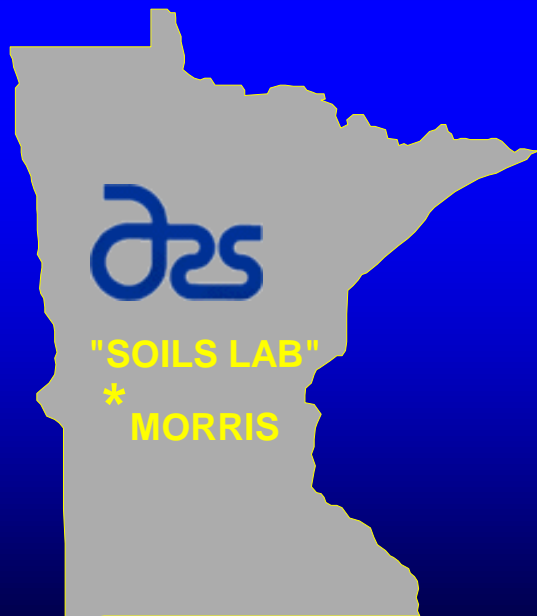


SDSU Extension & SWCS Annual Meeting

Sioux Falls, South Dakota Nov. 29, 2018

Soil Carbon Management: Soil health and ecosystem services

by
Don Reicosky,
(Soil Scientist, Emeritus)



USDA-ARS-MWA



**North Central Soil
Conservation Research
Laboratory Morris, MN
USA**

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Food Security (Sustainability)

It's all about
(mostly)

“C”

management!

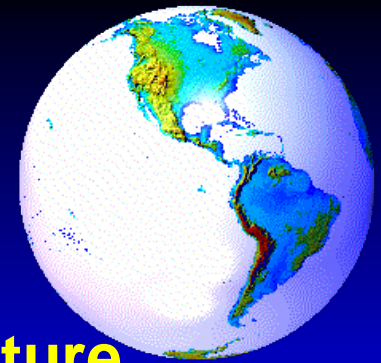
OUR HUNGRY WORLD

OUR THREATENED PLANET

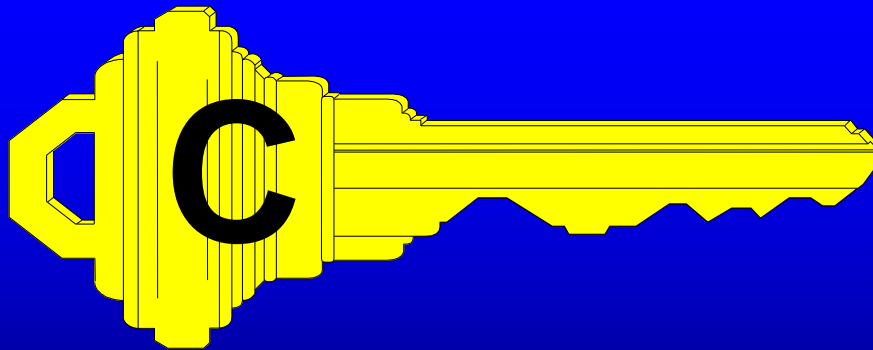
OUR CHILDREN'S FUTURE

OUR ONE CHANCE... Conservation Agriculture

All rest on “OUR LIVING SOIL” and “SOIL
HEALTH” that depends on soil organic carbon!



The “key” component is:



c a r b o n !



Focus on living soil!



Focus on soil carbon!
Think Carbon!

Nature's gift: carbon/SOM

Carbon = Soil Organic Matter

Soil Organic Matter = Carbon

Carbon is the key element in the >10,000 diverse chemical compounds that make up soil organic matter(SOM) that refers to the non-mineral portion of the soil.

% Carbon X 1.72 = % Soil Organic Matter

% Soil Organic Matter X 0.58 = % Carbon



Soil Is a living miracle!

Soil is a living biological system!

The soil is alive!

What makes the soil tick?

**Carbon is the framework and the
fuel of every living thing!**

Source: Bryan Jorgensen, no-till farmer, Ideal, SD

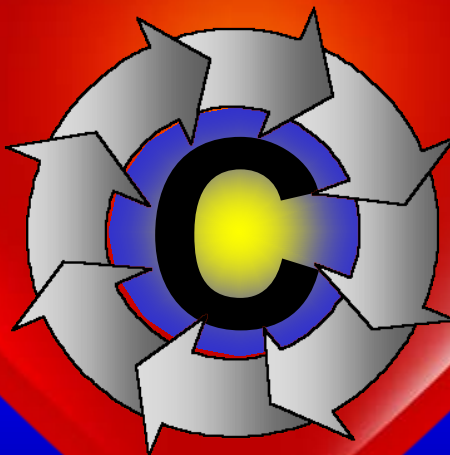
No Tillage


Cover Mixes

Carbon is the “heart” of soil health!

**Minimum
carbon
loss**

**Maximum
carbon
input**

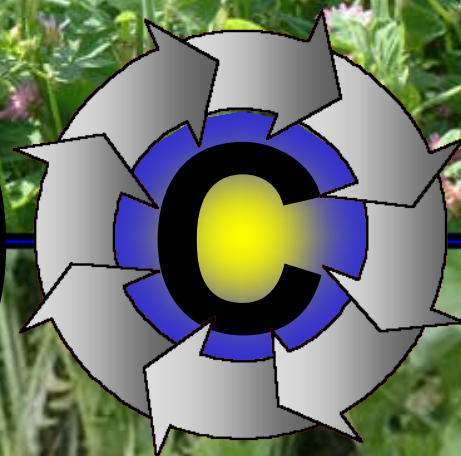




**“C”over
“C”rop
“C”ocktails**

**SOM is
58%
Carbon!**

**S
O
M**



“Carbon” coverings for the soil!

Soil protection 365 days a year!

Live crop biomass =
“active protective blanket”

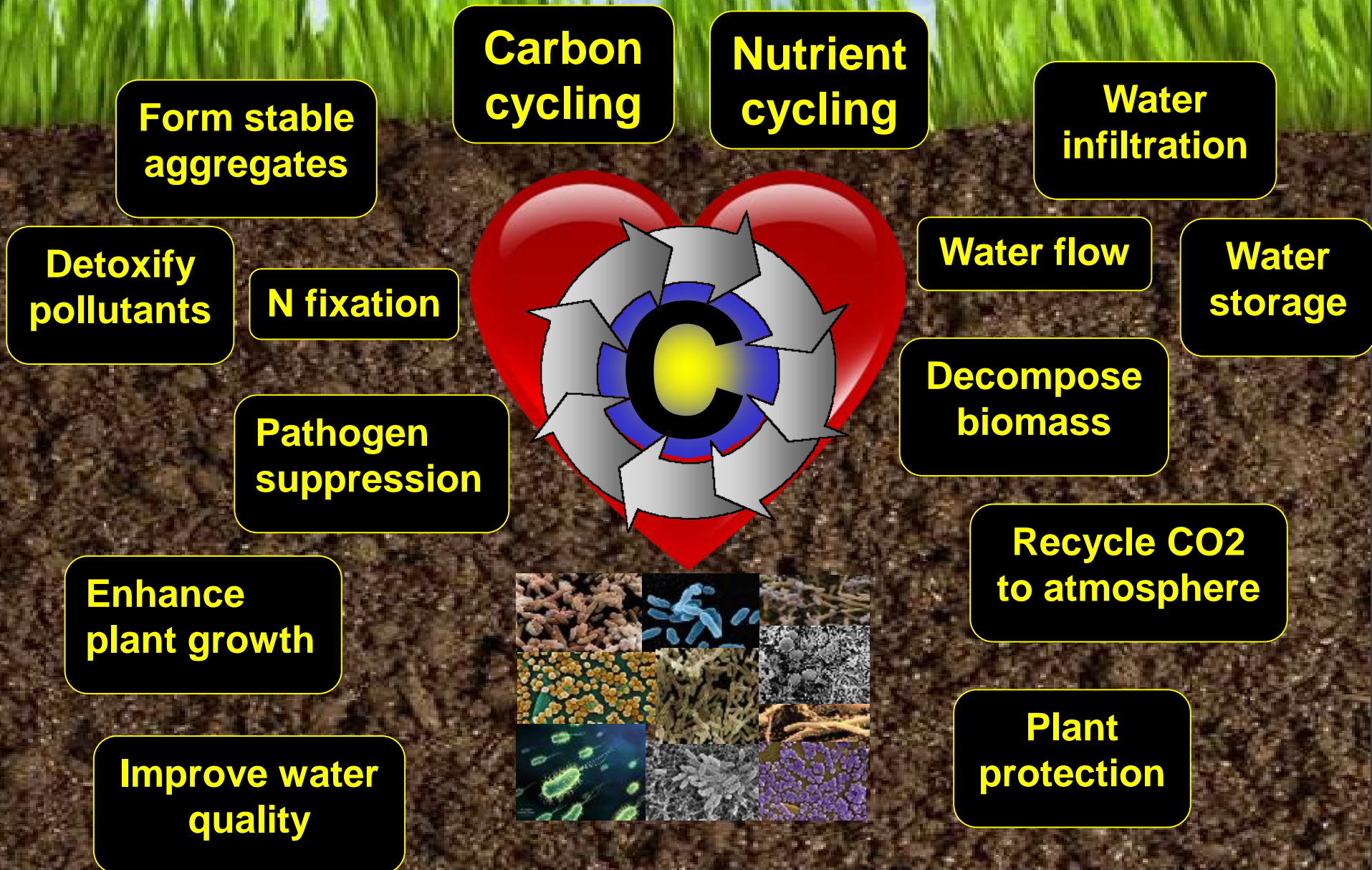
Plant biomass:

- 1. Living**
- 2. Dormant**
- 3. Dead**
- 4. Applied biomass, compost or manure**

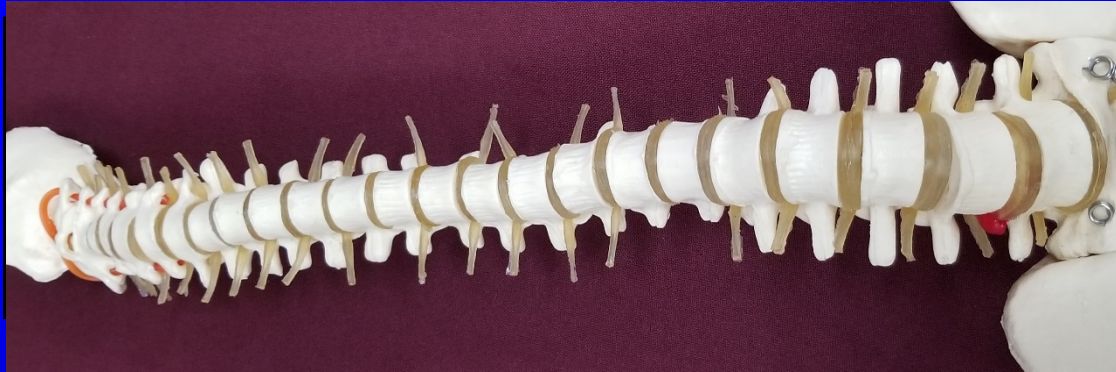
Dead crop residue =
“passive protective blanket”



The importance of healthy soil biology



Carbon is the “backbone network” to food security!



