UC RIVERSIDE
Environmental Sciences

USDA
Agricultural Research Service
U.S. Salinity Laboratory
Agricultural Water Efficiency
and Salinity Research Unit

Artificial Intelligence for
Sustainable Agriculture
www.ai4sa.ucr.edu

Do we need better soil maps
for field-scale water and nutrient management?

Elia Scudiero
Associate Research Agronomist

Workshop on Artificial Intelligence (AI) for Sustainable Agriculture

Salinas, CA. December 3, 2024


YES

Feeding the planet growing population

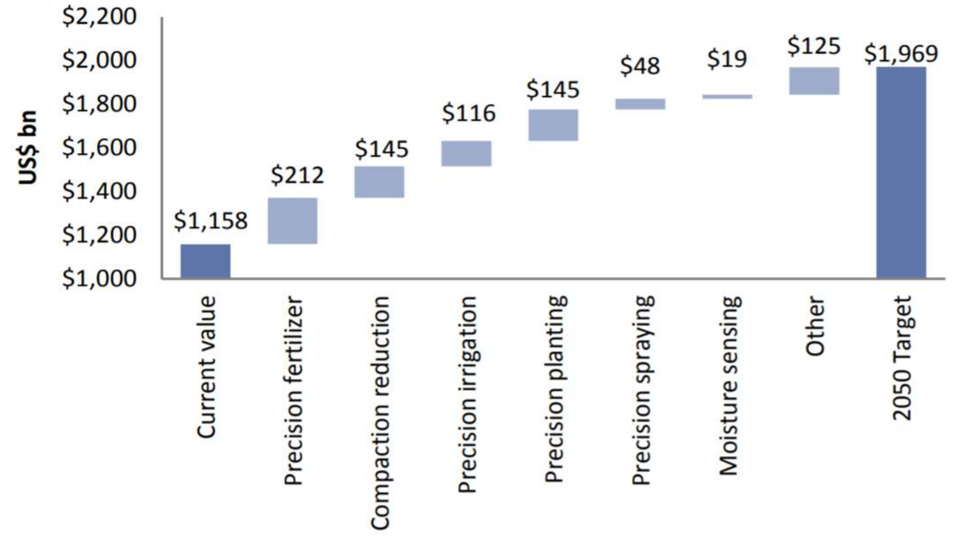
- Agricultural production should increase by >70% by 2050

- **USA's long-term sustainable agriculture goals**
  - Provide more profitable farm income
  - Promote environmental stewardship
  - Enhance quality of life for farm families and rural communities

- **Ongoing 4TH industrial revolution**

Rapid expansion of development and availability of agricultural technologies such as **robotics**, computer science (**artificial intelligence**), and **hardware and software** connected through the **Internet of Things**

Exhibit 9: Farming Tech is core to delivering a 70% increase in global crop production
Global crop value in US$ bn's

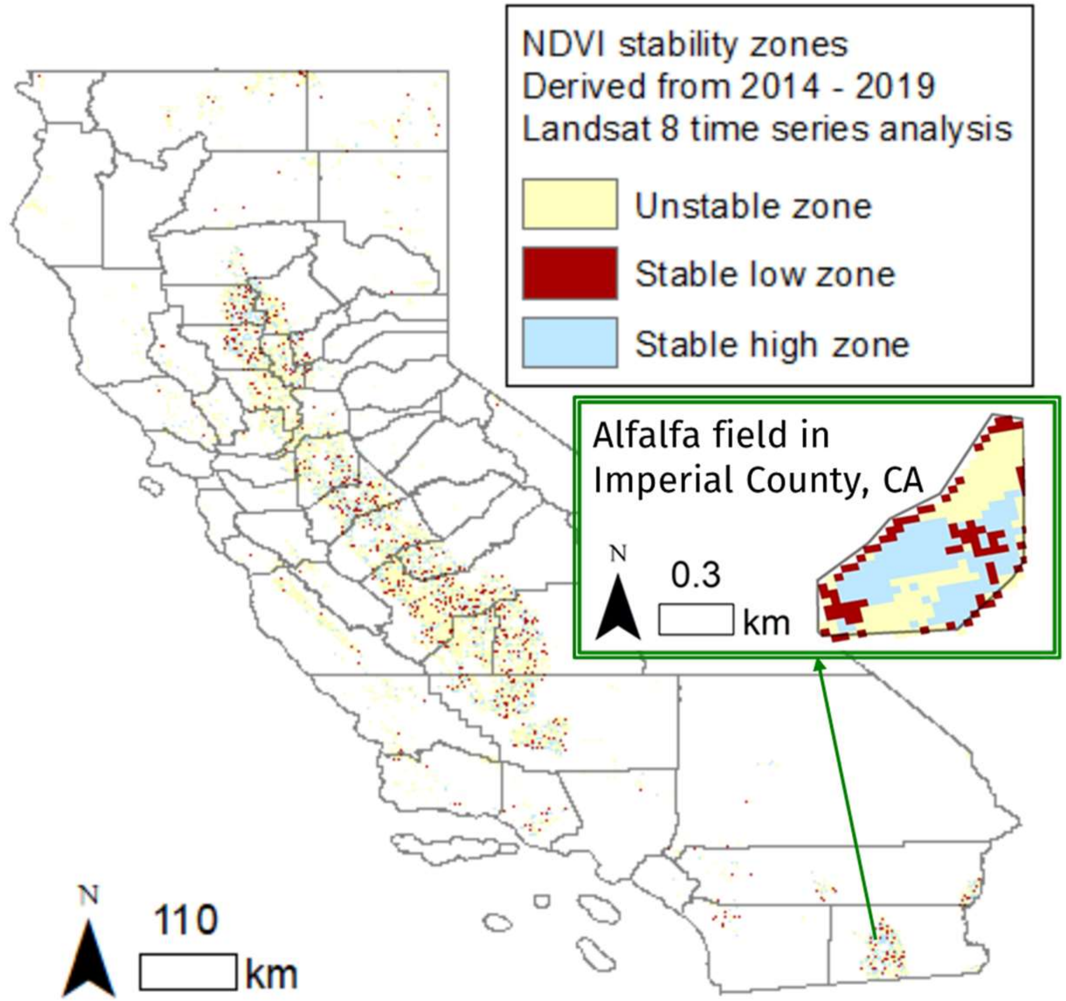


Source: Goldman Sachs Global Investment Research, Company Data.

