AST 426 :Precision Water and Nutrient Management I

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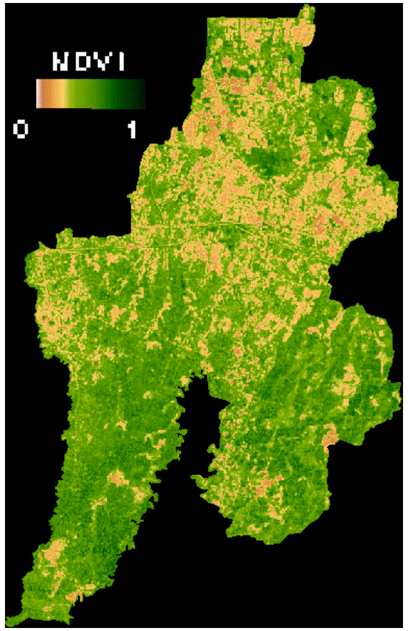
Recap: Which Indices to Use and When?

Early Growth Phase Indices

- NDVI, SAVI
- Early detection of plant vigor, nitrogen status, and initial stress signs



Mid to Late Growth Phase Indices

- GNDVI, NDRE, CWSI, Thermal Indices
- Monitor biomass accumulation, water stress, and disease progression
- Adjust irrigation schedules, manage nutrient applications, predict yield
- NDRE is a powerful tool for late-stage crop monitoring, offering deeper insights into crop health and aiding in precise agricultural management

Optimal Usage

- By combining indices such as NDVI for early growth stage and NDRE for later growth stages

Recap: Quiz

1. Why might NDVI be less effective in the later stages of crop growth?

- NDVI can become less effective in later stages because it tends to saturate in dense vegetation. As crops mature and develop multiple canopy layers, NDVI primarily captures data from the upper canopy, missing information from the lower layers. This leads to a reduced ability to detect subtle variations in plant health.

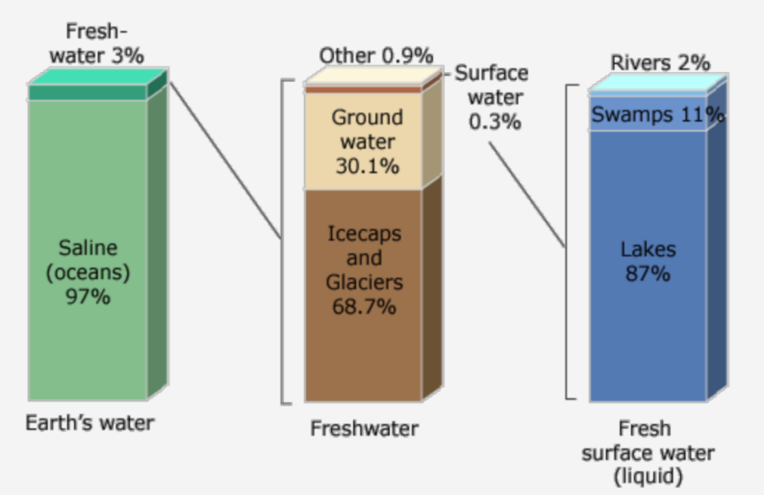
2. What are the typical NDRE value ranges, and what do they indicate about crop health?

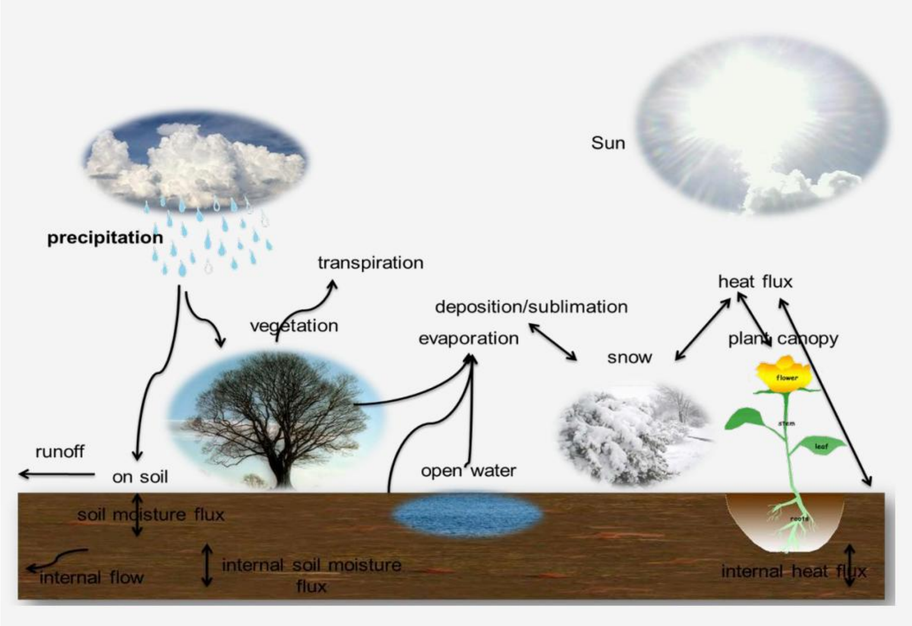
-1 to 0.2: Indicates bare soil or a developing crop.
0.2 to 0.6: May indicate an unhealthy plant or a crop that is not mature yet.
0.6 to 1.0: Represents healthy, mature, ripening crops.

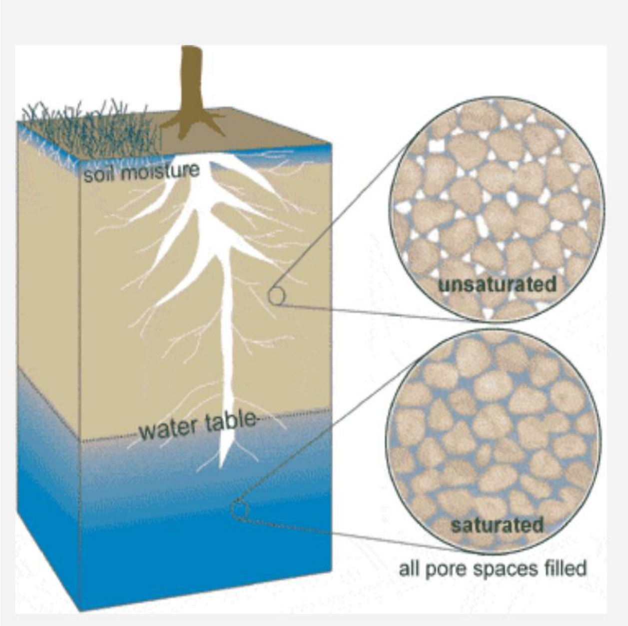
Precision Water Management

- Precision water management involves optimizing water usage based on specific crop needs, soil conditions, and environmental factors. It reduces water waste and maximizes efficiency.
- Goal is to deliver the right amount of water to the right place at the right time.
- Reduces costs and improves crop health
- Helps mitigate issues related to water scarcity and climate variability

