Carbon Sequestration & GHG Mitigation in Carinata Cropping Systems

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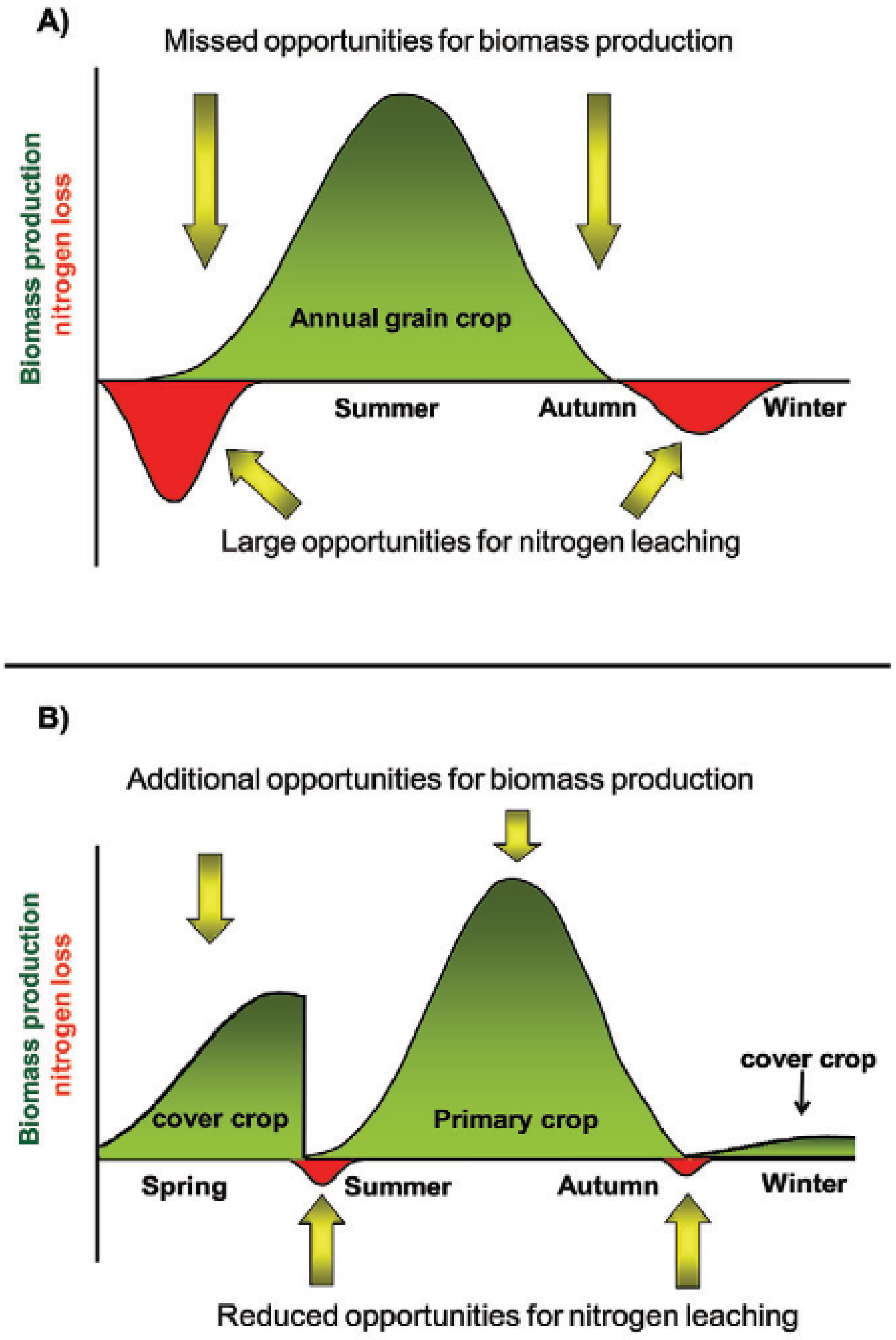
Sustainable bioenergy feedstocks

- Many bioenergy critiques focus on land use
- Win–win solutions improve both ***productivity*** & ***ecosystem services*** vs. current land management
- "Sustainable intensification"
  - Conventional intensification
  - Spatial intensification
  - Temporal intensification

Heggenstaller *et al.* (2008). Productivity and Nutrient Dynamics in Bioenergy Double-Cropping Systems. *Ag. Journal*, *100*(6), 1740–1748.

Heaton *et al.* (2013). Managing a second-generation crop portfolio through sustainable intensification. *Biofpr*, 7(6), 702–714.



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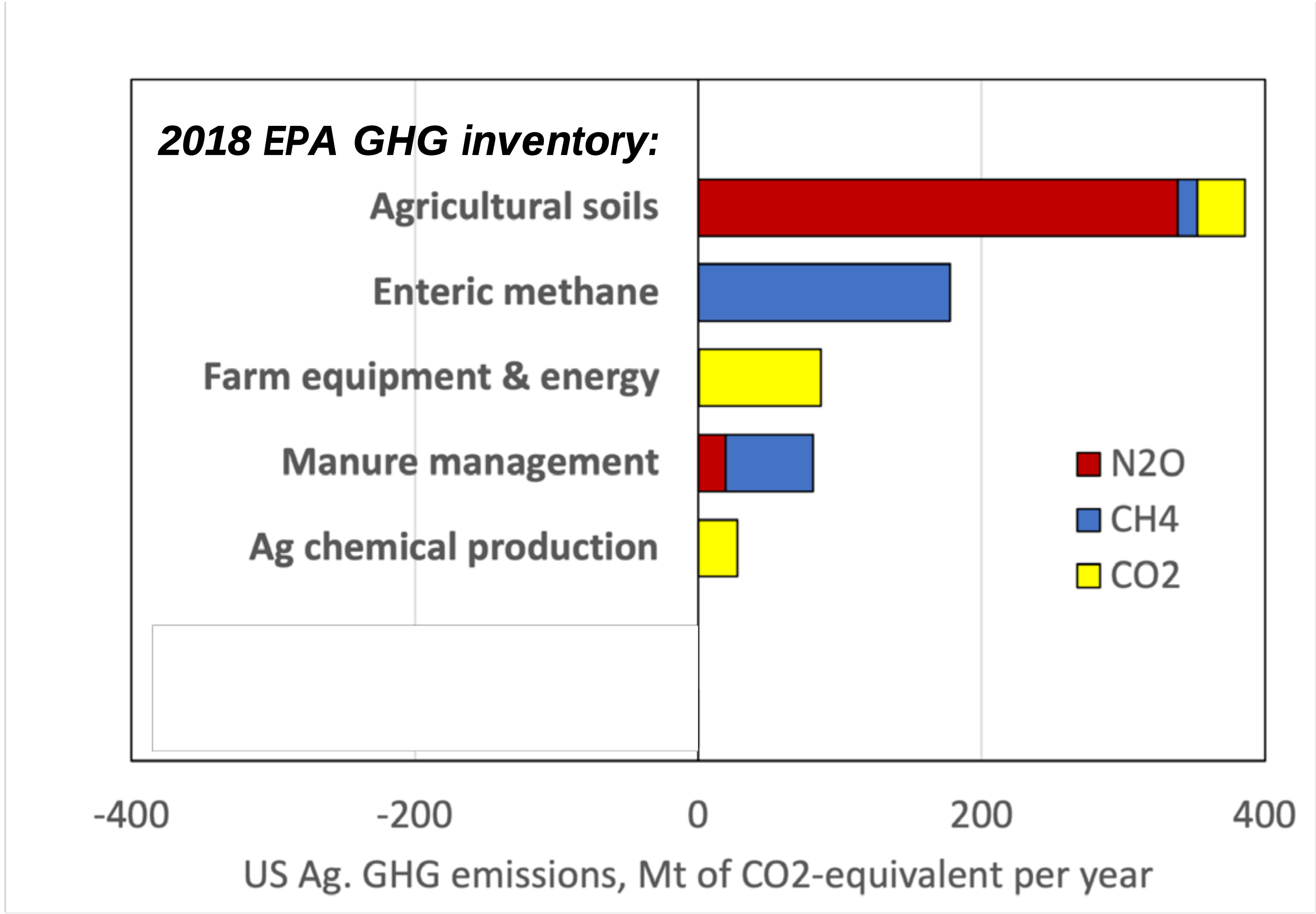
Soils dominate agricultural GHG balance

