Grassland Restoration from Cropland

Roser Matamala, Julie D. Jastrow,
R. Michael Miller
Argonne National Laboratory

Collaborators: Miquel Gonzàlez-Meler and
Sarah O'Brien
University of Illinois at Chicago

Washington, DC
December 8,9 2004

Rationale

- Land cover is an important determinant of soil C storage and dynamics.
- Conversion from native vegetation to cropland leads to a rapid depletion of SOM, estimated in 30-40% of the original SOM.
- Restoration of degraded soils and ecosystems is a major strategy for reversing SOM losses and enhancing soil C sequestration

- Re-growth of deciduous forests
- changes in agricultural practices
- and restoration of degraded ecosystems and CRP practices

Importance of grassland

- Soils originated under prairie are deep and fertile and have greater capacity to accumulate carbon than forests with similar environmental characteristics
- This soils were promptly converted to agricultural use since early settlement and constitute most of the Corn Belt Region of the U.S. Midwest.
- We want to determine the C sequestration potential of long-term cultivated land after restoration to grassland and the mechanisms involved.

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Restoration of Tallgrass Prairie at Fermilab

Fermilab was established in 1969 in Batavia, Illinois. The site had been farmland for over 100 years, with corn, wheat and dairy activities.

Restoration of native tallgrass prairie began in 1974. Annual plantings create a chronosequence of restorations encompassing over 400 hectares.

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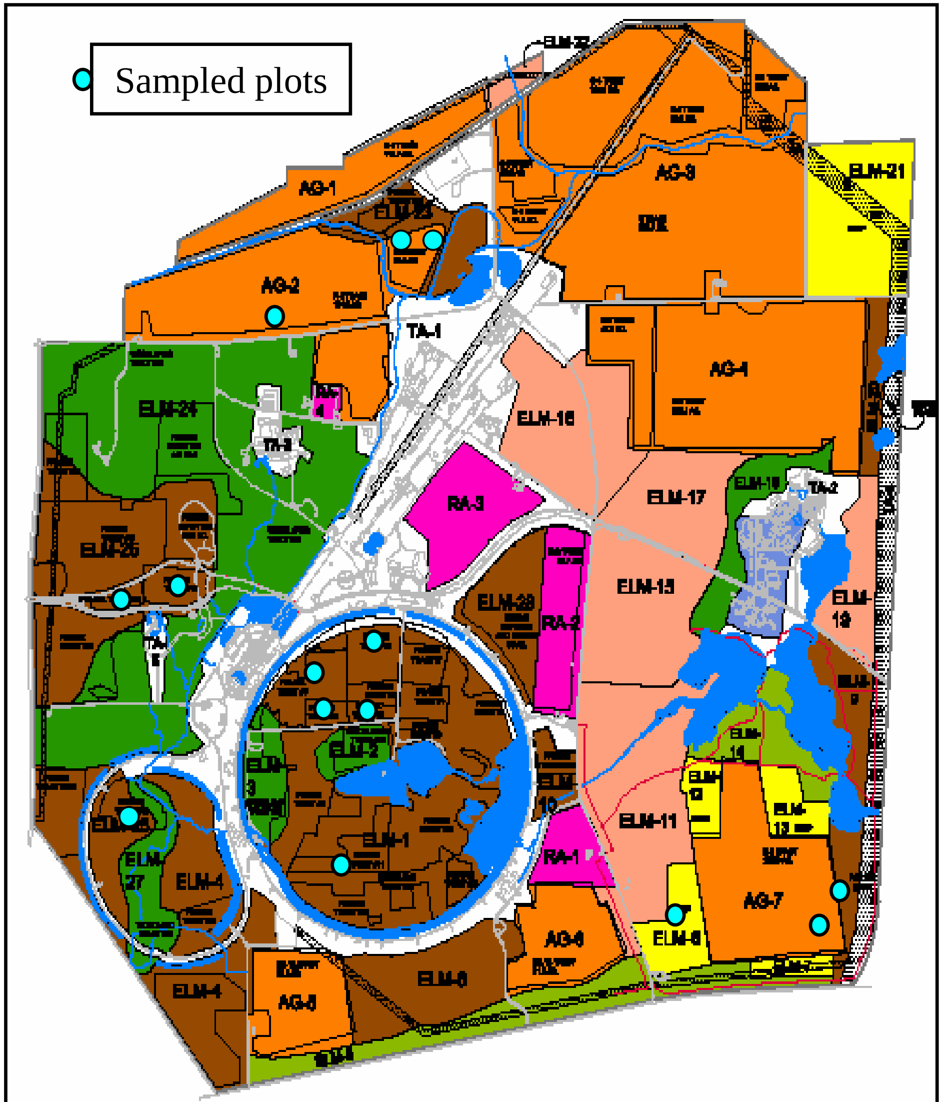
Prairie restoration process

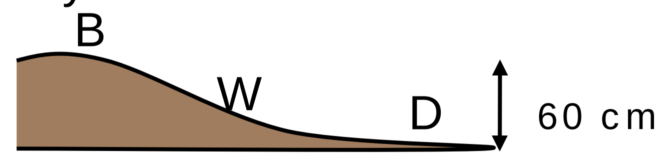
Initially the land is disked and seeded with prairie plant seeds. The landscape is dominated by species typical of old-field succession during the first few years after planting (annuals → biennials → weedy perennials).

Then, once litter buildup is sufficient to carry a fire, prairie grasses, C3 and C4 and forbs begin to out compete the weeds.