Why care about water management?







https://appliedsciences.nasa.gov/sites/default/files/2020-11/soilmoistureevappart1.pdf

- For each kilogram of water on earth, only 1 milligram is stored as soil moisture

Soil Moisture Monitoring in Precision Water Management

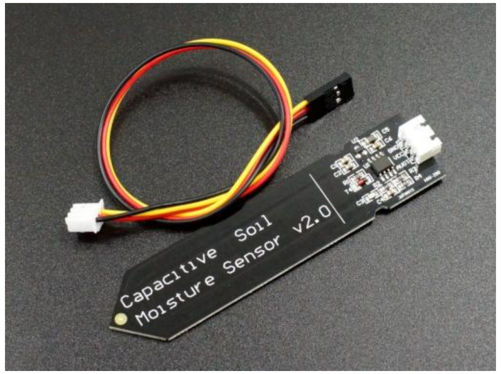
- Monitoring soil moisture helps determine when and how much to irrigate.

In-Field Sensors

i. **Time-Domain Reflectometry (TDR)**
   Measures soil moisture by analyzing changes in electrical signals.

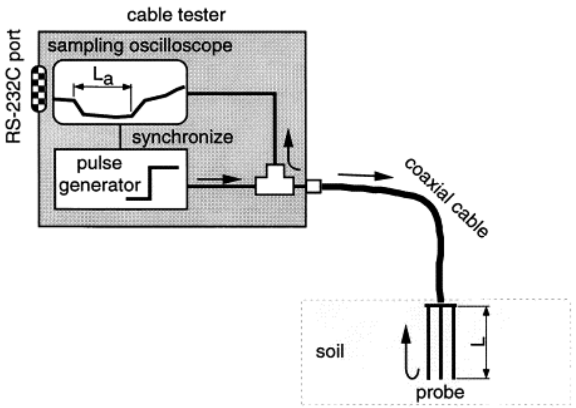
ii. **Capacitance Sensors**
   Detects moisture through changes in soil capacitance, often used in drip irrigation.

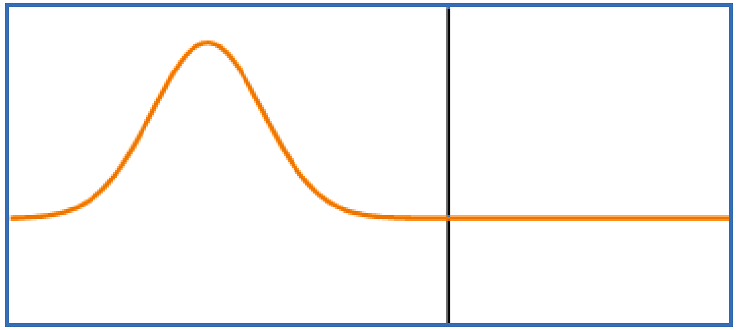
iii. **Neutron Probes**
   Highly accurate for deep soil moisture measurement.



Soil Moisture Monitoring in Precision Water Management

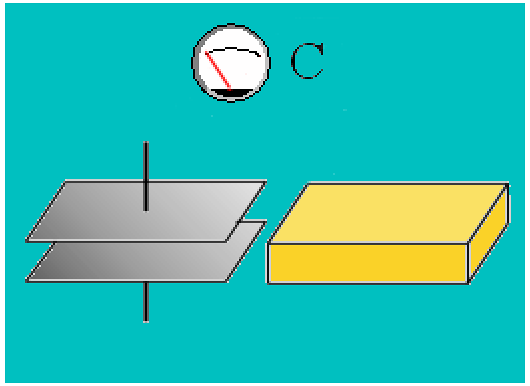
- **Time Domain Reflectometry (TDR) Sensor**
  - Provides highly accurate and reliable measurements across different soil types
  - Measures moisture at different depths within the soil profile
  - Enables continuous monitoring and data collection, essential for accurate irrigation scheduling

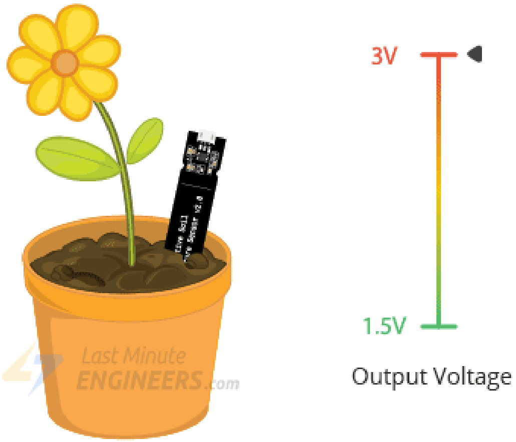




Soil Moisture Monitoring in Precision Water Management

- **Capacitance Sensor**
  - Estimates water content by measuring the soil's dielectric constant.
  - The dielectric constant changes with soil moisture levels.
  - The sensor generates an electromagnetic field, and as water content varies, the sensor detects changes in soil capacitance, which correlates to moisture levels.
  - Helps in determining optimal irrigation times and amounts





Soil Moisture Monitoring in Precision Water Management

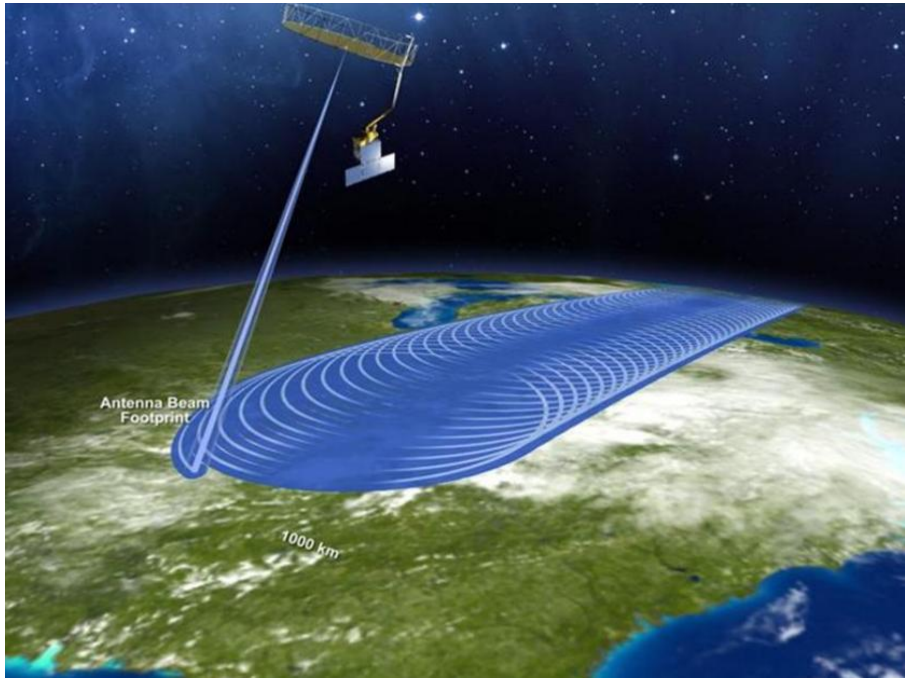
Remote Sensing

i. **Drones and satellites**
Provide moisture data over large areas, valuable for assessing variability across fields. Uses multispectral, hyperspectral and thermal imaging for this

