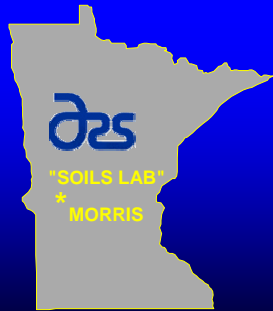


Indiana Certified Crop Advisors Conference

14-15 December, 2004 Indianapolis, IN

Tillage Effects on Gas Exchange and Soil Organic Matter.

by
D.C. Reicosky



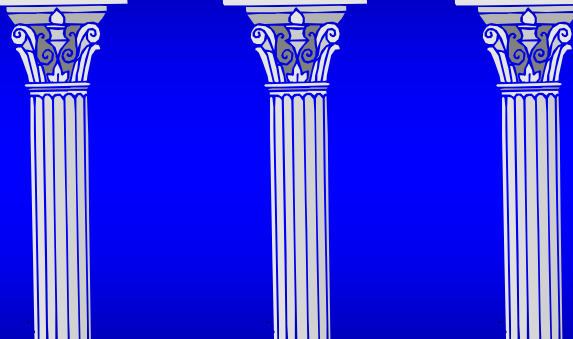
USDA-ARS-MWA

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



3 Pillars of Conservation Agriculture!

Conservation Agriculture

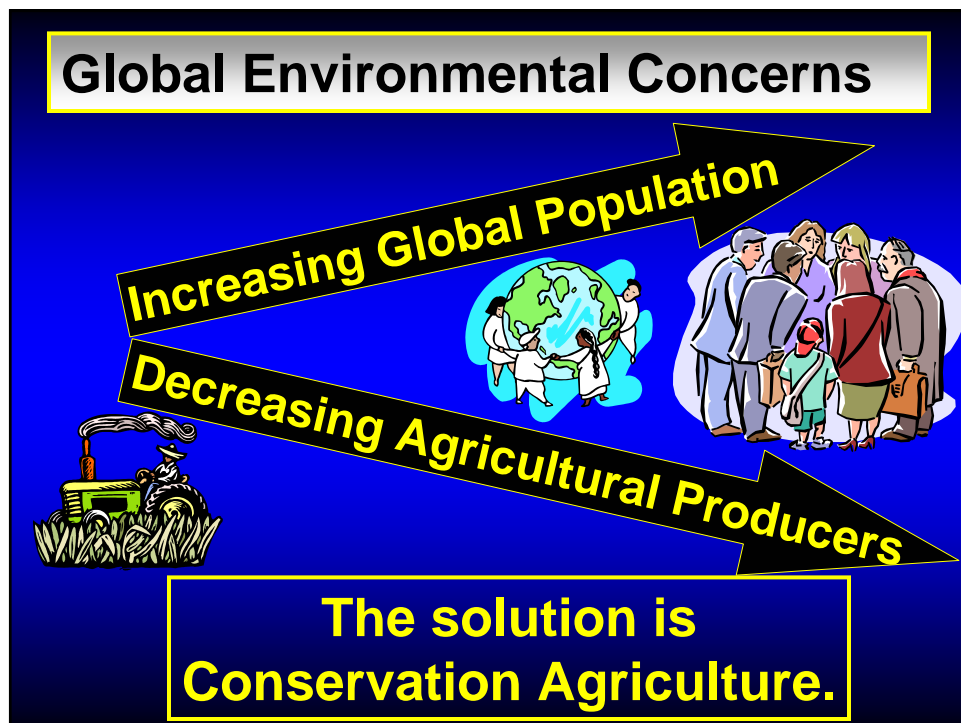


minimum
soil tillage

crop rotations/
cover crops

continuous
residue cover

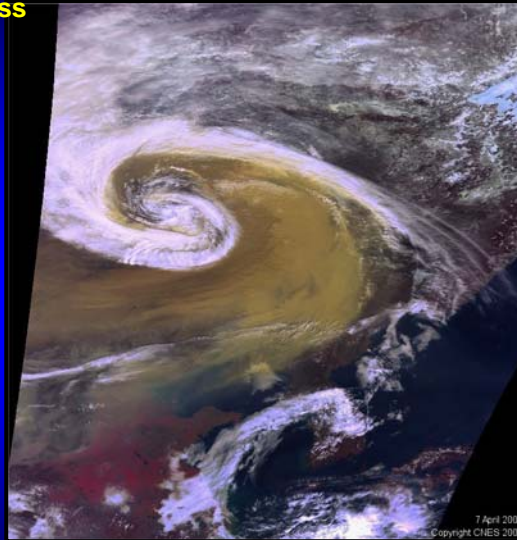
Soil Organic Carbon



DUST BOWL THREATENING CHINA'S FUTURE Lester R. Brown

**China Dust storm 2000 km across
(07/04/2001)**

News reports typically attribute the dust storms to the drought of the last three years, but the drought is simply bringing a fast-deteriorating situation into focus. Human pressure on the land in northwestern China is excessive. There are too many people, too many cattle and sheep, and too many plows. Feeding 1.3 billion people, a population nearly five times that of the United States, is not an easy matter.



The VEGETATION images show the storm over China, Mongolia, North and South Korea, where dust transport is clearly visible. The image is of April 7th, 2001.



Many water quality problems are a result of intensive tillage and rainfall that leads to erosion and sedimentation.

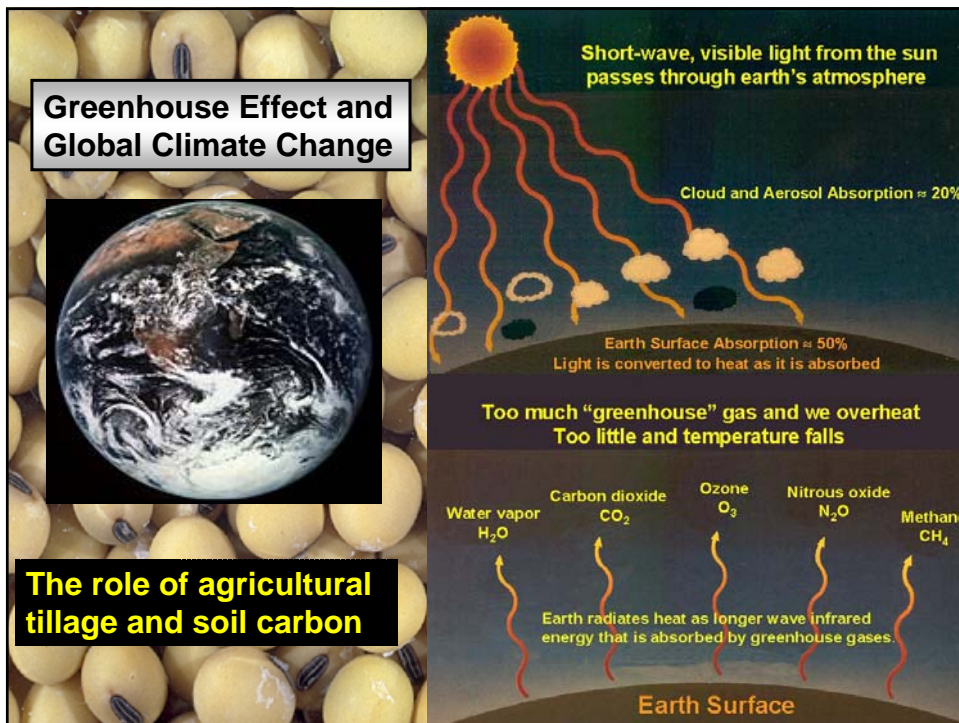
The National Academy of Sciences panel agreed that agriculture and storm runoff are jeopardizing water quality in about 21,000 bodies of water in the U.S.--from lakes and ponds to segments of streams and major rivers---that were determined to be too polluted for fishing and swimming.

Source: Associated Press, 16 June, 2001

Conservation Agriculture is carbon management. Conservation Agriculture is good for a lot of reasons. Climate change is just one of those reasons.



Global Perspective

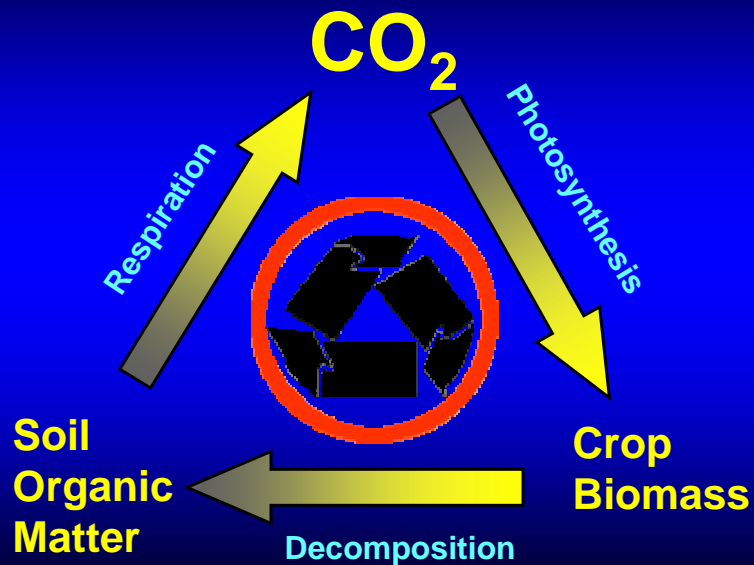


No. 1 Environmental Enemy in Production Agriculture

Intensive Tillage



Carbon Cycle in Agriculture



True Conservation Agriculture is carbon management.

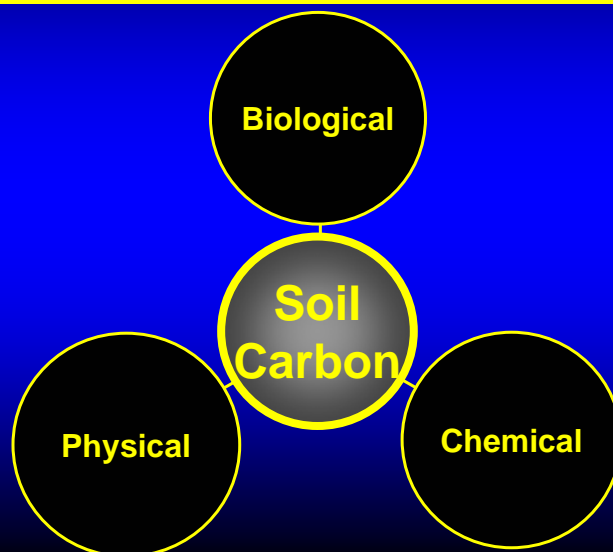
Conservation agriculture provides beneficial ecosystem services:

1. Food and fiber and biofuels
2. Less erosion, less pollution, clean water, fresh air, healthy soil, natural fertility, higher production, carbon credits, beautiful landscape, sustainability etc., etc.

.....

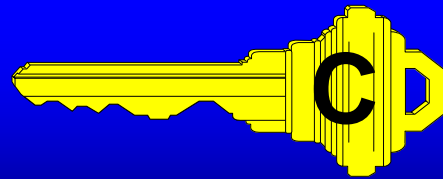
Soil carbon is a priceless key to the planet's health and our environmental quality.

Soil carbon is linked to all measures of soil quality.

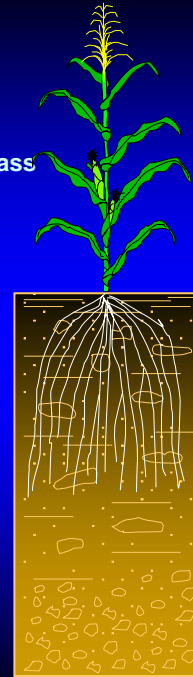


Soil organic matter is a mixture of residual **plant material** in various stages of decomposition and microbial biomass and all their bi-products.

The “key” component is:



carbon!



Are you burying your profits with your residue?



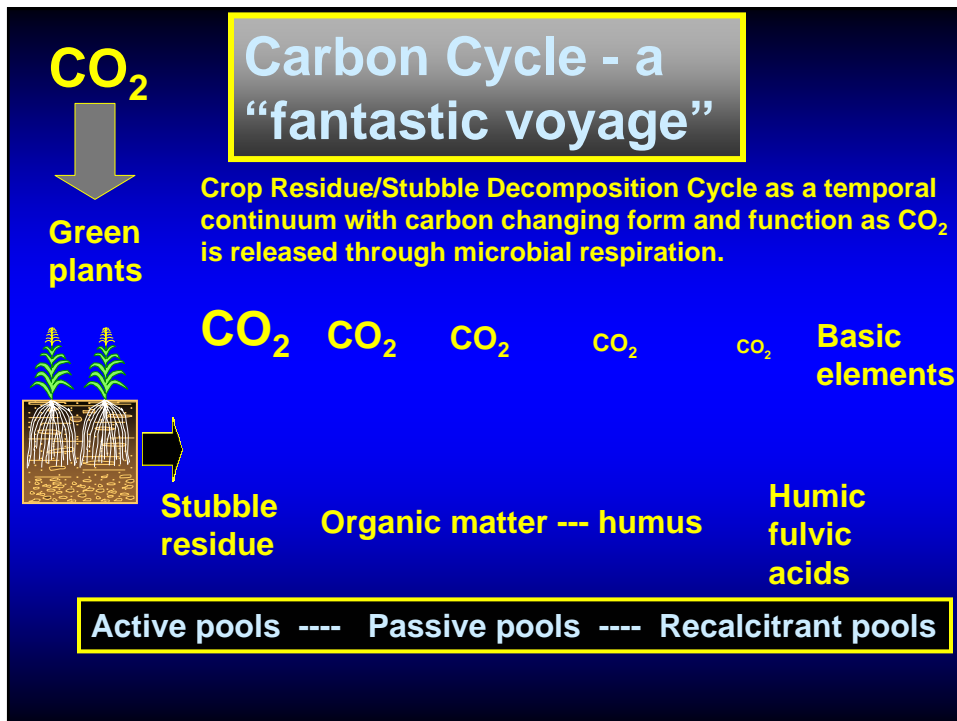
Incorporating crop residues with intensive tillage maximizes residue-soil contact and is the fastest way to convert soil organic matter to a “puff” of carbon dioxide.

