Real-time crop mask production using high-spatial-temporal resolution image times series

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1. **Introduction**
   - Dynamic cropland mask
   - State-of-the art
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2. Constructing a real-time classification system

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Dynamic cropland mask

Cropland mask is a binary mask product mapping the cultivated domain.

What is represented by the pixel? ... Is it a crop?

The cropland detection has been considered as a binary problem.
Dynamic cropland mask

The goal is to construct a classification system producing a cropland mask product following the real-time data acquisitions.

High-spatial-temporal resolution image times series
The dynamic cropland mask product involves the next three points:

- From the first dates of the year, we would like to forecast the cropland mask that we will have at the end of the season.

- The cropland mask will be updated progressively at each new acquisition.

- At the end of the season, the cropland mask will contain the regions where at least one crop has been planted along the year (not including grasslands either woody vegetation).
State-of-the art

- The **problem** of dynamic cropland map construction **has not been tackled** in the literature.

- **Unsupervised and supervised classification** approaches have been presented to generate land cover maps.

- In both cases, **previous knowledge** of the imaged scene is mandatory.

- **Supervised algorithms:** the previous knowledge is used **to teach the classification algorithms** how they can differentiate one class from another.
Real-time classification system

Classifier trained by using the previous year

Feature Extraction → Classification

Crop mask at $T_{t-2}$

Feature Extraction → Classification

Crop mask at $T_{t-1}$

Feature Extraction → Classification

Crop mask at $T_t$
Teaching by using data from previous years ...

**Why?** Because in real life, the ground truth data is available much later than the satellite images.

**Attention!** The acquisition dates change between consecutive years.

**Solution** : The use of crop patterns which do not depend on the annual acquisitions dates.
Looking for crop patterns ...

The NDVI profile allows us to reflect the different crop stages (planting, seedling, tassel, to maturation and harvesty.)

Example of NDVI profile describing an agriculture crop.
Looking for crop patterns ...

**Feature Extraction**

**Classification**

**NDVI**

16-Temporal features

5-Statitic features
(mean, std, ...)

Brightness, Greenness, ...

**F_{NDVI}^temp**

**F_{stat}** ...
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To achieve our goal, there are some questions that should be answered ...

- Which quality criteria will we use to evaluate the cropland mask product?
- Which features do we need to use?
- How many training samples do we need in order to correctly teach the classifier?
- Which supervised classifier must we use?
How to estimate the dynamic crop mask performances?

- **Accuracy** = Fraction of crops and no crops correctly classified.
- **Recall** = Fraction of crop correctly classified taking into account all the true crops.
- **Precision** = Fraction of crops classified as crops which are actually crops.
- **F-score** = The harmonic mean of precision and recall

\[
\text{Accuracy} = \frac{TP + TN}{TP + TN + FN + FP} \\
\text{Recall} = \frac{TP}{FN + TP} \\
\text{F-score} = \frac{2TP}{2TP + FN + FP} \\
\text{Precision} = \frac{TP}{FP + TP}
\]
To achieve our goal, there are some **questions that should be answered** ...

- Which quality criteria will we use to evaluate the cropland mask product?

- Which features do we need to use?

- How many training samples do we need in order to correctly teach the classifier?

- Which supervised classifier must we use?
Experimental Data

The experiments have been performed by using SPOT4-Take5 data, complemented by LANDSAT 8 data, as a proxy of Sentinel-2.

Area of study: Midi-Pyrénées, France

Pre-processing tasks: Gapfilling and resampling to 20m.

Ground truth data:

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>Number of crop pixels</td>
<td>162697</td>
</tr>
<tr>
<td>Number of no crop pixels</td>
<td>43521</td>
</tr>
</tbody>
</table>

Temporal domain: February to December
Feature discrimination analysis

The goal is to evaluate the discrimination of the proposed temporal and statistic features

Ideal case:
- The training and testing tasks are performed on the same year.
- All the possible dates composing the times series have been used.

