Mapping Water Use, Phenology and Productivity in Agricultural Landscapes by Fusing Multi-Sensor Data Products

P.I.: Feng Gao, Hydrology and Remote Sensing Lab, USDA-ARS
Science P.I.: Martha Anderson, Hydrology and Remote Sensing Lab, USDA-ARS
Co. I.: Bill Kustas, Hydrology and Remote Sensing Lab, USDA-ARS
Co. I.: Joe Alfieri, Hydrology and Remote Sensing Lab, USDA-ARS
Co. I.: Christopher Hain, NASA-Marshall Space Flight Center
Co. I.: Jason Otkin, University of Wisconsin
Co. I.: Hadi Jaafar, American University of Beirut

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Objectives:
Prototype methods for routine production of high spatiotemporal resolution
- evapotranspiration
- vegetation index
- phenology
- yield products

using a multi-sensor data fusion approach
Summary of Previous Work

• Surface Reflectance Data Fusion System
  Landsat, MODIS

• Evapotranspiration Data Fusion System
  GOES, MODIS and Landsat

• Crop Phenology Mapping
  retroactive phenology using full year of
  Landsat and MODIS

• Yield Anomaly and ESI
Proposed Improvements

• Surface Reflectance Data Fusion System
  Landsat, MODIS, Sentinel-2, VIIRS

• Evapotranspiration Data Fusion System
  Landsat, Sentinel-2, VIIRS, ECOSTRESS

• Crop Phenology Mapping
  real-time crop growth stages using partial year of L8, S2, MODIS/VIIRS

• Yield Products using VI, ET and phenology
Technical Approach

- Extend applications to more crop types (e.g., wheat, cotton, hay, vineyards etc.)
- Adapt ET and SR data fusion system to rangeland and pasture ecosystems
- Focus primarily on the USDA-ARS LTAR sites
- Supply irrigation management for vineyard operation in California (GRAPEX experiment)
- Collaborate on international studies (Czech Republic, Lebanon, Brazil and Spain)
- Utilize cloud computing (USDA-ARS SCINet, Google Earth Engine, Amazon Web Services etc.) for large area mapping
First Year Progress

• Refine tools and methods for new data products
  – VIIRS
  – Sentinel-2
  – ECOSTRESS

• Apply data fusion results for assessing
  – yield variability
  – water productivity
  – Land use and water use change
Assessing the Variability of Corn and Soybean Yields in Central Iowa
Added-value from Landsat-MODIS data fusion

### Detailed Table

<table>
<thead>
<tr>
<th>Dataset</th>
<th>$R^2_{t}$</th>
<th>RMAE$_{t}$</th>
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<td>Corn (2001–2015)</td>
<td>0.46</td>
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<tr>
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<td>Soybean (2001–2015, excluding 2003)</td>
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<td>0.72</td>
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Optimal Time Window for Yield Prediction

R²(corn, NDVI)

R²(corn, EVI2)

R²(soybean, NDVI)

R²(soybean, EVI2)
Fusing Landsat, Sentinel-2 and MODIS/VIIRS

Corn Yield (t/ha) vs Max_EVI2 (2016-2017)
- L8 (Δ)
- S2 (□)
- HLS (▲)
- MLS (●)

Soybean Yield (t/ha) vs Max_EVI2 (2016-2017)
- L8 (Δ)
- S2 (□)
- HLS (▲)
- MLS (●)

Polk: 23% corn; Others: 38-55%
Yield Variability from Landsat-8, Sentinel-2 and MODIS (GEE)
Daily ET at 30m resolution by fusing VIIRS/Landsat/S2/ECOSTRESS

Harmonized with VIIRS

Daily ET – Orlando, FL
ECOSTRES and Sentinel-2

- ECOSTRESS: 5 TIRS bands, no VNIR, ~3 days repeat at ~60m
- Sentinel-2: no TIRS, 13 VNIR and SWIR bands, 5 days repeat at 10-20m
- Combining ECOSTRESS and Sentinel-2 data allows more frequent ET estimation at field scales
- Sharpening LST imagery using VNIR and SWIR images (modified Data Mining Sharpening approach)
Sharpened LST (30m)
Yield and Water Productivity

<table>
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<tr>
<th>Year</th>
<th>ET</th>
<th>Yield</th>
<th>WP</th>
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<td><img src="Yield_2014.png" alt="Image" /></td>
<td><img src="WP_2014.png" alt="Image" /></td>
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</table>

- **ET (Seasonal evapotranspiration)**
  - Units: mm

- **Yield**
  - Units: Mg/ha

- **WP (Crop water productivity)**
  - Units: Mg/ha-mm
Expected Contributions to MOIDS/VIIRS

- Demonstrate synergistic value of multiple sensors for research and operational uses

- Daily 30-m SR and VI, combining Landsat, S2 and MODIS/VIIRS SR data
- Phenology extraction tools for crop and rangeland
- A streamlined 30-m, daily ET and water stress mapping algorithm, utilizing sharpened TIR products from Landsat, MODIS/VIIRS and ECOSTRESS
- A prototype field-scale yield mapping tool, combining information from the phenology, VI, ET and water stress data cubes
- Field-scale water productivity maps for evaluating crop water use efficiency and yield gaps over agricultural landscapes

- Provide inputs to the MODIS/VIIRS program relevant for agricultural applications