Chronosequence Studies



- Soil series:
  - Barrington, mesic silt loam
  - Wauconda, mesic silt loam
  - Drummer, wet mesic silty clay loam

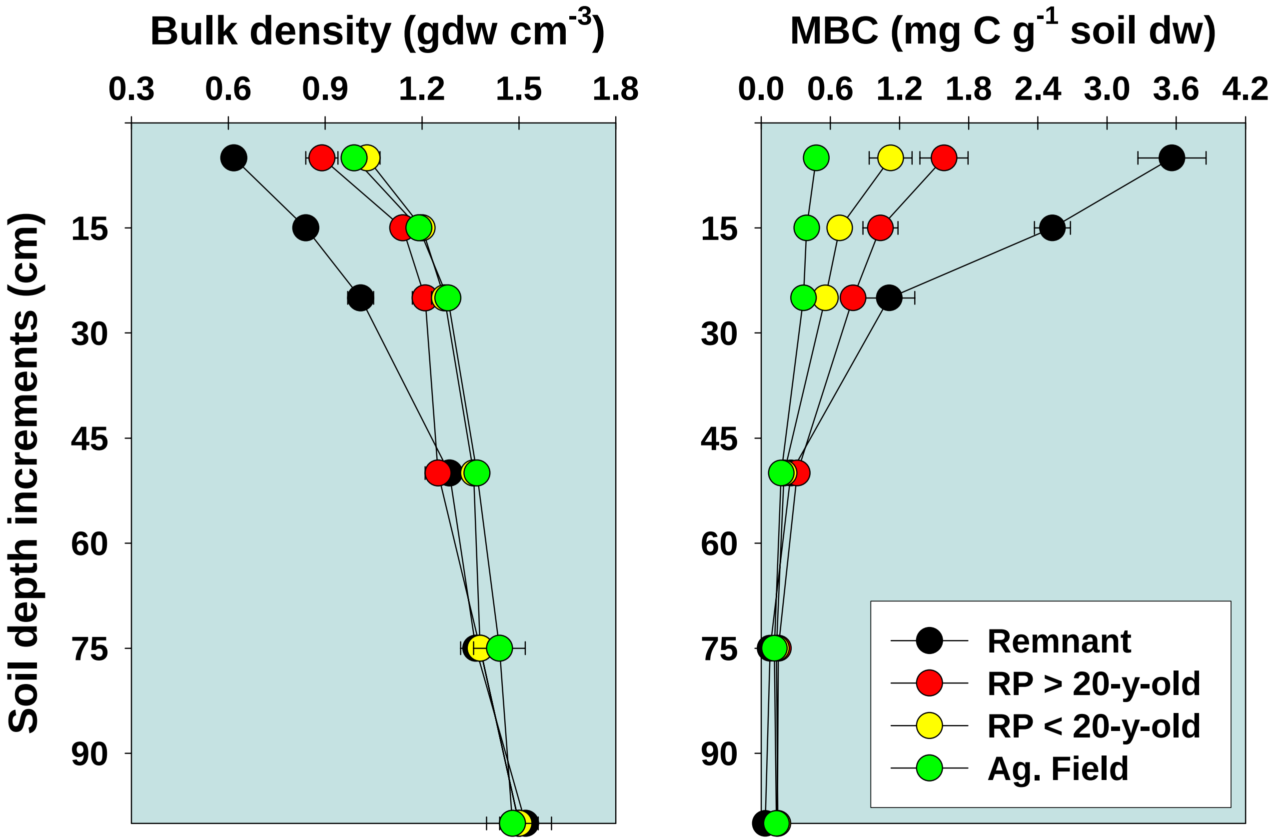


- Sites:
  - 3 remnants
  - 9 restored prairies

    (2,5,8,14,15,18,21,23,25 yrs old)
  - 4 cultivated fields
  - Sampling depth, 1 m