Classification considerations:
- The supervised Random Forest classifier has been selected.
- 500 samples for each class is used to train the classifier.
- The classification has been performed with 10 times.
### Feature discrimination analysis

Quality measures for Random Forest Classifier

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tbody>
<tr>
<td>Fscore</td>
<td>95.2</td>
<td>95.2</td>
<td>95.5</td>
<td>95.4</td>
<td>95.10</td>
<td>95.36</td>
<td>95.58</td>
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<tr>
<td>Accuracy</td>
<td>92.69</td>
<td>92.67</td>
<td>93.15</td>
<td>92.92</td>
<td>92.47</td>
<td>92.84</td>
<td>93.20</td>
<td>92.99</td>
<td>93.33</td>
</tr>
<tr>
<td>Precision</td>
<td>97.96</td>
<td>97.86</td>
<td>97.96</td>
<td>97.75</td>
<td>97.97</td>
<td>97.91</td>
<td>97.91</td>
<td>97.94</td>
<td>97.85</td>
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<tr>
<td>Recall</td>
<td>92.66</td>
<td>92.72</td>
<td>93.28</td>
<td>93.18</td>
<td>92.40</td>
<td>92.91</td>
<td>93.41</td>
<td>93.1</td>
<td>93.63</td>
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</tbody>
</table>

1: $F_{\text{temp NDVI}}$

2: $F_{\text{temp NDVI}} + F_{\text{stat 2ndDer}}$

3: $F_{\text{temp NDVI}} + F_{\text{stat Brightness}}$

4: $F_{\text{temp NDVI}} + F_{\text{stat Greenness}}$

5: $F_{\text{temp NDVI}} + F_{\text{stat Red}}$

6: $F_{\text{temp NDVI}} + F_{\text{stat Red}} + F_{\text{stat Greenness}}$

7: $F_{\text{temp NDVI}} + F_{\text{stat Greenness}} + F_{\text{stat Brightness}} + F_{\text{stat Red}}$

8: $F_{\text{temp NDVI}} + F_{\text{stat Brightness}} + F_{\text{stat Red}}$

9: $F_{\text{temp NDVI}} + F_{\text{stat Greenness}} + F_{\text{stat Brightness}}$
Feature discrimination analysis

Standard deviation of the quality measures obtained by the previous 10 test

<table>
<thead>
<tr>
<th>(1e-03)</th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<th>6</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Fscore</td>
<td>2.6</td>
<td>3.25</td>
<td>2.7</td>
<td>2.18</td>
<td>2.86</td>
<td>2.87</td>
<td>2.48</td>
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<td>2.00</td>
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<tr>
<td>Accuracy</td>
<td>4.0</td>
<td>4.6</td>
<td>3.8</td>
<td>3.19</td>
<td>4.21</td>
<td>4.16</td>
<td>3.46</td>
<td>5.02</td>
<td>3.09</td>
</tr>
<tr>
<td>Precision</td>
<td>1.5</td>
<td>2.1</td>
<td>1.7</td>
<td>1.71</td>
<td>1.94</td>
<td>1.91</td>
<td>1.59</td>
<td>1.50</td>
<td>1.43</td>
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<tr>
<td>Recall</td>
<td>6.3</td>
<td>8.0</td>
<td>6.4</td>
<td>5.51</td>
<td>6.96</td>
<td>7.34</td>
<td>5.87</td>
<td>7.72</td>
<td>4.92</td>
</tr>
</tbody>
</table>

1: \( F_{\text{temp\ NDVI}} \)
2: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ 2ndDer}} \)
3: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Brightness}} \)
4: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Greenness}} \)
5: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Red}} \)
6: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Red}} + F_{\text{stat\ Greenness}} \)
7: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Greenness}} + F_{\text{stat\ Brightness}} + F_{\text{stat\ Red}} \)
8: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Brightness}} + F_{\text{stat\ Red}} \)
9: \( F_{\text{temp\ NDVI}} + F_{\text{stat\ Greenness}} + F_{\text{stat\ Brightness}} \)

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To achieve our goal, there are some questions that should be answered ...

