Integrating Landsat 7, 8 and Sentinel 2 data in improving crop type identification and area estimation

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**Operational** crop type mapping using satellite data in the U.S. and Canada

- Satellite-based crop type maps
  - Cropland Data Layer (CDL), United States Department of Agriculture National Agricultural Statistics Service (USDA NASS)
  - Cropland Inventory (CI), Agriculture and Agri-Food Canada (AAFC)

- Pros
  - **Annual** update, 30 m resolution
  - Freely available
  - Highly **accurate** for major crops (> 85%)

- Cons
  - Typically released in Feb-Apr next year.
  - Tremendous training for classification (not publically available), **difficult to implement** in other countries
General approach to national-scale crop type area estimation

Near-term crop type indicator maps for stratification

Samples of in situ and/or high-resolution data for probability based area estimation

Current year crop type indicator map as regression estimator to reduce the uncertainty

Sample-based area estimate as constraint for final high-resolution map
Near term historical crop type as a current season stratifier
Two stage cluster sampling

In situ crop type reference data collection
Collecting field data

- High soybean stratum
- Medium soybean stratum
- Low soybean stratum
- Very low soybean stratum

4 vehicles
2 weeks
15,000 miles.
Soybean area estimate from field sample: \(340,916\) km\(^2\), derived in **early September, 2 months** ahead of harvest.

USDA NASS 2015 June survey: \(344,000\) km\(^2\)

USDA NASS 2016 January estimate: \(334,000\) km\(^2\)

1.0 % lower than 2015 June survey but 1.9 % higher than 2016 January estimate.

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Area (km(^2))</th>
<th>SE (km(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>99,598</td>
<td>9,442</td>
</tr>
<tr>
<td>Medium</td>
<td>94,783</td>
<td>8,086</td>
</tr>
<tr>
<td>Low</td>
<td>120,738</td>
<td>16,331</td>
</tr>
<tr>
<td>Very low</td>
<td>25,797</td>
<td>11,372</td>
</tr>
<tr>
<td>Total</td>
<td>340,916</td>
<td>23,463</td>
</tr>
</tbody>
</table>

Map accuracy validated using field sample

<table>
<thead>
<tr>
<th>Map</th>
<th>Soybean</th>
<th>Non-soybean</th>
<th>Sample total</th>
<th>User’s accuracy % (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>0.16</td>
<td>0.05</td>
<td>0.22</td>
<td>75 (5)</td>
</tr>
<tr>
<td>Non-soybean</td>
<td>0.09</td>
<td>0.69</td>
<td>0.78</td>
<td>88 (2)</td>
</tr>
<tr>
<td>Map total</td>
<td>0.25</td>
<td>0.75</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Producer’s accuracy % (SE)</td>
<td>64 (4)</td>
<td>93 (2)</td>
<td>Overall Accuracy % (SE) = <strong>86 (2)</strong></td>
<td></td>
</tr>
</tbody>
</table>
2015 growing season metrics from Landsat
Green = soybean 2015
South America
southern hemisphere
growing season soybean
cultivated area
South America
southern hemisphere
growing season soybean
cultivated area

2015-2016 growing
season soybean cover

>80%
>1%
South America
southern hemisphere
growing season soybean
cultivated area

No CDL Layer
Stratified using
near term
historical map

2015-2016 growing season soybean cover

>80%
>1%
2016-2017 South America cultivated soybean area estimate of: 55.3Mha +/- 6.5Mha

Brazil: 30.8 +/- 3.8
Argentina: 18.1 +/- 1.1
Soybean area estimates in Argentina

Soybean planted area for Argentina for the 2013/2014 growing season was estimated to be 15.40 (SE 0.73) million hectares.

MODIS-derived in-season soybean indicator and calibrated based on stratified regression estimator with Landsat-derived soybean as reference.

Provincial level comparison with USDA’s Foreign Agricultural Service estimate (total 19.8 Mha, 28% more than this study).

King et al. in review
Stratified random samples of wheat cover in Punjab, Pakistan (Rabi season 2013-14)
In Situ Sample Point Classification
Punjab wheat cover estimation

Landsat data are useful in quantifying wheat in an intensive growing region characterized by small fields (5ha mean field size).

Crop types, such as clover are associated with errors of commission.

Omission errors were associated with landscape complexity specifically mixed cropping and orchards.

Overall, our estimates were within 10% of the official statistics.

Landsat based estimates could be delivered before official estimates, well before harvest, and used as a reliable input for decision making and policy guidelines.
1. First we get the area estimate at the national scale early in the season.

2. Map wheat with views of the complete growing window
   • Used Rapid Eye as training for small field size (5m)
RapidEye (5m) archive searched
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Selected nine images within 2014-15 wheat growing season
RapidEye (5m) archive searched

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Trained and classified RE images

Converted to percent wheat land cover

Re-resampled to 30m Landsat scale
RapidEye (5m) archive searched

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Percent wheat RE composite used as training Landsat data
RapidEye (5m) archive searched

Selected nine images within 2014-15 wheat growing season

Trained and classified RE images

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Re-resampled to 30m Landsat scale

Percent wheat RE composite used as training Landsat data

Wall to wall percent wheat map derived from Landsat composite at 30m
Conclusions

- Landsat allows for operational crop type mapping that is annually updated at 30 m resolution, freely available, and highly accurate for major crops (>85%)
- Crop type indicator maps are valuable in providing sampling efficiencies that result in unbiased crop type area estimates with low uncertainty
- Regression estimators of current indicated crop extent reduced uncertainties by 25% in both the USA and Argentina
- Supplementing Landsat with high resolution rapid eye (5m) imagery for mapping in small holder agriculture
- End result includes an unbiased map of crop area with known accuracy
Thank You!

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The data and methods:

- **Input data:**
  Landsat metric (Dec 2013 – April 2014) created to map wheat in Punjab (Arvidon et al. 2001; Arvidson et al. 2006)
  - Data (136 Landsat 7, 145 Landsat 8 images) composited using cloud free pixels and spectral and thermal bands;
  - 750 multi-temporal metrics (Potapov et al. 2012)
  - Start/end point image composites
  - Rank-based metrics
Probability based training of pixels to wheat and non-wheat

- Training of the data to wheat and not-wheat (visual interpretation; experience of the area; crop phenology)