Soil Moisture Monitoring in Precision Water Management

Satellite Remote Sensing for Soil Water Management

- Satellite remote sensing involves using satellite-based sensors to collect data on soil moisture and water availability in agricultural fields.
- Provides large-scale and continuous monitoring of soil moisture.
- Essential for precision irrigation, drought assessment, and sustainable water resource management.
- Soil Moisture Index (SMI), NDVI



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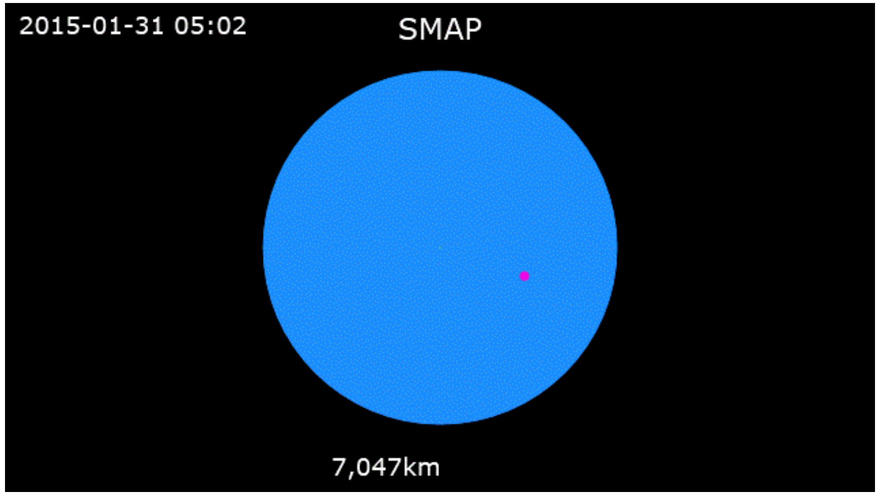
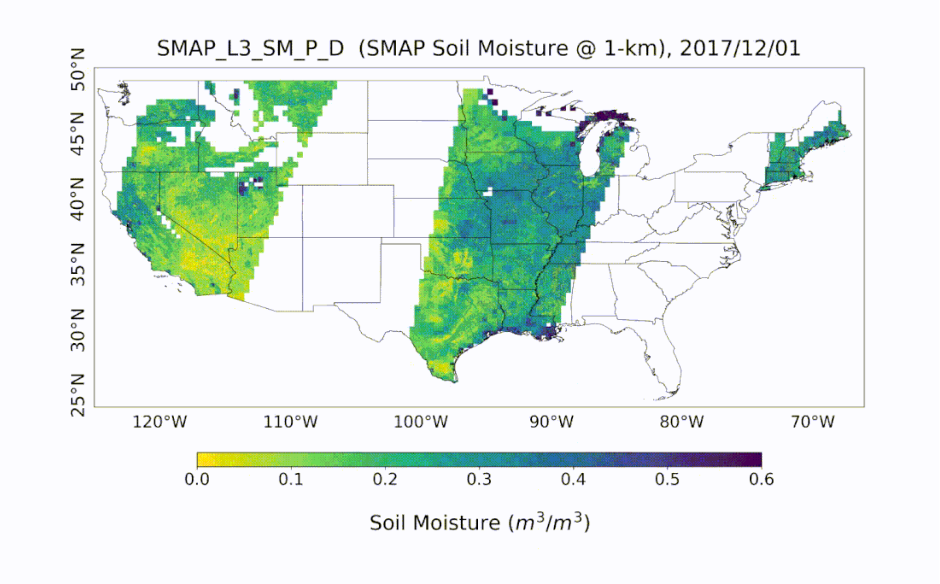
Common Satellites for Soil Water Management

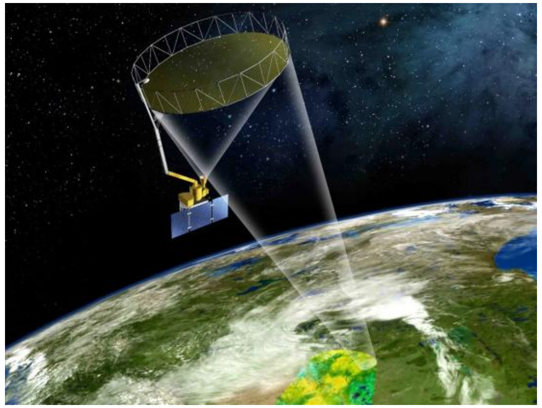
Satellite	Agency	Sensor(s)	Revisit Time	Soil Moisture Measurement Type
SMAP	NASA	L-Band Radiometer	Every 2-3 days	Surface soil moisture
Sentinel-1	ESA	C-Band Synthetic Aperture Radar (SAR)	6-12 days (depending on region)	Surface soil moisture through radar reflectance
MODIS	NASA	Optical (NDVI-based)	1-2 days	Vegetation moisture and stress
Landsat 8 & 9	USGS & NASA	Optical, Thermal Infrared	16 days	Vegetation and soil temperature
Aqua	NASA	Advanced Microwave Scanning Radiometer (AMSR-E)	Varies	Surface soil moisture, water vapor
GRACE-FO	NASA & GFZ	Gravity-based sensors	Monthly	Groundwater changes and storage
COSMO-SkyMed	ASI (Italy)	X-Band SAR	1-3 days	Surface moisture with high resolution