- Soil emissions of nitrous oxide (N_2O) are largest US ag GHG source
  - Bigger than fertilizer production, on-farm energy use, enteric methane, etc.
- Soils also have large potential to sequester carbon in organic matter

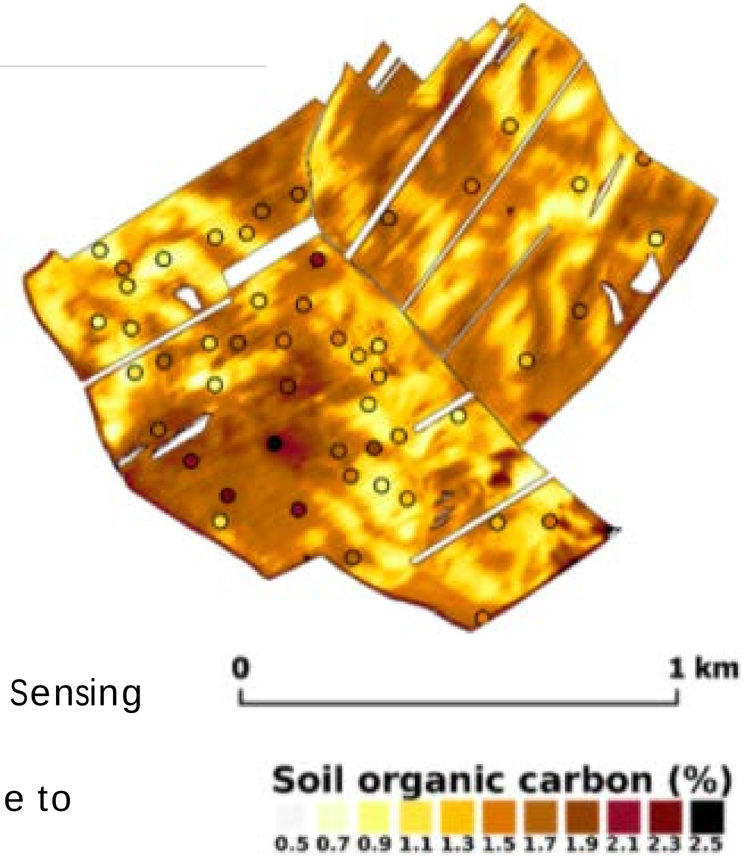


US EPA. (2020). *Inventory of U.S. greenhouse gas emissions and sinks: 1990-2018* (EPA 430-R-20-002). US Environmental Protection Agency.

National Academies of Sciences, Engineering, and Medicine. (2019). *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* (p. 25259). National Academies Press.

Soil Organic Carbon (SOC)

- Reflects balance between C inputs & losses via respiration
  - Cover-cropping increases root & shoot inputs, but may require additional tillage
- Measurement challenges:
  - Spatial heterogeneity
  - Detecting small change in large SOC pool
- Expectations:
  - Moderate sequestration (~0.6 Mg C ha^{-1} y^{-1}), esp. on fine-texture soils in temperate climates

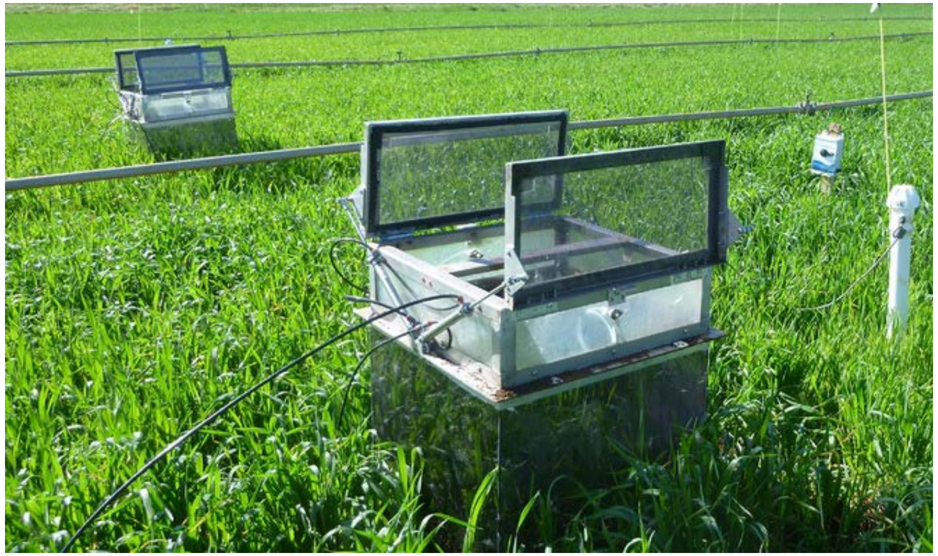


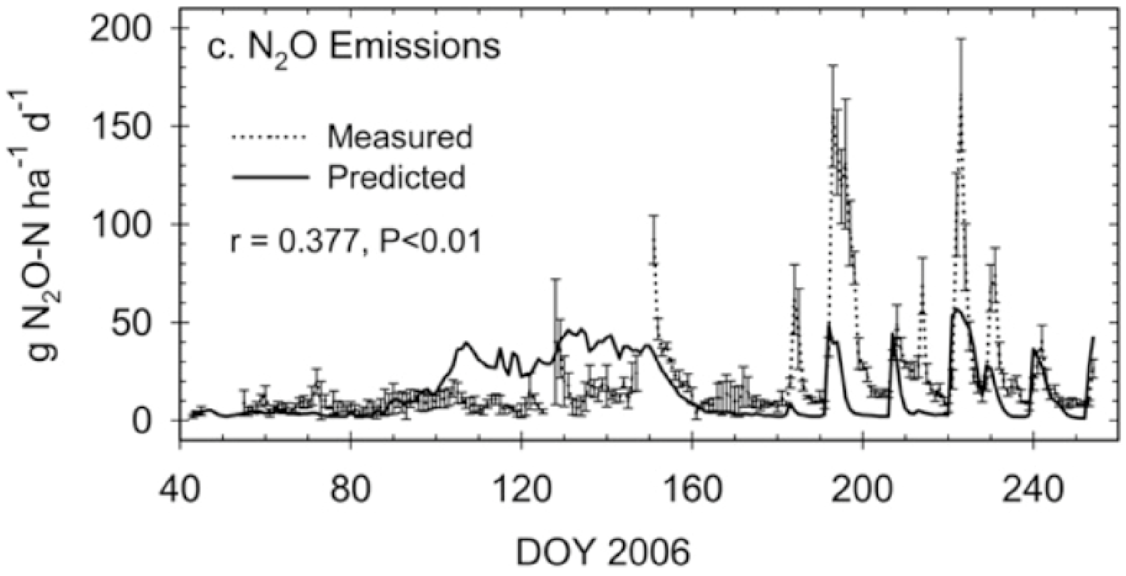
Žížala *et al.* (2019). Soil Organic Carbon Mapping Using Multispectral Remote Sensing Data. *Remote Sensing*, *11*(24), 2947.

Jian *et al.* (2020). A meta-analysis of global cropland soil carbon changes due to cover cropping. *Soil Biology and Biochemistry*, *143*, 107735.