4 E's of Conservation Agriculture

C

Sustainable Production

Credit: Victor Trucco, Roberto Peiretti



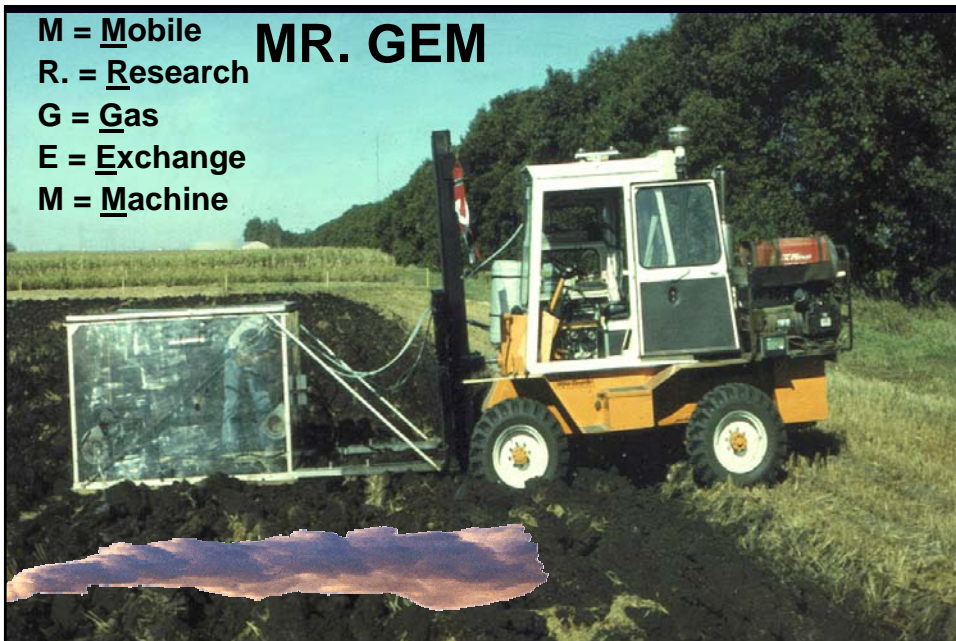
Agriculture has dug a “carbon hole” with intensive tillage.
Agriculture can now refill the “carbon hole” with less intensive tillage.

Tillage-induced Carbon Dioxide Loss

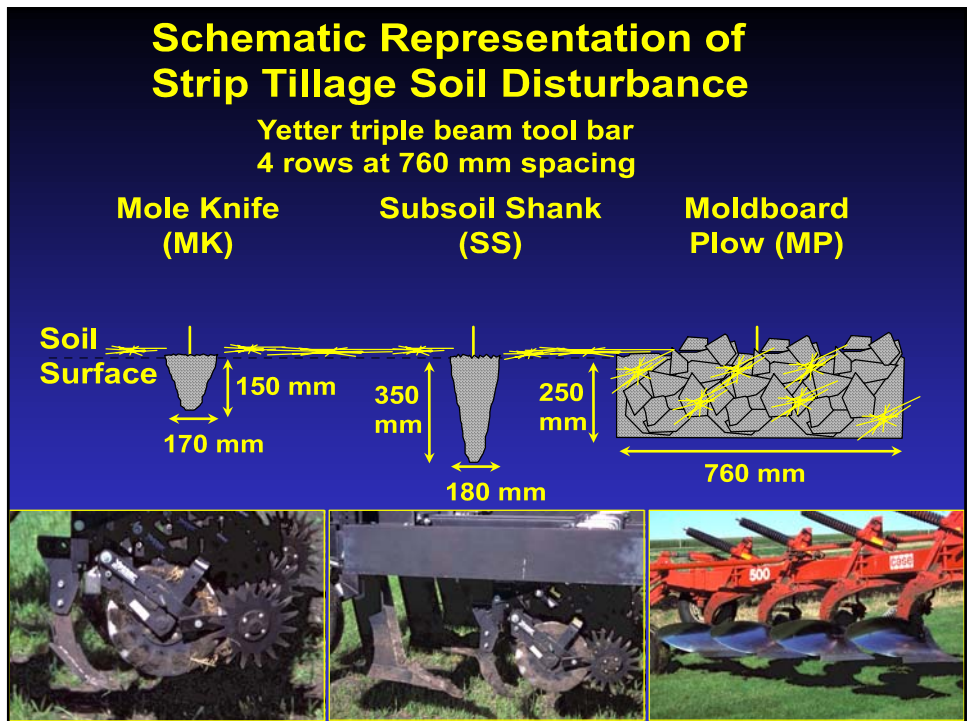
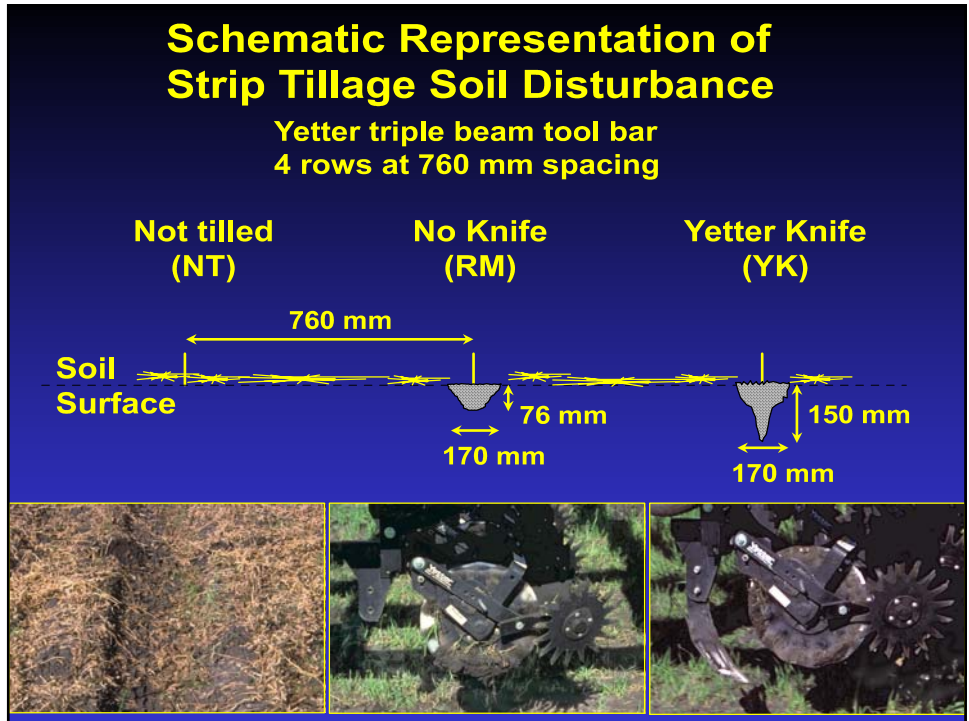


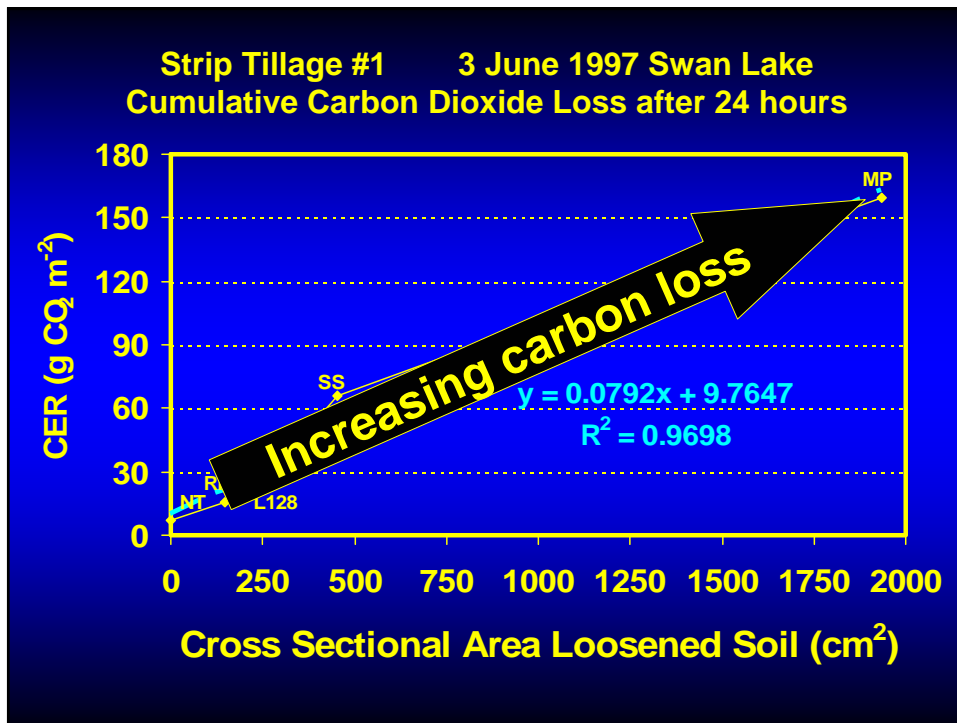
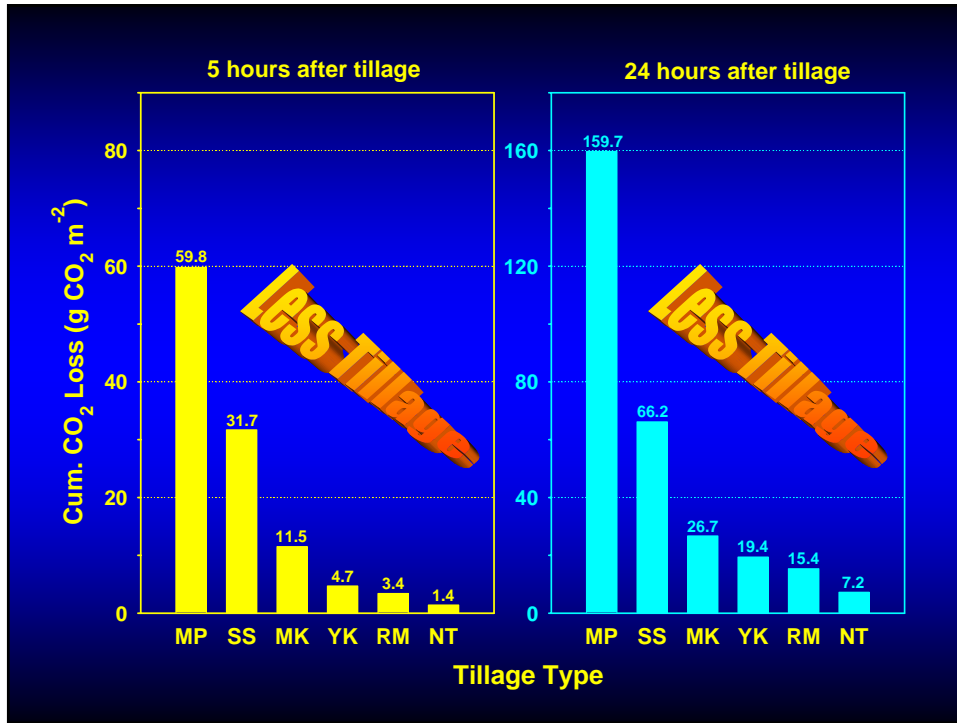
M = Mobile
R. = Research
G = Gas
E = Exchange
M = Machine

