OAK RIDGE National Laboratory

Assessing the Role of Soils in Carbon-Negative Bioenergy Landscapes

John Field

Environmental Sciences Division, ORNL

BETO Workshop on Bioenergy's Role in Soil Carbon Storage

March 29, 2022

ORNL is managed by UT-Battelle LLC for the US Department of Energy

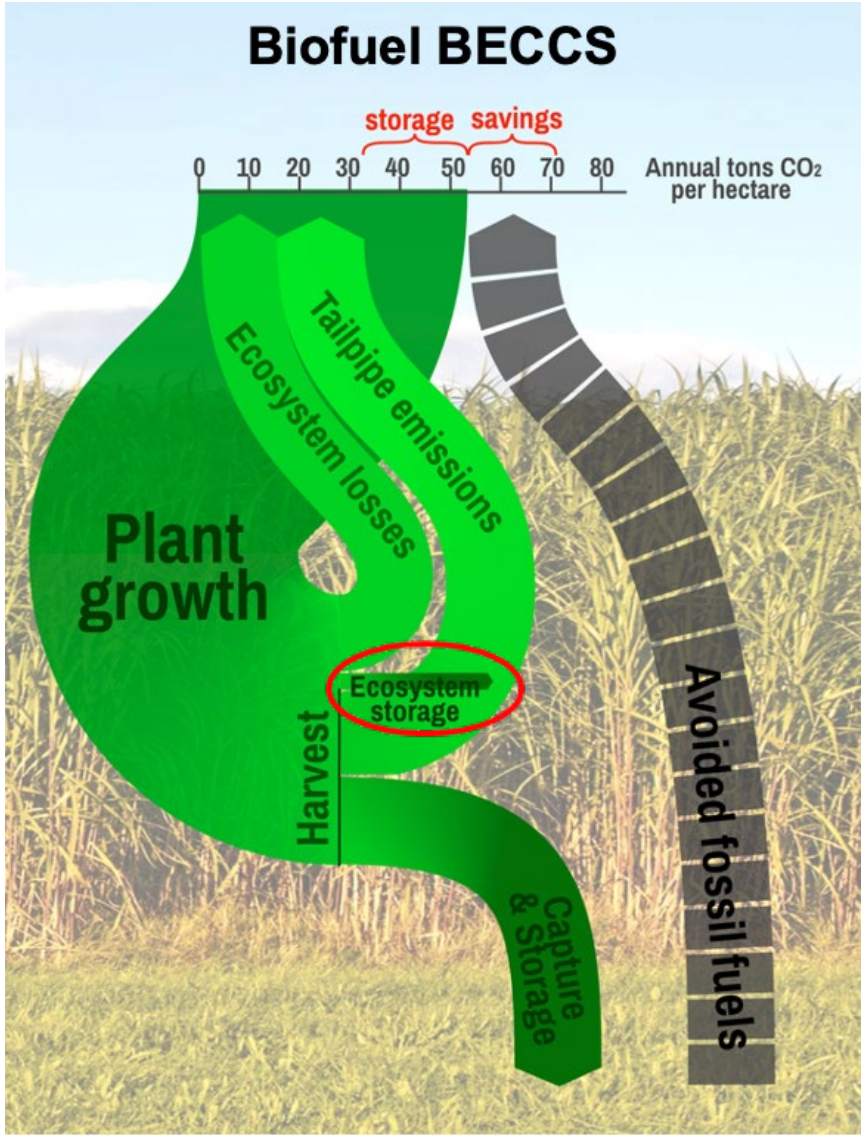
U.S. DEPARTMENT OF ENERGY

SOC and biofuels: liability or opportunity?

Feedstock	Study	Method	SOC change Mg C ha^{-1} y^{-1}	Footprint g CO2e MJ^{-1}
Corn grain	Lark *et al.* 2022	Semi-empirical model	–1.6[a]	+29.7
Corn stover	Liska *et al.* 2014	Semi-empirical model	–0.66	+70
Grasses on pasture land	Field *et al.* 2020	Process-based model	+0.9	–12.7
Grasses on abandoned cropland	Yang & Tilman 2020	Field trial observation	+1.1[b]	–134

[a] Domestic land use change total (primarily SOC)