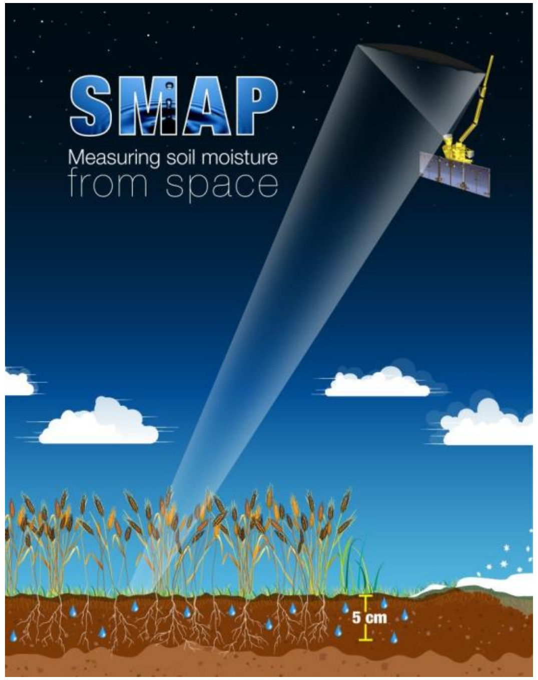
Soil Moisture Monitoring in Precision Water Management

Soil Moisture Active Passive (SMAP) Satellite for Soil Water Management







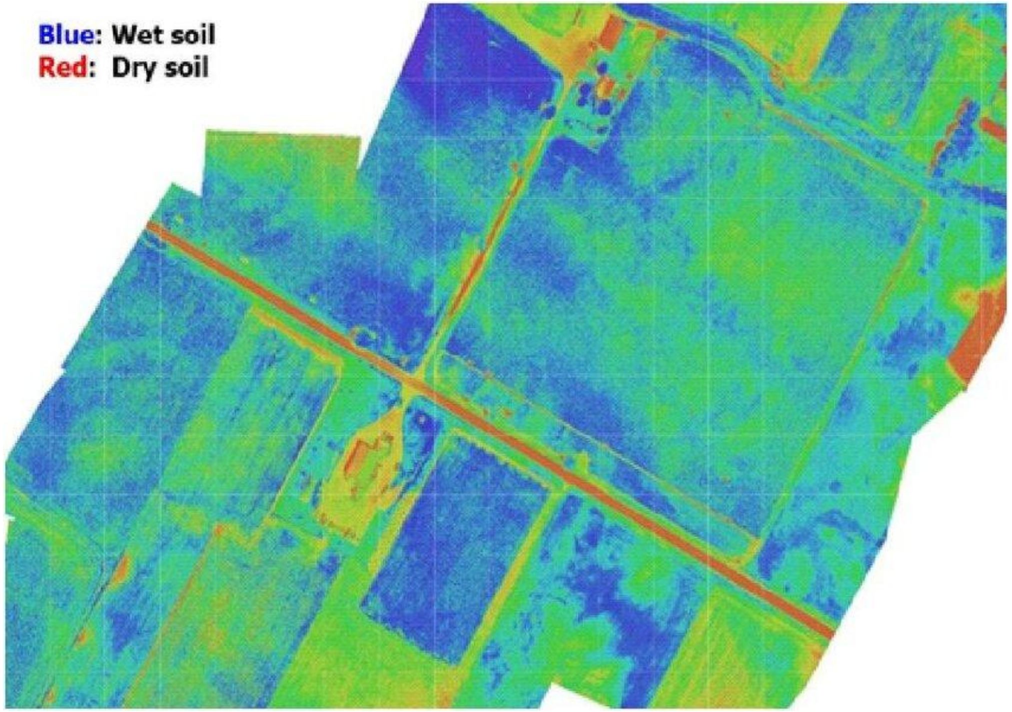


- Launch Date: January 31, 2015
- Measures surface soil moisture in the top 5 cm of soil
- Available as daily, 3-day, and 9-day composites
- Soil moisture data informs models that predict crop productivity
- Helps in planning for potential yield reductions due to water stress

Soil Moisture Monitoring in Precision Water Management

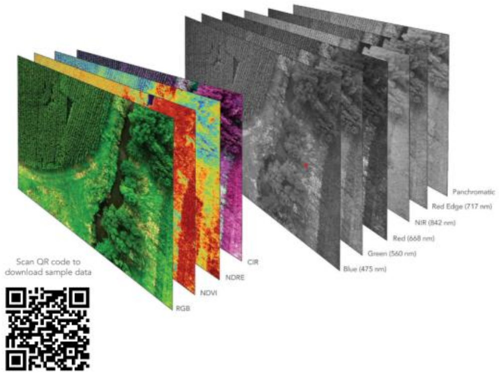
Drone Remote Sensing for Soil Water Management

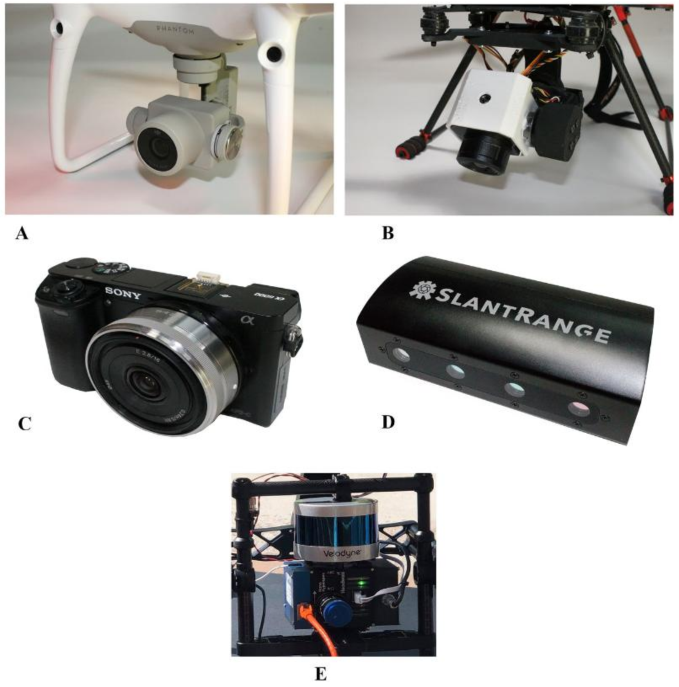
- Drone-based remote sensing involves using UAVs (Unmanned Aerial Vehicles) equipped with sensors to collect high-resolution data on crop water status and soil moisture
- Drones provide field-level detail that satellites may miss
- Enable frequent monitoring and fast data acquisition, ideal for time-sensitive water management