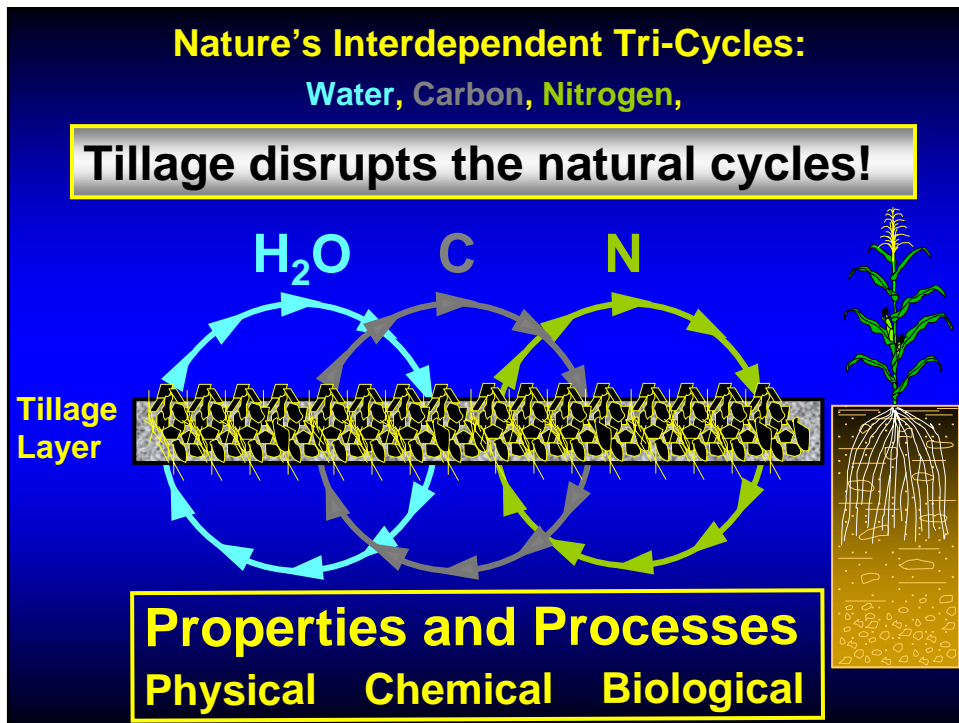
MR. GEM

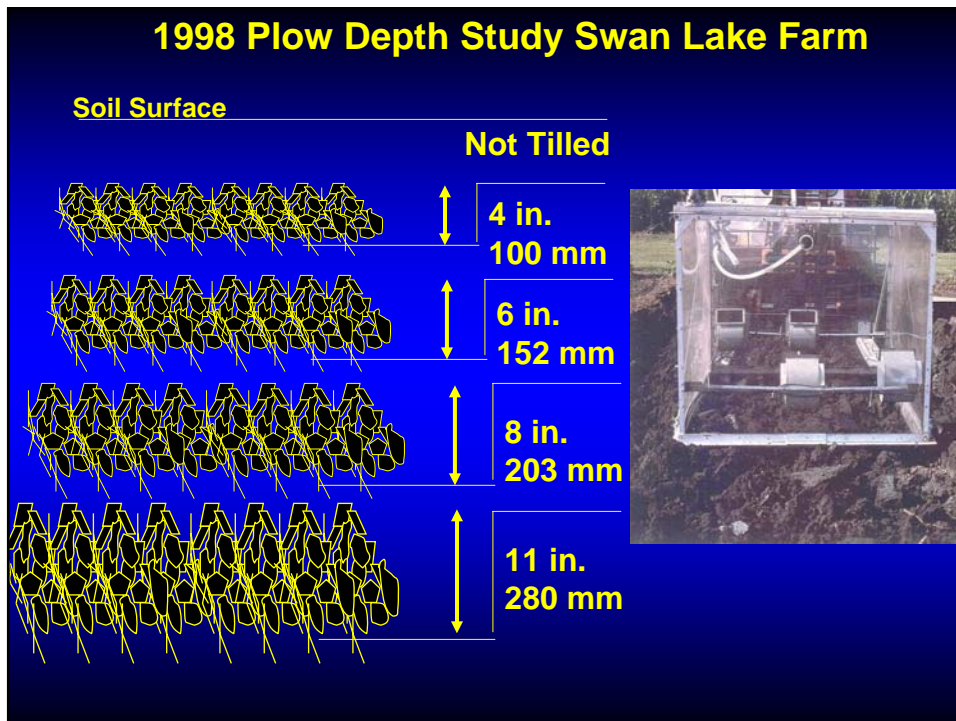
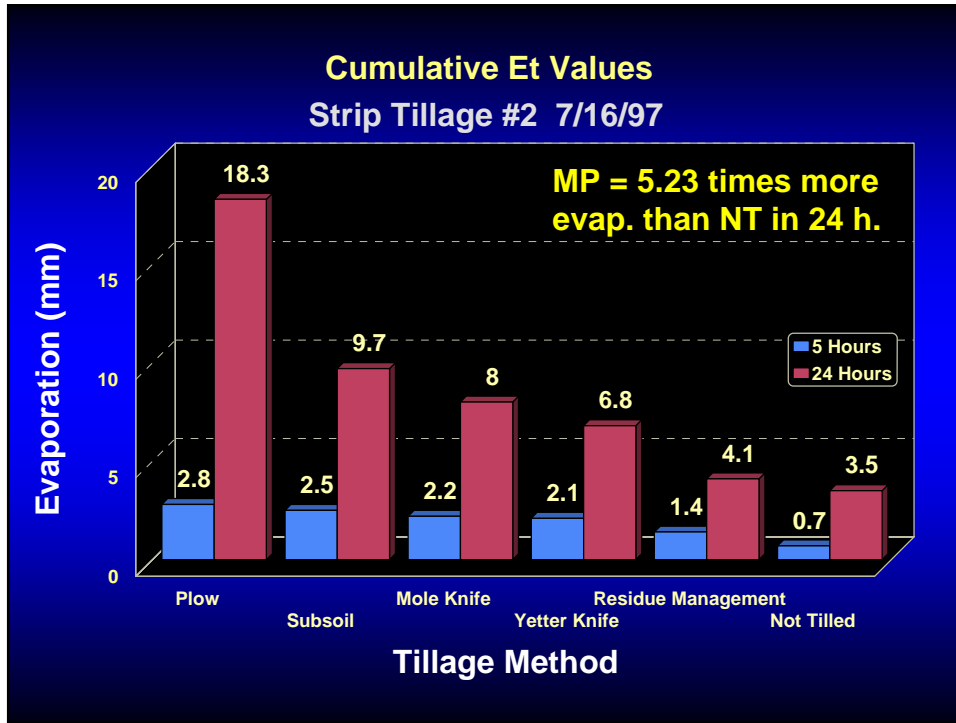


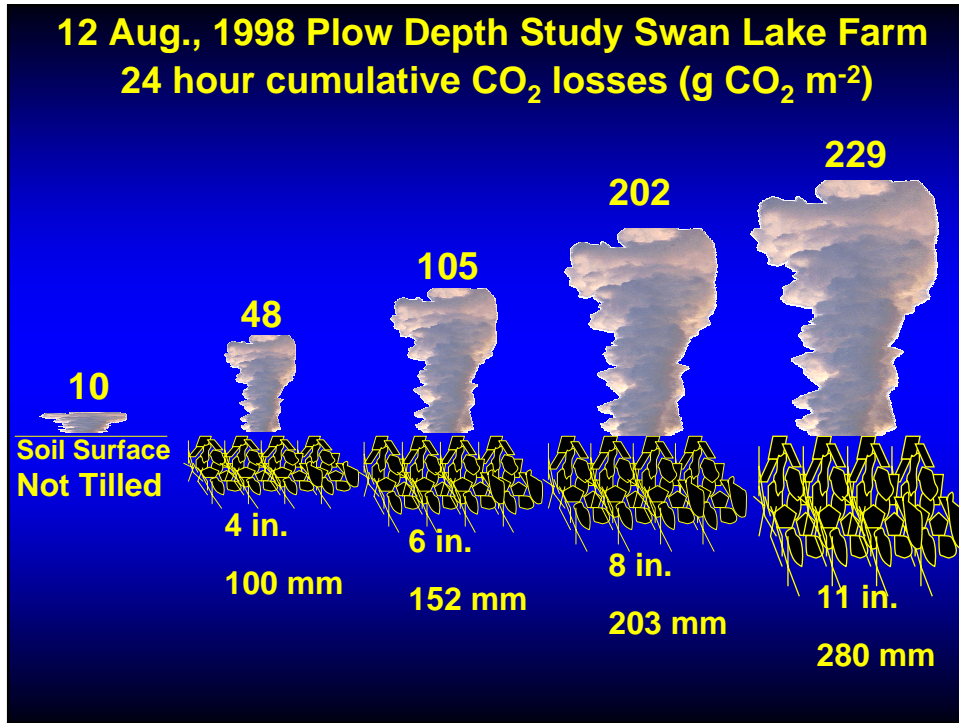
Invisible effects of invisible forces!











Research conclusion.

Short-term tillage-induced gas (CO₂ & H₂O) losses are directly proportional to the volume of soil disturbed in the tillage operation.

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



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.

Intensive Tillage destroys the biological and ecological integrity of the soil system.



**Before
Primary
Tillage**

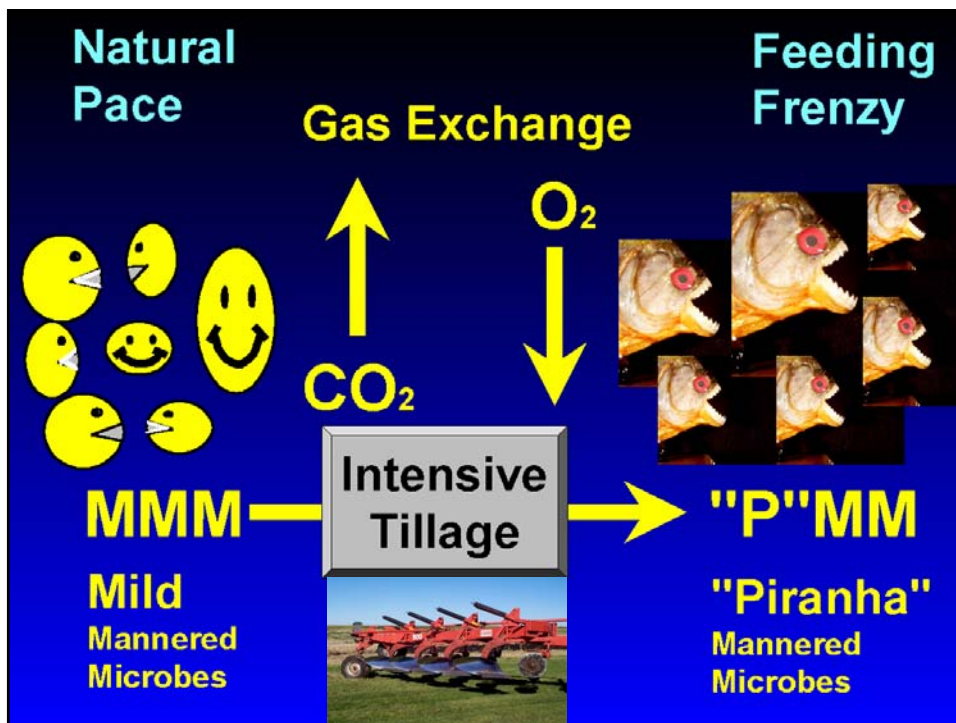


**After
Primary
Tillage**



**After
Secondary
Tillage**

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



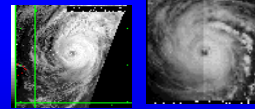
"Turmoil of Tillage"

The soil is a natural biological 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:

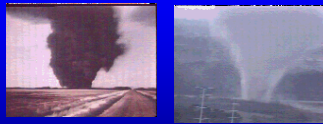
- earthquake



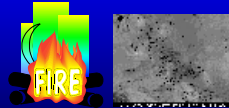
- hurricane



- tornado

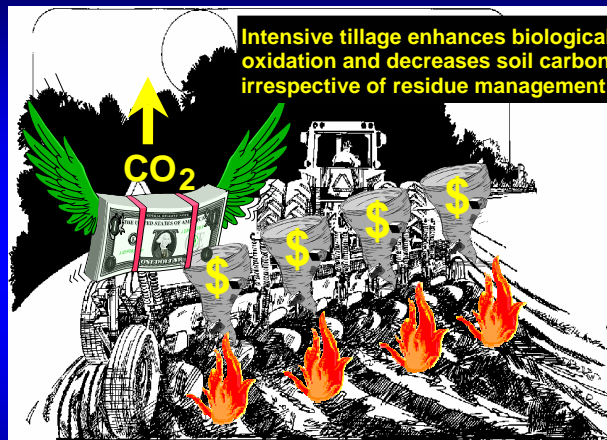


- forest fire

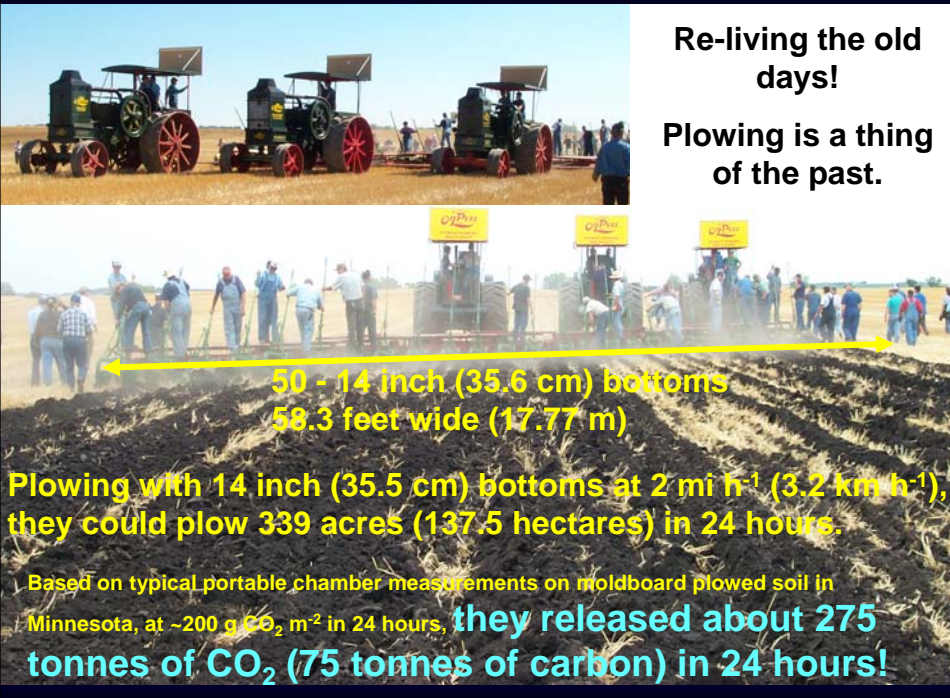


all rolled into one perturbation event.

