Terrestrial Carbon Sequestration: Processes, Practices, Potential

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The Goal:

Minnesota's Next Generation Energy Act

targets ambitious CO_2 emission reductions:

15% reduction	by 2015
30% reduction	by 2025
80% reduction	by 2050

Strategies to mitigate CO_2 emissions

DIRECT

Reduce use of fossil fuel

i.e.

Increase conservation,

Use of alternative energy sources

INDIRECT

Terrestrial C sequestration

i.e.

Land use & management changes

Policies rely heavily on terrestrial C sequestration to offset CO_2 emissions

ID Soil Conservation Commission:

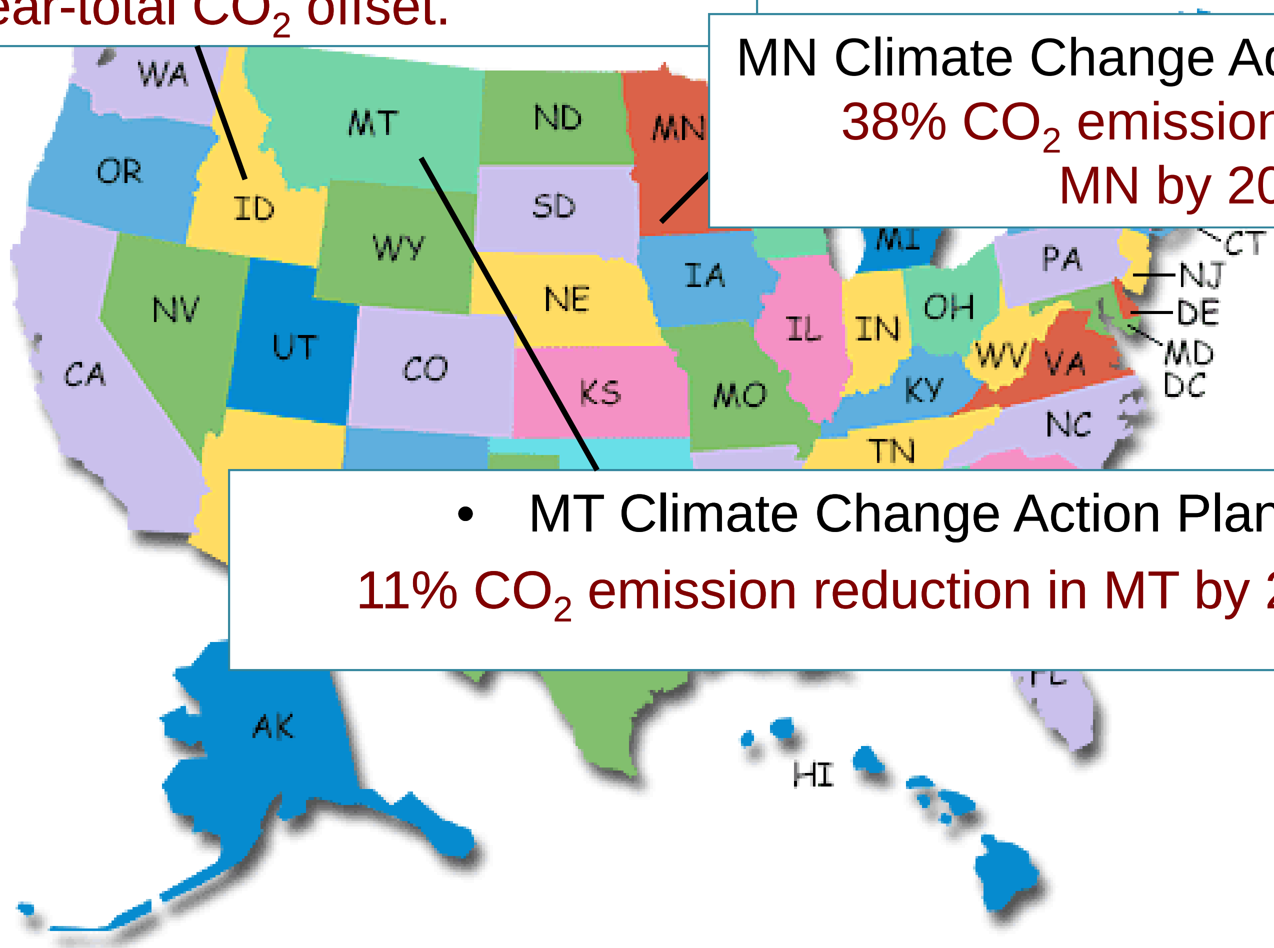
Near-total CO_2 offset.

MN Climate Change Advisory Group:

38% CO_2 emission reduction in MN by 2025.

