Mapping root-zone agricultural soil salinity across scales in California, USA

GLOBAL SYMPOSIUM ON
SALT-AFFECTED
SOILS

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Soil salinity

Salinity refers to the presence of Na^{+}, Mg^{2+}, Ca^{2+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_3^{-}, CO_3^{2-} in the soil solution.

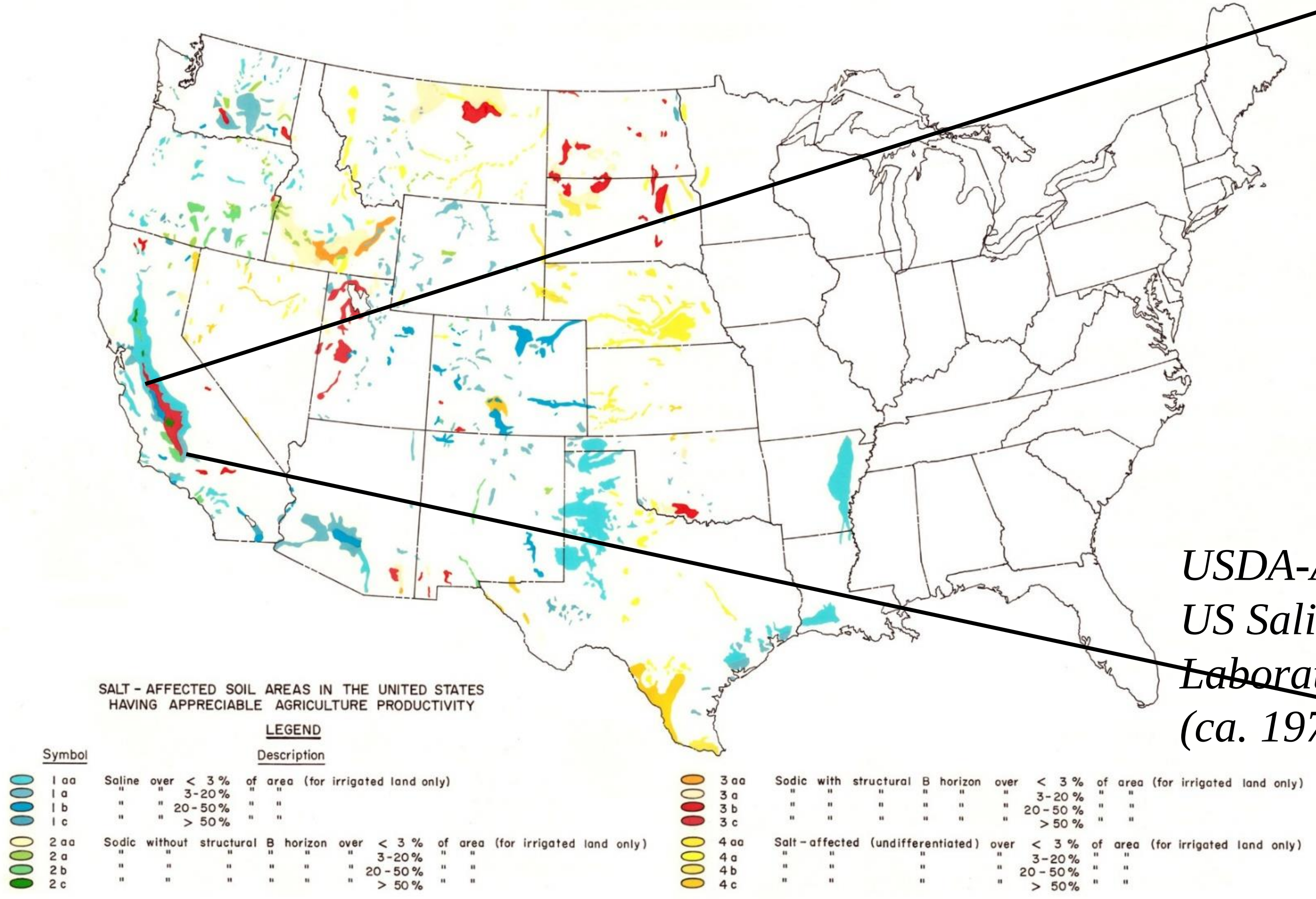
Usually measured as electrical conductivity of saturated soil extract (EC_e, dS m^{-1})

