Sequestering Carbon in Agricultural Soils:
A Natural Climate Solution

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Source: Modern Farmer

1

Modern agriculture continues to damage soil

Tillage, winter fallow, synthetic N fertilizer, heavy equipment

Many conventional ag practices lead to:
- **wind & water erosion,**
- **soil compaction,**
- **loss of organic matter**

bigag.com

Aaron Esser

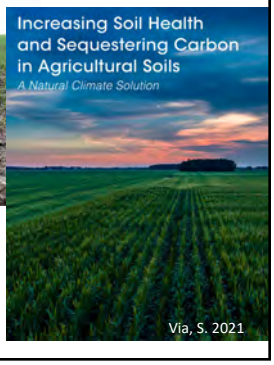
Tillage and bare soil increase vulnerability to flooding & drought, increasing financial risk from climate change

cropwatch.unl.edu

Kansas Dept of Agriculture

How can we turn this around?

Increase use of practices that boost soil health!



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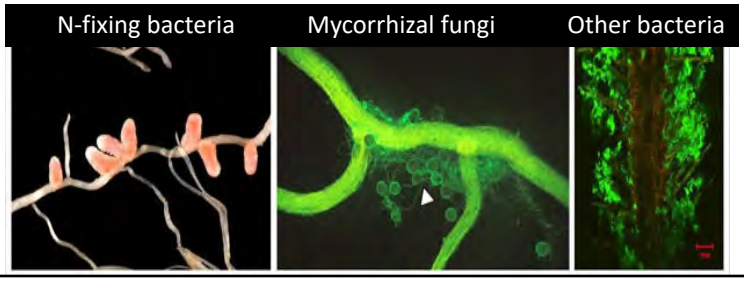
Soil health depends on organisms:
The secret life of soil

- 1t soil contains >1 BILLION microbes
- **Plants give** up to 40% of the sugar they make from photosynthesis to soil bacteria & fungi
- **Plants get** N, P, water, nutrients, protection from diseases, predators & abiotic stress



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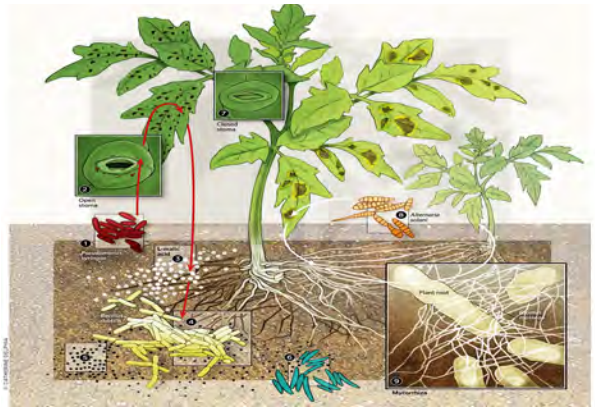
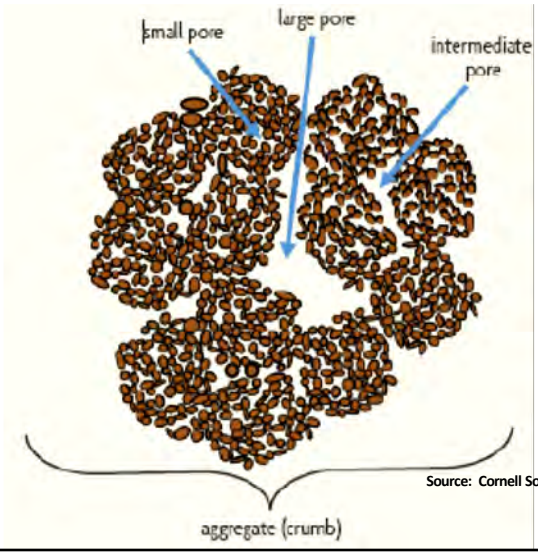
If we build healthy soil:
Naturally occurring bacteria & fungi can promote plant growth, fight pathogens & moderate stress



In unhealthy soil, need more synthetic nitrogen fertilizer, pesticides, fungicides & irrigation, increasing water pollution