- MT Climate Change Action Plan:

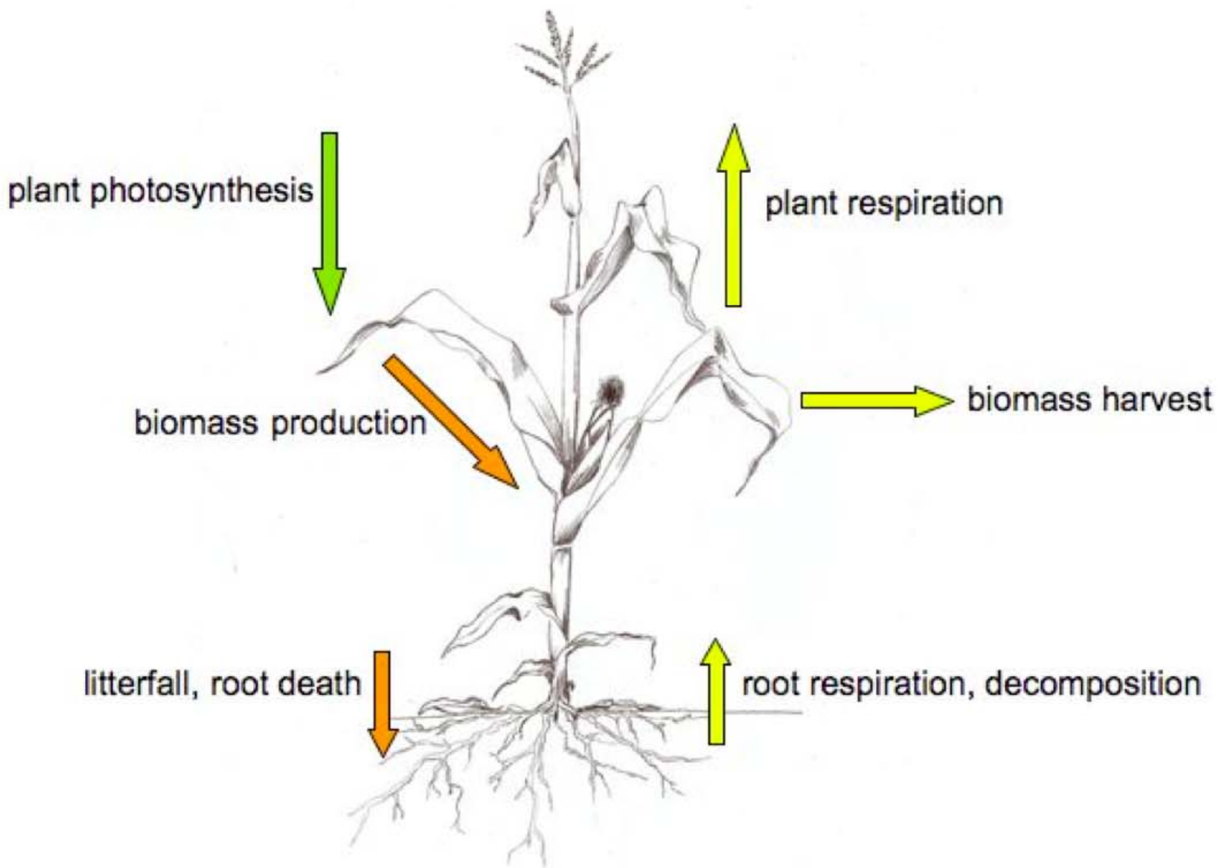
11% CO_2 emission reduction in MT by 2020.



