Factors Affecting Organic Carbon Stability/Sequestration in Agricultural Soils

Keith Paustian

Dept. Soil and Crop Sciences and Natural Resource Ecology Lab

Colorado State University
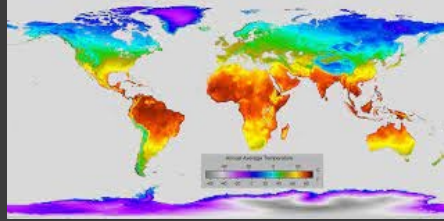
Fort Collins, CO
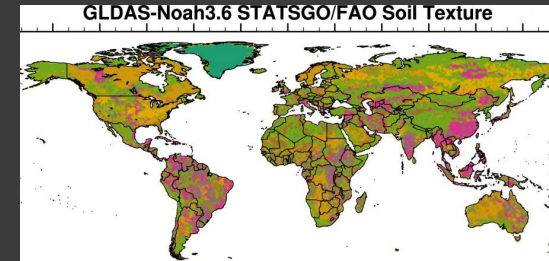
COLORADO STATE UNIVERSITY

DOE/BETO - Bioenergy's Role in Soil Carbon Storage – March 28-29, 2022
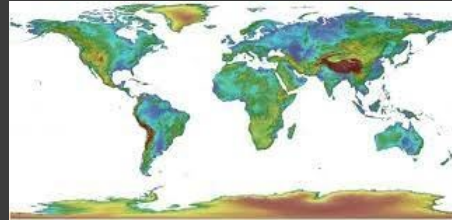
Factors controlling soil C sequestration

- Climate

- Soil properties (texture, minerology, depth)

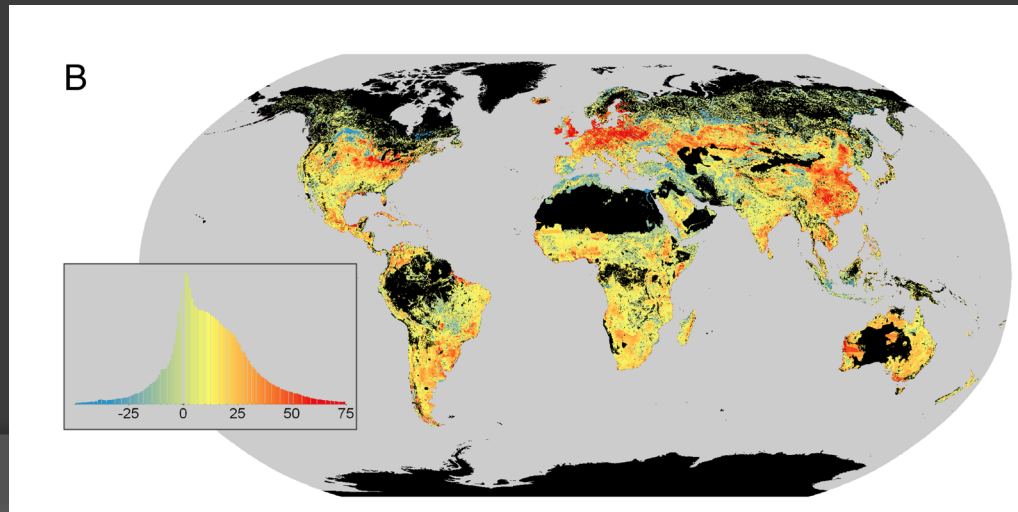GLDAS-Noah3.6 STATSGO/FAO Soil Texture
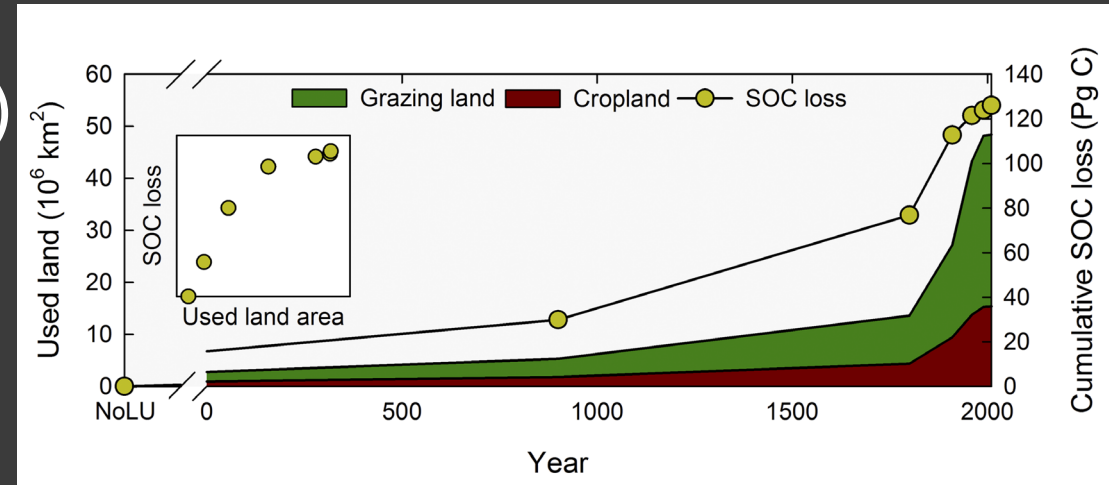
- Topography