4

Healthy soil is crumbly with stable aggregates built by soil organisms



Source: Cornell Soil Health Manual

Soil aggregates are made by living things in the soil

- roots & their exudates
- mycorrhizae & "glue"
- other sticky material from soil organisms

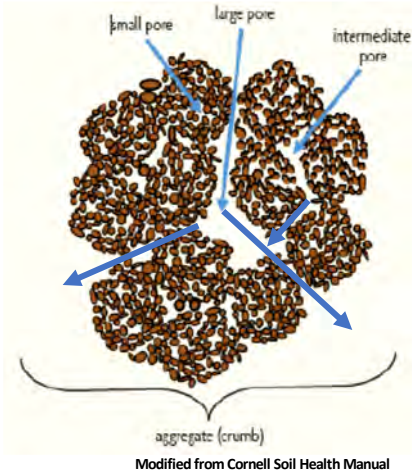
Aggregates are stable in water & provide crucial habitat for the soil food web

5

Healthy soil increases climate resilience by:

1. Reducing climate risk from increased flooding

Jim Lewis



Modified from Cornell Soil Health Manual

Because aggregates are water-stable

- pore structure is also stable
- increasing water infiltration
- allowing good drainage of stormwater

6

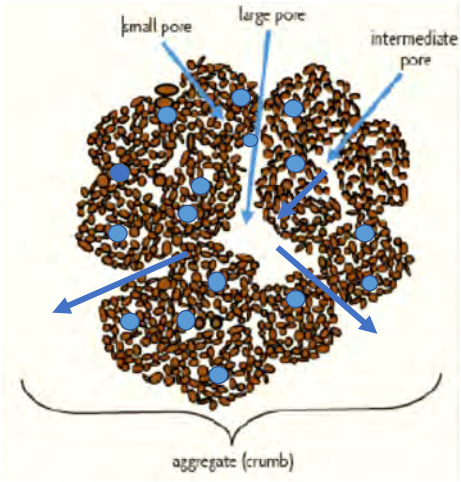
Healthy soil increases climate resilience by:

2. Reducing climate risk from increasing drought

farmanddairy.com

- water held in small pores within aggregates reduces drought risk

Soil health is the top "no regrets" strategy for climate resilience



Modified from Cornell Soil Health Manual

7

Soil can make agriculture part of climate solution!

- Land-based carbon sequestration is available now and is the most cost- effective way to reduce atmospheric CO_2 and store it in
  - forests
  - farms
- Carbon can be sequestered in soil & woody plants using many NRCS conservation practices now used to increase water quality

- **What are the practices?**
- **How much GHG reduction possible?**
- **How can we encourage farmers to use the practices?**

Urgency of reducing atmospheric CO_2 is increasing motivation to fund land-based carbon sequestration

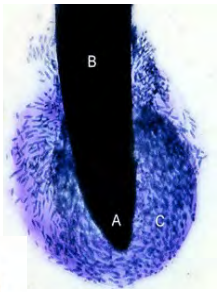
8

Carbon sequestration in agricultural soil

Plants absorb atmospheric C during photosynthesis and make sugar

- In healthy soil, up to 40% of this carbon is exuded from roots to feed microbes. This the largest source of stored carbon

- Carbon is stored in soil
  - within aggregates
  - by adsorption onto clay & minerals