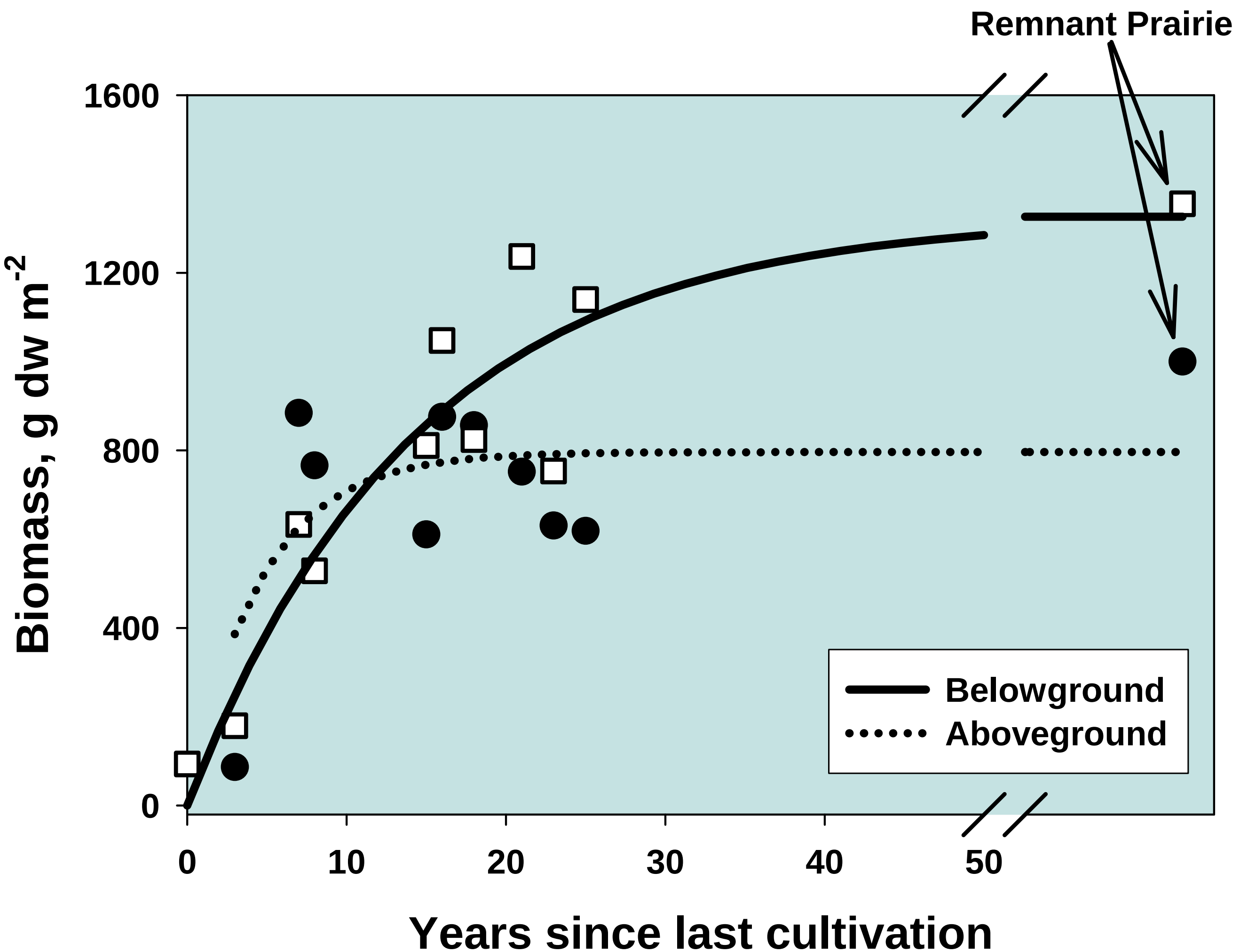
Cultivation results in changes to

- Above and belowground production
- Hydrology,
- SOM, bulk density
- Microbial community species and total mass



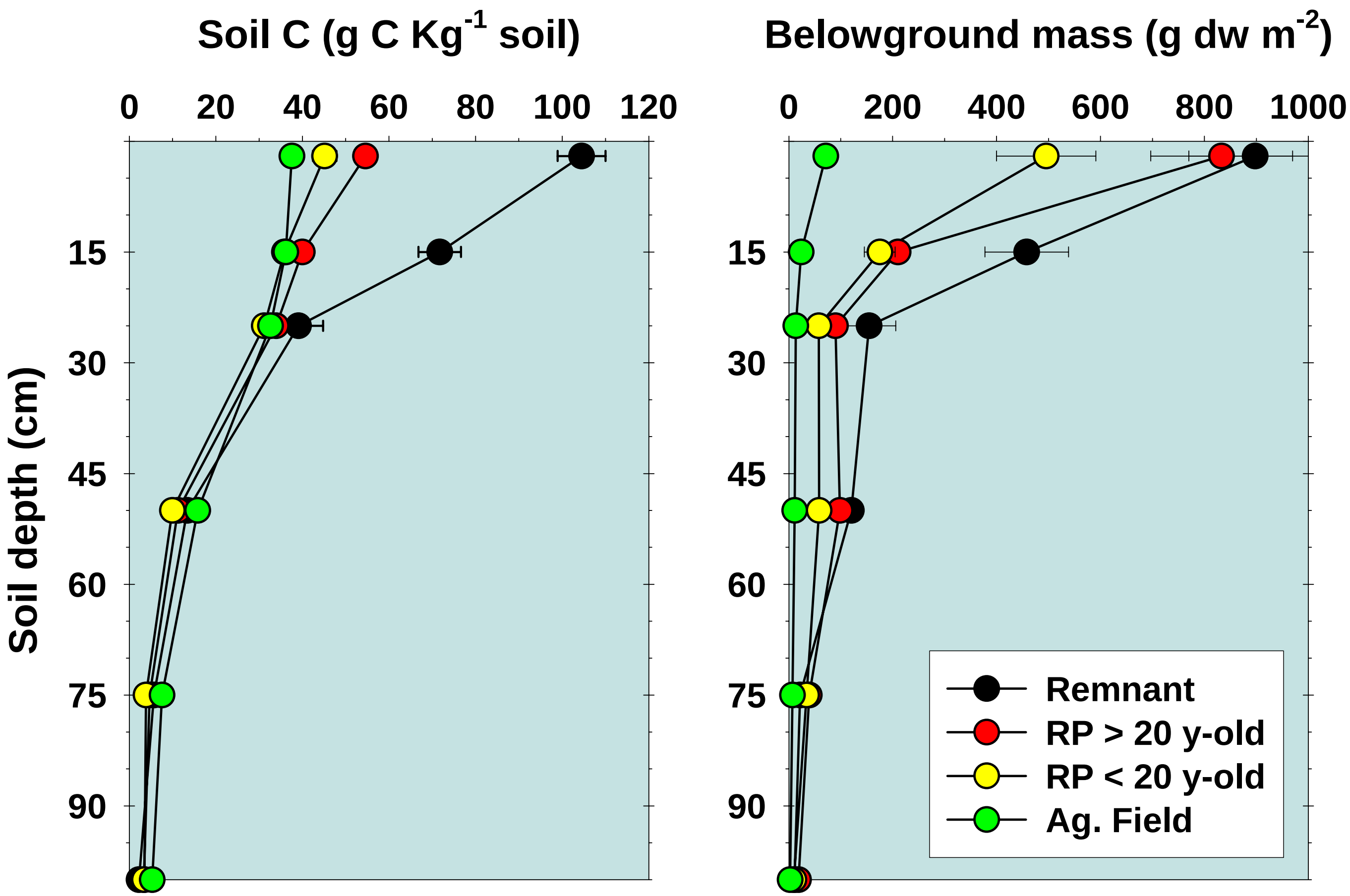
Recovery of C stocks in the vegetation:

the speed of recovery of the aboveground and belowground production is different



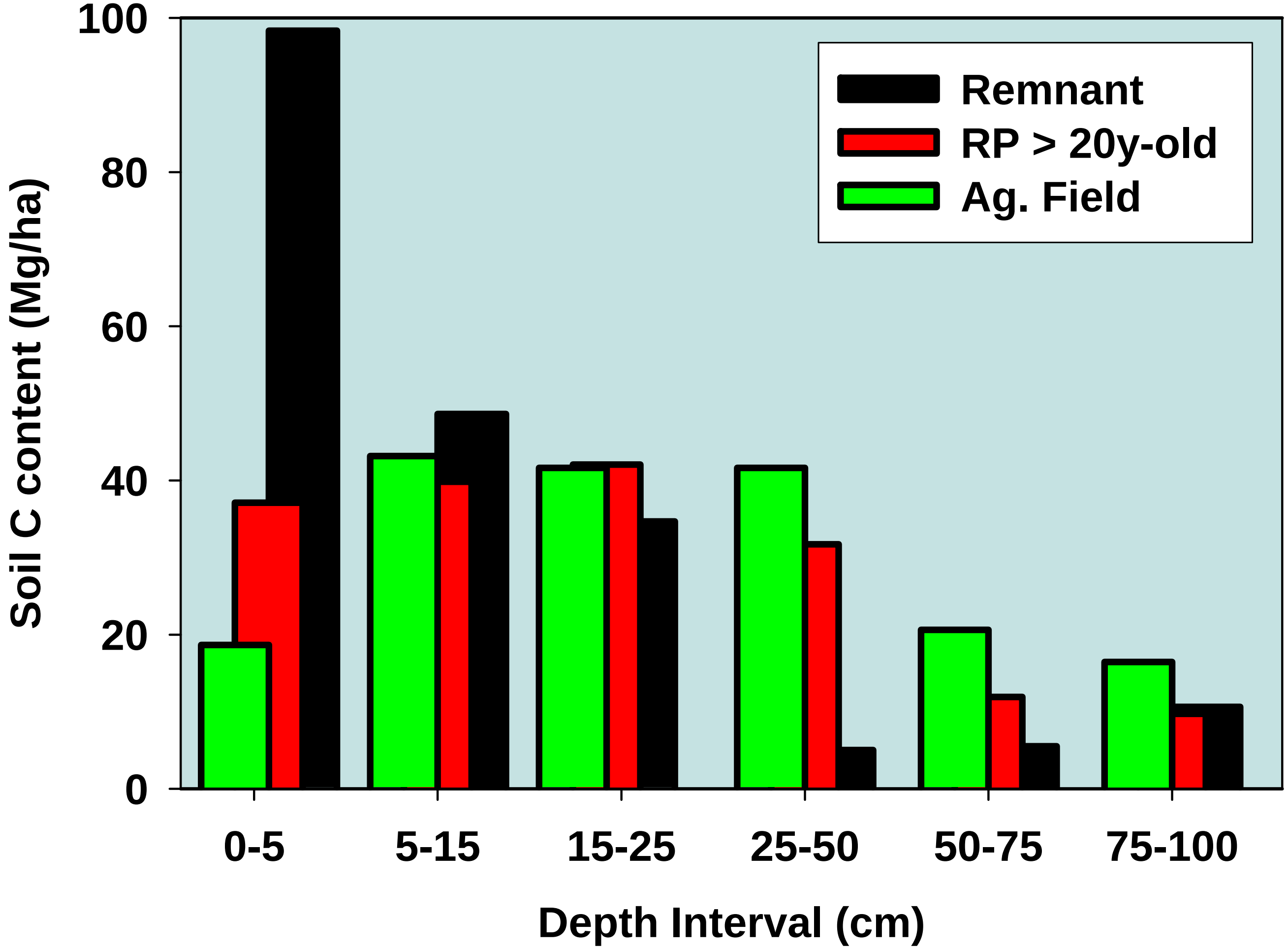
Recovery of soil C

- Depletion of SOM in the soil occurs at the depth of plowing
- Potential for long-term soil C accrual to 15 cm
- Root and rhizome inputs drive changes in soil C