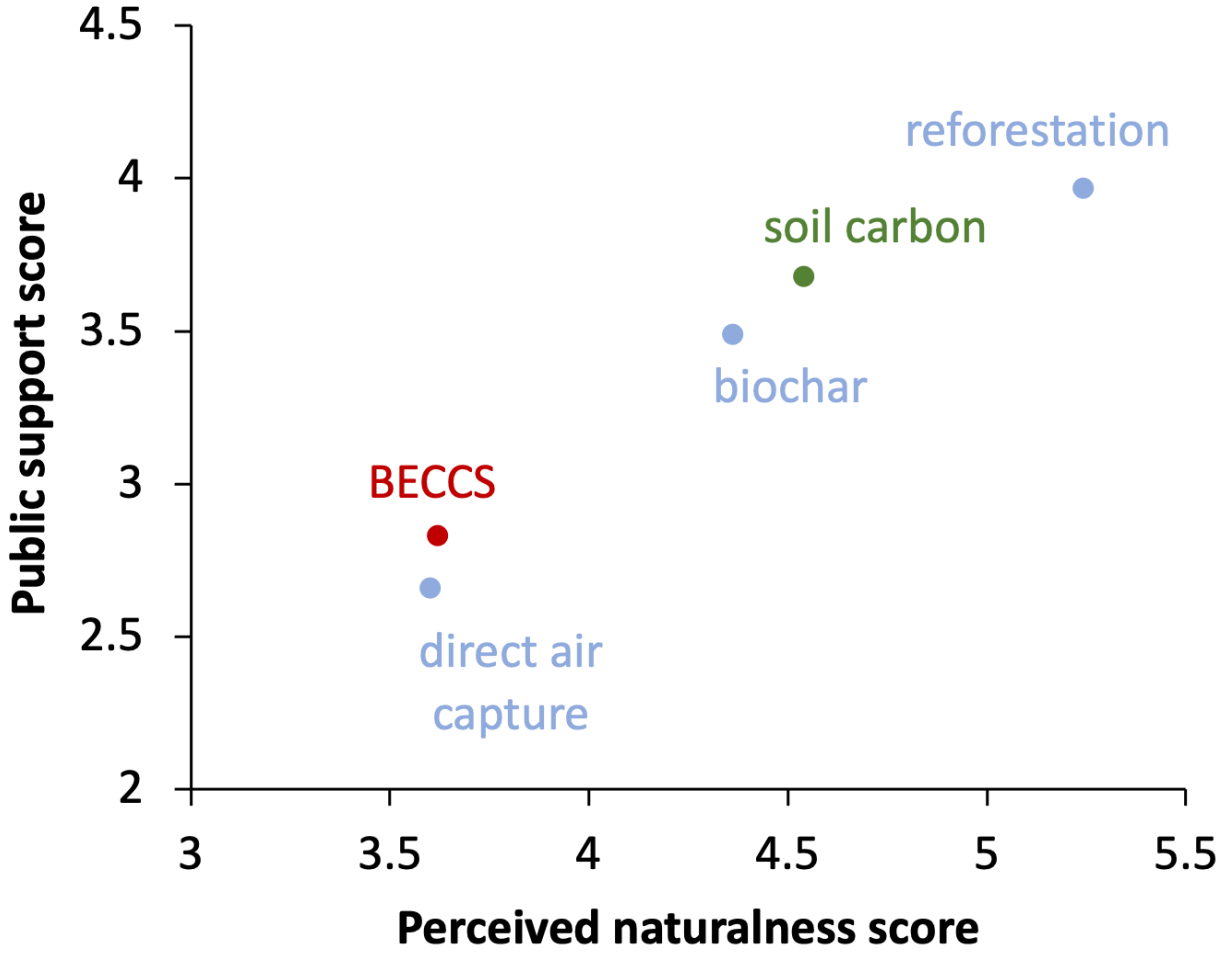
[b] SOC plus root biomass C



Field *et al.* (2020) *PNAS*

SOC punches above its CO_2-equivalent weight

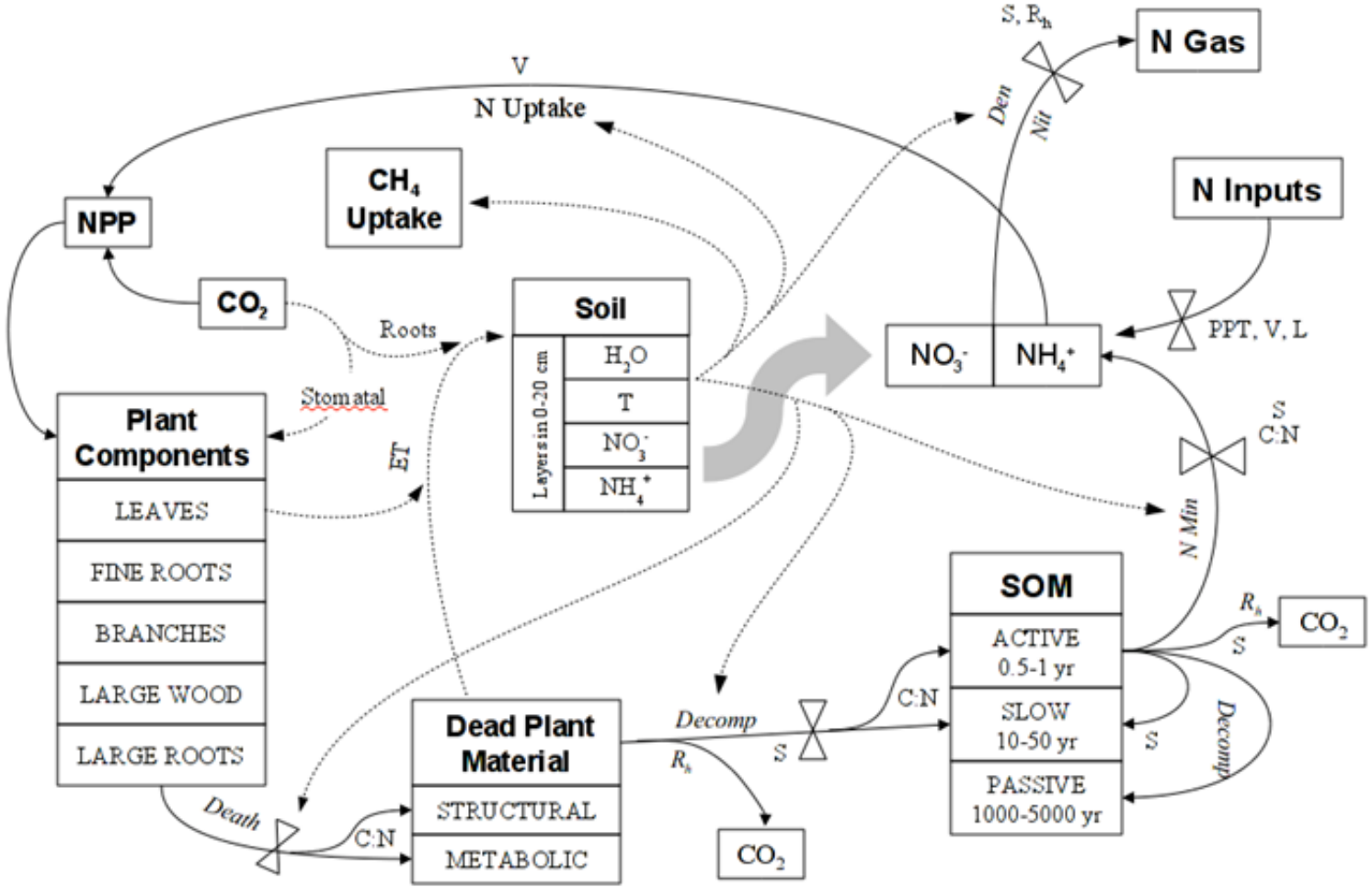
1. Soil health co-benefits
2. Increasing emphasis on C removal
3. Public perception of "naturalness"
4. **Unrealized potential for optimization?**
   a) **Management**
   b) **Landscape design**
   c) **Crop belowground traits**



