Managing No-Till Profits With Better Biology

Dr. Kris Nichols
USDA-ARS, Northern Great Plains Research Lab
Mandan, ND

January 17, 2014

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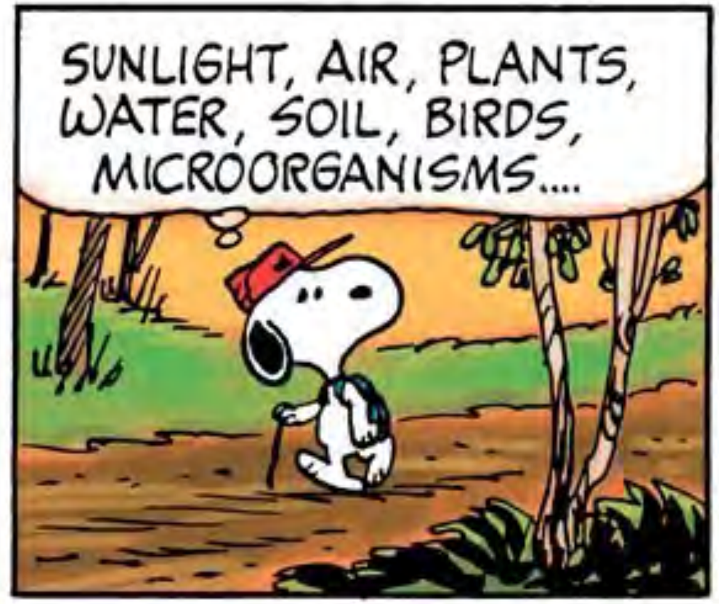
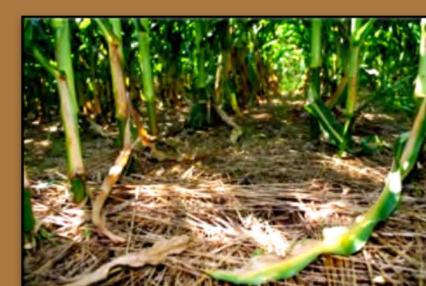
Resources



- Energy – Fossil fuels
- Clean Water
- Clean Air
- Food for growing population





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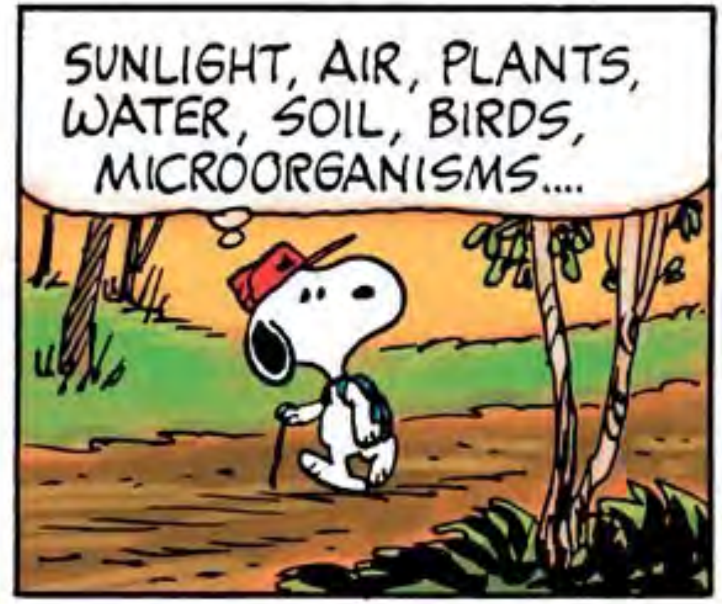

Fate of all rests on soil

Modified from Dr. Elissa Levine, NASA, and Natural Resources Conservation Service, Syracuse, NY

