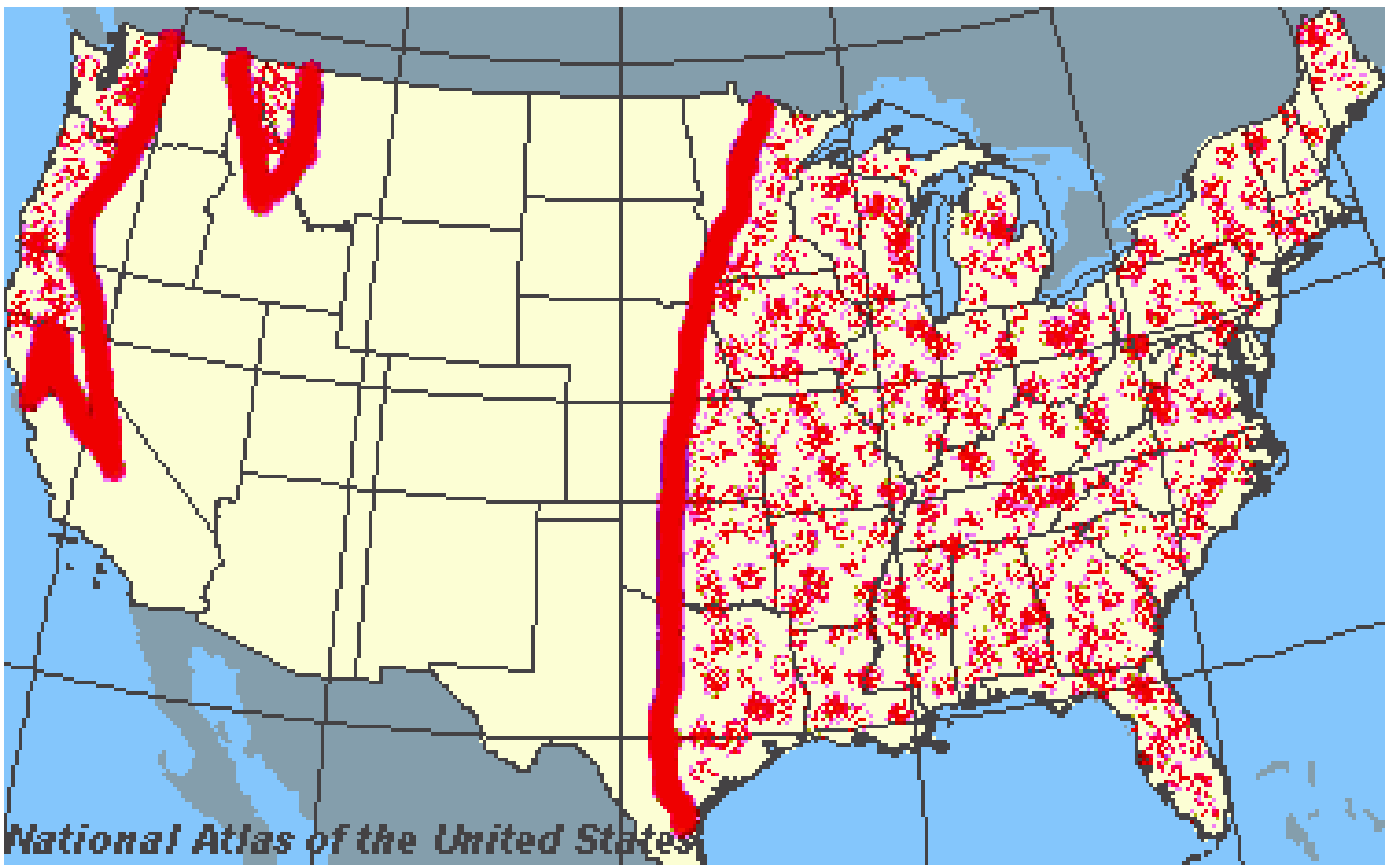
Carbon Cycling and Sequestration in Humid Grazinglands

Alan Franzluebbers (soil ecologist)
John Stuedemann (animal scientist)

USDA
Agricultural Research Service
Watkinsville
Georgia

Characteristics of Humid Grazinglands

Moisture regime



Precipitation
>600 mm · yr^{-1}

In the USA, eastern half of country and - 300 km of west coast

Characteristics of Humid Grazinglands

Other factors that distinguish regions

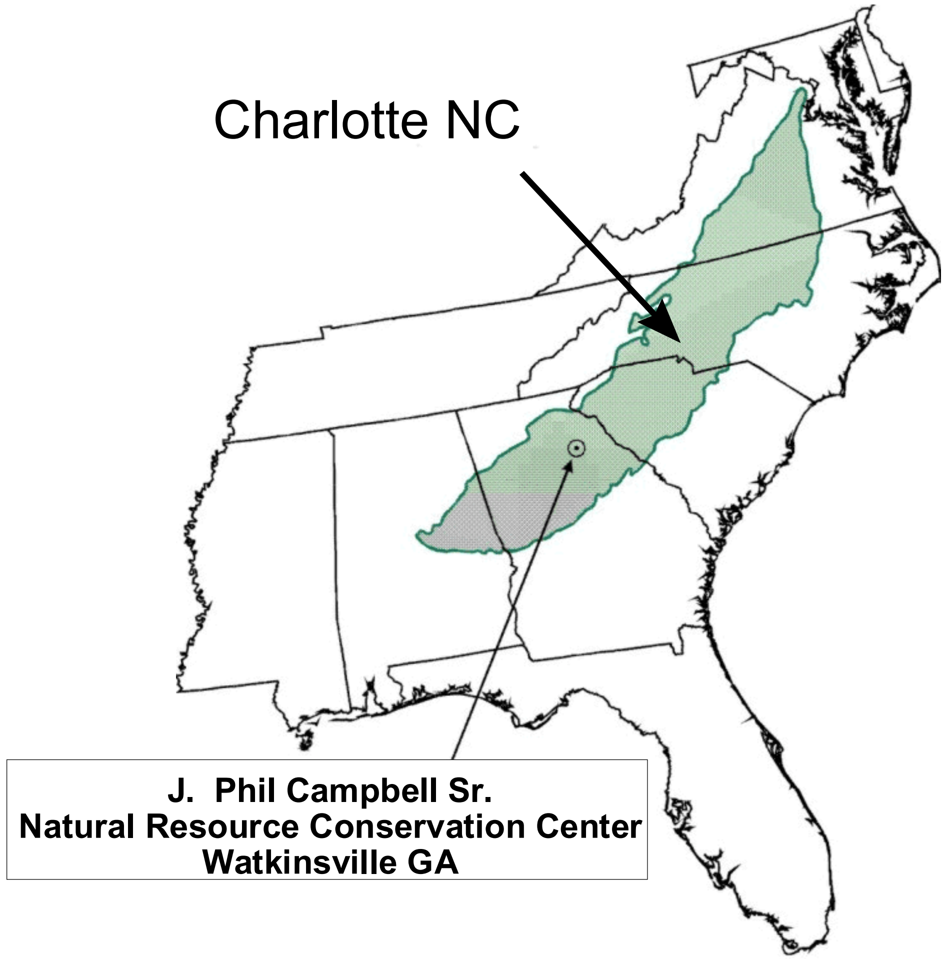
Generally **acidic soils**

Introduced plant species with
high productivity potential and
high forage quality