Non-saline (0-2 dS m^{-1})
Slightly saline (2-4 dS m^{-1})
Moderately saline (4-8 dS m^{-1})
Strongly saline (8-16 dS m^{-1})
Extremely saline (>16 dS m^{-1})

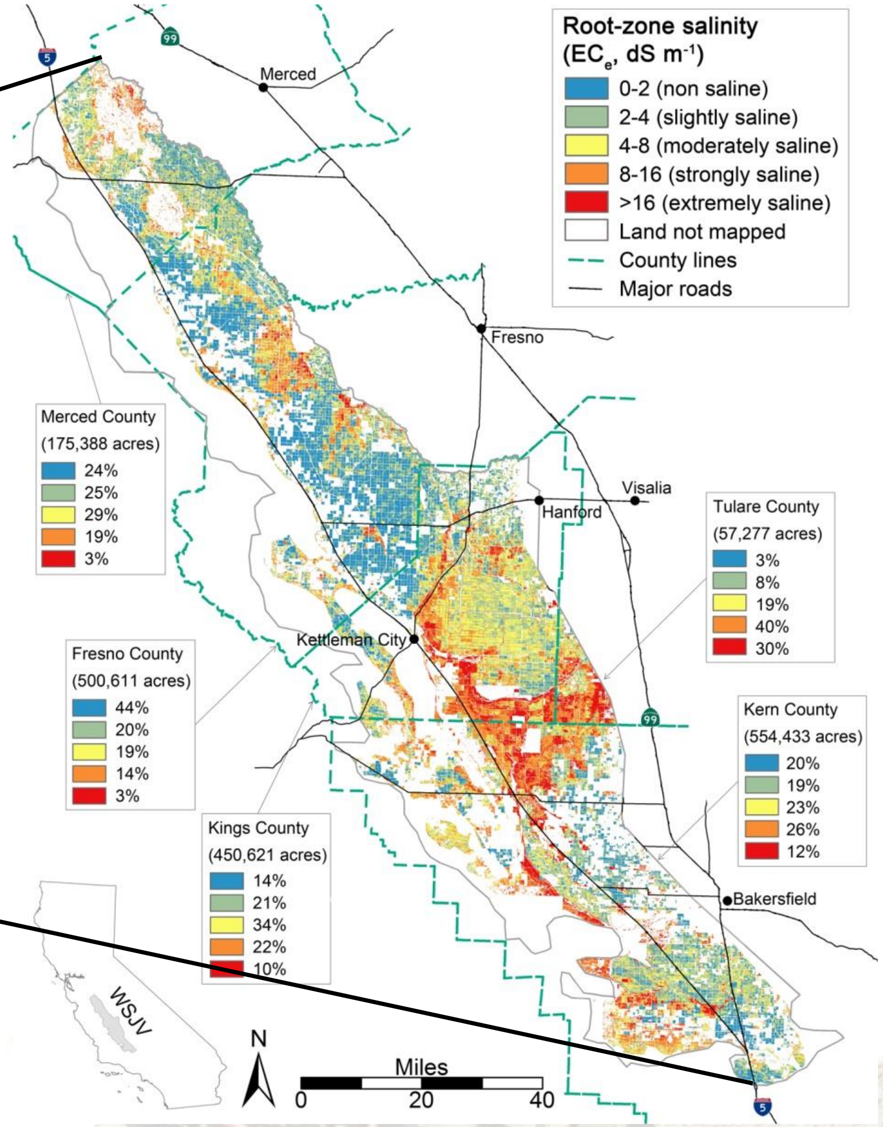
Salinity in the world (ITPS, 2015)

- 1 billion ha of land is salt-affected
- 20% of the ~300 million ha of irrigated **farmland** is estimated to be affected by salinity.
  - >50% found in four countries: China, India, Pakistan, and **United States**

Salinity in the USA



USDA-ARS US Salinity Laboratory (ca. 1970)



Scudiero et al. (2017). *California Agriculture*

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Spatial variability across different scales

Spatial variability of salinity influenced by multiple factors which result in high short-range variability at the field scale.

Often, because of different management (irrigation water quality) neighboring fields are characterized by dramatically different salinity levels.

