Operational Tillage Information System: Tracking Conservation Practices at Field to Watershed Scales

William A. Salas*, Steve Hagen and Ian Cooke

Applied GeoSolutions, LLC

July 13, 2016

C-AGG Meeting in Denver, CO
Background

- Numerous peer reviewed publications on the use of remotes sensing for mapping conservation practices, like tillage, cover cropping and artificial field drainage (tile drains).

- Most have been successful for small area mapping through detailed calibration for the that single locale, image set and time period.

- Challenge: how do we operationalize the system for consistent wide area mapping of crop residue dynamics, tillage systems and cover cropping over many years with well defined uncertainties?
Limitations of existing conservation data

- Traditional “wind-shield” survey method conducted by NRCS is expensive and prone to inconsistencies and inaccuracies.
- Systematic surveys of tillage practices stopped in 2004. CEAP/NASS surveys provide some information but no way to track practices in space and time.
- No consistent, systematic system in place for tracking residue management, tillage systems and cover crop systems.
- Need better data to define baseline use of conservation practices for tracking targets.
- Existing satellite-based approaches are promising, but are limited in the way they have been implemented:
  - typically single area for a single time period
  - often reliant on information from a single satellite

2. Automated Algorithms & GIScience Decision Tree

3. Validated Tillage Products

4. Web-GIS & Mobile Apps Data Delivery, Accounting, Monitoring, & Reporting Tools
OpTIS Approach
Overview

- Algorithms are applicable across a large set of sensors (optical and SAR), platforms (spaceborne, aerial and UAVs), spatial (meter to 250 meters) and temporal (daily to 16 day repeats)
- Data from multiple satellites*: Landsat, MODIS, AWIFS, Sentinel-1, -2, RapidEye (evaluating Skybox, Pleiades, etc)
- AGS is funded by NASA under Multi Sensor Land Imaging program – integration of Landsat and Sentinel-1 and Sentinel-2 for agricultural monitoring
- Goal for large area simulations without requiring recalibration
- Developed algorithms for “self-calibration” for new geographies and watersheds
- Tradeoffs between large area and watershed and site specific implementations
  - Client driven choices based on requirements and costs

* Most of these data sets are freely available, keeping costs lower.
OpTIS Big Picture

- **OpTIS**: With NASA and USDA-SBIR funding Applied GeoSolutions has developed technology that combines data from satellites with other geospatial data sets to map *crop residue* and *cover crops* over wide areas, going back through time.

- **OpTIS** proprietary algorithms are designed for multi-scale, operational and wide area applications.

- **Indiana Pilot**: We’ve applied the system in individual watersheds, but have not tested the system at the state level. This pilot project is designed to test the performance of the system when applied across the state of Indiana.

- **Future**: If the system works well in Indiana, we envision demand for a US-wide application.
A New Approach to Surveying Tillage Practices and Cover Crops in Indiana

APPLIED GEOSOLUTIONS

IN COLLABORATION WITH CTIC

FUNDED BY: USDA, HGBF, MONSANTO, JOHN DEERE, SOIL HEALTH PARTNERSHIP, INDIANA SOYBEAN ALLIANCE, AND INDIANA CORN MARKETING COUNCIL
Our approach

Products

- Our system provides detailed maps of **crop residue cover** and **cover crops**:
  - Temporal changes in crop residue fractions
  - Tillage in Fall & Spring
  - Annually, with date information.
  - Farm-field, county, & watershed level
  - Uncertainty maps
  - Trends
  - Continuous no-till
Review of the Goals and Objectives

Goal: Understand and rigorously evaluate how the OpTIS system performs when applied across a wide region (Indiana) over many years (2006-2015).

Objectives:

- Produce annual maps and tables at the county and watershed level of tillage practice category (% no till, % reduced till, % conventional till, % cover crop)
- Compare OpTIS estimates to field level estimates from the transect surveys in the pilot counties
- Compare OpTIS estimates to windshield transect survey results at the county scale across Indiana
- Produce a report summarizing the application of OpTIS across Indiana: accuracy, problems encountered, recommendations on next steps for scaling the application to national scale.
Our approach

Time series of observations

High temporal frequency data can be critical....
Compiled Field Data

- Field-based information:
- Historical transect information from 2009, 2011, 2013, and 2015 in the 7 pilot counties (IN Dept. Ag)
Landsat Processing

- Geospatial data – Landsat (5, 7, and 8)

Generate Indices

- NDVI
- NDTI
- STI
- CRC
MODIS Processing

- Geospatial data – MODIS
- MODIS MOD43A4 BRDF surface reflectances
- 463 m spatial resolution
- Rolling 16-day composite every 8 days

NDVI  NDTI  STI  CRC
Compile Ancillary Geospatial Data

- Geospatial data – Algorithm uses soils, weather, crop type, topography, etc for operational algorithm.
- PRISM precipitation associated with each Landsat image (3 day window prior to acquisition) and MODIS composite (16 day window associated with composite period)
- NASA CDL for crop information: used as priors in decision tree/classification algorithms
- County and HUC8 boundaries
- NRCS Soils data (SSURGO and STATSGO)
Our approach
Convert satellite data to crop residue cover estimates

