Managing soil to improve infiltration and water holding capacity: Carbon management.

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The Global Crises

- Financial
- Terrorism
- Energy Supply
- Environmental Degradation
- Food security
- Health Equity
- Climate Change

Our good earth

The future rests on the thin layer of soil beneath our feet
There is pressure on our earth resources and food security!

9,000,000,000 people by 2050

1,440,000,000 ha cropland (3.56 billion acres)
We are “sandwiched” in a very fragile system!

Carbon is Critical!

Very thin, fragile atmosphere.

7,018,456,957 people

Very thin, fragile soil.
OUR HUNGRY WORLD
OUR THREATENED PLANET
OUR CHILDREN’S FUTURE
OUR ONE CHANCE… Conservation Agriculture
All rest on “OUR LIVING SOIL” that depends on soil carbon!

The “key” component is:

\[ \text{Carbon} \]
“Curiosity” is looking for carbon on Mars!

Photo Source: NASA
3 Keys to Conservation Agriculture!

1. Minimal soil disturbance
2. Continuous residue cover
3. Diverse rotations and/or cover crops

Soil Organic Carbon
The devil is in the details!
Beckism #101

Plants are the main source of our food/energy generation.
View the plant as carbon!
(~ 45% C)
Plant Power
Carbon capture
Carbon storage
Energy storage
Food source
Energy source
Soil carbon input
Environmental benefits
Quality of Life

Conservation depends on plant management!
Carbon is the “C” that starts “C”onservation!

Conservation is our first step toward food security!
Soil organic matter acts like a “sponge” for water retention and release to plants.

Soil high in carbon is rich in “spongy organic matter” that releases nutrients to crops and holds more than its own weight in water.
Available water capacity (AWC) is analogous to a bucket. The larger the “bucket”, the more water stored available to the plants.

\[ \text{AWC} = \text{textural water} + \text{SOM “sponge” water} \]

Sand, silt, clay

Source: Dept. of Agriculture Bulletin 462, 1960
Organic Matter (OM) % by weight

Available Waterholding Capacity (AWC) (% by Volume)

Sand, $AWC = 3.8 + 2.2(OM)$, $r^2 = 0.79$

Silt loam, $AWC = 6.3 + 2.8(OM)$, $r^2 = 0.76$

Silty clay loam, $AWC = 9.2 + 3.7(OM)$, $r^2 = 0.58$

SOM increases available water holding capacity!

Sand soil
Available Water holding Capacity (AWC)
(cm H₂O/ 25 cm soil)
(in. H₂O/ ft. soil)

SOM = 0%  1%  2%  3%
1.0 cm  0.48 in.  1.5 cm  0.72 in.  2.0 cm  0.96 in.  2.6 cm  1.25 in.

Silt loam soil

Available Water holding Capacity (AWC)
(cm H2O/ 25 cm soil)
(in. H2O/ ft. soil)

0% SOM
2.3 cm 1.10 in.
1% SOM
3.2 cm 1.54 in.
2% SOM
4.2 cm 2.02 in.
3% SOM
5.1 cm 2.45 in.

Carbon is the center of the “Soil Magic Triangle”.

- Biological
- Physical
- Chemical
Ecosystem Services

Our Resources

- Sun
- Air
- Water
- Soil

Food
Feed
Fiber
Fuel
Soil degradation:

1. Inversion tillage
2. Crop residue removal

Soil restoration:

1. No tillage systems
2. Crop residue retention + cover crops

Source: Jerry Hatfield
Tillage-induced Carbon Dioxide Loss

No. 1 Environmental Enemy in Production Agriculture
Invisible effects of invisible forces!
Increasing carbon loss

y = 0.0792x + 9.7647

R² = 0.9698

Strip Tillage #1  3 June 1997 Swan Lake
Cumulative Carbon Dioxide Loss after 24 hours

Cross Sectional Area Loosened Soil (cm²)

CER (g CO₂ m⁻²)
Figure 1. Fuel use as related to tillage intensity (data from Archer and Reicosky 2009).
Previous work showed tillage-induced CO₂ emissions were proportional to soil volume disturbed.

What do large “no till” seeders due to CO₂ emissions?
Comparison of No Till Drills

Low disturbance drill

High disturbance drill
Low disturbance drill
Non disturbed
High disturbance drill
Disc Harrow
Moldboard Plow
$\text{CO}_2$ & $\text{H}_2\text{O}$ loss from Low vs High Disturbance Drills

- **CO$_2$ loss (gCO$_2$/m$^2$/h):**
  - None: 0.38
  - Low: 0.35
  - High: 3.01

- **Evaporation (mm/h):**
  - None: 0.17
  - Low: 0.35
  - High: 0.70

The graph compares the CO$_2$ loss and evaporation for different disturbance types (None, Low, High).
There’s a jungle full of life living in your belly button!

Your belly button is crawling with billions of bacteria, in all shapes, sizes and appetites.

It’s warm, dark and moist, a perfect home for bacteria.

The tiny bacteria in the “jungle of microbial diversity” are generally harmless.

Everybody’s bellybutton carries a different cast of characters.

Minneapolis Star Tribune, 12/7/2012. Jiri Huler, Lead scientist, NCSU

There’s a jungle full of life living in your soil!

The bellybutton project is out to “educate the public about the role of bacteria play in our world. Bacteria are always present on our skin and in our bodies.”

Your soil is crawling with billions of critters (bacteria, fungi, arthropods, nematodes, worms, and animals) in all shapes, sizes and appetites.

The temperature is variable, it’s dark and moist, a perfect home for soil biology.