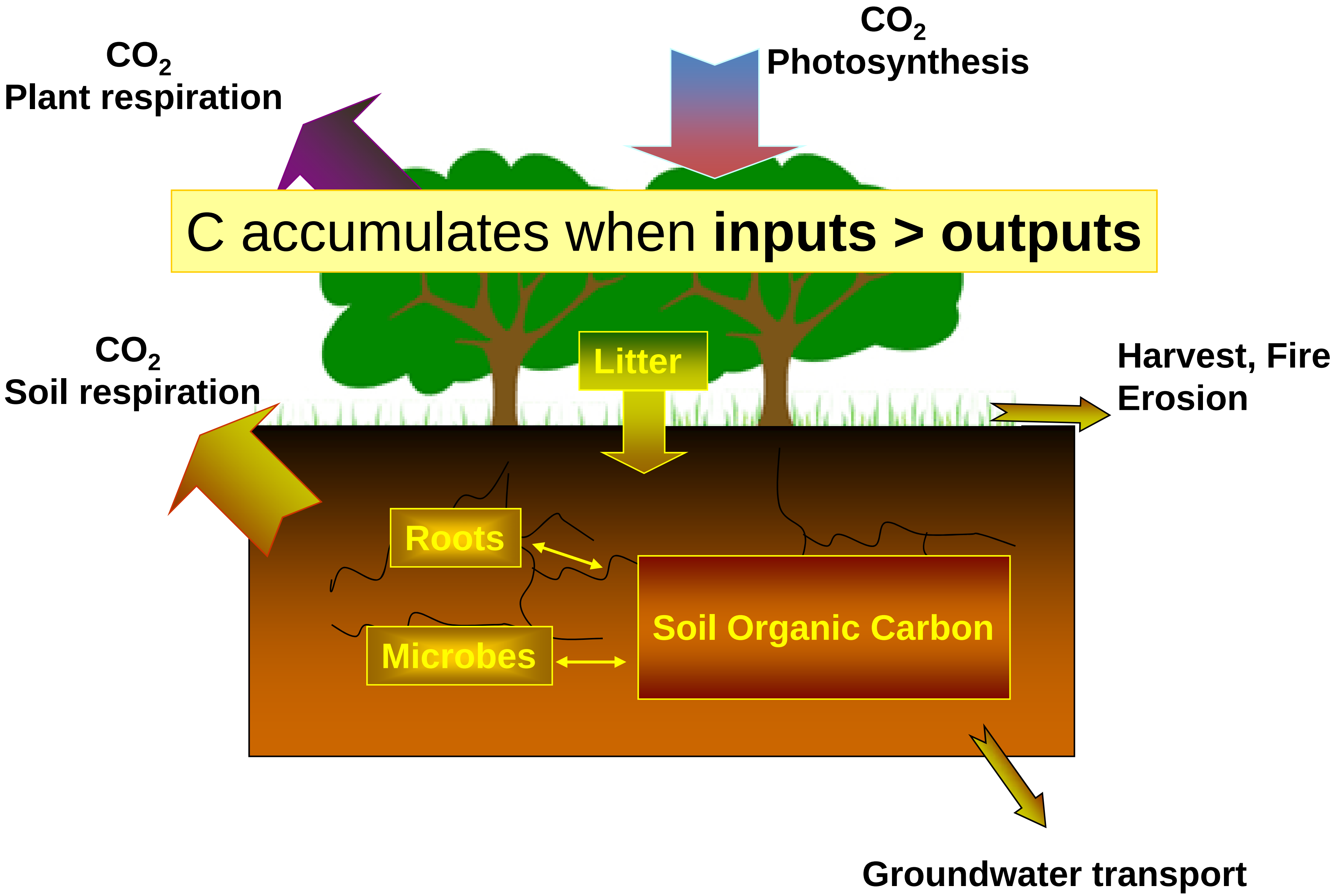
What is Terrestrial Carbon Sequestration?

- Accumulation of C (carbon) in a terrestrial “pool” at the expense of the atmospheric pool

