27th Annual NATIONAL NO-TILLAGE CONFERENCE

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Soil Carbon Management:

Biodiversity, Soil health and ecosystem services

By

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2019 National No-Till Conference.

A mix of many on-farm observations and data alongside university collected data is a good thing — it adds diversity, credibility and understanding.

My mission is to get you to "think":

Carbon

Biodiversity

- Natural Systems
- Sustainability
- Integration
- Synergy
- Holistic
- Resilience
- Regenerative
- Integrity farming
- Decency farming
- Smart farming

Food Security (Sustainability)

It's all about "C" management!

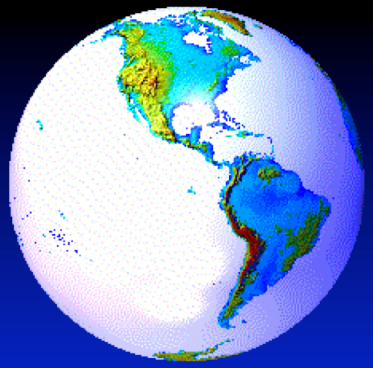
OUR HUNGRY WORLD

OUR THREATENED PLANET

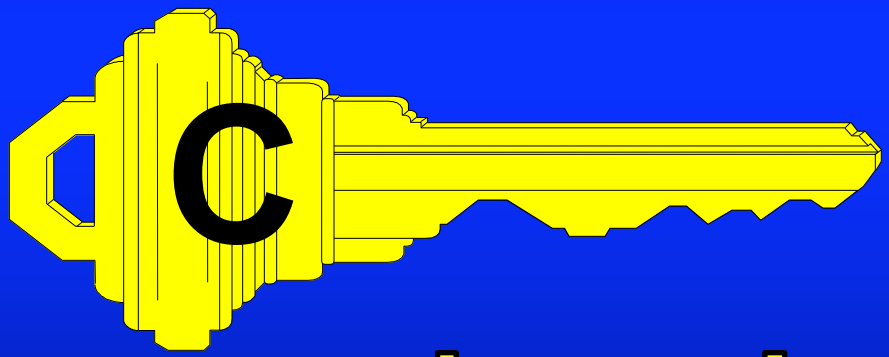
OUR CHILDREN'S FUTURE

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!

Think Carbon!
Think Biodiversity!

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

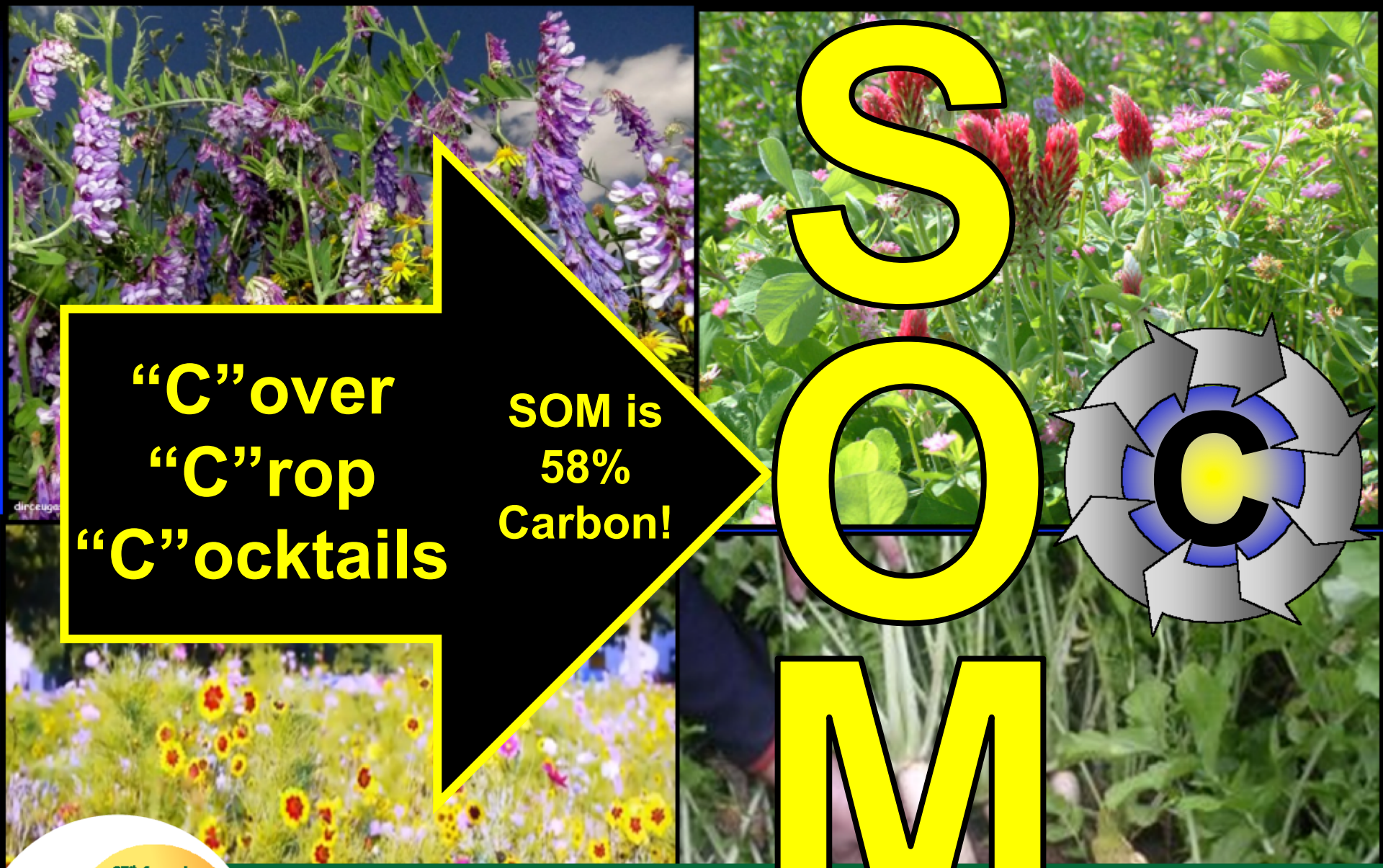
No Tillage

Cover Mixes

Carbon is the "heart" of soil health!