C-C-C-C-C-C-C-C-C-C-C-C-C

Carbon is the Backbone:



- C** is captured in photosynthesis
- C** is nature's free energy source
- C** is our free energy source
- C** exudates feed soil biology
- C** residues feed soil biology
- C** residues protects against soil erosion
- C** increases nutrient cycling
- C** increases soil structure
- C** increases infiltration
- C** increases water holding capacity
- C** increases water use efficiency(WUE)
- C** enhances soil health
- C** enhances human health
- C** enhances ecosystem services
- C** is the "C" that starts "C"onservation

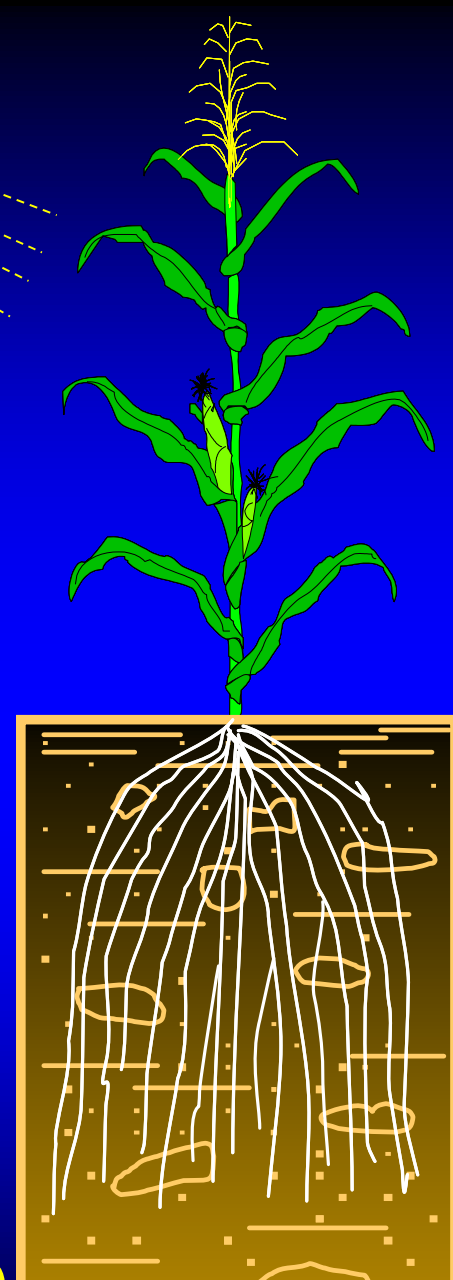
C enhances food security

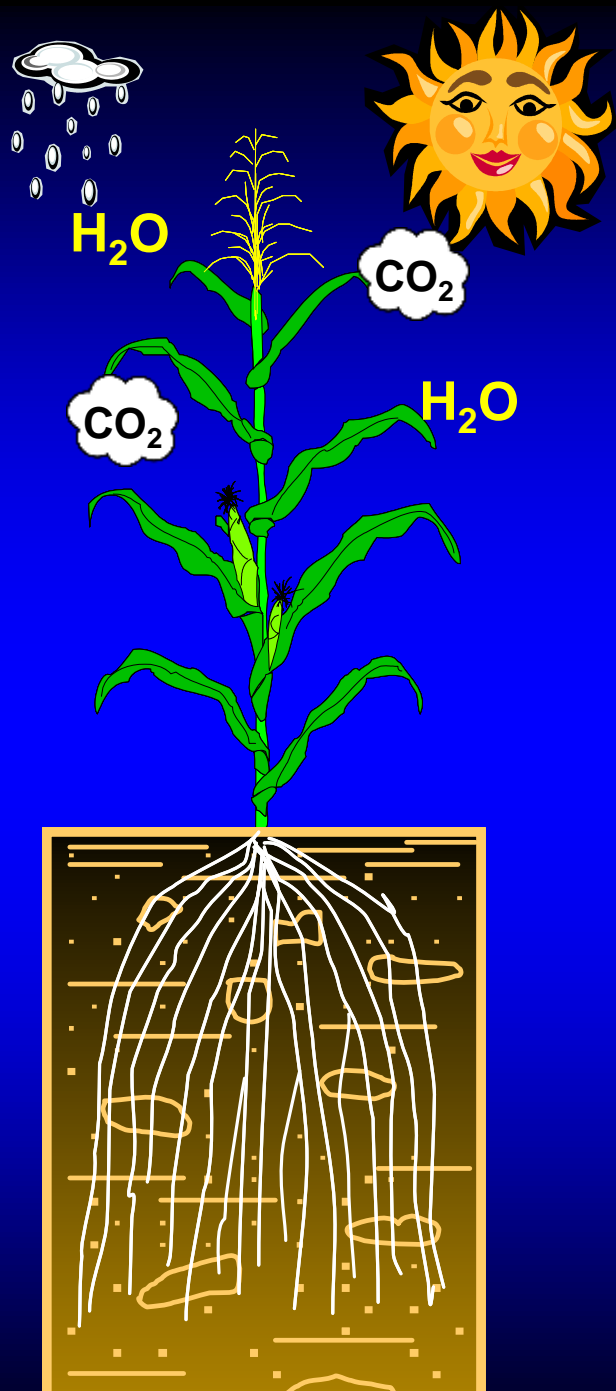
The sun powers all life through the Carbon Cycle!

The power of diversity is
strong in natural systems!

Plants are the main source of
our food/energy generation.

Soil is the Earth's living skin.





**Sunlight is the only
energy for life on earth!**

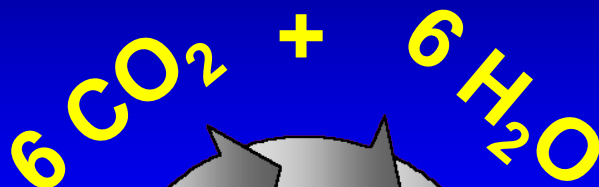
**Agriculture producers
manage plants to
capture solar energy
and transform it into
biochemical carbon
energy (food) that
feeds all life on earth.**

**Maximize use of
sunshine hours**

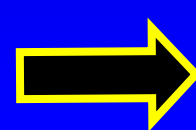
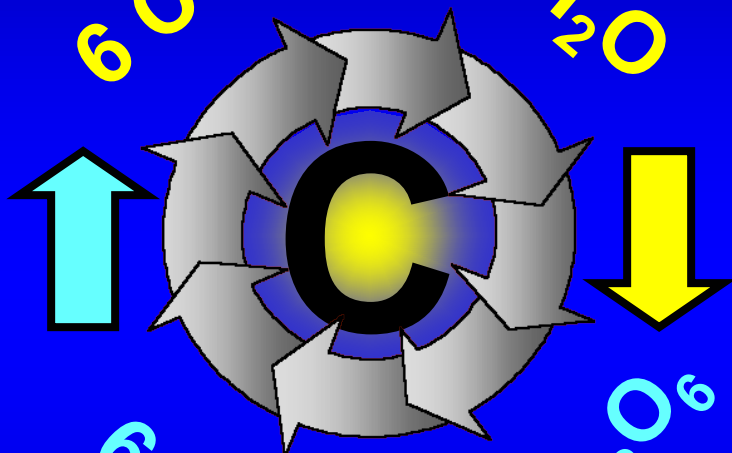
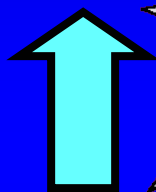


The Carbon Cycle

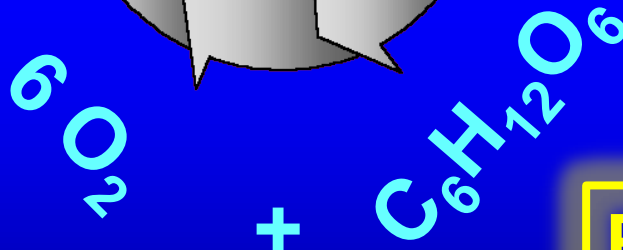
Photosynthesis



Energy
Release



Energy
Capture



Respiration

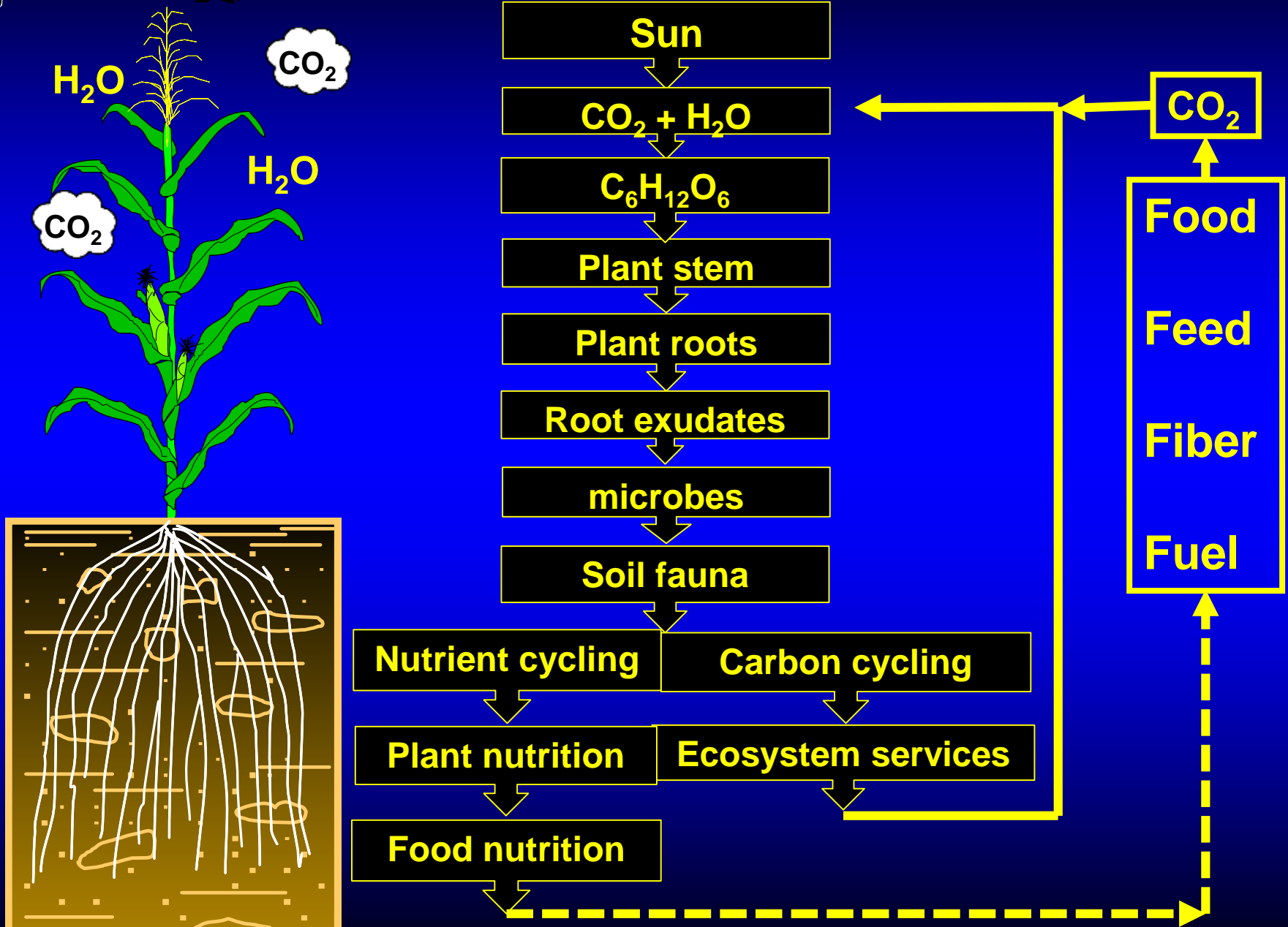


The devil is
in the
details!

Beckism #101

Plants are the
main source of
our food/energy
generation.

Carbon energy flow path



Multi-Species Cover Crop Benefits

Carbon role in related benefits

- **immediate yield increases**
- Increases biological diversity
- rate improvements in soil health, C is fauna food
- increases in soil organic matter, carbon input

The bottom line in CA!

The synergistic simplicity with minimum soil disturbance (**minimizes C and soil loss**) and the use of diverse rotations and cover crop mixes (**maximizes soil coverage and C input**) for soil diversity protection and regeneration benefits in CA.

- Tap roots penetrate soil pans
- Fibrous roots enhances bio pore formation
- Enhances plant diversity that enhances biological diversity
- **Combats insects/pests**
- **Breaks disease cycles**
- **Mitigates climate extremes (temperature and water)**
- “Planting green” benefits of extra time for cover and carbon input
- Cover crop mix C:N ratio helps control decomposition rate

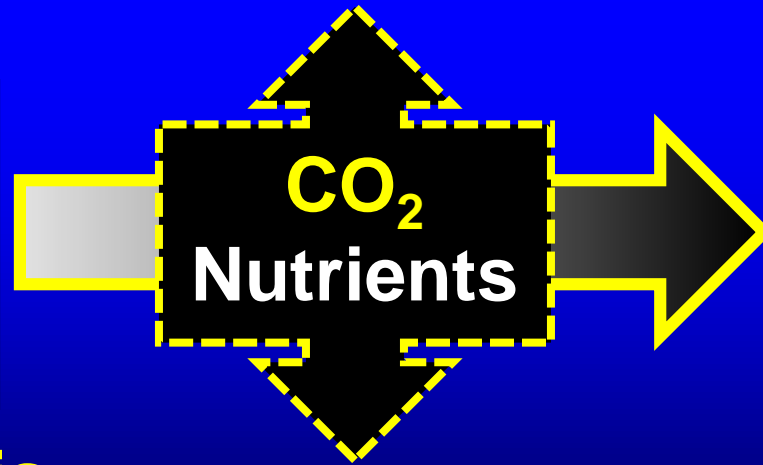
“Organic matter functions mainly as it is decayed and destroyed. Its value lies in its dynamic nature.”

