The Utility and Limitations of Remote Sensing in Land Use Change Detection and Conservation Planning

Steffen Mueller, PhD, Principal Economist
Ken Copenhaver, CropGrower LLC

Presentation to:
US Environmental Protection Agency
June 8, 2017
UIC - Key Research Efforts

• Biofuels/Ethanol Life Cycle Analysis
  o Impact of sustainable production practices on life cycle emissions
  o Member, Expert Working Group, California Low Carbon Fuel Standard Development
• Collaboration with Argonne National Laboratory to inform GREET Biofuels and Ag Feedstock pathway
  o Long term collaboration, 15+ joint papers and publications
• International Ag and Ethanol Feedstock Certification
  o Board Member of International Sustainability and Carbon Certification (ISCC); Biggest certifier of bioproducts under the EU RED
  o Certification methodology development for qualifying US produced biofuels for export to EU and Japan
  o Support development of the GRAS Global Risk Assessment Services Tool
• Sustainable Ag and Pollinator Habitat Work
  o Coordinator, Illinois Monarch Butterfly Initiative
  o US Fish and Wildlife Service Support, National Fish and Wildlife Foundation Grant Recipient
• Urban Air Emissions Impact: EPA MOVES modeling to determine combustion emissions from biofuels blends
Presentation Overview

• Review Recent Publications on:
  o Land Use Expansion – and Error in Analyses
  o Marginal Lands
• Identification of Field Buffers via Remote Sensing
• GRAS Land Use Sustainability Tool
• Emerging Microsats
New Publication on Error in Land Use Expansion Studies
New 2017 Study on Remote Sensing Errors in Land Use Analysis

• Some studies assert that ecologically important, carbon-rich natural lands in the United States are losing ground to agriculture.

• We investigate how quantitative assessments of historical land-use change (LUC) to address this concern differ in their conclusions depending on the data set used in 20 counties in the Prairie Pothole Region using:
  o the Cropland Data Layer,
  o a modified Cropland Data Layer dataset,
  o data from the National Agricultural Imagery Program,
  o and in-person ground-truthing.

We find:
  o The Cropland Data Layer analyses overwhelmingly returned the largest amount of LUC with associated error that limits drawing conclusions from it.
  o Analysis with visual imagery estimated a fraction of this LUC.
  o Clearly, analysis technique drives understanding of the measured extent of LUC; different techniques produce vastly different results that would inform land management policy in strikingly different ways.
  o Best practice guidelines are needed.
Figure 1. Total cropland hectares and individual crop hectares from 1926 to 2015.\textsuperscript{9}
CDL vs. NAIP vs. Groundtruthing

Photo name: luc-02-Dec-2015-09-10-58.jpg
View to north
Ground truth: Pond
Lat, long: 47.96352 -96.6211
Using the Cropland Data Layer or the Modified Cropland Data Layer (with aggregated classes) produces significantly higher land use change than NAIP and ground truthing.
New Publication on Marginal Lands
Land availability for growing feedstocks at scale is a crucial concern for the bioenergy industry.

Feedstock production on land not well-suited to growing conventional crops, or marginal land, is often promoted as ideal, although there is a poor understanding of the qualities, quantity, and distribution of marginal lands in the United States.

We examine the spatial distribution of land complying with several key marginal land definitions at the United States county, agro-ecological zone, and national scales, and compare the ability of both marginal land and land cover data sets to identify regions for feedstock production.

We conclude that very few land parcels comply with multiple definitions of marginal land.
New Mapping Work on Extent of Agricultural Field Buffers
Methodology: Step One

Satellite Imagery Collected in late Spring or Fall
(when grass is growing but crop not on field)

Sentinel-2A 10-meter
Multispectral Satellite Imagery

Create Vegetation Index

Threshold to select only buffers (yellow)

High Pass Edge Detection Filter
Methodology: Step Two

Only analyze buffers “within agricultural land”

2015 USDA Cropland Data Layer
Identifies areas in agriculture (yellow and green)

Only analyze buffers identified as agriculture
Red buffers are in agriculture, yellow are not

Use just agriculture (no roads) to clip buffers
Application 1: Optimize/Extend Pollinator Pathways

Buffer between Riparian areas

Forest Wetlands
Herbaceous Wetlands
Application 2: Integrate Layers with Existing Software Products