Species that **respond to inputs** of
fertilizer and management variables

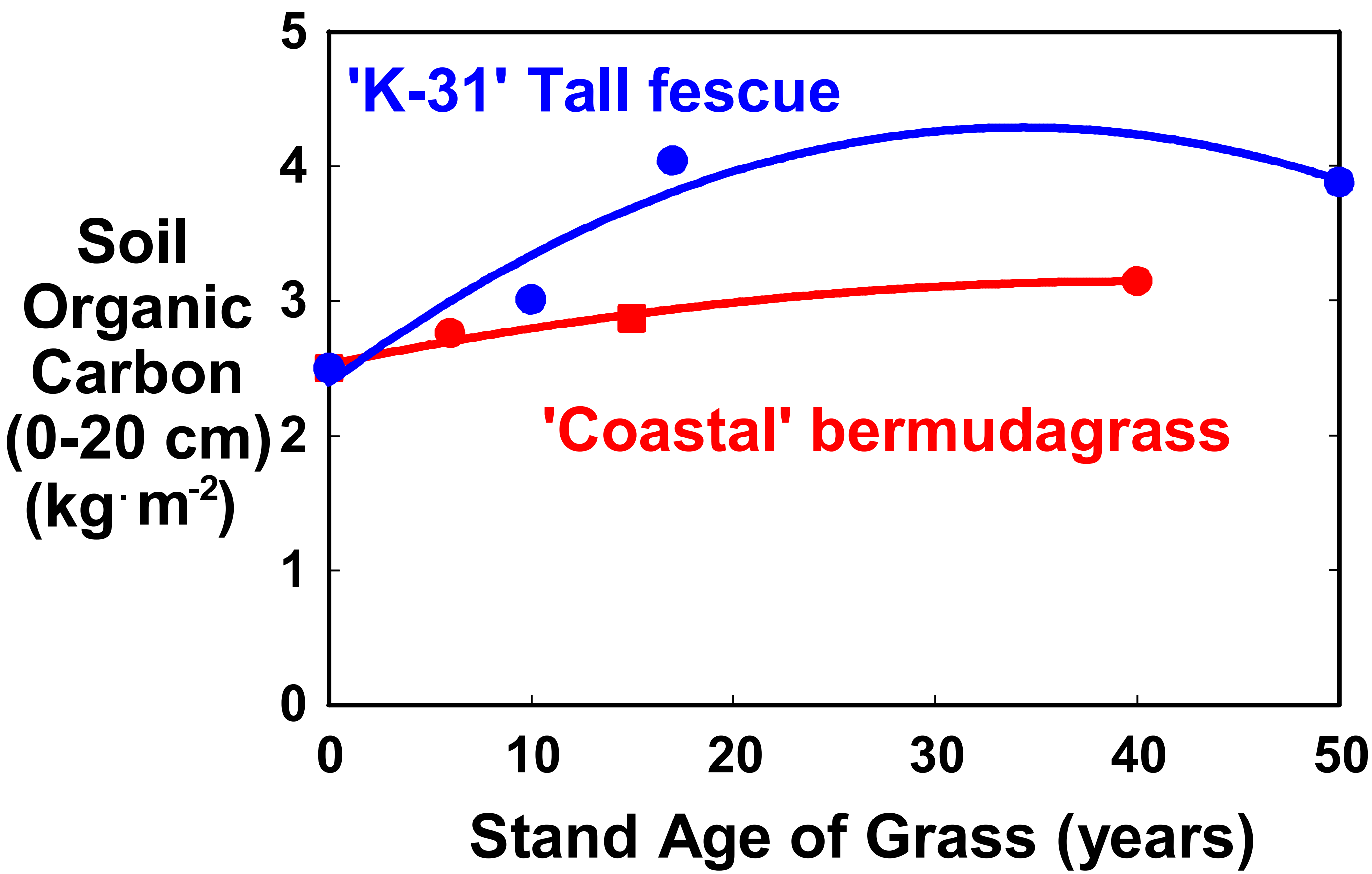
Utilization of forage is **diverse**,
including intensive rotation,
extensive, and
haying

In the southeastern USA,
nearly **year- round** grazing potential
(i.e., both warm- and cool-season)



Plant Species Effect on Carbon Cycling

Can plant species affect soil C accumulation?



Soil organic C sequestration rate during 25 years

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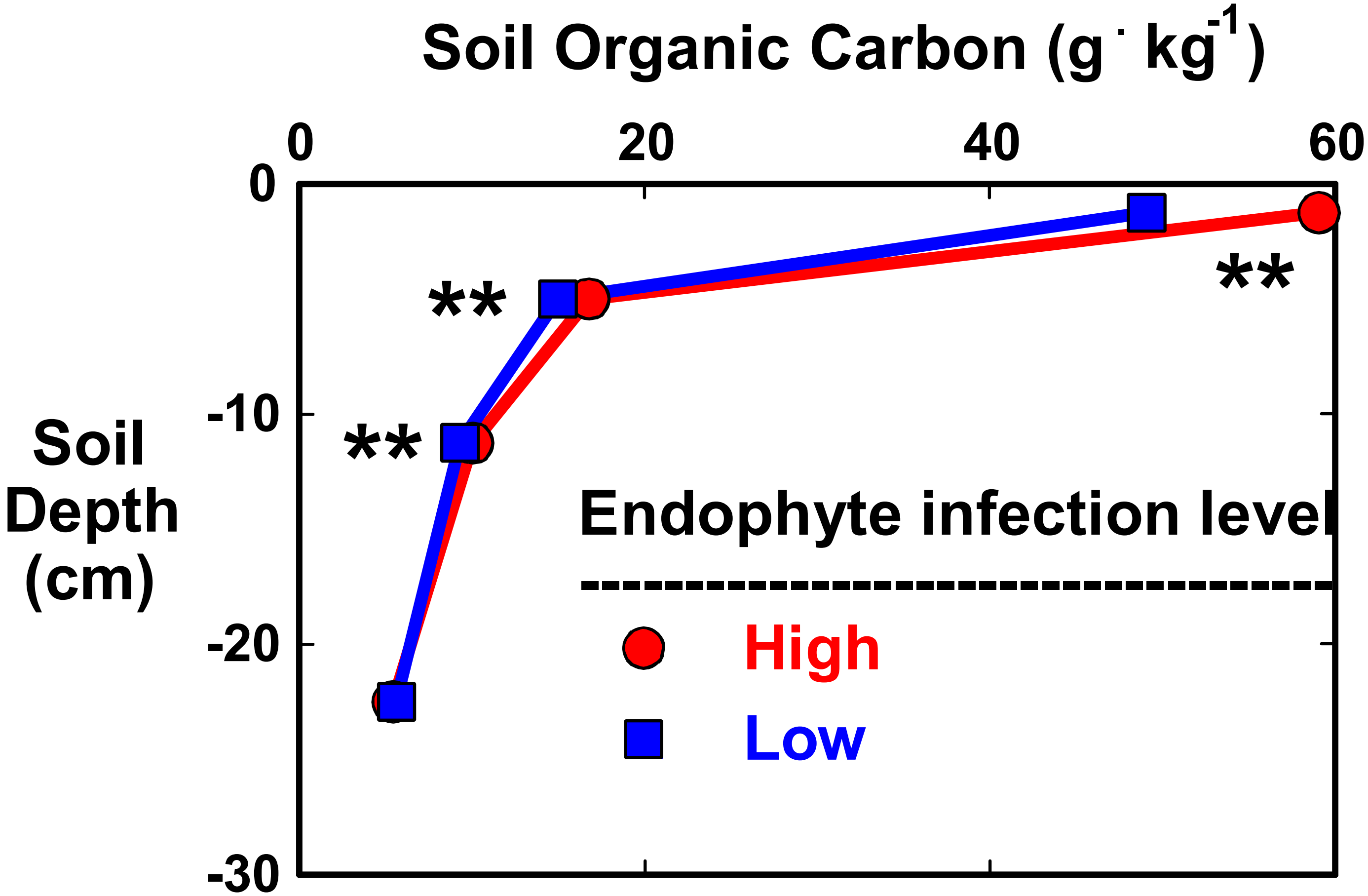
78 g · m^{-2} · yr^{-1}

26 g · m^{-2} · yr^{-1}

Different opportunites for growth during the year.