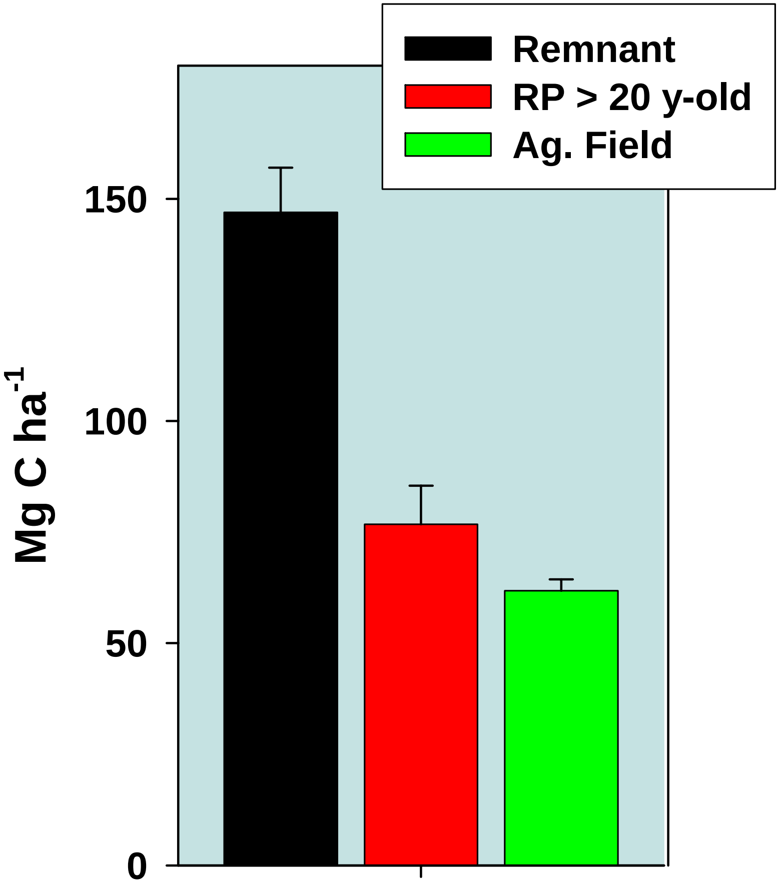


Soil C content in equivalent soil mass

C losses and future gains



C sequestration potential of restored prairie on Drummer soils

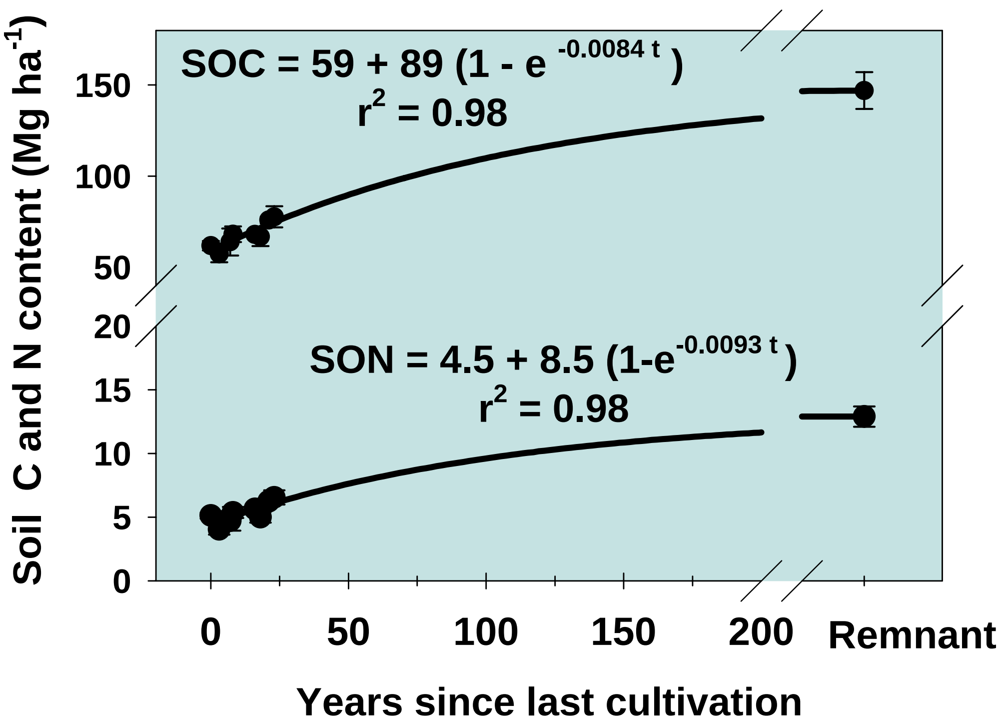


Total C content to 0.15 m depth

- Cultivated wet mesic drummer soils that have undergone prairie restoration have a carbon storage potential of about:
  - 80 Mg ha^{-1}

  In the 0-15 cm of the soil profile.