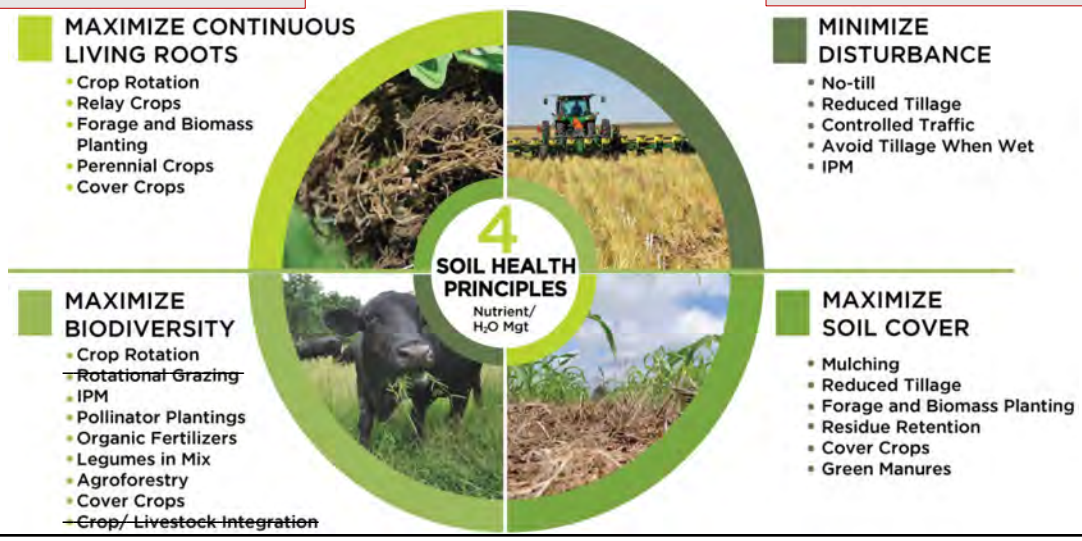


9

Natural Resources Conservation Service (NRCS) principles:
All about the microbes

Feed the microbes

Protect their habitat

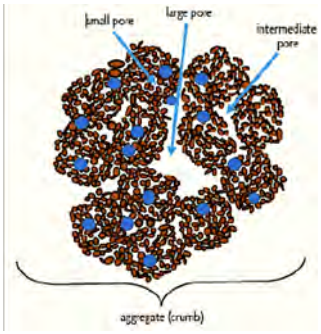


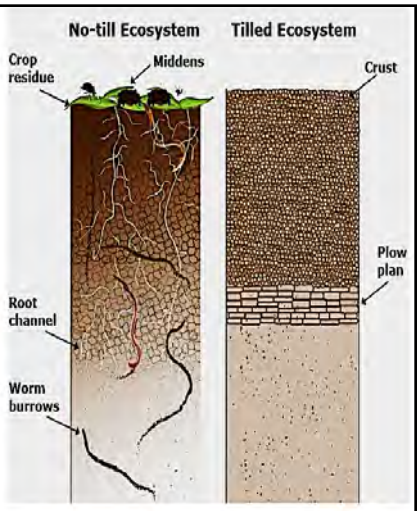
10

Example: No-Till

No-till a key element of soil health

- Maintains soil aggregate structure
- Less carbon loss through decomposition that occurs when tillage breaks soil aggregates
- Better water infiltration and storage, less erosion, less compaction, less fuel use



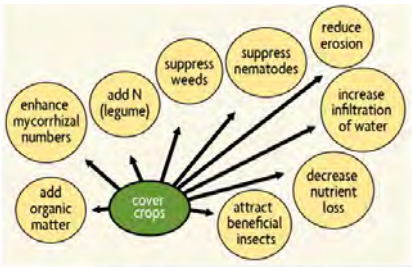


Tillage breaks up soil aggregates

11

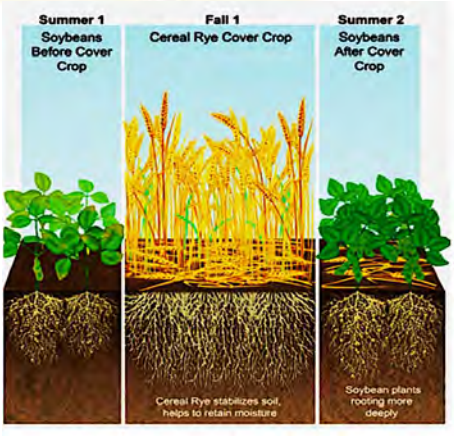
Example: Cover crops

Photo Credits: Jason Johnson, NRCS



- reduce erosion
- add organic matter
- increase microbial diversity (esp. mixtures)
- living roots (instead of fallow) feed microbes
- increase aggregation
- can increase infiltration by >600x (SARE)
- fight weeds and more…