Source: W. Albrecht, 1938

Carbon Cycling



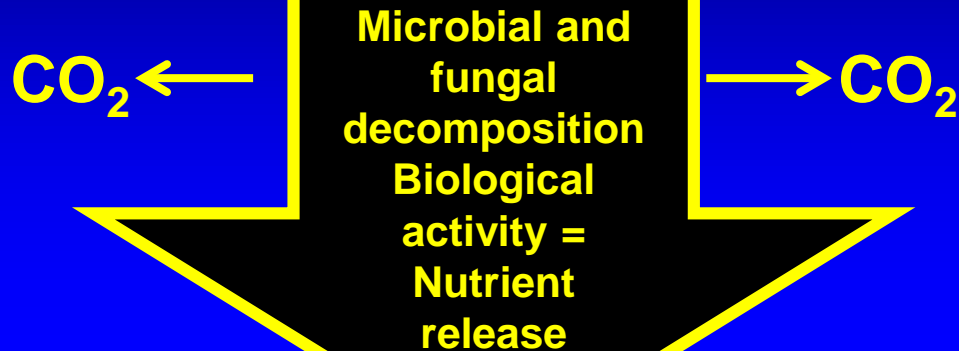
**Crop Biomass is
~46% carbon!**



**SOM is
~58% carbon!**

Natural Fertility

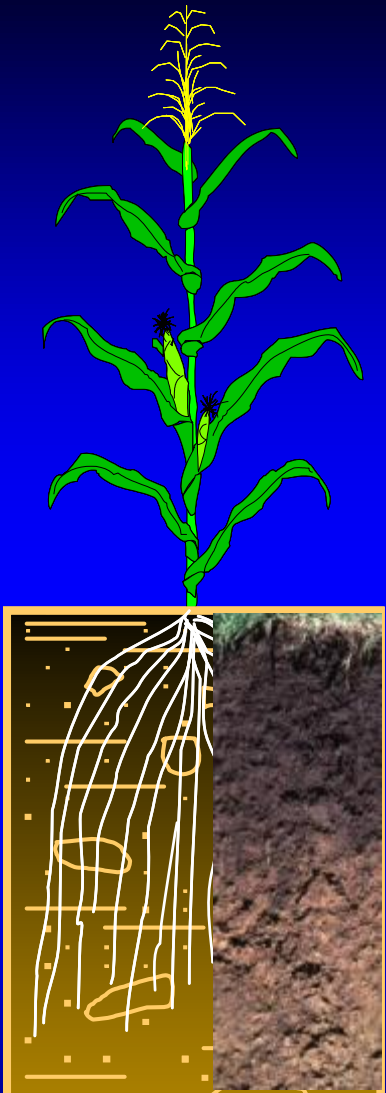
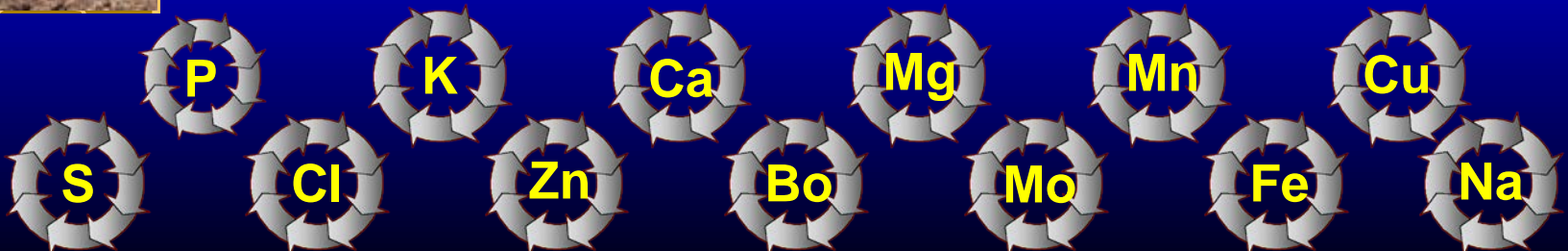
Crop biomass ~ 46 %C



Soil organic matter = 58 %C

Difference = 12 %C

C, H, O, N



Can we win the struggle with land degradation?"

Water - immediately visible



Wind - immediately visible



Erosion

Erosion

Erosion

Erosion

Erosion

Aerobic - invisible



Erosion

Erosion

Erosion

Erosion

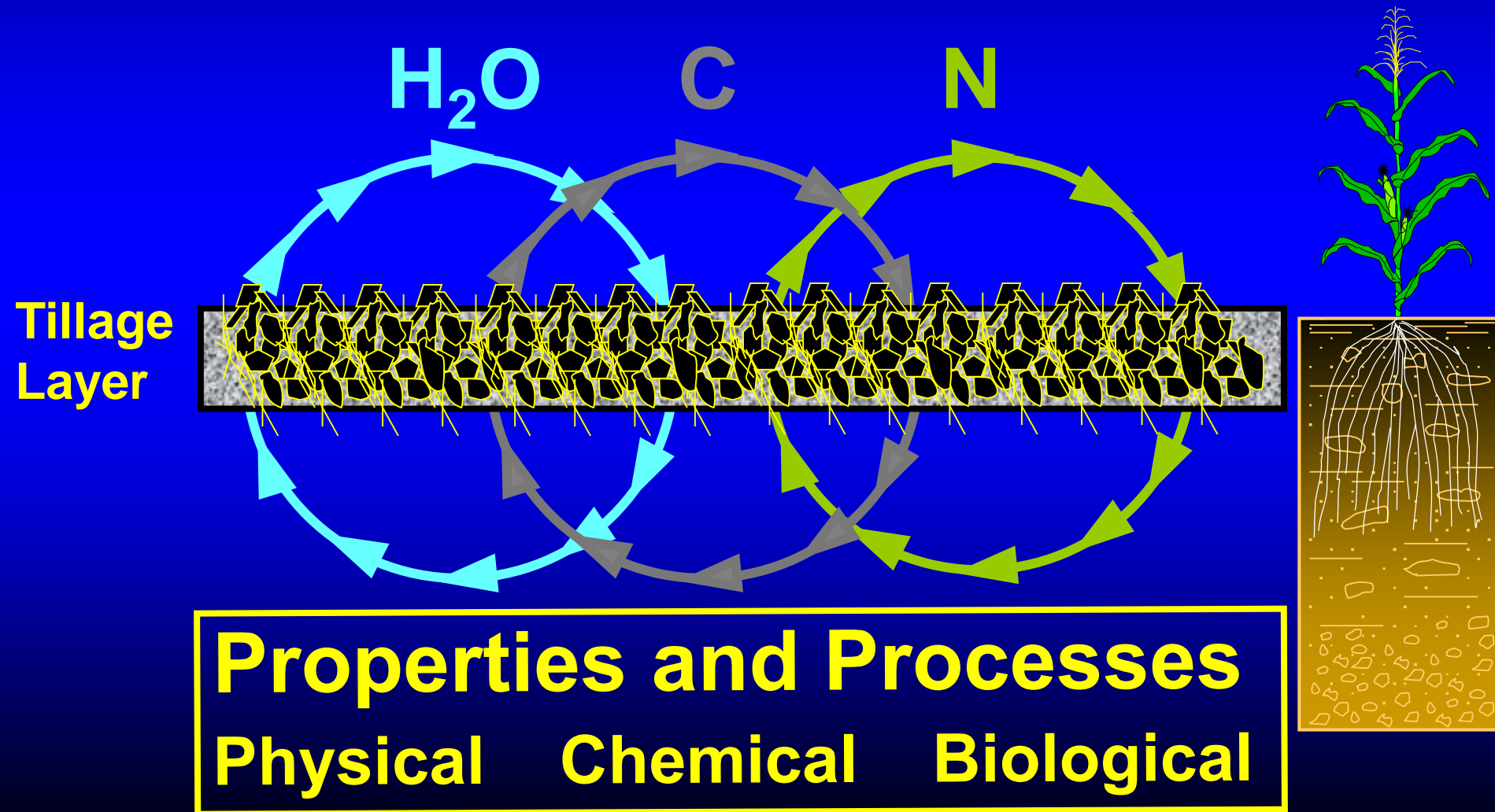
Tillage - slowly visible



Nature's Interdependent Tri-Cycles:

Water, Carbon, Nitrogen,

Tillage disrupts the natural cycles!



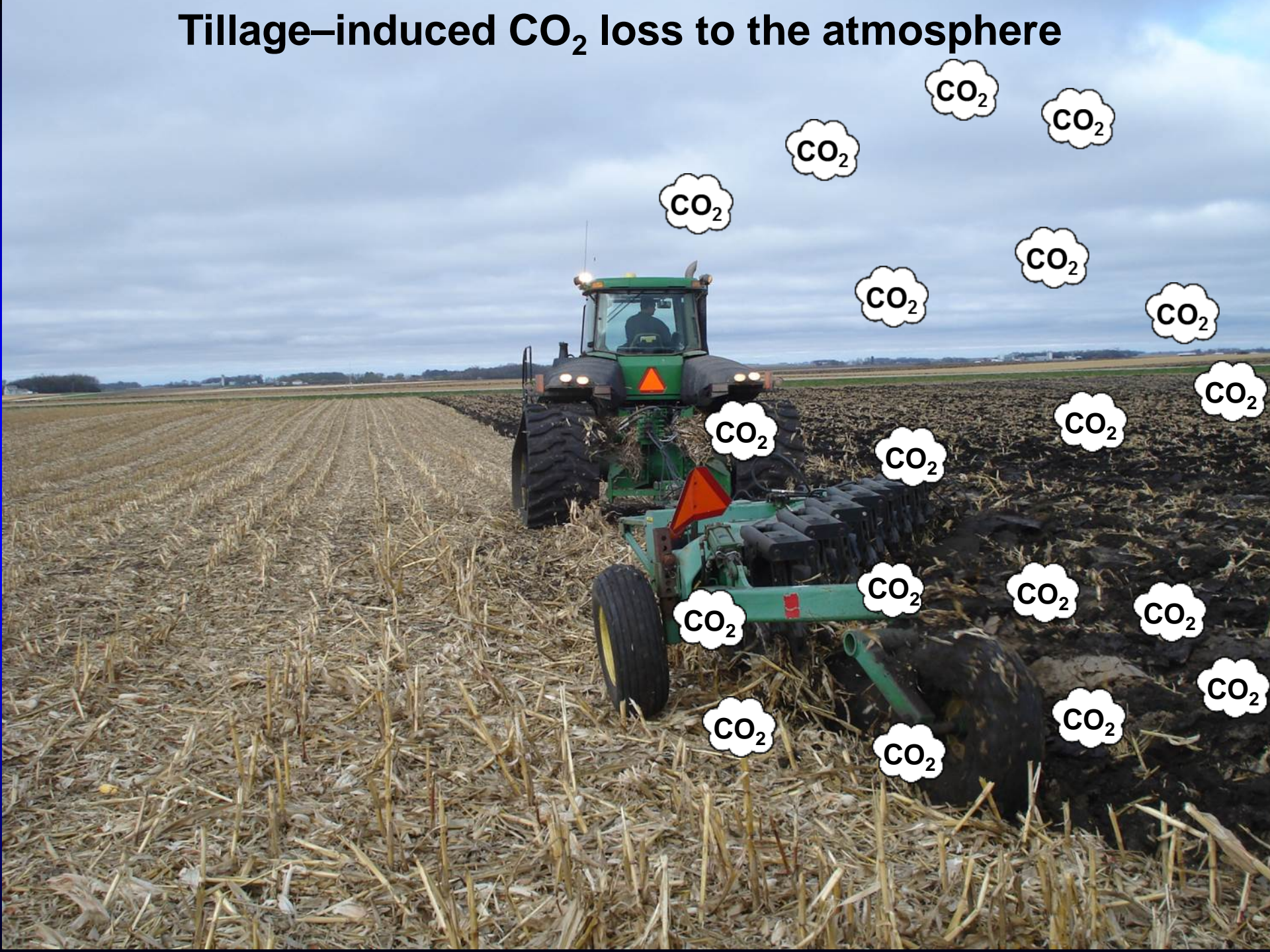
No. 1 Environmental Enemy in Production Agriculture