Invisible effects of invisible forces!



Tillage very effectively facilitates biochemical degradation of organic matter.



Re-living the old days!

Plowing is a thing of the past.

**50 - 14 inch (35.6 cm) bottoms
58.3 feet wide (17.77 m)**


Plowing with 14 inch (35.5 cm) bottoms at 2 mi h⁻¹ (3.2 km h⁻¹), they could plow 339 acres (137.5 hectares) in 24 hours.

Based on typical portable chamber measurements on moldboard plowed soil in Minnesota, at ~200 g CO₂ m⁻² in 24 hours, **they released about 275 tonnes of CO₂ (75 tonnes of carbon) in 24 hours!**

World plowing Record in 2003!

Massey Ferguson MF 8289 387 HP tractor

Setting world records degrading our resources!



Plowed 251.5 ha (621 ac) in 24 hours or 8.35 l ha⁻¹ = 2100 l fuel!

Based on typical portable chamber measurements on moldboard plowed soil in Minnesota, at ~200 g CO₂ m⁻² in 24 hours, **they released about 503 tonnes of CO₂ (137 tonnes of carbon) in 24 hours!**

The official WORLD GUINNESS Crop Seeding Record

The official WORLD GUINNESS Record established on Thursday, April 24th, 2003 in the village of Majskoye in the Dnipropetrovsk Region of UKRAINE:

Field area on Agro-Soyuz Corporation farm in conservation tillage seeded to barley and fertilized within a 24 hour period: 571.9 hectares (1,412.59 acres).

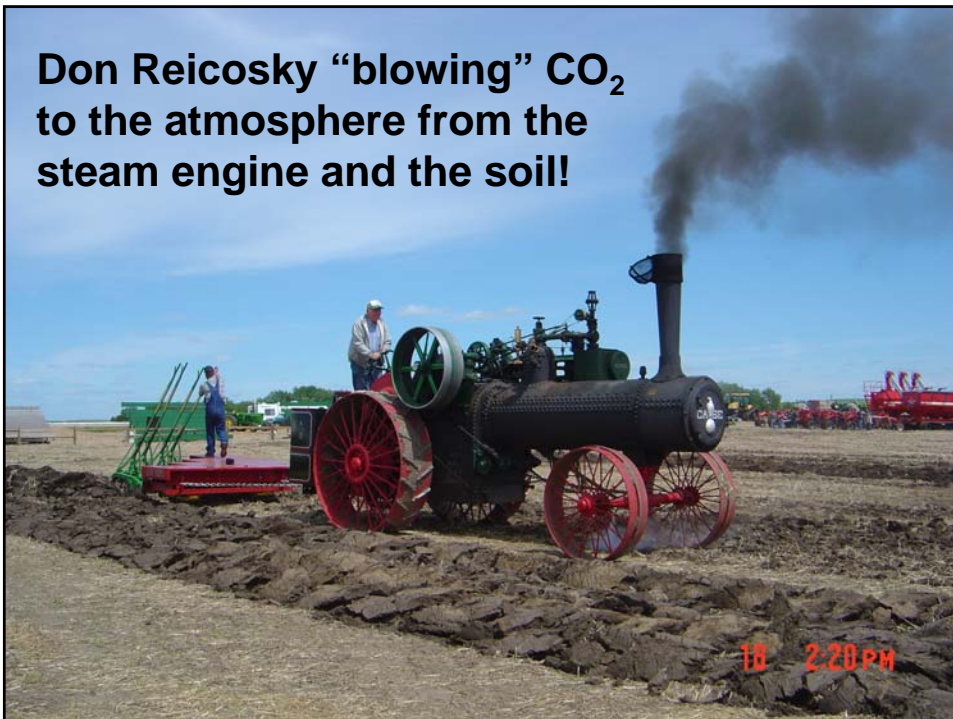


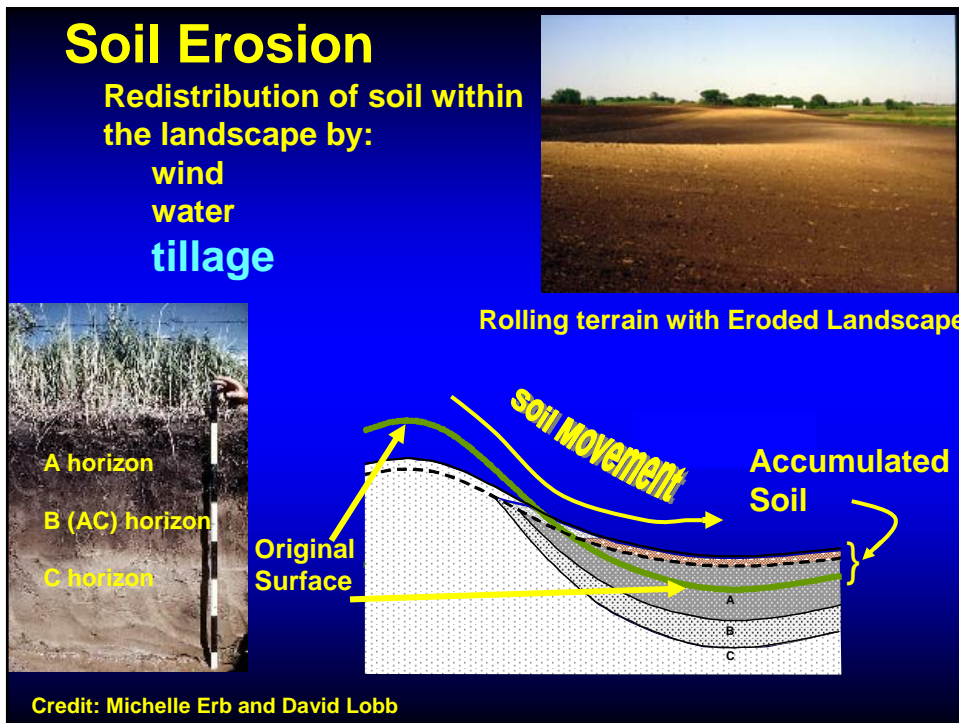
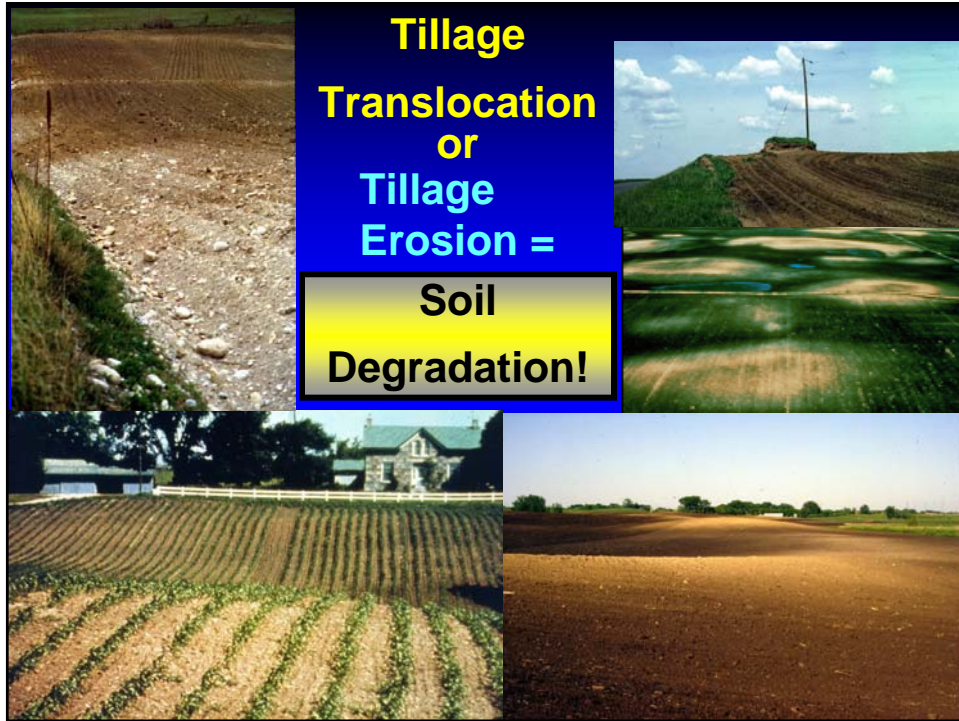
572 ha in 24 h
@ 3.84 l ha⁻¹
= 2196 l fuel.

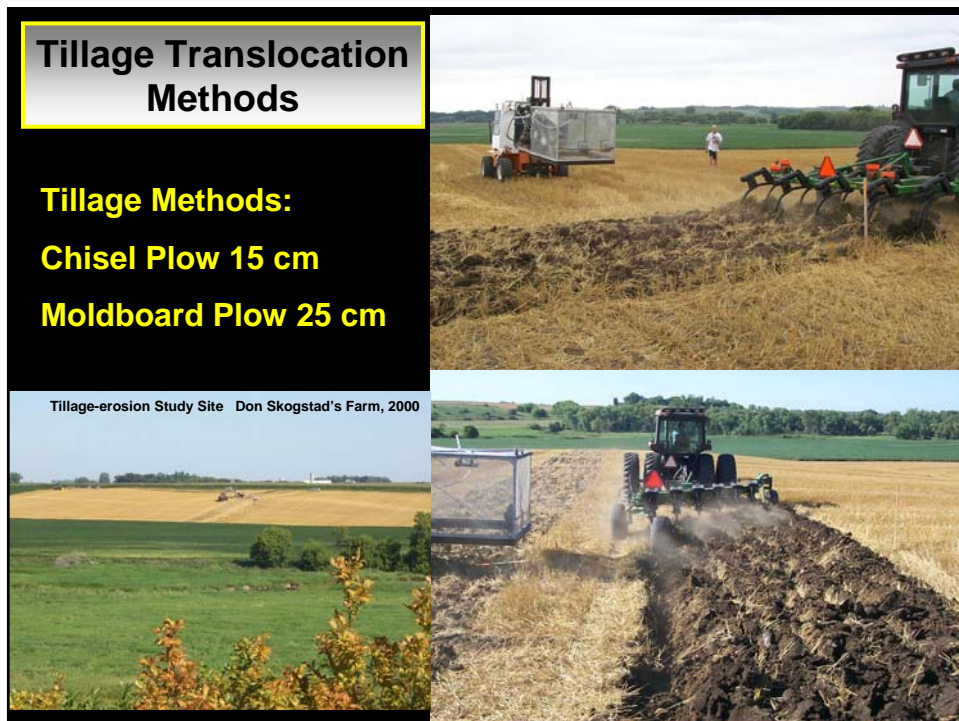
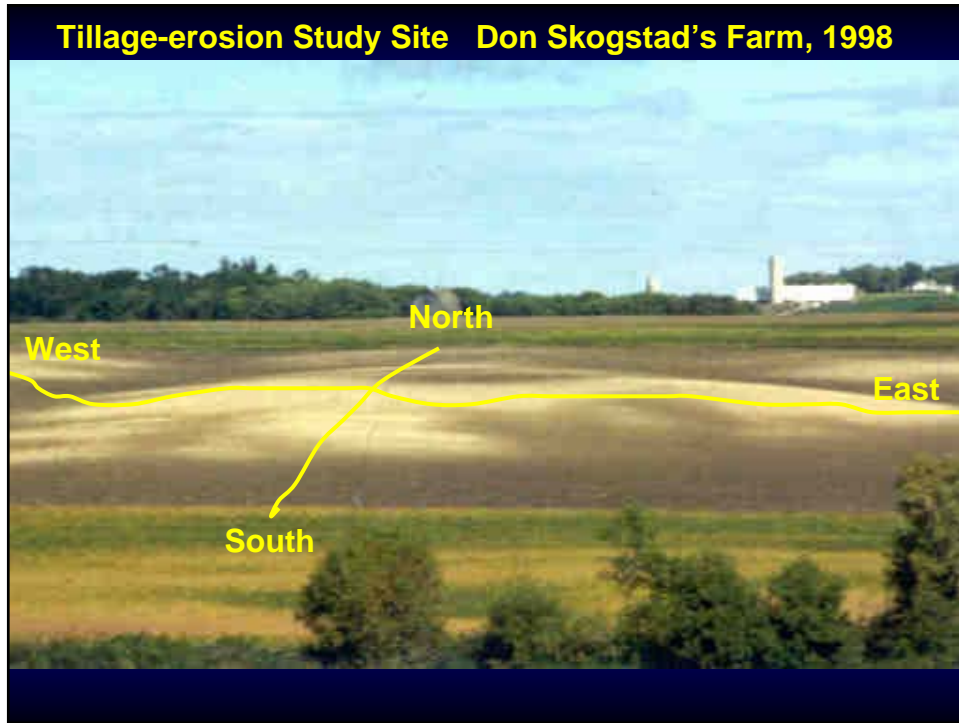