April 19, 2012 Landsat 7 image
(R-SWIR1, G-NIR, B-Red)
Livingston County example (Streator, IL)

Estimate of crop residue cover
(Brown: 0%; Yellow: 40%; Green: 80%)
Our approach

Estimate tillage practice from residue cover over large areas

Estimate of crop residue cover
(Brown: 0%; Yellow: 40%; Green: 80%)

Livingston County example (Streator, IL)

Field-level Tillage Practice
(Brown: CT; Yellow: RT; Green: NT)
Statewide Crop Residue Maps

2006  2007  2008  2009  2010

2011  2012  2013  2014  2015

% Residue Cover
- 0-10
- 11-20
- 21-30
- 31-40
- 41-50
- > 50
Maps are created at 30m pixel resolution.

% Residue Cover
- 0-10
- 11-20
- 21-30
- 31-40
- 41-50
- > 50
Example Results

% Residue Cover
- 0-10
- 11-20
- 21-30
- 31-40
- 41-50
- > 50
Results will be distributed at HUC8/10 and County Scales
Classification of tillage systems

% Residue Cover
- 0-10
- 11-20
- 21-30
- 31-40
- 41-50
- > 50

0-15 CT
15-40 RT
> 40 NT
Monitors Temporal Changes in Residue

Temporal False Color Composite of RC estimate:
Black – low RC; Yellow – high RC; Red – high to low

0-15 CT
15-40 RT
> 40 NT
Compile Results at Field, Watershed and County scales
Challenges: Gaps in Landsat Timeseries

2009 Residue (Landsat) NO GAPS

2008 Residue (Landsat & MODIS) FILLED
User defined “Allowable” Confidence

**Challenges – Data gaps**

**Option 1: unweighted average of all high confidence observations**

<table>
<thead>
<tr>
<th>County</th>
<th>Ag. Acres in County</th>
<th>% covered by high confidence observations</th>
<th>% covered by low confidence observations</th>
<th>% covered by no estimate</th>
<th>% no till corn in high confidence obs.</th>
<th>% no till bean in high confidence obs.</th>
<th>% corn in high confidence obs.</th>
<th>% bean in high confidence obs.</th>
<th>% corn in county</th>
<th>% bean in county</th>
<th>% no till in county</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000s</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Adams</td>
<td>150</td>
<td>50</td>
<td>39</td>
<td>11</td>
<td>34</td>
<td>62</td>
<td>70</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>42.4</td>
</tr>
<tr>
<td>Allen</td>
<td>210</td>
<td>74</td>
<td>16</td>
<td>10</td>
<td>41</td>
<td>68</td>
<td>60</td>
<td>40</td>
<td>40</td>
<td>60</td>
<td>51.8</td>
</tr>
</tbody>
</table>

**Option 2: weighted average of high confidence observations by % crop in county (CDL)**

<table>
<thead>
<tr>
<th>County</th>
<th>Ag. Acres in County</th>
<th>% covered by high confidence observations</th>
<th>% covered by low confidence observations</th>
<th>% covered by no estimate</th>
<th>% no till corn in high confidence obs.</th>
<th>% no till bean in high confidence obs.</th>
<th>% corn in high confidence obs.</th>
<th>% bean in high confidence obs.</th>
<th>% corn in county</th>
<th>% bean in county</th>
<th>% no till in county</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000s</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Adams</td>
<td>150</td>
<td>50</td>
<td>39</td>
<td>11</td>
<td>34</td>
<td>62</td>
<td>70</td>
<td>30</td>
<td>50</td>
<td>50</td>
<td>48.0</td>
</tr>
<tr>
<td>Allen</td>
<td>210</td>
<td>74</td>
<td>16</td>
<td>10</td>
<td>41</td>
<td>68</td>
<td>60</td>
<td>40</td>
<td>40</td>
<td>60</td>
<td>57.2</td>
</tr>
</tbody>
</table>
OpTIS Cover Crop Mapping

- Mapping presence and absence of cover crops.
- Categorize types of cover cropping:
  - Winter-kill
  - Spring-kill
  - Commodity
- System separates volunteer regrowth from intended cover crops using spatial-temporal filters

Winter-killed cover crops (yellow) cover crops that survive into the spring (green), and commodity cover crops that are harvested the following summer (brown). Grey areas do not have cover crops and black areas are non-agriculture or missing data. Landsat imagery from three time periods (26 December 2013, 11 April 2014, and 17 June 2014)
OpTIS Cover Crop Mapping

Improvements with more frequent observations:

Winter-killed cover crops (yellow), cover crops (green), and commodity crops (brown). Grey areas are areas that do not have cover crops, and black areas are non-agriculture or missing data. Landsat imagery from October 2013 through June 2014 was used in an operational algorithm that accounts for clouds and image timing variability.
Next Steps – Field Level Validation

- Validate Crop Residue Cover estimates and the Winter Cover Crop maps on the field level
Next Steps – County Scale Validation

- Validate Crop Residue Cover estimates and the Winter Cover Crop maps on the county level

% Residue Cover
- 0-10
- 11-20
- 21-30
- 31-40
- 41-50
- > 50

% of County in No Till
- 10 - 26
- 26 - 38
- 38 - 48
- 48 - 60
We have completed the validation, need to provide results to USDA and Funders/CTIC before releasing the results, performance and products.