Soil Moisture Monitoring in Precision Water Management

Drone Remote Sensing for Soil Water Management



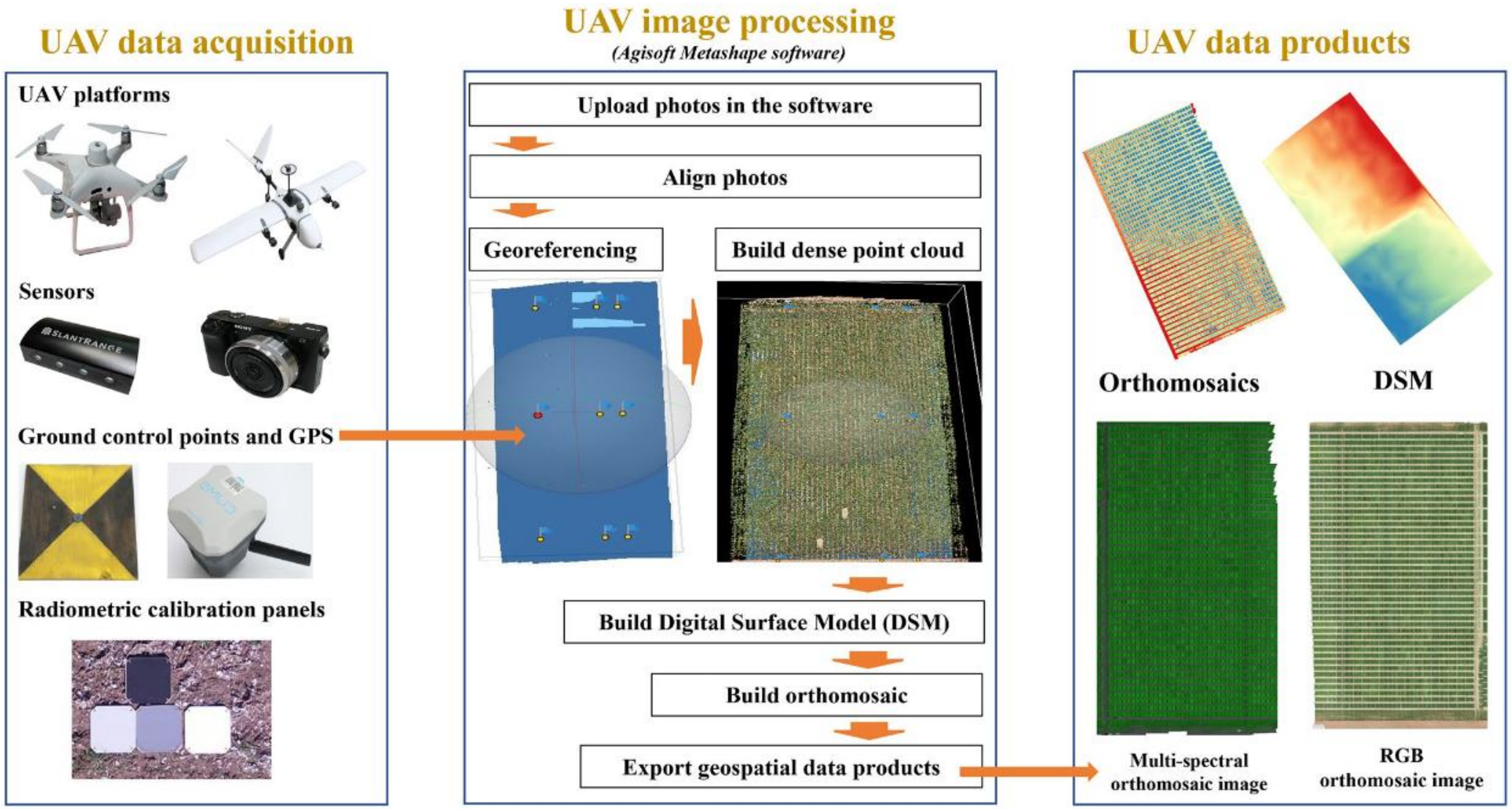


https://ageagle.com/wp-content/uploads/2022/08/AgEagle-RedEdge-P-Brochure-EN.pdf

Acharya, B. S., Bhandari, M., Bandini, F., Pizarro, A., Perks, M., Joshi, D. R., ... & Sharma, S. (2021). Unmanned aerial vehicles in hydrology and water management: Applications, challenges, and perspectives. Water Resources Research, 57(11), e2021WR029925.

Soil Moisture Monitoring in Precision Water Management

Drone Remote Sensing for Soil Water Management



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Soil Moisture Monitoring in Precision Water Management

Drone Remote Sensing for Soil Water Management

Indices	Equation	Use	References
Normalized Difference Vegetation Index, NDVI	$\frac{NIR - R}{NIR + R}$	Biomass, water stress	Jackson et al., 1980
Wide Dynamic Range Vegetation Index, WDRVI	$\frac{a * NIR - R}{a * NIR + R} (0 < a < 1)$	Vegetation fraction, leaf area	Gitelson, 2004
Renormalized Difference Vegetation Index, RDVI	$\frac{R800 - R670}{(R800 + R670)\ \hat{}\ 0.5}$	Biomass, soil moisture	Roujean and Breon, 1995
Optimized Soil Adjusted Vegetation Index, OSAVI	$\frac{(1 + 0.16)(R800 - R670)}{(R800 + R670 + 0.16)}$	Soil color, moisture	Rondeaux et al., 1996
Enhanced Vegetation Index, EVI	$2.5 * \left(\frac{NIR - R}{NIR + (6 * R) - (7.5 * B) + 1}\right)$	Biomass	Jiang et al., 2008
Moisture Stress Index, MSI	$\frac{R1600}{R820}$	Leaf water content	Hunt et al., 2005
Normalized Difference Water Index, NDWI	$\frac{R860 - R1240}{R860 + R1240}$	Foliar water content	Stimson et al., 2005
Normalized Difference Infrared Index, NDII	$\frac{R820 - R1600}{R820 + R1600}$	Canopy water content	Hardisky et al., 1983
Maximum Difference Water Index, MDWI	$\frac{Rmax - Rmin}{Rmax + Rmin}$	Plant water status	Eitel et al., 2006
Soil Adjusted Vegetation Index, SAVI	$\left(\frac{NIR - R}{NIR + R}\right) * (1 + L)$	Soil color, moisture, background variability	Qi et al., 1994

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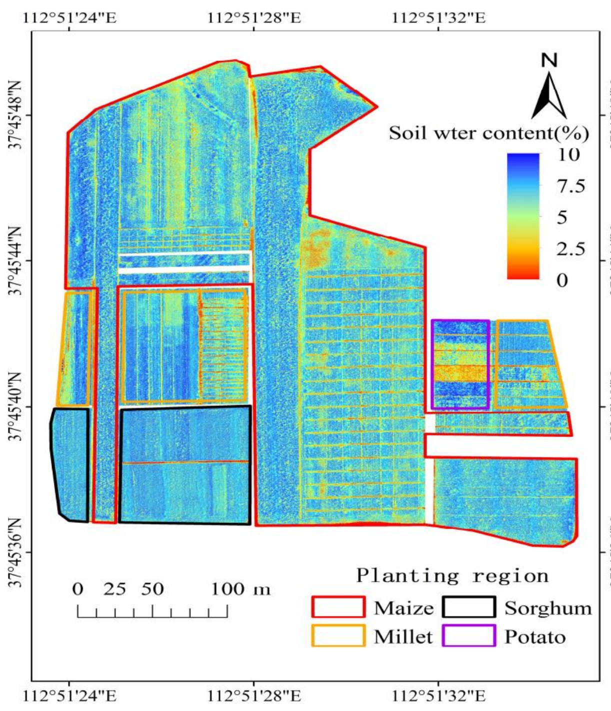