Within-field temporal stability of NDVI time series (2014 – 2019)

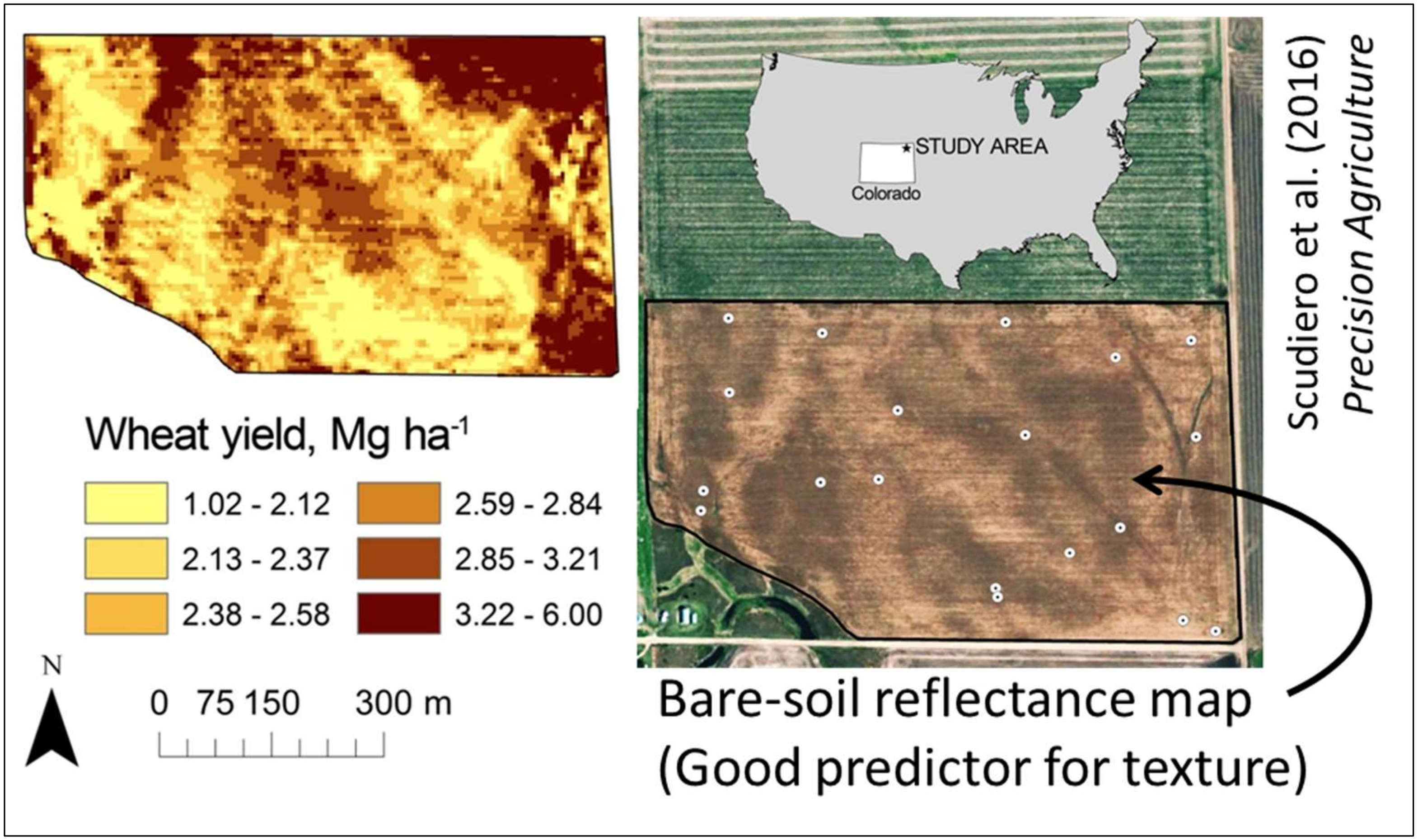
>**Stable high areas**: local NDVI-peak above average for all years, bottom 20th percentile of multi-year temporal variability

>**Stable low areas**: local NDVI-peak always below average, bottom 20th percentile of multi-year temporal variability