Rate of C and N accrual after prairie restoration

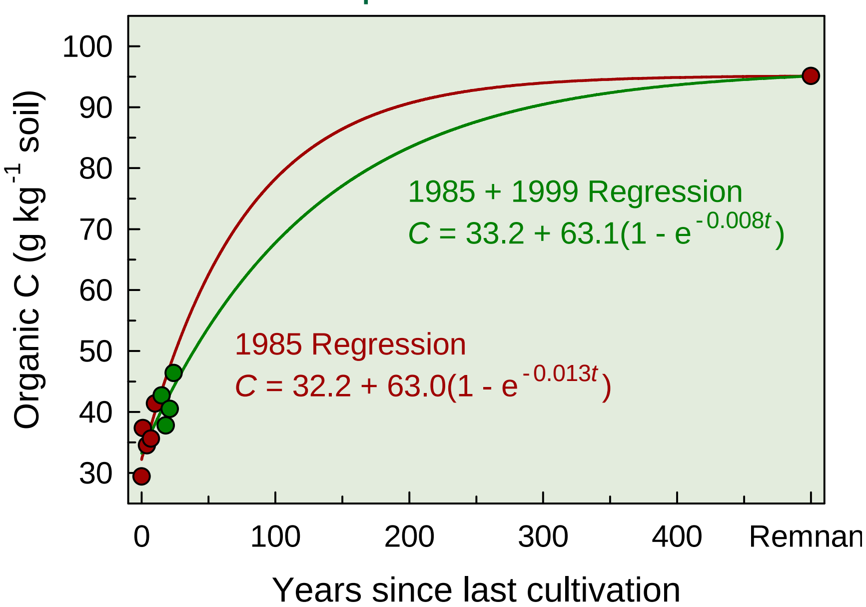


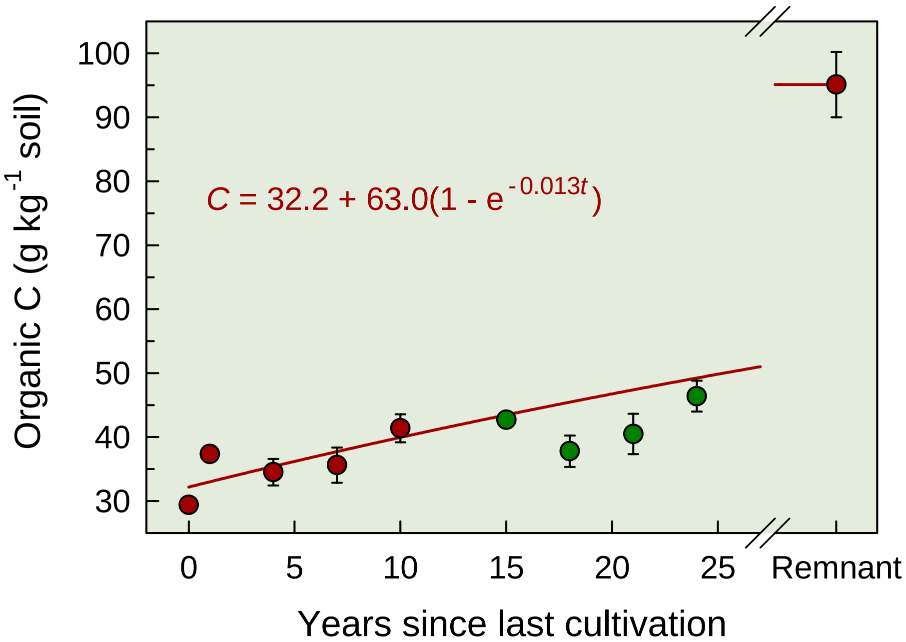
- The rate of C accrual of the restored prairie on drummer soil is steady and rapid, accounting for:
  - 0.67 Mg C ha^{-1}
  - 0.07 Mg N ha^{-1}

  In the 0-15 cm of the soil profile.
- 50% of the potential C sink can be achieved in about 60 yrs.

Validation of the chronosequence approach: Predicted versus observed

0-10 cm depth





Age	Predicted	Measured
15	43.4	42.7
18	45.3	37.8
21	47.2	40.5
24	49.0	46.4

Average difference = - 4.4

Paired t test $p = 0.075$

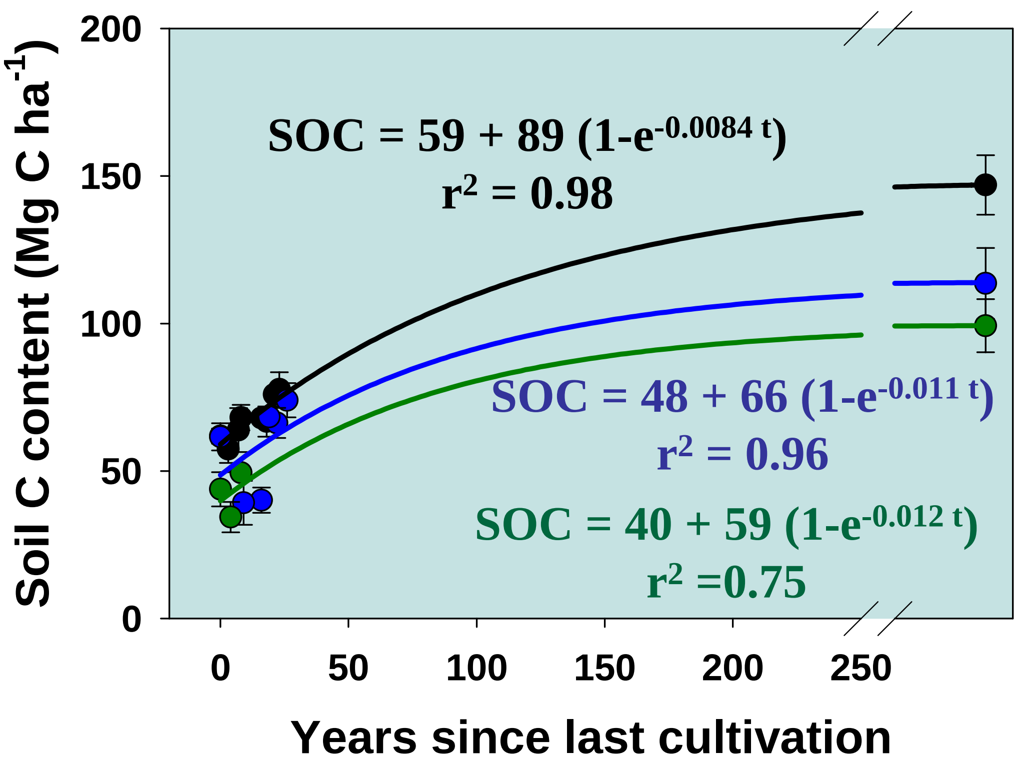
What factors affect the rate of C accrual

- **Effects of soil type**:
  - Moisture content
  - Soil stabilization
  - Nitrogen

- **Effects of plant diversity**:
  - Grassland with C_3 species versus grasslands with C_3-C_4 mixed species