Plant Species Effect on Carbon Cycling

Neotyphodium infection of tall fescue



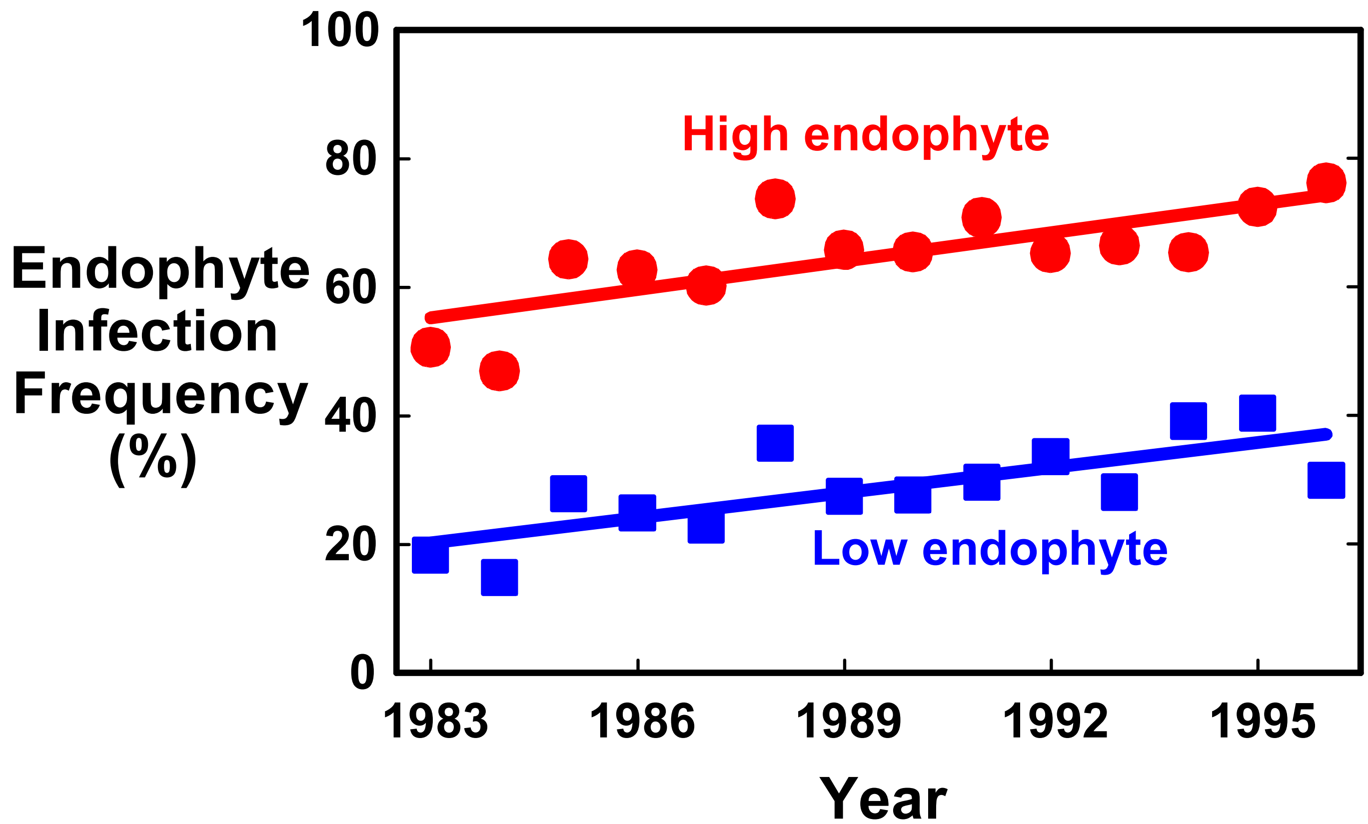
CMIN-to-SOC

Low		High
98	**	78
43	*	38
26	*	23
16		16

(mg · g^{-1} SOC · 24 d^{-1})

Plant Species Effect on Carbon Cycling

Endophyte infection and stand persistence of tall fescue



Stand composition in May 2001 (18 yr)

	Low	High
Tall fescue	54	74
Bermudagrass	21	8
Winter annual grass	7	1
Broadleaves	6	3
Bare ground	12	14

Plant Species Effect on Carbon Cycling

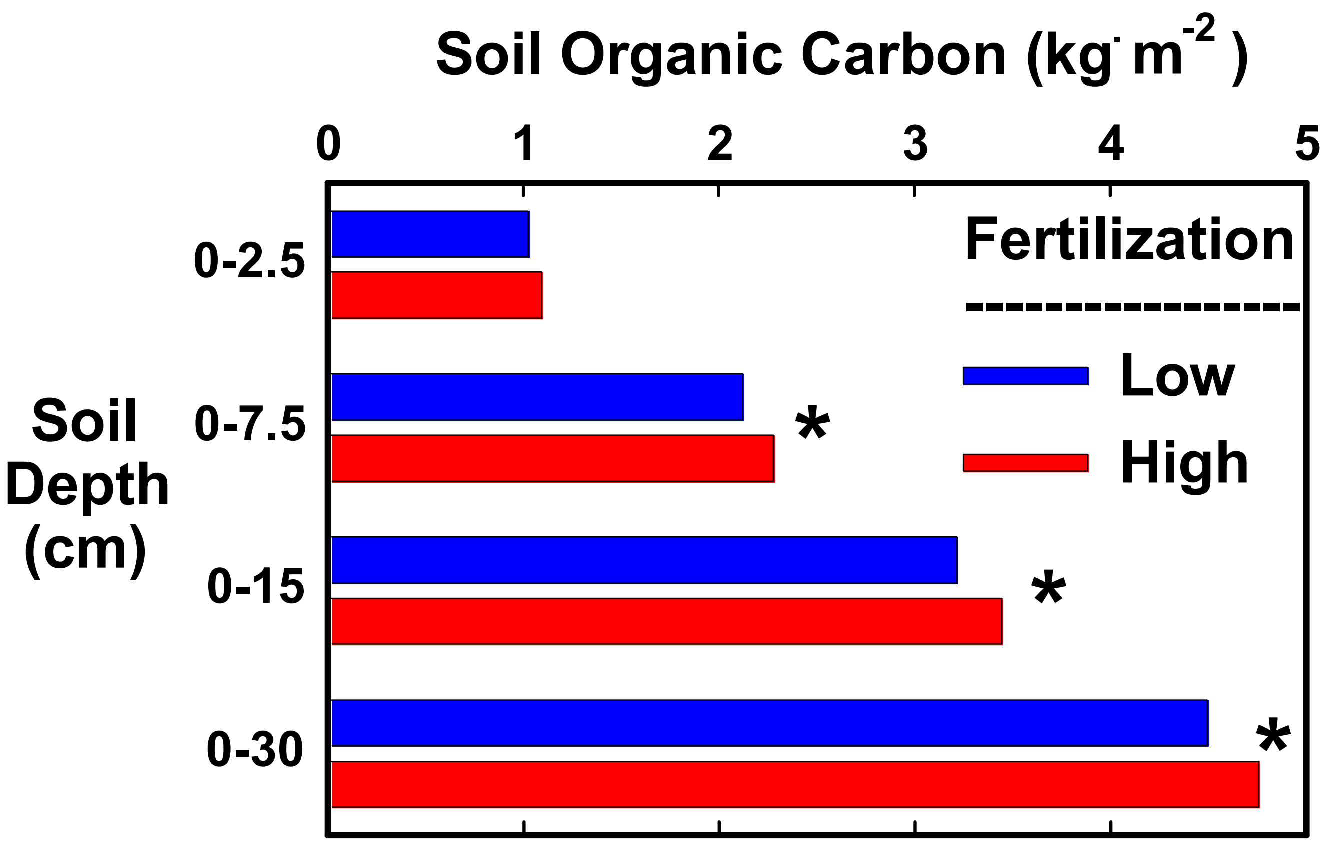
Direct impact of endophyte infection on soil microorganisms

Addition of tall fescue leaf tissue on:

	E +	Pr>F	E -
Soil Microbial Biomass C ($mg \cdot kg^{-1}$ soil)	196	0.12	293
Potential C Mineralization ($mg \cdot kg^{-1}$ soil $\cdot$ 32 d^{-1})	1227	0.06	1256

Fertilization Effect on Carbon Cycling

Low (**13.4-1.5-5.6**) and high (**33.6-3.7-13.9**) fertilization of tall fescue (g N-P-K $\cdot m^{-2} \cdot yr^{-1}$) during 15 years