Conventional Tillage Promotes
SOM Oxidation and Soil Degradation

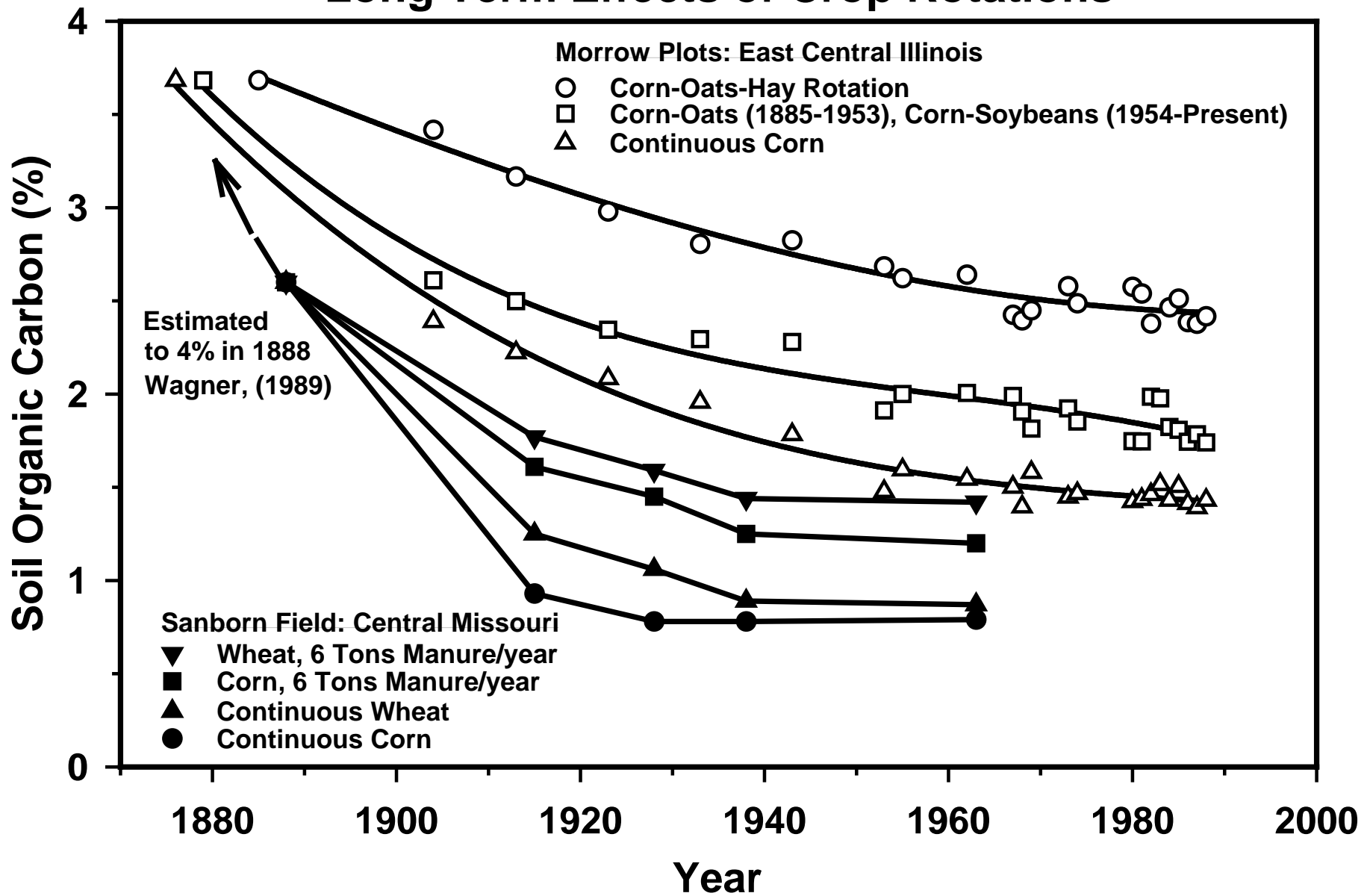
Tillage-induced Carbon Dioxide Loss



Tillage-induced CO₂ loss to the atmosphere



Long Term Effects of Crop Rotations



Summary in intensive agriculture:

1. Soil organic carbon continues slow decline.
2. Cropping systems can make a difference.

Possible explanations for soil carbon decline.

1. Carbon removed in grain harvested (~ 1/3 C fixed)
2. Intensive tillage - moldboard plow and disk harrow.
3. Changing from perennial species (60 to 90 % of biomass below ground) to annual agronomic species (15 to 20 % of biomass below ground).
4. Increased organic matter mineralization as a result of increased use of inorganic nitrogen fertilizers. (Lit. cit. Green et al., 1995, SSSAJ 59:453-459.)
5. Increased tile drainage to increase soil aeration in **Midwest USA** . (Baker, J.M., Ochsner, T.E., Venterea, R.T., Griffis, T.J. 2007. Tillage and soil carbon sequestration-What do we really know? Agriculture, Ecosystems and Environment, 118 (1-4), pp. 1-5.)

M = Mobile
R. = Research
G = Gas
E = Exchange
M = Machine

MIRAGE



Invisible effects of invisible forces!

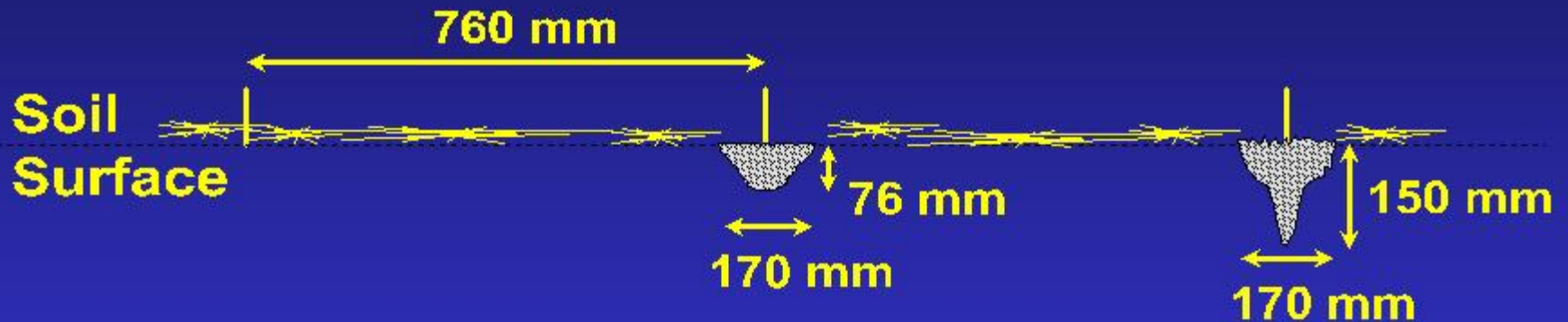
Schematic Representation of Strip Tillage Soil Disturbance

Yetter triple beam tool bar
4 rows at 760 mm spacing

Not tilled
(NT)

No Knife
(RM)

Yetter Knife
(YK)



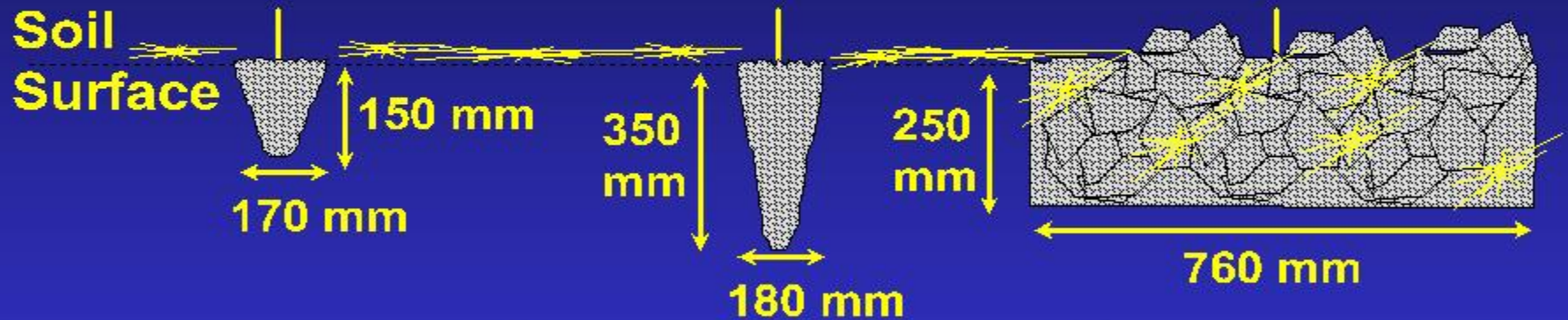
Schematic Representation of Strip Tillage Soil Disturbance

Yetter triple beam tool bar
4 rows at 760 mm spacing

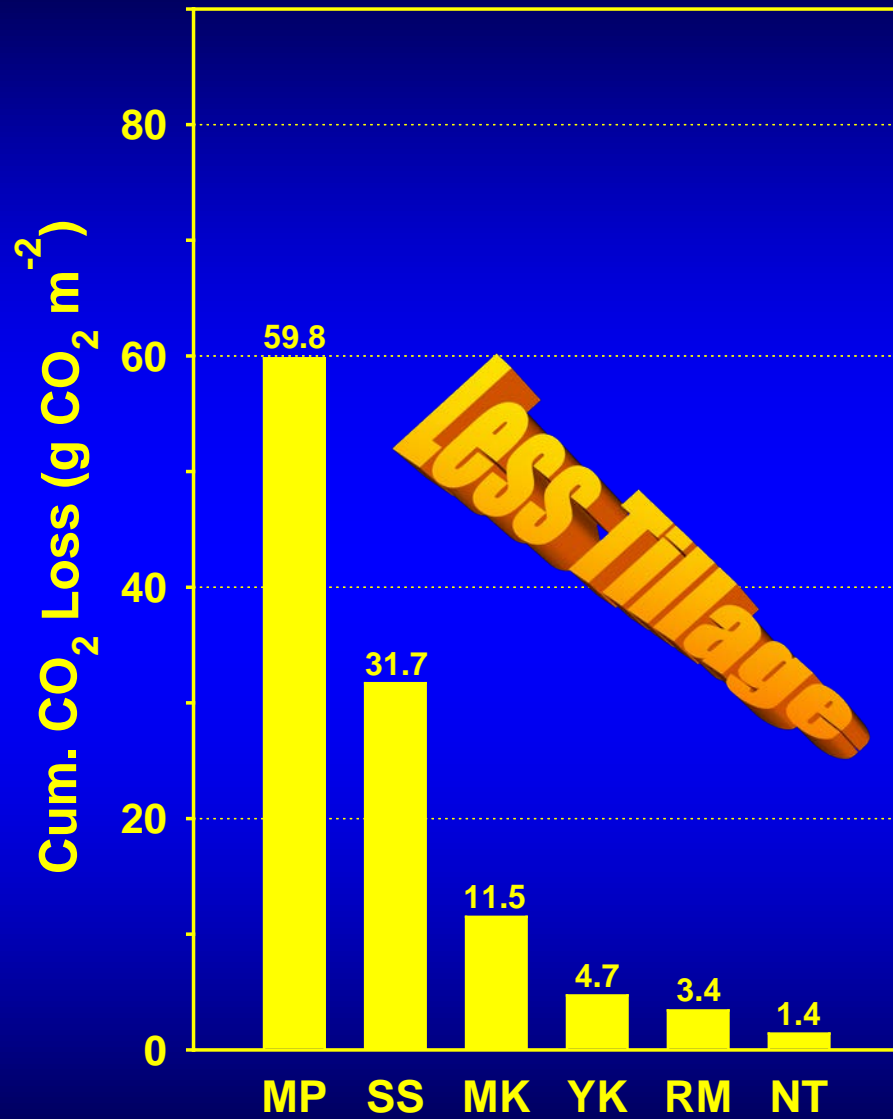
Mole Knife
(MK)

Subsoil Shank
(SS)