Carbon exchange

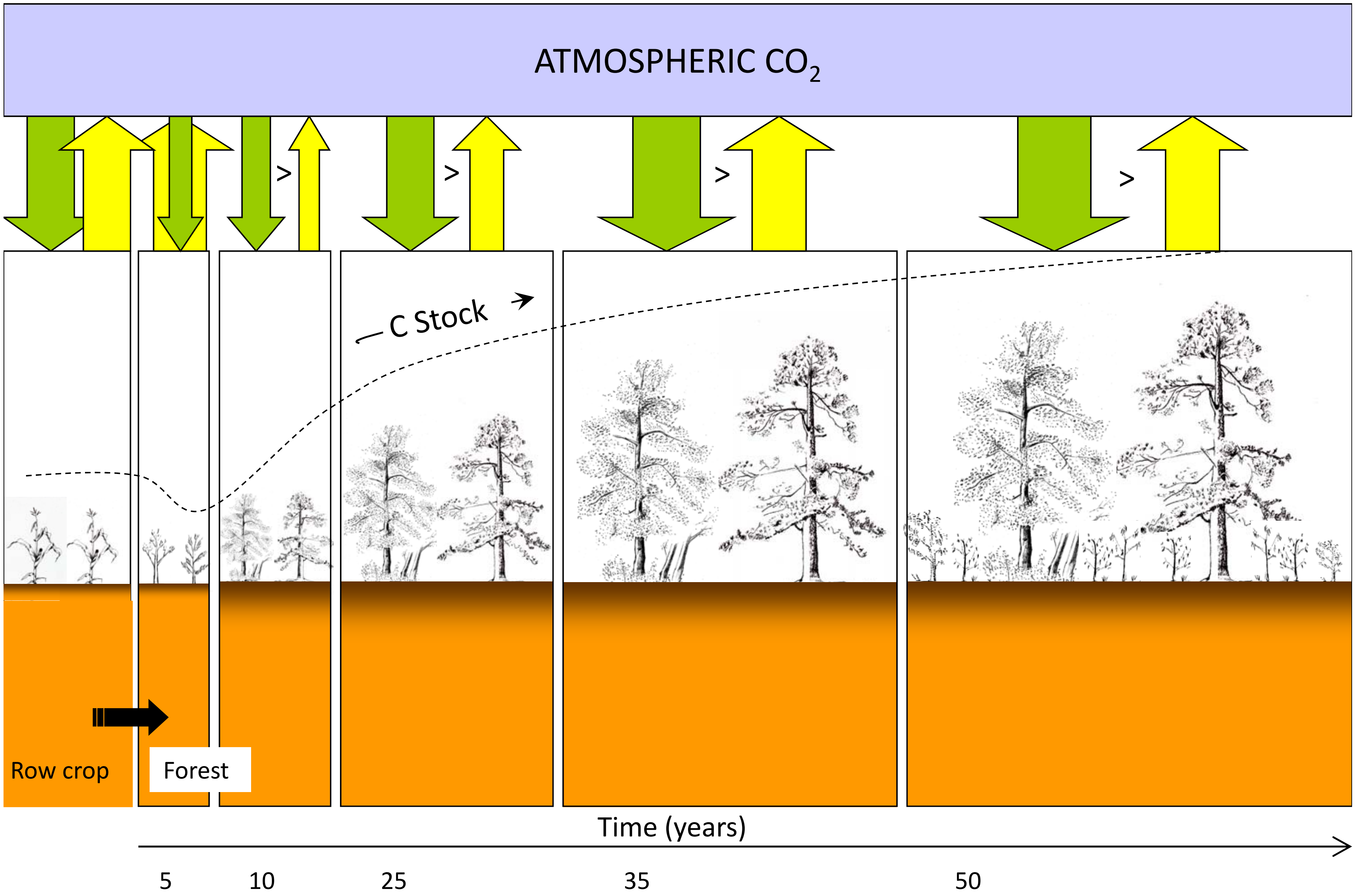


Terrestrial Carbon Cycle



To sequester C we need to:

- Increase biomass or
- Increase soil organic matter
- Requires changes in land use or management


