### Crop-CASMA: A Web-based GIS Application for Soil Moisture and Vegetative Condition Monitoring

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**Disclaimer:** The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or U.S. Government determination or policy.



#### Outline

- Background
  - NASS Mission
  - NASA SMAP Mission
- Crop-CASMA Application & Interface
- Crop-CASMA Data
  - Soil Moisture
  - Vegetation Condition
- Demonstration
- Applications
- Resources







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**Crop-CASMA (Crop Condition and Soil Moisture Analytics)** 



### **USDA National Agricultural Statistics Service (NASS)**

- NASS's mission is to provide timely, accurate, and useful statistics in service to U.S. agriculture
  - Using a variety of survey, census, geospatial, and remote sensing data including soil moisture and vegetation condition data



#### Cropland Data Layer

#### Why is soil moisture information important?

Soil moisture data are critical to plan crop planting, forecast yields, track droughts, monitor excess moisture conditions, and monitor floods







NASA SMAP Video: <u>https://www.youtube.com/watch?app=desktop&v=bWnlpRPbaSc</u>



#### NASA – Soil Moisture Active Passion (SMAP) Mission

SMAP tracks soil moisture conditions around the globe. Every three days, SMAP acquires soil moisture data of the entire earth.





NASA SMAP Video: <u>https://www.youtube.com/watch?app=desktop&v=bWnlpRPbaSc</u>



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#### **Collaborators & Funding Support**

- Dr. Zhengwei Yang & Rick Mueller, USDA NASS
- Dr. Rajat Bindlish & Dr. Pan-Wei Liu, NASA GSFC
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- Crop-CASMA Developer: Dr. Zhengwei Yang (<u>Zhengwei.Yang@usda.gov</u>)





#### **Crop-CASMA (Crop Condition and Soil Moisture Analytics)**

- Crop-CASMA is a web-based geospatial application
  - Designed to facilitate the utilization of the remotely sensed geospatial soil moisture (SM) and vegetation index data
  - Data derived from NASA Soil Moisture Active Passive (SMAP) and Moderate Resolution Imaging Spectroradiometer (MODIS) missions
  - Designed to assess conterminous U.S. soil moisture and crop vegetation conditions





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#### **Crop-CASMA (Crop Condition and Soil Moisture Analytics)**

- Online assessment tools include:
  - Visualization
  - Analysis
  - Anomaly assessment
  - Animation
  - Zonal statistics
  - Data dissemination
  - Outreach support





Crop-CASMA: <u>https://cloud.csiss.gmu.edu/Crop-CASMA/</u>



#### **Crop-CASMA Major Tools**



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Crop-CASMA: <a href="https://cloud.csiss.gmu.edu/Crop-CASMA/">https://cloud.csiss.gmu.edu/Crop-CASMA/</a>

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#### SMAP (Soil Moisture Active Passive) Data

- NASA Soil Moisture Active Passive (SMAP) measures soil moisture from the top 5cm of the soil column
- SMAP Level-4 datasets assimilate SMAP observations into physically-based numerical models of the land surface water, energy, and carbon cycles
- Level-4 soil moisture data (SPL4SMGP) has the following characteristics:
  - Topsoil moisture (top 5cm) and root zone soil moisture (top 1m)
  - 9km spatial resolution
  - Daily multiple outputs every 3 hours (8 measurements per day)





#### **Crop-CASMA Soil Moisture Data**

- Data derived from SMAP:
  - **9km** 3-hour, daily, and weekly topsoil and rootzone moisture data
  - **1km** daily, 3-day, and weekly topsoil moisture data
  - 9km daily and weekly and 1km weekly topsoil and rootzone moisture anomaly data
  - 9km topsoil and rootzone moisture and 1km weekly topsoil moisture NASS categorical condition data