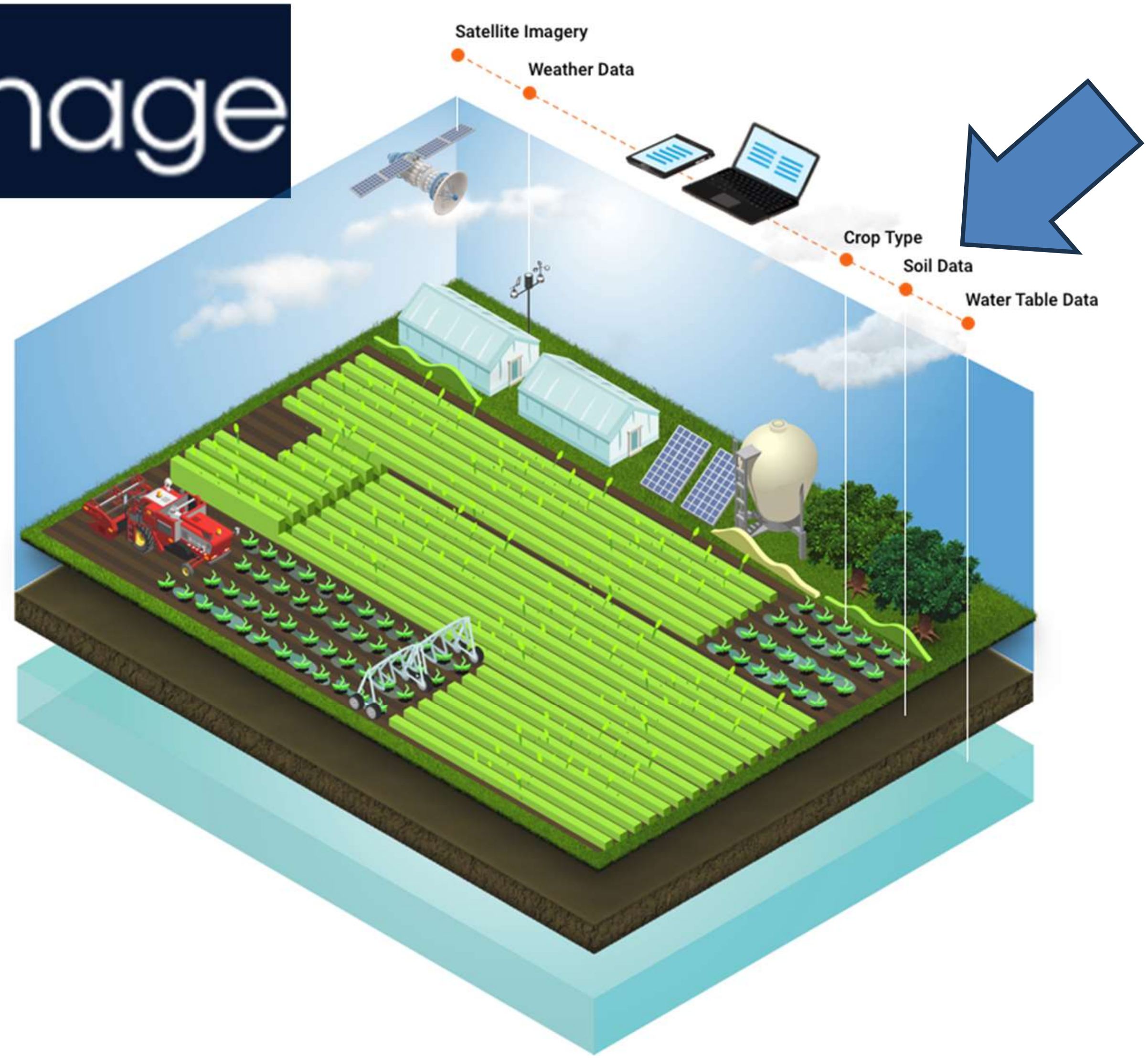
Collaboration with Ahmed Eldawy's Lab.
Big Raster and Vector Query Processing
Electrical & Computer Engineering, UC Riverside

Soil spatial variability drives *most* of yield spatial variability



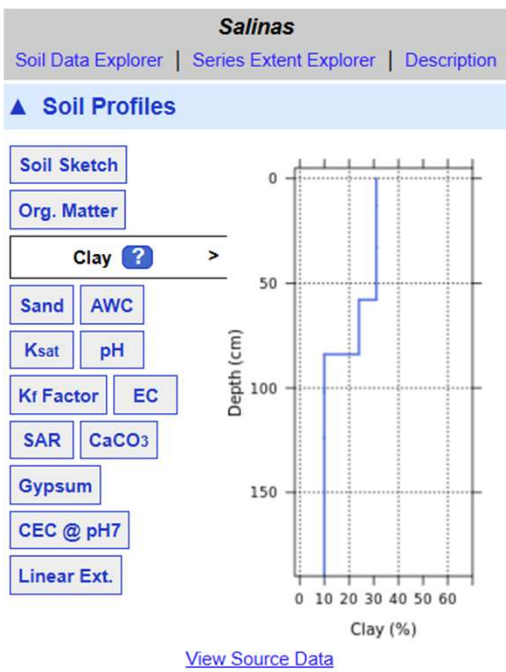
CropManage

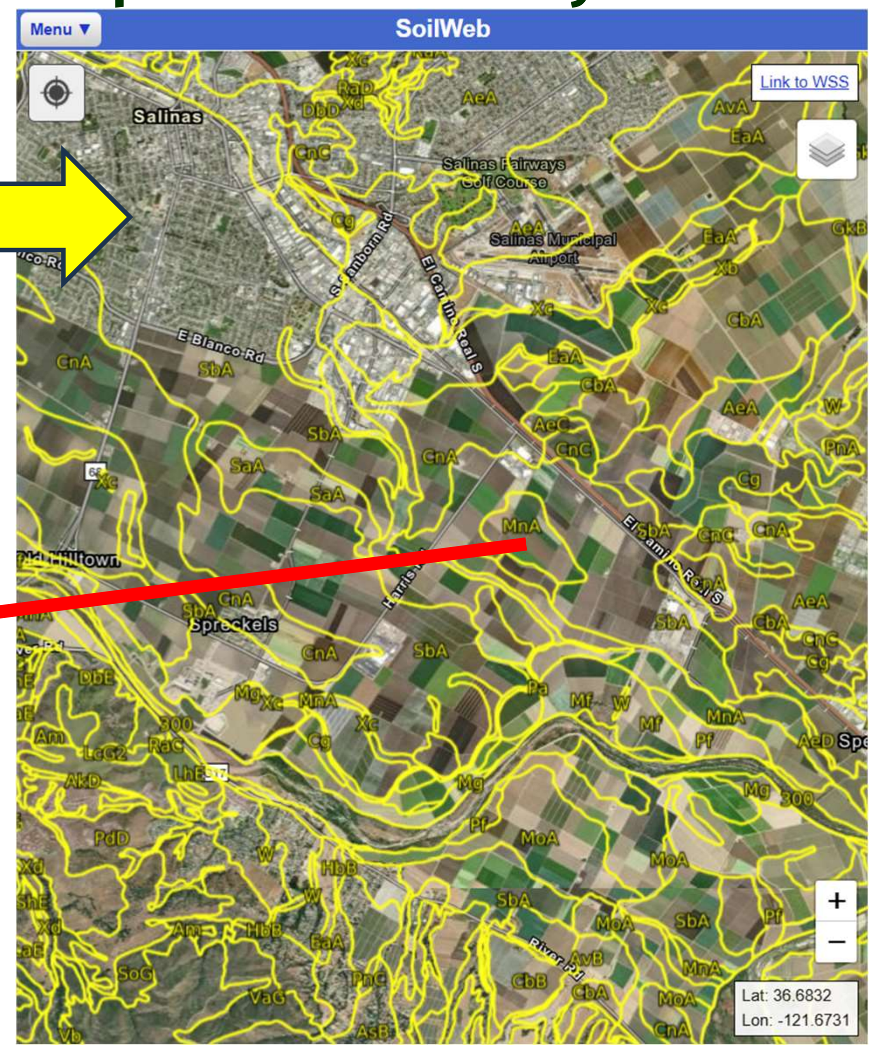
Soil maps are used as an input in decision support models