Minimum carbon loss

Maximum carbon input



“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 cycling

Nutrient cycling

Form stable aggregates

Water infiltration

Detoxify pollutants

N fixation

Water flow

Water storage

Pathogen suppression

Decompose biomass

Recycle CO2 to atmosphere

Enhance plant growth

Plant protection

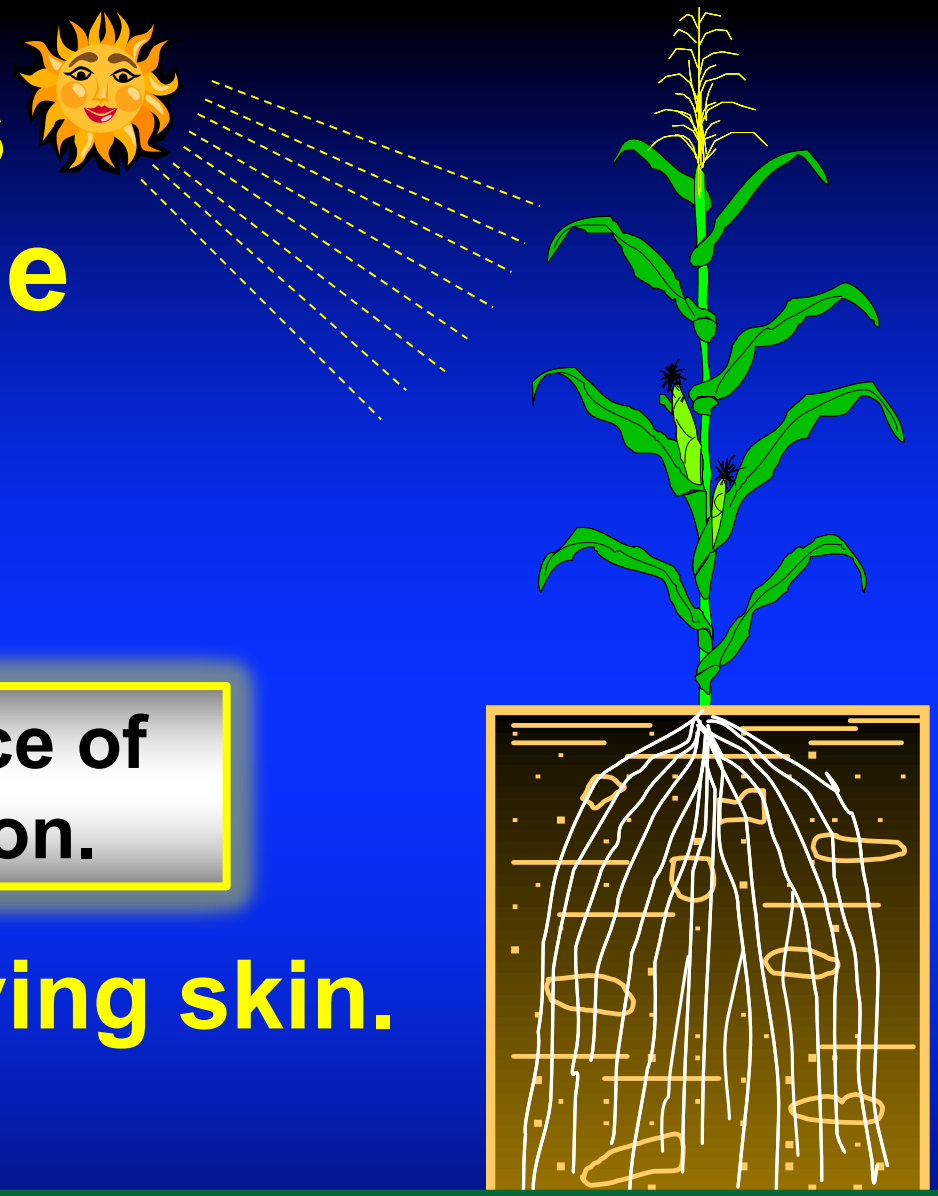
Improve water quality

Carbon is the "Backbone" of Food Security:

- 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

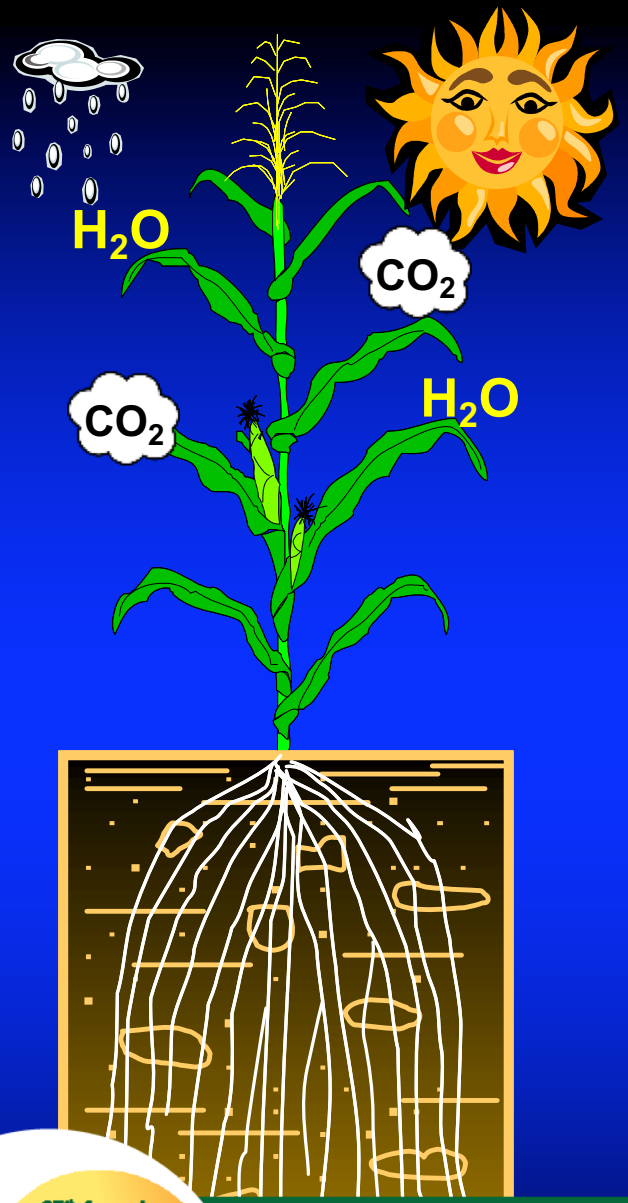
The sun powers all life through the Carbon Cycle!



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.

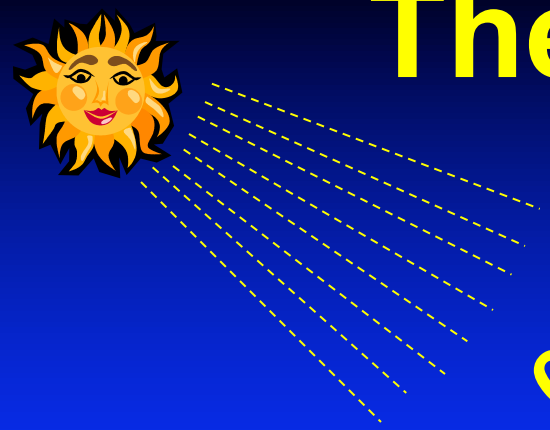


Sunlight is the only energy for life on earth!

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

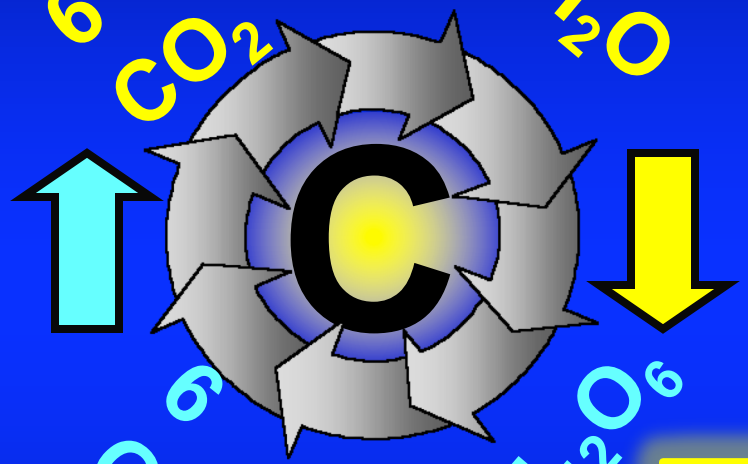
The Carbon Cycle



Photosynthesis

$6\ CO_2 + 6\ H_2O$

Energy Release



Energy Capture

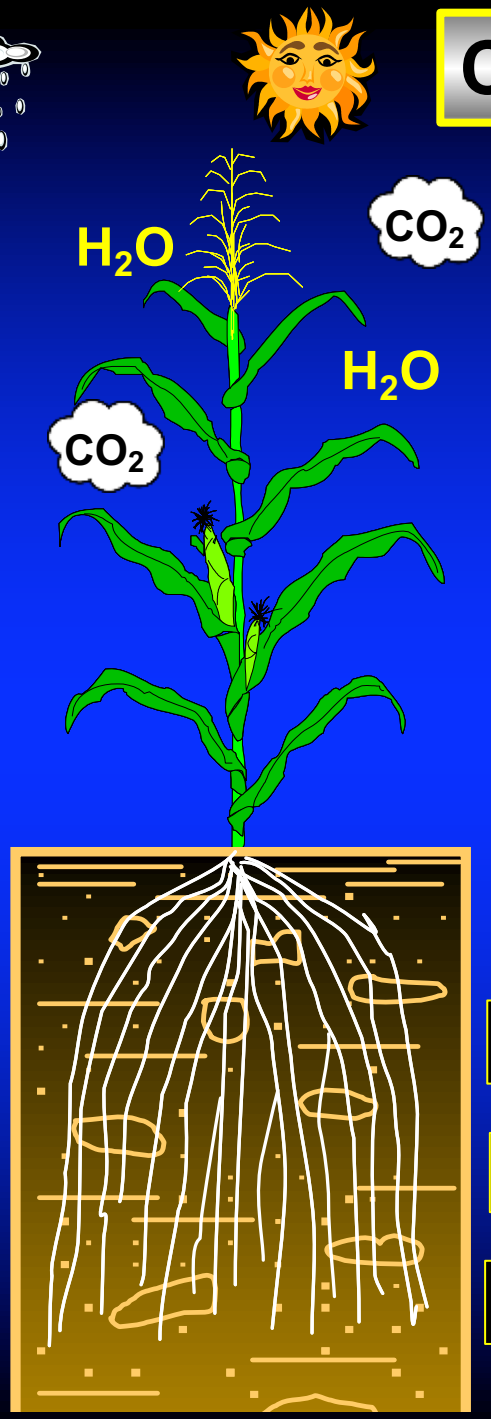
The devil is in the details! Beckism #101