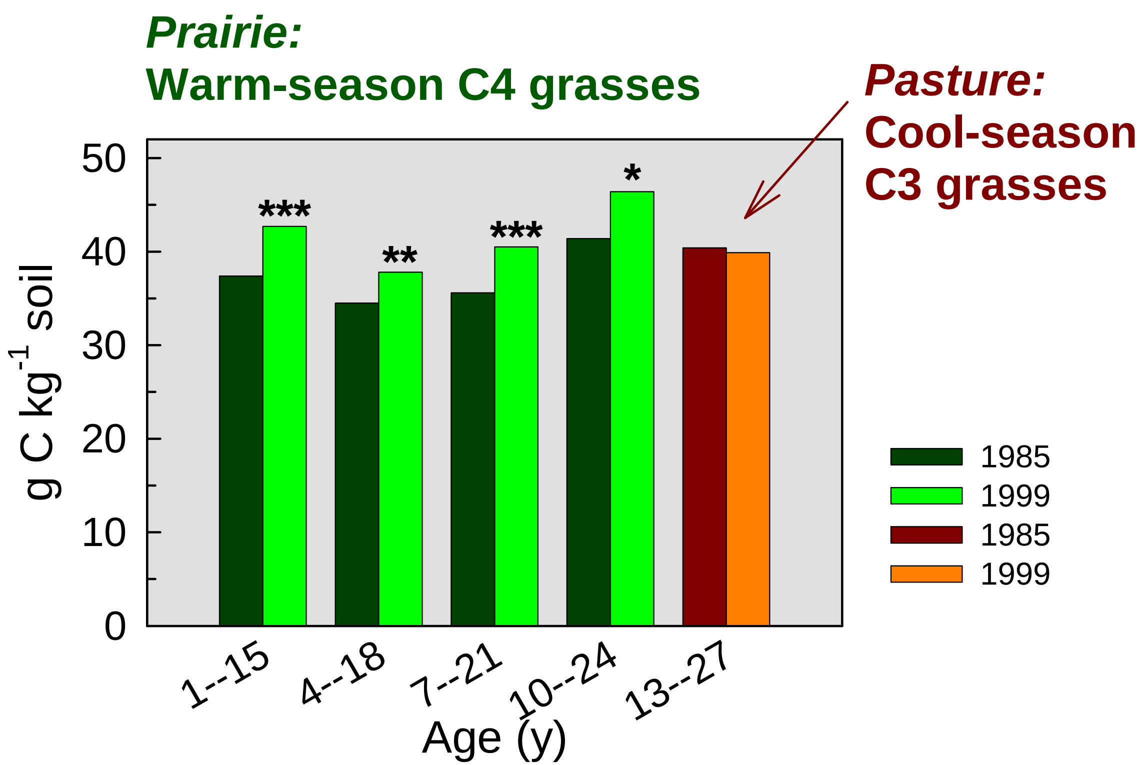
How does soil type affects the rate of C accrual

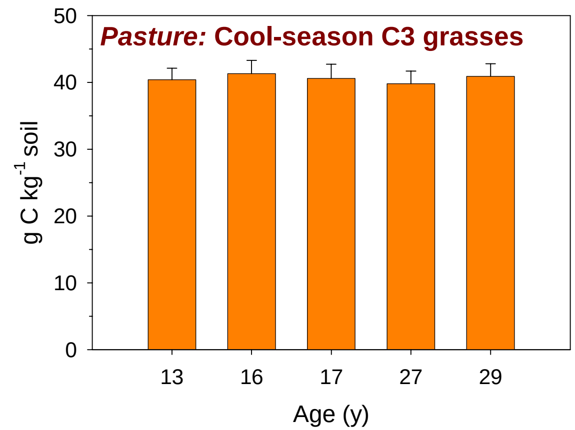
- Equilibrium C depends on moisture
- Initial rates of C accrual similar
- Time to equilibrium may vary



Soil C 0-15 cm	D	W	B
Ce *Mg C ha*$^{-1}$	150	114	100
1/*k*	120	90	83
$t_{50\%}$ y	60	42	42
$t_{95\%}$ y	355	270	250

Grassland type influences soil C accrual





Repeated measure of marked sampling sites

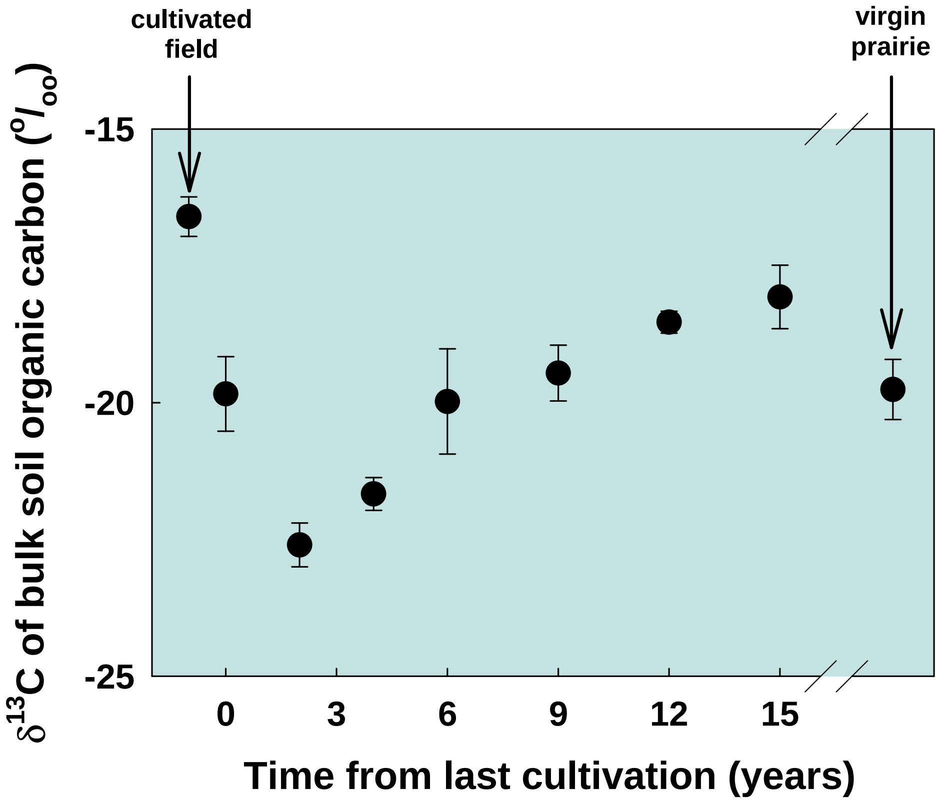
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$
based on paired t tests.
0-10 cm depth