The tiny critters in the “jungle of microbial diversity” are generally harmless.

Everybody’s soil carries a different cast of characters.
Earthworms, insects and rodents are the most visible components of the “living soil” team. They work in tandem with soil microorganisms and fungi to contribute to aeration and nutrient cycling as part of a “soil factory” team effort.
Intensive Tillage destroys the biological and ecological integrity of the soil system.

Before Primary Tillage
After Primary Tillage
After Secondary Tillage
Intensive soil tillage opens the “all you can eat buffet” for the birds and microbes.

Earthworms are allergic to cold steel! Mike Bell

Tillage creates twin problems:
-- Accelerated soil degradation
-- Accelerated soil erosion
"Turmoil of Tillage"

The soil is a natural living system that contains a lot of life and when tilled intensively is dramatically changed. It can be considered analogous to human reaction to a combination of:

- earthquake
- tsunami
- forest fire
- hurricane

all rolled into one perturbation event!
Dead crop residue = “passive protective blanket”

Both are food sources for the soil biology!

Live crop biomass = “active protective blanket”
Which is better for the soil biology? “Pulling” iron? vs “Pushing” carbon!
Natural Fertility

Crop biomass ~ 46 %C

Soil organic matter = 58 %C

Difference = 12 %C

Microbial and fungal decomposition
Biological activity = Nutrient release

C, H, O, N

P, K, Ca, Mg, Mn, Cu, S, Cl, Zn, Bo, Mo, Fe, Na
Terminology Transition away from Tillage

We need to change our vocabulary!

Conservation Management

Emphasize conservation
De-emphasize tillage

Emphasize crop residue management
De-emphasize soil disturbance

Carbon Management

Conservation without compromise!
Conservation tillage is a broad term used to define “any” tillage system with primary objective of “reducing soil and water loss.”

Conservation tillage, however, has “loose limits” on the definition of soil disturbance and residue management.
“Conservation Tillage” dilemma

“Conservation Tillage” terminology leads to confusion due to the diversity of machinery that leads to the wide range of soil disturbance and crop residue burial. We need more attention to quantitative details in understanding the most critical factors for soil degradation related to soil tillage and crop residue removal/burial.
Tillage Soil/Residue Disturbance Continuum

- Conventional Tillage
- "Conservation Tillage"
- No Tillage

Tillage/Plant Type

- Decreasing intensity and frequency of soil disturbance
- Increasing crop residues covering soil

Volume soil disturbed

HD = High Disturbance
LD = Low Disturbance
Conservation:

“Touch the earth lightly, use the earth gently, Nourish the life of all the world in our care.”
Source: Shirley Erina Murray, 1992

The action of conserving something, in particular. Preservation, protection, or restoration of the natural environment, natural ecosystems, vegetation, and wildlife.

Conservation is a word to be respected, revered and used to describe agriculture. However, conservation does not belong in the same sentence with tillage.
What is Conservation Tillage?

The phrase “conservation tillage” is an oxymoron. An oxymoron is a figure of speech in which incongruous or contradictory terms appear side by side.

Any form of intensive tillage is not a form of conservation for the way intensive tillage degrades and fractures the natural soil structure. Tillage destroys or disturbs the ecosystems of soil fauna so important for nutrient cycling. Tillage moves the soil down slope via tillage erosion. Intensive tillage loosens the soil and buries the crop residue, allowing the soil to dry, setting up the system for severe erosion with the next high-intensity rainfall event.
Tillage Soil Disturbance Continuum

Most disturbance

Conventional Tillage

“Conservation Tillage”

Least disturbance

No Tillage

Conventional Tillage

Zero Conservation

Much tillage

“Conservation Tillage”

Some Conservation

Some tillage

Direct Seeding

Much Conservation

Zero tillage
Conventional tillage = inversion tillage
Conservation tillage = non-inversion tillage
Direct seeding is close to nature’s way!

Nature’s way

No till

Conservation tillage

Conventional tillage

Biological tillage

Minimum disturbance to 5 cm

Non-inversion tillage to 46 cm

Inversion tillage to 30 cm

After Hartwig Callsen
“Connect the dots around Conservation Agriculture”

- Decreased compaction
- Reduced air pollution
- Improved soil biology
- Increased SOM
- Improved infiltration
- Next node:
  - Minimum soil disturbance
  - Time savings
  - Reduced labor requirements
  - Reduced machinery wear
  - Energy savings
  - More wildlife
  - Higher soil H2O
  - Reduced soil erosion
  - Continuous crop residue cover
  - Diverse rotations/cover crops
  - Improved soil biology
  - Improved infiltration
  - Improved water quality
  - Improved soil biology
Soil Carbon Sequestration

Environmental benefits are spokes that emanate from the Carbon hub.

- increased water holding capacity and use efficiency
- increased cation exchange capacity
- reduced soil erosion
- improved water quality
- improved infiltration, less runoff
- decreased soil compaction
- improved soil tilth and structure
- reduced air pollution
- reduced fertilizer inputs
- increased soil buffer capacity
- increased biological activity
- increased nutrient cycling and storage
- increased diversity of microflora
- increased adsorption of pesticides
- gives soil aesthetic appeal
- increased capacity to handle manure and other wastes
- more wildlife

Agriculture’s Wheel of Fortune!
Conservation as in Conservation Agriculture is our only option.

Save a little time
Save a little money
Save little carbon
Save a little planet
Stop Erosion. Save Carbon. Park the Plow!

Credit: Ken Scott, Clear Lake, IA
Carby Carbon

Keep your carbon footprint small and manage carbon for ecosystem services!

Best done with Conservation Agriculture!