Sweet *et al.* (2021) *Climatic Change;* Field *et al.* (2020) *PNAS*

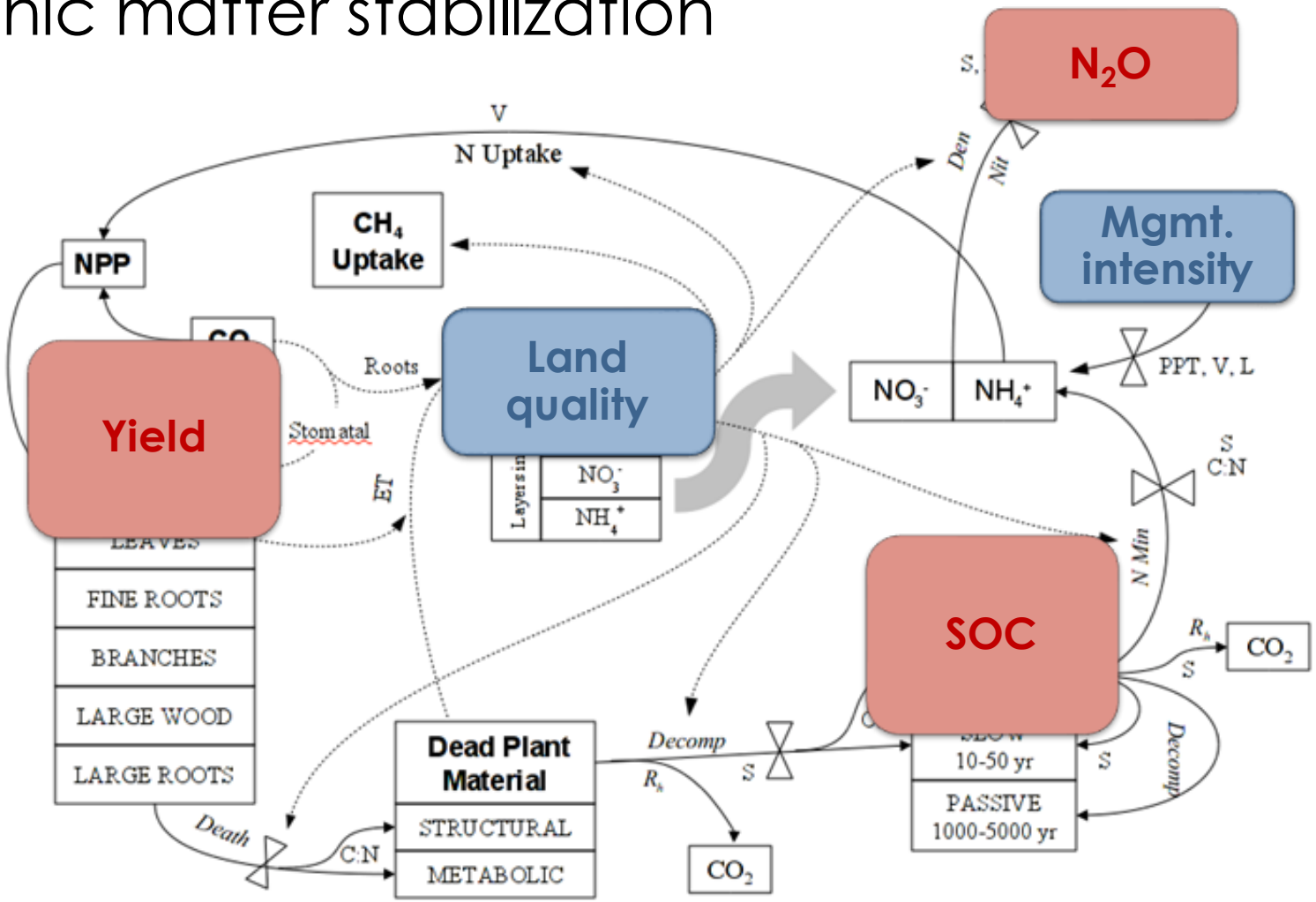
Process-based ecosystem models

- DayCent simulates C & N cycling during plant growth, death, decay, soil organic matter stabilization
- INTEGRATED modeling of:
  - Land quality
  - Mgmt. intensity
  - Yields
  - SOC response
  - Nitrous oxide (N_2O) emissions