#### **Original 9km SMAP Level-4 3-hour Data**

Iowa, U.S. September 21, 2016 **Top Soil Moisture** X Volu 1:30am 4:30am 7:30am 10:30am 6 (cm<sup>3</sup>) 0.65 10:30pm 1:30pm 4:30pm 7:30pm





SMAP Legend

0.00

0.05

0.10 0.15 - 0.20 0.25 0.30 0.35 0.40 0.45

> 0.50 0.55

- 0.60



#### Aggregated 9km SMAP Level-4 Daily Average Data

Iowa, U.S. September 18-25, 2016 Top Soil Moisture









#### Aggregated 9km SMAP Level-4 Weekly Average Data

Iowa, U.S. September 2015 & 2016 Top Soil Moisture







September 2016 (wet)





### Disaggregated 1km SMAP (THySM) Data

- Derived from SMAP Level-2 data using MODIS surface temperature and soil texture data (thermal inertia model)
- 1km resolution, topsoil moisture only
- 3-day and weekly composite
- Similar derivative data products





Weekly Average Topsoil Moisture August 30 – September 6, 2016





#### **Soil Moisture Validation Network**



Unbiased RMSE for 1km SMAP Data using in situ sites



Liu, P.-W., R. Bindlish, B. Fang, V. Lakshmi, P. O'Neill, Z. Yang, M. Cosh, T. Bongiovanni, D. Bosch, C. Holifield Collins, P. Starks, J. Prueger, M. Seyfried, and S. Livingston, 2020. "Assessing Disaggregated SMAP Soil Moisture Product in the United States." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. Vol. 14, pp: 2577-2592, https://doi.org/10.1109/JSTARS.2021.3056001.



#### 9km vs. 1km SMAP Data



SMAP 9km Weekly Topsoil Data May 10-16, 2021, Iowa, U.S. SMAP 1km Weekly Topsoil Data May 10-16, 2021, Iowa, U.S.





#### **Crop Soil Moisture Anomaly Data**

• Soil moisture anomaly (SMA) index indicates the deviation of current SM level from the historical SM average

SMA is defined as follows:

$$SMA = \frac{SM - SM_m}{SM_m} \times 100\%$$

*SM* – current soil moisture value

 $SM_m$  – historical average soil moisture value







#### **NASS Categorical Soil Moisture Condition Data**



0.40 0.45 0.50

0.55 /cm 0.60

0.65



Item	Districts								Chata	Last	Last	
	NW	NC	NE	WC	С	EC	SW	SC	SE	State	week	year
	(days)											
Days suitable	4.0	1.7	2.0	4.1	3.1	4.0	4.5	4.3	6.4	3.6	3.3	4.8
	(percent)											
Topsoil moisture												
Very short	0	0	0	0	0	0	0	0	11	1	1	0
Short	4	0	1	0	1	1	0	4	15	2	3	4
Adequate	70	40	42	83	73	68	82	87	72	67	77	84
Surplus	26	60	57	17	26	31	18	9	2	30	19	12
Subsoil moisture												
Very short	0	0	0	0	0	0	0	4	9	1	1	1
Short	5	0	1	5	3	0	0	6	18	4	4	5
Adequate	73	51	55	83	84	73	95	85	71	73	81	83
Surplus	22	49	44	12	13	27	5	5	2	22	14	11



#### **NASS Categorical Soil Moisture Condition Data**



USDA



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#### **Crop-CASMA Vegetation Condition Data**

- Crop-CASMA can provide daily and weekly vegetation condition products from 2000
- Data derived from MODIS:
  - NDVI (Normalized Difference Vegetation Index)
  - VCI (Vegetation Condition Index)
  - MVCI (Mean Vegetation Condition Index) – NDVI anomaly







#### **Normalized Difference Vegetation Index (NDVI)**

- NDVI quantifies vegetation by measuring the difference between nearinfrared (which vegetation strongly reflects) and red light (which vegetation absorbs)
- Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths and absorbs more red and blue light



 $NDVI = \frac{NIR - Red}{NIR + Red}$ 

![](_page_26_Picture_5.jpeg)

![](_page_26_Picture_6.jpeg)

#### **Vegetation Condition Index (VCI)**

- VCI compares the current NDVI to the minimum historical NDVI value observed in the same period in previous years
- It indicates where the currently observed NDVI value is situated between the historical extreme values (minimum and maximum) relatively
- VCI is used to identify drought and determine the onset.