High-resolution remote sensing is an ideal covariate to capture such short-scale changes

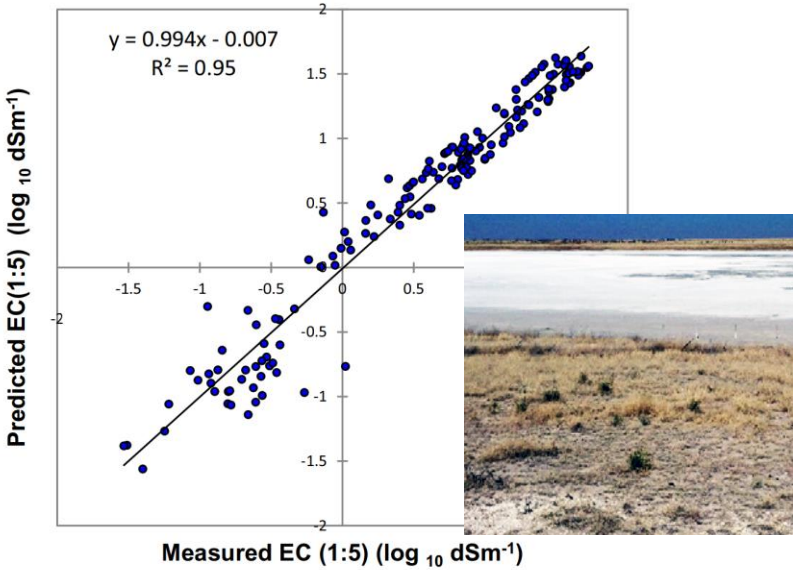
What's needed?

- Select target property (*Root-zone* soil salinity)
- Ground truth (Field protocols)
- Ground truth (Regional-scale sampling scheme)
- Remote sensing (and other covariates)
- Evaluation strategies

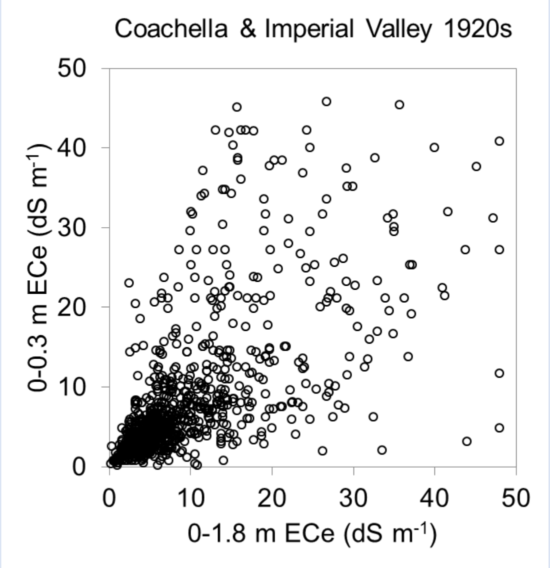
Surface Vs. root zone soil salinity

Surface Soil Salinity

GREAT PAPER → Aldabaa et al. (2015). Combination of proximal and remote sensing methods for rapid soil salinity quantification. *Geoderma*, 239, 34-46.



Mapping **root zone** soil salinity is more relevant in agricultural soils
>> surface salinity levels are not a reliable direct indicator of subsurface salinity levels