Soil nitrous oxide (N_2O)

- During nitrification ($NH_4^+ \rightarrow NO_3^-$) & denitrification ($NO_3^- \rightarrow N_2$), fraction of N lost as N_2O
  - 300x the warming impact of CO_2
- Measurement challenges:
  - Extreme spatial & temporal heterogeneity
- Expectations:
  - 1% of all added synthetic or organic N lost as N_2O
    - 100 kg N ha^{-1} y^{-1} ➔ 0.13 Mg C_e ha^{-1} y^{-1}

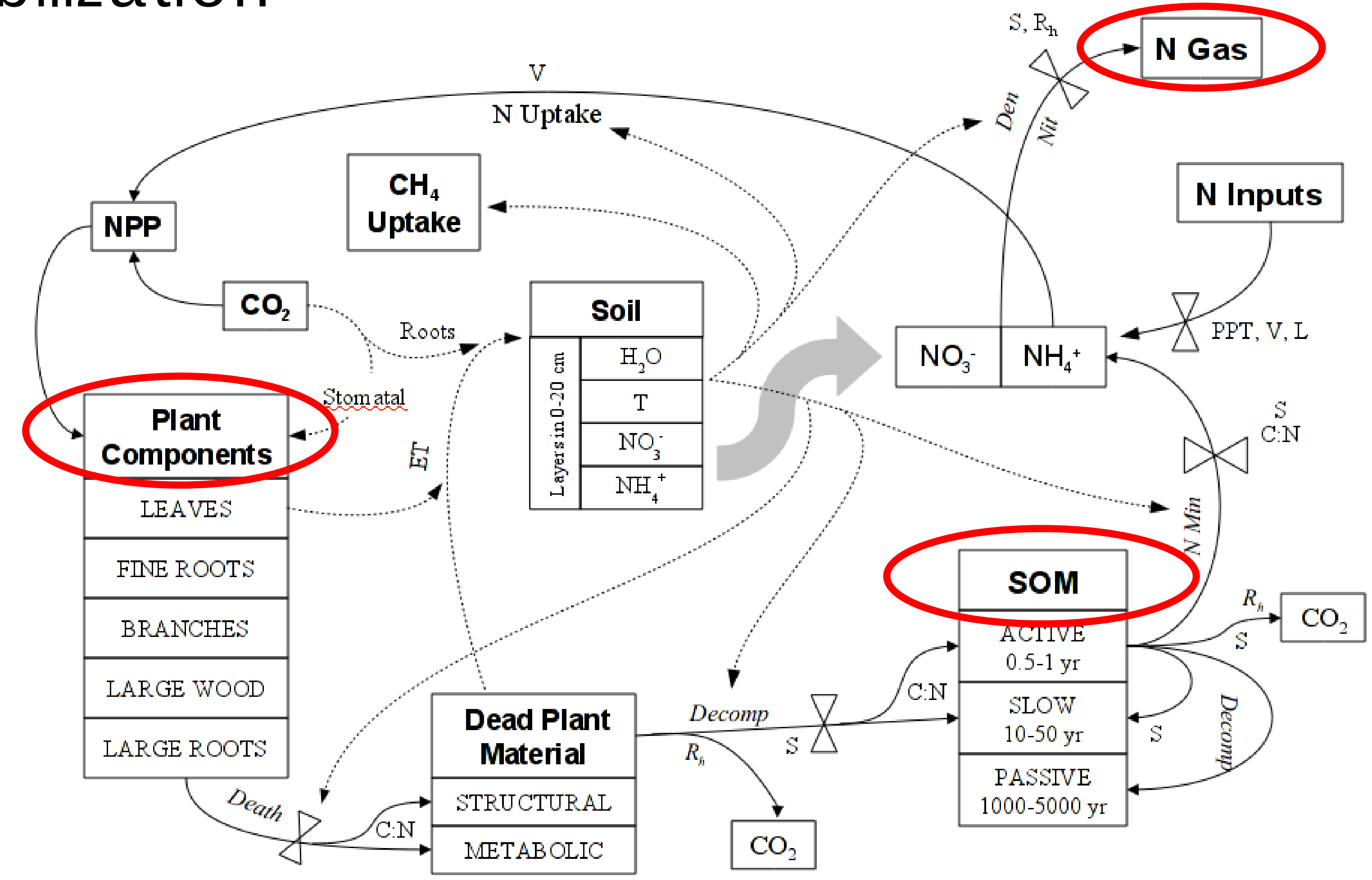




Jarecki *et al.* (2008). Comparison of DAYCENT-Simulated and Measured Nitrous Oxide Emissions from a Corn Field. *J. Env. Quality*, *37*(5), 1685.

DayCent process-based ecosystem model

- Simulates C&N cycling during plant growth, death, decay, soil organic matter stabilization
- Sensitive to:
  - Latitude
  - Climate
  - Soil texture, depth
  - Management
  - Land use history
- No topography or damage from frost or water-logging



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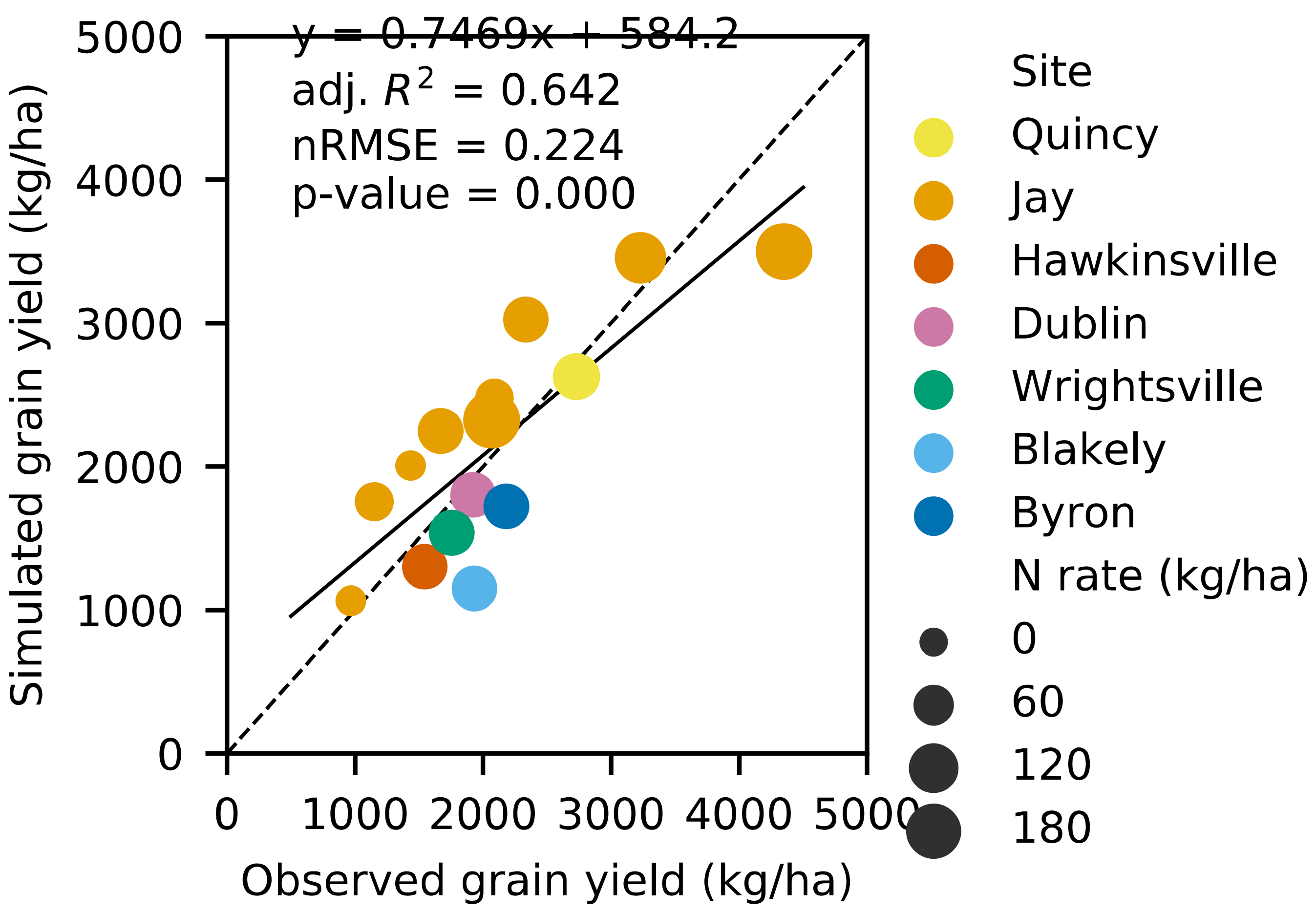
Field data, calibration & validation