$6\ O_2 + C_6H_{12}O_6$

Respiration

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

Carbon energy flow path



Sun

$CO_2 + H_2O$

$C_6H_{12}O_6$

Plant stem

Plant roots

Root exudates

microbes

Soil fauna

Nutrient cycling

Carbon cycling

Plant nutrition

Ecosystem services

Food nutrition

CO_2

Food

Feed

Fiber

Fuel

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

Source: W. Albrecht, 1938

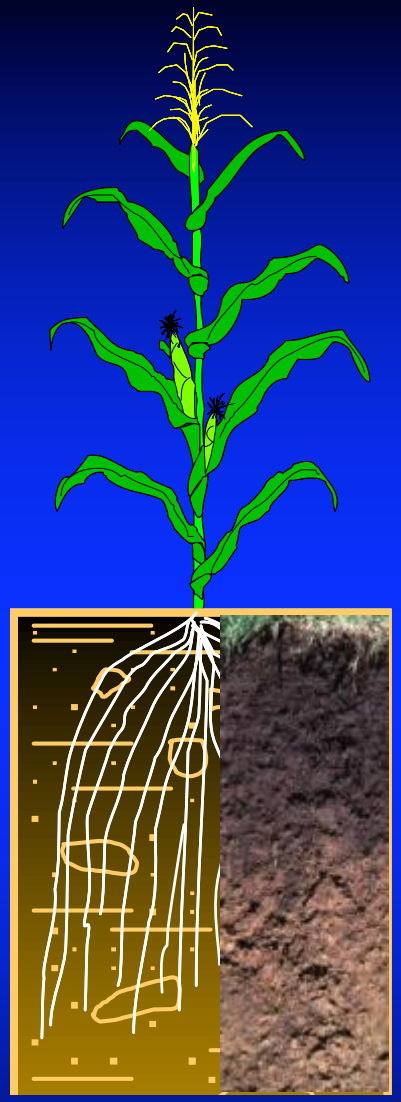
Carbon Cycling

Crop Biomass is ~46% carbon!

CO_2
Nutrients

SOM is ~58% carbon!

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

Required Plant Nutrients

From Air

Carbon	C
Hydrogen	H
Oxygen	O

Macro-nutrients

Nitrogen	N
Phosphorous	P
Potassium	K
Calcium	Ca
Magnesium	Mg
Sulphur	S

Micro-nutrients

Boron	B
Molybdenum	Mo
Zinc	Zn
Iron	Fe
Chlorine	Cl
Manganese	Mn
Copper	Cu
Silicon	Si
Aluminum	Al

Trace element such as cadmium (Cd), lead (Pb) and mercury (Hg) have no biological function in plants and animals

Additional Micronutrients:

Barium Ba
Cadmium Cd
Antimony Sb
Selenium Se
Cobalt Co
Sodium Na
Iodine I
Fluorine Fl
Chromium CR
Titanium Ti
Vanadium V

Nature's Resources

Sun 

Soil

Water 

Air

Intellect 

Biodiversity

Food Security

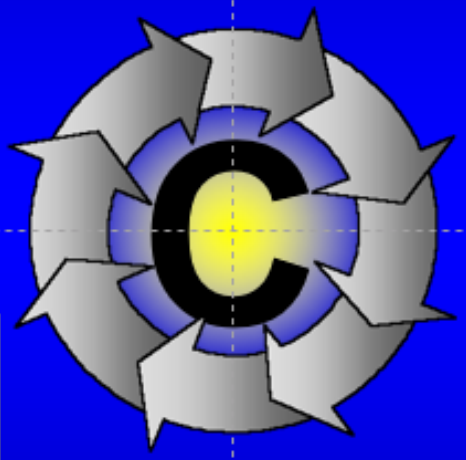
Biodiversity enables:
Sustainability, Food Security Resilience, Synergy, Profit

The role of carbon in biodiversity in Conservation Agriculture.

increases stability of the system

increases resistance to exotic species

increases carbon storage



increases the productivity of the system

reduces nutrient losses to groundwater

more efficient in nutrient capture

effects are more pronounced with increasing CO_2 and N application

decreases susceptibility to disease

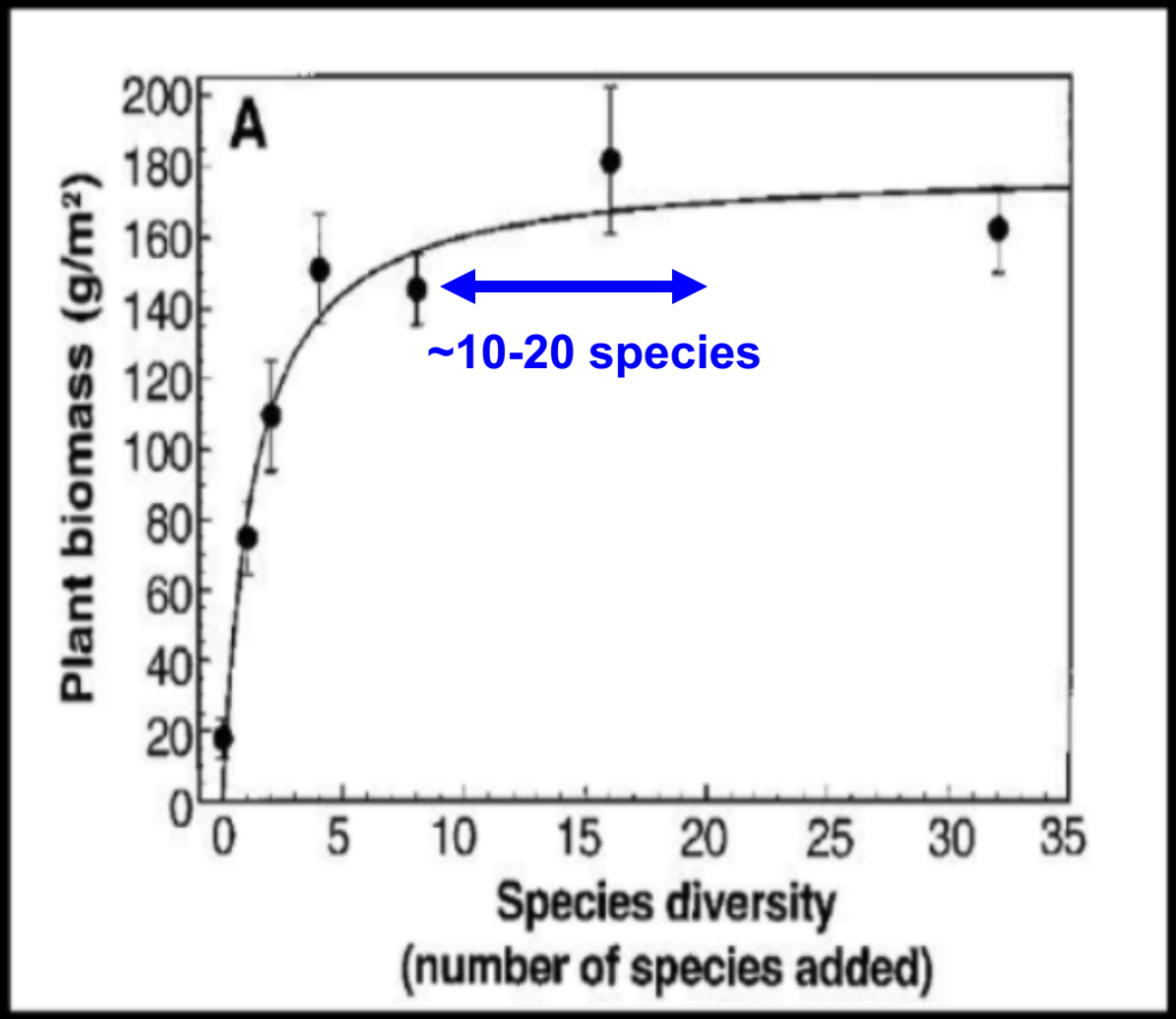
Biodiversity is an element of sustainability and is necessary for harmony and stability.

Why have plant diversity?

- Solar Energy capture as long as biologically possible
- Spatial and temporal variation
- Diverse carbon and nutrient sources
- To spread risks
- Increase the potential for synergy
- To control pests and diseases
- To better handle climate extremes
- Increase total productivity of the system
- Natures way

Liebig, M.A., D.W. Archer, and D.L. Tanaka. 2014. Crop diversity effects on near-surface soil condition under dryland agriculture. Appl. Environ. Soil Sci. vol. 2014, Article ID 703460, 7 pages. doi:10.1155/2014/703460.

