AGVISE Seminars

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Tillage and Carbon Management: Nutrient Re-cycling Synergies.

by

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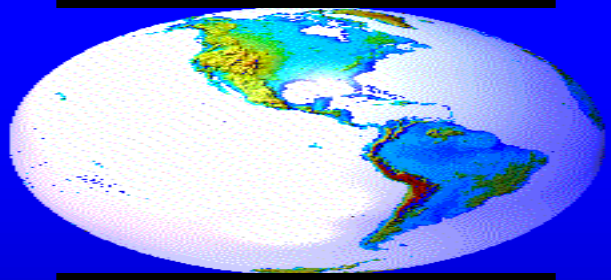
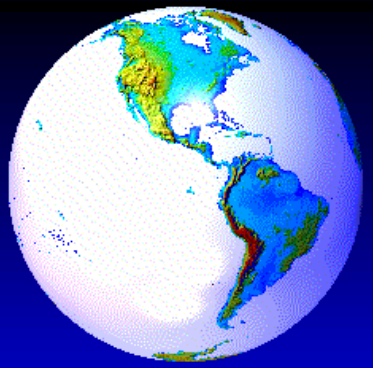
There is pressure on our earth resources and food security!

9,000,000,000 people by 2050



1,440,000,000 ha cropland (3.56 billion acres)



OUR HUNGRY WORLD

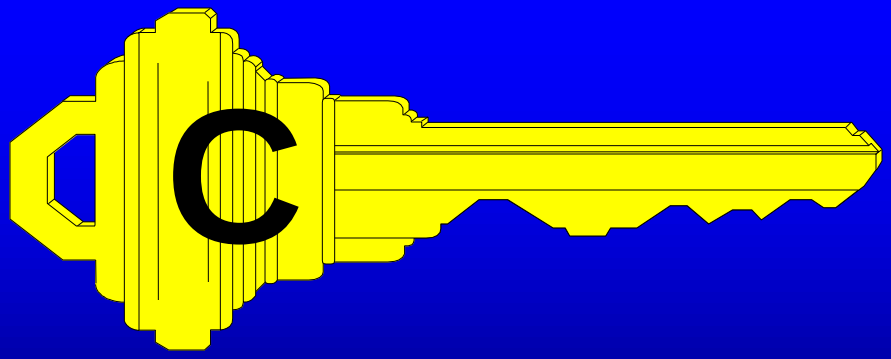
OUR THREATENED PLANET

OUR CHILDREN'S FUTURE

OUR ONE CHANCE… Conservation Agriculture

All rest on "OUR LIVING SOIL" that depends on soil organic carbon!

The "key" component is:



c a r b o n !

No Tillage

Cover Mixes

Carbon is the "heart" of soil health!

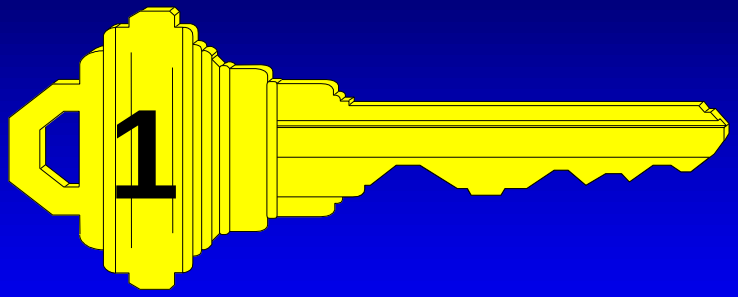
Minimum carbon loss

Maximum carbon input

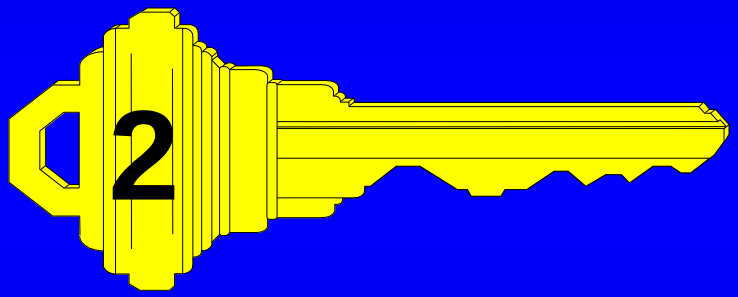
Food Security

Soil Organic Carbon

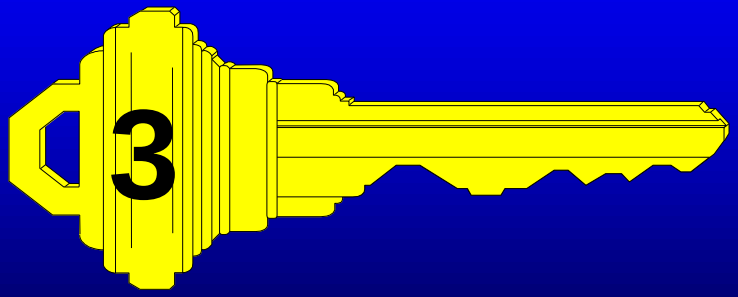
3 Keys to Conservation Agriculture!



Minimal soil disturbance



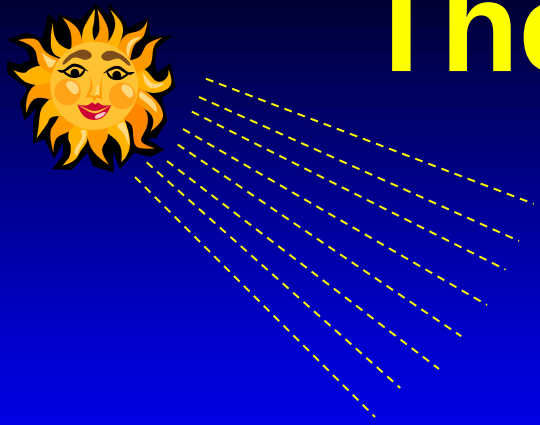
Continuous residue cover



Diverse rotations or synergy crops

Soil Organic Carbon

The Carbon Cycle



Photosynthesis

$6CO_2 + 6H_2O$

Energy Release

C

Energy Capture

$6O_2 + C_6H_{12}O_6$

Respiration

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

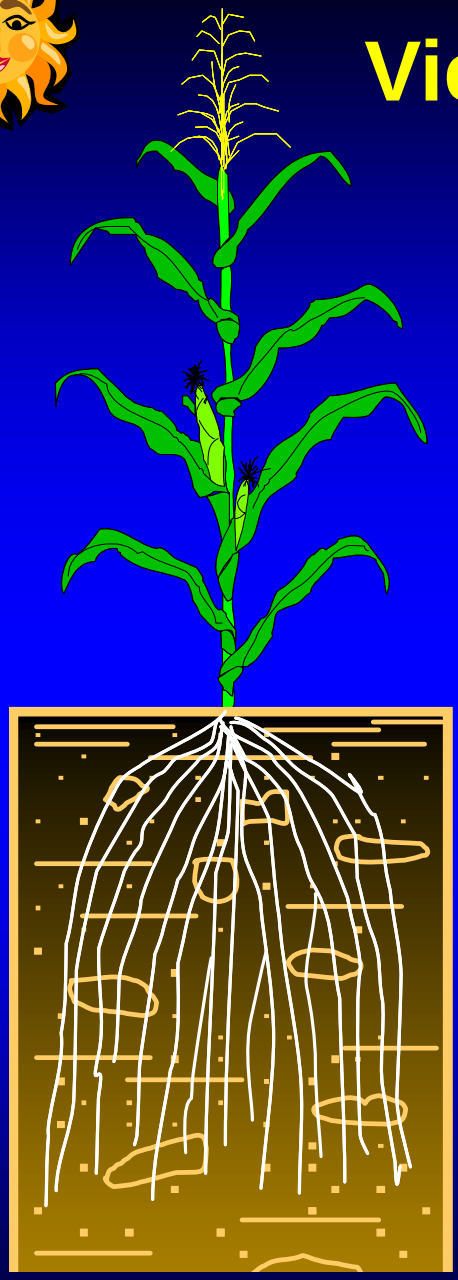
Food source

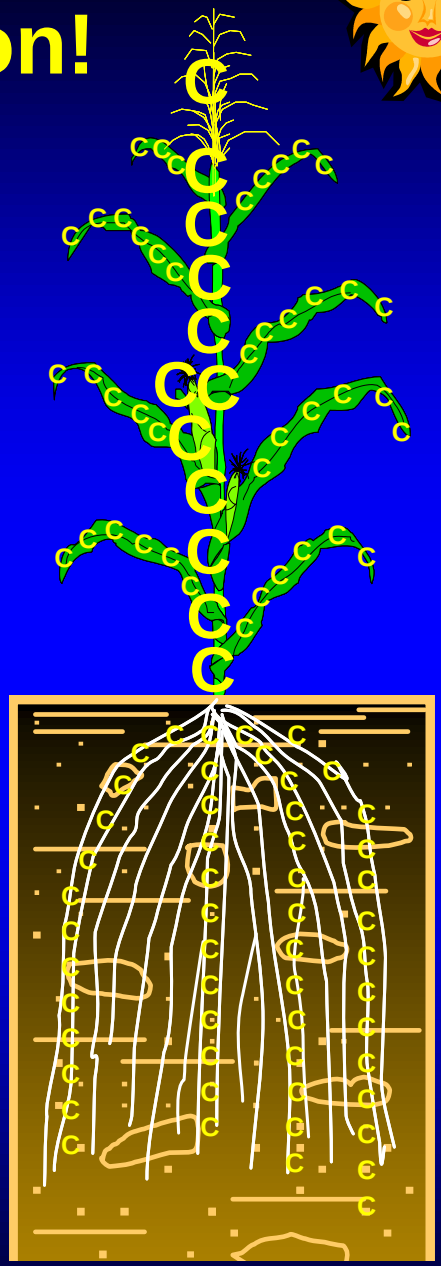
Energy source

Soil carbon input

Environmental benefits

Quality of Life

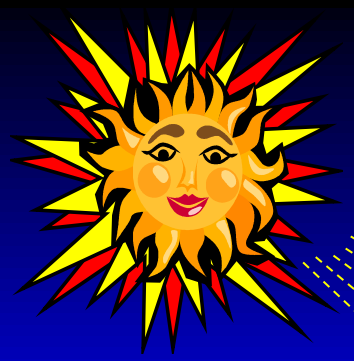




Carbon is the “C” that starts “C”onservation!

Conservation is more about plant management than soil management because of the importance of carbon.

