prevalence</td>
<td>0.06333</td>
<td>0.1422</td>
<td>0.02444</td>
<td>0.7700</td>
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<tr>
<td>Balanced Accuracy</td>
<td>0.94777</td>
<td>0.9283</td>
<td>1.00000</td>
<td>0.9505</td>
</tr>
</tbody>
</table>