- **Previous land use**

Soil carbon debt of 12,000 years of human land use

Jonathan Sanderman[a,1,2], Tomislav Hengl[b,1], and Gregory J. Fiske[a]

2017

~133Pg C (500 Pg CO_2) lost from soils due to human LU

Factors controlling soil C sequestration

- Climate

- Soil properties (texture, minerology, depth)

- Topography

- Previous land use

- **Future land management –** <u>Purposed</u> for building soil C stocks

Practice and technologies for sequestering soil C

- **Existing 'best management practices' (BMPs)**
  - Conventional conservation practices that can be more widely adopted

Widespread implementation of existing soil C building practices

We have data!; >50 LTEs in US, 100s globally

Diversified crop rotations

Cover crops

No-till

Improved grazing systems

Grassland restoration

Restoration of peat soils

Agroforestry

Compost

CO$_2$

Increasing C inputs

Decreasing C losses

Harvest

Soil carbon
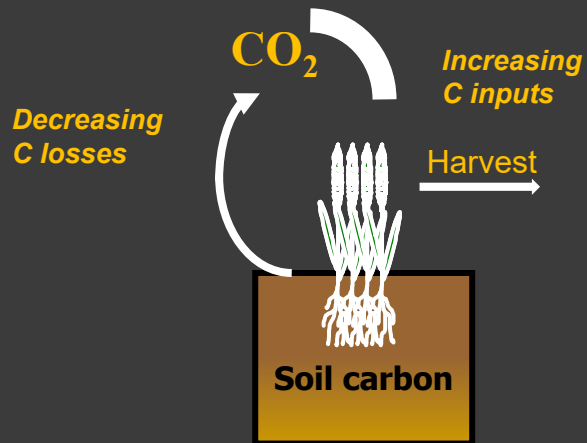
No till, cover crops, intensified rotations

Meta-analyses of no-till adoption
0.0-0.5 tonne C/ha/y

Meta-analyses of cover crops
0.3-0.4 tonne C/ha/y

Set-aside, grassland restoration, conversion to pasture

System	ΔSOC tC/ha/y	Source
Cropland to pasture (global)	0.87	Conant et al. 2017
Restored prairie	0.77	Tillman et al. 2006
Cropland to pasture (SE USA)	0.84	Franzluebbers 2010

Practice and technologies for sequestering soil C

- Existing 'best management practices' (BMPs)
  - Conventional conservation practices that can be more widely adopted