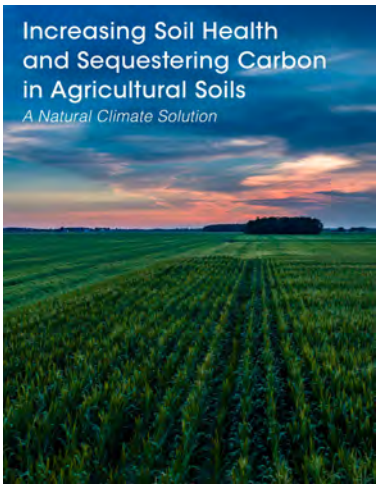
Credits: SARE



12

Identifying research-based practices for sequestering C in agricultural soils

- **Reviewed recent reports** about soil carbon sequestration, plus primary literature
- **Evaluated scientific support** for carbon sequestration through NRCS agricultural practices
- **Developed list of 24 recommended NRCS carbon-sequestering practices**
- **Used COMET-Planner to quantify GHG benefits of each practice** (see Appendix 2 for "COMET Explainer")



Via, S. 2021. IWLA & NWF.

13

Greenhouse Gas Reductions From Agriculture: Recommended Practices for Carbon Sequestration

NRCS Conservation Practice	Description of practice	GHG Reduction (Tonnes CO2e/ac-yr)				
		MD	NY	IL	CO	OR
Cropland Management						
Residue and Tillage Management - No-Till (CPS 329)	Intensive Till to No Till or Strip Till	0.51	0.43	0.73	0.30	0.23
Conservation Crop Rotation (CPS 328)	Decrease Fallow Frequency or Add Perennial Crops to Rotations	0.22	0.22	0.22	0.26	0.24
Cover Crops (CPS 340)	Add Legume Seasonal Cover Crop (50% Fertilizer N Reduction)	0.59	0.22	0.64	0.11	0.07
	Add Non-Legume Seasonal Cover Crop (25% Fertilizer N Reduction)	0.30	0.12	0.49	0.11	0.04
Nutrient Management (CPS 590)	Reduce Synthetic N Fertilizer by adding Dairy Manure	0.13	0.11	0.21	0.05	0.09
Edge-of-field: add herbaceous plants						
Forage and biomass planting (CPS 512)	Cropland to grass, forage or biomass, harvested	0.60	1.25	0.88	0.31	0.60
Conservation Cover (CPS 327) / Riparian herbaceous cover (CPS 390) / Contour buffer strips (CPS 332) / Field border (CPS 386) / Filter strip (CPS 393) / Grassed waterway (CPS 412) /	Convert Cropland to Permanent Unfertilized Grass or Grass & Legume Cover	0.39	0.97	0.97	0.41	0.39

From: Via, S. 2021. Increasing Soil Health and Sequestering Carbon in Agricultural Soils: A Natural Climate Solution. Izaak Walton League of America and National Wildlife Federation. 70 pp.

See Appendix 2 of report for "COMET Explainer"

USDA Agricultural Research Service

GHG reduction data from COMET-Planner, analyzed by Dr. Jennifer Moore, AFT & ARS, using CaRPE. https://farmland.org/carpetool.

14

Greenhouse Gas Reductions From Agriculture: Recommended Practices for Carbon Sequestration						
NRCS Conservation Practice	Description of practice	GHG Reduction (Tonnes CO2e/ac-yr)				
		MD	NY	IL	CO	OR
Edge-of-field- add woody plants						
Tree/Shrub Establishment (CPS 612)	Conversion of Annual Cropland to a Farm Woodlot	8.86	12.10	9.19	24.97	8.86
Riparian Forest Buffer (CPS 391)	Replace Strip of Cropland Near Watercourses/Water Bodies with Woody Plants	5.56	6.60	7.12	8.36	5.56
Alley Cropping (CPS 311) or Multi-story cropping (CPS 422)	Replace 20% of Annual Cropland with Woody Plants	1.77	2.42	1.84	4.99	1.77
Hedgerow Planting (CPS 422)	Replace Strip of Cropland with 1 Row of Woody Plants	4.89	13.10	NA	10.16	4.89
Grazing						
Prescribed/Rotational Grazing (CPS 528)	Forage Removal) with Intensive Grazing Management (40% Forage Removal)	0.04	0.01	0.03	0.01	0.01
Range Management	Seeding Adapted Perennial or Self-Sustaining Forages to Improve Grassland	0.50	0.43	0.50	0.34	0.43

Via, S. 2021. Increasing Soil Health and Sequestering Carbon in Agricultural Soils: A Natural Climate Solution. Izaak Walton League of America and National Wildlife Federation. 70 pp.