The influence of species diversity on ecosystem processes



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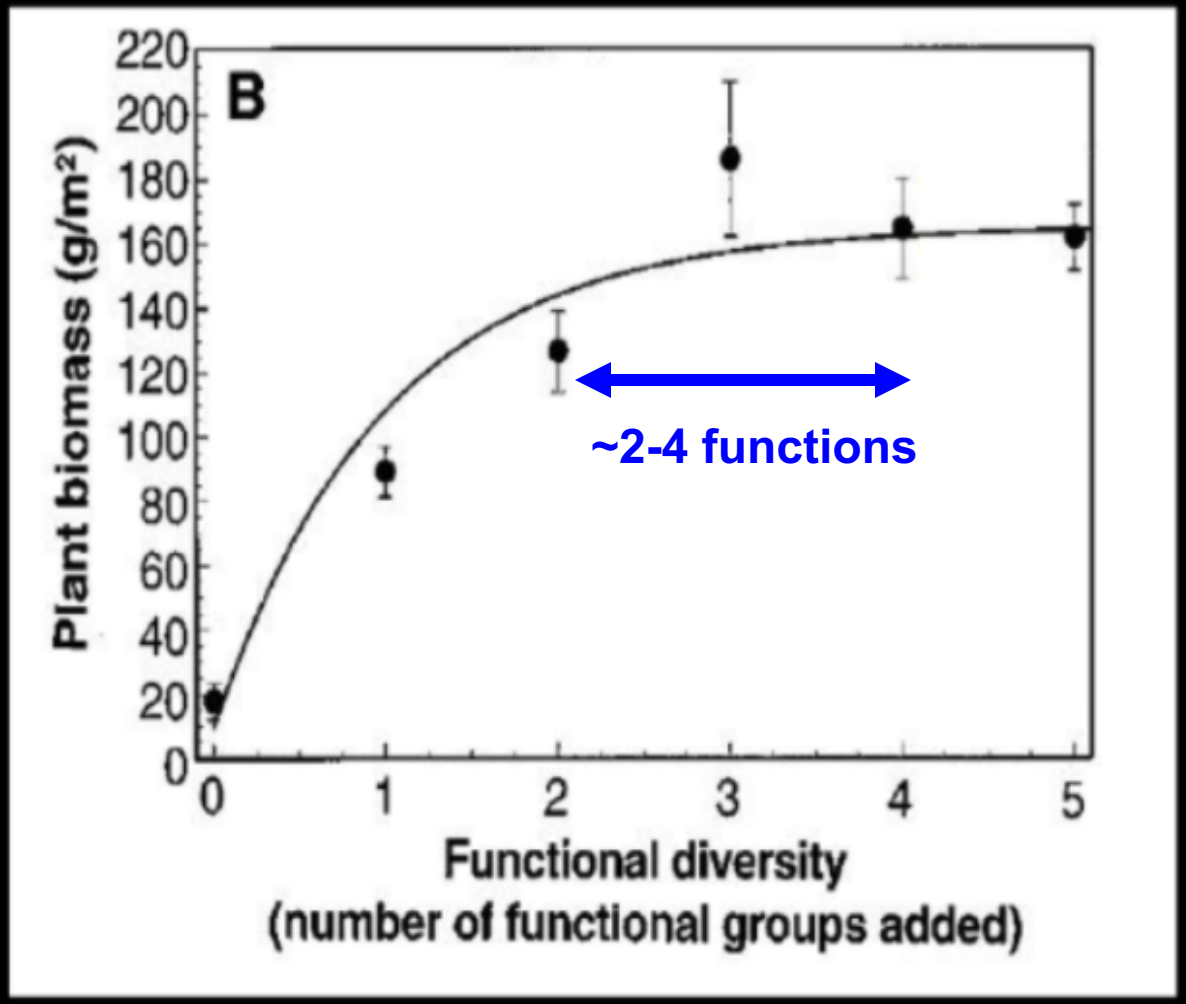

Tilman, David, et al. (1997). "The influence of functional diversity and composition on ecosystem proceeses". Science. 277 (5330): 1300–1302.

Why "C"over "C"rop "C"ocktails?

Biodiversity

Carbon

Nutrients

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.

Best for carbon input & nutrient cycling!

Simple rotations with high yields

Cover crops

Alternate crops

New bio-fuel crops

Compound rotations

Complex rotations

Simple with Perennial rotations

Stacked rotations

The devil is in the details!

Beckism #101

Diversification

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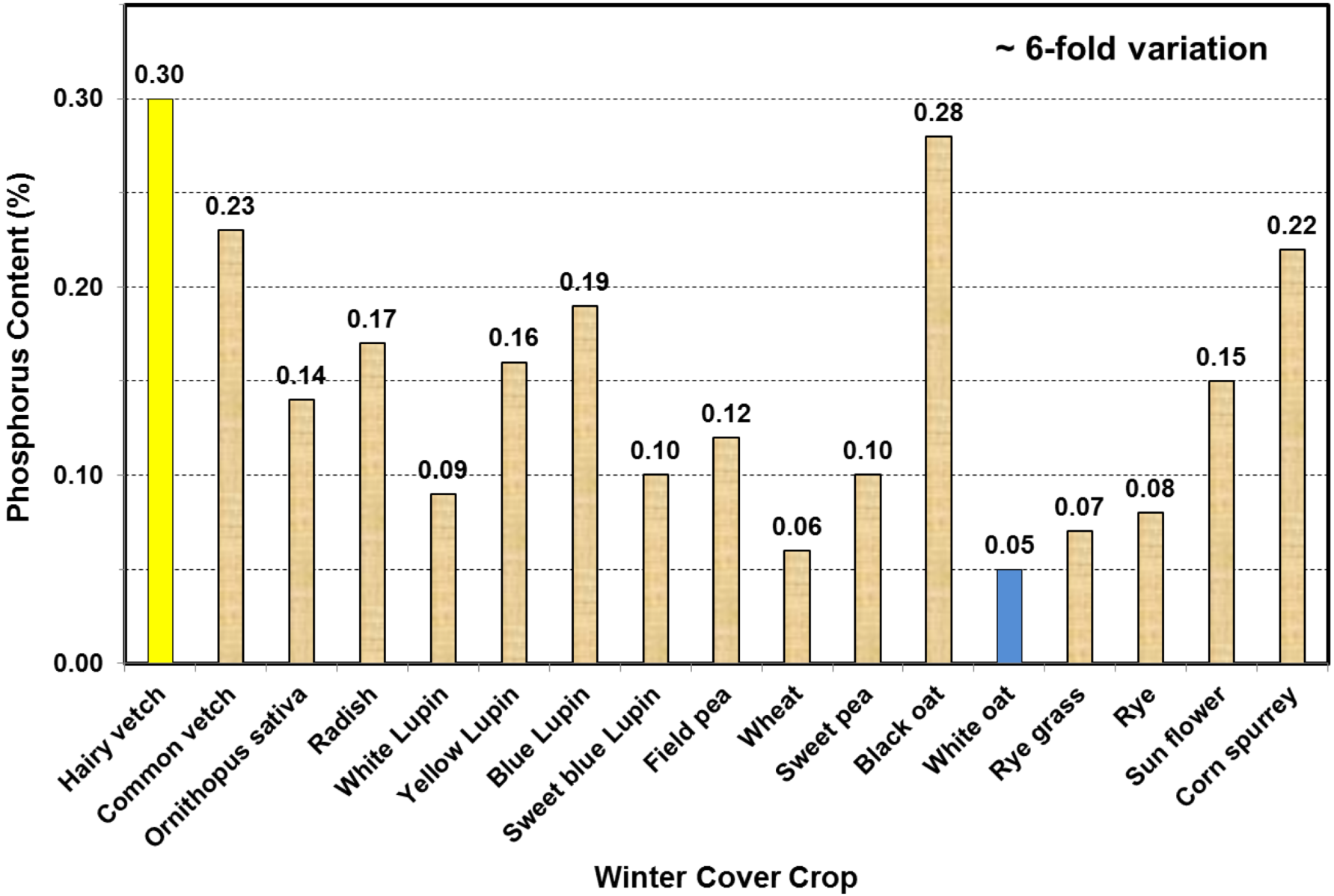
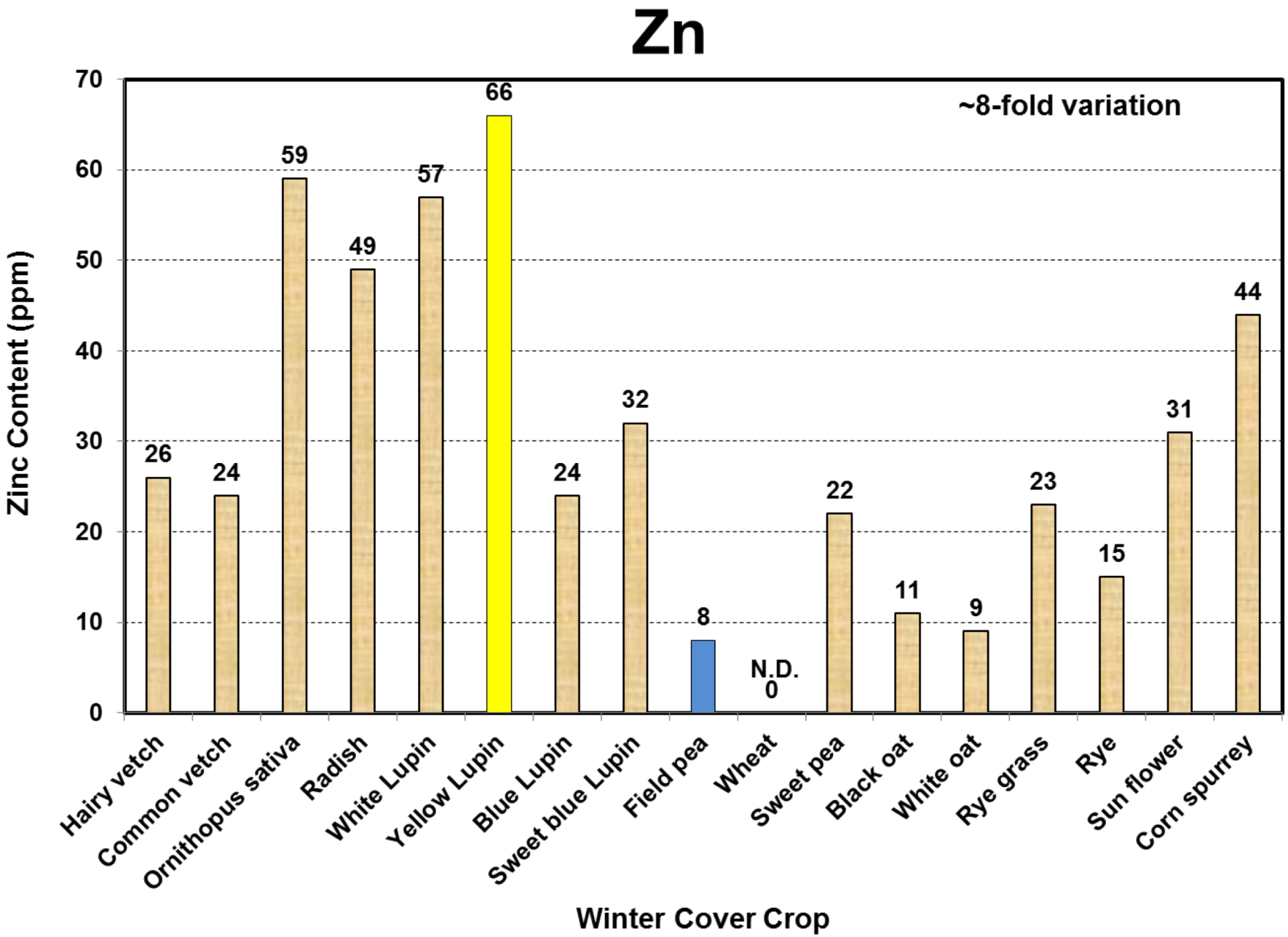


