Field size estimation, past and future opportunities

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Why Study Field Sizes?

The size of agricultural fields is:

• a fundamental description of rural landscapes

• of biophysical, ecological and economic importance

• indicative of the degree of agricultural capital investment, mechanization, and labor intensity

• through time is indicative of agricultural changes
Farmers ripping up fence line and clearing tree lot to increase field size (5th September 2015, one mile north of Brookings, SD)
Importantly, Landsat has both suitable resolution & length of record to capture field size changes in many parts of the world.

Landsat 30m observations since 1982
Conterminous United States (CONUS) Motivation

Histogram from 109,000 agricultural fields (> 1 acre) digitized from Landsat data acquired in 1977 – 1980 over parts of the Mid-West and Canada

What would this histogram look like for:

• all CONUS ?

• every decade ?

Field Extraction Methodology

Computational methodology designed to be

• fully automated
• no training data
• no human interactions

• needed for CONUS 30m Landsat application
Use Landsat time series

Example WELD Weekly Products
Week 27: July 8 - 14 2008

10 Years of Alaska and CONUS Landsat 7 ETM+ 30m products
http://weld.cr.usgs.gov

gridded calibrated 30m Landsat reflectance
weekly, monthly, seasonal and annual products
Use Landsat time series

Example WELD Weekly Products
Week 28: July 8 - 14 2008

10 Years of Alaska and CONUS
Landsat 7 ETM+ 30m products
http://weld.cr.usgs.gov
Use Landsat time series

Example WELD Weekly Products
Week 29: July 15 - 21 2008

10 Years of Alaska and CONUS
Landsat 7 ETM+ 30m products
http://weld.cr.usgs.gov
USDA National Agricultural Statistics Service

**Cropland Data Layer (CDL)**

based on supervised classification of many satellite data, lots of training data, and interactive refinements

Pixel-based products unable to extract separated and coherent fields
Big-picture algorithm processing flow

52 weeks of WELD 2010 Landsat 5 & 7 weekly images

edge intensity map

USDA NASS 2010 Cropland Data Layer (CDL)

Extracted fields

Computer vision approach

Binary crop mask
Field Extraction Results
WELD Tile
h13v12
Northern High Plains, Texas

Texas

5000 x 5000 30m pixels
Automatically extracted field objects

Texas

5000 x 5000 30m pixels
WELD Tile
h05v13
Imperial Valley, CA

California

5000 x 5000 30m pixels
Automatically extracted field objects

California

5000 x 5000 30m pixels
Field size
= \((30 \times 30) m^2\sum \text{number pixels}\)
2010 CONUS crop field size map
(mean field size in 7.5 x 7.5 km grid cells)

4,182,777 crop fields extracted

derived from all 13,666 sunlit Landsat 5 and 7 scenes available in the U.S. Landsat archive for December 2009 to November 2010
Validation
Validation Sites

- 48 sites distributed in the top 16 U.S. states by harvested area
- each site ~ 7.5 x 7.5 km
- >5,800 reference fields manually selected from Landsat 5 and Google-Earth images over the 48 sites for comparison with the automatically extracted fields
Validation example: a California site ~ 7.5 x 7.5 km

Extracted fields & reference field polygons (one-to-one matched, over-split, under-split, missed)

Validation results over 48 validation sites
- 81.4% of the >5,800 reference fields correctly extracted
- mean of <2% mean-field-size difference with <5% standard deviation

Object-based accuracy metrics

<table>
<thead>
<tr>
<th>Site</th>
<th>Ref. #</th>
<th>Extr. #</th>
<th>one to one</th>
<th>matching ratio</th>
<th>over-split</th>
<th>under-split</th>
<th>Ref. mean size</th>
<th>Extr. mean size</th>
<th>mean size diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA3</td>
<td>161</td>
<td>149</td>
<td>139</td>
<td>86.3%</td>
<td>1</td>
<td>8</td>
<td>318.7</td>
<td>315.7</td>
<td>-0.9%</td>
</tr>
</tbody>
</table>
Validation example: a Missouri site ~ 7.5 x 7.5 km