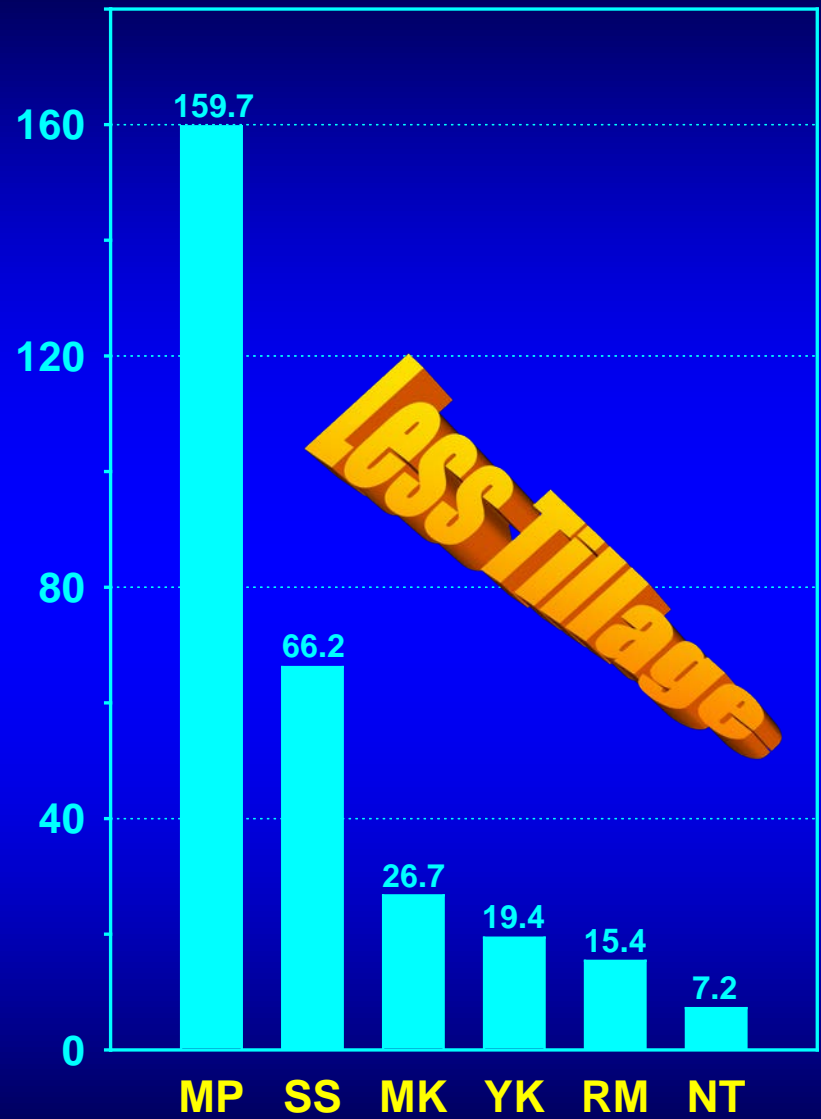
Moldboard
Plow (MP)



5 hours after tillage

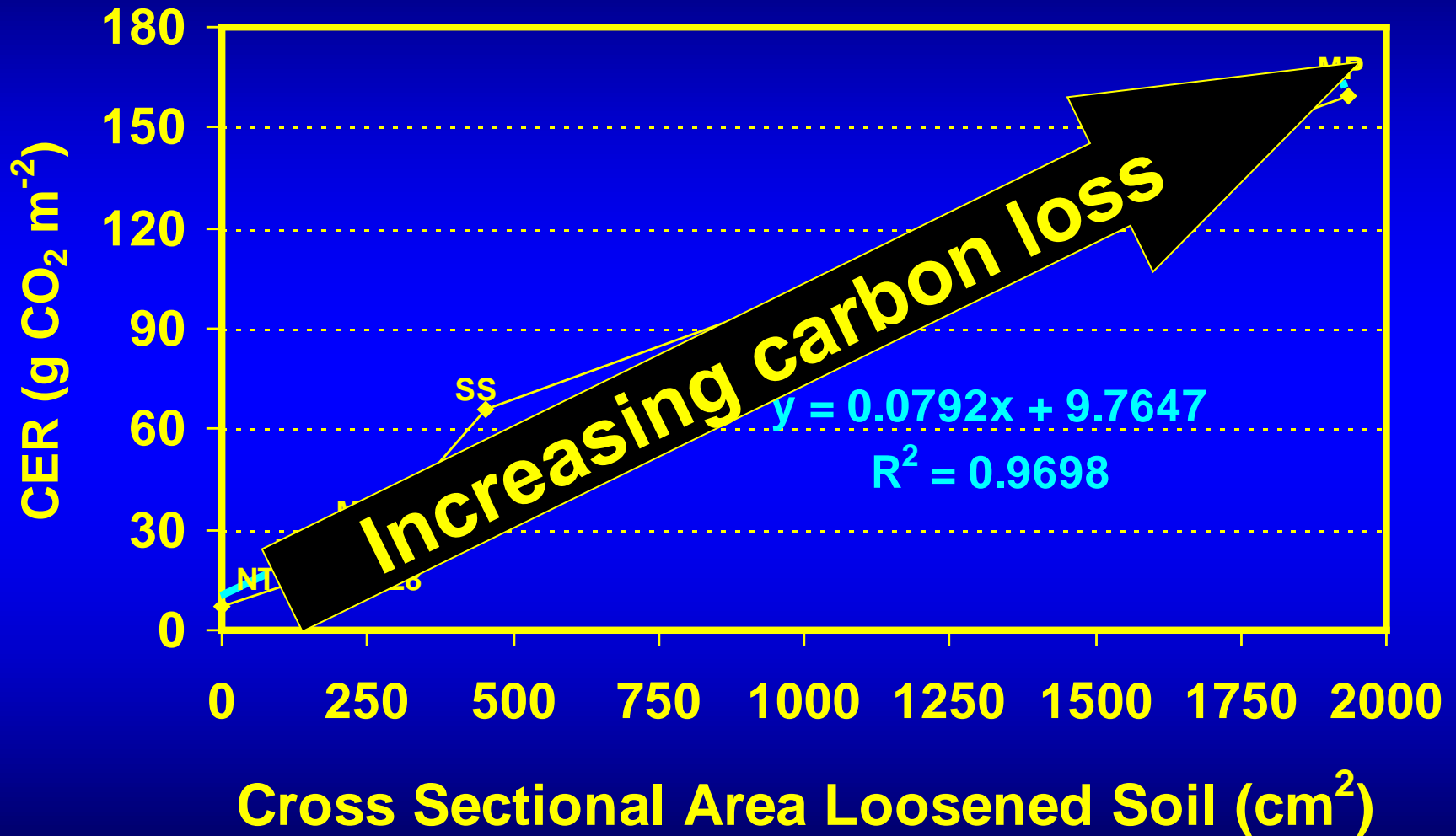


24 hours after tillage



Tillage Type

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



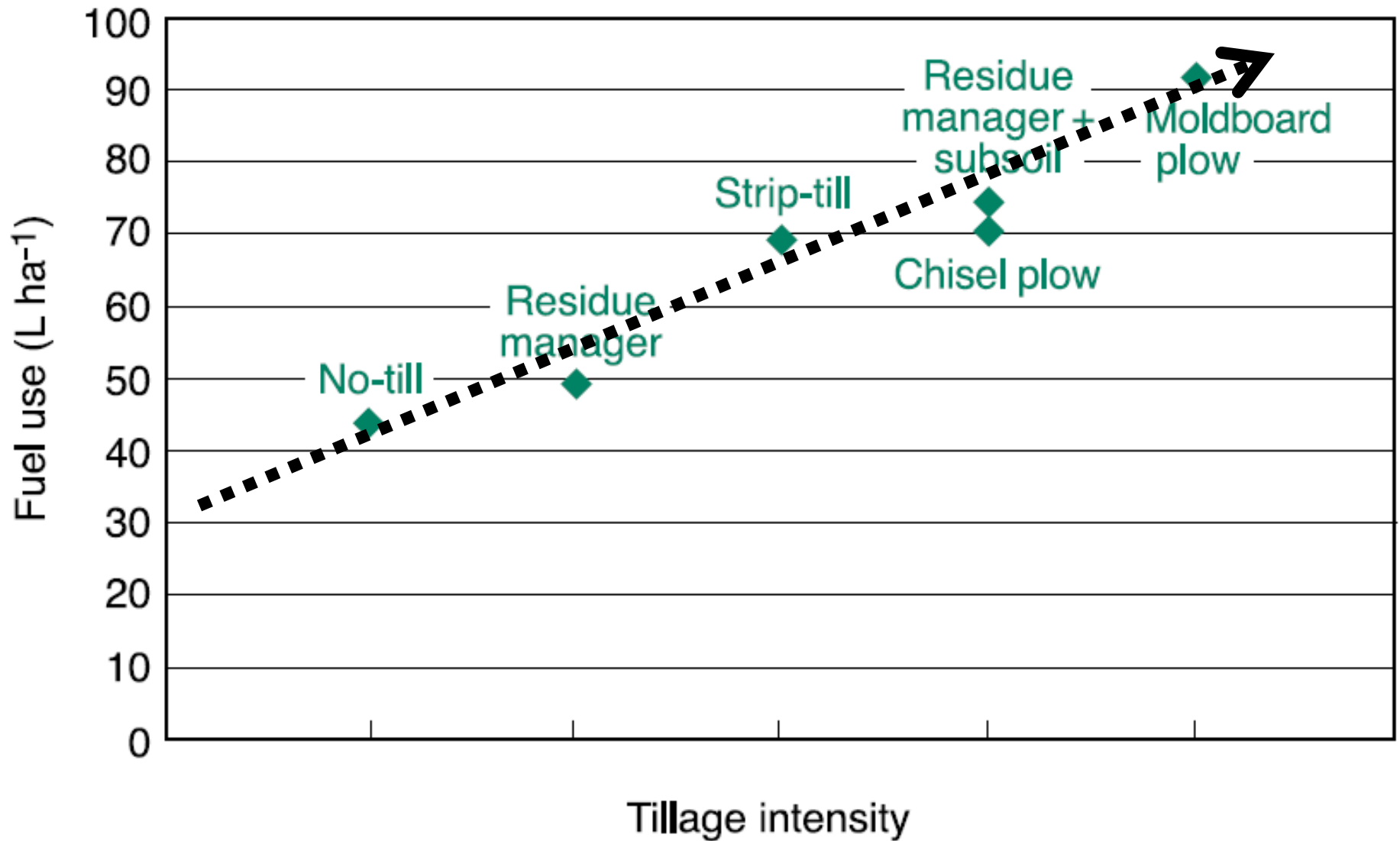
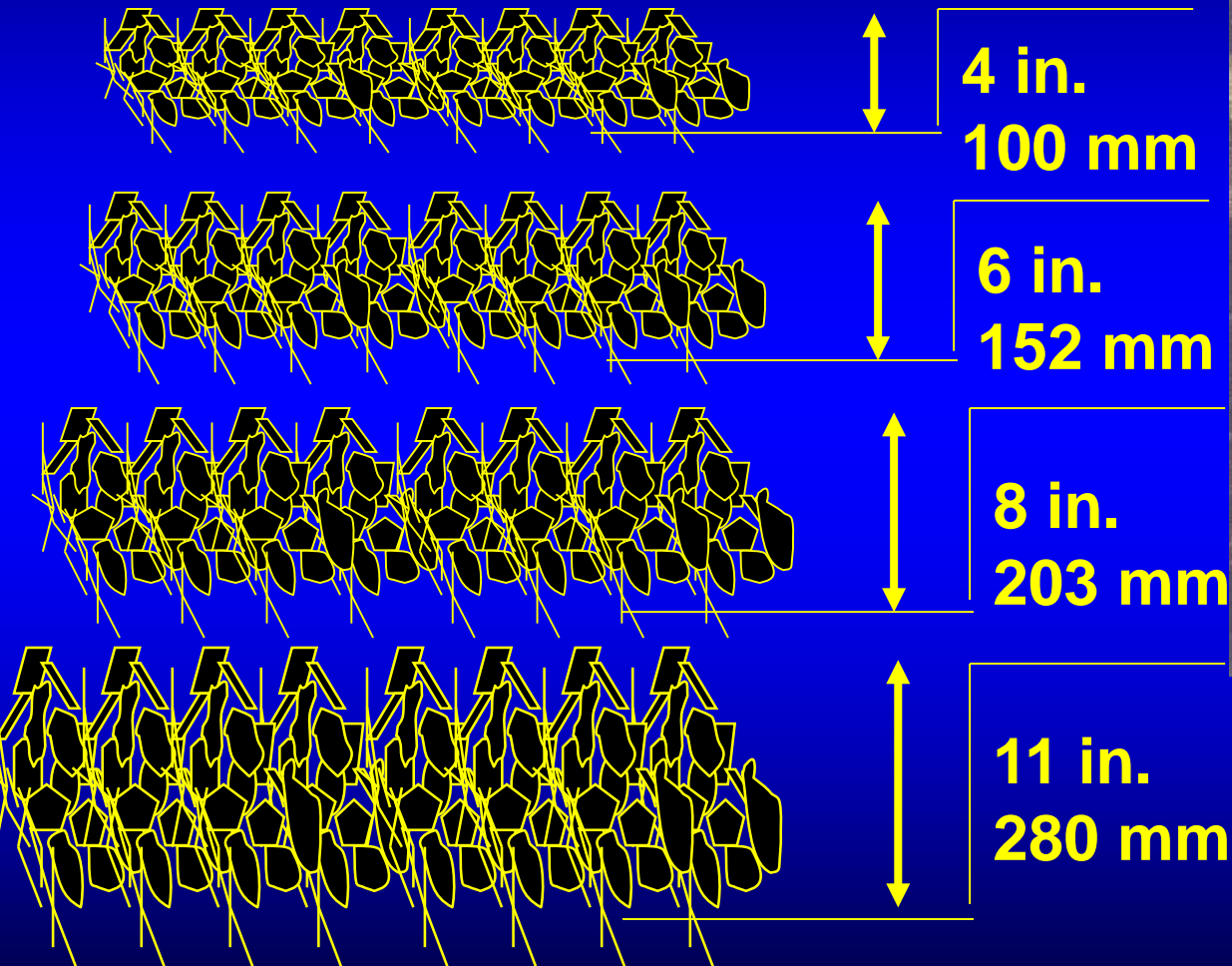


Figure 1. Fuel use as related to tillage intensity (data from Archer and Reicosky 2009).