Ecosystem Services



Our Resources

Sun

Air

Water

Soil

Food

Feed

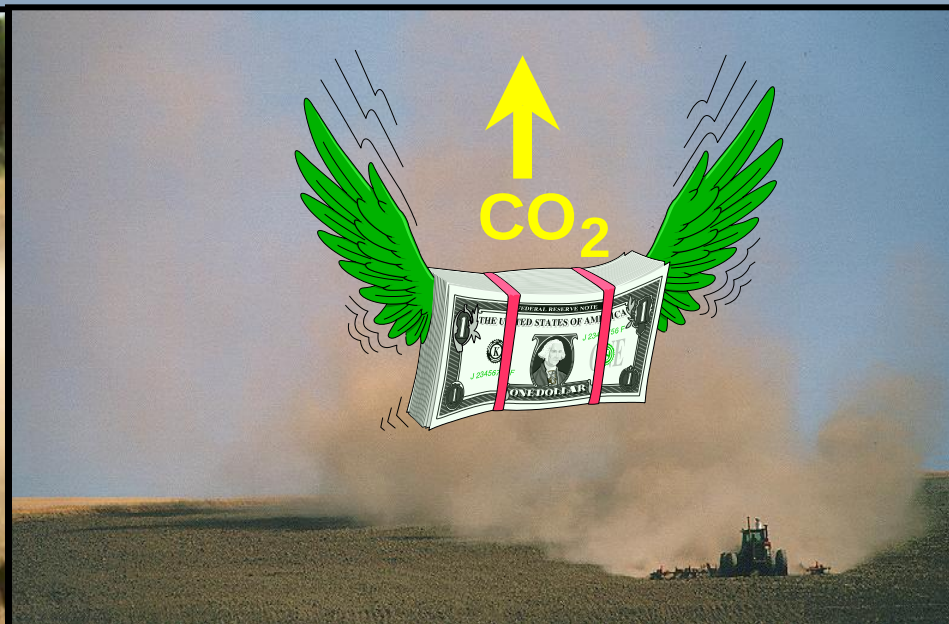
C

Fiber

Fuel

No. 1 Environmental Enemy in Production Agriculture

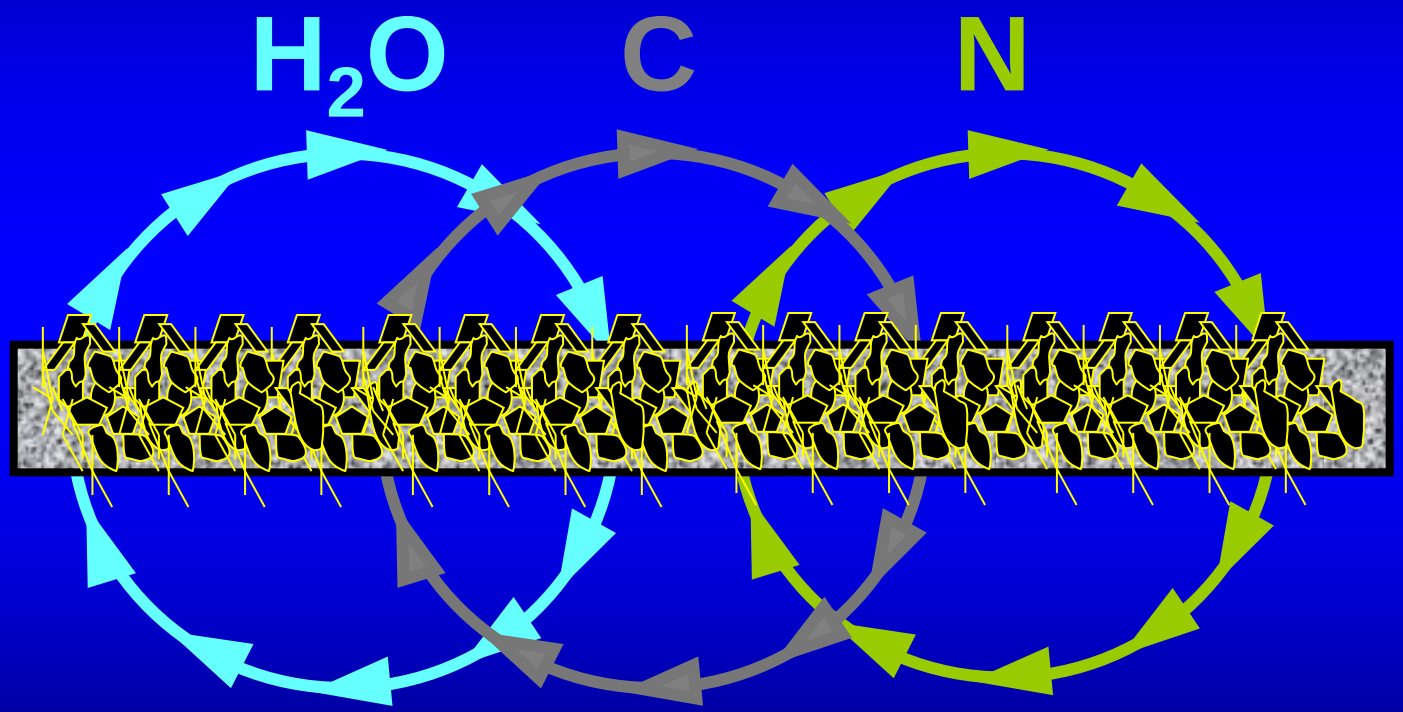
Tillage-induced Carbon Dioxide Loss

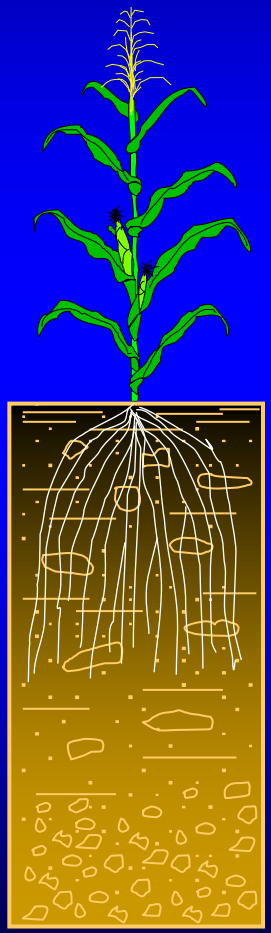


Nature's Interdependent Tri-Cycles:

Water, Carbon, Nitrogen,

Tillage disrupts the natural cycles!





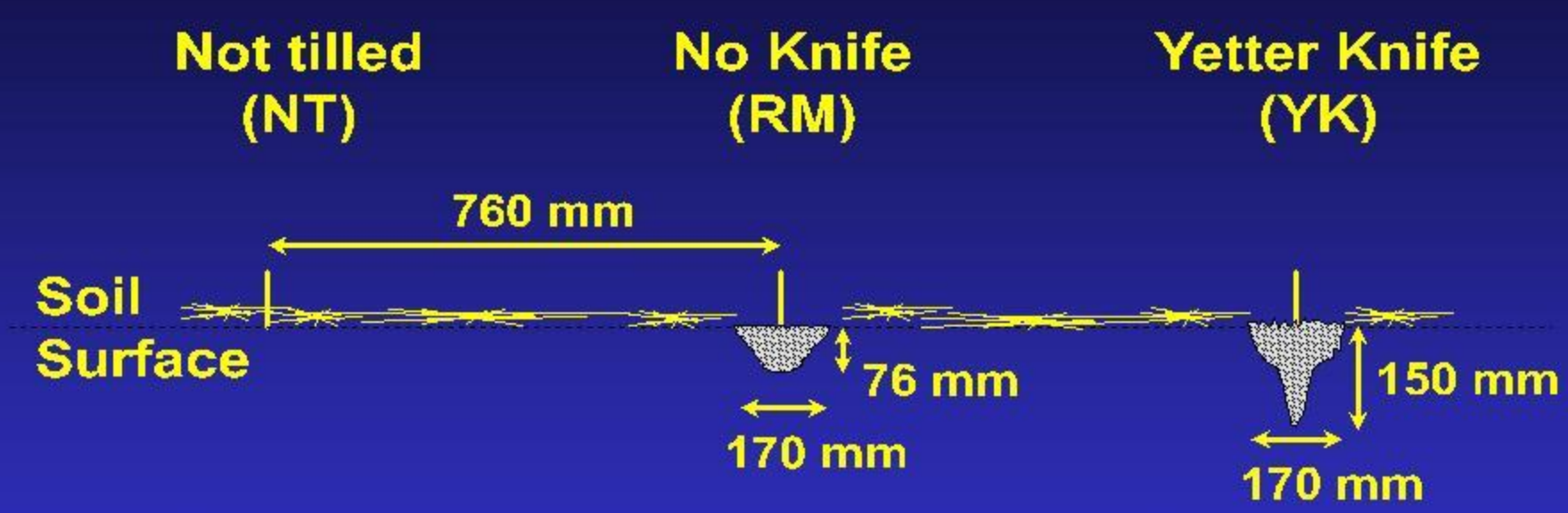
Properties and Processes

Physical Chemical Biological

Invisible effects of invisible forces!

Schematic Representation of Strip Tillage Soil Disturbance

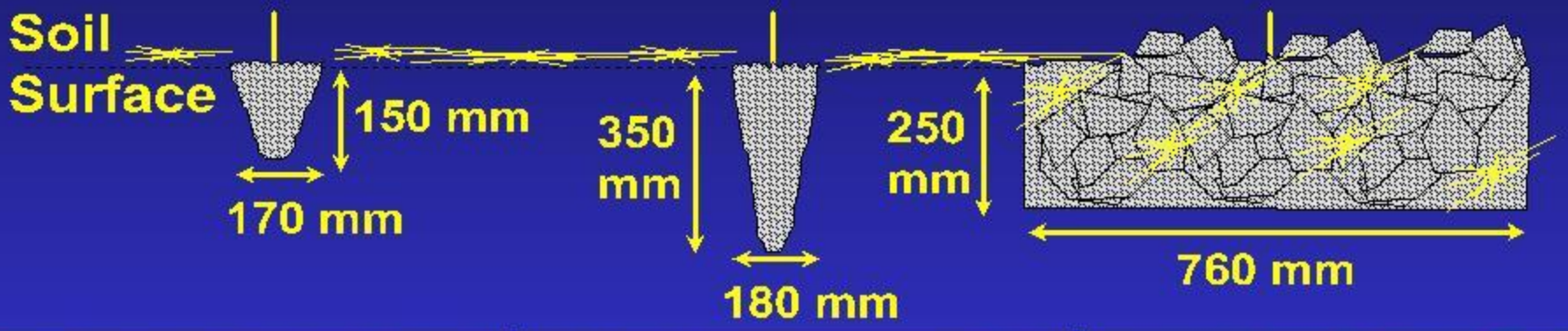
Yetter triple beam tool bar
4 rows at 760 mm spacing