- **Frontier technologies**
  - Practices in early stage of development
  - Practices with significant technical or economic constraints to widespread adoption

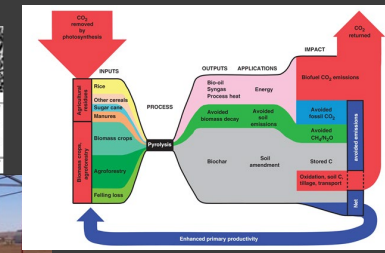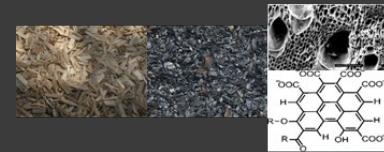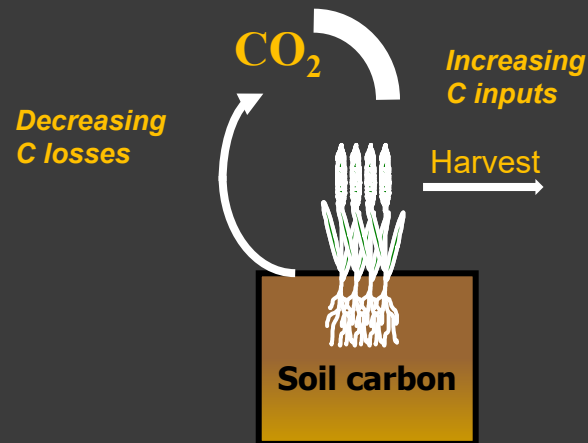# Research and Development of 'frontier technologies'

Data lacking, estimates from 'feasibility' assumptions

Biochar amendments

Annual crops with enhanced roots

Perennial grains

Organic matter deep burial

CO_2

Decreasing C losses

Increasing C inputs

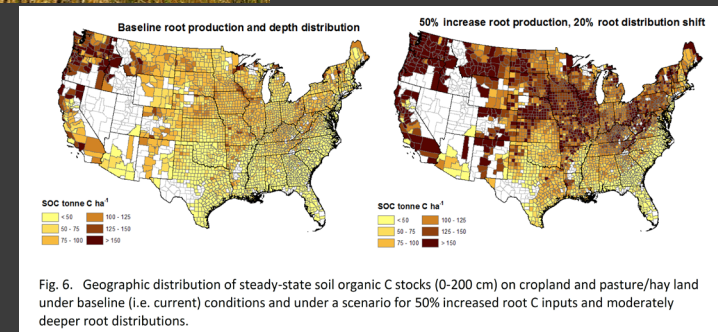Harvest

Soil carbon

Courtesy Land Institute

Fig. 6. Geographic distribution of steady-state soil organic C stocks (0-200 cm) on cropland and pasture/hay land under baseline (i.e. current) conditions and under a scenario for 50% increased root C inputs and moderately deeper root distributions.