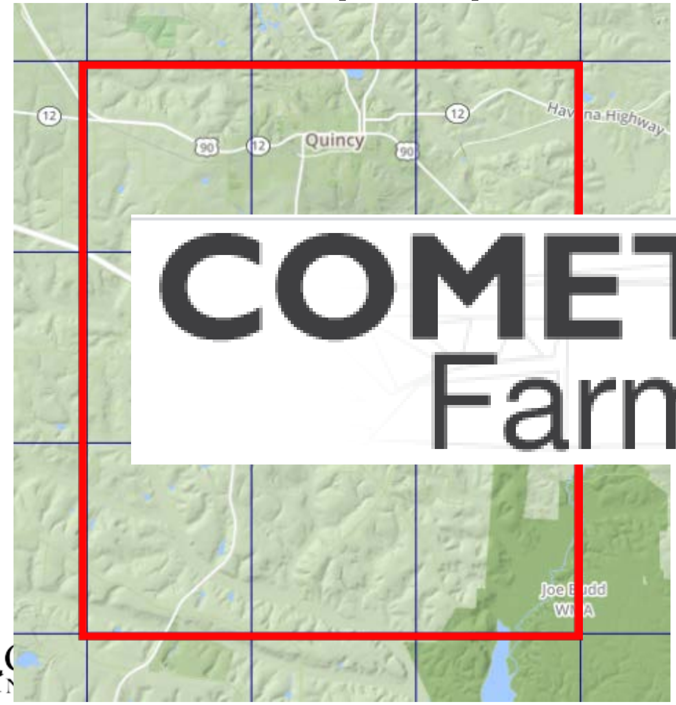
Site (season)	Data type(s)	Use
Quincy FL (2015/16)	-Plot-scale yield response to N fertilizer rates -Tissue C:N ratios -Root:shoot ratios	Calibration
Quincy FL (2017/18)	-Plot-scale grain & biomass yield	Validation
Jay FL (2017/18, 2018/19)	-Plot-scale yield response to N fertilizer rates	Validation
Five field-scale sites in GA (2015/16)	-Field-scale average grain yield	Validation



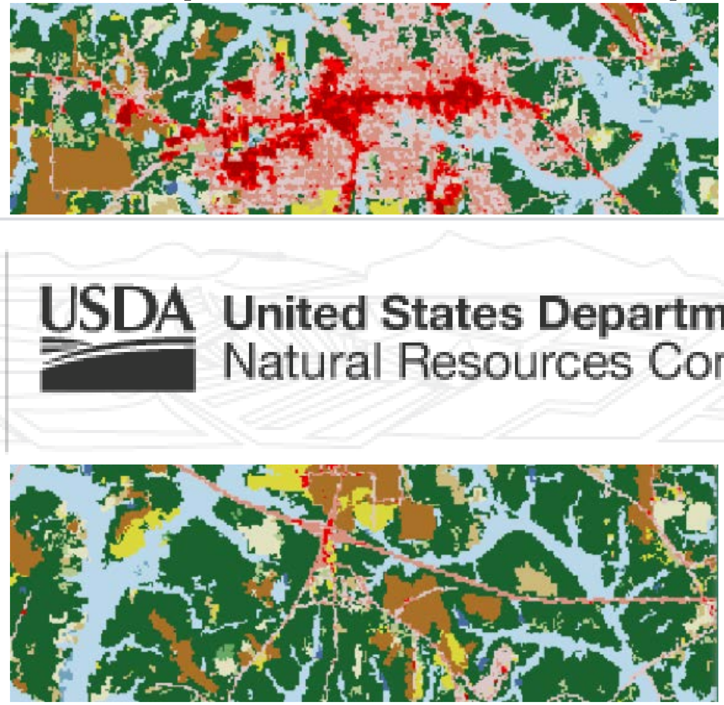
Model scenarios & data inputs

- All annual cropland in region modeled as *cotton–cotton–peanut* ➔ *cotton–**carinata**–cotton–peanut*
  - **Base case**: 2 disk passes for field prep, mid-Nov. planting, 89 kg N ha^{-1} (split), late May harvest
  - **Low-C mgmt. cases**: no-till, ~~or poultry litter as N source~~

PRISM (12 km)



NLCD (240 m; NASS-corrected)



SSURGO (vector)