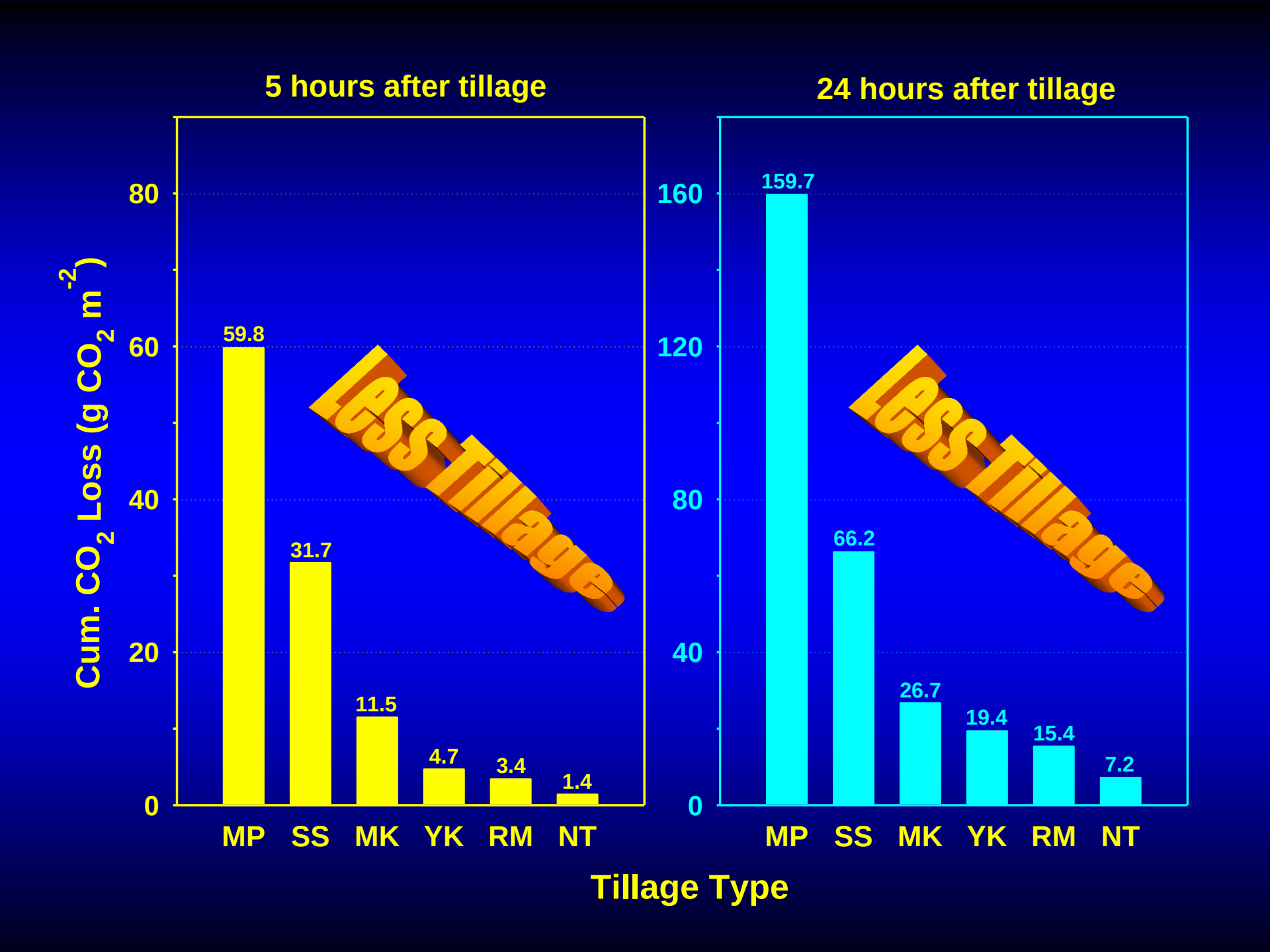


Schematic Representation of Strip Tillage Soil Disturbance

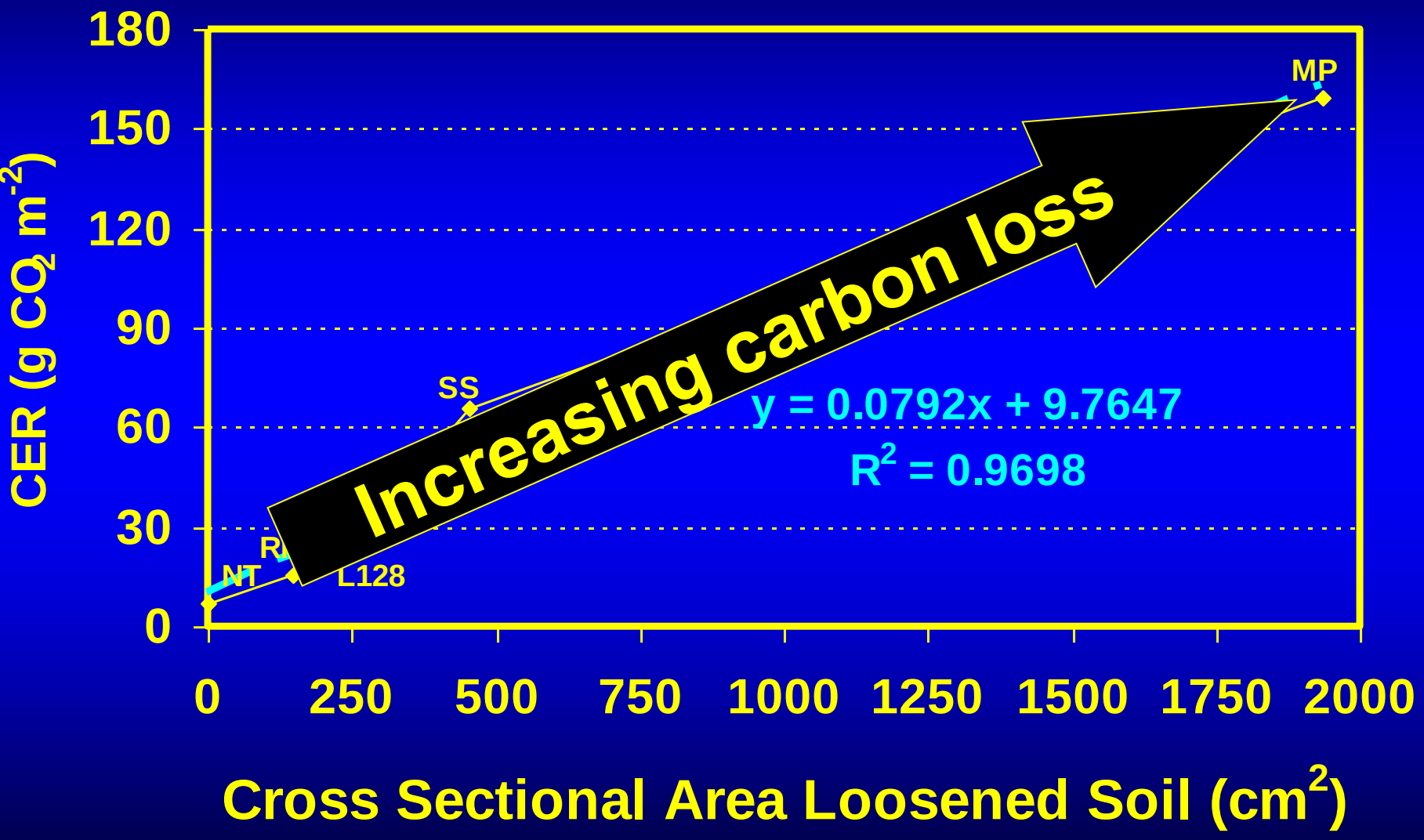
Yetter triple beam tool bar
4 rows at 760 mm spacing

Mole Knife (MK) | **Subsoil Shank (SS)** | **Moldboard Plow (MP)**




5 hours after tillage
24 hours after tillage
Cum. CO_2 Loss (g CO_2 m^{-2})
80
60
40
20
0
160
120
80
40
0
59.8
31.7
11.5
4.7
3.4
1.4
159.7
66.2
26.7
19.4
15.4
7.2
MP
SS
MK
YK
RM
NT
Less Tillage
Less Tillage
Tillage Type

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



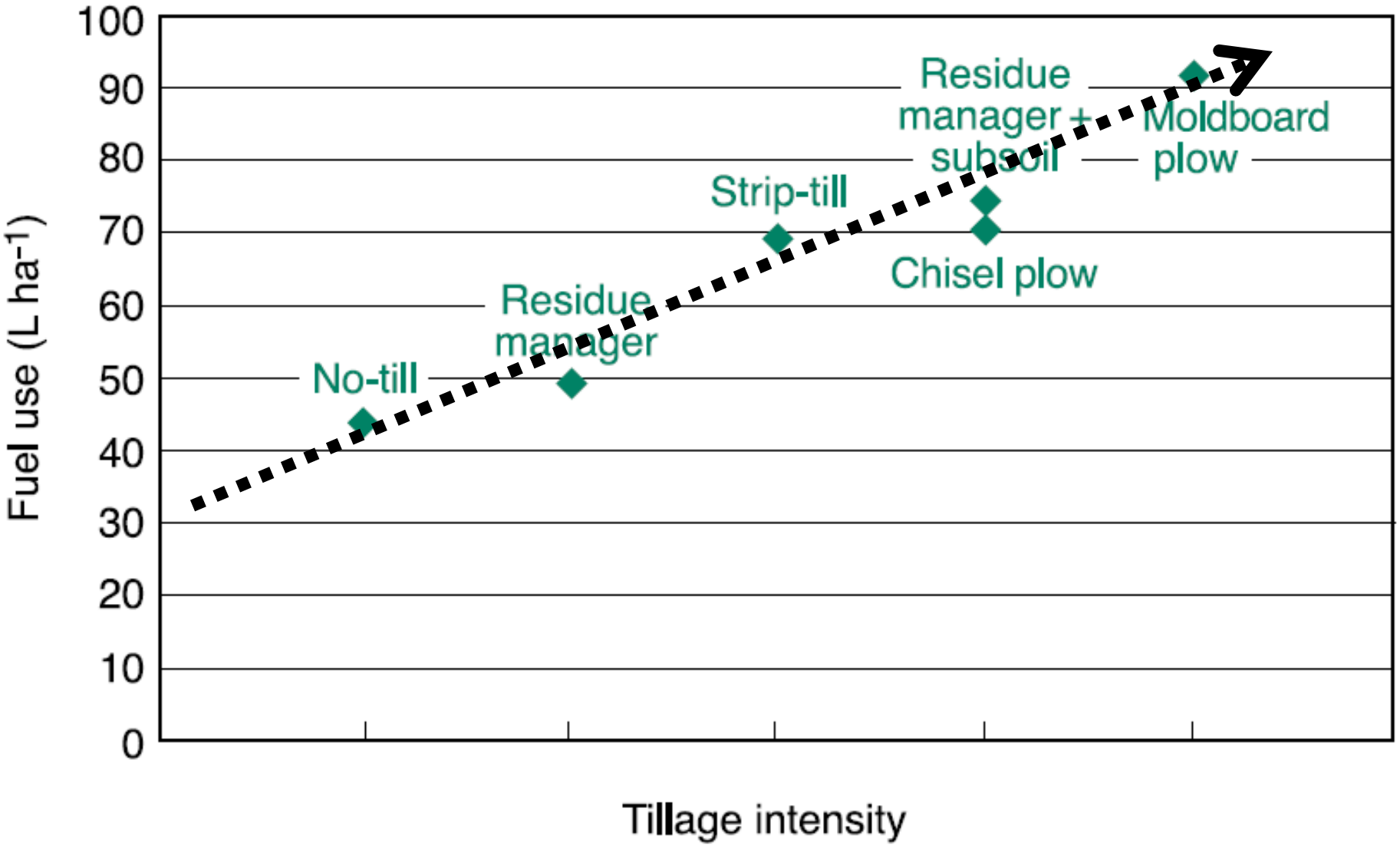
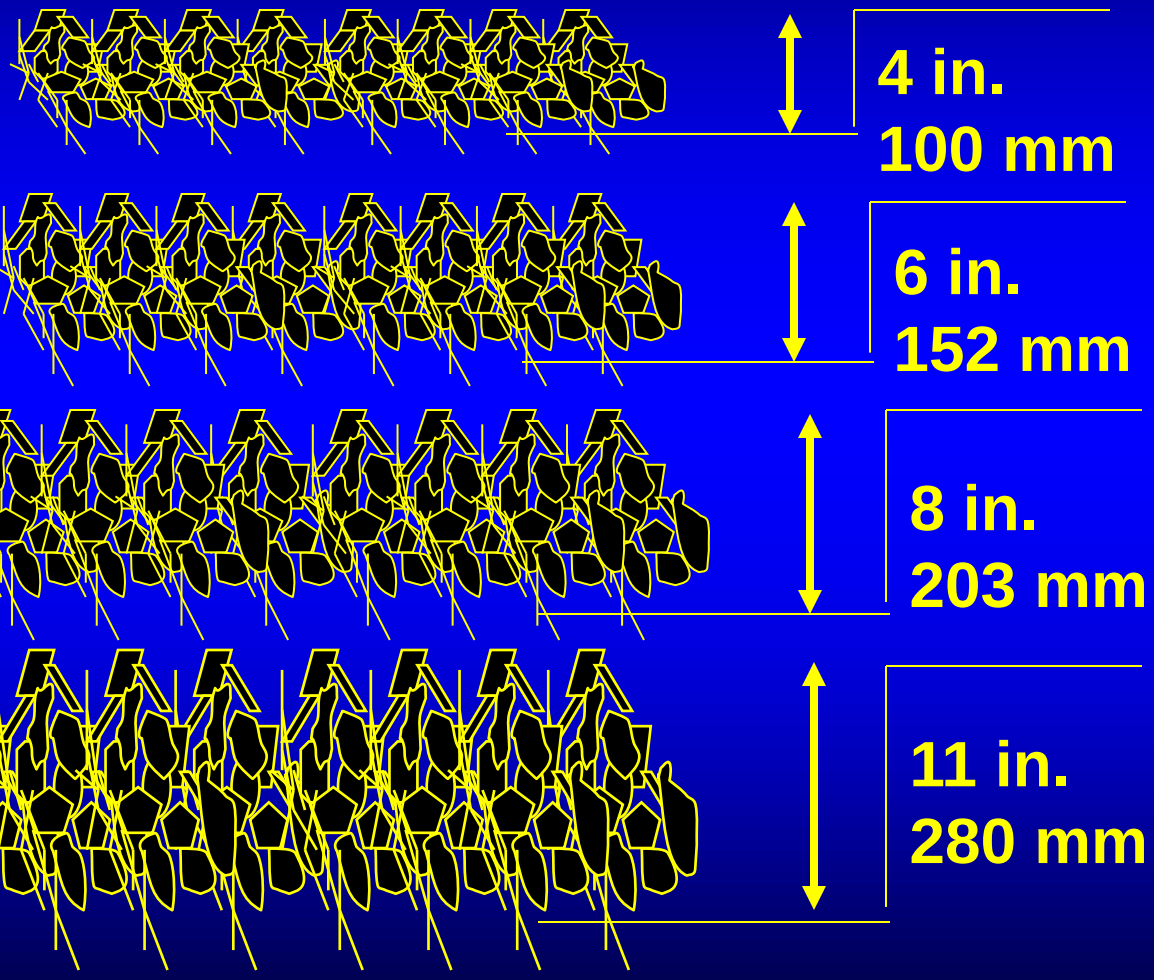


Figure 1. Fuel use as related to tillage intensity (data from Archer and Reicosky 2009).