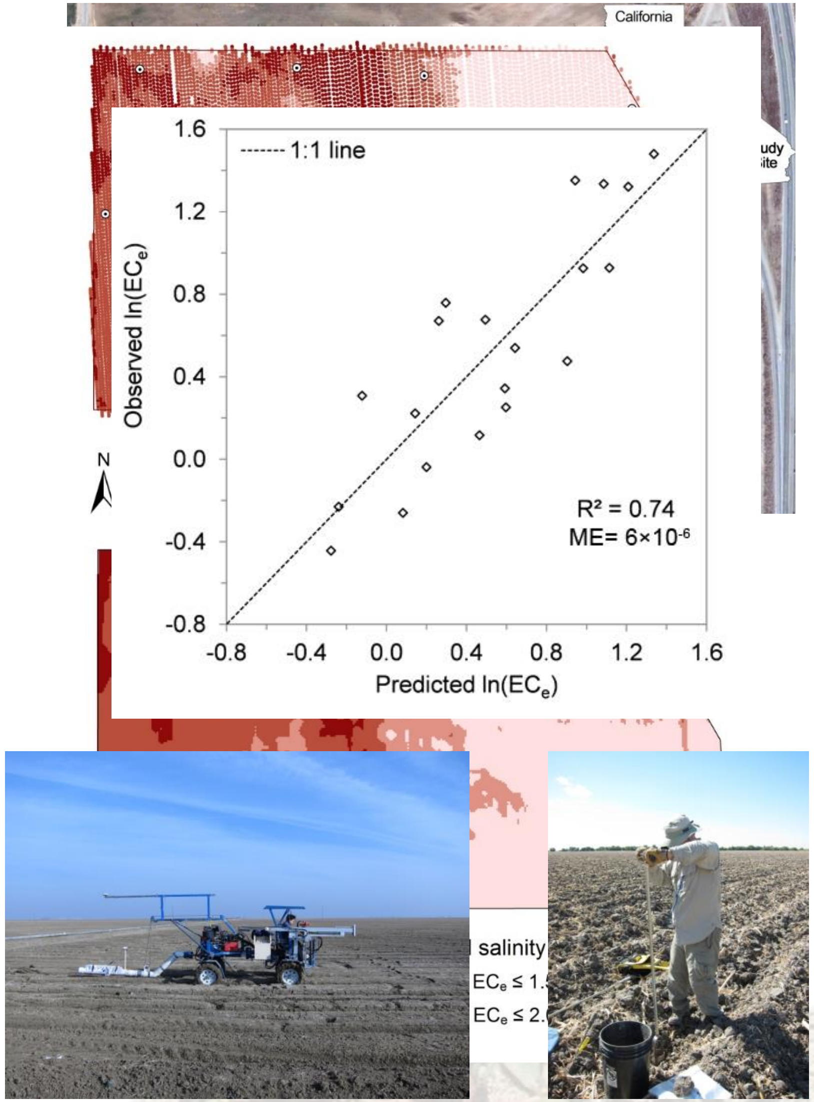


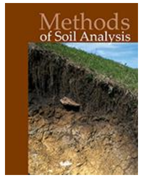
Scudiero et al. (In preparation)

Apparent Electrical Conductivity (ECa) – Directed soil sampling

Developed by Corwin and colleagues in the past 40 years

- Mapping soil salinity at a
  32.4-ha field near San Jacinto, CA
- >16,000 Apparent electrical conductivity measurements (EC_a) [sensor measurements for the 0-1.5 m soil profile]
- *“ECa-directed soil sampling”*
  Select 20 soil sampling locations
  - Salinity (EC_e) measured for the 0–1.2 m soil profile
- EC_a–salinity linear modeling
- Spatial interpolation of regression estimations
- Map salinity at the same resolution of the selected satellite product (e.g., 30x30 m pixels)