Paustian et al. 2016 ARPA-E

Estimates of global 'technical' potentials for atmosphere CO_2 removal to soils
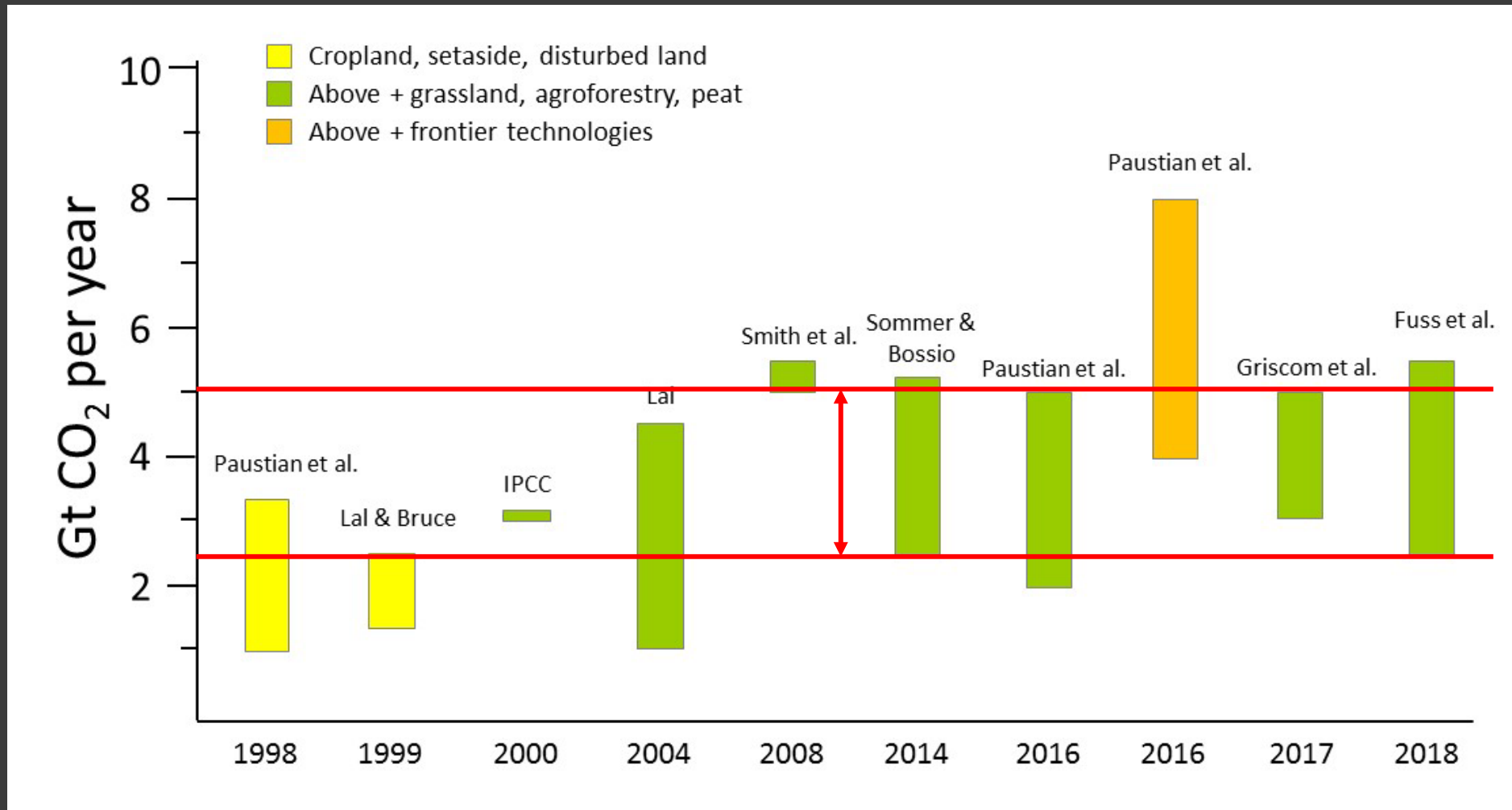
Quantifying soil C stocks changes & GHGs is a difficult job!

- Emissions/sinks are dispersed, non-point source – spatially & temporally **variable**.

- **Low signal-to-noise ratio** for annual changes

- Rates of C stock change are controlled by **many** interacting processes.

Improving accuracy and reducing costs are key to increasing investment in soil C as a decarbonization approach.

Microsoft's million-tonne CO_2-removal purchase – lessons for net zero

Lucas Joppa, Amy Luers, Elizabeth Willmott, S. Julio Friedmann, Steven P. Hamburg & Rafael Broze

Priorities for improved soil C measurement and monitoring capabilities

- National soil monitoring system that leverages NRI

- More tightly integrated modelling and observational platforms utilizing big data approaches (e.g. high-resolution RS, ground sensors and mgmt. data)

- Next-gen field performance 'test bed' facilities for evaluating 'frontier technologies'