Web Soil Survey (SSURGO) USDA-NRCS National Cooperative Soil Survey MAPS

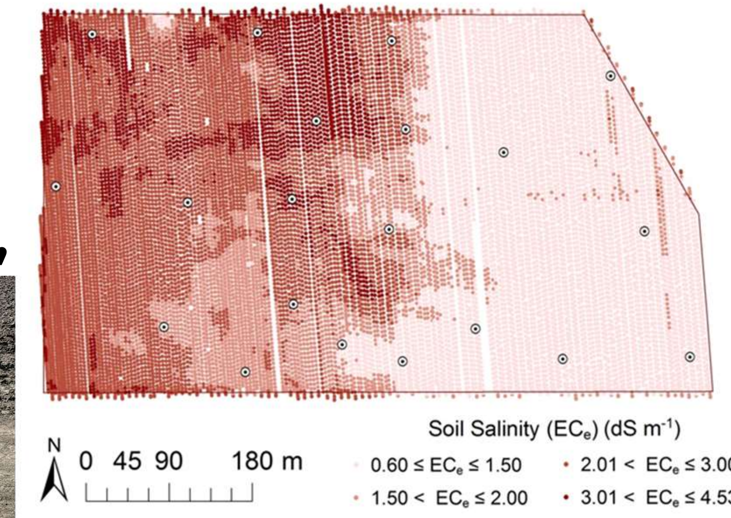
- Web Soil Survey (SSURGO) from USDA-NRCS's National Cooperative Soil Survey
  is an invaluable source of information
- https://casoilresource.lawr.ucdavis.edu/gmap/
- Fairly accurate at broad spatial scales
- **Often, not sufficiently accurate at the field scale**





How are the SSURGO soil maps doing in the Salinas Valley?

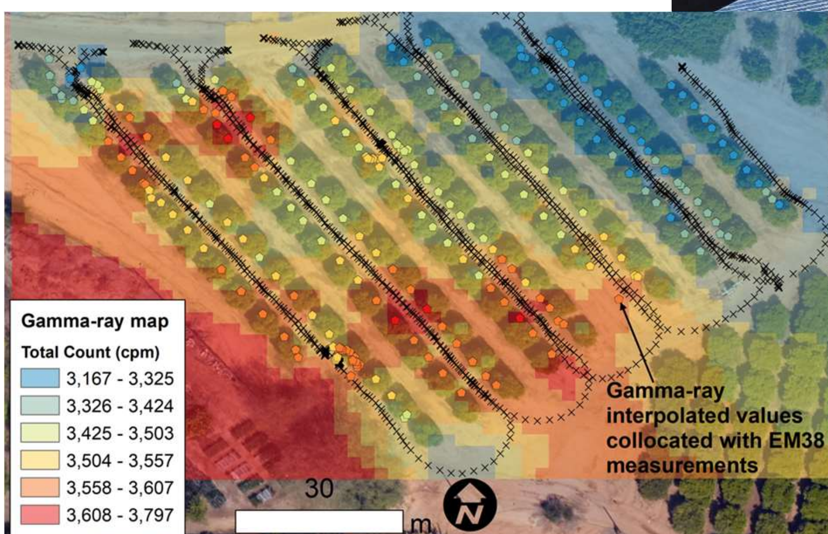
Texture, Water Content, Salinity, Gravel, ...

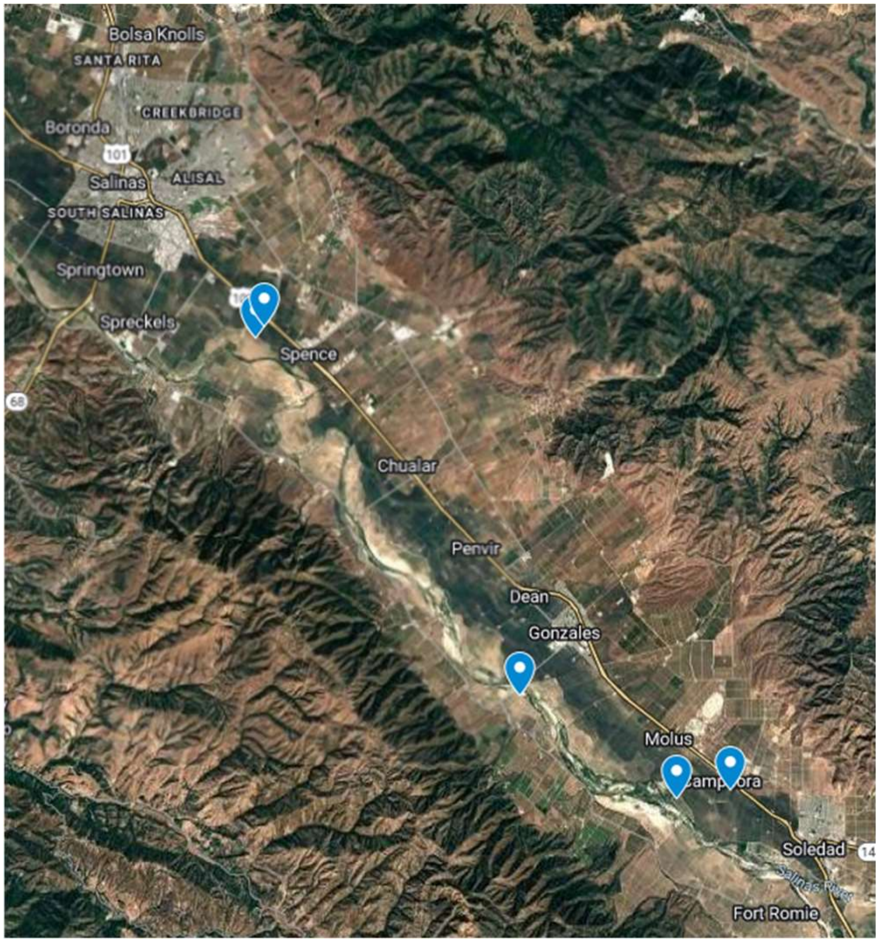


CMD Mini-Explorer 6L – Electromagnetic Induction – soil apparent electrical conductivity