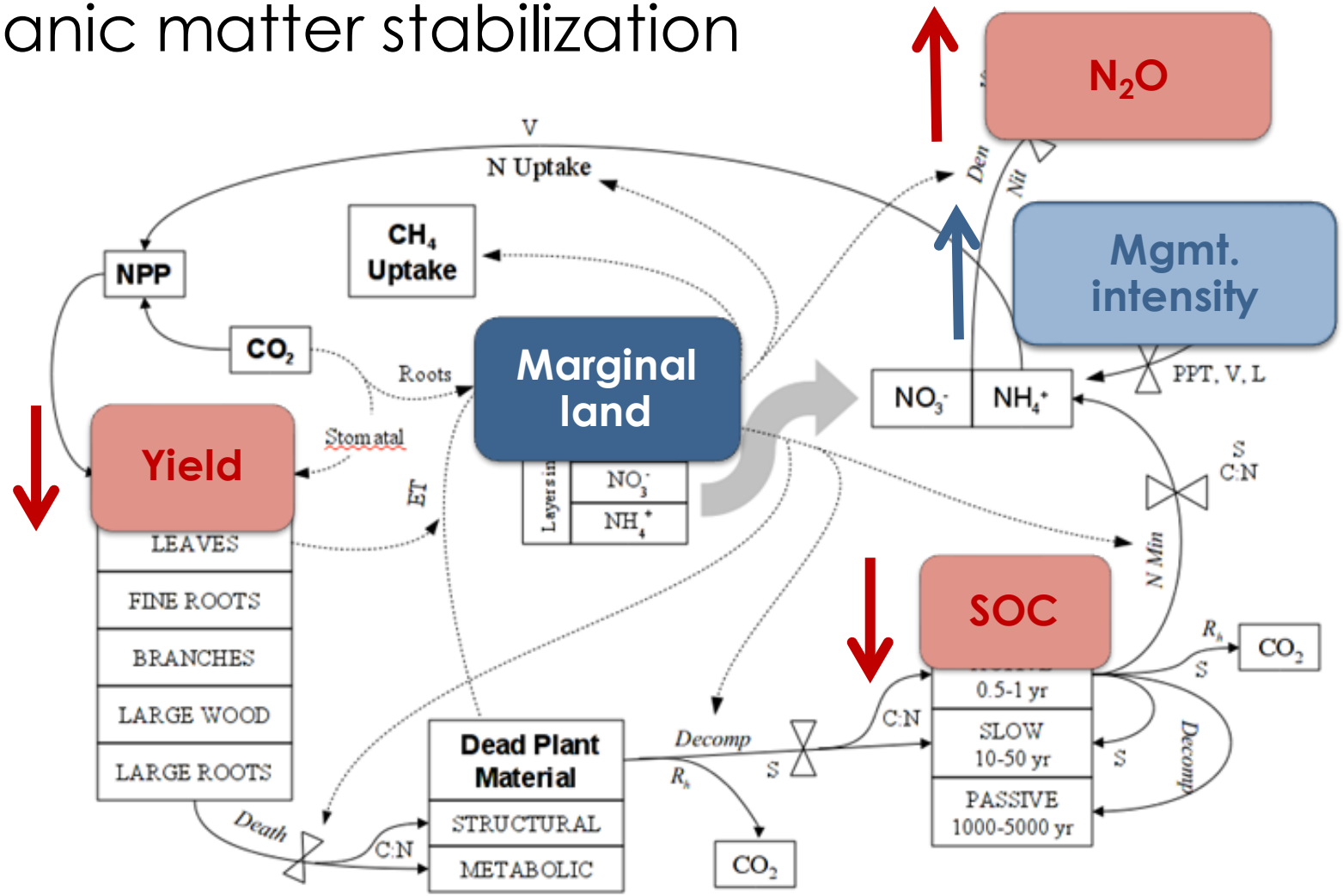
Process-based ecosystem models

- DayCent simulates C & N cycling during plant growth, death, decay, soil organic matter stabilization
- INTEGRATED modeling of:
  - Land quality
  - Mgmt. intensity
  - Yields
  - SOC response
  - Nitrous oxide (N_2O) emissions