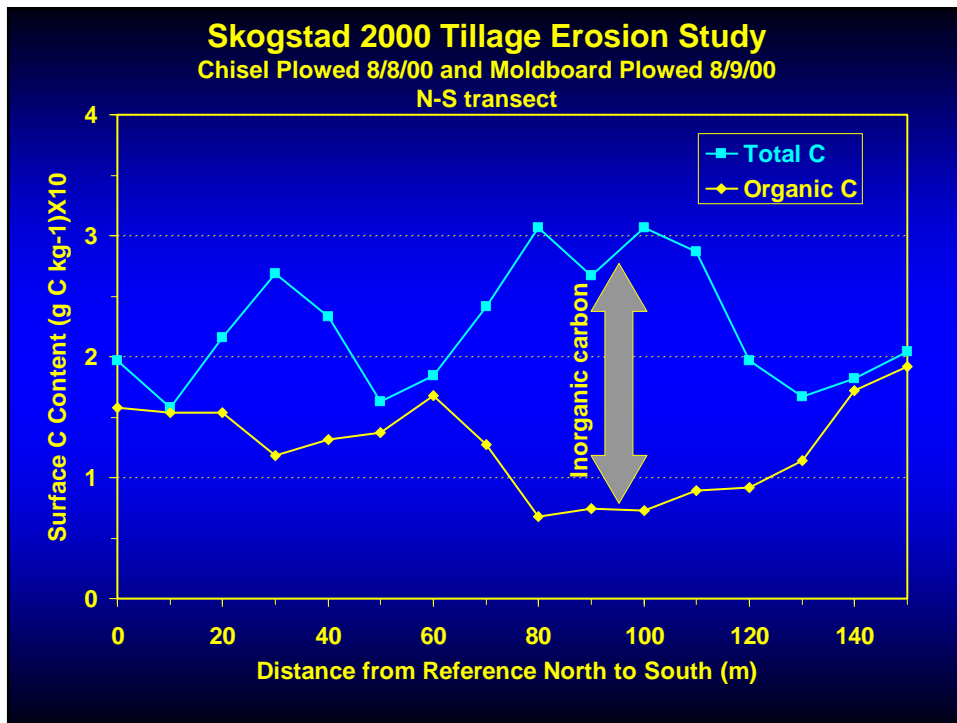
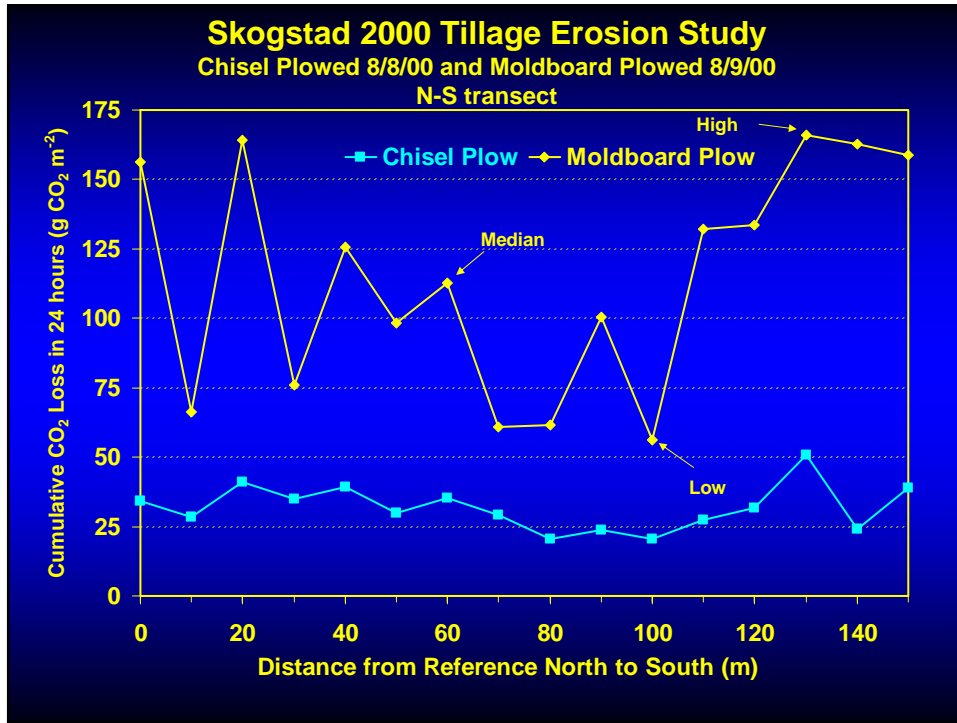
Setting world records for protecting our resources!

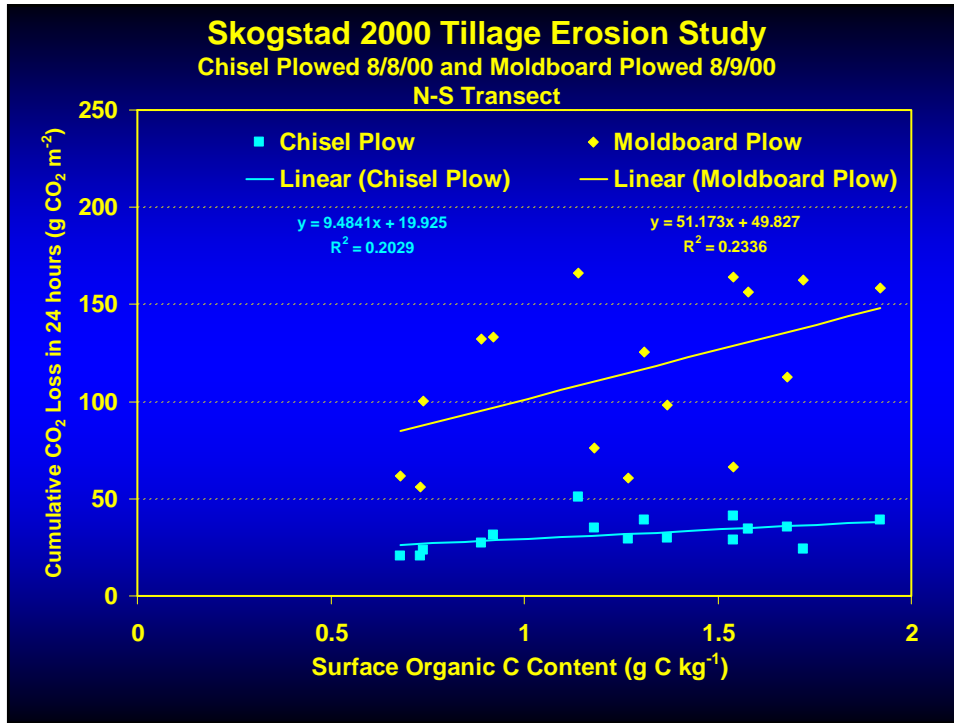
Don Reicosky “blowing” CO₂ to the atmosphere from the steam engine and the soil!









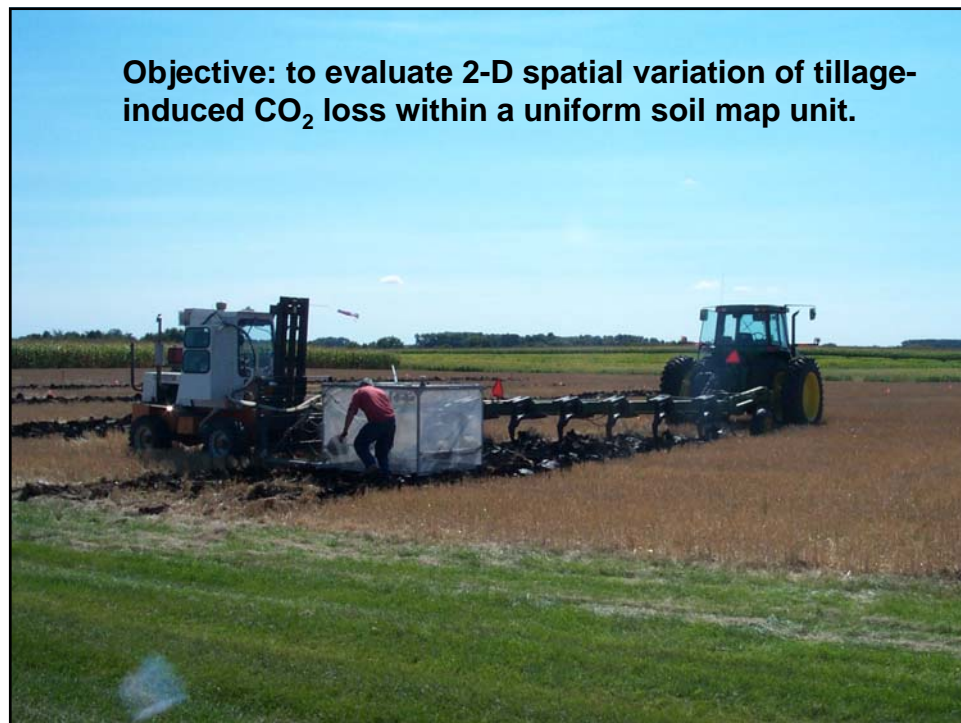
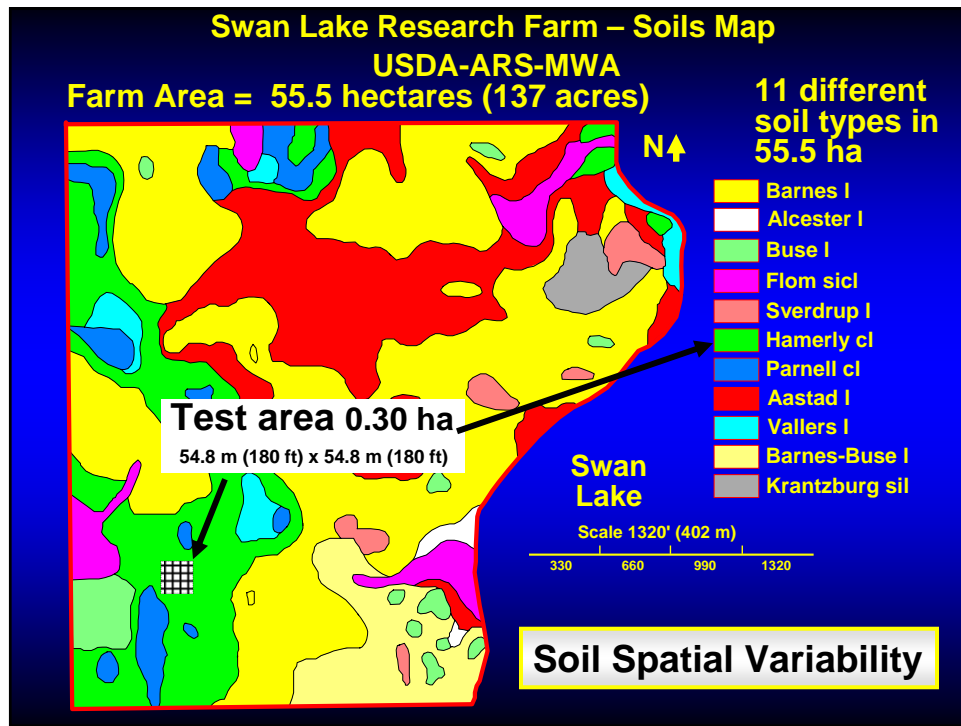