- RS700 – Gamma Ray Spectrometer – Gamma Ray Total count, U, K, Th

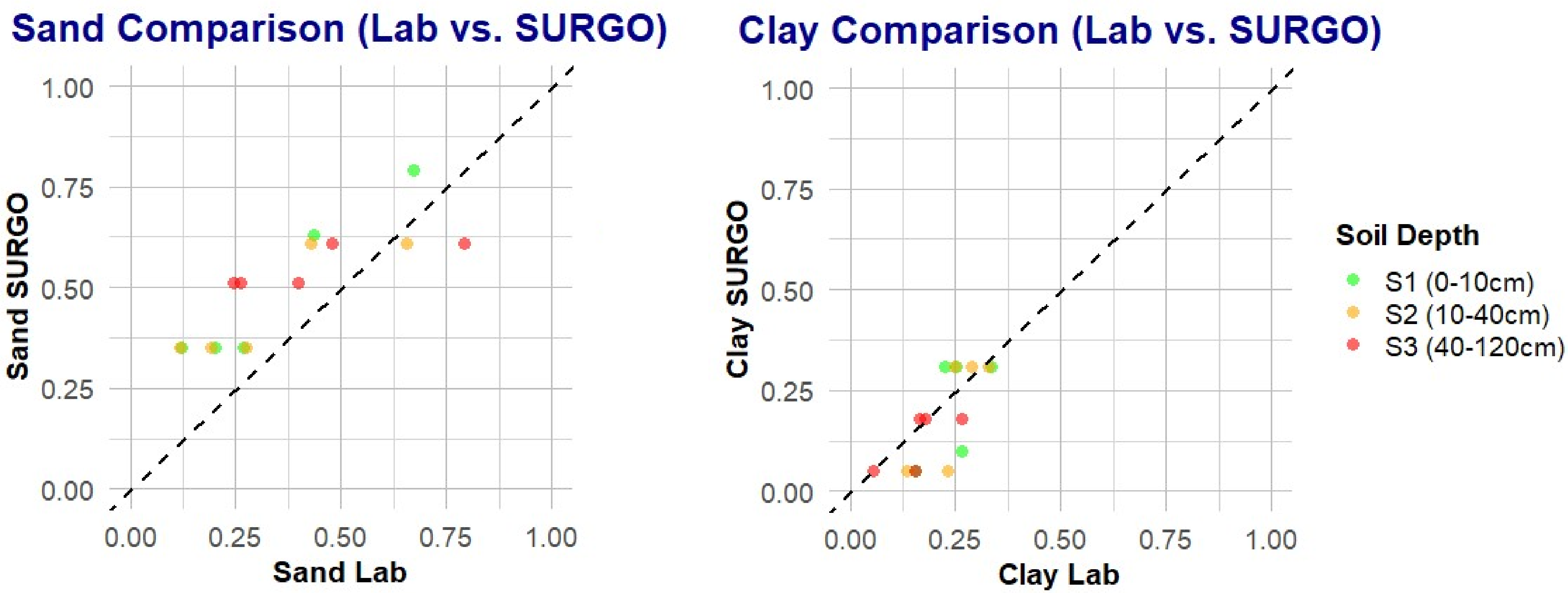
Texture, clay mineralogy, (0 to 30~50cm)