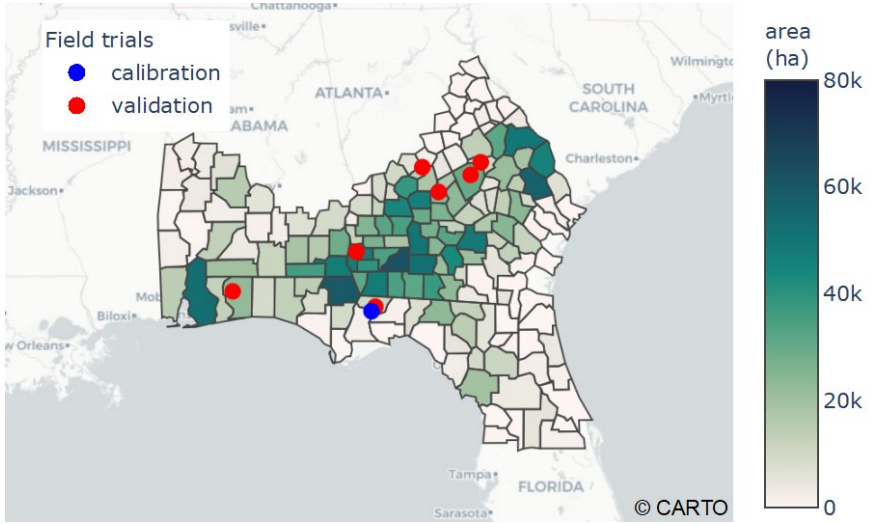
Process-based ecosystem models

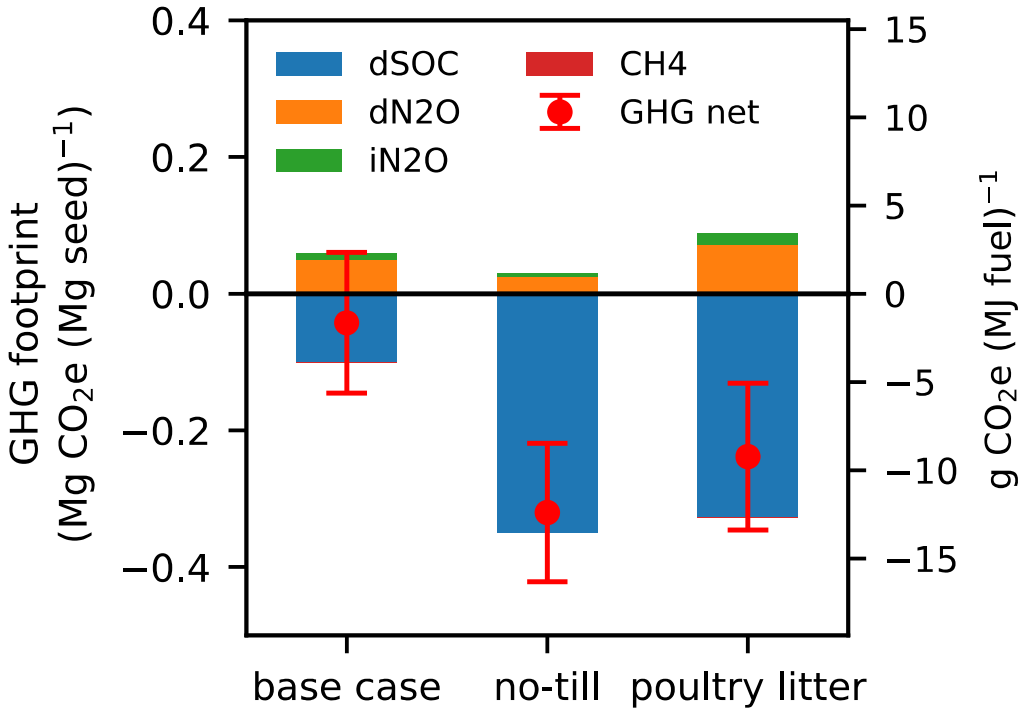
- DayCent simulates C & N cycling during plant growth, death, decay, soil organic matter stabilization
- INTEGRATED modeling of:
  - Land quality
  - Mgmt. intensity
  - Yields
  - SOC response
  - Nitrous oxide (N_2O) emissions



Optimization: crop management

- How to manage a novel crop (*Brassica carinata*) for SAF production and SOC?
  - >1 billion liters SAF in AL/GA/FL
  - SOC outcome sensitive to mgmt.
- **Net SOC benefit: +0.07 Mg C ha^{-1} y^{-1} (–11 g CO_2e MJ^{-1})**