County and HUC scale results will be publically available and distributed by AGS and CTIC

Final report with full results and validation completed by end of August, 2016.
Potential Expansion across the Continental USA

- Covering all counties in the continental USA with at least 50,000 acres of harvested cropland in 2007 (US Census) will require the analysis of about 350 path/rows. In Indiana, we analyzed 12 path/rows. If the requirements are loosened to those counties with 75,000 or 100,000 acres of cropland, 300 or 270 path/rows are required for analysis, respectively.
Potential Expansion across the Continental USA

- Crop acreage in Indiana and the USA
  - Corn, Soy, Hay, and Wheat make up 90+% of Indiana acreage but only 70% of the US acreage
  - Sorghum and cotton are rare in Indiana but plentiful across the US
  - Need to test algorithms for additional cropping systems.

<table>
<thead>
<tr>
<th>Crop</th>
<th>US 2015 harvested</th>
<th>IN 2015 harvested</th>
<th>US Percentage</th>
<th>IN Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>325669000</td>
<td>12330000</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Soybean</td>
<td>84449000</td>
<td>5690000</td>
<td>25.9</td>
<td>46.1</td>
</tr>
<tr>
<td>Corn</td>
<td>88900000</td>
<td>5490000</td>
<td>27.3</td>
<td>44.5</td>
</tr>
<tr>
<td>Hay</td>
<td>38202000</td>
<td>330000</td>
<td>11.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Wheat</td>
<td>48454000</td>
<td>305000</td>
<td>14.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Oats</td>
<td>1220000</td>
<td>9000</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Dry edible beans</td>
<td>1656800</td>
<td>0</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Proso millet</td>
<td>430000</td>
<td>0</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Canola</td>
<td>1524200</td>
<td>0</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Sugarbeets</td>
<td>1140000</td>
<td>0</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1060400</td>
<td>0</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Rice</td>
<td>2744000</td>
<td>0</td>
<td>0.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Sunflower</td>
<td>1611000</td>
<td>0</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Peanuts</td>
<td>1565000</td>
<td>0</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Barley</td>
<td>2919000</td>
<td>0</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Sorghum</td>
<td>7773000</td>
<td>0</td>
<td>2.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Rye</td>
<td>314000</td>
<td>0</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Cotton</td>
<td>9000000</td>
<td>0</td>
<td>2.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Tobacco</td>
<td>3209500</td>
<td>0</td>
<td>0.1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Source: NASS (“ALL” row is planted; others are harvested)
Potential Expansion across the Continental USA: Validation Data

- Depending on funding available, 10 – 30 areas should have intensive field visits that include:
  - 20-40 fields each
  - 3-8 total visits; 1-2 in the fall and 2-6 in the spring
  - GPS confirmation and photos
  - Field estimates and measurements
  - ~$17,000 per area; ~$200,000 to $500,000

- Work with the conservations districts to collect this information?
On-going OpTIS Improvements

- Improve temporal resolution
- Improves accuracy of OpTIS
- Enhances specificity of timing of management events: dates of tillage, estimates of cover crop emergence, fractional cover and biomass modeling

Integration of Sentinel data
- Sentinel-1: C-band SAR imagery, use IW mode (VV and VH; 10 meter), 6-12 day repeat, no cloud problems, sensitive to soil moisture, roughness and plant biomass.
- Sentinel-2: Optical, VIS-SWIR, 10-20 meter with 5-10 day repeat

Integration with crop models, soils and weather data to improve cover crop development, biomass, N uptake and reductions in soil loss
Use of OpTIS Products – Support USDA Needs

- USDA National Inventory:
  - relies in part of historical survey data, annual data would be beneficial
  - Data on persistent use of conservation practices (e.g. continuous no-till), frequency of cover cropping, etc – Improve inventory
  - Spatially link with soils and climate for Daycent modeling.

- Effectiveness of conservation programs
  - Having time series of acres in conservation practices will support assessments of the effectiveness of the conservation programs
  - CEAP Program
Use of OpTIS Products – USDA Building Blocks for Climate Smart Ag

- Need good baseline activity data on existing conservation practices.
- Products will improve USDA baseline quantification.
- Products can improve quantification of progress toward Soil Health Building Block goal.
- Products can provide transparent verification of changes in activities, coupled with validated models, will provide more rigorous verification.
Use of OpTIS Products – Opportunities/Concerns

- Spatial and temporal information on adoption of conservation practices – data for understanding impacts of practices on yield variability and yield loss risks for possible crop insurance applications.

- MRV for Ecosystem Markets

- Improve characterization of conservation programs: e.g. cover crop rigor

- Integration with crop models, soils and weather data to improve cover crop development, biomass, N uptake and reductions in soil loss.

- Concerns: balance between privacy concerns and scale of analysis?

Need community support for National Implementation
Thank you.

Questions?

Contact email: wsalas@agsemail.com