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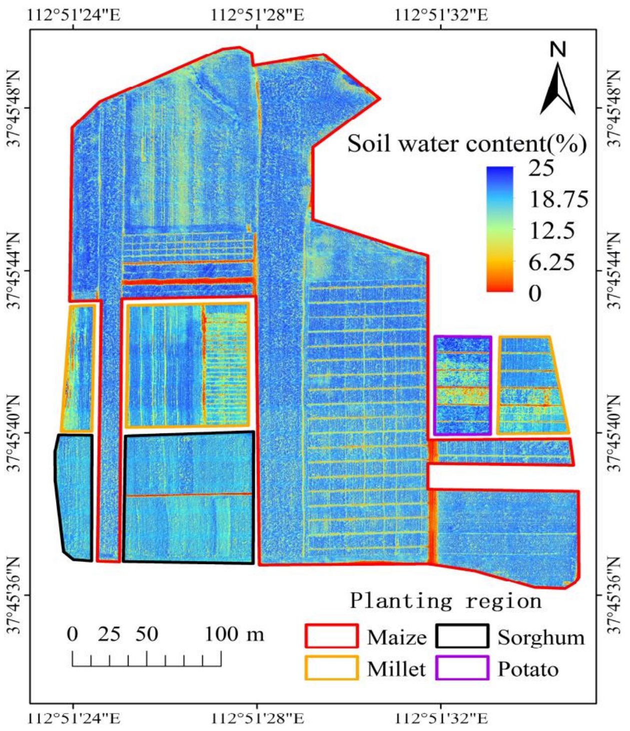
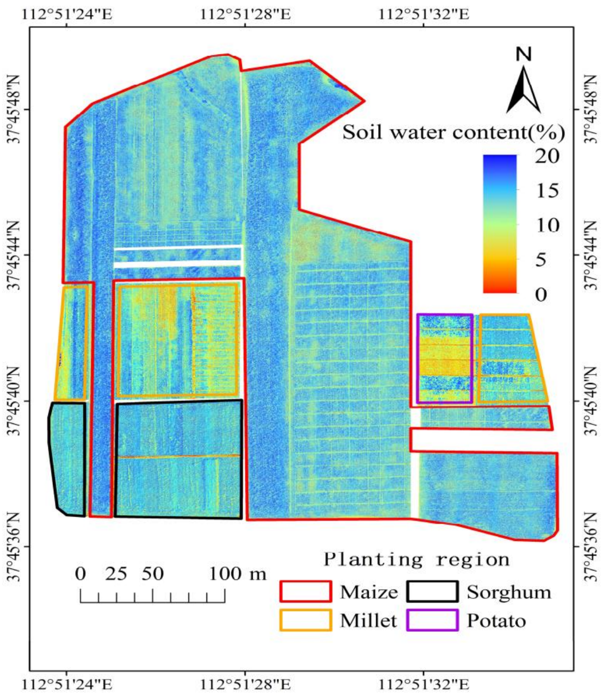