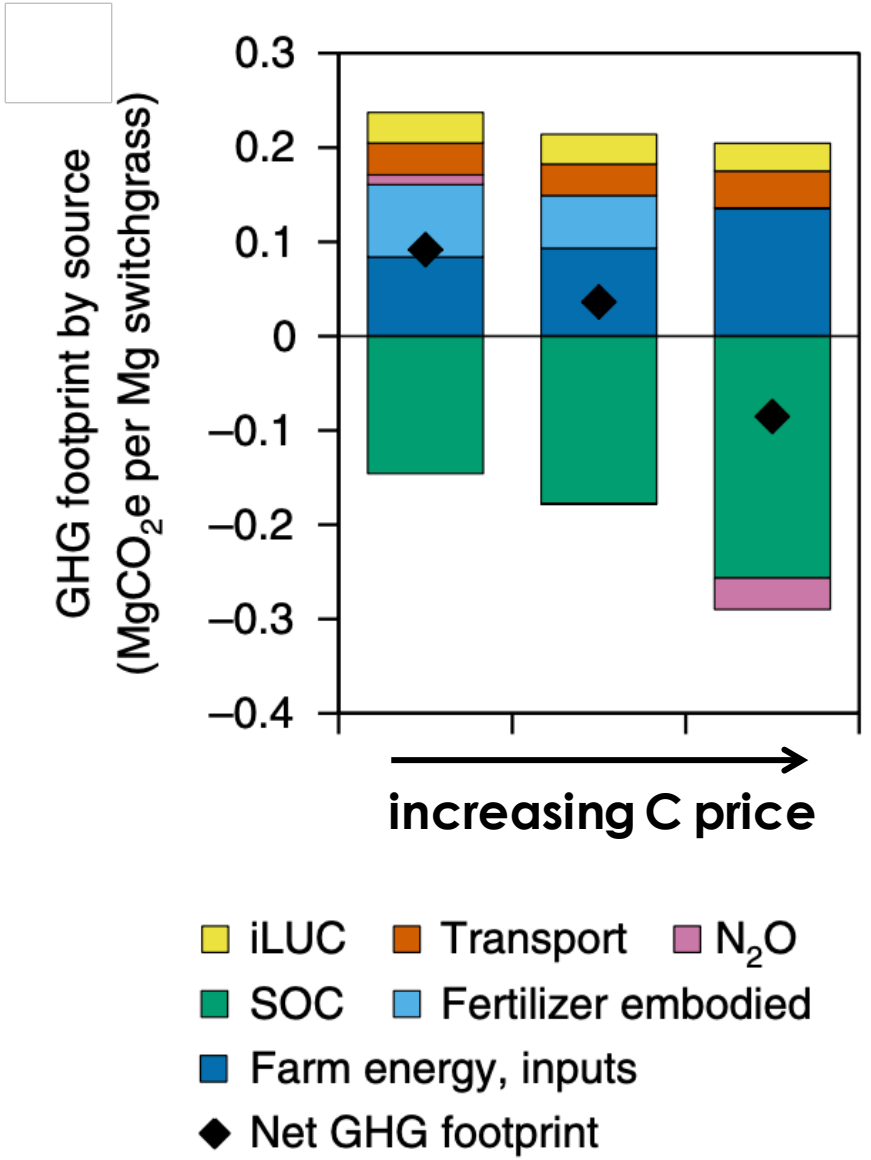




Field et al. (in press) *Frontiers in Energy Research*

Optimization: Landscape design

- Where/how to cultivate switchgrass for commercial biorefinery?
  - Target soils with greatest C-storage capacity
  - Limit N additions
- **Net SOC benefit: 0.45 Mg C ha^{-1} y^{-1} (–13 g CO_2e MJ^{-1})**
  - **Full life-cycle benefit: –20 g CO_2e MJ^{-1}**