![](_page_27_Figure_4.jpeg)

![](_page_27_Picture_5.jpeg)

#### Mean Vegetation Condition Index (MVCI)

 MVCI represents the deviation of the vegetation to "normal" vegetation or multiple-year mean

![](_page_28_Figure_2.jpeg)

![](_page_28_Picture_3.jpeg)

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![](_page_29_Figure_1.jpeg)

## Crop-CASMA Bemonstration

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![](_page_29_Figure_3.jpeg)

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![](_page_29_Picture_5.jpeg)

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0.30 Noisture 0.35 0.40 0.45 (cm/cm/ 0.55 0.60 1 0.65 E Crop-CASMA (Crop Condition and Soil Moisture Analytics) About News Publication Documentation 🖛

![](_page_30_Figure_1.jpeg)

# NASS Soil Moisture Data ka Markovicka Applications

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![](_page_30_Figure_3.jpeg)

**Crop-CASMA (Crop Condition and Soil Moisture Analytics)** 

![](_page_30_Picture_5.jpeg)

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#### Soil Moisture Map for NASS Crop Weather Report

![](_page_31_Picture_1.jpeg)

![](_page_31_Picture_2.jpeg)

![](_page_31_Picture_3.jpeg)

#### **Non-Response Imputation for Soil Moisture Survey**

• SMAP data can be used as an imputation data source for nonresponse for soil moisture survey data

![](_page_32_Figure_2.jpeg)

![](_page_32_Picture_3.jpeg)

![](_page_32_Picture_4.jpeg)

#### **Decision Support for Weekly Categorical Soil Moisture Condition Assessment**

	Divels	A	Crop-CASMA	NASS Reported	
Pixeis		Acreages	Percentage	Percentage	
No Data	0	0	0.00	0.00	
<b>Very Short</b>	0	0	0.00	0.00	
Short	11,664	180,139	0.37	1.00	
Adequate	1,789,776	27,641,412	66.55	72.00	
Surplus	1,082,160	16,712,946	33.08	27.00	
Total	2,883,600	44,534,498	100.00	100.00	

- Error sources:
  - Big pixel size
  - Data collection timing
  - Observations

![](_page_33_Figure_6.jpeg)

![](_page_33_Picture_7.jpeg)

![](_page_33_Picture_8.jpeg)

- Topsoil moisture anomaly greater than 30% could be considered very abnormal
  - This means there is 30% more soil moisture than normal conditions
- Example: Delta Flooding in June 2021
  - 35% of the cultivated area in the Delta region is above 30% SM anomaly

![](_page_34_Figure_5.jpeg)

Produced by VegScape - http://nassgeodata.gmu.edu/VegScape

![](_page_34_Picture_7.jpeg)

![](_page_34_Picture_8.jpeg)

- Specific crops in soils with greater than 30% greater soil moisture than normal conditions during the period from June 7 – 13, 2021
- Total acreage by state determined by official 2020 NASS estimates
- Crop type percentages determined by 2020 Cropland Data Layer