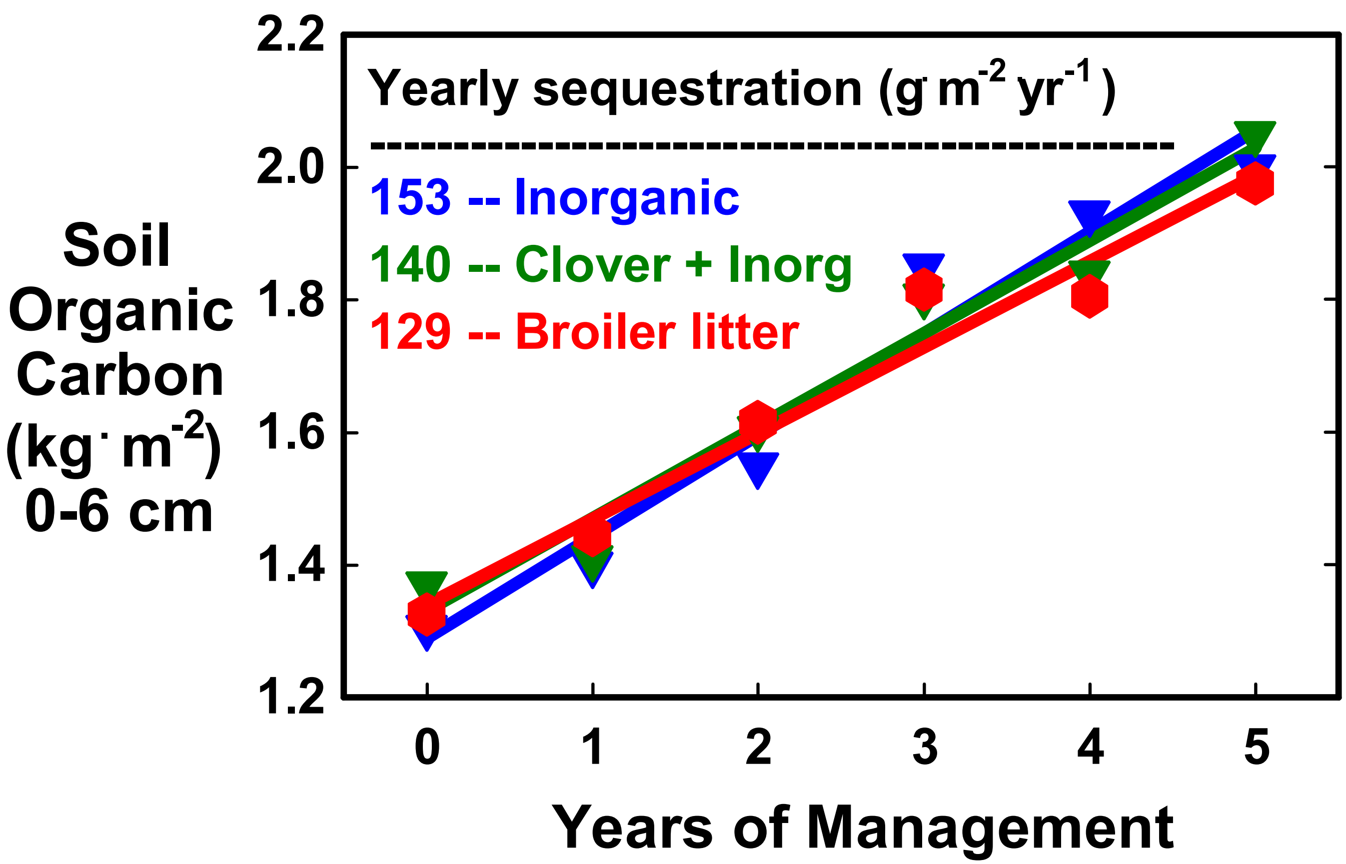
Total gain in soil organic C between low and high fertilization was 260 $g \cdot m^{-2}$ (0-30 cm). [17 $g \cdot m^{-2} \cdot yr^{-1}$]

Carbon cost of fertilization was 152 $g \cdot m^{-2}$ [using 0.5 g C $\cdot g^{-1}$ N applied (IPCC, 1996)].

+108 $g \cdot m^{-2}$ balance

Fertilization Effect on Carbon Cycling

Grazed 'Coastal' bermudagrass following eroded cropland
Each system with - 20 g N · m^{-2} · yr^{-1}

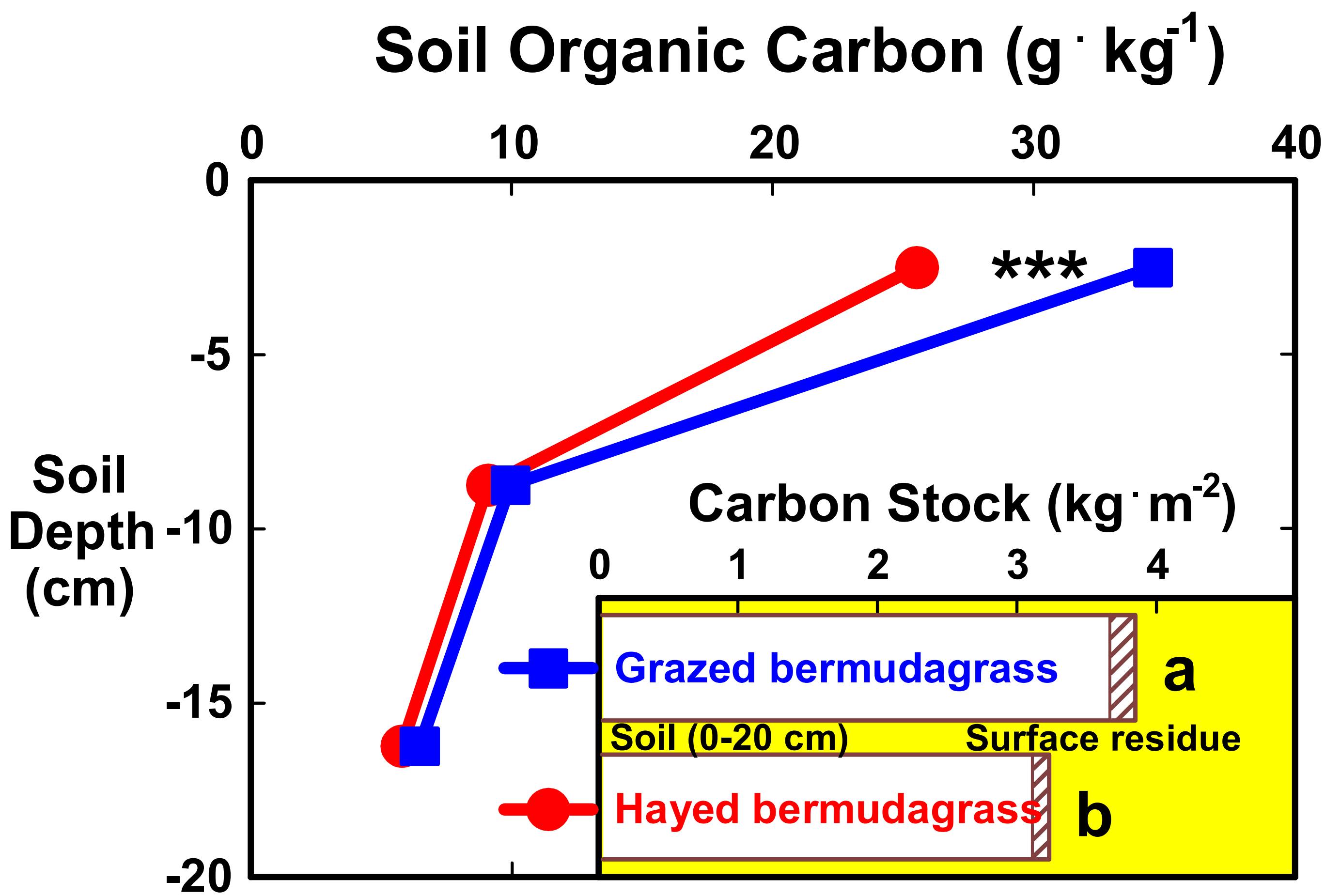


Whether nutrients were derived from organic or inorganic sources, soil carbon sequestration was equally high.

Carbon cost of fertilization (i.e., 11 g · m^{-2} · yr^{-1}) was low (7-9%) relative to soil C gain.

Harvest Management Effect on Carbon Cycling

Does grazing affect soil organic C accumulation?



Three pairs of 3-ha fields (15-19-year-old stands).