ATMOSPHERIC CO2
>
>
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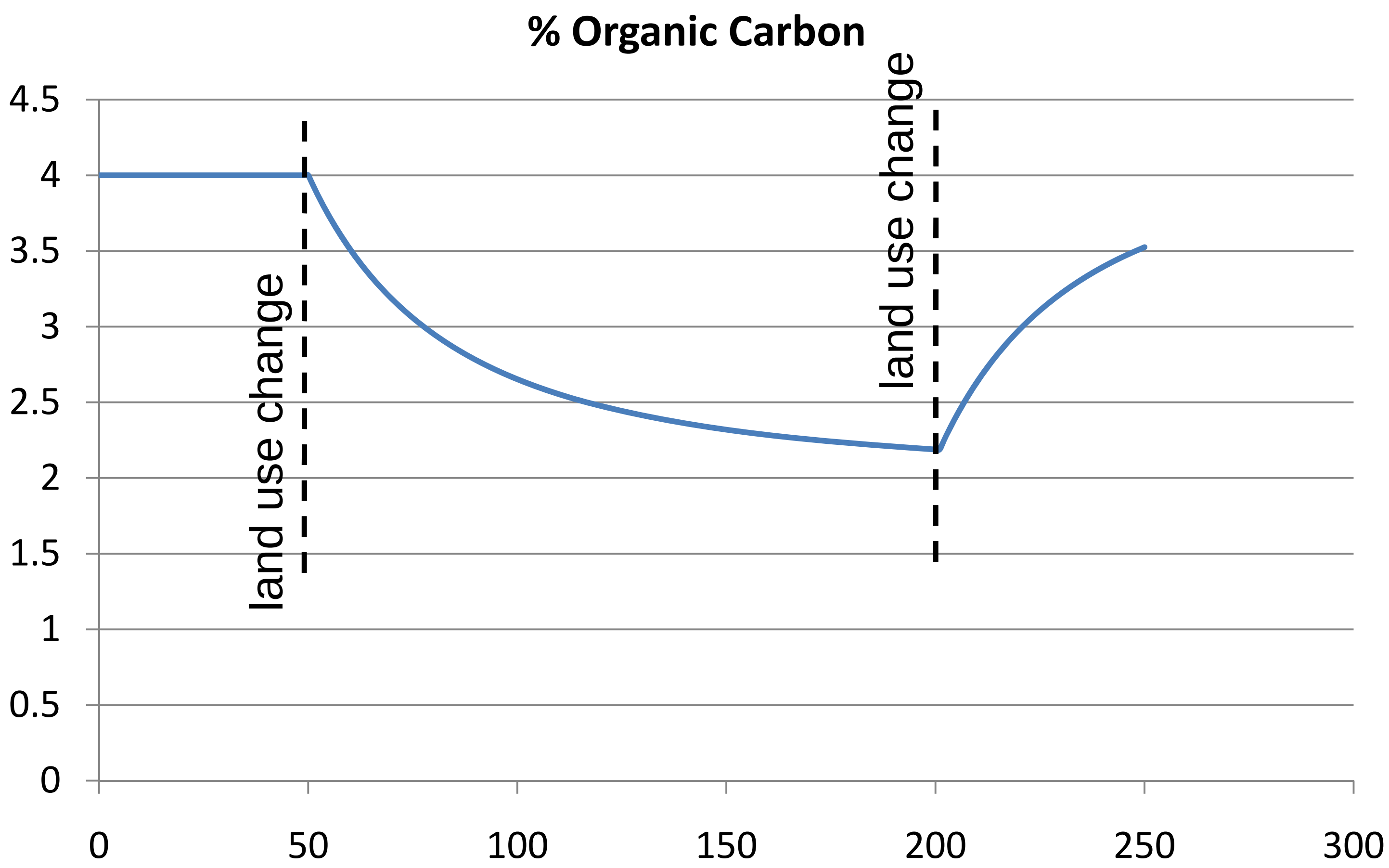
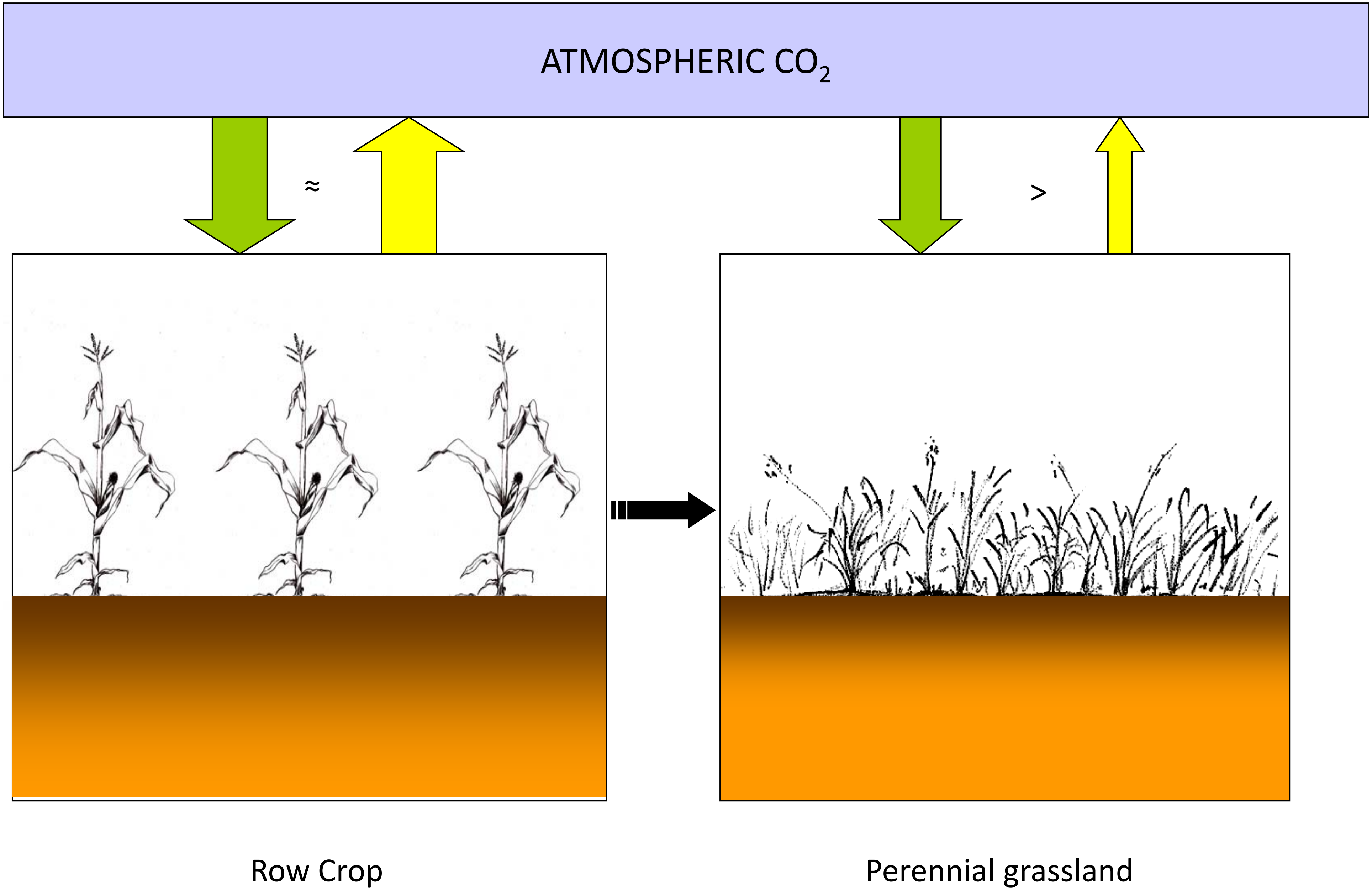
C Stock
Row crop
Forest
Time (years)
5
10
25
35
50