Topsoil Moisture Anomaly (1km, June 7-13, 2021)									
Crean Trans	Arka	insas	Louis	siana	Mississippi				
	Total	Percentage	Total	Percentage	Total	Percentage			
	Acreage	of crop type	Acreage	of crop type	Acreage	of crop type			
crop rype	(Official	> 30% Soil	(Official	> 30% Soil	(Official	> 30% Soil			
	2020 NASS	Moisutre	2020 NASS	Moisutre	2020 NASS	Moisutre			
	Estimate)	Anomaly	Estimate)	Anomaly	Estimate)	Anomaly			
Corn	620,000	35.64%	500,000	23.52%	510,000	52.04%			
Soybeans	2,820,000	37.22%	1,040,000	13.58%	2,090,000	59.31%			
Cotton	525,000	37.38%	170,000	22.86%	530,000	50.14%			
Rice	1,461,000	42.06%	480,000	8.42%	166,000	68.39%			

![](_page_35_Picture_5.jpeg)

![](_page_35_Picture_6.jpeg)

- SMAP values converted into NASS categories which include Very Short, Short, Adequate, and Surplus
- Example: Delta Flooding in June 2021
  - 43% of the cultivated area in the Delta region is in Surplus

![](_page_36_Picture_4.jpeg)

Produced by VegScape - http://nassgeodata.gmu.edu/VegScape

![](_page_36_Picture_6.jpeg)

![](_page_36_Picture_7.jpeg)

- Specific crops in soils with surplus soil moisture during the period from June 7 – 13, 2021
- Total acreage by state determined by official 2020 NASS estimates
- Crop type percentages determined by 2020 Cropland Data Layer

Topsoil Moisture Categorical (1km, June 7-13, 2021)									
	Arka	insas	Loui	siana	Mississippi				
	Total	Total Percentage		Percentage	Total	Percentage			
Cron Type	Acreage of crop typ		Acreage	of crop type	Acreage	of crop type			
стор туре	(Official	with Surplus	(Official	with Surplus	(Official	with Surplus			
	2020 NASS	Soil	2020 NASS	Soil	2020 NASS	Soil			
	Estimate)	Moisture	Estimate)	Moisture	Estimate)	Moisture			
Corn	620,000	50.26%	500,000	40.00%	510,000	19.28%			
Soybeans	2,820,000	51.63%	1,040,000	58.67%	2,090,000	12.24%			
Cotton	525,000	30.60%	170,000	49.17%	530,000	20.89%			
Rice	1,461,000	50.76%	480,000	86.43%	166,000	5.92%			

![](_page_37_Picture_5.jpeg)

![](_page_37_Picture_6.jpeg)

#### **Crop-CASMA** Data used in NASS Research

- Early Planting Estimation Modeling Research
- Crop Growth Models for yield prediction (WOFOST, EPIC, etc.)
- Crop Growth and Condition Modeling

![](_page_38_Picture_4.jpeg)

![](_page_38_Picture_5.jpeg)

#### **Potential Applications**

- Supplement to NASS soil moisture reporting
- Freely available soil moisture maps for outreach
- Drought and flood disaster assessment and monitoring
- Crop growth and condition monitoring and modeling
- Water resource management
- Market decision support
- Planting and irrigation management decision support

![](_page_39_Picture_8.jpeg)

![](_page_39_Picture_9.jpeg)

![](_page_40_Figure_0.jpeg)

![](_page_40_Picture_1.jpeg)

**Crop-CASMA (Crop Condition and Soil Moisture Analytics)** 

![](_page_40_Picture_3.jpeg)

#### How to Learn More

- Crop-CASMA <u>User Guide</u> and <u>Developer Guide</u>
- NASA ARSET (Applied Remote Sensing Training Program)
  - <u>Applications of Remote Sensing to Soil Moisture and</u>
    <u>Evapotranspiration</u>
  - <u>Remote Sensing of Drought</u>

![](_page_41_Picture_5.jpeg)

![](_page_41_Picture_6.jpeg)

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![](_page_42_Picture_9.jpeg)

![](_page_42_Picture_10.jpeg)

#### **Thank You**

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NASA SMAP Video: <u>https://www.youtube.com/watch?app=desktop&v=bWnlpRPbaSc</u>

![](_page_43_Picture_6.jpeg)

![](_page_43_Picture_7.jpeg)