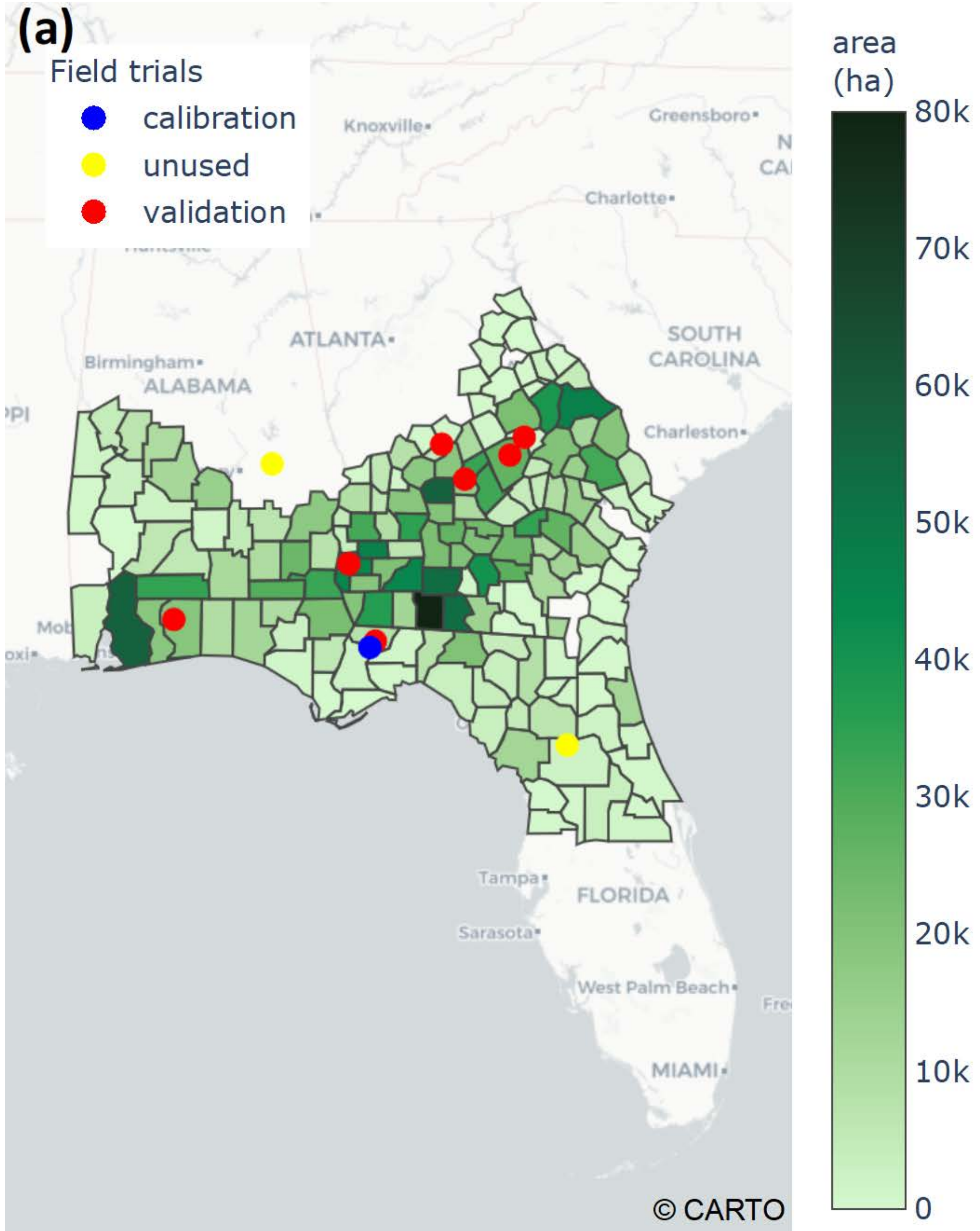
COMET Farm

USDA United States Department of Agriculture
Natural Resources Conservation Service

Colorado State University

Assessment area

- 2.3 Mha of annual cropland in frost-free zone (as per NLCD, Alam & Dwivedi 2019)
- Gradients in temp, precip
- Strong diversity of soils– sandy in FL, moderate in AL & GA



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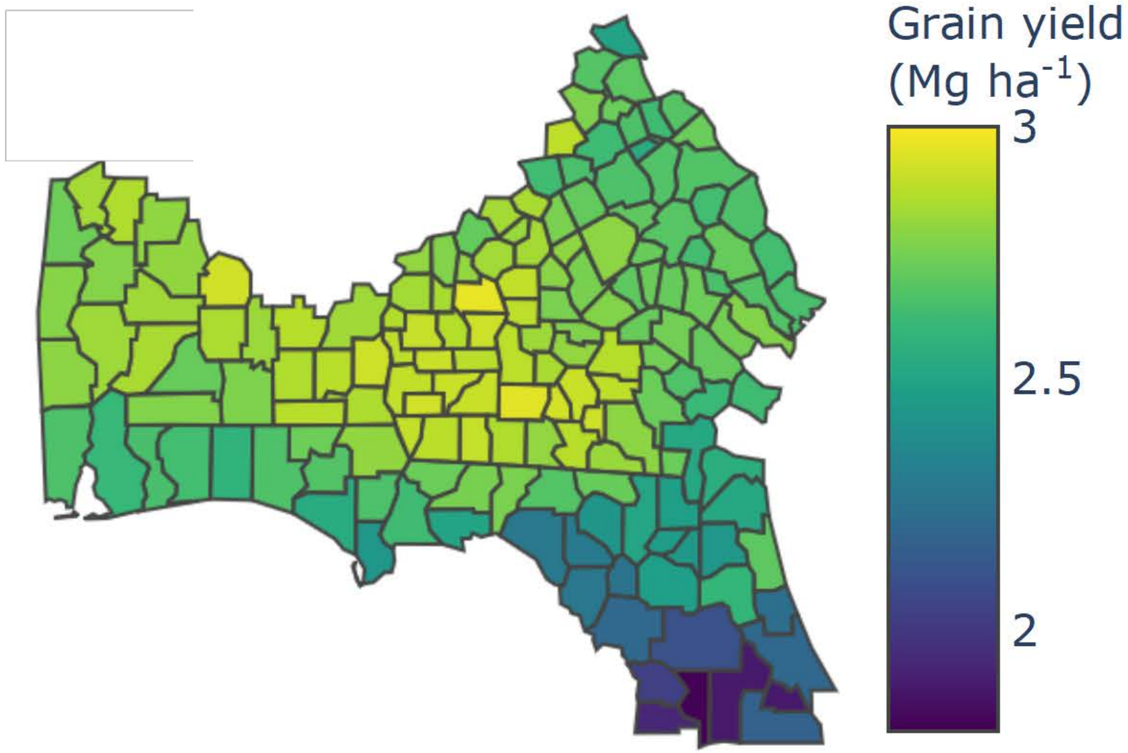
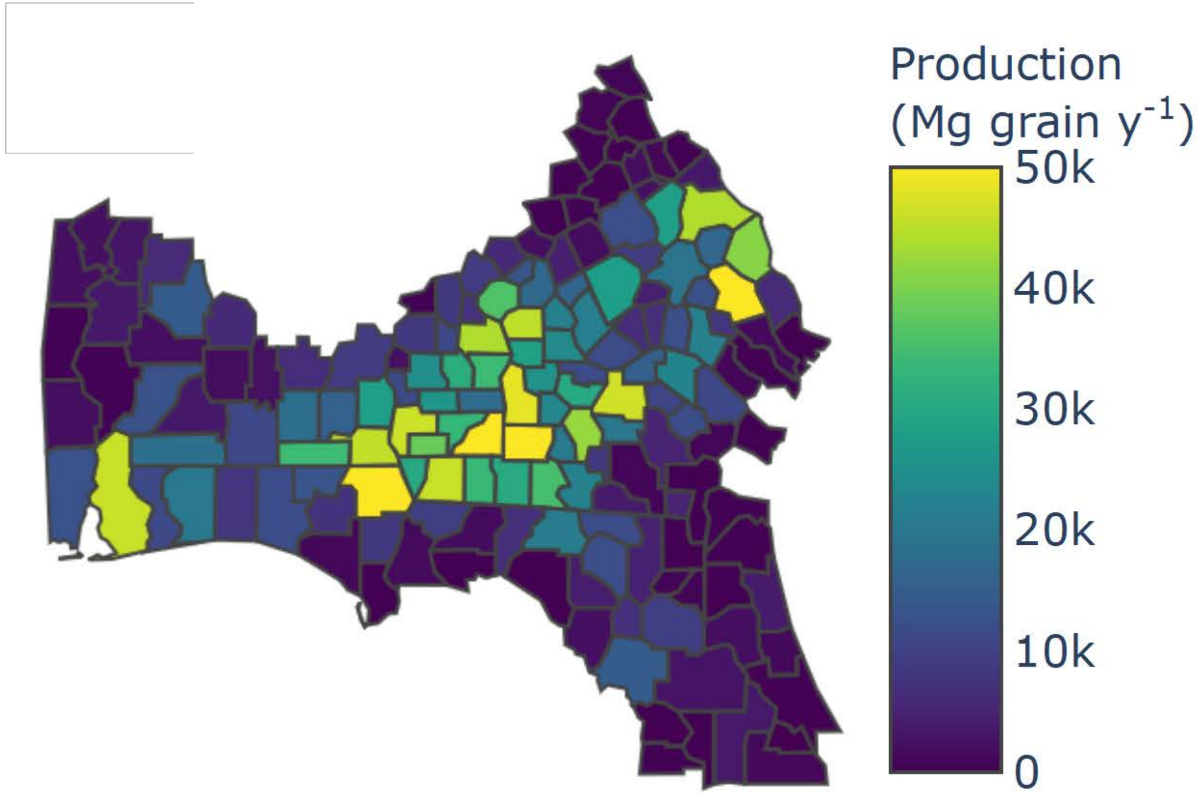
Regional carinata production