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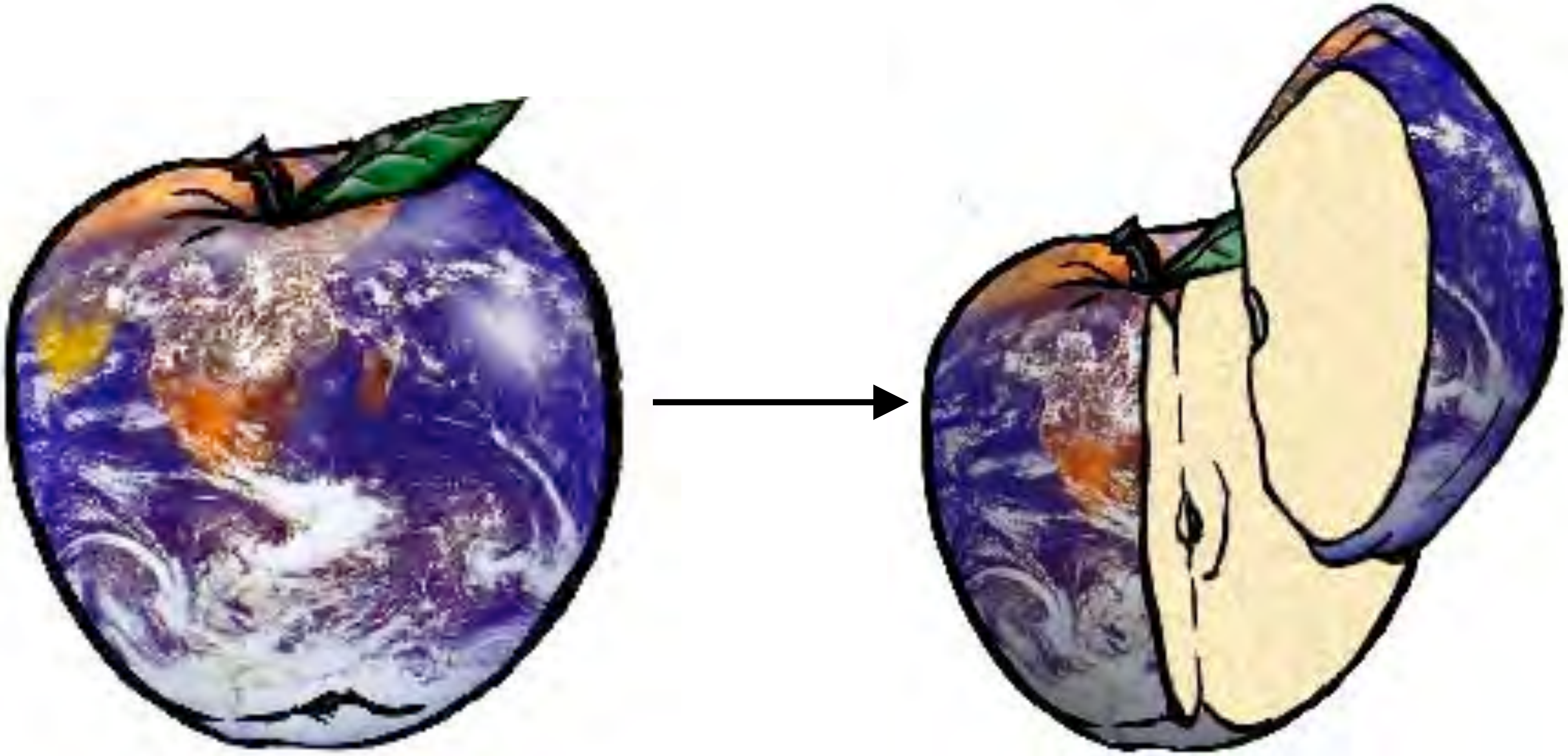