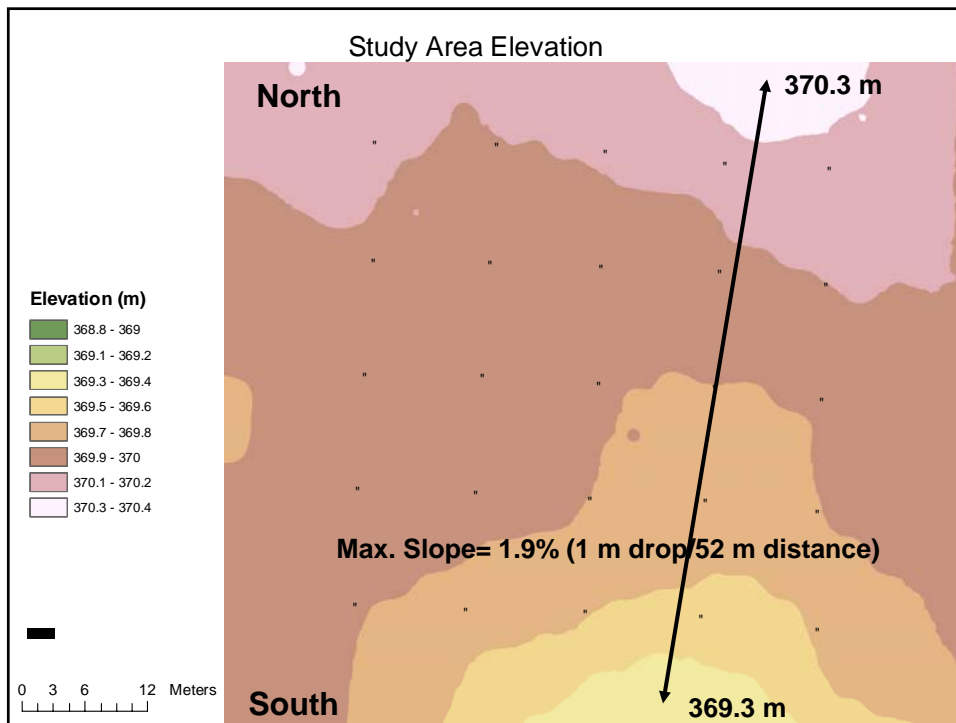
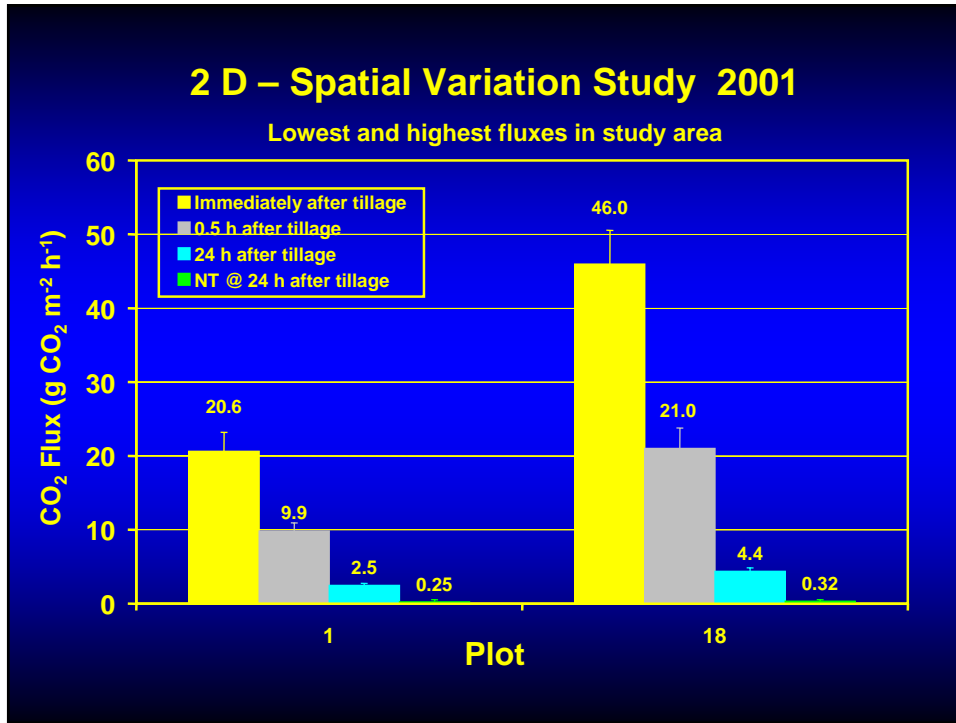
Research conclusion.

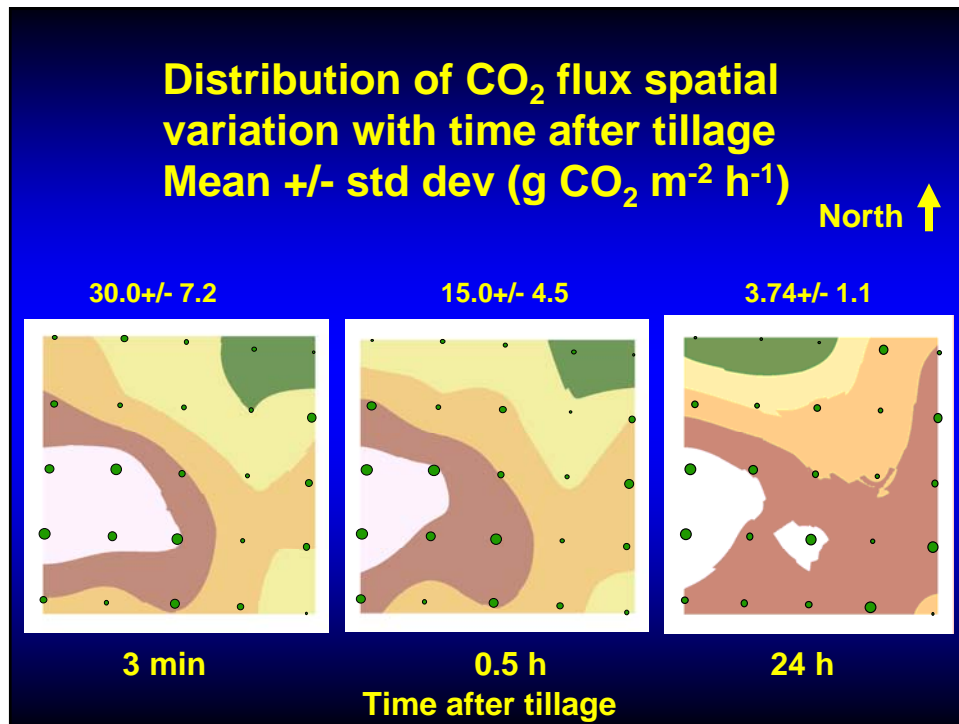
Impacts of tillage and water erosion

- Loss of topsoil in eroded areas
- Decreased soil organic carbon
- Lower available water and nutrient holding capacity
- Decreased soil health and reduced yield
- Increased spatial variability
- More management skills and equipment required










Research conclusion.

Spatial variation of tillage-induced gas (CO₂ & H₂O) losses within a relatively level and uniform soil type can vary as much as two-fold.

Everglades Agricultural Area
Everglades Research and Extension Center
Belle Glade, FL

Soil Marker Post



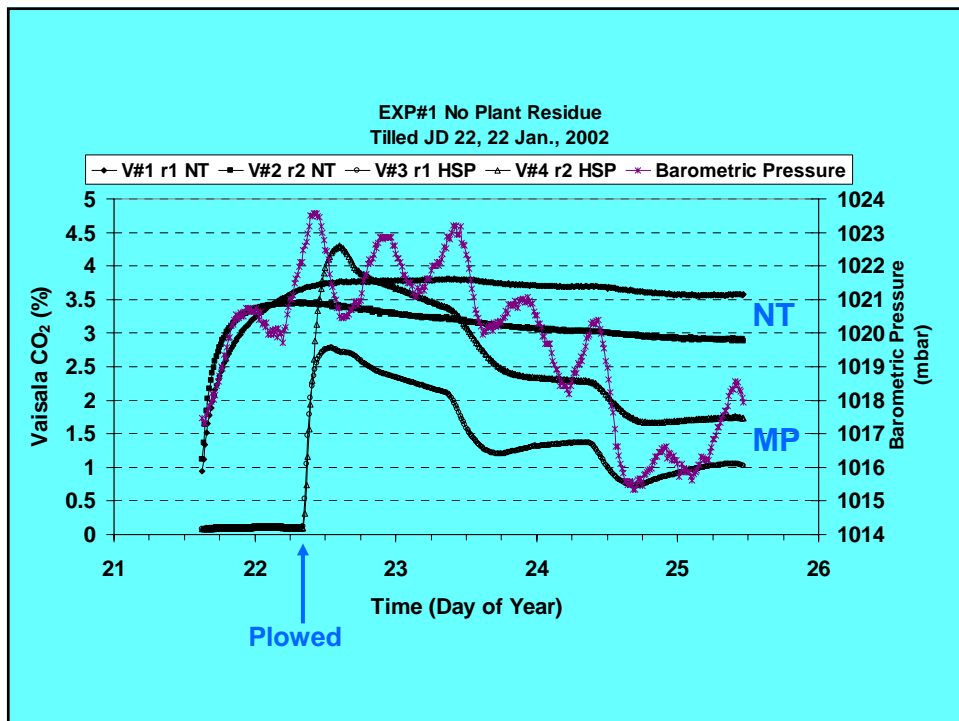
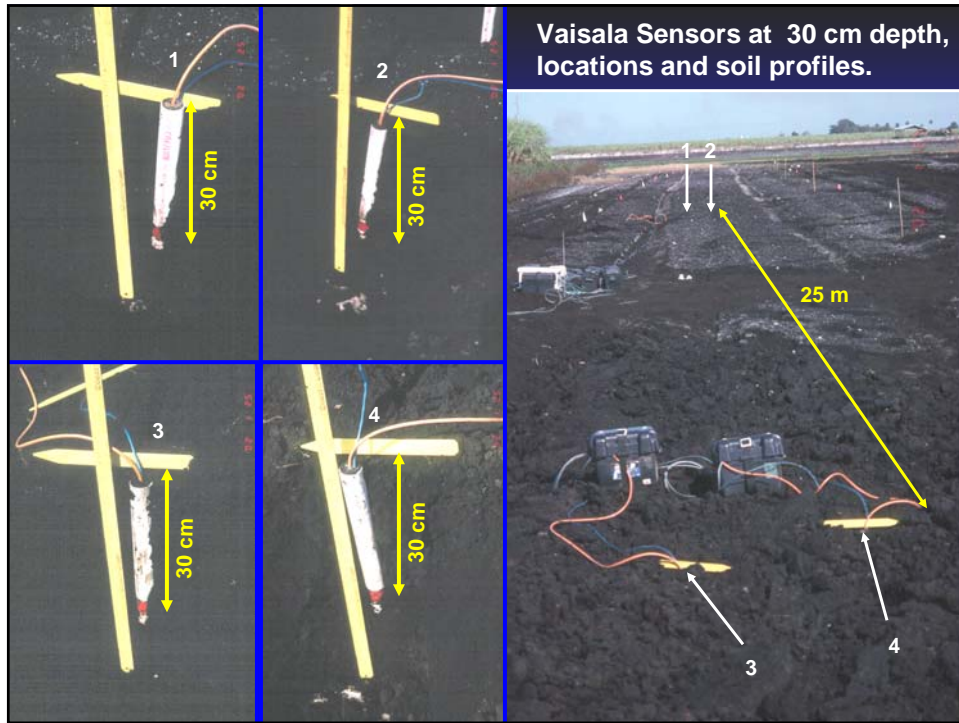
General Objective:
to understand tillage effects on soil subsidence and microbial respiration in organic soils.

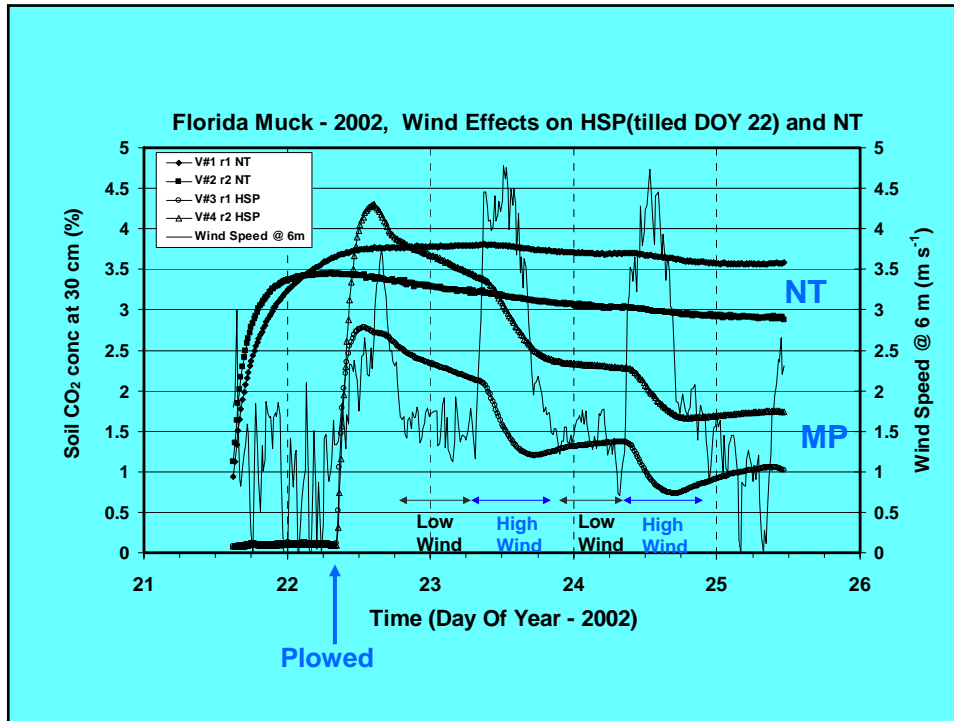
Specific Objective:
to determine the effect of no-tillage, deep plowing and wind speed on soil CO₂ concentrations in peat or muck soils that are 90% organic matter.