Carbon-depleted landscapes



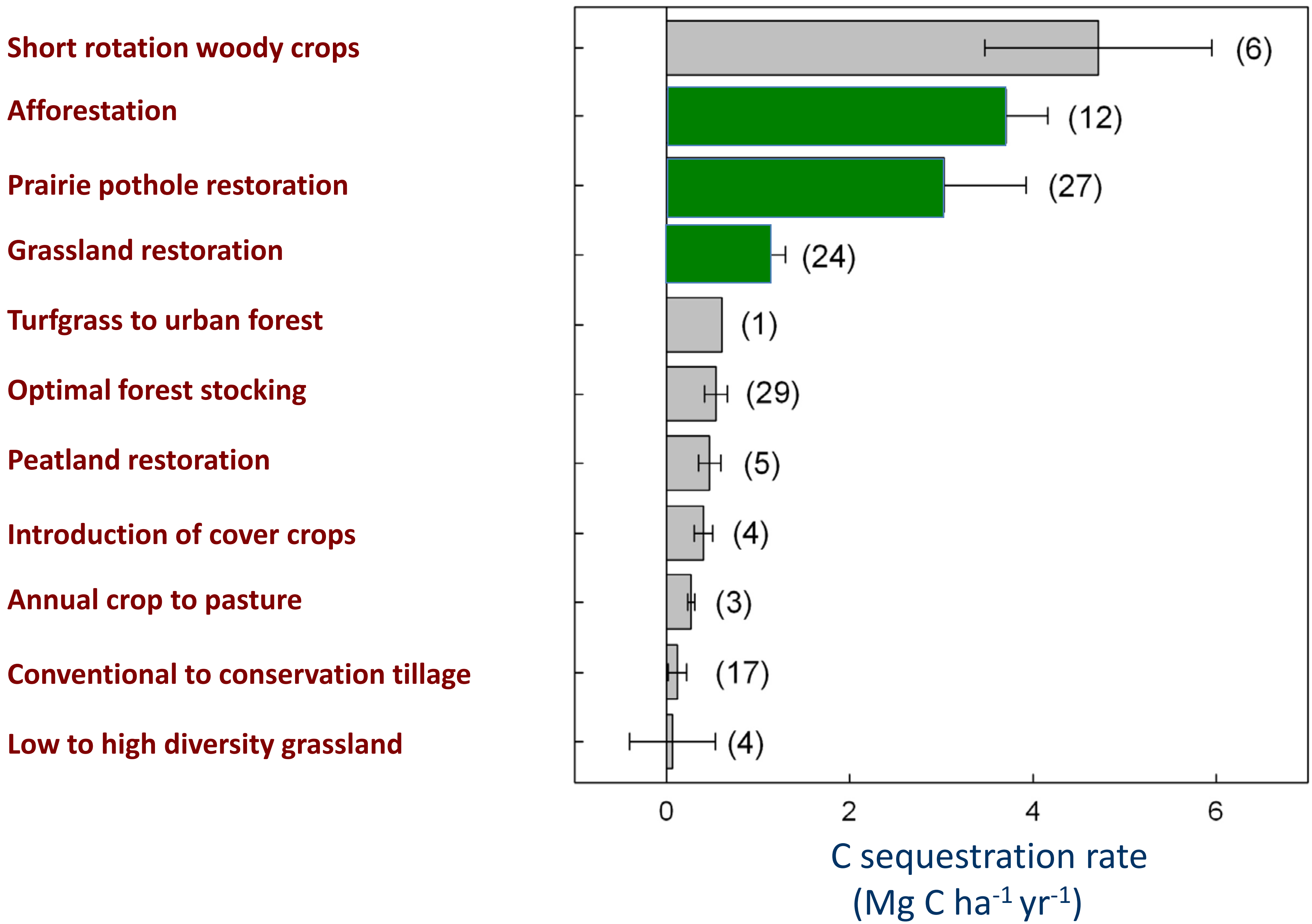

ATMOSPHERIC CO_2
≈
>
Row Crop
Perennial grassland

Processes Responsible for Terrestrial Sink

- Enhanced sinks due to atmospheric changes:
  - CO_2 fertilization
  - N fertilization (effective for biomass, but not necessarily for soils)
- Enhanced sinks due to land use/land management
  - Fire suppression
  - Woody encroachment
  - Forest regrowth following agricultural abandonment
- Enhanced sinks due to climate change
  - longer growing season

Processes Counteracting Terrestrial C Sink Now and in the Future

- Ozone
- Climate change: drought - reduce plant growth
- Climate change: warming - enhanced respiration of soil C
- Permafrost melting: 400 Mt C in permafrost
- Peatland drainage due to climate or agriculture
- Deforestation/biomass burning