Calegari et al 1993. *Adubacao ao verde no sul do Brasil, 2nd edn. AS-PTA, Rio de Janeiro, 346 pp.*



Calegari et al 1993. *Adubacao ao verde no sul do Brasil, 2nd edn. AS-PTA, Rio de Janeiro, 346 pp.*

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!

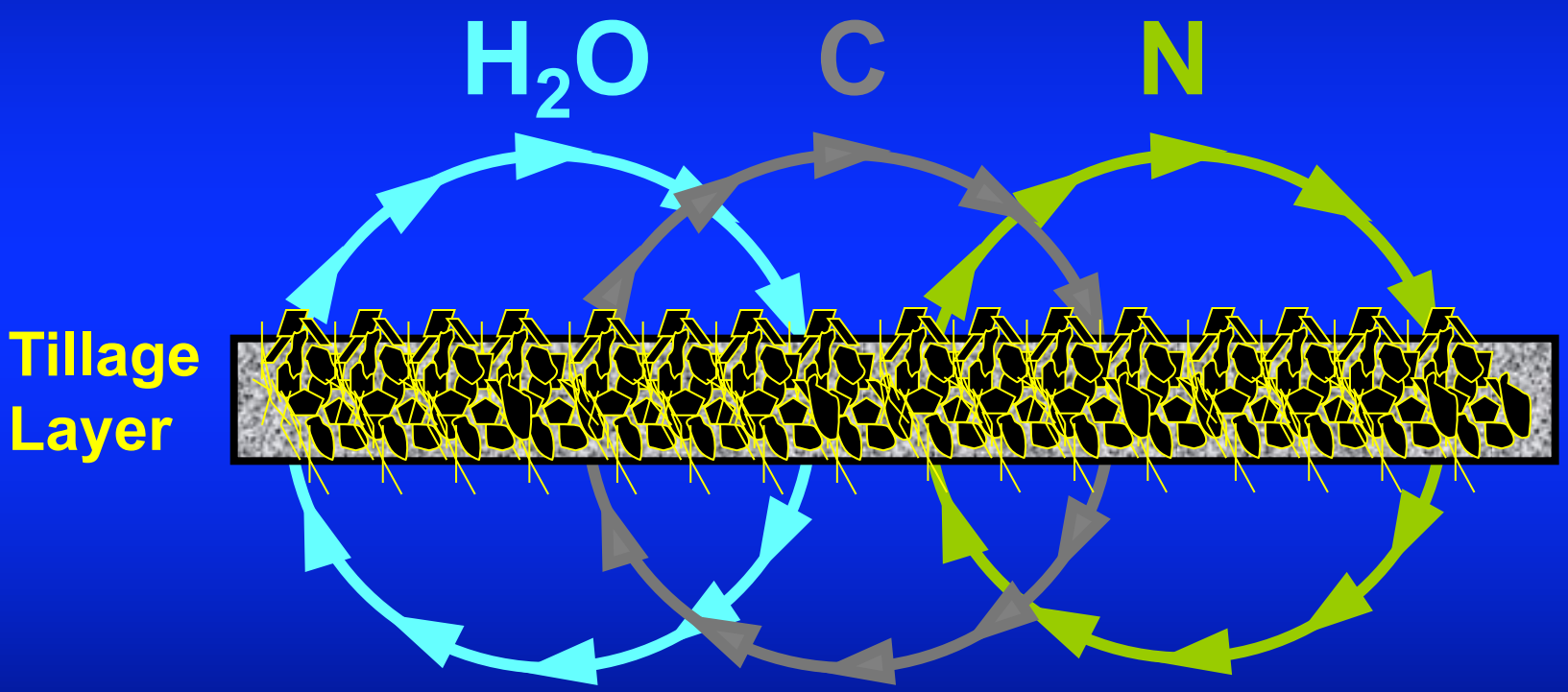
The synergistic simplicity with minimum soil disturbance (minimizes C and soil loss) and the use of diverse rotations and cover crop mixes (maximizes soil coverage and C input) for soil diversity protection and regeneration benefits in CA.

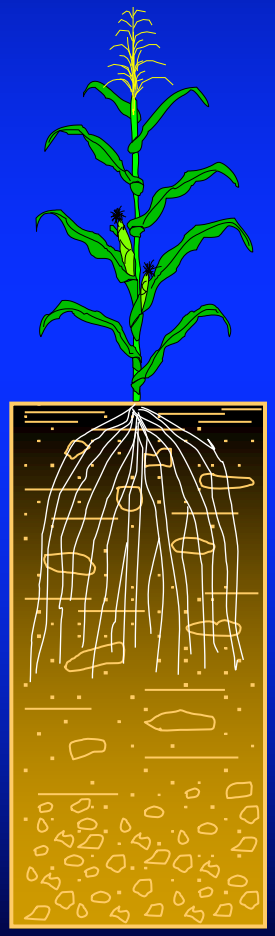
- Tap roots penetrate soil pans
- Fibrous roots enhances bio pore formation
- Enhances plant diversity that enhances biological diversity
- Combats insects/pests
- Breaks disease cycles
- Mitigates climate extremes (temperature and water)
- "Planting green" benefits of extra time for cover and carbon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

Nature's Interdependent Tri-Cycles:

Water, Carbon, Nitrogen,

Tillage disrupts the natural cycles!