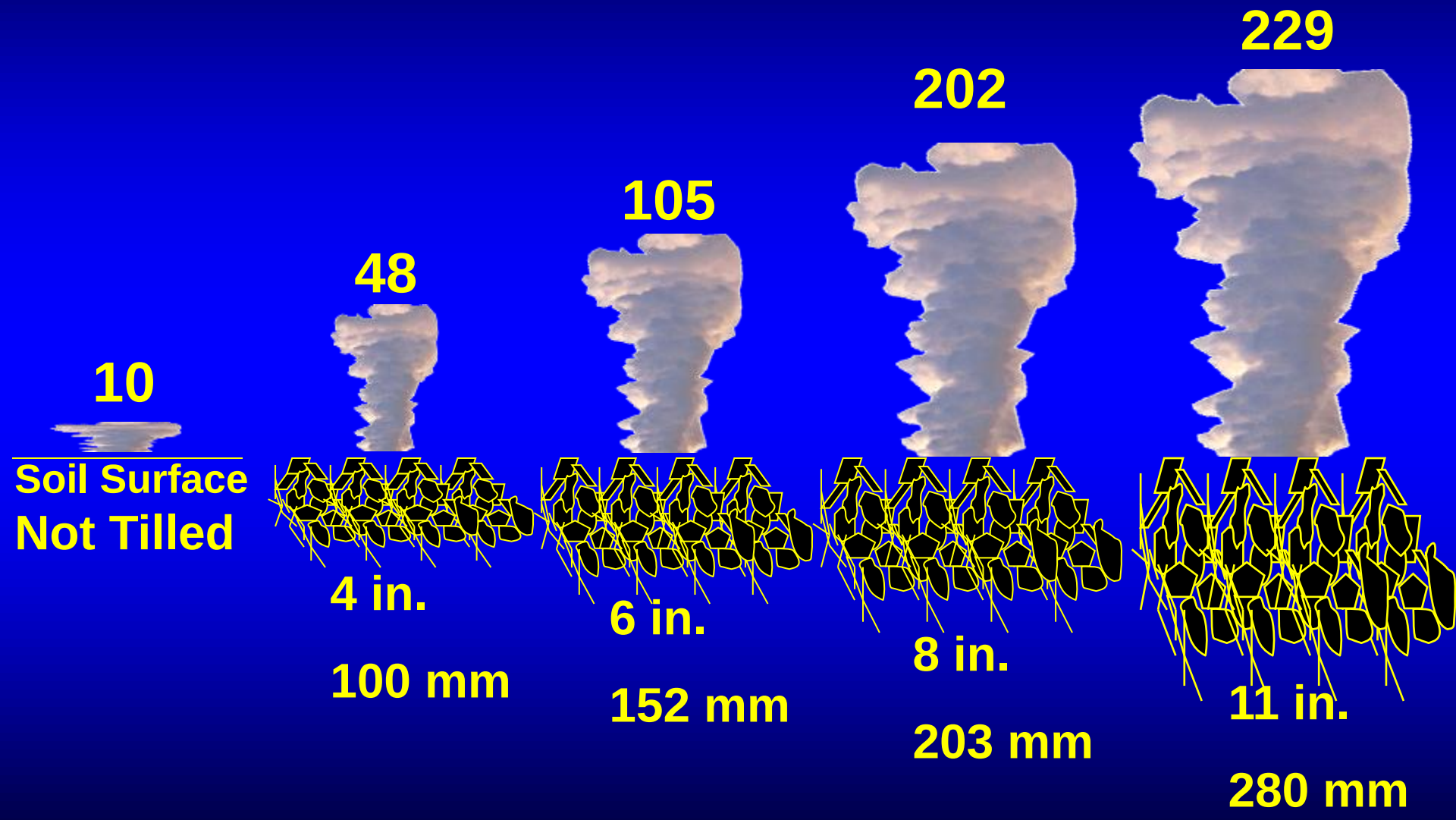
1998 Plow Depth Study Swan Lake Farm

Soil Surface

Not Tilled



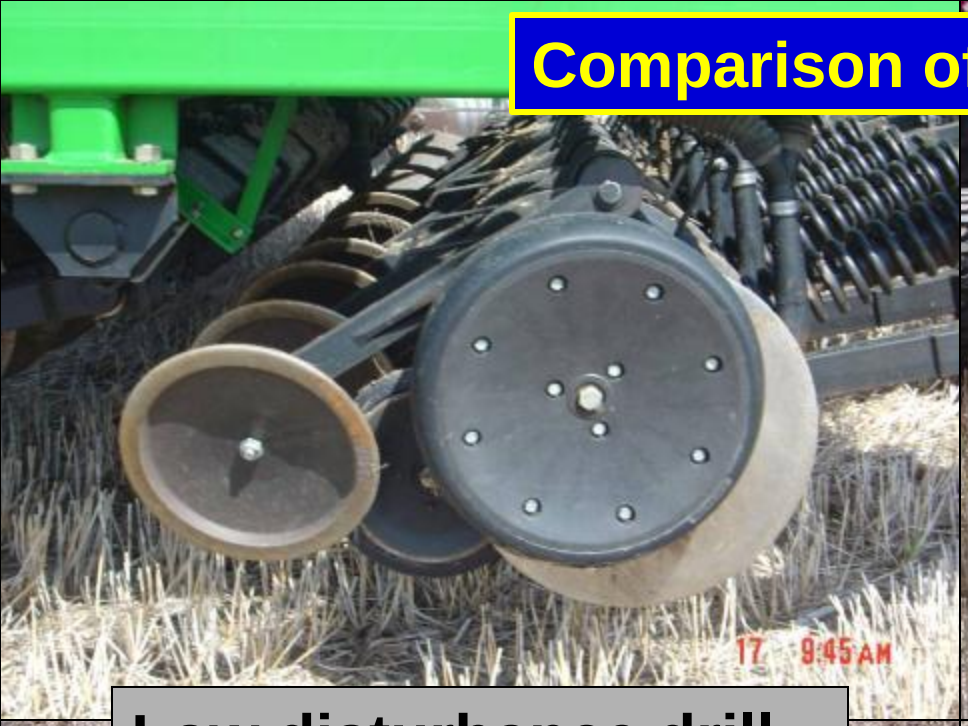
12 Aug., 1998 Plow Depth Study Swan Lake Farm
24 hour cumulative CO_2 losses (g CO_2 m^{-2})



Previous work showed tillage-induced CO_2 emissions were proportional to soil volume disturbed.

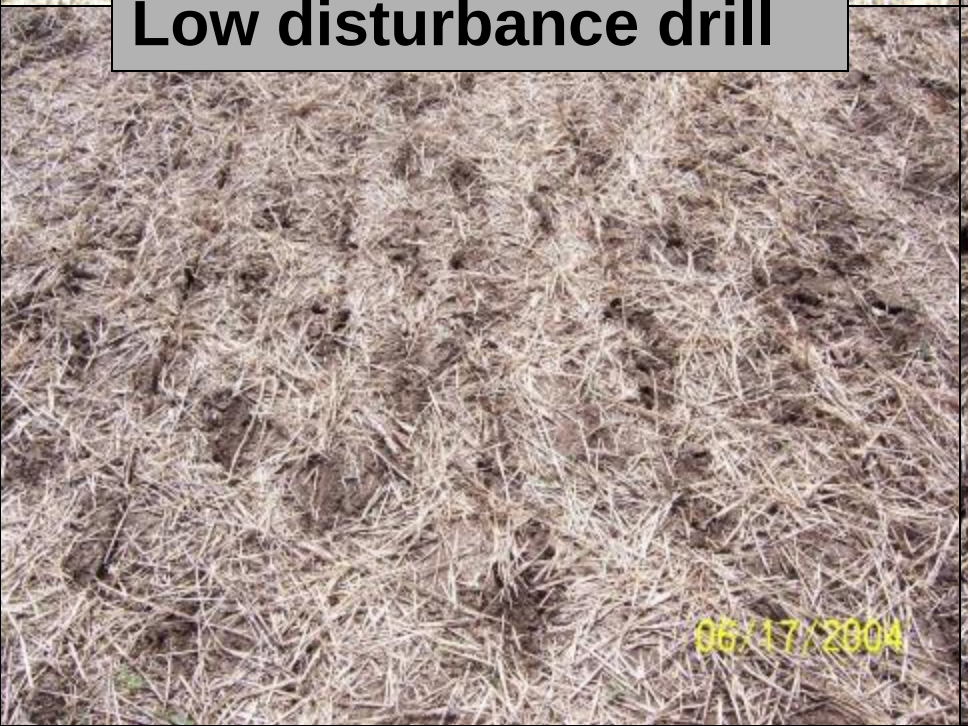
What do large “no till” seeders due to CO_2 emissions?