- Fairly sensitive to N rate assumption





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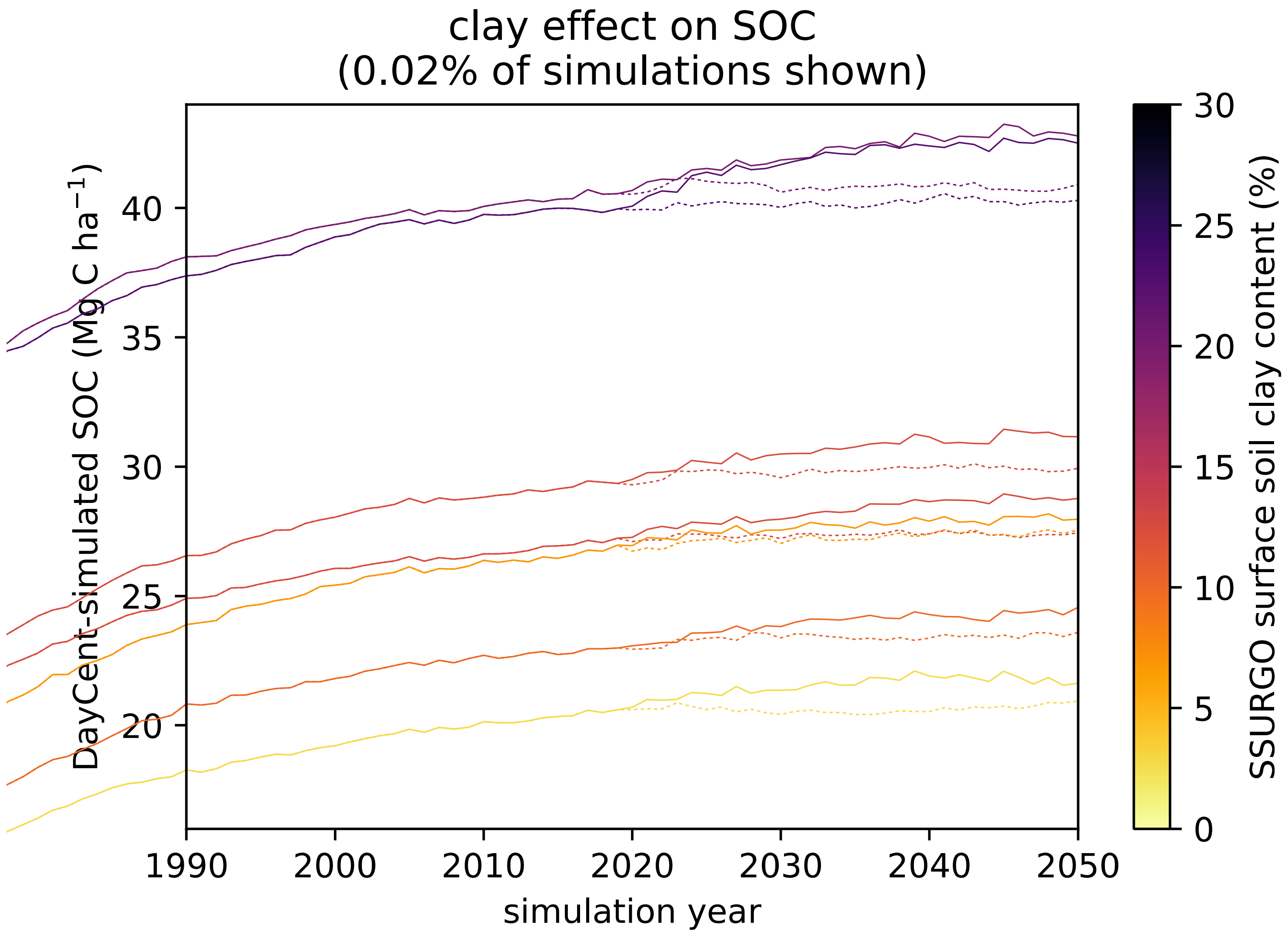
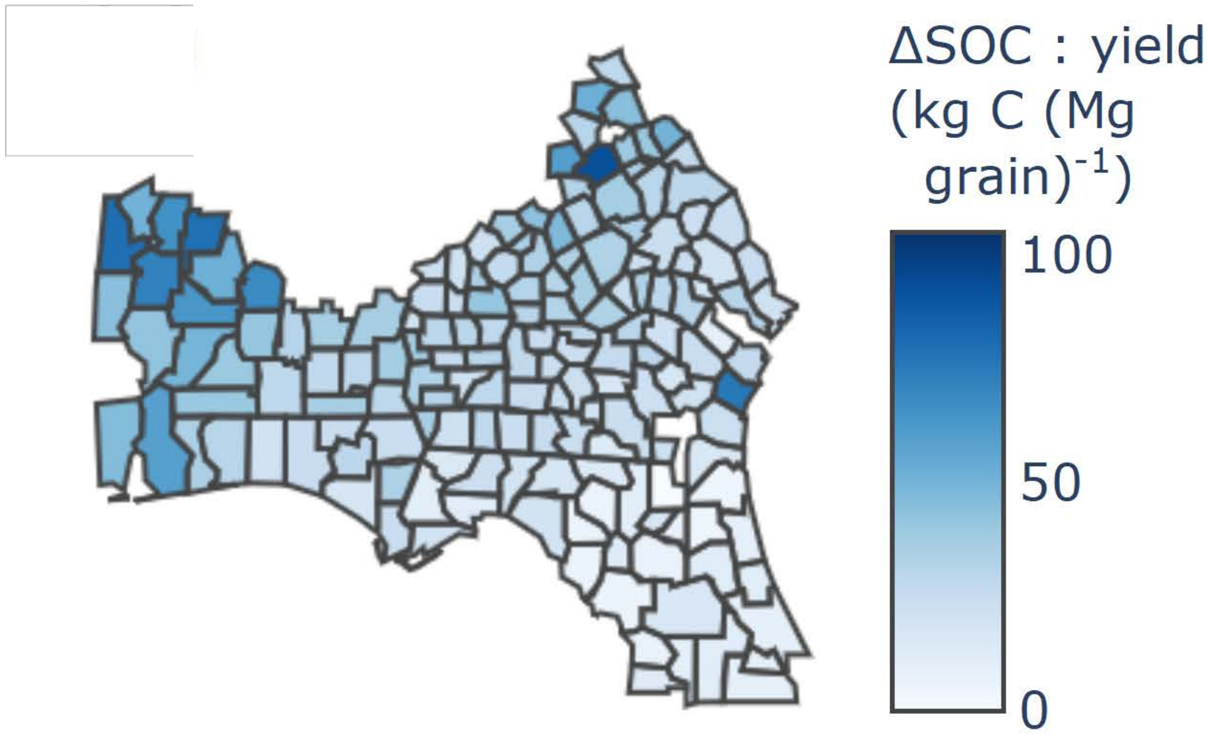
Select SOC results