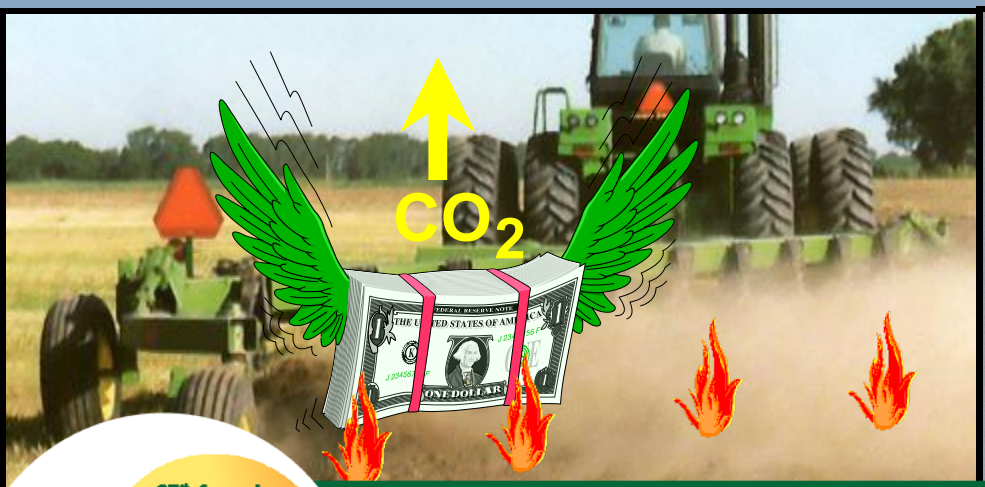
Properties and Processes

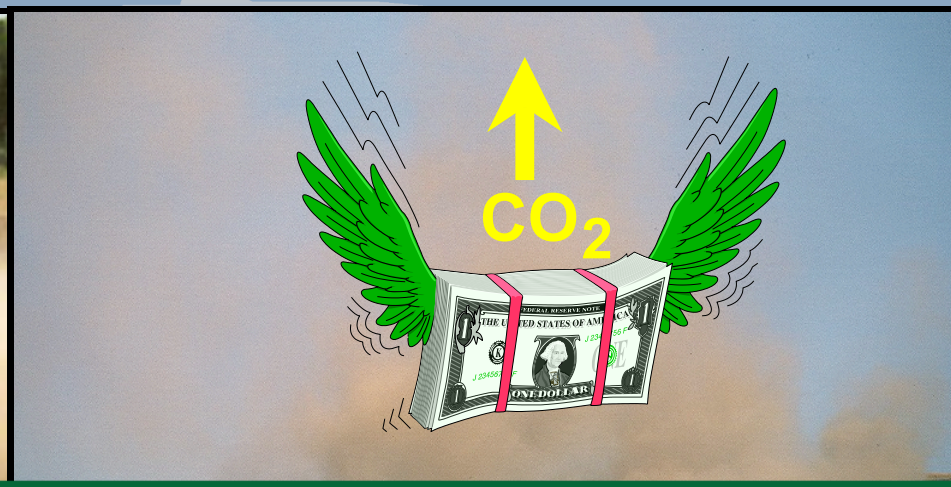
Physical Chemical Biological

No. 1 Environmental Enemy in Production Agriculture

Conventional Tillage Promotes SOM Oxidation and Soil Degradation

Tillage-induced Carbon Dioxide Loss

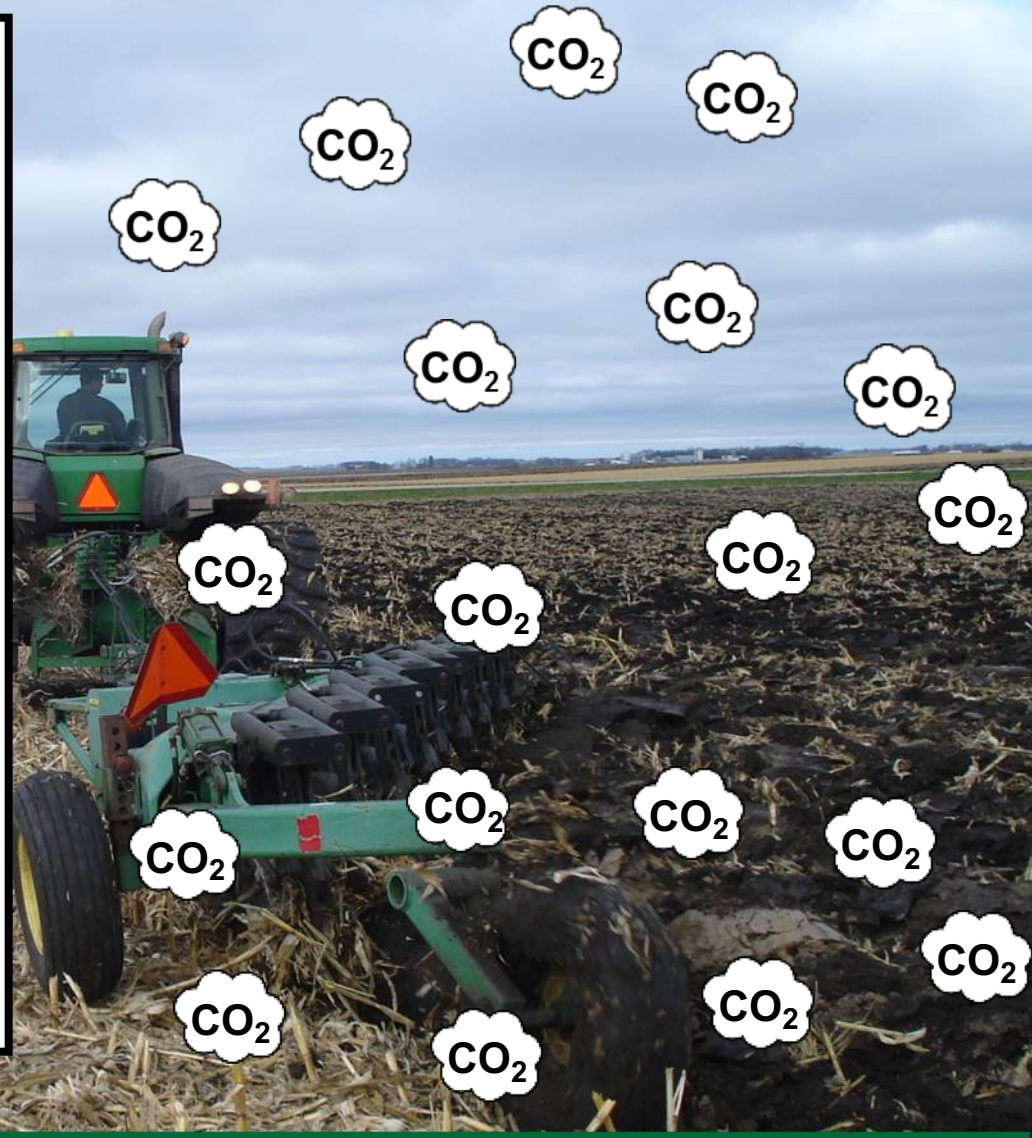




Tillage–induced CO_2 loss to the atmosphere

Tilled soils are vulnerable to:

raindrop impact; soil crusting; wind, water, and tillage erosion; temperature extremes; water extremes; biology destruction; carbon loss; biodiversity loss; increased runoff; decreased infiltration; increased evaporation; increased leaching; increased pollution;



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

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

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!