1998 Plow Depth Study Swan Lake Farm

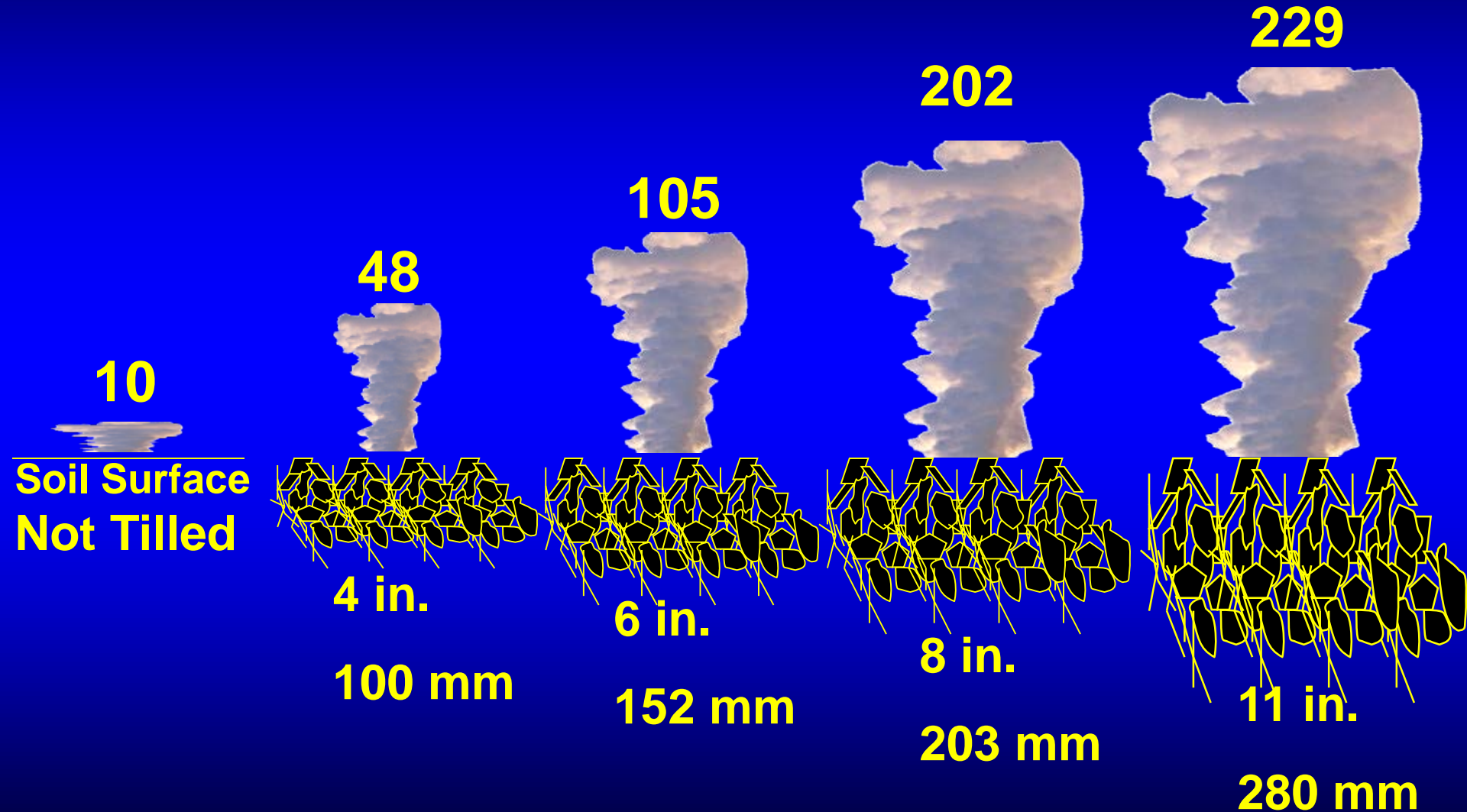
Soil Surface

Not Tilled



12 Aug., 1998 Plow Depth Study Swan Lake Farm

24 hour cumulative CO₂ losses (g CO₂ m⁻²)



Denmark



Intensive soil tillage opens the “all-you-can-eat buffet” for the birds and microbes.

Minnesota, USA



Tillage creates twin problems:
-- Accelerated soil degradation
-- Accelerated soil erosion

Tillage is a biotic disturbance!

“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



asteroid impact



forest fire



tsunami



hurricane

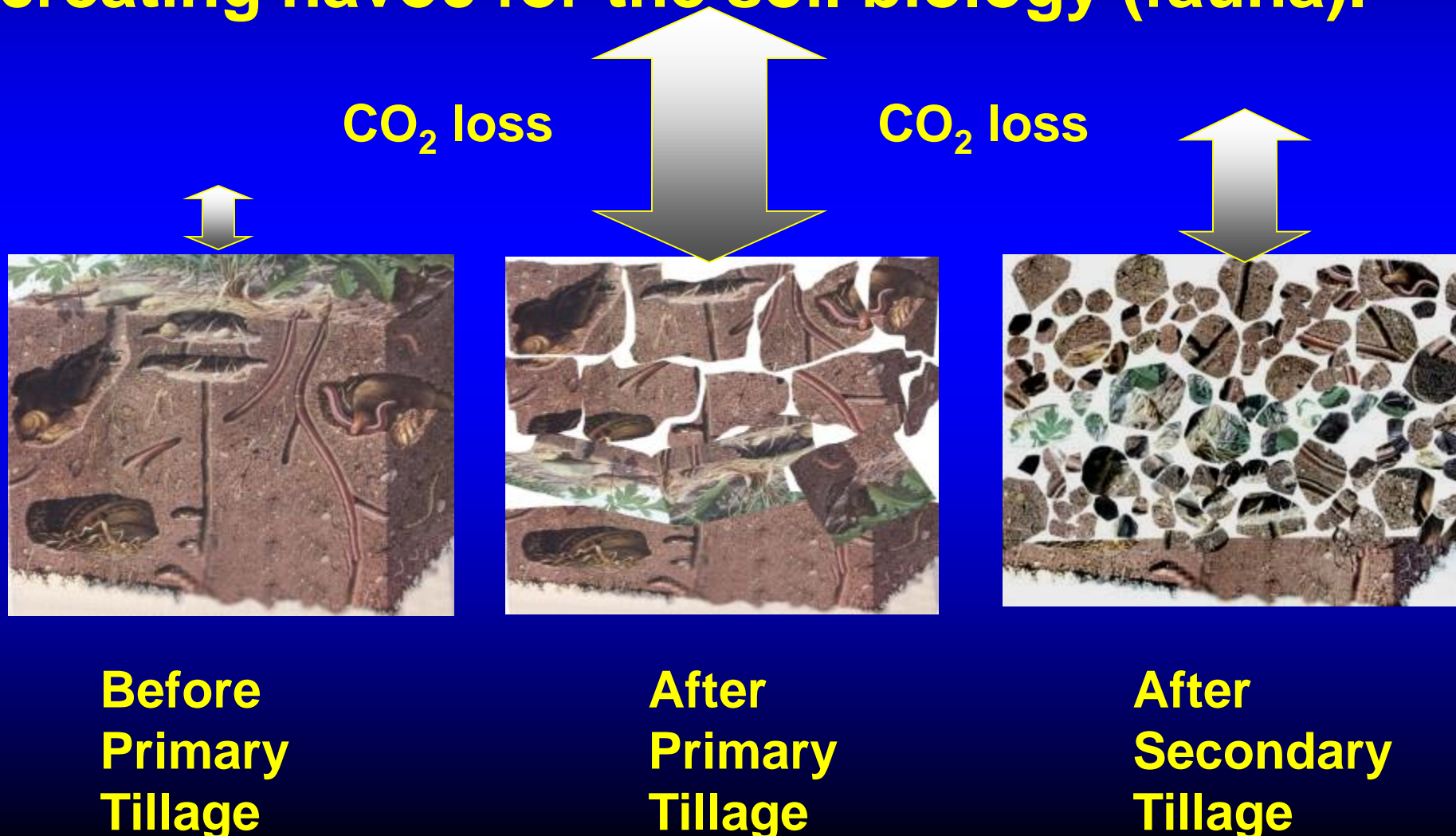


tornado



all rolled into one perturbation event!

Intensive tillage “butchers the biology” in the soil. It cuts, slices, and dices the soil and blend’s, mixes, and inverts the soil creating havoc for the soil biology (fauna).



Tillage creates a priming effect for some microbes as well as the complete destruction fungal hyphae network structure of the mycorrhizal fungi and micro arthropods.

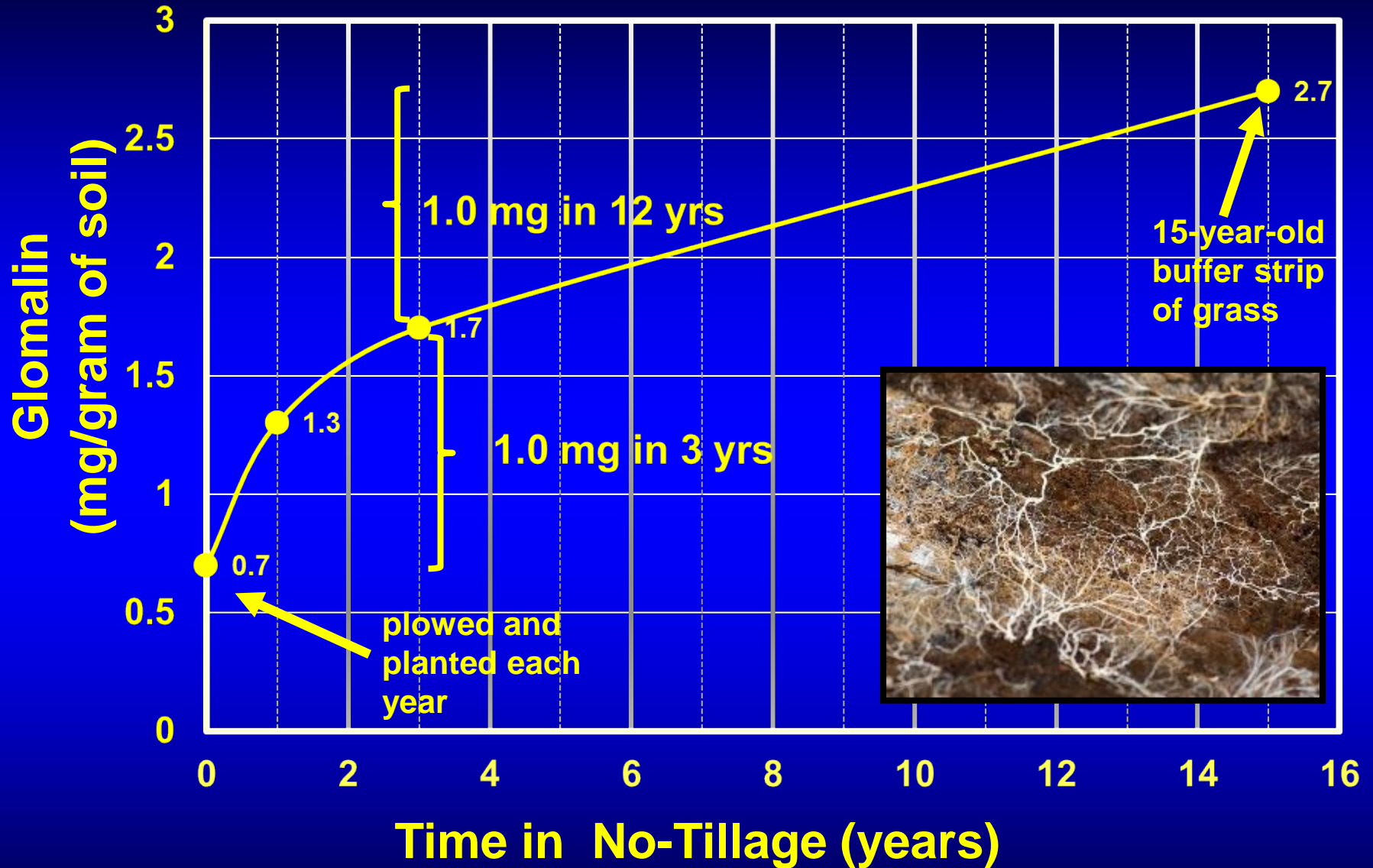
↑ Fungi:Bacteria Ratio ↑ C & N storage

If we want to store more carbon and nitrogen within the soil for subsequent crops we must try to maximize the fungi:bacteria ratio which means virtually no soil disturbance because of the way any tillage destroys the delicate fungal network.