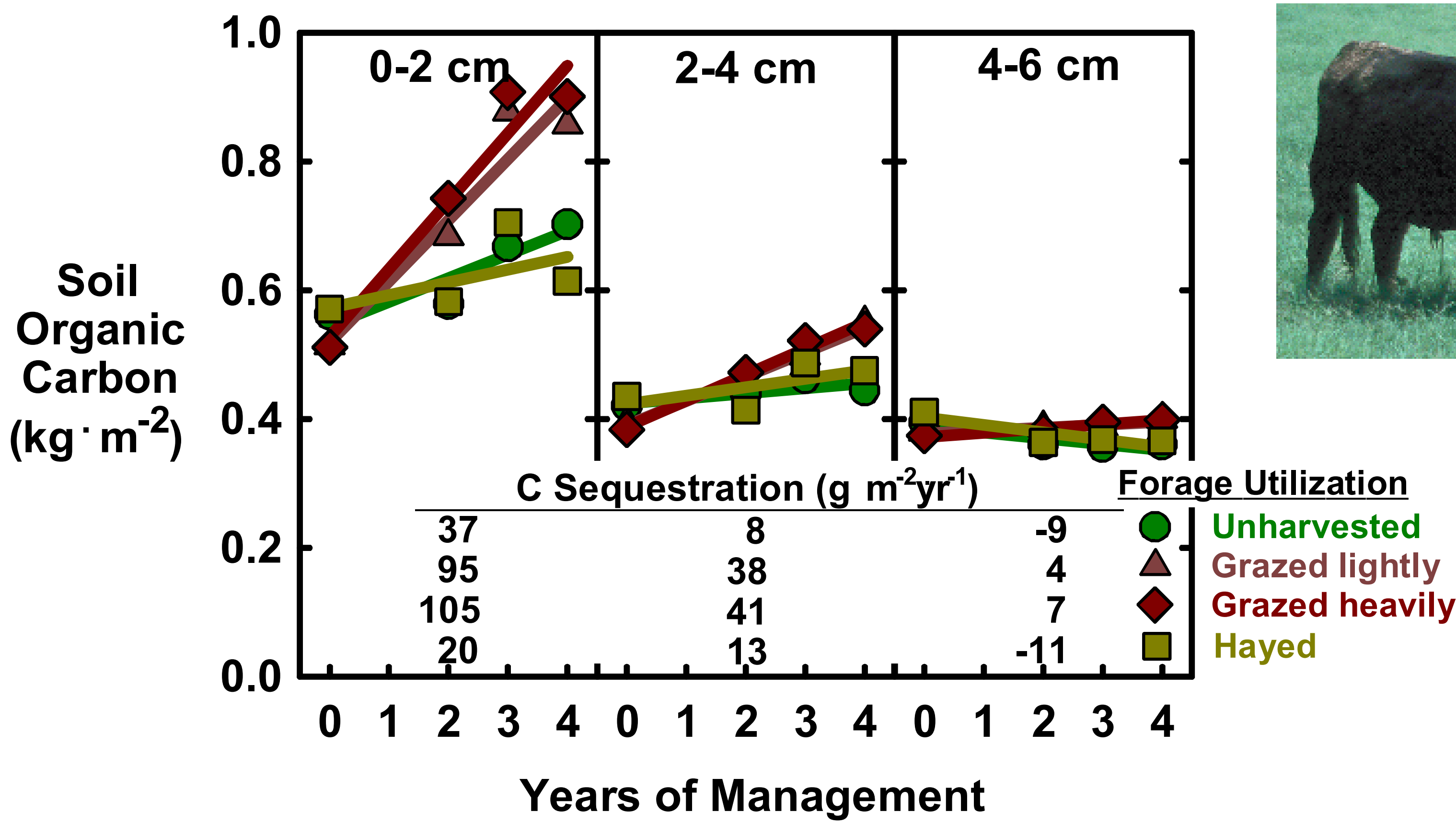
Grazed by cow-calf herd periodically throughout year.

Harvested for hay 3-4 times · yr^{-1}.

Î 42 g · m^{-2} · yr^{-1}

Harvest Management Effect on Carbon Cycling

Would not unharvested grass have greater soil C sequestration?

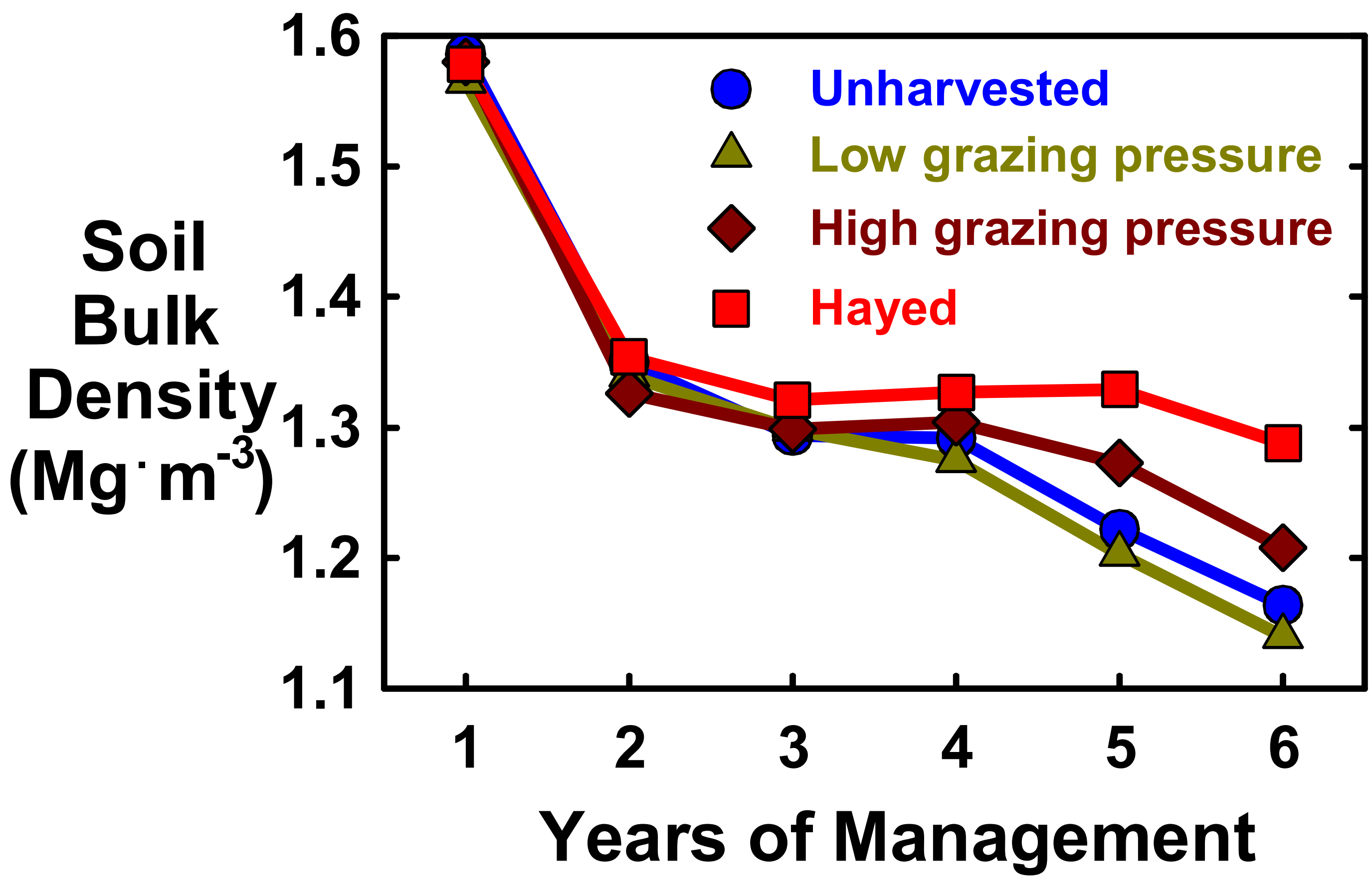


Soil (0-6 cm)	Surface residue
36	49
137	42
153	30
22	17

$(g \cdot m^{-2} \cdot yr^{-1})$

Harvest Management Effect on Carbon Cycling

Don't grazing systems have negative impacts on surface soil properties, which lead to land degradation?