Soil Subsidence of 155 cm in 60 years without tillage or ~2.5 cm yr⁻¹.



Tillage and Wind effects on soil CO₂ concentration.





Invisible forces of aerodynamics lifts carbon dioxide out of tilled soil.

MOLDBOARD PLOW

BEFORE AFTER

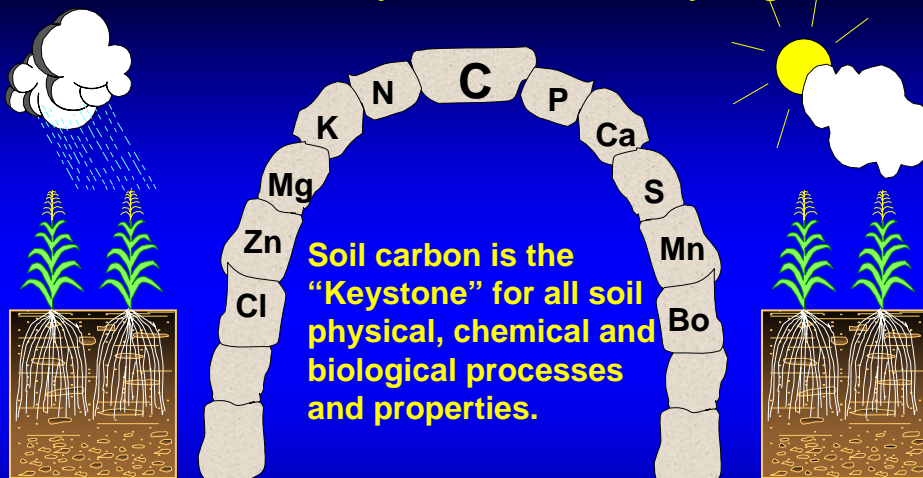
Tillage loosens the soil (i.e. changes soil air permeability) and enables rapid soil gas exchange. Soil carbon dioxide is sucked and swirled into turbulent eddies on into the atmosphere. Oxygen enters the large voids to enhance microbial activity.

Tillage unlocks the potential microbial activity by creating more reactive surface area for gas exchange on soil aggregates that are exposed to a higher ambient oxygen concentration (21%). Tillage also breaks the aggregates to expose "fresh" surfaces for enhanced gas exchange and perhaps more carbon loss from the interior that may have a higher carbon dioxide concentration.

Research conclusion.

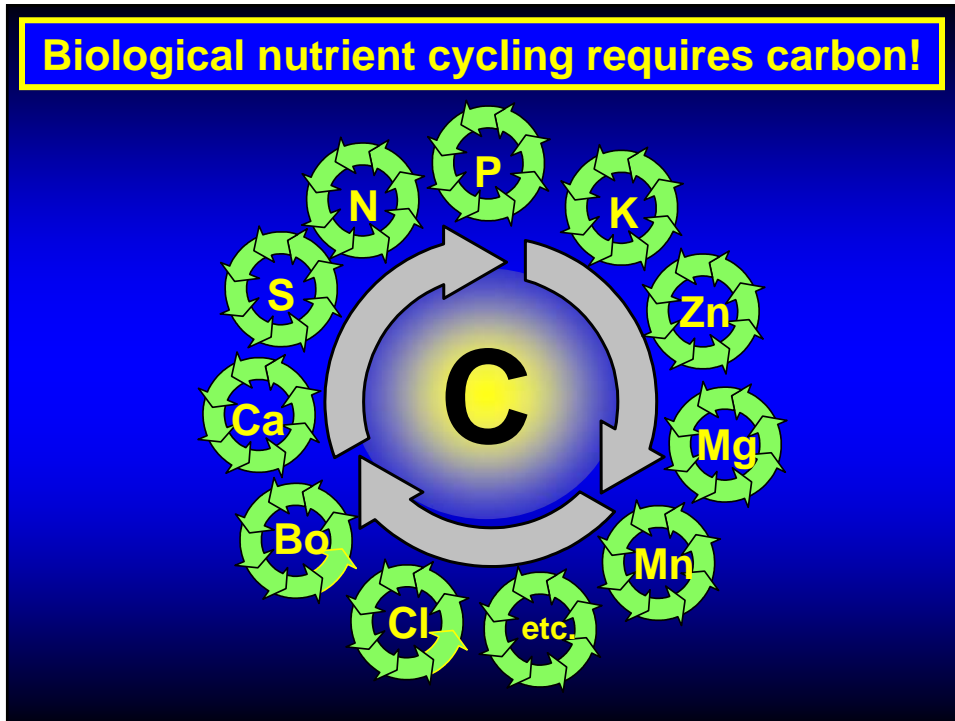
Short-term tillage-induced gas (CO_2 & H_2O) losses are related to natural wind and pressure affects.

Carbon is a "keystone" in nutrient cycling!



Management platform

fertility, variety, irrigation, species, cover crop, manure, rotations, tillage, soil type, erosion, timing,



Nutrient Balance and Carbon Sequestration.

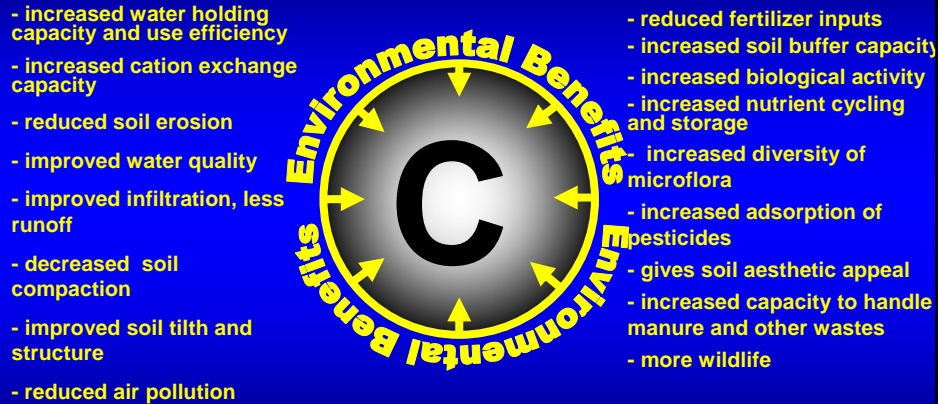
Net carbon sequestration requires other nutrients.

7 – 10 units of C per unit of N
50 –60 units of C per unit of P
70 – 80 units of C per unit of S

Balanced fertilization is needed for both crop uptake and carbon sequestration!

Rattan Lal, 27 Jan., 2000

Many environmental benefits point to carbon!



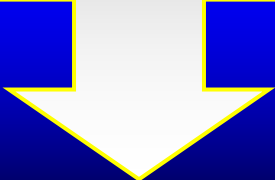
The role of carbon in biodiversity in Conservation Agriculture.

1. Biodiversity increases stability of the system.
2. Biodiversity increases the productivity of the system.
3. Biodiversity increases carbon storage and Carbon sequestration.
4. Biodiversity reduces nutrient losses to groundwater and is more efficient in nutrient capture.
5. Biodiversity decreases susceptibility to disease.
6. Biodiversity increases resistance to exotic species.
7. Biodiversity effects are more pronounced with increasing carbon dioxide and nitrogen application.


Credit: Clarence Lehman, Director Cedar Creek Nat. History Area, MN May 22, 2003

Best for carbon input!

Simple rotations with high yields
Cover crops
Alternate crops
New bio-fuel crops
Compound rotations
Complex rotations
Simple with Perennial rotations
Stacked rotations






Diversification

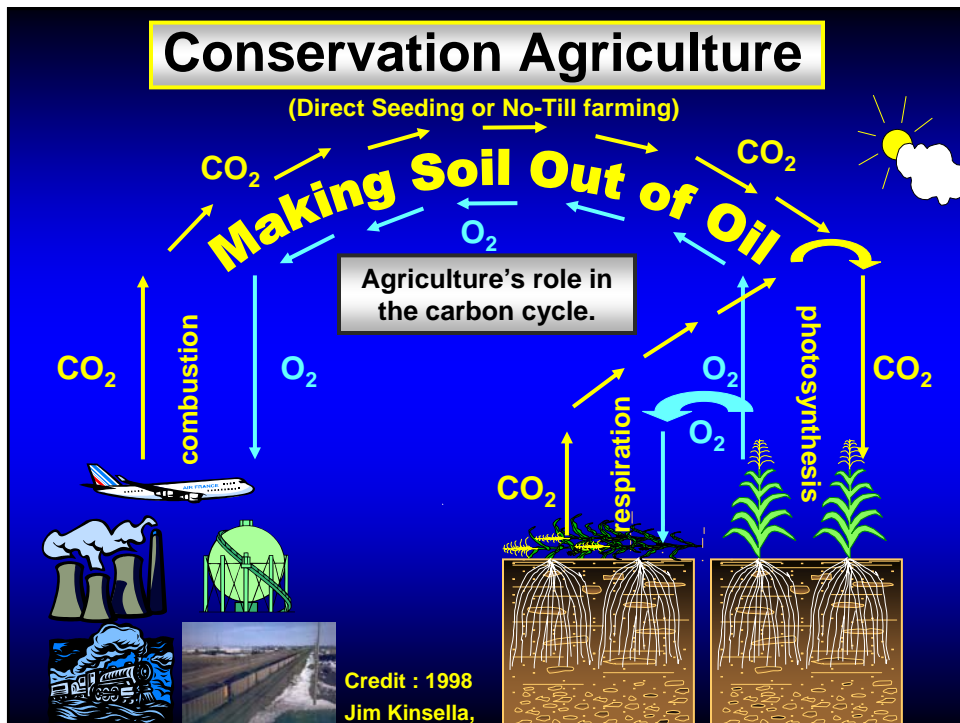
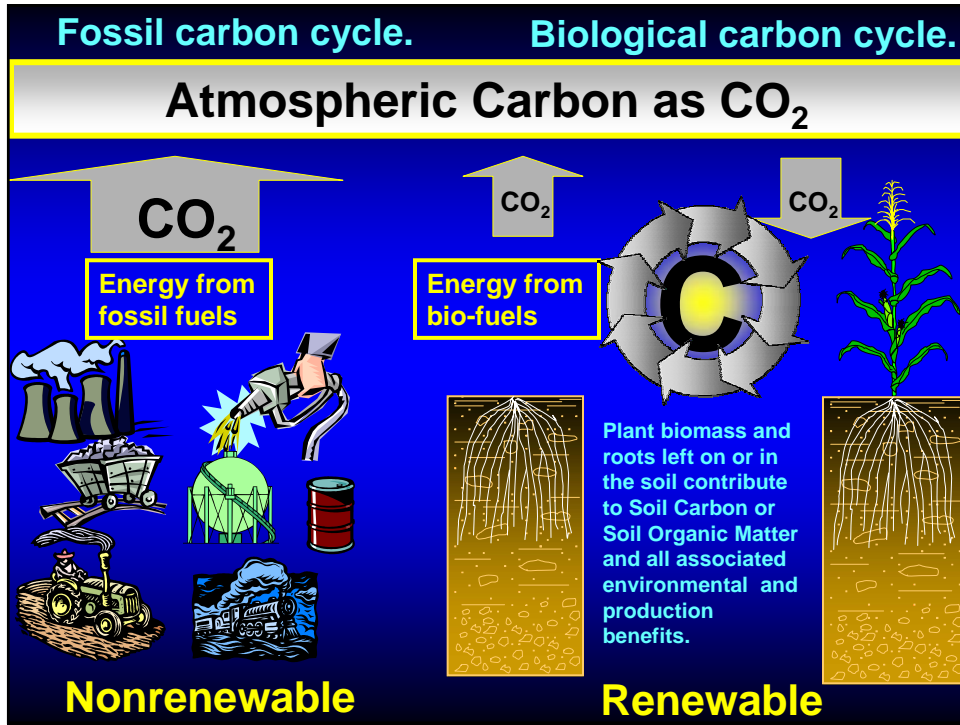


The devil is in the details!
Beckism #101

Atmospheric Carbon as CO₂

Time Frame of Carbon Cycles

<p>Fossil carbon cycle. Cycle time is millions of years for fossil carbon.</p> 		<p>Biological carbon cycle. Cycle time is 1 - 10 years for biological carbon.</p> 
<p>Nonrenewable</p> <p>The major strength of biofuels is the potential to reduce net carbon dioxide emissions to the atmosphere.</p>		<p>Renewable</p>



Conservation Agriculture

Manage soil carbon!
“Delay Decay”



Conservation Agriculture is a Win-Win Strategy!