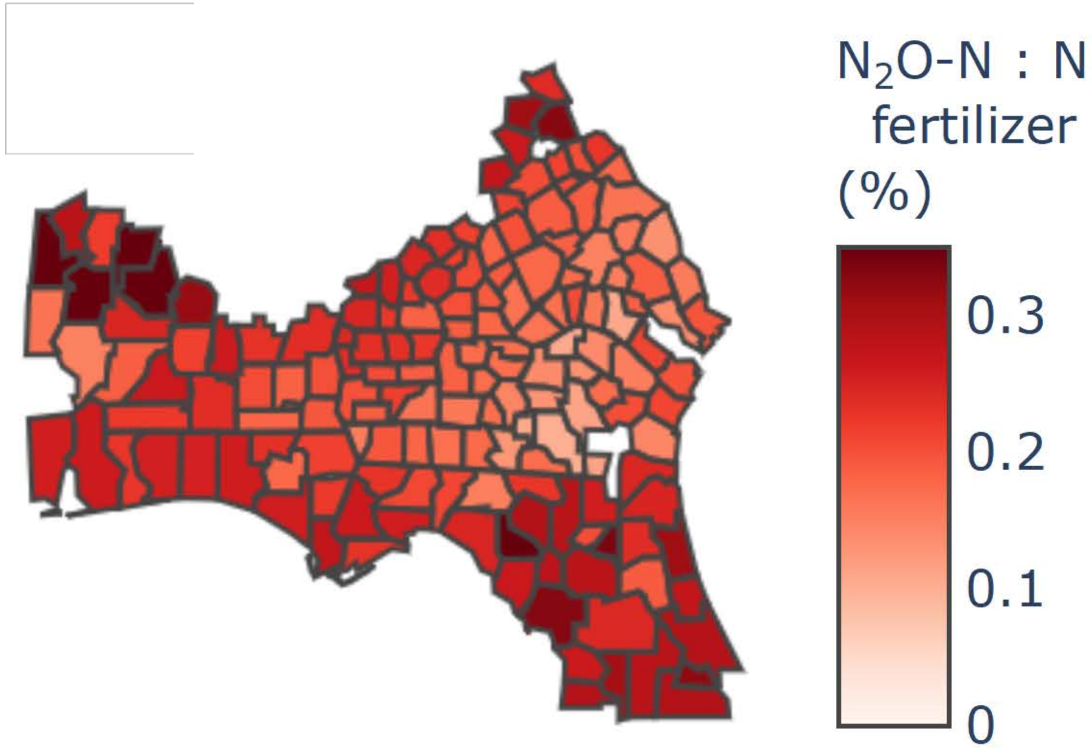
- Diff between business-as-usual & carinata cases
- High-clay soils have higher total SOC, and greater SOC gain from carinata



Regional soil GHG results

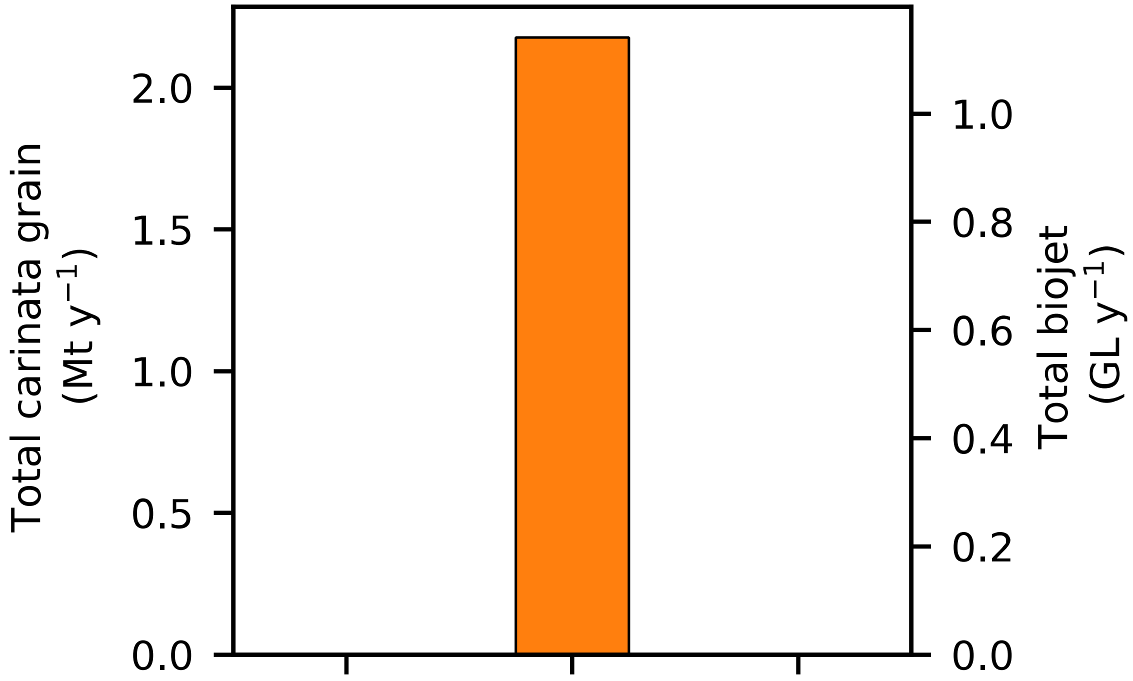
- Fairly sensitive to N rate assumption

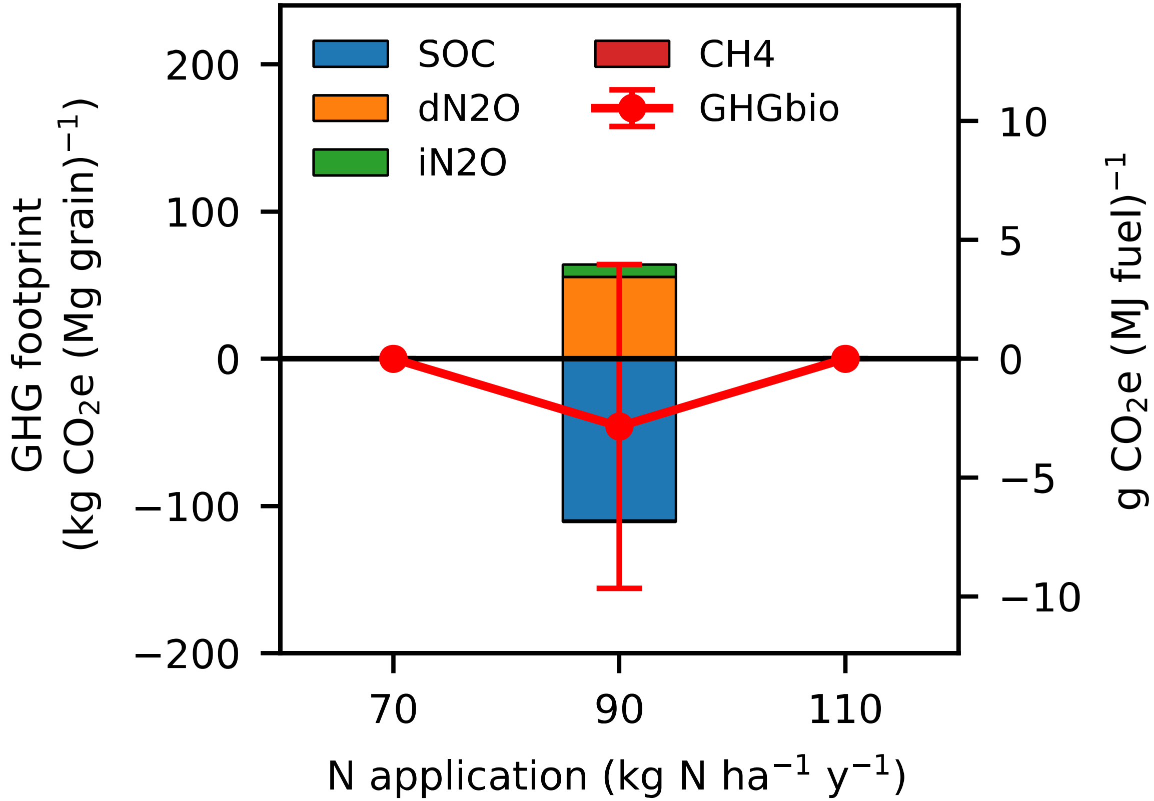




Regional scenario results

- Annual production of ~1 billion liters of SAF
- Modest SOC sequestration > new N_2O emissions
  - Makes soils a net-negative GHG sink