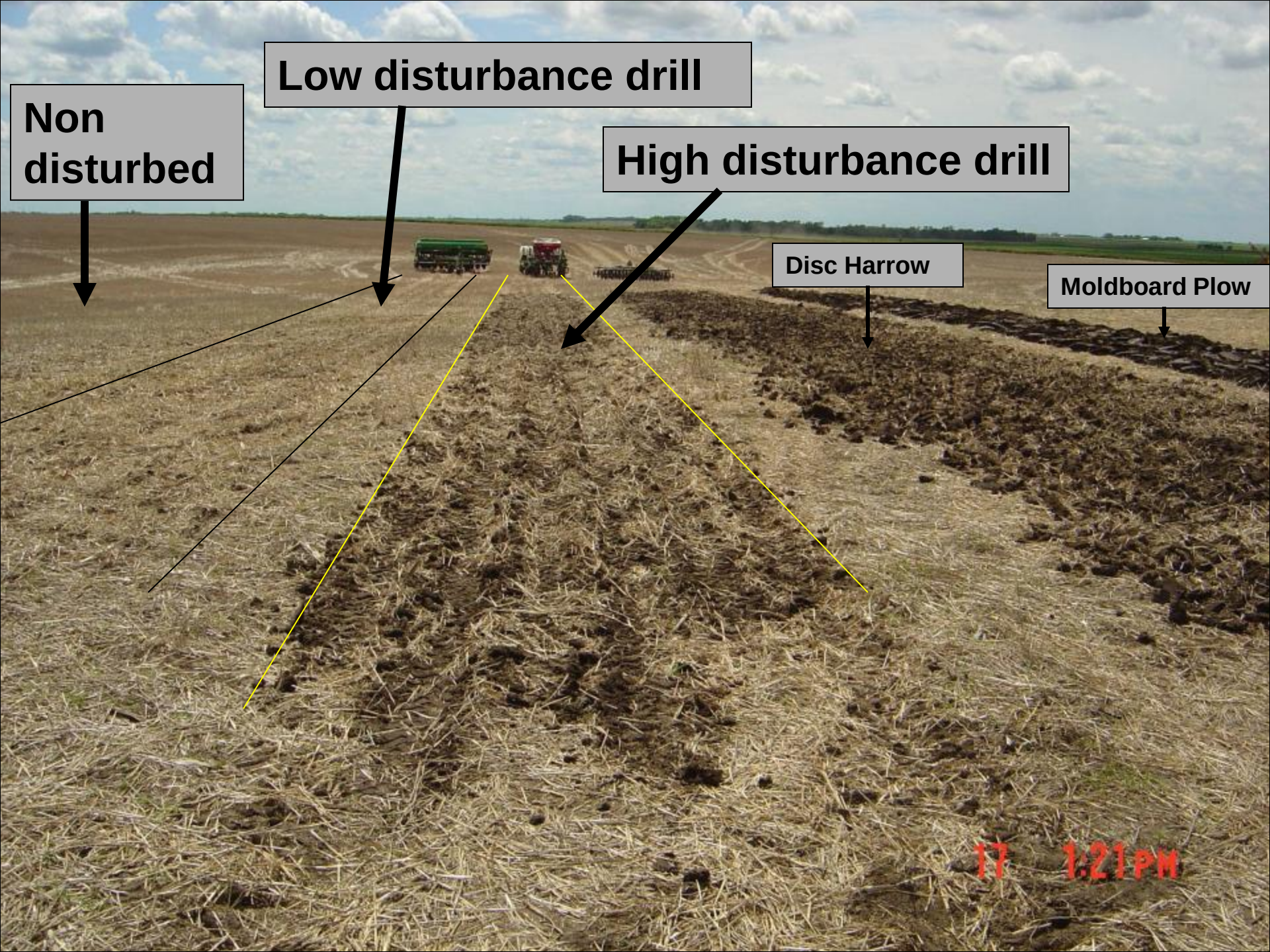
Comparison of No Till Drills

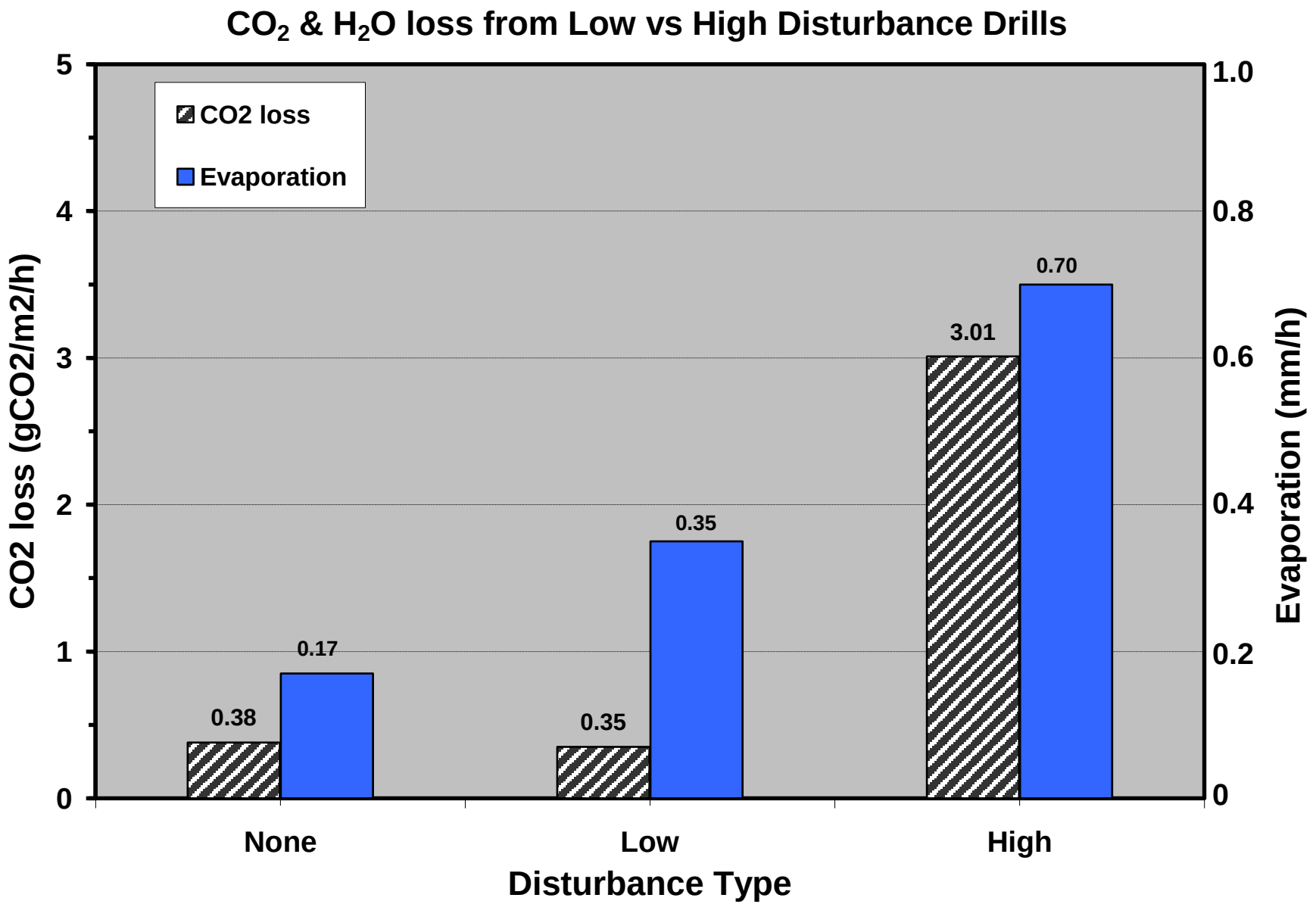


Low disturbance drill

High disturbance drill




Non disturbed
Low disturbance drill
High disturbance drill
Disc Harrow
Moldboard Plow
17 1:21 PM


CO_2 & H_2O loss from Low vs High Disturbance Drills
CO2 loss
Evaporation
CO2 loss (gCO2/m2/h)
Evaporation (mm/h)
0
1
2
3
4
5
0
0.2
0.4
0.6
0.8
1.0
0.38
0.17
0.35
0.35
3.01
0.70
None
Low
High
Disturbance Type

There's a jungle full of life living in your belly button!

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."

What's 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!

What's in your soil?

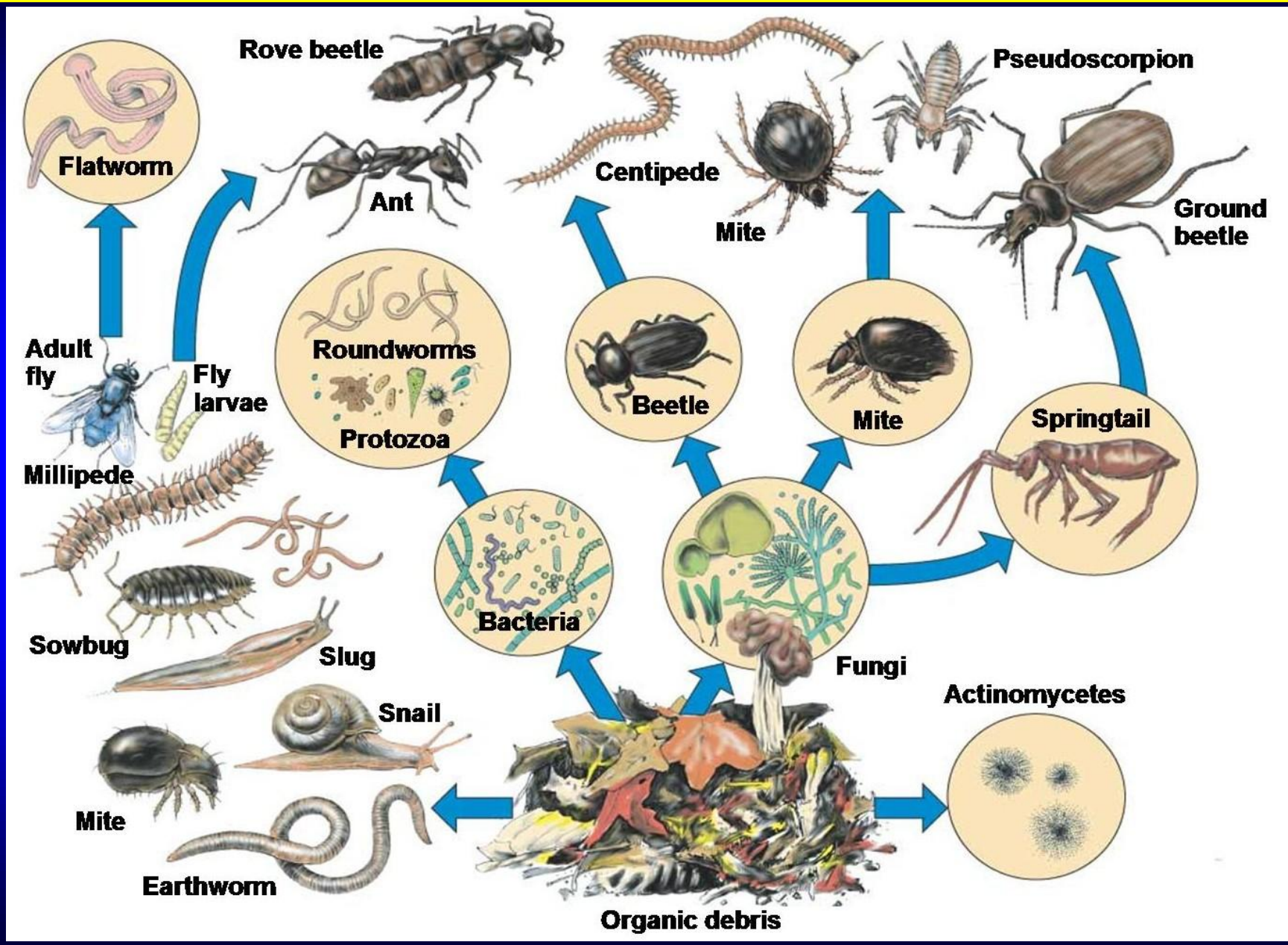
Your soil is crawling with billions of critters (bacteria, fungi, arthropods, nematodes, worms, and animals) in all shapes, sizes and appetites.

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.

5% OF SOIL ORGANIC MATTER IS LIVING ORGANISMS



http://www.rw.ttu.edu/2302_butler/chapter6.htm

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.

** Soil Biology Team **
The “living soil”

Most “soil critters” are bothered by tillage!

Earthworms, insects and rodents are the most visible components of the “living soil” team. They work in tandem either soil microorganisms and fungi to contribute to aeration and nutrient cycling as part of a “soil factory” team effort.

Earthworms are “nature’s” plow (and a lot more!)

A healthy population of earthworms will construct 3178 km of small burrows and 1192 km of pencil thick burrows in a hectare of soil. Earthworms will move tons of nutrients and soil on each hectare every year and are our natural soil mixers.

Nightcrawler's compost pile called a midden

Source: http://davidkusel.com/farm/nightcrawler1.htm

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).