- E.g Agsolver and others
- This is a profit comparison where one field zone was put into pollinator habitat which increased field profitability because it was put into CP42 (Pollinator adder to CRP program) and secondly because of reduced inputs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Acreage</td>
<td>143.3 ac</td>
</tr>
<tr>
<td>Average Yield</td>
<td>179.2 bu/ac</td>
</tr>
<tr>
<td>Profit</td>
<td>$101.64/acre</td>
</tr>
<tr>
<td>ROI</td>
<td>13.9 %</td>
</tr>
</tbody>
</table>
Application 3: Local Watershed Analysis

**Land Use**

- **Crops**
- **Pasture/Grass**
- **Forest**
- **Developed**
- **Water**
- **Wetlands**

**HONEY CREEK UPPER MACOUPIN CREEK**

**Acres in Buffers**

- **2005**
- **2010**
- **2016**
Application 4: Compare Current Buffers to 1940 Aerial Imagery

Only performed for Five Mile Creek

1940 Imagery

2015 Imagery

Essentially, no in-field buffers were in place in 1940.
Smaller field sizes
Time consuming process as 1940 imagery is not geo-referenced
International Sustainability and Carbon Certification (ISCC): Developer of GRAS Land Use Tool
Global Risk Assessment Services

https://www.gras-system.org/
New Software for Sustainability Assessment:
Global Risk Assessment Services Tool (GRAS) for United States Domestic LUC Analysis

- Feedstocks are not grown on deforested lands; Verify use of large, mature crop areas
- Applicable for US corn/soy feedstocks
- Use of NAIP Imagery (1-2 m resolution)
- Side by side viewer of pre 2008 and current image for direct comparison
- Overlay protected areas, carbon masks, LUC risk masks
New Software: GRAS Tool for Global Land Use Analysis – Ensure Biofuels Feedstocks Do not come from Deforested Lands

- Particularly applicable for South American Feedstocks (sugarcane, corn soy) and S/E Asia (Palm, etc.)
- Use of MODIS Enhanced Vegetation Index (300 Images) going back to 2000.
- Differentiate among the types of green cover, see the history of the land, assess double cropping and detect LUC.
- Grassland has EVI value of 0.3-0.4. The same would apply for perennial trees such as rain forests but on a higher EVI value of about 0.6. Conversion would appear as a clear change in

[Graph showing Enhanced Vegetation Index over time with LUC in Sept 2005]

- Typical for grass/shrubs
- Typical for agricultural crops
- Double Cropping
Emerging Remote Sensing Technologies: Microsats
### Current and Future Satellite Imagery