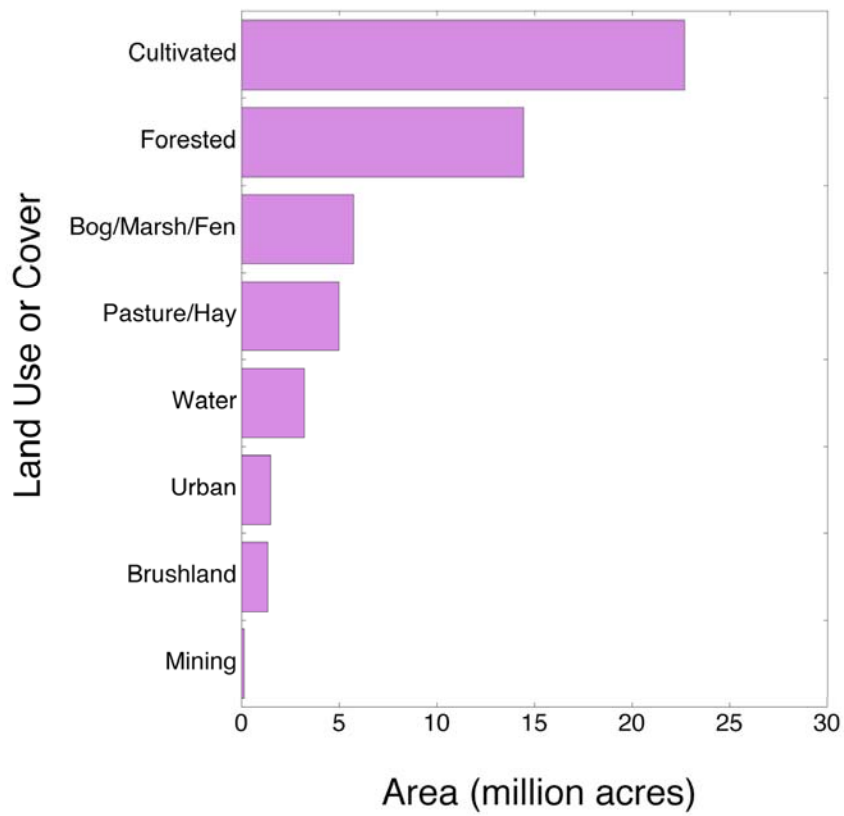


Short rotation woody crops
Afforestation
Prairie pothole restoration
Grassland restoration
Turfgrass to urban forest
Optimal forest stocking
Peatland restoration
Introduction of cover crops
Annual crop to pasture
Conventional to conservation tillage
Low to high diversity grassland
(6)
(12)
(27)
(24)
(1)
(29)
(5)
(4)
(3)
(17)
(4)
0
2
4
6
C sequestration rate
(Mg C ha^{-1} yr^{-1})

Minnesota Land Use

Land Use Category	Million Acres in 1990 (% of Total)
Urban	1.47 (2.7)
Cultivated	22.69 (42.0)
Pasture / Hay	4.98 (9.2)
Brushland	1.33 (2.5)
Forested	14.43 (26.7)
Bog / Marsh / Fen	5.73 (10.6)
Mining	0.15 (0.3)
Water	3.21 (6.0)
Total	53.99 (100.0)

Minnesota Land Use



Can we really offset CO_2 emissions by changing the way we use the land?

(if yes, how much?)

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Dept of EEB

Dept of Forest Resources

Scenario 1

- Land area required to achieve the MNCCAG recommendations of 38% of the 2025 reductions coming from terrestrial C sequestration
  - 50% from afforestation
  - 50% from prairie (perennial grasslands)

Scenario 2

- Relative percent of the 2025 reductions that can be obtained by converting 10% of MN agricultural lands to prairie or forest as ecologically appropriate.
  - 50% to forest
  - 50% to prairie

Results: Scenario 1

- To achieve 38% of the 2025 targeted reductions would require the conversion of:
- 1.56 million acres of row crop land to forest
- 5.38 million acres of row crop land to prairie

- the combined acres would represent 25.8% of Minnesota's 22.69 million acres of cropland

Results: Scenario 2

- Conversion of 5% of Minnesota row crop land to forest and 5% to prairie would sequester:
- 6.24 million metric tons of CO_2 by afforestation
- 1.81 million metric tons of CO_2 by prairie restoration