29th Aug

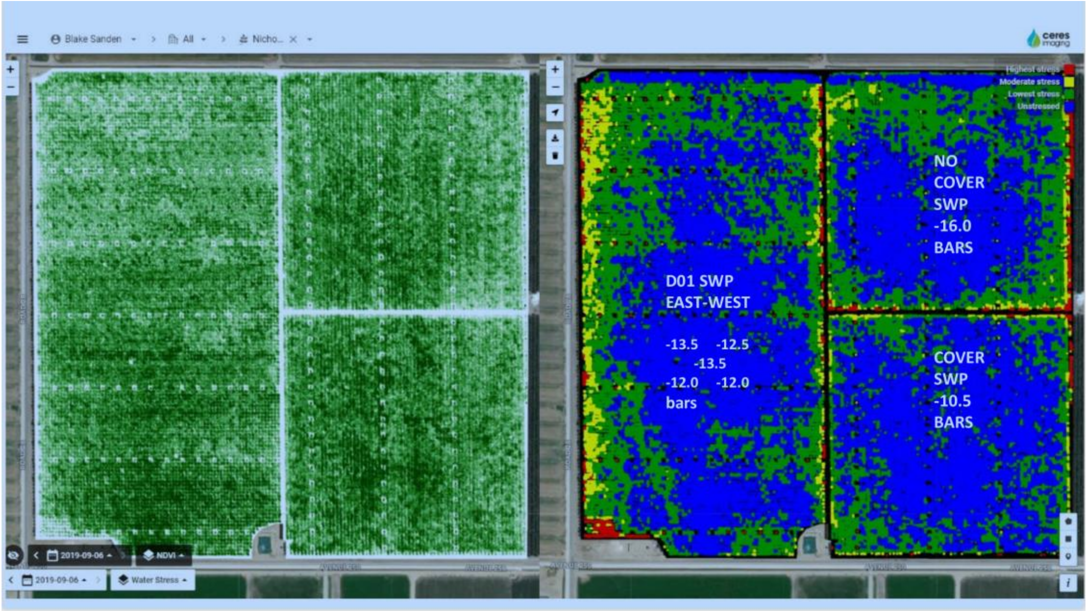


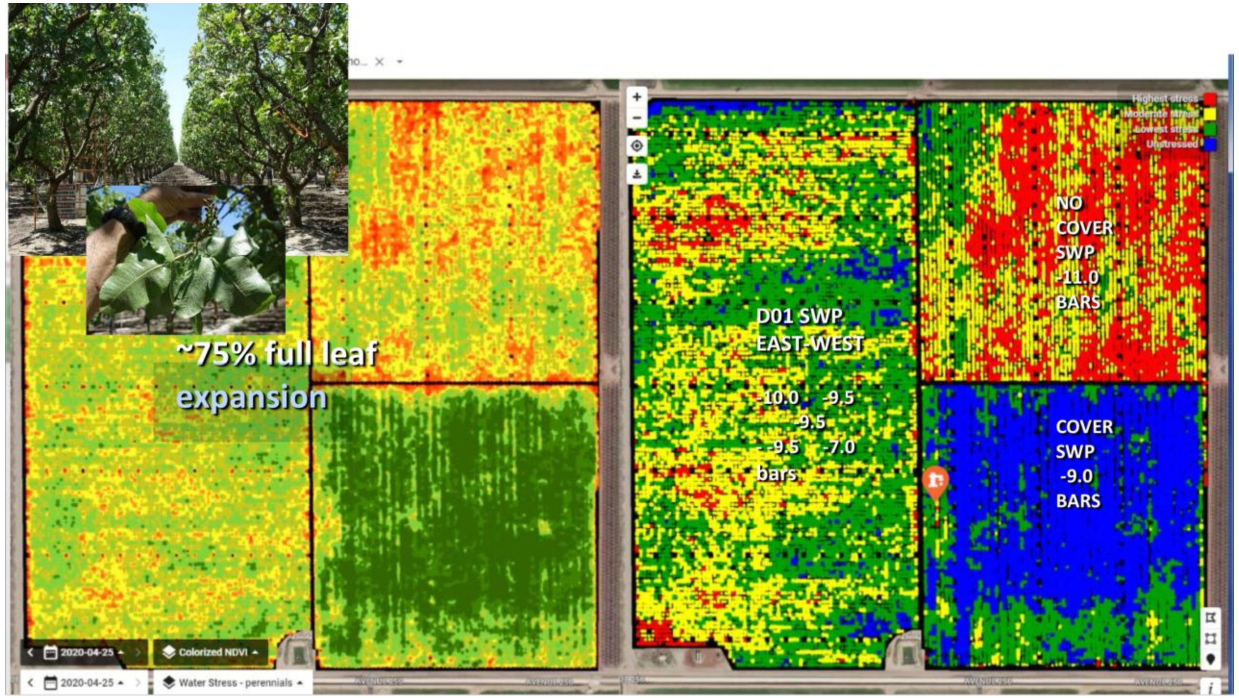
30th Sept

Qu, T., Li, Y., Zhao, Q., Yin, Y., Wang, Y., Li, F., & Zhang, W. (2024). Drone-Based Multispectral Remote Sensing Inversion for Typical Crop Soil Moisture under Dry Farming Conditions. Agriculture, 14(3), 484.

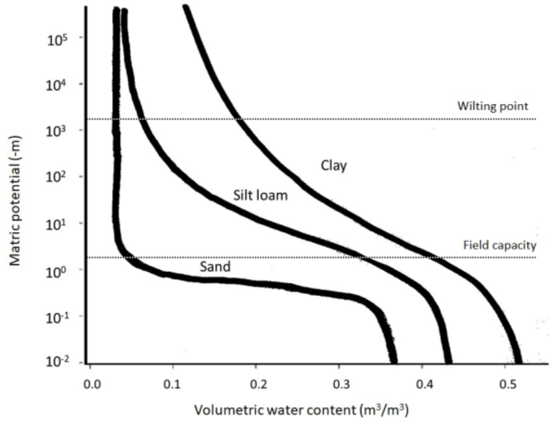
Soil Moisture Monitoring in Precision Water Management

Drone Remote Sensing for Soil Water Management





- Actively growing cover crops, like Brome grass, influenced remote sensing data by affecting canopy temperatures and reflectance. This was especially noticeable in the Eastside location after a rain, where cover crops significantly cooled canopy temperatures.



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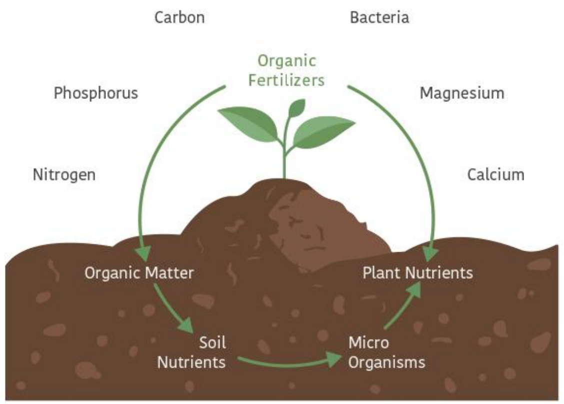
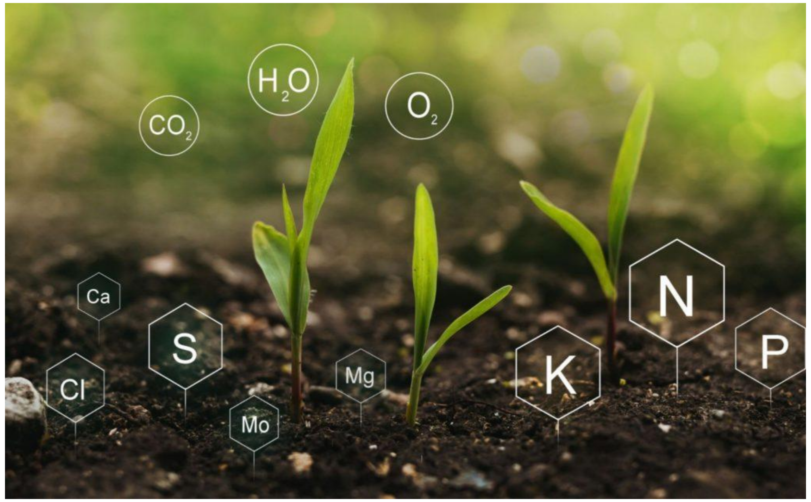
Precision Nutrient Management

- Precision nutrient management is the site-specific application of fertilizers based on soil and crop needs.
- Goal is to optimize nutrient use by delivering the right amount to the right place at the right time.
- Reduces nutrient runoff and minimizes environmental harm.
- Decreases fertilizer costs by applying nutrients only where needed
- Ensures crops receive the optimal nutrient levels for healthy growth and yield