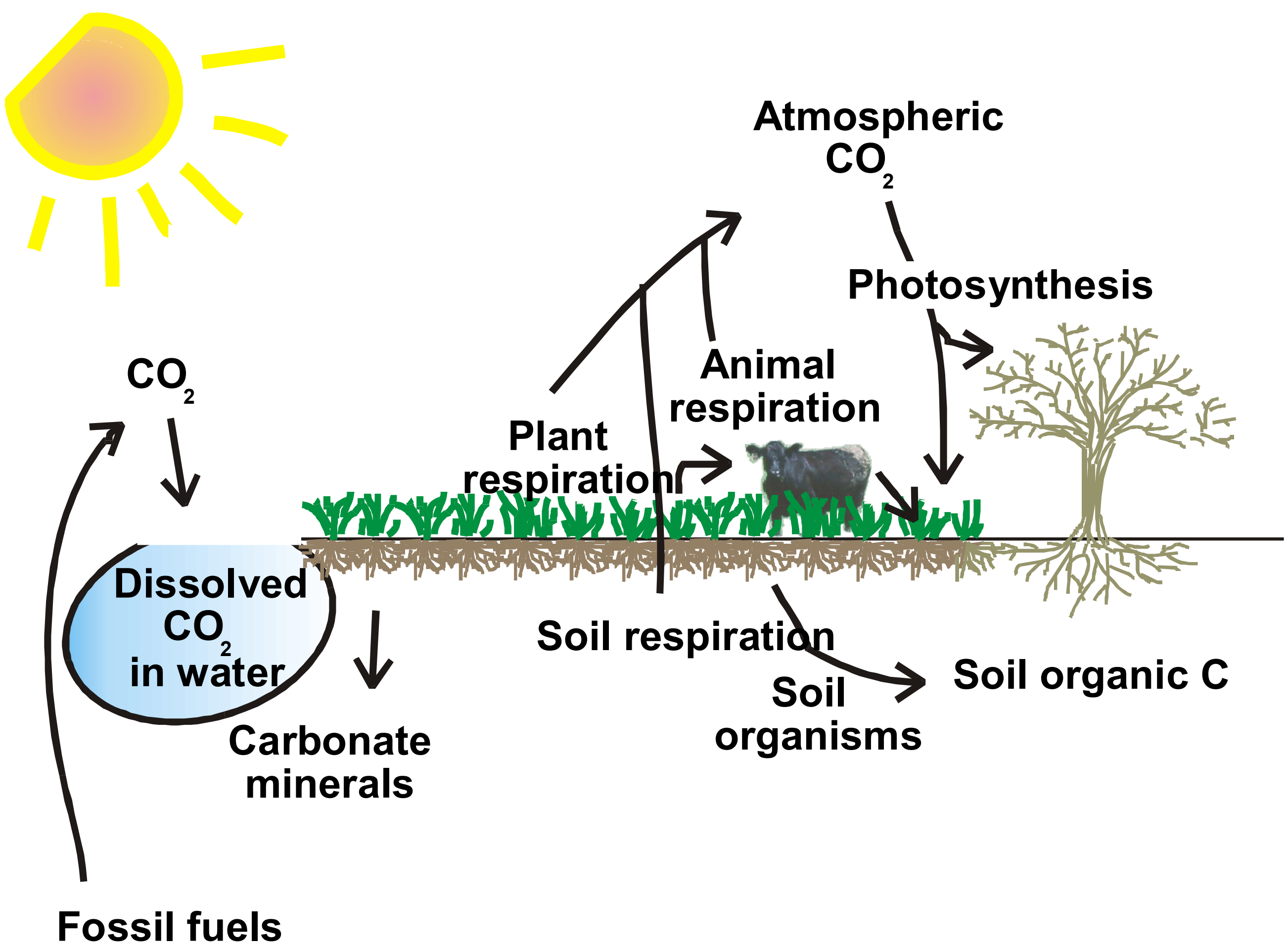
Soil depth of 0-6 cm.

Grazing reduced bulk density compared with haying.

Higher grazing pressure increased bulk density compared with unharvested management.

Ecological Return on Management Investment

SOC storage reduces net CO_2 emission from soil



Assuming gross primary productivity of 1000 g C · m^{-2} · yr^{-1}, then

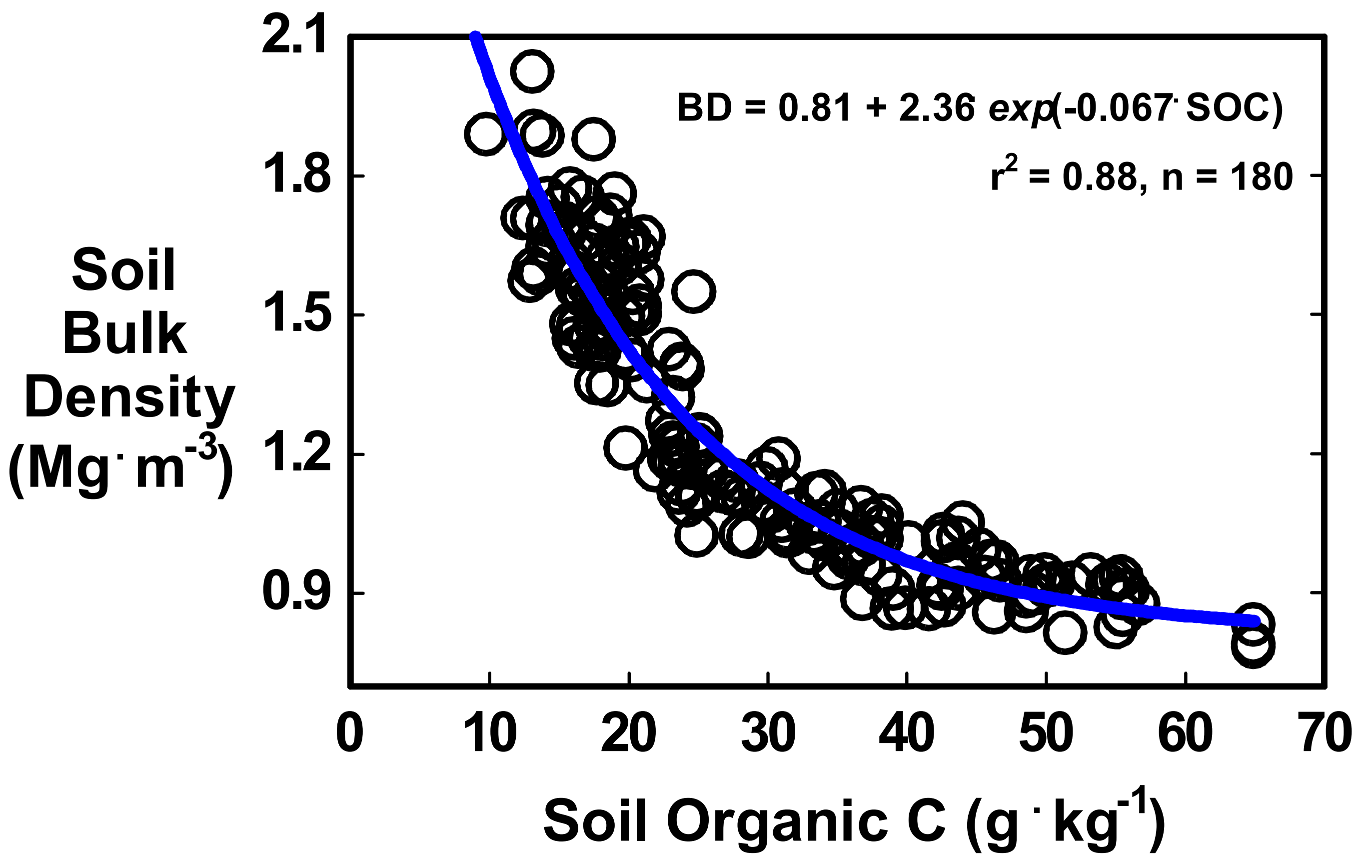
- 500 g C · m^{-2} · yr^{-1} respired by plants
- 500 g C · m^{-2} · yr^{-1} fixed as dry matter

Key issue:
How to manage land to convert plant dry matter into SOC?