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GHG reduction data from COMET-Planner, analyzed by Dr. Jennifer Moore, AFT & ARS, using CaRPE. https://farmland.org/carpetool.

15

Why use models like COMET-Planner instead of direct field measurements of C?

Measuring C in soil is difficult and expensive

- need to take very careful samples of 1m in depth & handle samples with specific protocols

Carbon can be highly variable even within single fields

- many deep and precise samples are needed

Carbon added by management practices each year is tiny relative to amount already in the soil, so very hard to detect statistically significant increase

Sampling by farmers unlikely to show any change

16

Using COMET-Planner to quantify GHG benefits of practices

- Utilizes the best available science for GHG accounting in agriculture
- Coupled to national databases specifying climate, soil and land cover data to multi-county level
- Uses process-based models (DAYCENT) & empirical emissions factor models
- Evaluates GHG consequences of using a NRCS carbon-sequestering practice instead of a conventional practice (the baseline)

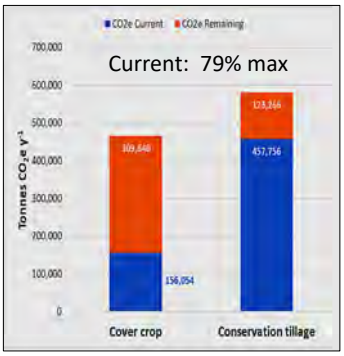
(See Appendix 2 of report for "COMET-Explainer")

17

How much GHG reduction could we get from 100% adoption of no-till & cover crops??

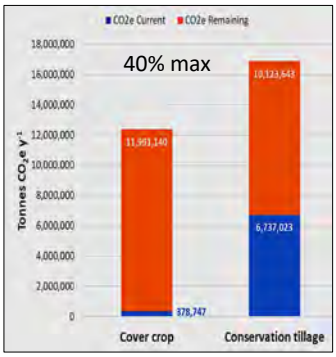
Maryland

Maximum: 0.5 $MMtCO_2e/yr$



****Illinois****

Maximum: 29.2 $MMtCO_2e$



******** This is equal to ********

- **Growing 17.3 m trees 10 yrs**
- **removing 226,000 cars/yr**

- **Growing 483 m trees 10 yrs**
- **removing 6.3 m cars/yr**

GHG reduction data from COMET-Planner, analyzed by Dr. Jennifer Moore, using CaRPE. https://farmland.org/carpetool.

18

What would it take to increase the use of these practices?

- Provide incentives?
- Make key equipment more widely available?
  - interseeders, roller-crimpers…
- Provide more information about the economic benefits of the recommended carbon-sequestering practices?
  Also, important to consider social science aspects of adoption

19

Economic Benefits to Farmers: **Soil health**

- Increased soil health allows reduced use of costly inputs: synthetic N fertilizer, herbicides, pesticides, fuel, irrigation
- It can take time to reap full benefits, but savings help profits grow even if short-term yield declines
- Healthy soil reduces weather risks & stabilizes yields
- New federal incentives & carbon trading= more $$

20

Economic Benefits to Farmers: No-till

Using figures from an NRCS study:
every pass over a 50-acre field costs $426

Maryland 2013: 965,000 acres no-till row crops
If it takes 3 passes to till for planting, MD farmers saved 12.2 million gallons fuel and ~ $25 million by using no-till!

See Chapter 3 of report for more examples

21

Environmental & health benefits to society of carbon-sequestering practices

- Increased habitat & biodiversity
- Improved water quality, & flood protection
- Reduced erosion, sediment & dust
- Less nitrate in water reduces water treatment costs
- Better ecosystem services worth up to $3500/acre*)

*Farmland LP Impact Report 2018, cited in Via, S. 2021.

- Societal benefits justify public funding for incentives
- Market-based offsets purchased by corporations don't reduce GHG

22

Practices that improve soil health increase agricultural resilience to climate change and make agriculture part of the climate solution

Incentivizing carbon-sequestering practices is a triple win:

-for the environment, for farmers, for society

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23