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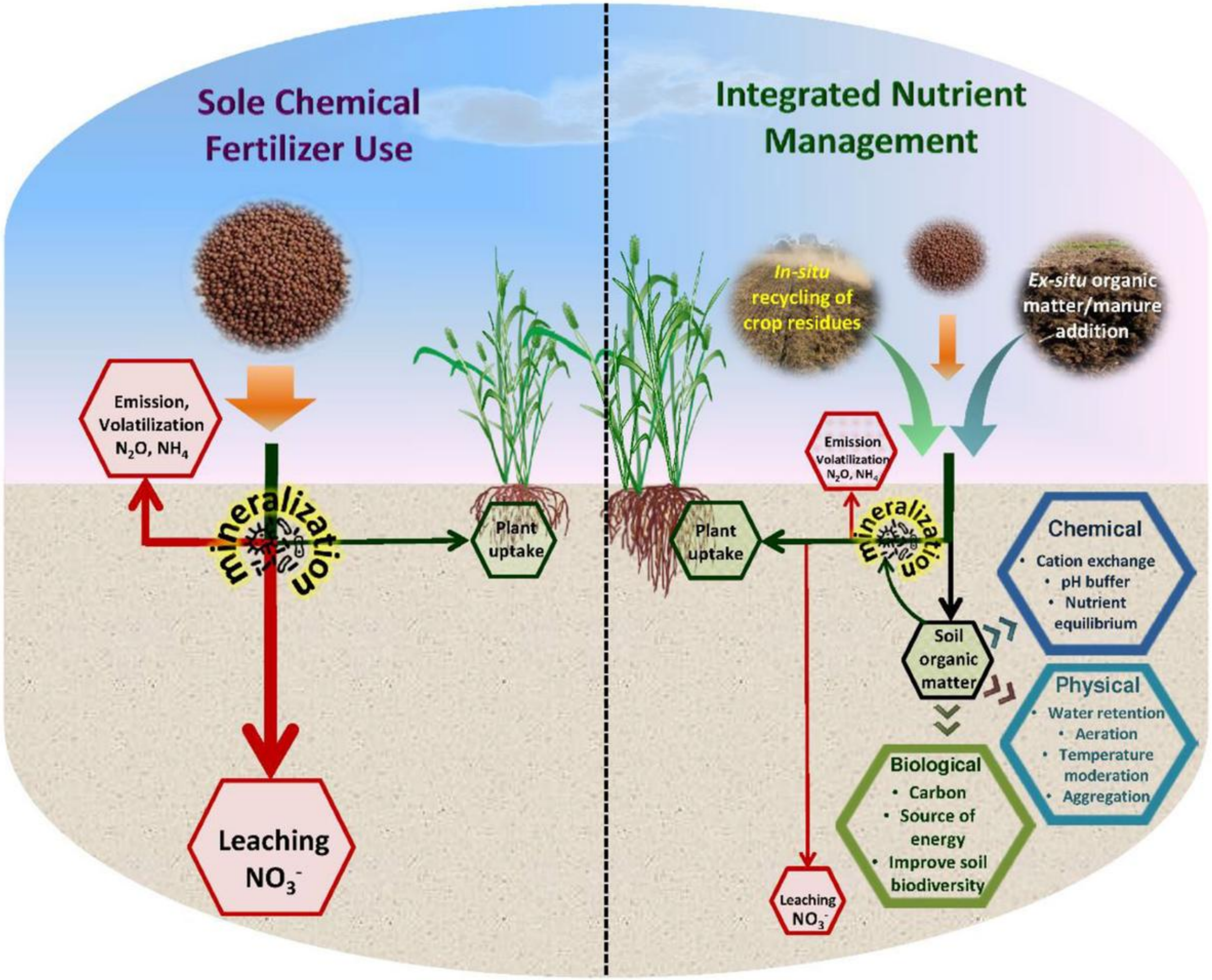
Precision Nutrient Management



Bhardwaj, A. K., Malik, K., Chejara, S., Rajwar, D., Narjary, B., & Chandra, P. (2023). Integration of organics in nutrient management for rice-wheat system improves nitrogen use efficiency via favorable soil biological and electrochemical responses. Frontiers in Plant Science, 13, 1075011.

Tool and Technologies for Precision Nutrient Management

- Use of GPS for geolocated soil samples
- GIS mapping to visualize spatial variability of nutrients across the field
- In-field sensors that measure pH, nitrogen, phosphorus, potassium levels, and electrical conductivity
- Decreases fertilizer costs by applying nutrients only where needed
- Drones and satellites capture multispectral or hyperspectral images to assess crop health
- Automated spreaders, sprayers, and applicators adjust nutrient application based on prescription maps

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Tool and Technologies for Precision Nutrient Management

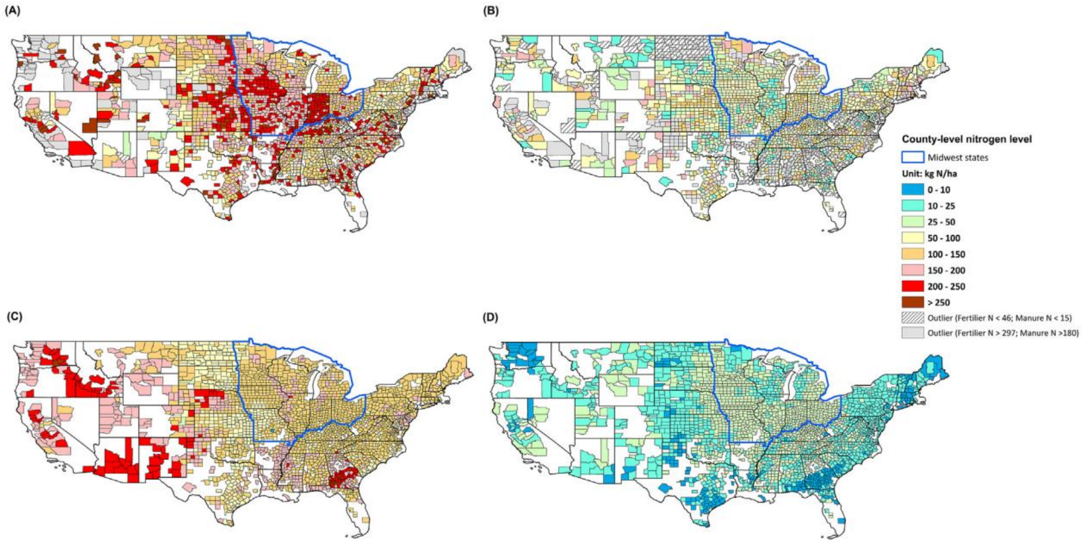

Fig. 2. County-level corn-specific **(A)** nitrogen (N) fertilizer application rates (N = 2269), **(B)** manure N application rates (N = 1741), **(C)** N needs (N = 2460), and **(D)** N credits (N = 2460) for conterminous U.S. The fertilizer and manure N application rates were estimated with a top-down area-allocation approach using farm survey and sales data. N rates higher than 297.2 kg N ha^{-1} and lower than 46.3 kg N ha^{-1} were considered outliers for fertilizer, and higher than 179.8 kg N ha^{-1} and lower than 14.6 kg N ha^{-1} were considered outliers for manure. The N needs and credits were estimated using empirical equations that consider corn yield, crop type prior to corn, and soil characteristics. Midwestern states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, Wisconsin) constituting the main U.S. corn production area are delimited with a blue boundary. Areas shown in white did not report corn planted area.

Xia, Y., Kwon, H., & Wander, M. (2021). Developing county-level data of nitrogen fertilizer and manure inputs for corn production in the United States. Journal of Cleaner Production, 309, 126957.

Tool and Technologies for Precision Nutrient Management

[Prescription maps for Variable Rate Application | PIX4Dfields Tutorials]

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Tool and Technologies for Precision Nutrient Management

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Quiz

What index will you prefer to generate your Nitrogen prescription map for precision nutrient management practices?

Next Lecture

Precision Water and Nutrient Management II