CO_2 loss

CO_2 loss

Before Primary Tillage

After Primary Tillage

After Secondary Tillage

Tillage is an abiotic 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 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

Conservation Agriculture

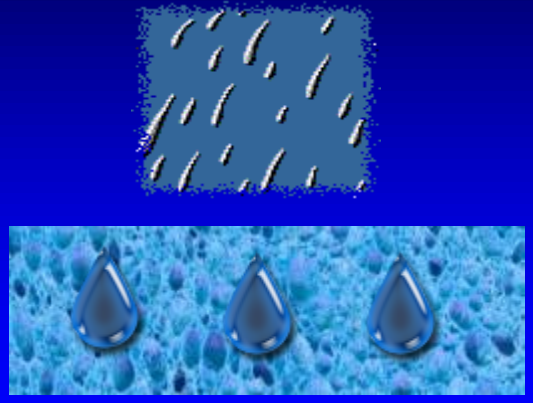
Carbon Management

No Till, Zero Till, Direct Seed

No “flow” **No “blow”** **No “glow”**

Soil organic matter acts like a "sponge" for water retention and release to plants.

sponge



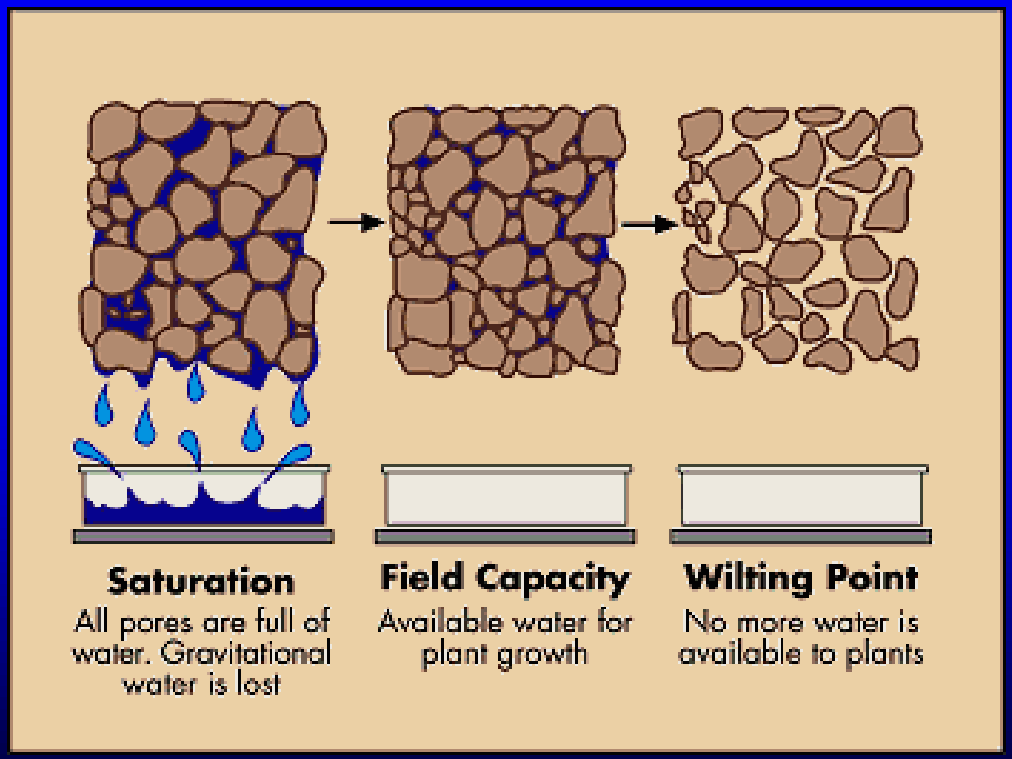
SOM "sponge"

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.

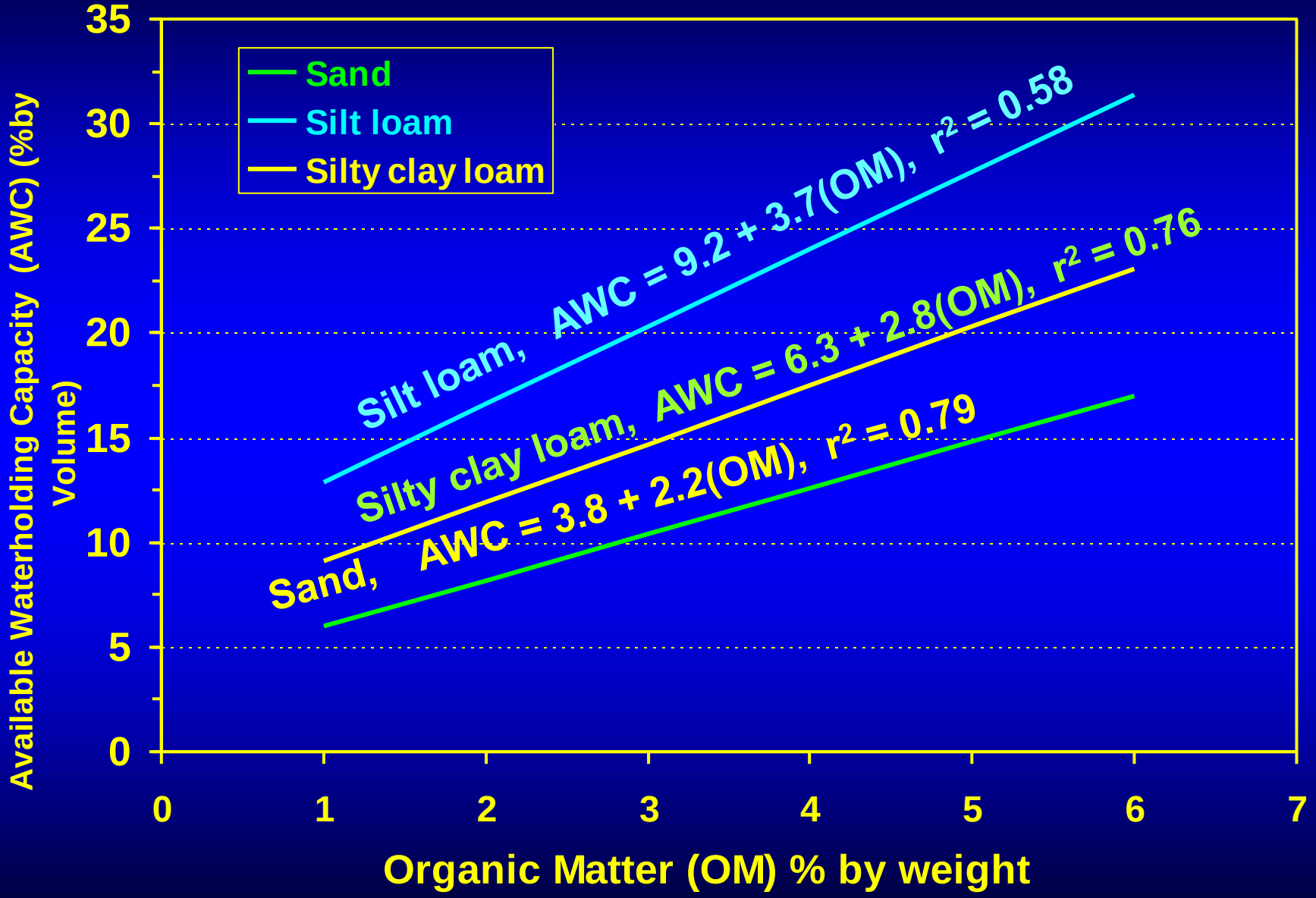
AWC = textural water + SOM "sponge" water

Sand, silt, clay



Source: Dept. of Agriculture Bulletin 462, 1960

SOM increases available water holding capacity!



Source: Berman Hudson, 1994. JSWC 49:189-194

Sand soil

Available Water holding Capacity (AWC)

(cm H2O/ 25 cm soil)

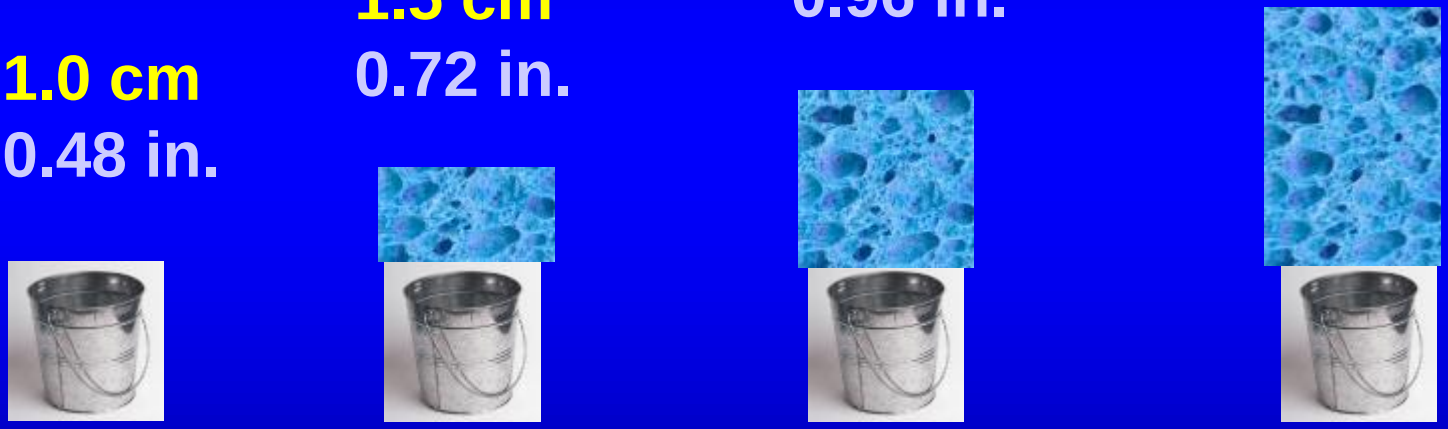
(in. H2O/ ft. soil)

1.0 cm
0.48 in.

1.5 cm
0.72 in.

2.0 cm
0.96 in.

2.6 cm
1.25 in.



SOM = 0% soil matrix water + Soil organic matter "sponge" water

1%

2%

3%

Source: Berman Hudson, 1994. JSWC 49:189-194.

Silt loam soil

Available Water holding Capacity (AWC)

(cm H2O/ 25 cm soil)

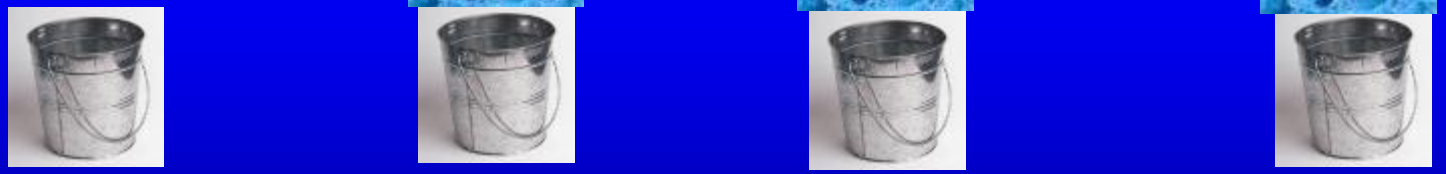
(in. H2O/ ft. soil)

2.3 cm
1.10 in.

3.2 cm
1.54 in.

4.2 cm
2.02 in.

5.1 cm
2.45 in.



SOM = 0% **1%** **2%** **3%**

soil matrix water + Soil organic matter "sponge" water

Source: Berman Hudson, 1994. JSWC 49:189-194.

Food Security

Conservation is not a burden on the budget

Conservation is an investment in food security

Conservation is all about carbon. Excel in carbon management.

“Conservation tillage” is poor conservation!

Tillage type	Total runoff rate	Sediment conc.	Sediment loss	Rel. Loss
	(mm)	(g L^{-1})	(Mg ha^{-1})	(--)
Conventional moldboard plowing to a depth of 18 cm followed by two diskings	45.0b	36.4c	15.5c	52
Conservation chisel-plow tillage with straight-shank chisel plow	28.9b	12.5b	3.3b	11
No tillage direct seeding	7.6a	4.7a	0.3a	1

Source: Seta, A. K., R. L. Blevins,* W. W. Frye, and B. J. Barfield. 1993. Reducing Soil Erosion and Agricultural Chemical Losses with Conservation Tillage. J. Environ. Qual. 22:661-665 (1993)(table 1)

Poor "Conservation" Has Consequences!

Conventional tillage
(inversion)
- unprotected soils.

A 3 to 4 inch deep fan of mud fills the bottom of this large, steep and unprotected field. Multiple gullies scar the sloping land at this location.

"Conservation tillage"
(non-inversion)
- poorly protected soils.

Even good residue management is no longer enough to protect soil and water, supporting practices such as grass waterways and buffers are needed to stand up to heavy rains.

No Tillage
(direct seeding)
- fully protected soils.

Last year's crop residue-with tall stalks left in the soil-help protect this field. No till and residue management help prevent soil erosion and polluted runoff

Photo credits: Environmental Working Group, 2013

“Conservation tillage”

- a broad term used to define “any” tillage system with primary objective of “reducing soil and water loss.”