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Spatial Resolution</th>
<th>Spectral Resolution</th>
<th>Temporal Resolution</th>
<th>Cost</th>
<th>Launch Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Government:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landsat 8</td>
<td>30 meter</td>
<td>Visible, NIR, Thermal</td>
<td>Every 17 days</td>
<td>Free</td>
<td>2013</td>
</tr>
<tr>
<td>Sentinel 2a</td>
<td>10 meter</td>
<td>Visible, NIR</td>
<td>Approximately 5 days</td>
<td>Free</td>
<td>2015</td>
</tr>
<tr>
<td>NigeriaSats</td>
<td>22 meter to 4 meter</td>
<td>Visible, NIR</td>
<td></td>
<td></td>
<td>2006 to present</td>
</tr>
<tr>
<td><strong>Commercial:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GeoEye-1</td>
<td>2m multi/0.5 pan</td>
<td>Visible, NIR</td>
<td>2 to 8 days</td>
<td>$$$$$*</td>
<td>2008</td>
</tr>
<tr>
<td>Pleiades-1A</td>
<td>2m multi/0.5 pan</td>
<td>Visible, NIR</td>
<td>Daily</td>
<td>$$$$$</td>
<td>2011</td>
</tr>
<tr>
<td>Pleiades-1B</td>
<td>2m multi/0.5 pan</td>
<td>Visible, NIR</td>
<td>Daily</td>
<td>$$$$$</td>
<td>2012</td>
</tr>
<tr>
<td>WorldView-1</td>
<td>0.5 meter pan</td>
<td>Panchromatic</td>
<td>2 days</td>
<td>$$$$$</td>
<td>2007</td>
</tr>
<tr>
<td>WorldView-2</td>
<td>2m multi/0.5 pan</td>
<td>Visible, NIR</td>
<td>1 to 4 days</td>
<td>$$$$$</td>
<td>2009</td>
</tr>
<tr>
<td>WorldView-3</td>
<td>1.24 multi/0.31 pan</td>
<td>Visible, NIR, SWIR</td>
<td>1 to 5 days</td>
<td>$$$$$</td>
<td>2014</td>
</tr>
<tr>
<td>SPOT6 and SPOT7</td>
<td>6 meter multi/1.5 meter pan</td>
<td>Visible, NIR</td>
<td>1 day</td>
<td>$$</td>
<td>2008</td>
</tr>
<tr>
<td>Blackbridge</td>
<td>6 meter multi/1.5 meter pan</td>
<td>Visible, NIR</td>
<td>1 day</td>
<td>$</td>
<td>2008</td>
</tr>
<tr>
<td>EROS-B</td>
<td>0.7 meter pan</td>
<td>Panchromatic</td>
<td>6 days</td>
<td>$$$$</td>
<td>2006</td>
</tr>
<tr>
<td>Deimos-2</td>
<td>4 meter multi/1 meter pan</td>
<td>Visible, NIR, Panchromatic</td>
<td>3 days</td>
<td>$$</td>
<td>2014</td>
</tr>
<tr>
<td>SkySat-1 and 2</td>
<td>2 meter multi/0.9 meter pan</td>
<td>Visible, NIR, video panchromatic</td>
<td>5 days</td>
<td>N/A</td>
<td>2013 and 2014</td>
</tr>
<tr>
<td>Kompssat-3</td>
<td>2.8 multi/0.7 pan</td>
<td>Visible, NIR, Panchromatic</td>
<td></td>
<td>$$</td>
<td>2012</td>
</tr>
<tr>
<td>SSTL</td>
<td>4 meter multi/1 meter pan</td>
<td>Visible, NIR, Panchromatic</td>
<td></td>
<td>N/A</td>
<td>2015</td>
</tr>
<tr>
<td><strong>Still to come:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eros-C</td>
<td>0.3</td>
<td></td>
<td></td>
<td>N/A</td>
<td>2017</td>
</tr>
<tr>
<td>Satellogic</td>
<td>1 meter multi/0.5 pan</td>
<td>Visible, NIR, Panchromatic</td>
<td>Every 15 minutes</td>
<td>N/A</td>
<td>2015</td>
</tr>
<tr>
<td>Planet Lab Doves</td>
<td>3 to 5 meter</td>
<td>Visible</td>
<td>Daily</td>
<td>N/A</td>
<td>2015</td>
</tr>
<tr>
<td>UrtheCast</td>
<td>Video</td>
<td>Visible</td>
<td>Daily</td>
<td>N/A</td>
<td>2019</td>
</tr>
<tr>
<td>SkySat</td>
<td>2 meter multi/0.9 meter pan</td>
<td>Visible, NIR, video panchromatic</td>
<td></td>
<td>N/A</td>
<td>2015</td>
</tr>
<tr>
<td>NorStar</td>
<td>N/A</td>
<td>Thermal, hyperspectral</td>
<td>multiple daily</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>WorldView-4</td>
<td>1.36 meter multi/34cm pan</td>
<td>Visible, NIR, Panchromatic</td>
<td></td>
<td>N/A</td>
<td>2016</td>
</tr>
</tbody>
</table>

*To make sense for commercial, production agriculture (corn, wheat, soy) needs to come down to $
Microsatellite Imagery

- Past limitations of availability and cost will likely become a non-factor.
- The Applications for the technology exist.
- Will technology factors limit use:
  - Tying point on ground to point on satellite image
  - Accuracy of information products
- Satellite companies, investing millions, need to offer information products to meet revenue goals.
- Will not want to sell imagery as a commodity.
- Competition will reduce price, number of companies but enough?
Current Satellogic satellites:
Weekly 100 meter hyperspectral imagery

June 2017 satellite launch:
Weekly 1 meter multispectral, 30 meter hyperspectral
Contact

• Steffen Mueller 312-316-3498
• Ken Copenhaver 217-377-0071