10% . 50 g C · m^{-2} · yr^{-1}

Ecological Return on Management Investment

Effect of SOC on bulk density and potential water retention



Water (cm) held at saturation capacity to a depth of 20 cm

6.4

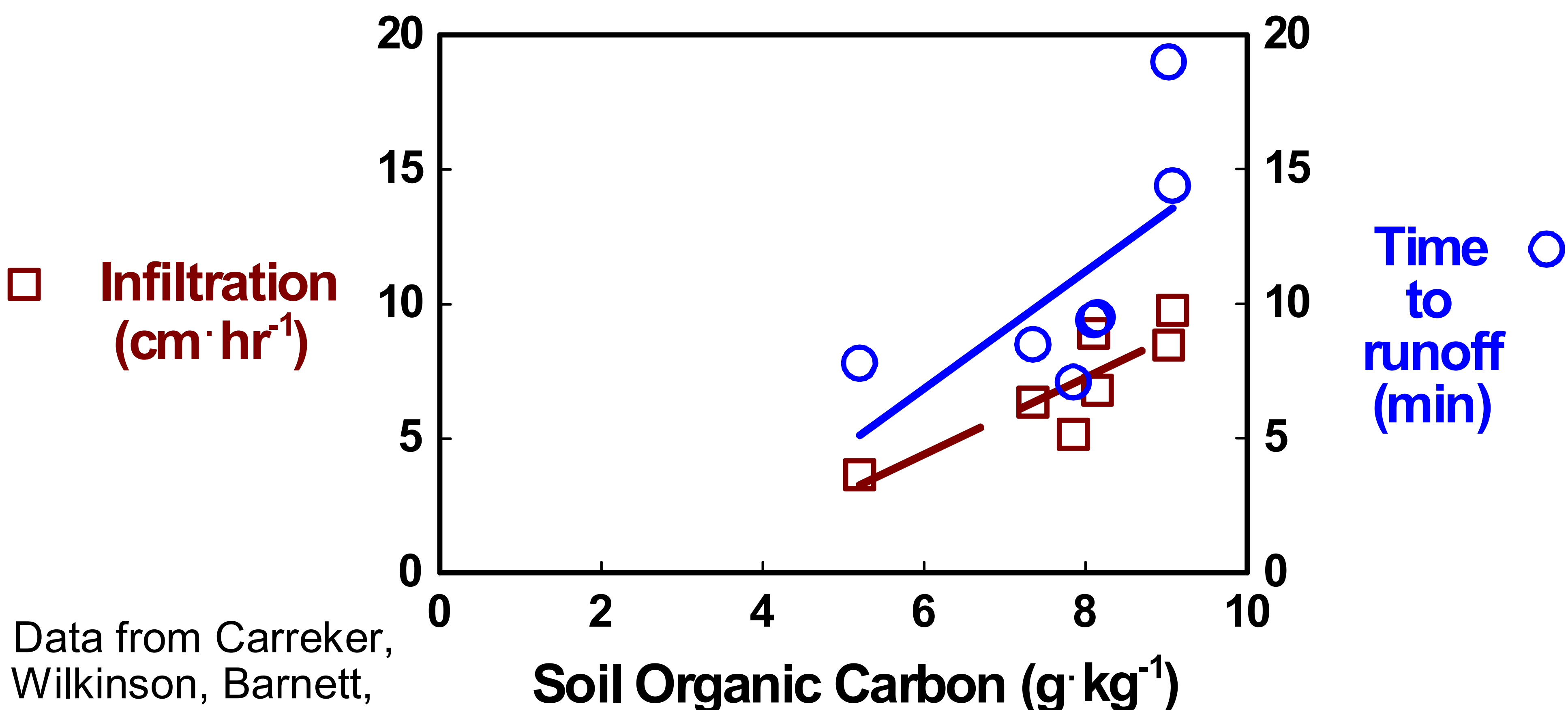
8.7

10.9

13.2

Ecological Return on Management Investment

Effect of soil organic C on water infiltration



Data from Carreker, Wilkinson, Barnett, Box (1977)

Ecological Return on Management Investment

Soil organic matter sequesters nutrients for long-term fertility

The increase in soil organic C during a 5-year study with different management styles of grass following tilled cropland, resulted in sequestration of nitrogen (applied at 21.4 $g \cdot m^{-2} \cdot yr^{-1}$).

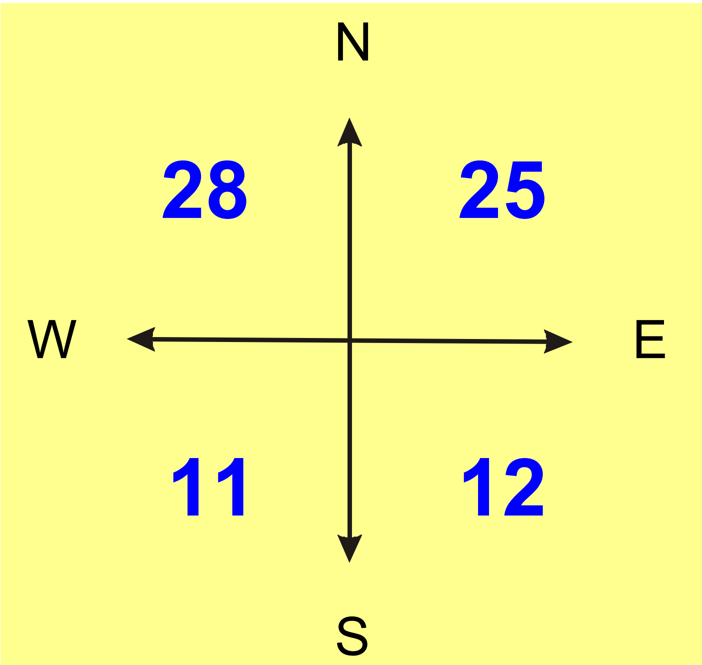
Nitrogen pools ($g \cdot m^{-2} \cdot yr^{-1}$):

Harvest system	Residue	Soil $N_{(0\text{-}6\ cm)}$	Hay	Animal gain
Unharvested	2.7	**7.3**	0	0
Low grazing pressure	2.1	**14.7**	0	0.6
High grazing pressure	1.7	**16.3**	0	0.7
Hayed	0.8	3.0	**12.2**	0

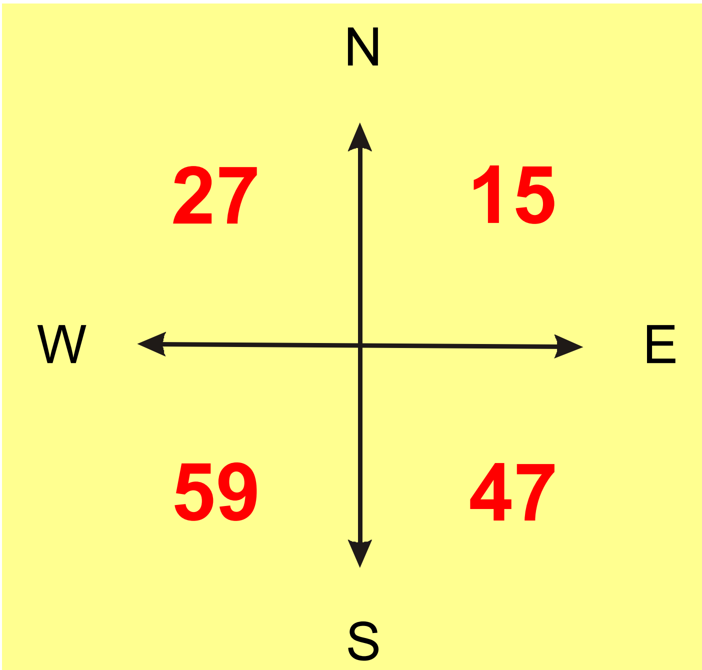
Ecological Return on Management Investment

Effect of soil organic C on soil organisms

Soil Organic C
(mg g^{-1} soil)