Kuzyakov, Yakov. 2010. Priming effects: Interactions between living and dead organic matter. Soil Biology and Biochemistry Volume 42, Issue 9, September 2010, Pages 1363–1371.

Six, J., S. D. Frey, R. K. Thiet, and K. M. Batten. 2006. Bacterial and Fungal Contributions to Carbon Sequestration in Agroecosystems. Soil Sci. Soc. Am. J. 70:555–569.

Glomalin content



"Glomalin: Hiding Place for a Third of the World's Stored Soil Carbon" was published in the September 2002 issue of Agricultural Research magazine. Sara Wright

The “living soil”, a biological system.

Mammals - gophers, moles, mice, groundhogs

Earthworms - night crawlers, garden worms

Insects and mollusks - ants, beetles, centipedes, snails, slugs

Microfauna - nematodes, protozoa, rotifers≈

Microflora - fungi, yeast, molds, mychorhiza

Actinomycetes - smaller than fungi, act like bacteria

Bacteria - autotrophs, heterotrophs, rhizobia, nitrobacter

Algae - green, blue-green

≈



“That soil fauna and microbial action
is the equivalent of grazing two
African elephants per acre.”

Source: Jerry Hatfield, the director of USDA’s National Laboratory for Agriculture and the Environment in Ames, Iowa.

Natural synergy

→ **Worms = Roots**
(bio-pores)
Roots = Worms ←

Bio-pores enable OM (root) penetration, provide aeration more & deeper H₂O channels for H₂O storage & accessibility

Bio-pore channels provide a buffet enriched with C, NO₃, available phosphate, polysaccharides & other nutrients

Bio-pores stimulate other soil fauna and microbial activity for more CO₂ respiration



Photo:
Frédéric
Thomas

Bio-pores by cover crop roots and earthworms allow deeper agronomic crop rooting

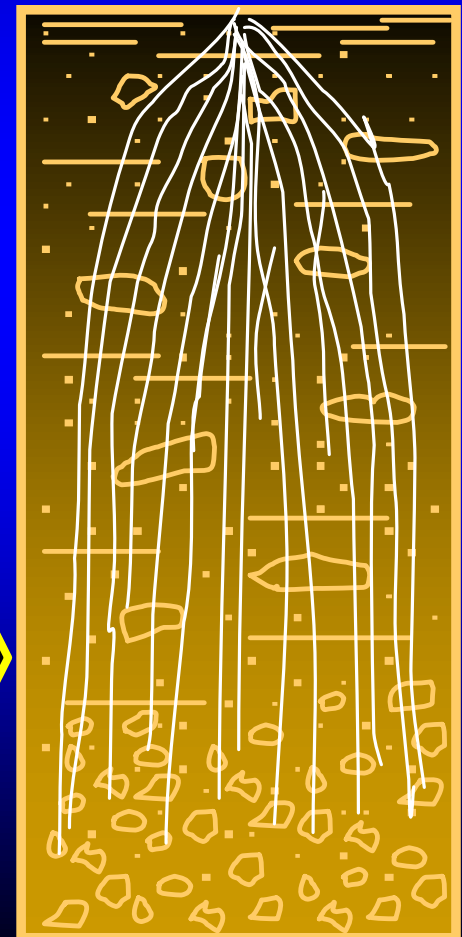


Deeper rooting provides a larger reservoir for storage of water from previous rain, which can be used during later season droughts.



+ 76 mm
of stored
water

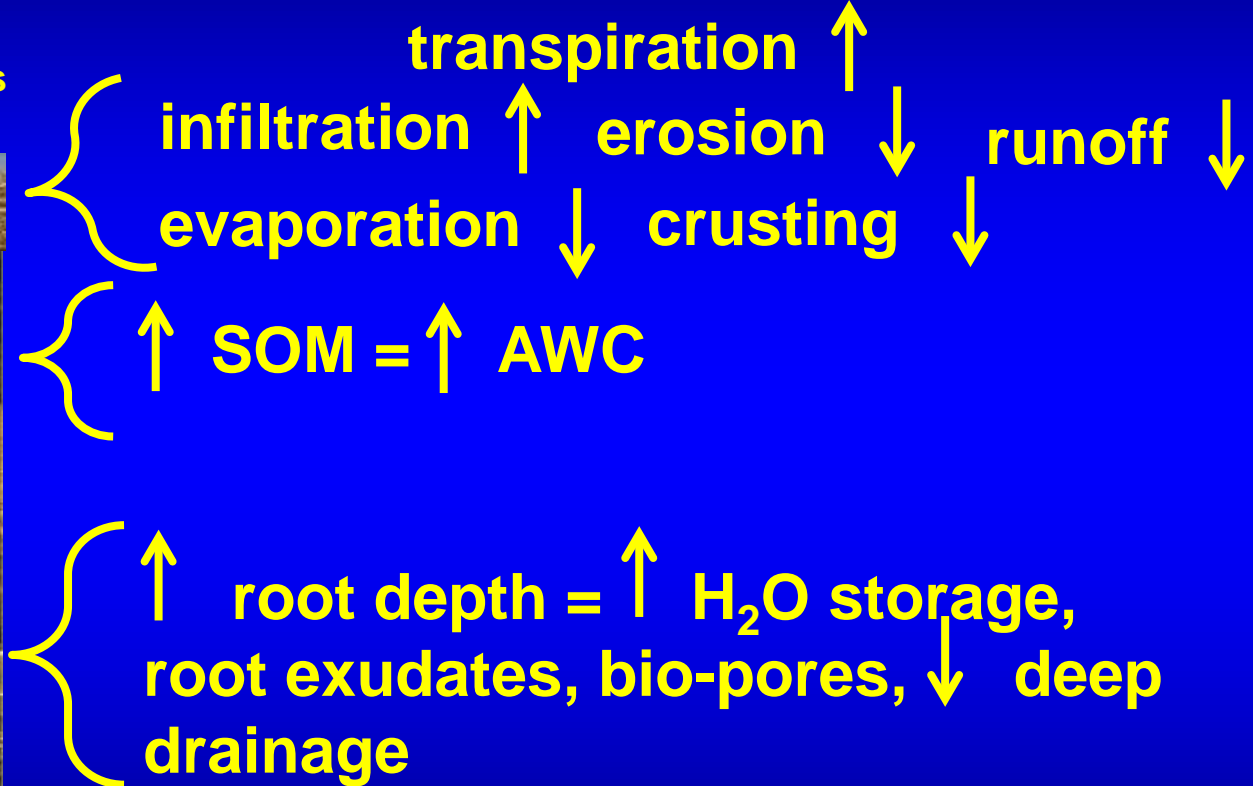
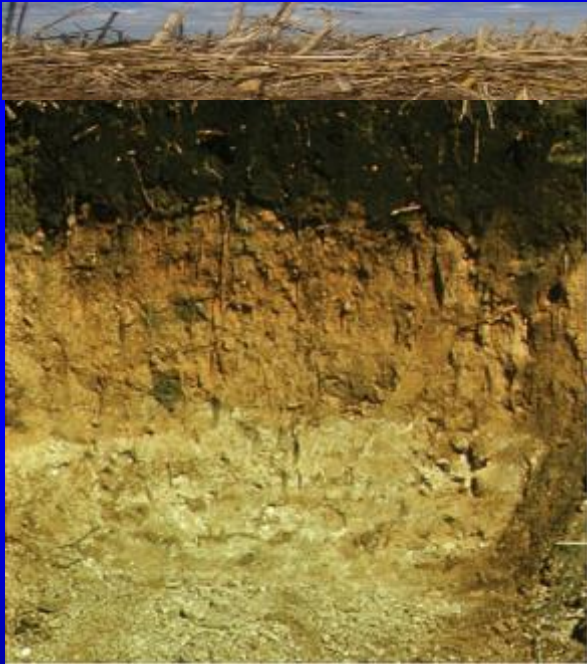
+ 91 cm
rooting
depth



Plant carbon is our greatest water management tool!

Mulch layer

(keeps sun from soil, moderates temperature, vapor barrier)



Good carbon management is required for maximum water use efficiency.

The small amounts of water saved in a typical annual crop growing season by carbon management can add up.

Mulch effect (evap)	~3.0 in (~ 76 mm)
Infiltration/runoff	~3.0 in (~ 76 mm)
SOM +1% = storage	~2.0 in (~ 51 mm)
Cover roots access	~3.0 in (~ 76 mm)

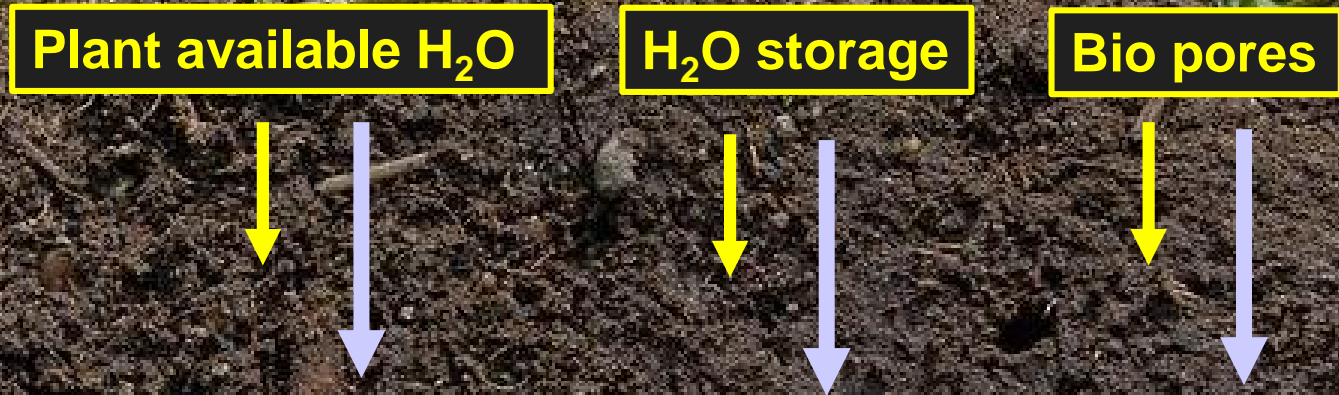
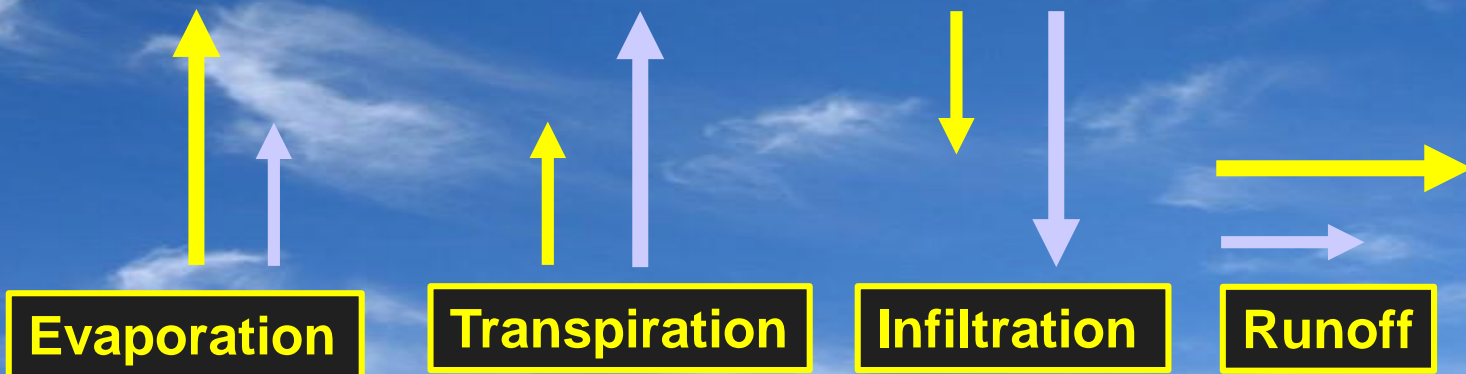
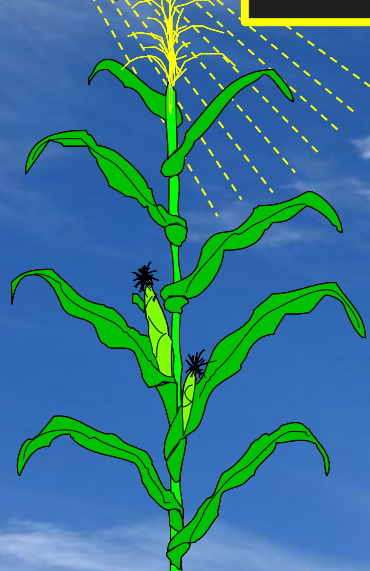
Seasonal Total ~11.0 in (~ 279 mm)
H₂O Due to C Mgt.