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 ~ 2 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 H_2O channels for H_2O storage & accessibility

Bio-pore channels provide a buffet enriched with C, NO_3, available phosphate, polysaccharides & other nutrients

Bio-pores stimulate other soil fauna and microbial activity for more CO_2 respiration

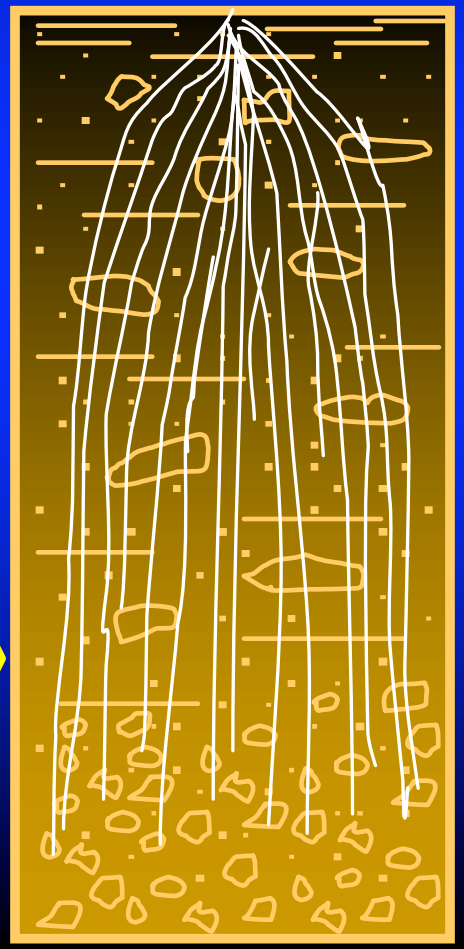
Farming 6 ft. deep rather than 3 ft. deep.

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.

+ 3 in of stored water

+ 3 ft rooting depth



Plant carbon is our greatest water management tool!

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

transpiration ↑

infiltration ↑ erosion ↓ runoff ↓

evaporation ↓ crusting ↓

↑ SOM = ↑ AWC

↑ root depth = ↑ H_2O storage, root exudates, bio-pores, ↓ deep drainage

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.

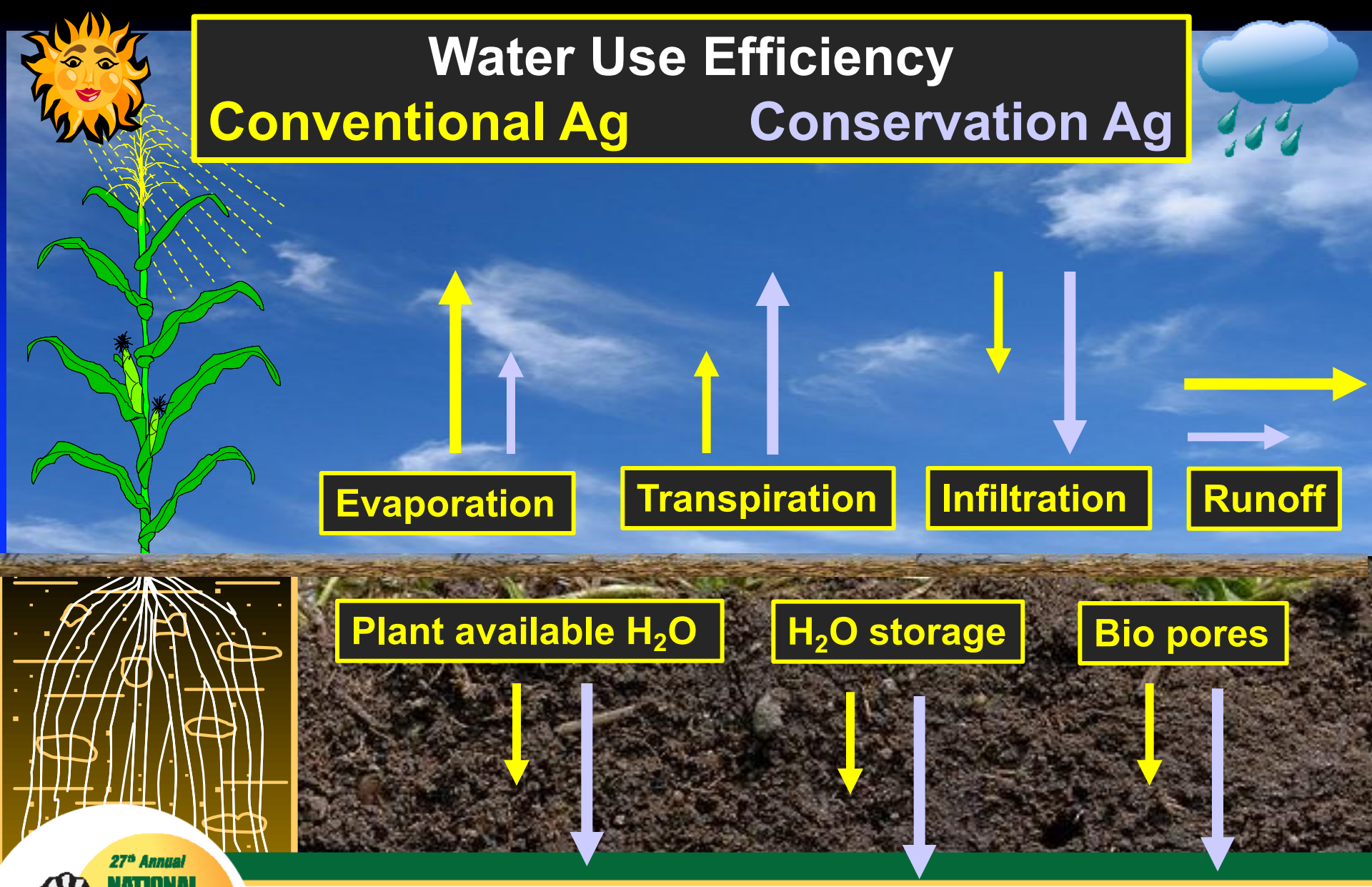
Mulch effect (evap)	~3.0 in (~ 76 mm)
Infiltration/runoff	~3.0 in (~ 76 mm)
SOM +1% = storage	~2.0 in (~ 51 mm)
Cover roots access	~3.0 in (~ 76 mm)

Seasonal Total H_2O Due to C Mgt. ~11.0 in (~ 279 mm)

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**



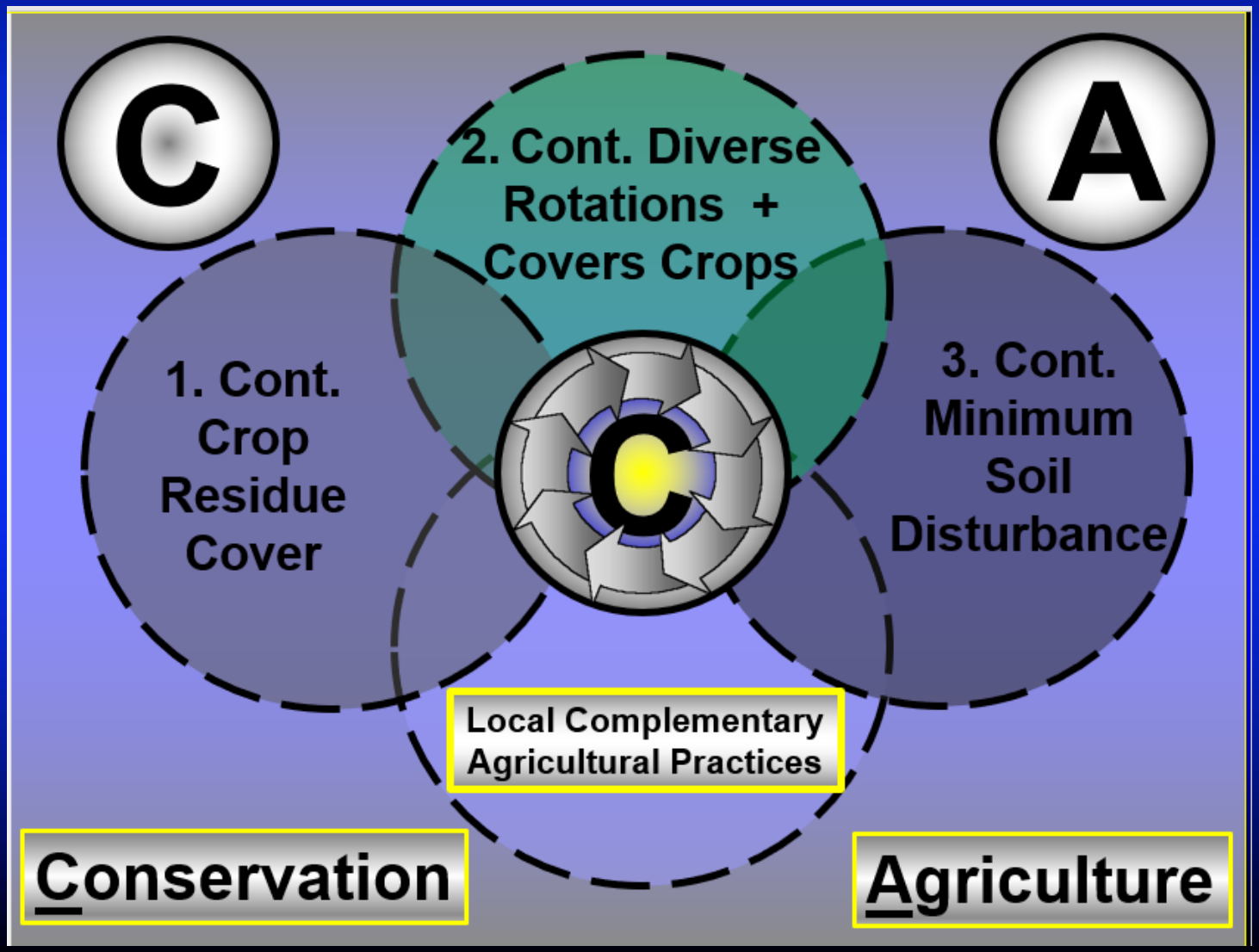
Working With Mother Nature Improving Soil Health.