Conservation tillage has very “loose limits” on the definition of soil disturbance and residue management.

The term “conservation tillage” fuels a misguided sense of entitlement and conservation.

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.



Most “conservation tillage” is more “tillage” than “conservation”. Conservation tillage is oversold for its conservation benefits, the concept is good, but the actual practice is bad.



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!

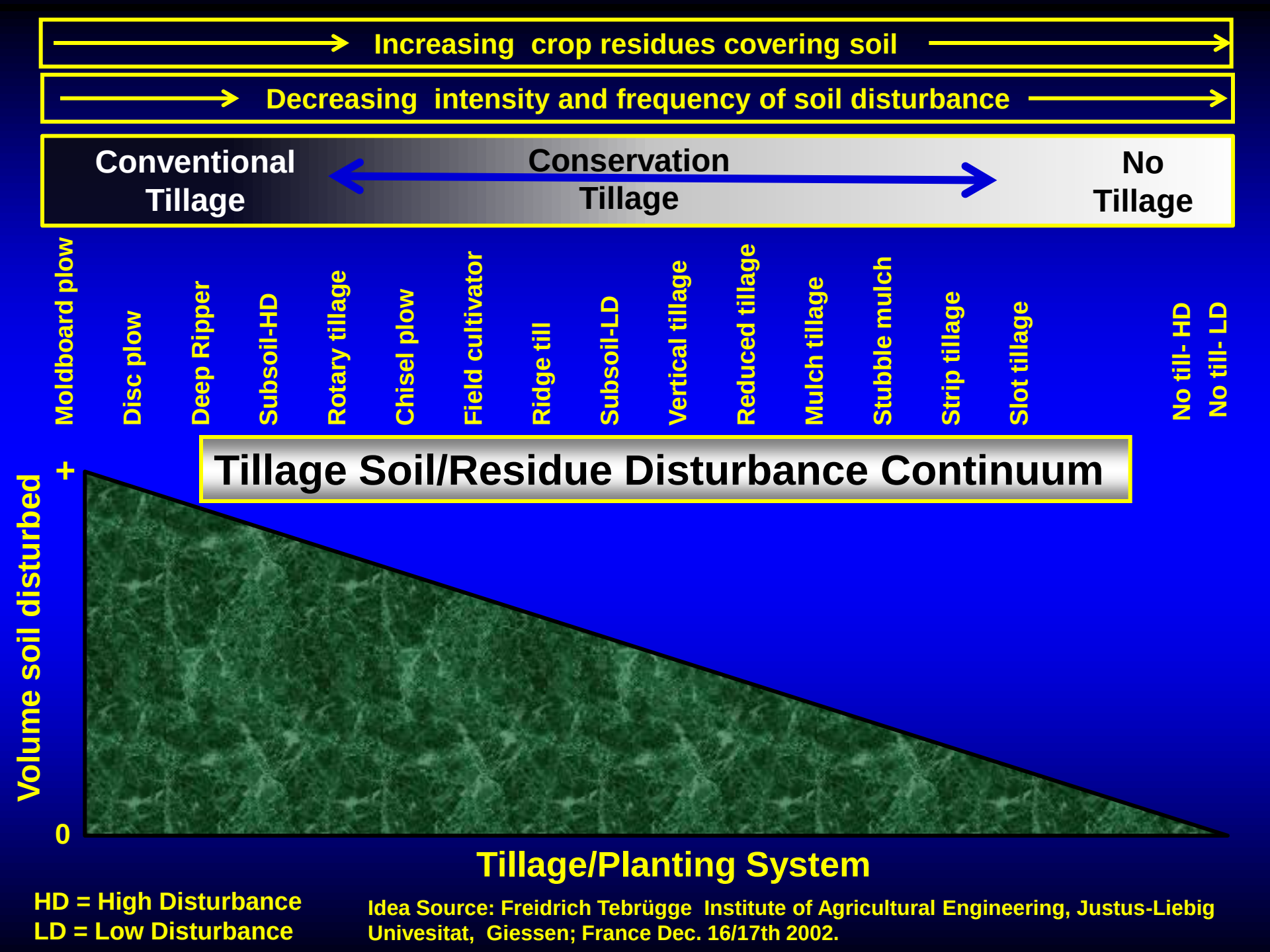
Conservation:

**“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.


Increasing crop residues covering soil
Decreasing intensity and frequency of soil disturbance
Conventional Tillage
Conservation Tillage
No Tillage
Moldboard plow
Disc plow
Deep Ripper
Subsoil-HD
Rotary tillage
Chisel plow
Field cultivator
Ridge till
Subsoil-LD
Vertical tillage
Reduced tillage
Mulch tillage
Stubble mulch
Strip tillage
Slot tillage
No till- HD
No till- LD
Tillage Soil/Residue Disturbance Continuum
Volume soil disturbed
+
0
Tillage/Planting System
HD = High Disturbance
LD = Low Disturbance
Idea Source: Freidrich Tebrügge Institute of Agricultural Engineering, Justus-Liebig Univesitat, Giessen; France Dec. 16/17th 2002.

Tillage Soil Disturbance Continuum

Most disturbance

Least disturbance

Conventional Tillage ⟷ Conservation Tillage ⟷ 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!

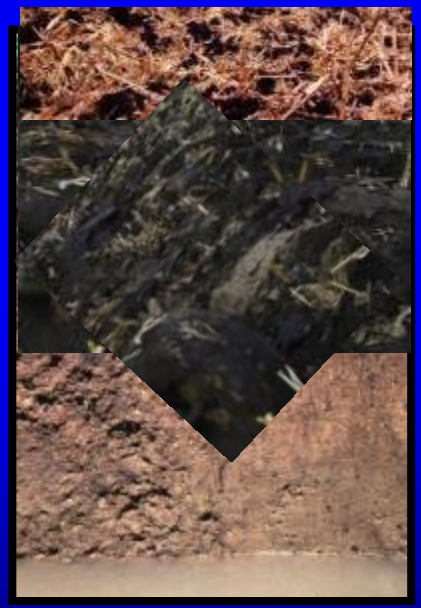
Nature's way

Biological tillage

No till

Minimum disturbance to 5 cm

Conservation tillage



Non-inversion tillage to 46 cm

Conventional tillage

Inversion tillage to 30 cm

After Hartwig Callsen

True "C"onservation is carbon management

The two primary practices that contribute to the largest amount of conservation are:

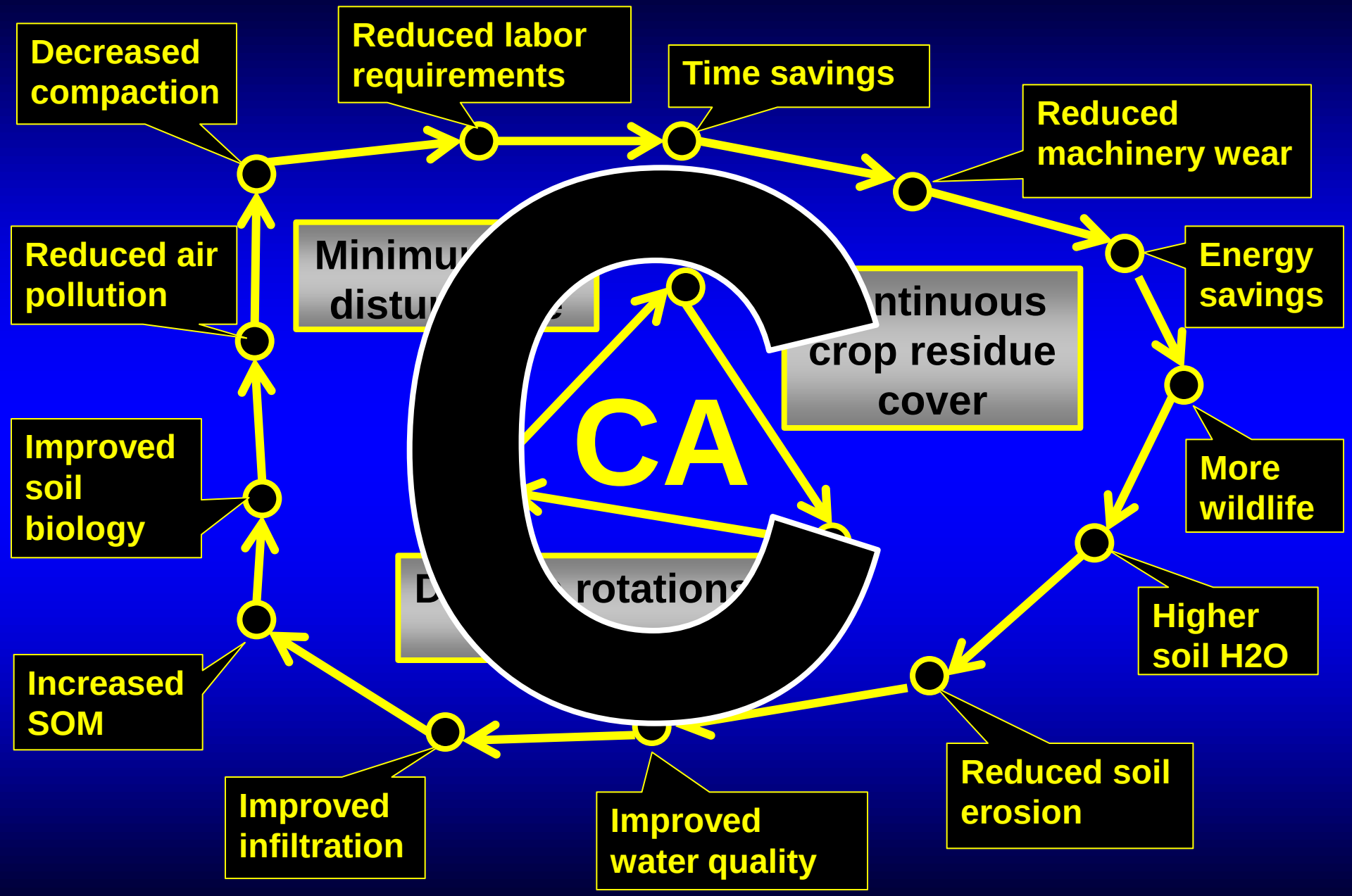
1.No Tillage

minimizes soil carbon loss.

2.Synergy crops

maximizes soil carbon input.

“Connect the dots around Conservation Agriculture”



“Carbon” coverings for the soil!

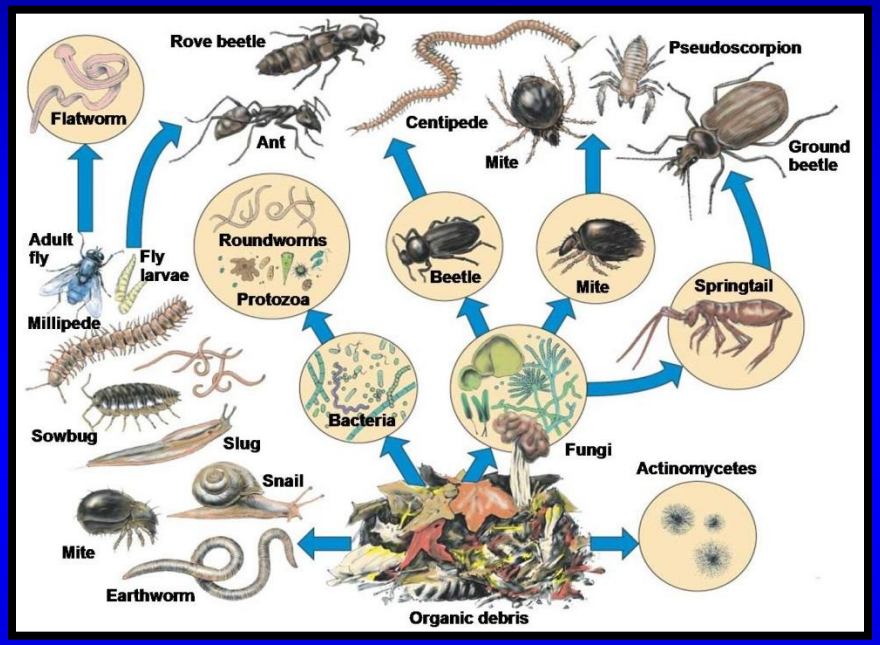
Live crop biomass =
“active protective blanket”

Both are food sources for the soil biology!