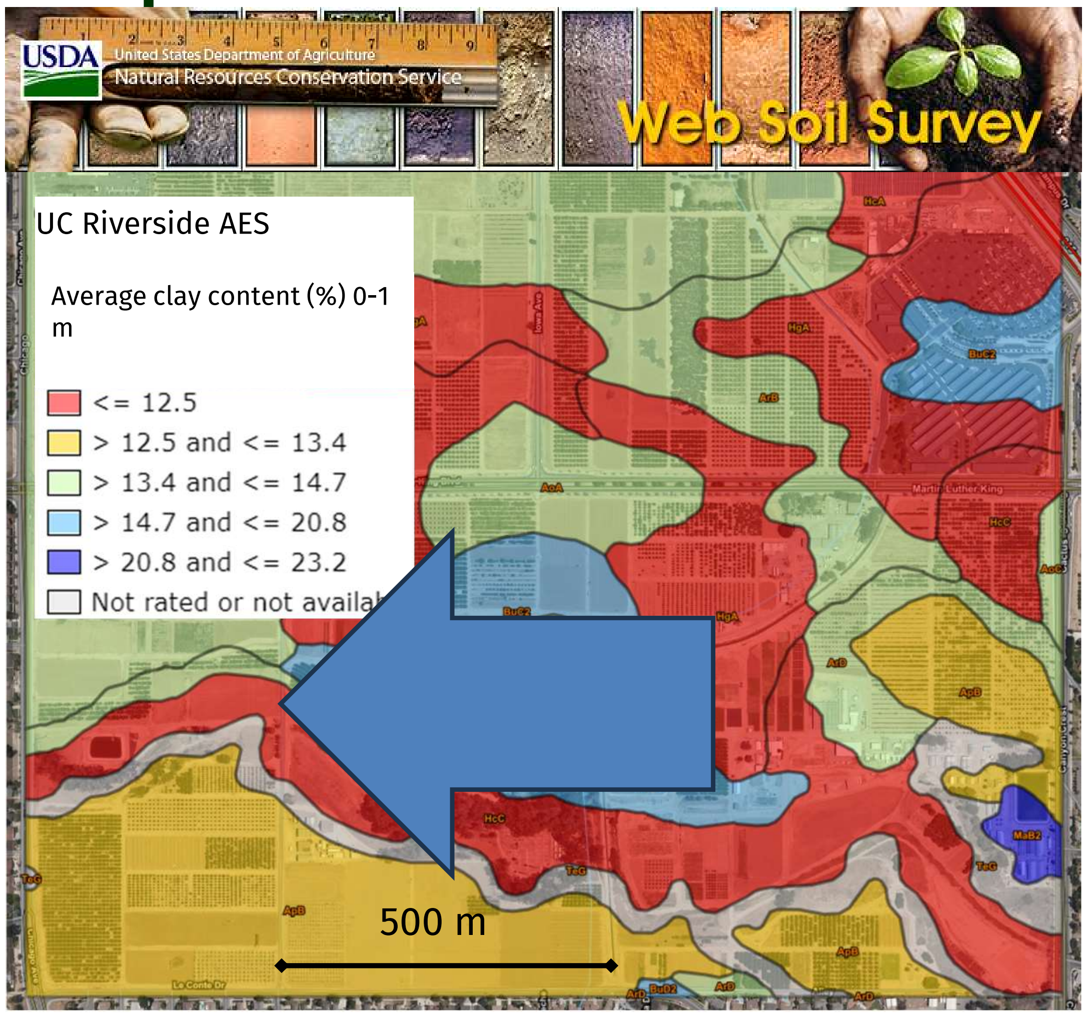


- Soil sampling at multiple depths

How are the SSURGO soil maps doing in the Salinas Valley?



A look at USDA soil maps at UC Riverside

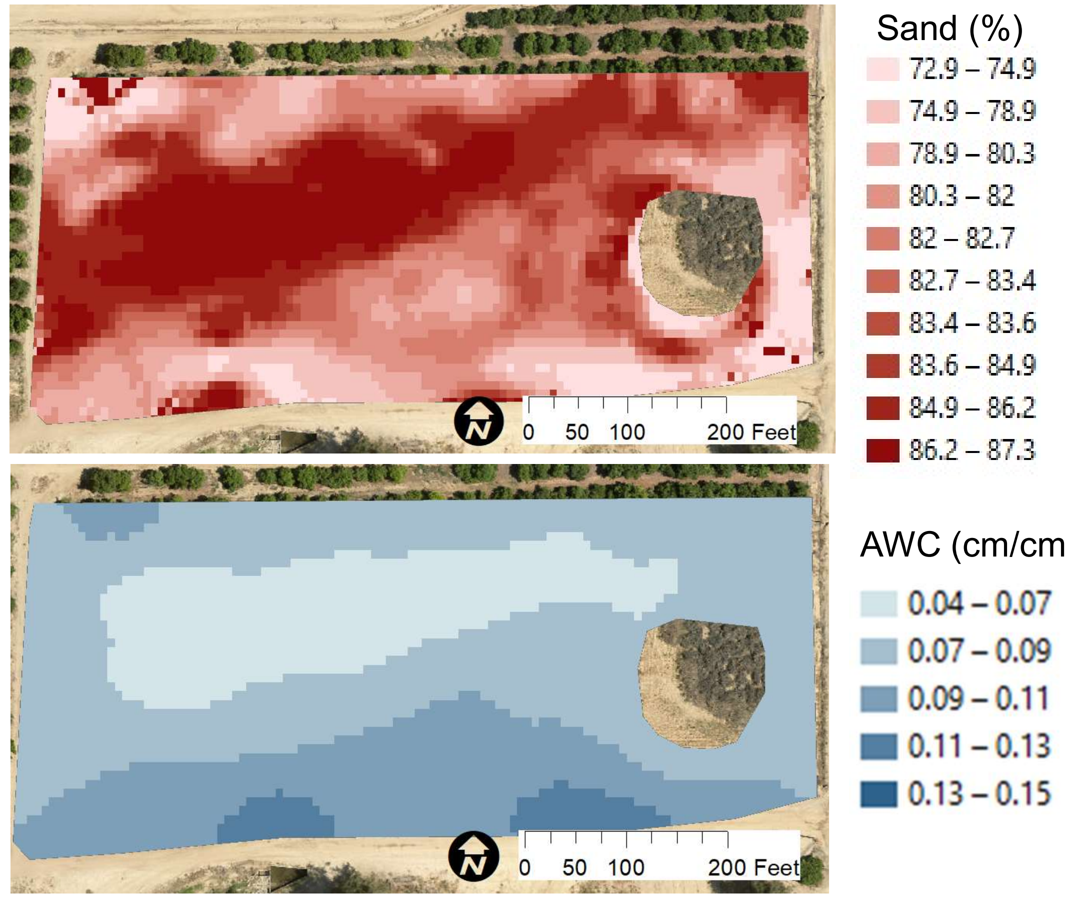


USDA Maps are not suitable for precision agriculture … but sensor derived maps are!

USDA Soil Maps

Sandy Loam	*Sandy Loam*
Topsoil *68.8* cm	Topsoil 20 cm
Sand 22.1%	Sand 68 %
Clay 7.5%	Clay 12.5 %
AWC 0.10 cm/cm	AWC 0.13 cm/cm