"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 Systems: Spend less to make more!



CA SYSTEMS

Global Food Security

1. Cont. Crop Biomass Cover

2. Diverse Rotations + Cover Crops

3. Minimum Soil Disturbance

Local adaption of technology, nutrient and pest management.

Conservation Agriculture

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

Unknown costs

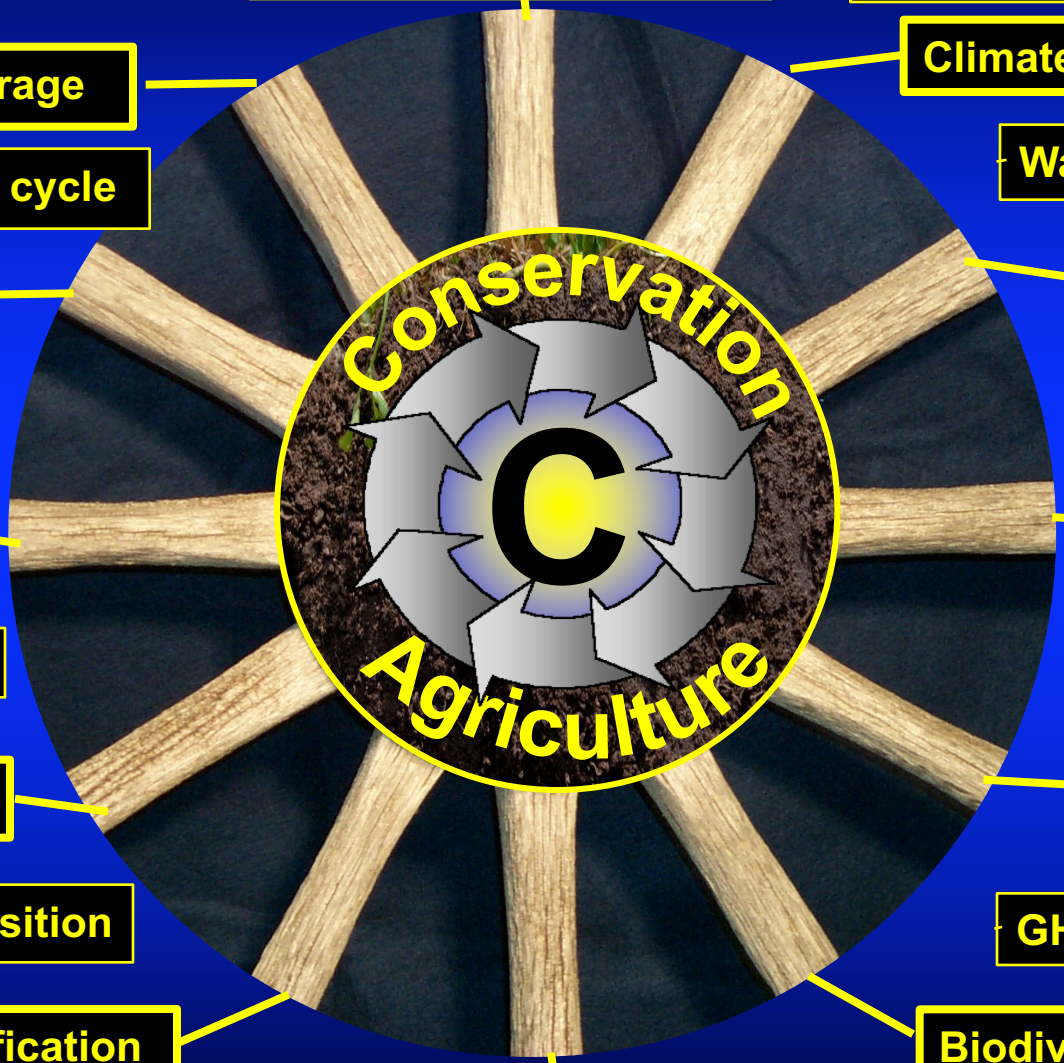
2. Environmental quality for all

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



- Water use efficiency
- Food, feed, fiber, fuel
- Nitrogen fixation
- Carbon storage
- Climate regulation
- Carbon capture & cycle
- Water capture & cycle
- Genetics
- Nutrient cycling
- Recreation
- Nutrient storage
- Infrastructure
- Organism Habitat
- Pollinator habitat
- Erosion control
- Cultural heritage
- Flood mitigation
- Waste decomposition
- GHG regulation
- Water purification
- Biodiversity
- Pest suppression
- Pharmaceuticals
- Raw materials

Our soils contain "living biological partners" enabling carbon and nutrient cycling synergies.

Soil degradation is caused by one word:

Tillage

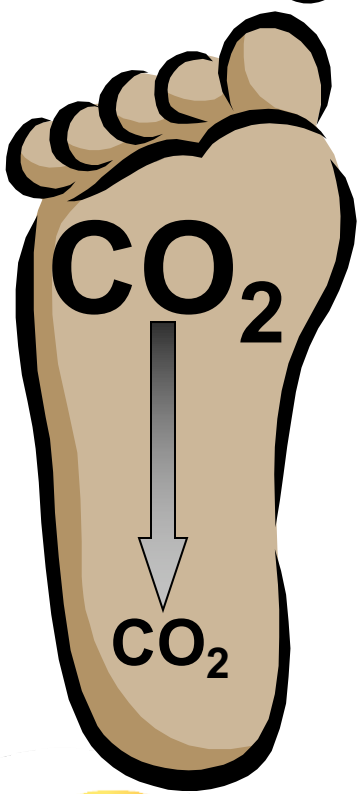
Soil recovery is accomplished by one word:

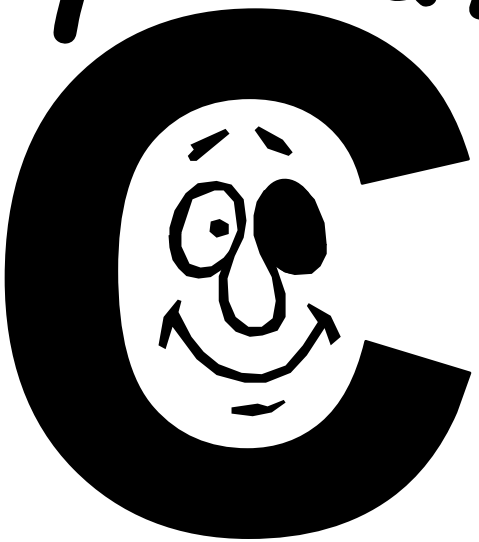
Carbon

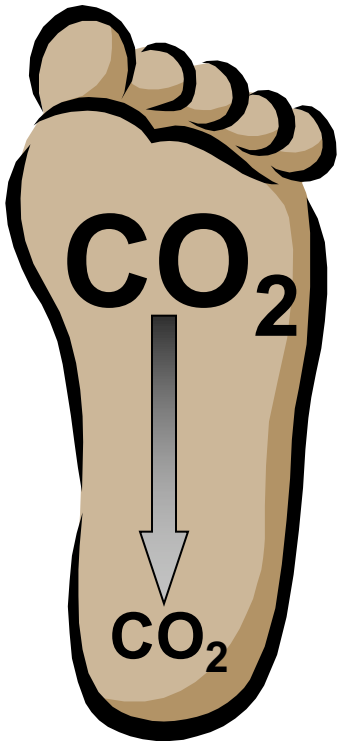
Soil health maintenance is accomplished by one word:

Carbon

Carby Carbon







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

Be a "Mega-voice" for Carbon management!