Dead crop residue =
“passive protective blanket”

Diversity enables a more sustainable system.

Multi-tasking with cover crops!
More than just erosion control!



1. Fit cover crops into the rotation
2. Cover the soil 100% of the time
3. Carbon input 100% of the time

You can't have soil biology without plants as their host.

http://www.rw.ttu.edu/2302_butler/chapter6.htm

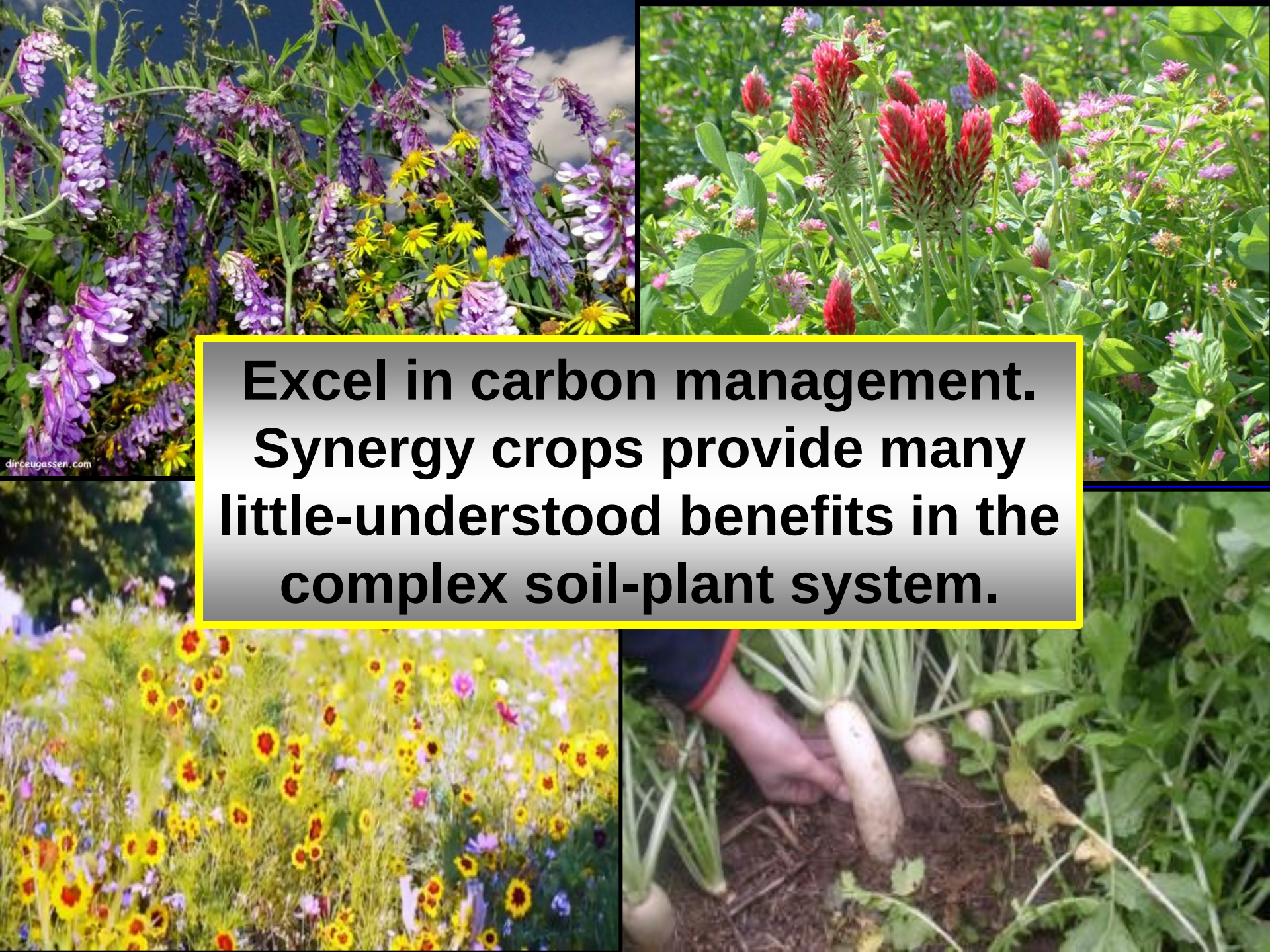
Photo credit: Jill Clapperton

Biodiversity

"C"over "C"rop "C"ocktails

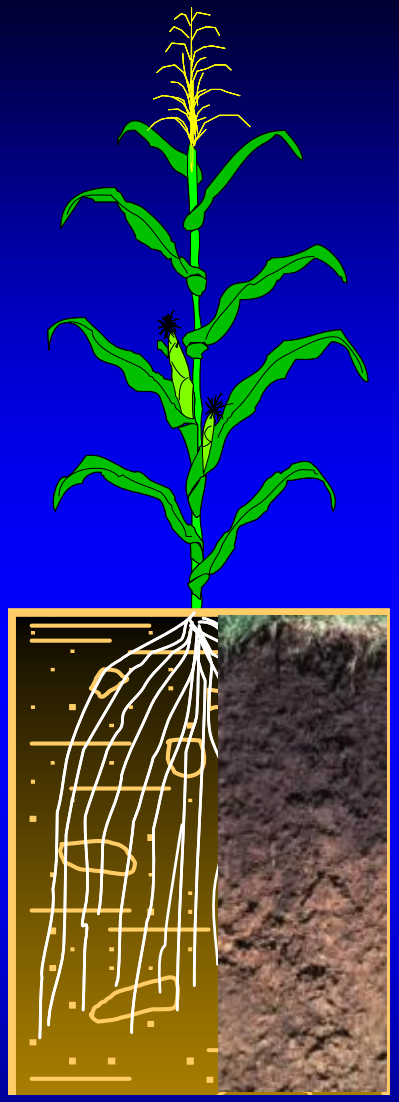
Synergy Crops

Bringing together the individual crop benefits into a community of crops whose synergistic effects to subsequent crops are greater than the sum of the individual crop contributions.



Excel in carbon management. Synergy crops provide many little-understood benefits in the complex soil-plant system.

Natural Fertility



Crop biomass ~ 46 %C

CO_2 ← Microbial and fungal decomposition Biological activity = Nutrient release → CO_2

Soil organic matter = 58 %C

Difference = 12 %C

C, H, O, N

P K Ca Mg Mn Cu

S Cl Zn Bo Mo Fe Na

Which is better for the long term?

“Pulling” iron?

vs

“Pushing” carbon!

Food Security

No Tillage

C

Cover Crops

Sustainability

Min. soil disturbance
Min. soil loss
Cont. crop residue cover
Diverse rotations
Min. carbon loss

Soil protection
Feed the soil biology
Manage water
Recycle nutrients
Max. carbon input

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

Carbon

- 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!

Soil Health Umbrella

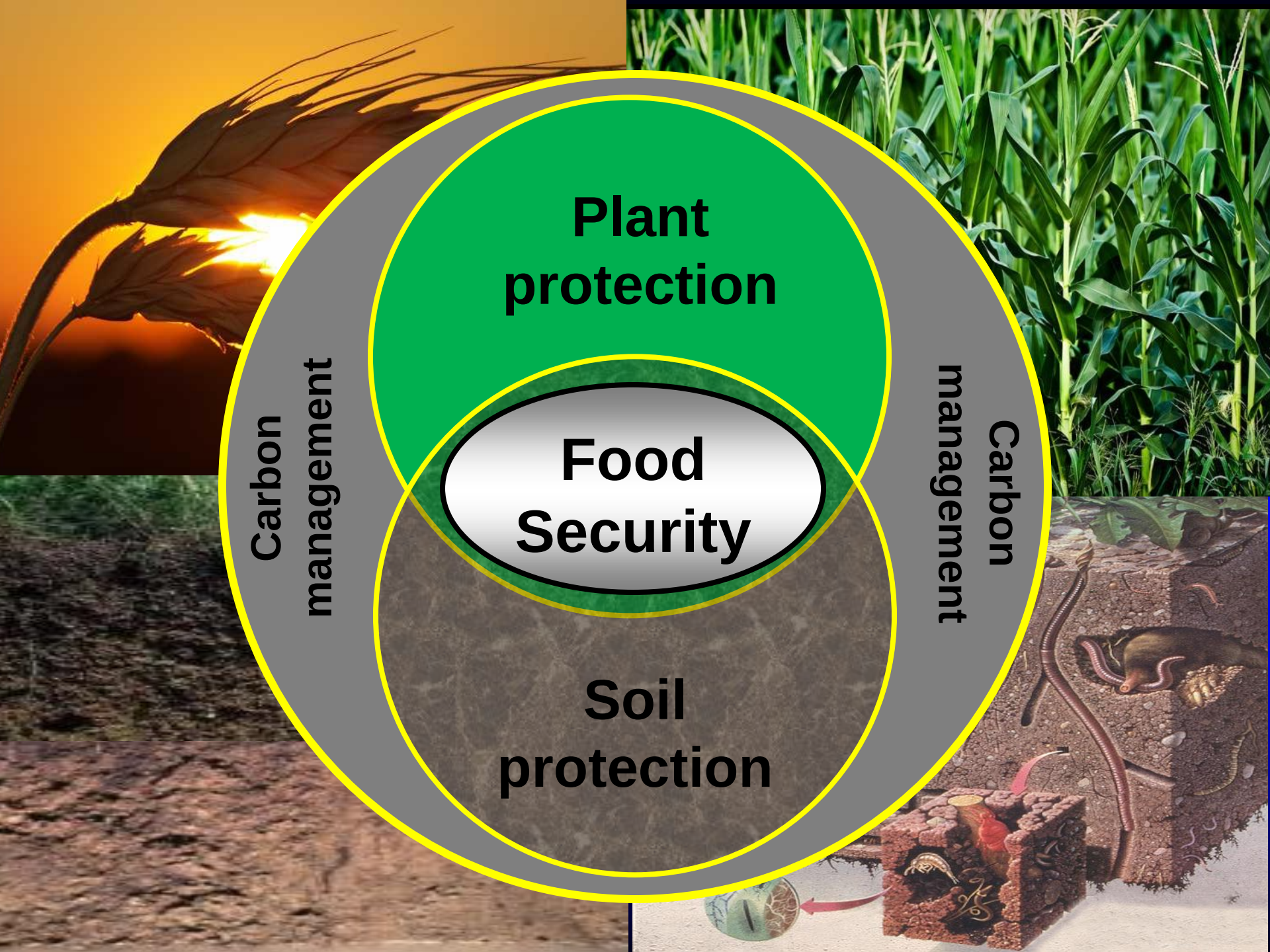
Decrease runoff
Decrease erosion (water, wind, tillage)
increase infiltration
Decrease evaporation
Increase soil water and air quality
Reduce biological disturbance
Enables bio-pore formation
Decrease inputs
Cope with climate extremes
Decrease crusting
Improved soil tilth
Improves soil structure

Increase profitability
Improve water quality
Improve quality of life of farmers
Promote biodiversity
Intensify production
Reduce the C footprint and emission of GHG
Reduce the energy costs

Increase soil organic matter
increase H2O holding capacity
increase water use efficiency
Recycle nutrients
Increased biological activity
Increased biodiversity
Decrease pollution
Store more water
Reverse soil degradation
Regenerate soil
Increases soil biological activity
N source, N scavenger,

Time to pack away those plows!

Credit: Ken Scott, Clear Lake, IA


Plant protection
Food Security
Soil protection
Carbon management
Carbon management


Carby Carbon
C
CO_2
CO_2
CO_2
CO_2
Keep your carbon footprint small and manage carbon for ecosystem services!
Best done with Conservation Agriculture!