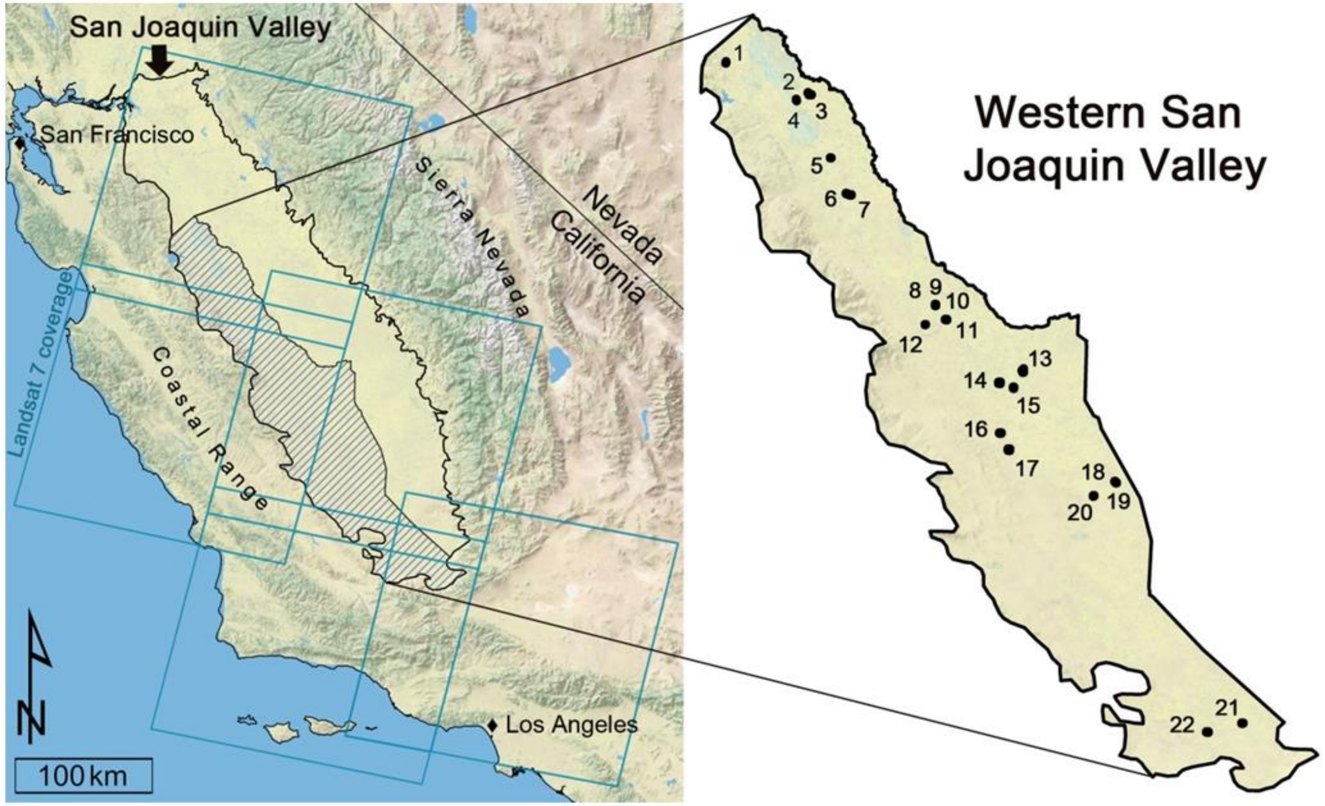




Corwin, D.L., Scudiero, E., 2016. Field-Scale Apparent Soil Electrical Conductivity, In: Logsdon, S. (Ed.), Methods of Soil Analysis. Soil Science Society of America, Madison, WI, USA. doi: 10.2136/methods-soil.2015.0038

Ground-truth measurements

- 22 fields sampled in 2013 (ca. 550 ha) in western San Joaquin Valley, CA
- **~6000 ground truth cells (30x30 m resolution).** Overall accuracy $R^2 = 0.93$



Try to get a representative sampling scheme:

- ➢ Soil type
- ➢ Irrigation management
- ➢ Crop type
- ➢ Climatic regions
- ➢ Other factors known to influence spatial variability of soil salinity

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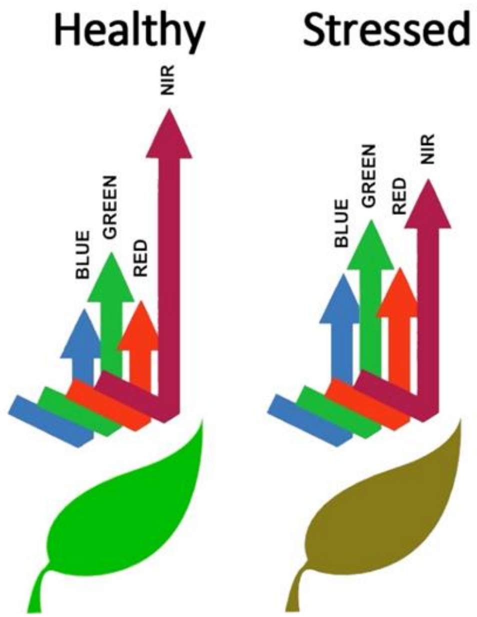
Root-zone salinity via crop canopy measurements

Surface reflectance is influenced by:

- Relative crop status
  → **stressed vs. non-stressed**
  (e.g., B,G,R → photosynthesis activity; NIR → turgor; thermal imagery can also be used)
- Crop type
- Growth stage
- Soil type (texture, SOC, iron, salt crust, …)
- A variety of vegetation indices can be used