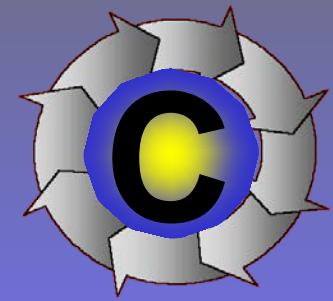
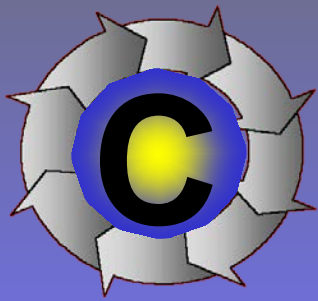
The sum of all of these small amounts of water loss saved due to carbon management plus other synergies of carbon will go towards food security and ecosystem services.



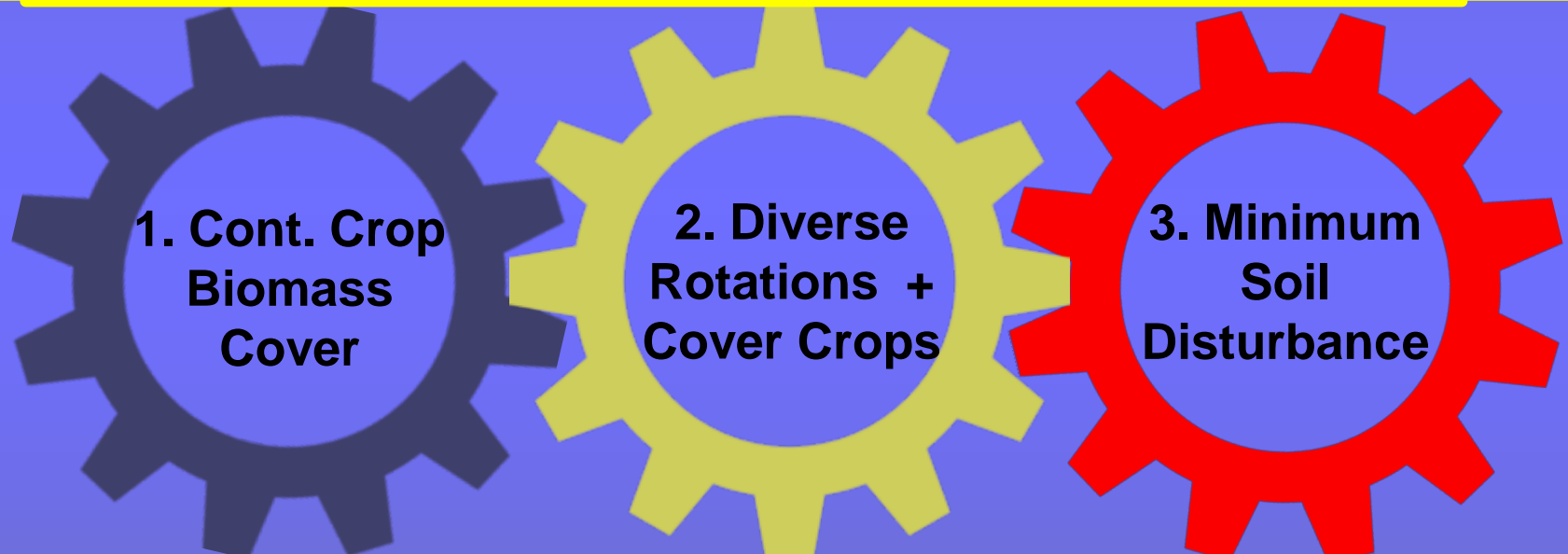
Water Use Efficiency

Conventional Ag Conservation Ag





In **Global Food Security** s



Local adaption of technology, nutrient and pest management.

Conservation Agriculture

Working With Mother Nature Improving Soil Health.

“As to methods, there may be a million and then some, but principles are few. The man who grasps principles can successfully select his own method.” Ralph Waldo Emerson

CA is Nature's way!

- **Continuous minimum soil disturbance**
- **Continuous maximum carbon input**
- **Continuous maintenance of biodiversity**

Conservation Agriculture is cost-effective!

1. Profitable for the farmers



Decreased input costs:

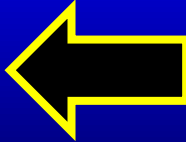
- Fuel > 50%
- Labor > 50%
- Equipment >~ 40-50%
- Repair and maintenance > 40%
- Nitrogen fertilizer > 50%
- Pesticides > 50%
- Water Management >30%

Anecdotal data

CA avoided costs:

- ✓ Erosion, runoff
- ✓ Pollution, algae
- ✓ Environmental cost (GHG)
- ✓ Social cost
- ✓ Rehabilitation of degraded soils
- ✓ Regenerates ecosystem services
- ✓ Climate extreme mitigation

2. Environmental quality for all



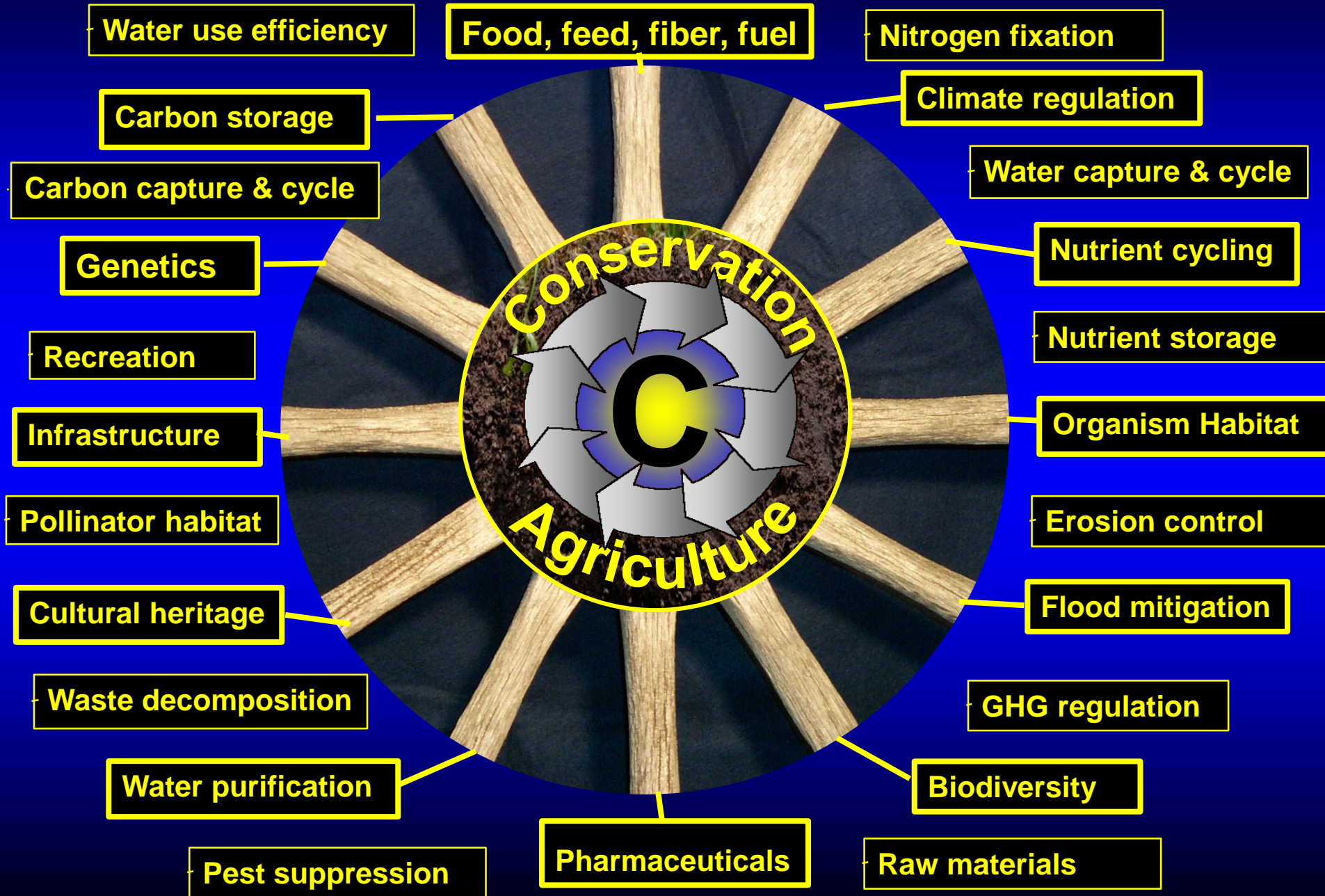
**Wheel is a symbol of strength, unity,
resilience and progress.**



**Spokes are individual environmental or ecosystem
benefits emanating from a carbon axel through the hub
of Conservation Agriculture Systems.**

Agriculture's Wheel of Fortune!

Carbon → CAS → Ecosystem functions



**Our soils contain “living biological partners”
enabling carbon and nutrient cycling synergies.**

**Soil degradation is caused by
one word:**

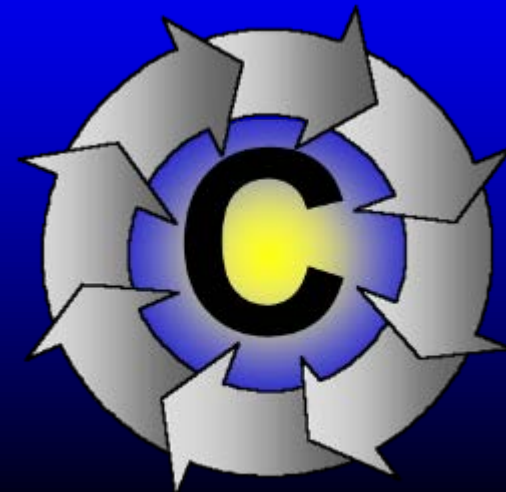
Tillage

**Soil recovery is accomplished by
one word:**

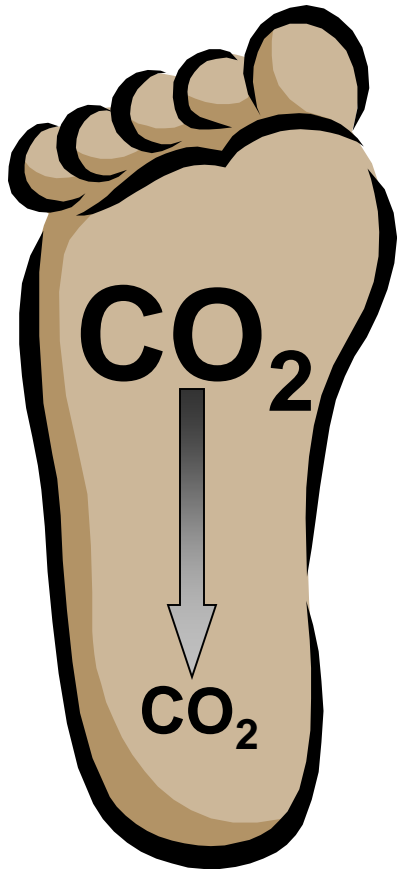
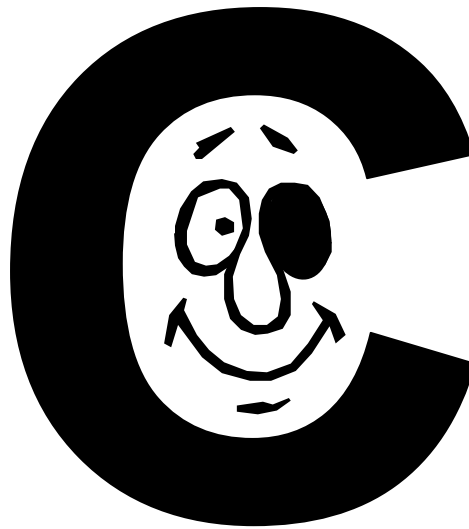
Carbon

**Soil health maintenance is
accomplished by one word:**

Carbon



Carby Carbon



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

**Be a “Mega-voice” for
Carbon management!**