- Which quality criteria will we use to evaluate the cropland mask product?
- Which features do we need to use?
- How many training samples do we need in order to correctly teach the classifier?
- Which supervised classifier must we use?
The goal is to evaluate the robustness of the limited amount of training data in the supervised learning.

Ideal case:

- The training and testing tasks are performed on the same year.
- All the possible dates composing the times series have been used.

Classification considerations:

- The supervised Random Forest classifier has been tested.
- The classification has been performed 10 times for a different number of training samples.
- The image features are $F_{\text{NDVI}}^{\text{temp}} + F_{\text{Greenness}}^{\text{stat}} + F_{\text{Brightness}}^{\text{stat}}$
Selecting the number of training samples...
To achieve our goal, there are some **questions that should be answered** ...

- Which quality criteria will we use to evaluate the cropland mask product?
- Which features do we need to use?
- How many training samples do we need in order to correctly teach the classifier?
- Which supervised classifier must we use?
Real-time classification analysis

The goal is to evaluate the classification performances along the year

Ideal case:

- The training is done by using all the image acquisitions.
- The feature extraction and the classification tasks are done at each temporal acquisition.

Classification considerations:

- The supervised Random Forest and SVM classifiers have been tested.
- 500 samples for each class is used to train the classifier.
- The image features are $F_{\text{NDVI}}^{\text{temp}} + F_{\text{Greenness}}^{\text{stat}} + F_{\text{Brightness}}^{\text{stat}}$
Real-time classification analysis

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Real-time classification analysis

Accuracy (100 %)

- Grassland and meadows RF
- Permanent cropland RF
- Forest or woody areas RF
- Shrub–land RF
- Artificial surfaces RF
- Water bodies RF
- Wheat RF
- Maize RF
- Sorghum RF
- Barley RF
- Soybeans RF
- Peas RF
- Rapeseed RF
- Sunflower RF
Goal: To evaluate the cropland mask obtained at 2013 in a large area.

How to proceed?

- Using the farmer’s area declaration of 2012.
- In France, it corresponds to the "Registre Parcellaire Graphique".
- The cropland mask is then evaluated in a larger area

Ground truth data:

The number of Crop samples at 2012: 1409302
The number of No Crop samples at 2012: 15425698
Evaluating cropland mask results

Cropland mask obtained by **SPOT4-Take5** data, complemented by **LANDSAT 8** data at **2013**.
Evaluating cropland mask results

The 93.9 % of crop pixels at 2012 has been perfectly detected. The 6.09 % of crop pixels at 2012 has been detected as no crops.

The 71.8 % of no crop pixels at 2012 has been perfectly detected. The 28.2 % of no crop pixels at 2012 has been detected as crops.

Quality criteria

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>58.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fscore</td>
<td>37.3</td>
</tr>
<tr>
<td>Recall</td>
<td>93.9</td>
</tr>
<tr>
<td>Precision</td>
<td>23.3</td>
</tr>
</tbody>
</table>

Ground truth data

| The number of Crop samples at 2012 : | 1409302 |
| The number of No Crop samples at 2012 : | 15425698 |

What happened to the no crop pixels ??
Evaluating cropland mask results

- Around the 5% of crop fields change between two consecutive years.
- The border of the fields are not included in the ground truth data.

The good detection appears in green. False alarm color is red. Missing crops are in blue.
The farmer’s area declaration was forgotten ...

The good detection appears in green. False alarm color is red. Missing crops are in blue.
Evaluating cropland mask results

- Some small crop fields have been detected ...

The good detection appears in green. False alarm color is red. Missing crops are in blue
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Conclusions

- A real-time classification system has been presented here in order to produce accurate cropland masks along the crop season.
- Features not depending on acquisition dates have been proposed in this study.
- Real-time classification results are very promising (around 75% in the middle of the season)
- The importance of having the onset of greenness and senescence have been shown.
The classification system will be tested on 15 different sites.

The spatial information will be included in the methodology (region-based approach).

The robustness of the classification system to the data variability between two consecutive years will be studied.