Canopy Response Salinity Index

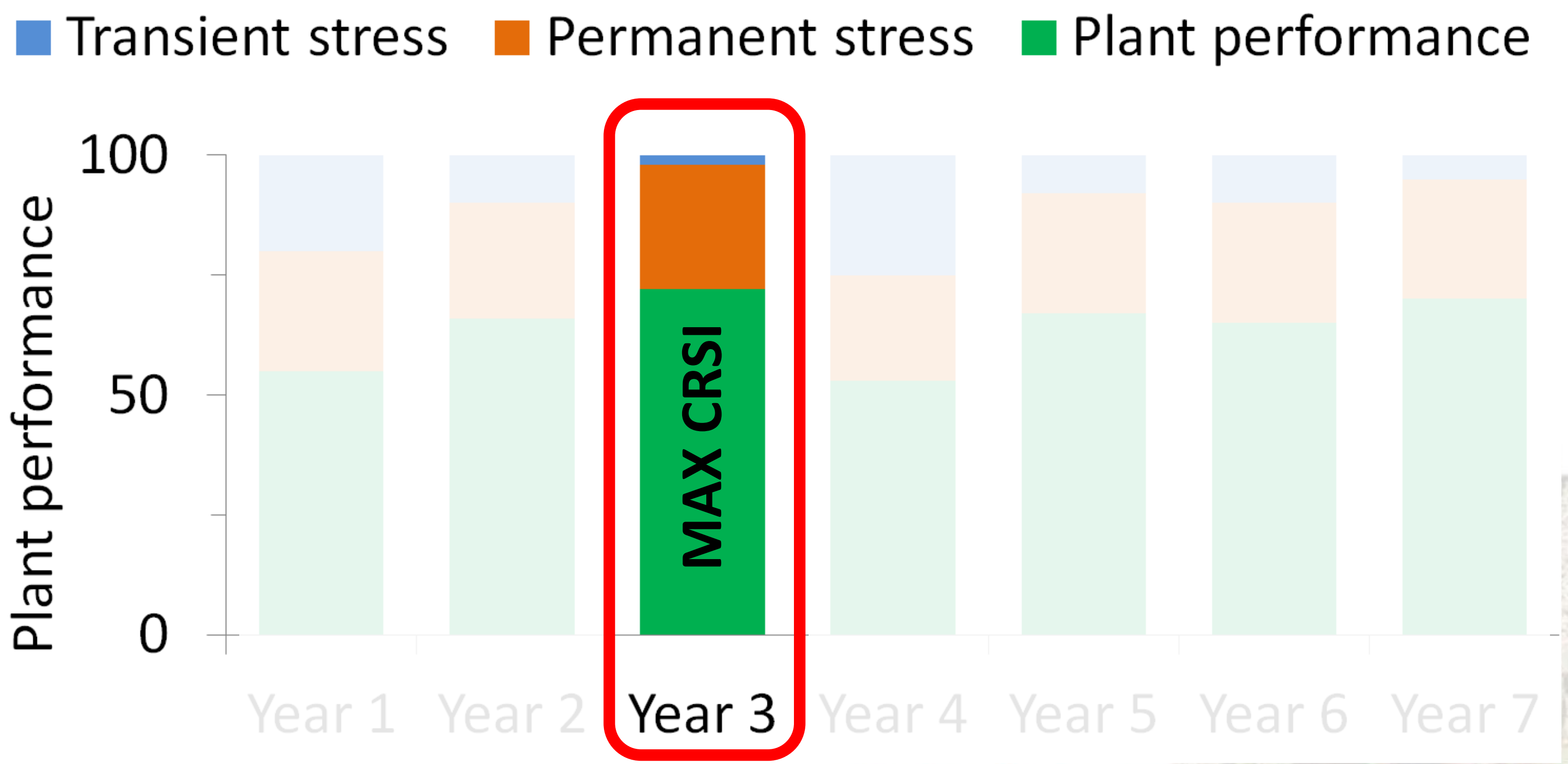
$$CRSI = \sqrt{\frac{(NIR \times R) - (G \times B)}{(NIR \times R) + (G \times B)}}$$

[a] Landsat 7 spectral bands: blue (B), green (G), red (R), near-infrared (NIR)

GROUND-TRUTH SAMPLING IS NEEDED!!

Multiyear max CRSI and soil salinity

- Under similar management, **salinity stress (permanent stress)** is fairly constant in the root-zone through a limited amount of time
- Plant performance (measured with CRSI) is maximum when transient stress sources are at minimum→ **salinity effect on plant growth is highlighted**



Soil salinity Vs. multiyear max CRSI (and additional covatiates)

ECe ~ Multi-year Max CRSI

+ weather info for the selected year

+ crop type/ irrigation management

+ soil type / particle size information

Before publishing your map:

- Spatially-independent cross-validation (e.g., leave-one-field-out)
- Independent data
- Ask a farmer!