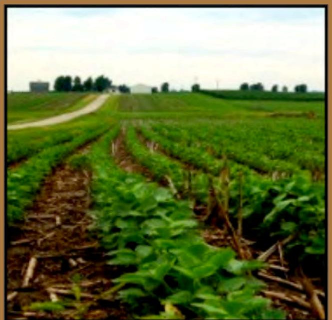
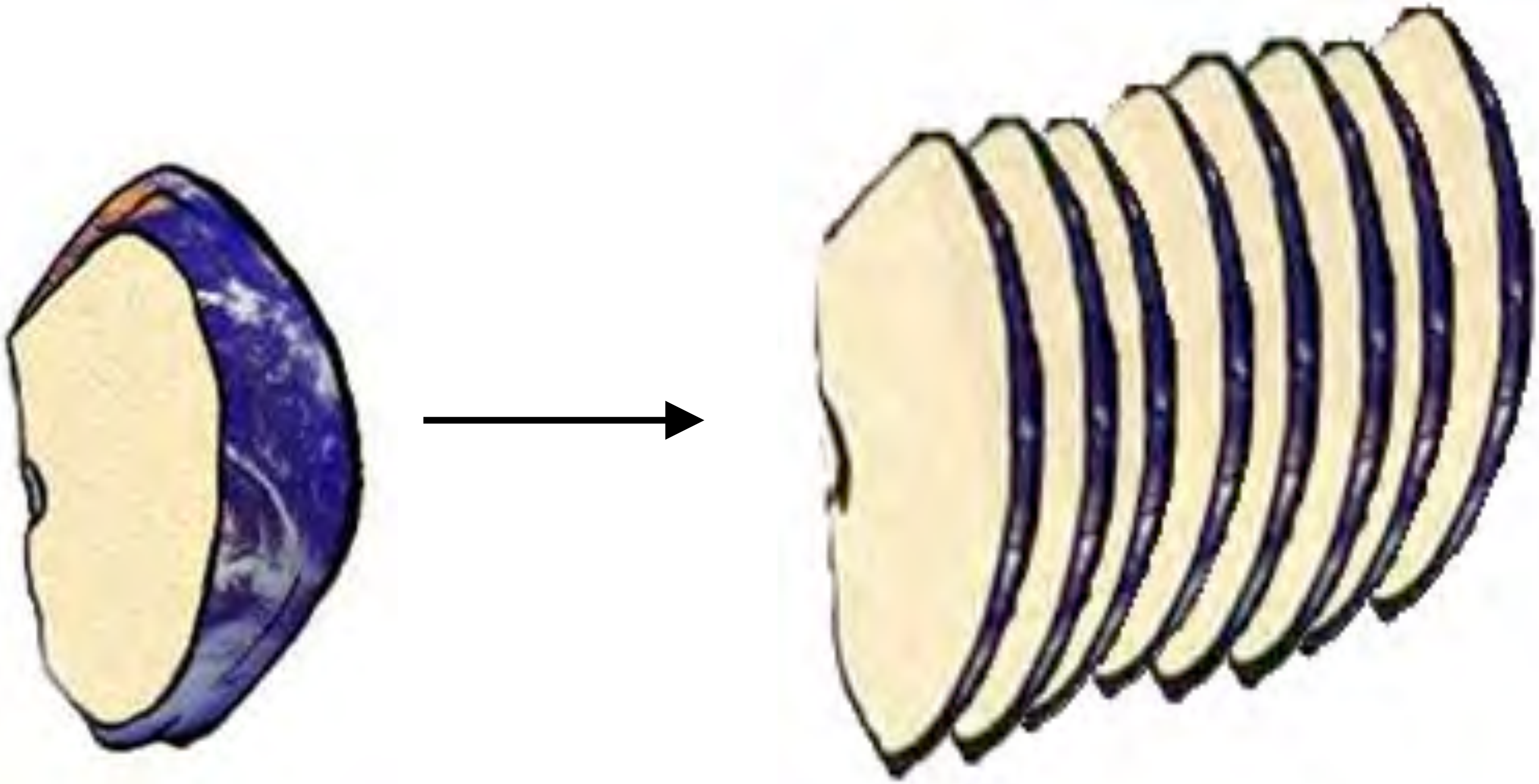