Win #1

**Growing
food and
fiber to feed
the world.**

Win #2

**Protecting the
environment
and all its
resources.**

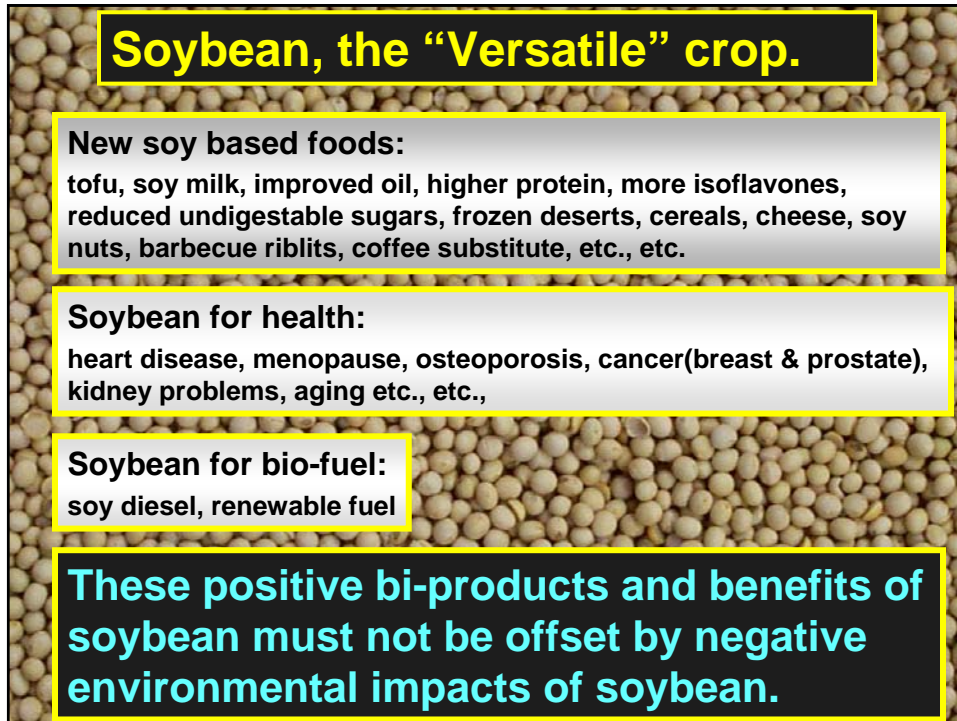
A lot of responsibility for farmers!



Crops as the primary soil carbon input!

Soybean Research Challenges





Soybean, the “Versatile” crop.

New soy based foods:
tofu, soy milk, improved oil, higher protein, more isoflavones, reduced undigestible sugars, frozen deserts, cereals, cheese, soy nuts, barbecue riblits, coffee substitute, etc., etc.

Soybean for health:
heart disease, menopause, osteoporosis, cancer(breast & prostate), kidney problems, aging etc., etc.,

Soybean for bio-fuel:
soy diesel, renewable fuel

These positive bi-products and benefits of soybean must not be offset by negative environmental impacts of soybean.

Soybean Rhizosphere effects on carbon loss
Mollisol, Konza Prairie, 2.3 %C, 0.2% N, pH=7.6

Cumulative soil-derived CO₂- C during season

	%		mg C g ⁻¹ soil
No plants			
0 - NPK	100		0.58
L - NPK	100	100%	0.59
H - NPK	100		0.57
Soybean			
0 - NPK	275		1.60
L - NPK	262	264%	1.60
H - NPK	256		1.35
Wheat			
0 - NPK	201		1.05
L - NPK	186	196%	1.04
H - NPK	201		1.03

Source: Chen et al., 2003. SSSAJ 67: 1418-1427

Soybean effects on current soil carbon

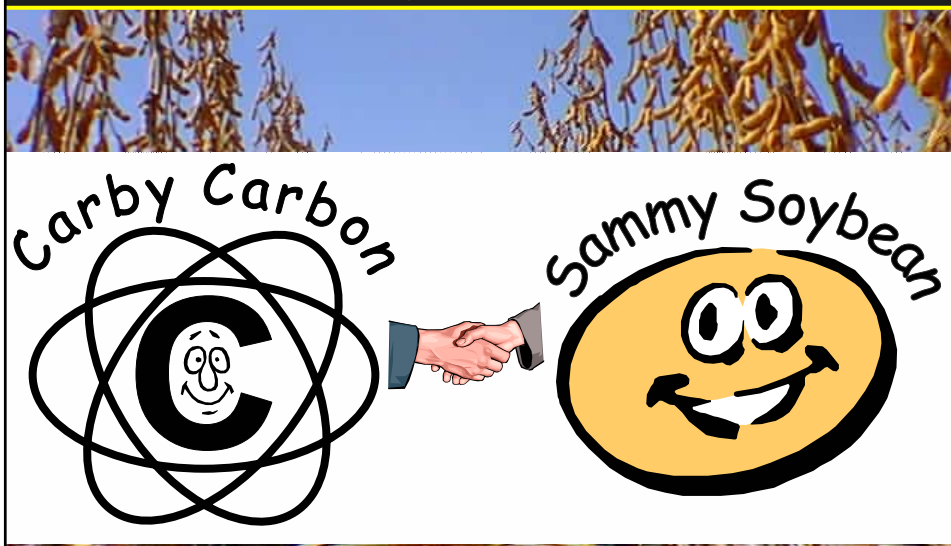
Change in C in top 20 cm after 13 years continuous corn and 4 years continuous soybean (g m^{-2})

	Residue returned		Residue removed	
	0 kg N ha ⁻¹	200 kg N ha ⁻¹	0 kg N ha ⁻¹	200 kg N ha ⁻¹
NT	+58	-1017	-348	-279
MP	-435	-782	-393	-430
CP	-313	-218	-258	-184

Overall relation after 13 yr of continuous corn followed by 4 yr continuous soybean suggests a 24 % decrease in SOC after soybean!

Source: Layese et al., 2002. Soil Sci. 167(5): 315-326.

What do we have to do to bring “Carby Carbon” and “Sammy Soybean” together for the environment?

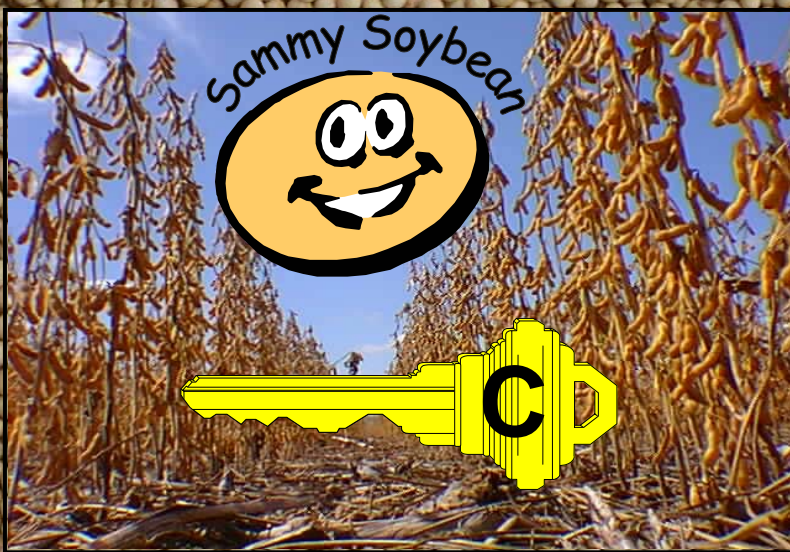


What can we do to improve soybean and soil carbon relationships?



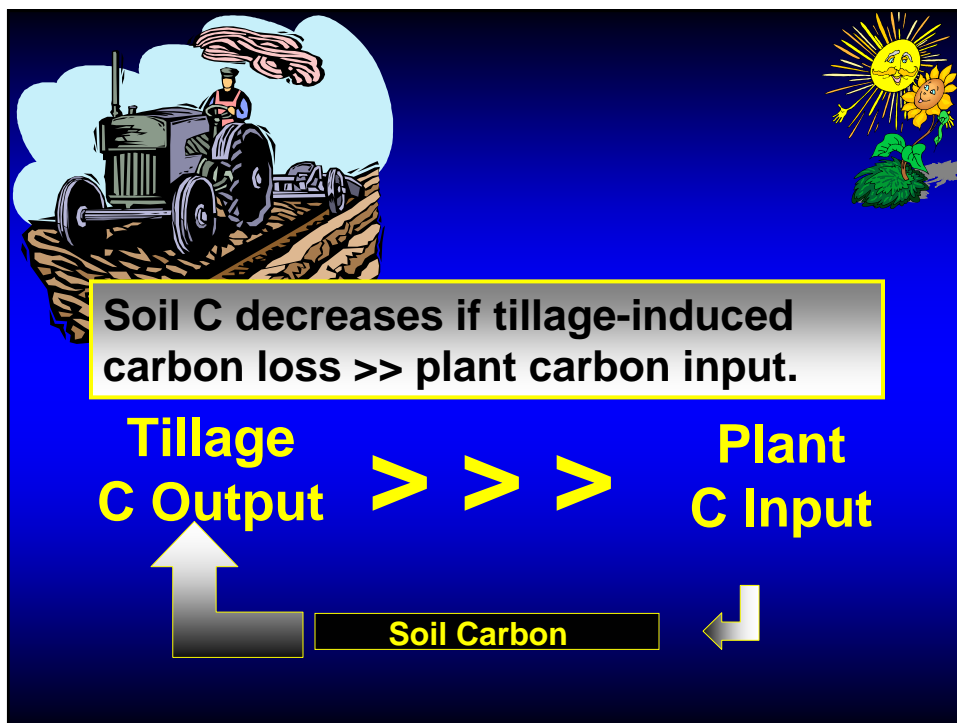
- Increase grain yield, oil and protein content
- Increase root and above ground biomass
- Increase resistance to pests and disease
- Increase Nitrogen fixation capacity
- Decrease Shoot:root ratio
- Increase C:N ratio and resistance to decomposition
- Develop soybean as renewable biofuel
- Use direct seeding techniques with cover crops
- Use diverse rotations in Conservation Agriculture

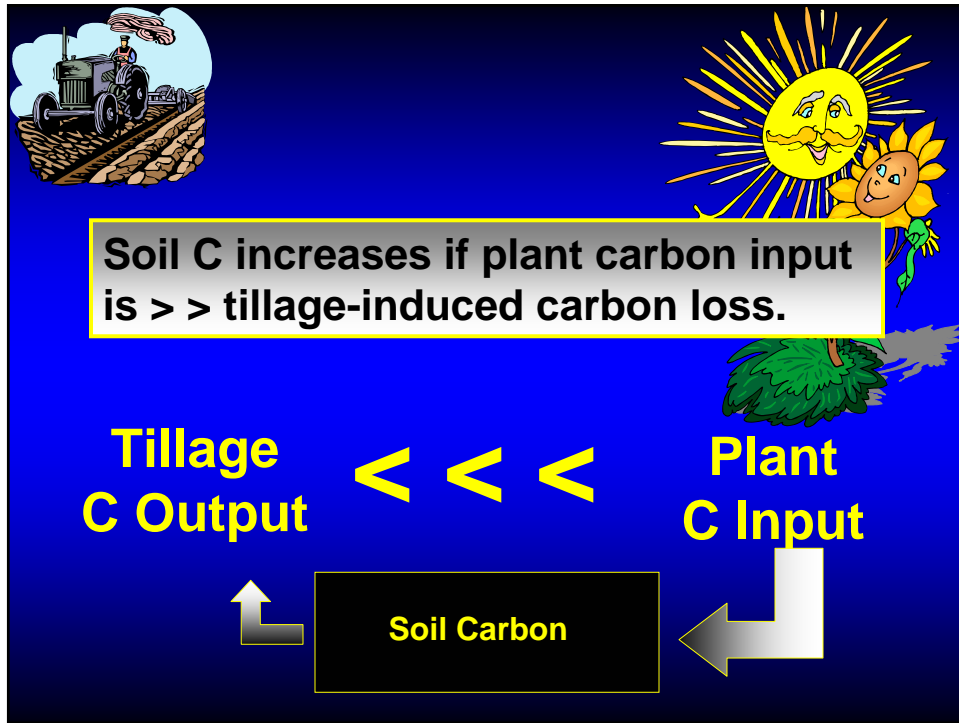
Ask not what soybean production can do for you.
Ask what you can do to make soybean production sustainable.



Research conclusion.

Soil carbon management in soybean production is very challenging and requires more diverse crop rotations and/or cover crops to be a sustainable system.





Conservation Agriculture is Carbon Management!

Economic prosperity
Environmental protection
Energy conservation
Ethics - Social Responsibility

Direct seeding is a new technology that provides food, fiber and bio-fuels that helps protect the environment.