EC_a-derived soil maps



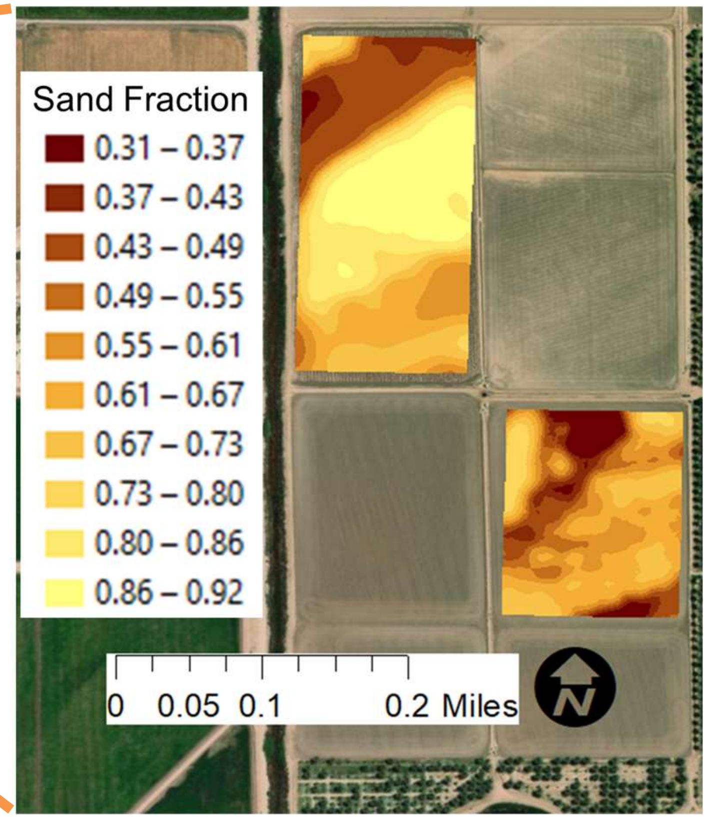
Scudiero et al., 2024

What are high-resolution maps good for?

Mapping soil spatial variability at the meter resolution

Bard Water District, Imperial County, CA

Collaboration with Charles Sanchez, UofA, AI4SA Co-PI



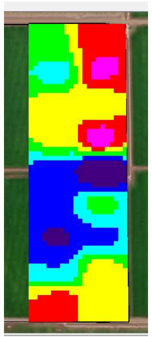
We used on-the-go soil sensing to map sand content in 10 fields

California *Ag. Order 4.0* Nitrogen Removal Regulations

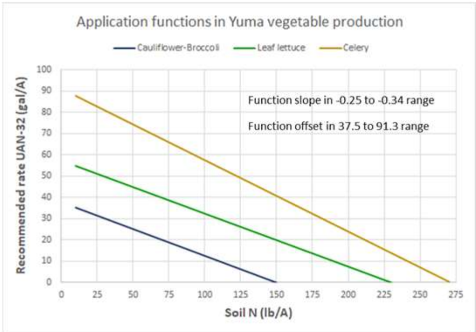
- Current limit is 500 lb/acre of nitrogen after crop removal.
- **In 2051, maximum of 50 lb/acre of nitrogen after crop removal**
- Is Precision Ag a viable tool to help farmers meeting these N reduction goals?
  – *4R approach: Right source, Right rate, Right time, Right place*
- Soil-texture derived **VARIABLE-RATE NITROGEN** zones in the Bard Water District are showing high yield with a **20-30% N input reduction**
  (Research with Charles Sanchez, UofA, AI4SA Co-PI)