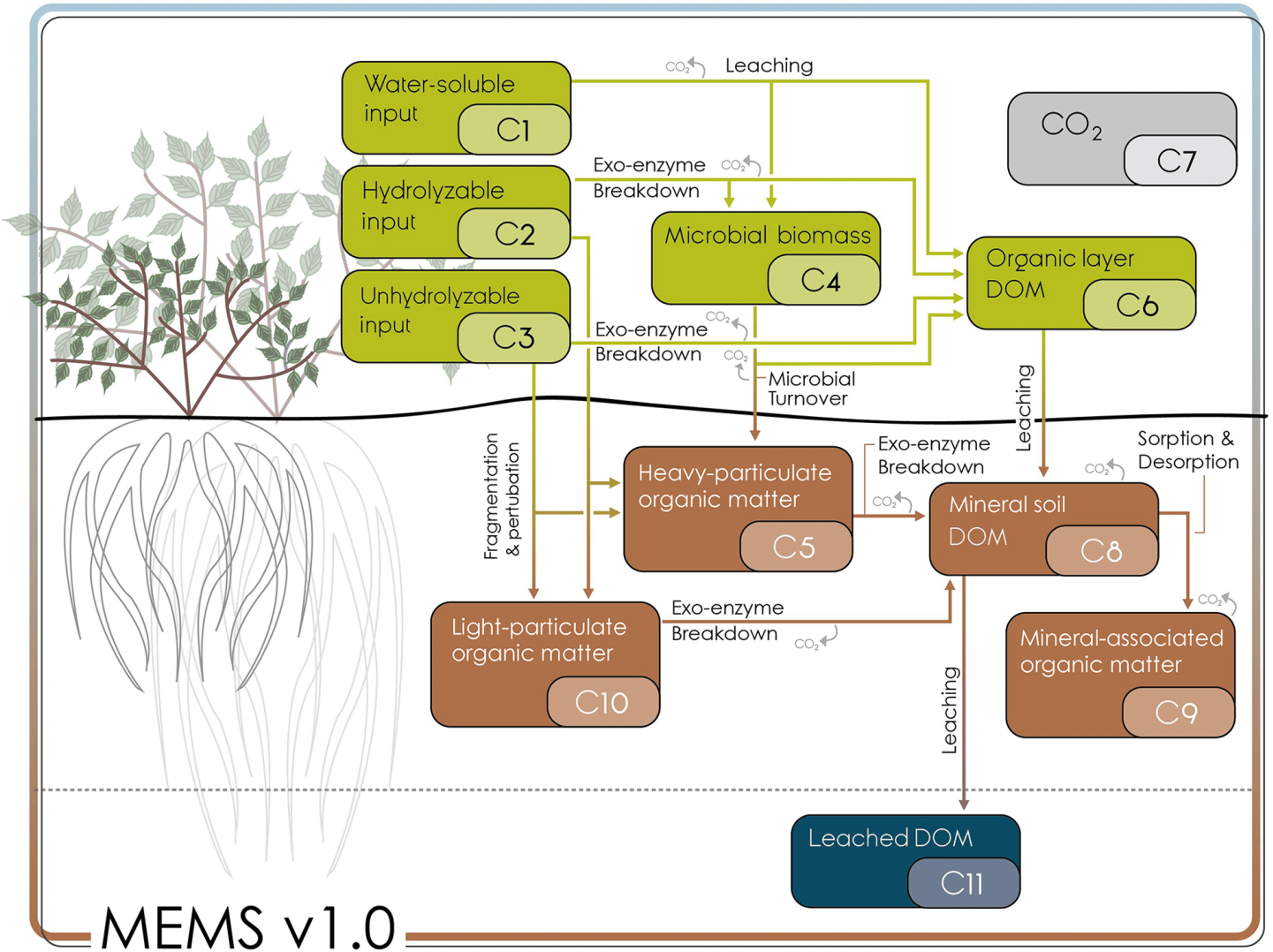
Field *et al.* (2018) *Nature Energy*

Optimization: crop belowground traits

- Can SOC be improved without sacrificing aboveground biomass ***quantity*** or ***quality***?
  - Greater root biomass, deeper in soil
  - More recalcitrant chemistry?
- Center for Bioenergy Innovation (CBI) evaluating diverse populations of switchgrass & poplar for:
  - Above- & belowground biomass, composition
  - Microbial communities
  - Soil C pools

Gaps & opportunities: new models & "marginal" land

- Legacy models missing:
  - Different forms of SOC
  - Saturation effects
  - Deep soil C
- Value in new-paradigm models such as MEMS (CSU) & Cycles (PSU)
- Is "marginal" land marginal in SOC?
  - i.e., low productivity and/or highly disturbed



MEMS model: Robertson *et al*. (2019) *Biogeosciences*
Marginal land definitions: Khanna *et al*. (2021) *GCB Bioenergy*

Acknowledgements

- Various DOE, USDA & other funding sources
- Erin Webb, Melanie Mayes, Udaya Kalluri, Brian Davison & others at ORNL
- Keith Paustian, Francesca Cotrufo & others at CSU Natural Resource Ecology Laboratory

Email: FieldJL@ornl.gov