- ⇨ Prairie increments verify modeled rates
- ⇨ Pasture grasses reached equilibrium by 13 years
  - ➢ Lower productivity (fertilizing might raise equilibrium)
  - ➢ Timing and quality of inputs affect decomposition
  - ➢ Length of effective growing season

There is a change in the source of the SOM with age

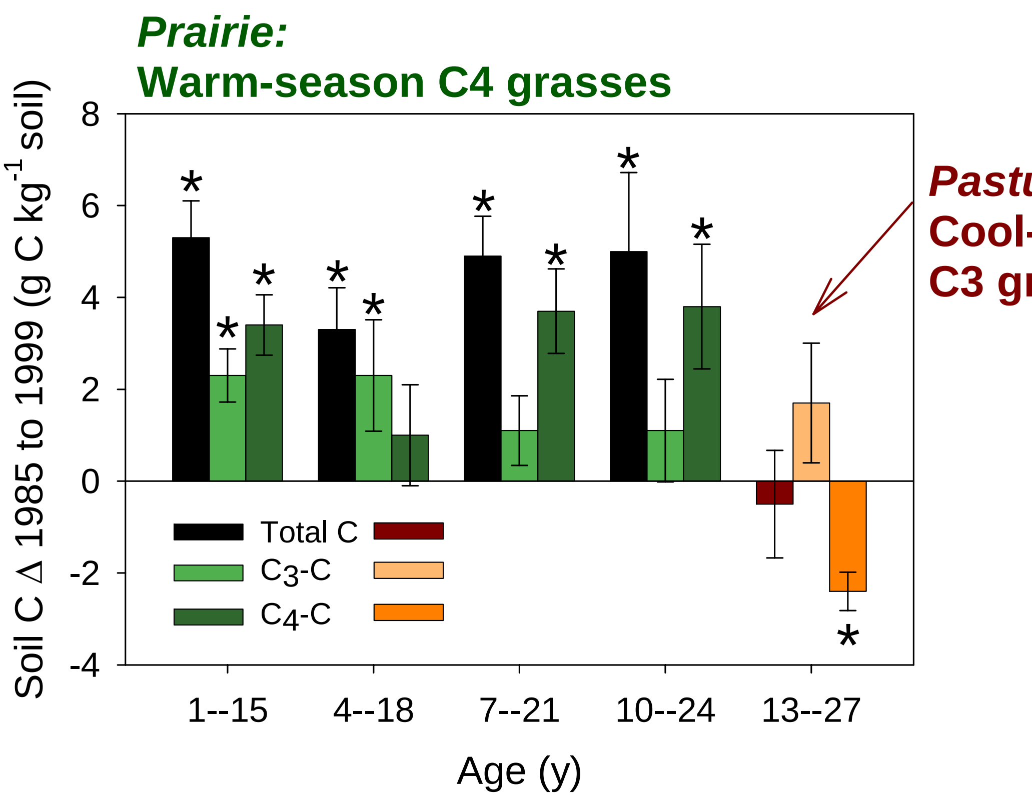
C_3-C is rapidly incorporated into SOM but, C_4-C appears to accrue steadily after initial stages of restoration.

From a C-management point of view, is C_3 or C_4 better for transferring atmospheric carbon to the belowground?.



Stable isotopes indicate C sources

- In prairie, C_4-C generally accounts for most of accrual
- C_3 pasture are balancing loss of C_4-C
- This indicates that C_3 derived C cycles at different speed than C_4-derived C



Isotopic Partitioning of Soil Respired CO_2 ($\mu molCO_2 m^{-2}s^{-1}$)

Soil Respiration **Late 2001**		
Site (age in yrs)	**C_3**	**C_4**
Remnant prairie	**6.4**	**13.1**
C_3 pasture	**11.3**	**0.0**
Restored prairie (23yrs)	**6.5**	**12.7**
Restored prairie (9yrs)	**4.2**	**6.8**
Restored prairie (2yrs)	**8.2**	**5.1**

Soil Respiration **Early 2002**		
Site (age in yrs)	**C_3**	**C_4**
Remnant prairie	**7.8**	**0.04**
C_3 pasture	**6.7**	**0.0**
Restored prairie (24yrs)	**5.6**	**3.1**
Restored prairie (10yrs)	**3.5**	**5.3**
Restored prairie (3yrs)	**7.9**	**0.3**

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Conclusions

- **Cultivation causes a depletion of SOM at the depth of plowing and a redistribution of C to deeper depth.**

- **The recovery of aboveground cover to levels of a remnant prairie occurs in the first 10 years of restoration. But the recovery of the belowground is slower and takes approximately 40 years. Belowground productivity is the main factor for SOM recovery.**

- **Prairie restoration of croplands recovers SOM at an average rate of 0.67 Mg C ha^{-1} y^{-1} in the surface 15 cm of the soil during initial stages of restoration. Nitrogen follows C recovery.**

- **Soil type, moisture and slope influences the capacity of the soil to accrue carbon. Wet soils accrue more carbon although it needs a longer period of time.**

- **The presence of C_4 grasses increases the accrual of soil carbon.**

Significance & Summary

- Restored prairies can sequester up to 80 Mg C ha^{-1} in the first 15 cm of the soil profile, reaching 50% of this potential in about 60 years.
- The C sequestration potential of restored grassland depends on soil and vegetation types.
- Models might have underestimated C sequestration potential for grasslands.

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