OUTCOMES:
- Increase in farmer profit
- Reduced environmental impact

Soil texture based zones



Zone N recommendations based on soil and plant tests



Variable Rate Nutrient Management

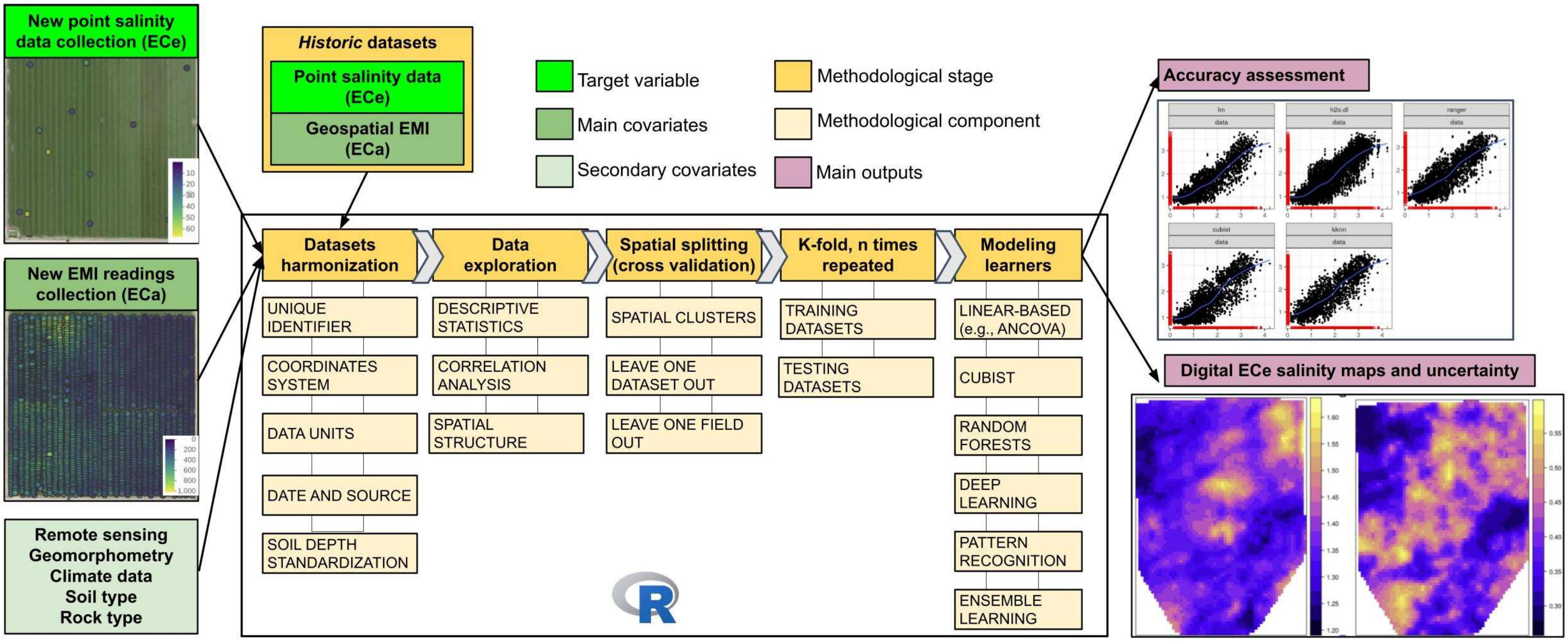
Pre-Planting and In-season

AI (derived) soil maps

CASE 1: you are a soil scientist surveying fields for your clients

Workflow for automated sensor calibration and soil mapping

→ Example for soil salinity mapping with ECa data



Guevara et al. In Preparation

AI (derived) soil maps

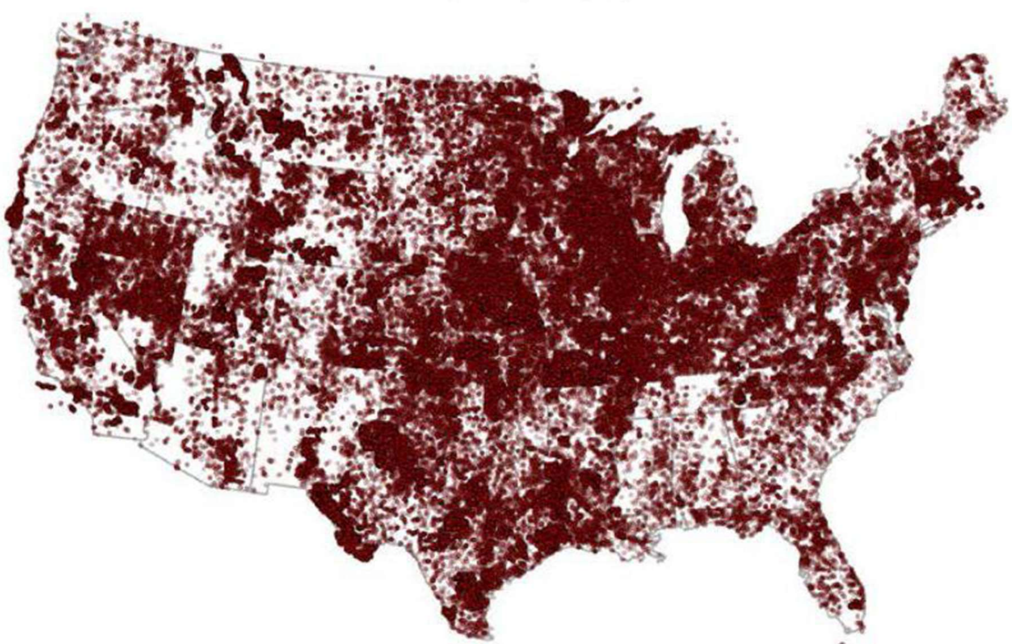
CASE 2: you want to use AI-generated maps for the entire state (or broader scales)

Combining publicly available soil data with big data and AI

- USDA’a National Soil Information System (NASIS) database contains in situ observations made over the years by soil surveyors over the United States.

- Hundreds of thousands of soil measurements in the US
  - Similar information globally

- AI uses remote sensing data, climate data …. To predict spatial variability of soil properties: texture, SOC, ….

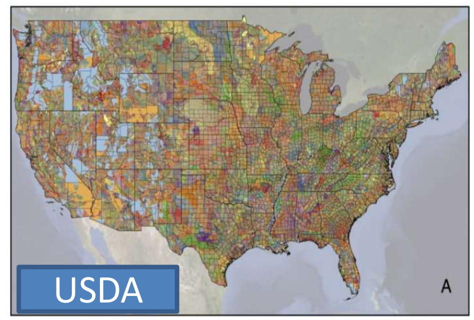


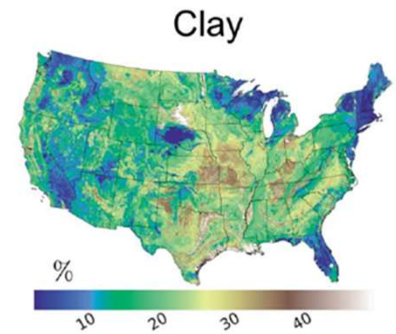
Ramcharan et al 2019

Machine learning –based soil maps (Duke University – AI4SA)

POLARIS Soil Properties: 30-m Probabilistic Maps of Soil Properties Over the Contiguous United States

Chaney et al. (2016). *Geoderma*
Chaney et al. (2019). *Water Resources Research*





Towards POLARIS v2: Leveraging Hierarchical Soil Classification and Regression Kriging to Assemble New Soil Properties Maps over California and Beyond

Authors	Chengcheng Xu, Elia Scudiero, Nathaniel W Chaney
Publication date	2023/12
Journal	AGU Fall Meeting Abstracts
Volume	2023

Do we need better soil maps?

- In many cases, yes.
  - Accurate high-resolution maps help quantifying spatial variability
    - Helping answer questions: is a field sufficiently homogeneous or should I consider site-specific management of agronomic inputs?
- How do we make accurate soil maps at a single field?
  - A combination of on-the-go soil sensors and soil laboratory analyses can be used to generate maps
    - Soil sampling & laboratory analyses are very expensive
- How to produce inexpensive soil maps with AI?
  - Leveraging field scale surveys over many fields and using limited soil sampling
    - Once an AI model is calibrated the need for new soil sampling decreases substantially
  - *Work-in-progress*: Using USDA point data and field scale surveys, AI can create accurate high-resolution accurate maps

Thanks for your attention!

Elia Scudiero, Ph.D.
Associate Research Agronomist
UC Riverside, Environmental Sciences
USDA-ARS, U.S. Salinity Laboratory
elia.scudiero@ucr.edu

@EliaScudiero

Digital Agronomy Lab website

Funding sources and co-investigators

“Artificial Intelligence for Sustainable Water, Nutrient, Salinity, And Pest Management in The Western U.S.”
Elia Scudiero (PD); **Hoori Ajami; Ray Anderson; Khaled Bali; Michael Cahn; Nate Chaney; Karletta Chief; Ahmed Eldawy; Andrew French; Raj Khosla; Milt McGiffen; Connie Nugent; Vagelis Papalexakis; Alexander Putman; Monique Rivera; Charles Sanchez; Kurt Schwabe; Todd Skaggs; George Vellidis** (Co-PDs)

NIFA-AFRI Grant Number: 2020-69012-31914