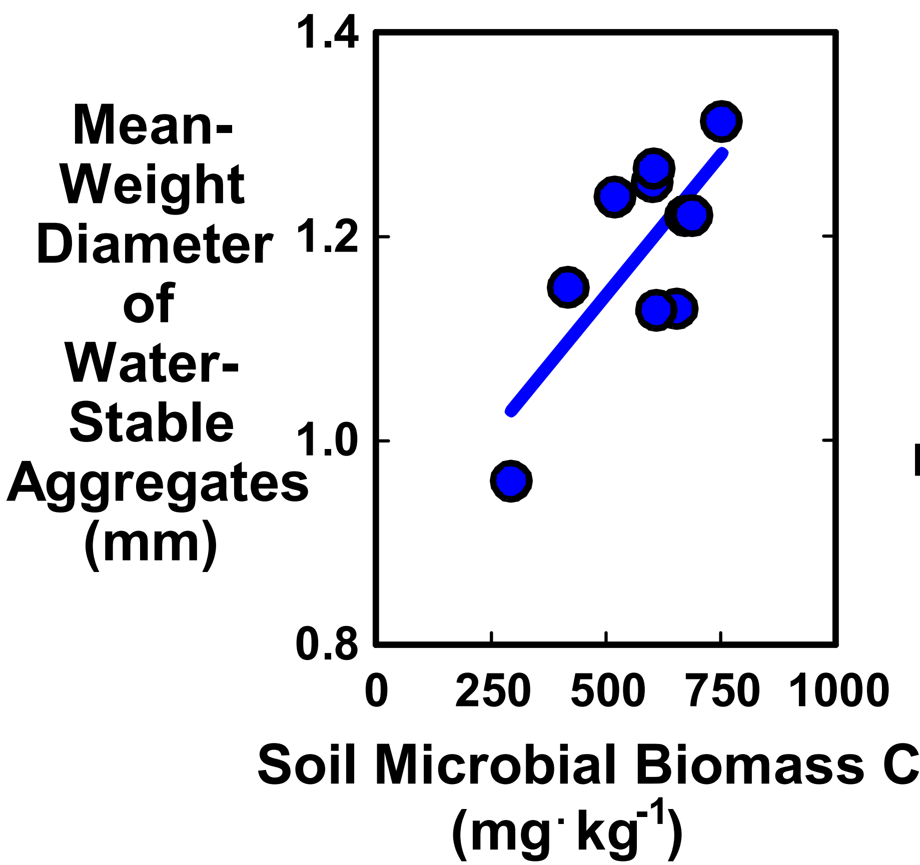


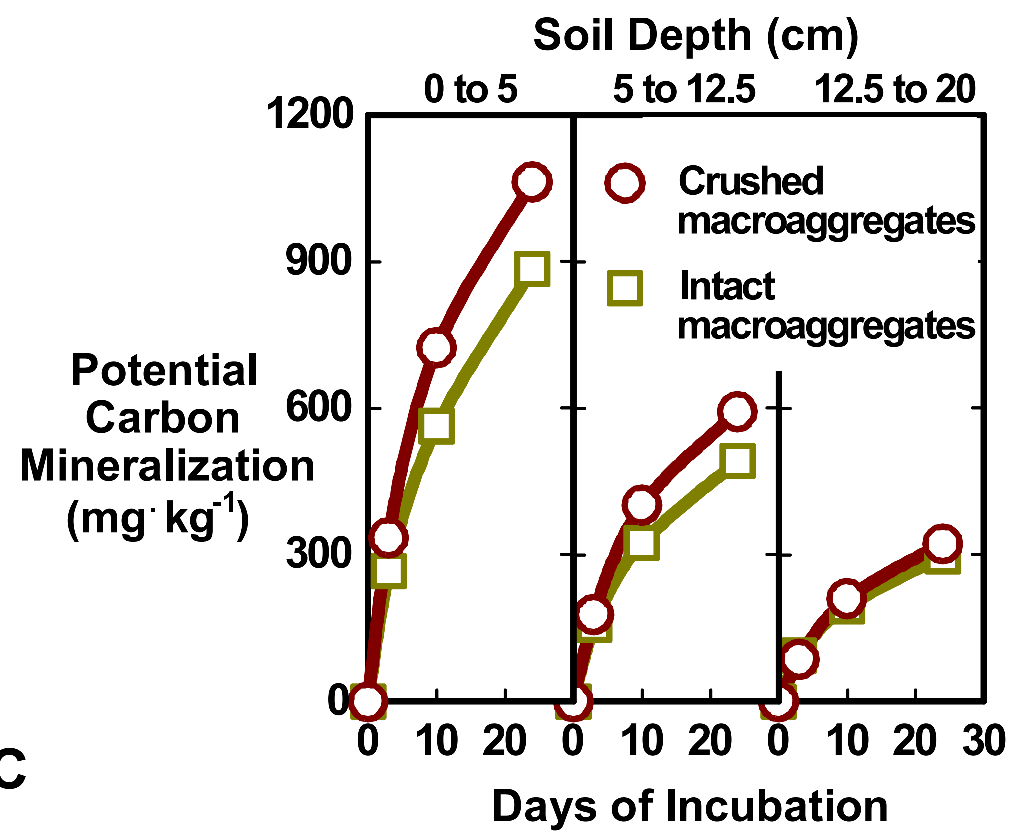
Soil Microbial Biomass C
(mg g^{-1} SOC)



Ecological Return on Management Investment

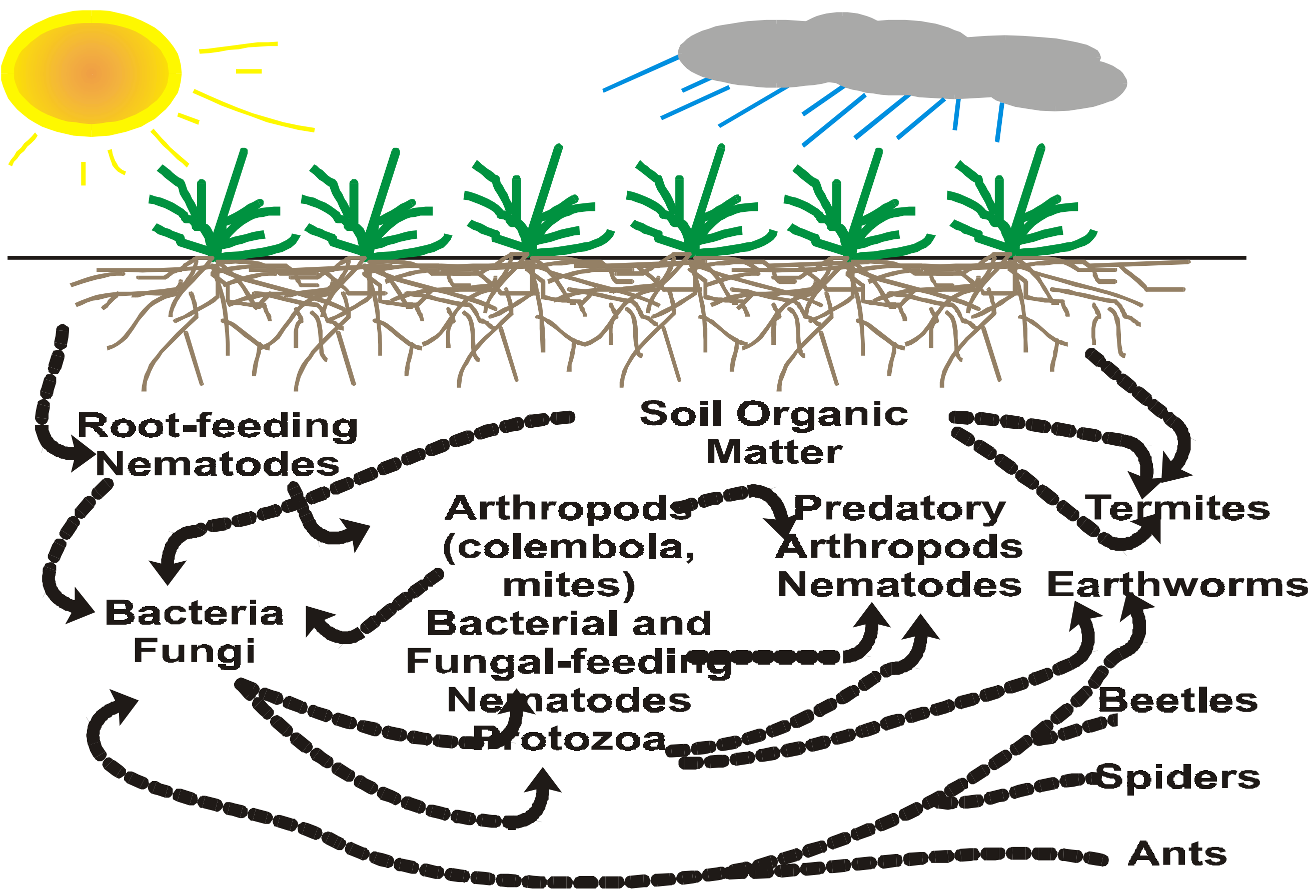
Biological and physical associations





Ecological Return on Management Investment

Biological diversity and ecosystem stability



Increasing soil organic C generally increases biological diversity and ecosystem stability through biotic interactions of the soil food web

- ☐ competition
- ☐ exclusion

Economic Return on Management Investment

Soil organic C and grazing

Property	Unharvested	Hayed	Grazed
Forage yield (kg/ha/yr)	0	7600	0
Live-weight gain (kg/ha/yr)	0	608	625
Gross return ($/ha/yr)	0	1003	1031
Input costs ($/ha/yr)	minimal	450	300
Net return ($/ha/yr)	**<0**	**553**	**731**
Soil organic C (kg/ha/yr)	**650**	**290**	**1400**
Other ecological benefits	?	??	??
Economic value of ecological benefits	???	???	???

Summary

Soil organic matter improves soil function . . .

- as a plant growth medium
  - increases nutrient reservoir
  - buffers pH changes
  - improves rooting environment (structure, porosity)
  - harbors plant-growth promoting rhizobacteria
- to help regulate and partition water flow in the environment
  - increases water infiltration
  - increases water retention
- as an environmental buffer
  - increases biological diversity for ecosystem stability
  - harbors microorganisms for decomposition and detoxification
  - mediates water quality impacts
  - reduces greenhouse gas emission

Outlook

Need for research

What are the forage mixes that provide the greatest soil organic C accumulation?

- Are these mixes the same that could create an optimum balance with agronomic productivity and economic return?
- Are these mixes similar on a wide range of soils?

- What are the biophysical limits under which cattle grazing systems impart negative and positive effects on carbon cycling and ecological function?

  - Are there soil type interactions with climatic regime?
  - Does management style interact with the environment?