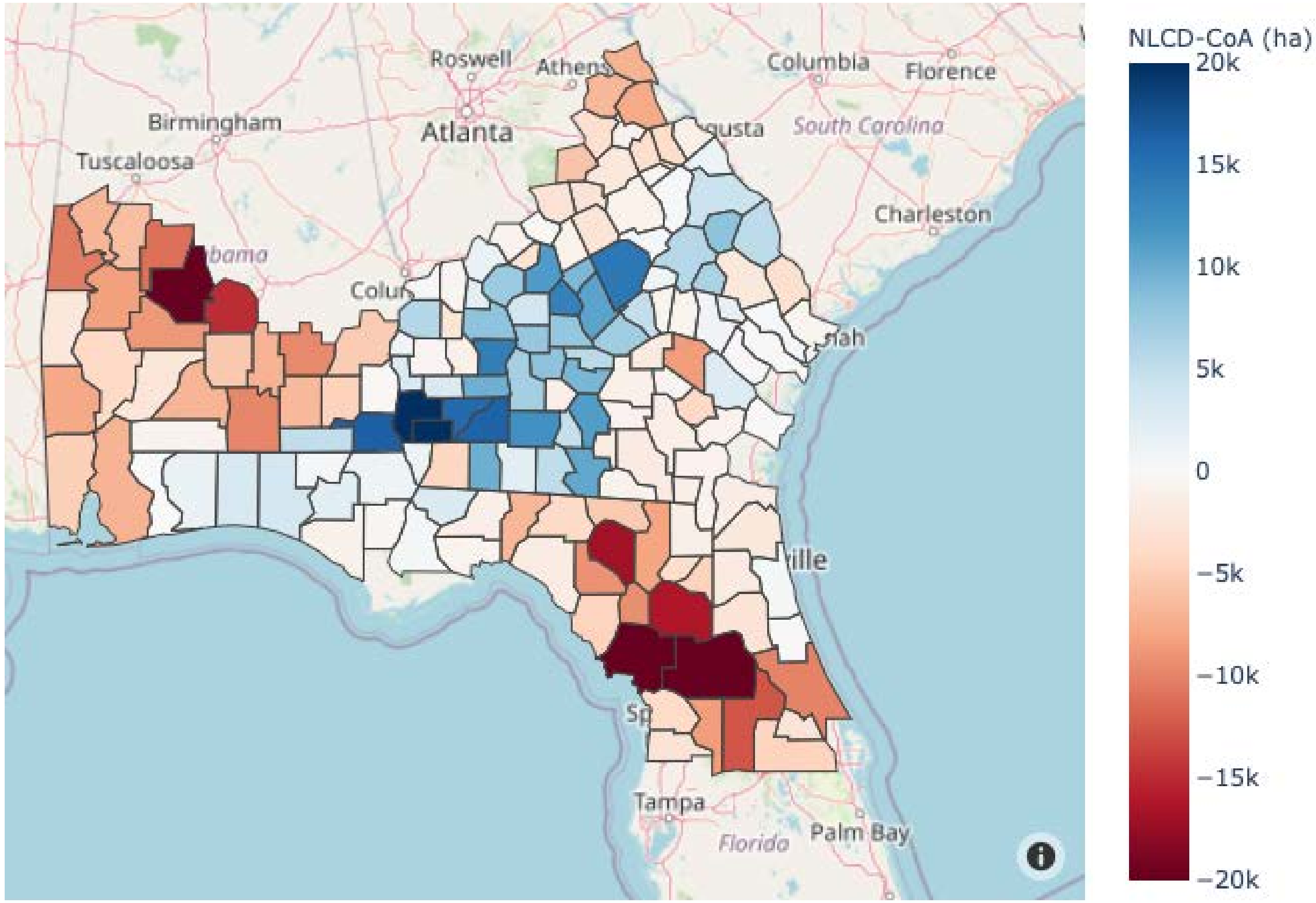


Conclusions

- DayCent can typically reproduce carinata seed yields (unless planted late)
- Production of up to 1 billion gallons of SAF annually from carinata cover crops in this region
  - Yield rates >2.5 Mg seed ha^{-1}, except sandy FL soils
- Modeling suggests a modest associated soil C sink
  - SOC increase > new N_2O emissions
  - Net effect equivalent to –3 g CO_2e MJ^{-1} fuel

Ongoing work

- Aligning NLCD w/ NASS
- Finishing poultry litter case simulations
- Preparing associated collaborative publication
  - Targeting a special SAF issue in *Frontiers in Energy Research*
- Full LCA integration w/ Dwivedi group



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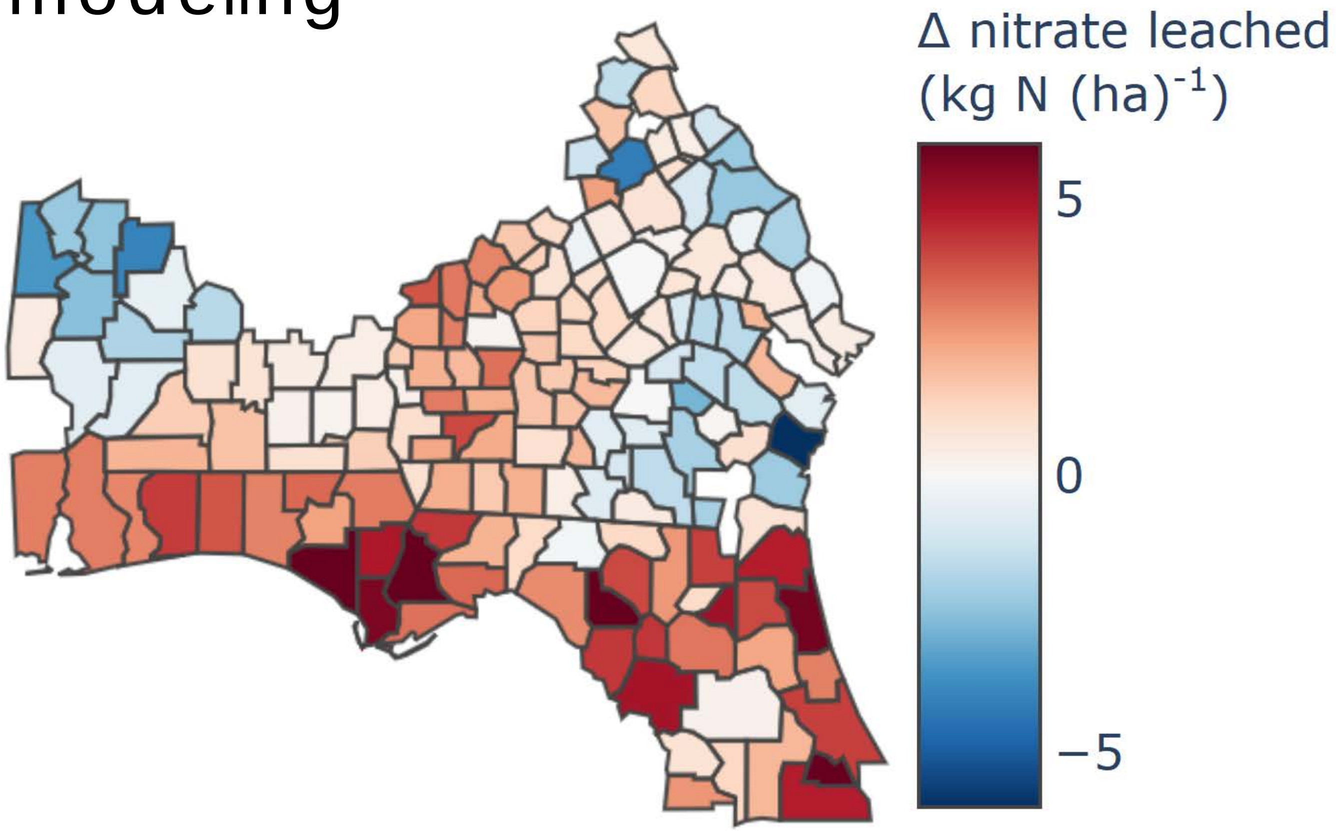
Nitrate leaching results

- Generally a small increase, except in areas of finer-textured soils and less annual precipitation
- Have not yet been validated or harmonized against ongoing SPARC SWAT modeling



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