<table>
<thead>
<tr>
<th>Site</th>
<th>Ref. #</th>
<th>Extr. #</th>
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<th>Extr. mean size</th>
<th>mean size diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>MI 1</td>
<td>134</td>
<td>134</td>
<td>96</td>
<td>71.6%</td>
<td>14</td>
<td>13</td>
<td>464.9</td>
<td>447.5</td>
<td>-3.7%</td>
</tr>
</tbody>
</table>

object-based accuracy metrics
CONUS 2010
crop field size histogram

4,182,777 fields extracted
**CONUS 2010**

Crop field size histogram

4,182,777 fields extracted

**Field area percentage =**

\[
\frac{\sum \text{(field area in histogram bin)}}{\sum \text{(CONUS field area)}}
\]
California 2010
crop field size histogram

116,888 fields extracted

Google-Earth image. ~5.5 x 5 km subset in California near Corcoran
Iowa 2010
crop field size histogram

308,917 fields extracted

Google-Earth image. ~5.5 x 5 km subset in Iowa near Eagle Grove
2010 CONUS CDL majority crop map
(with ≥ 10% CDL crop pixels in 7.5 x 7.5 km grid cells)

- corn
- soybeans
- alfalfa
- wheat (winter, spring and durum wheat)
- cotton
- other crops
2010 CONUS crop field size map
(mean field size in 7.5 x 7.5 km grid cells)

4,182,777 crop fields extracted
derived from all 13,666 sunlit Landsat 5 and 7 scenes available in the U.S.
Landsat archive for December 2009 to November 2010
CONUS 2010 field size histograms for the major crops

Field area percentage (%) vs Field size (km$^2$)

- Corn (yellow)
- Soybean (green)
- Alfalfa (pink)
- Wheat (black)
- Cotton (red)
Largest Extracted Field

Google-Earth image (acquired on 8/18/2010)

2010 CDL (CDL classified as cotton in the annual 2008 to 2014 product)

3,200 acres (5 square miles!) Gaines, Texas
Future Work

(but needs funding ...)
Global Field Extraction

- **field size categories from geo-wiki information**
- **qualitative field size information only and unknown quality**

GLOBAL WELD 3 years (2009-2011) of monthly & annual Landsat 5 & 7 composites atmospherically corrected Nadir BRDF-Adjusted Reflectance

HDF format products at: [http://globalweld.cr.usgs.gov/collections](http://globalweld.cr.usgs.gov/collections)

GeoTiff format products at: [http://globalweld.cr.usgs.gov](http://globalweld.cr.usgs.gov)

Native resolution visualizations at: [http://go.nasa.gov/2kLcKto](http://go.nasa.gov/2kLcKto)
Landsat 8

400 × 400
30 m pixels

August 23 2016

California
Sentinel 2A

1200 × 1200
10 m pixels

August 23 2016

California
Landsat 8

400 × 400
30 m pixels

August 23 2016

California
Some fields too small to be discernable with Landsat or Sentinel-2 data

India - Punjab, 15 x 15km scene

Landsat 7 ETM+ 30m (10/28/2002)  
Quickbird-2 2.5m (10/07/2003)
Some fields too small to be discernable with Landsat or Sentinel-2 data

China - Jiangsu province, 15 x 15km scene

Landsat 5 TM 30m (03/23/2005)  Quickbird-2 2.5m (04/07/2005)
Summary

- Landsat time series provide sufficient information to detect crop fields in an automated way using a computer vision based approach across the U.S.

- First-ever U.S. wall-to-wall satellite-based field extraction demonstrated (using WELD processed Landsat 5 and 7).

- Validation results over 48 validation sites
  - 81.4% of the >5,800 reference fields correctly extracted
  - mean of <2% mean-field-size difference with <5% standard deviation

- New moderate resolution satellite data will provide improved global agricultural monitoring where field sizes are small
  - Landsat-8 30m data have better quantization and signal/noise characteristics than previous Landsats
  - Sentinel-2 has Landsat-like bands at 10m & 20m

- We have been contacted by the National Geospatial-Intelligence Agency (NGA) to investigate the approach on NGA commercial high-resolution data under a Cooperative Research and Development Agreement (CRADA).
References


Acknowledgements

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