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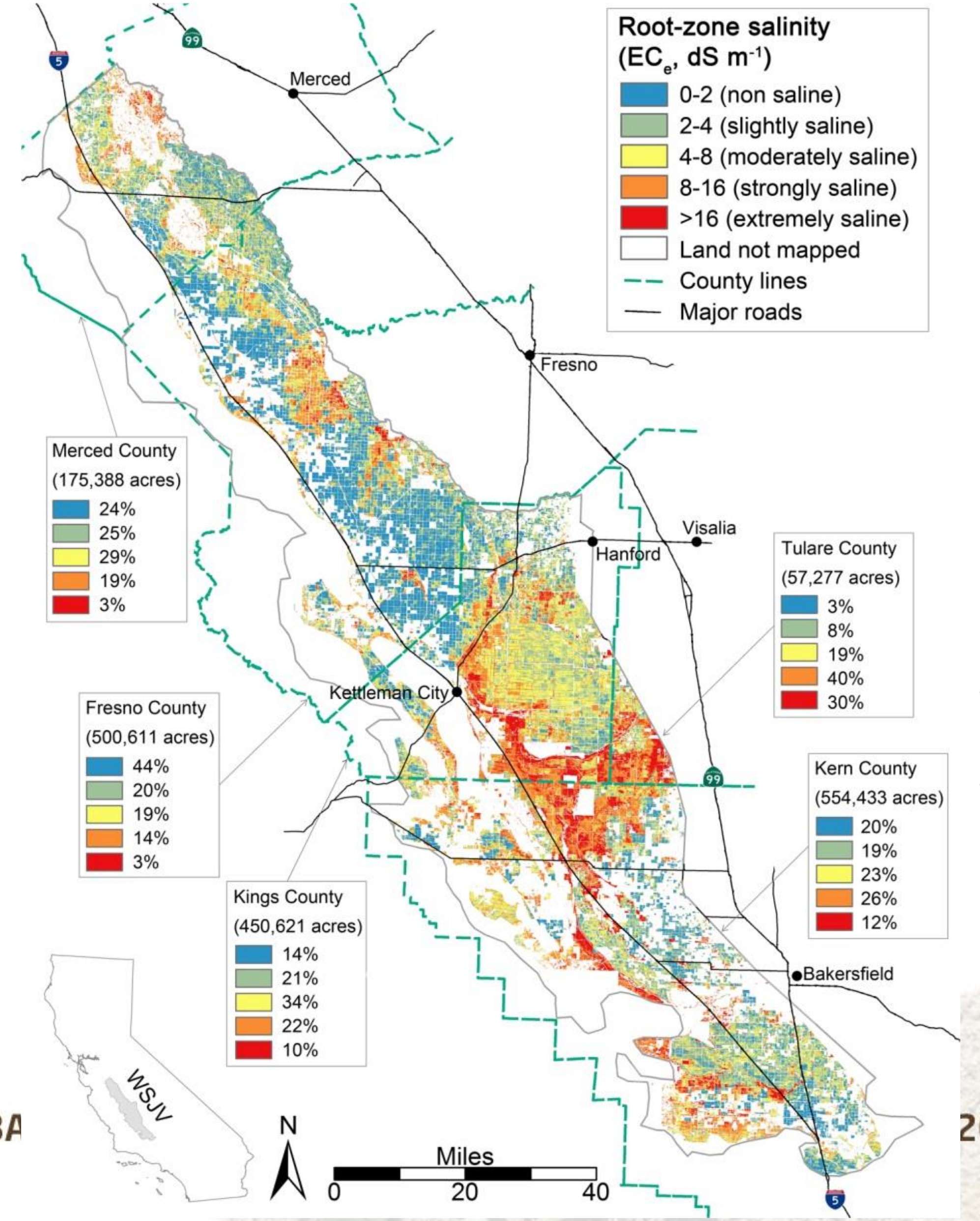

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Limitations and research gaps

- Uncertainty of predictions at low salinity values
- Halophyte reflectance properties are problematic
- Published work does not focus on tree crops
  (complex spatiotemporal dynamics of salinity in the root zone especially with micro-irrigation)
- Selection of satellite products
  (need for high spatial and temporal resolution for VIS+NIR+Thermal)
- Improve root-zone depth for different crops
  (x soil x management)

- Current work: spatiotemporal prediction model
  (with ground-truth data spanning over 30 years)

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