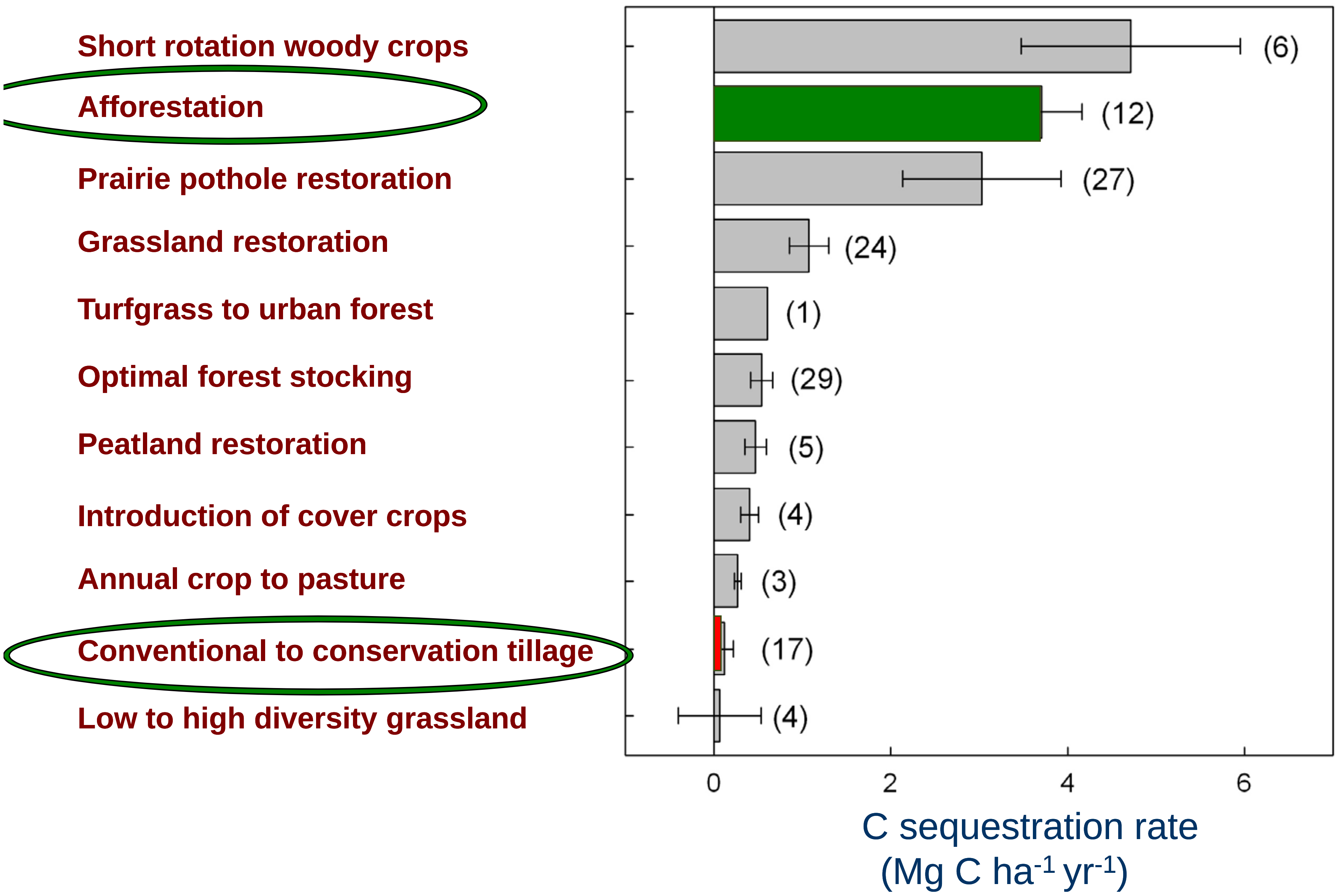
- the total quantity of CO_2 sequestered (8.05 MT) by converting 2.27 million acres (10%) of row crop lands represents 5.3% of Minnesota's 2002 emissions of 151 MT CO_2

Is this acceptable?

Direct or indirect C mitigation strategies?

INDIRECT		DIRECT
ca. 5.3% CO_2 emission reduction	≅	*ca. 5.3% CO_2 emission reduction*
Conversion of 2.3 million acres of agricultural land into other uses.		Increase fleet fuel efficiency in the region from 20 to 24 mpg.

What About No-till and Conservation Tillage?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C sequestration rate
(Mg C ha^{-1} yr^{-1})

No-till and Conservation Tillage

- Advantages:
  - Agricultural lands remain working lands
  - Can be applied to extensive acreages
- Problems:
  - Burgeoning evidence that no-till simply re-distributes C compared to conventional tillage, but that the overall C balance is not significantly different, if at all
  - Reversals

Peatlands: A Special Case

- Globally, peatlands comprise only 3% of soils
- However, they contain ~33% of all C stored in soils
- Minnesota peatlands contain roughly 4,250 Mt C, or approximately 745 tonnes of C per acre
- Protecting peatlands should be a high priority

Conclusions

CO_2 Emission reduction goals for MN:

15% by 2015

30% by 2025

80% by 2050

Achievable through land use change: 3 - 5 %

Land use change can help sequester C, but other measures have to be undertaken to reach Minnesota's goals, first of all reduction of CO_2 emissions.

Conclusions

CO_2 mitigation plans that rely heavily on terrestrial C sequestration are overly optimistic.

Offset > 5% of CO_2 emission

by land use change is unrealistic.

- Efforts should be made to protect existing C sinks
- peatlands and forests in Minnesota contain enormous C stocks; their loss will only exacerbate the problem

- C sequestration should be tied to land use / land management practices that provide other ecosystem services, such as increased wildlife habitat and enhanced biodiversity, erosion reduction, and water quality improvements
- These land uses typically sequester carbon

Year	1987	1992	1997	2002	2007
CRP and WRP (million acres)	0.54	0.91	1.26	1.63	1.93