¾ planet is water





Cut ¼ into 8 pieces (1/32 each)

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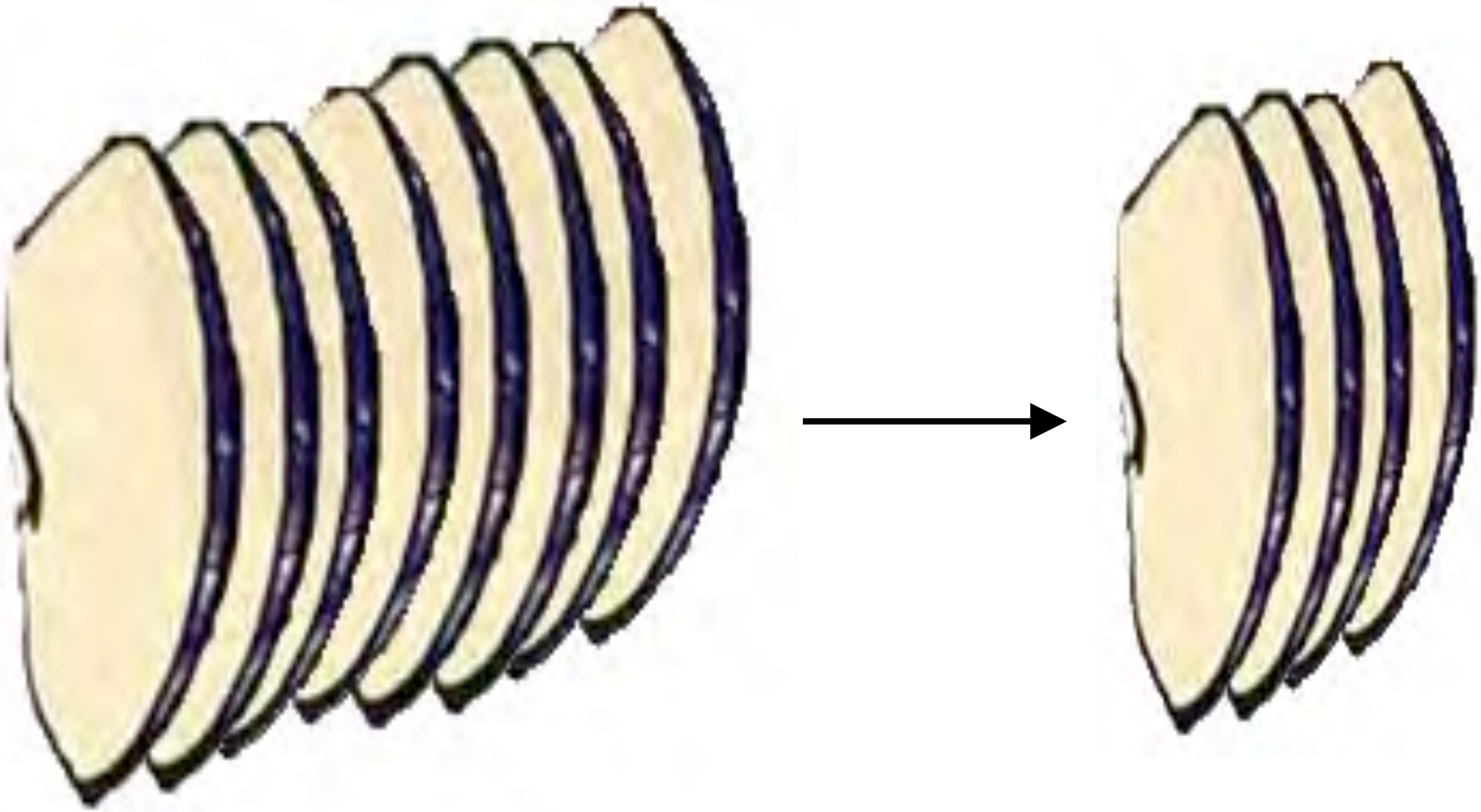
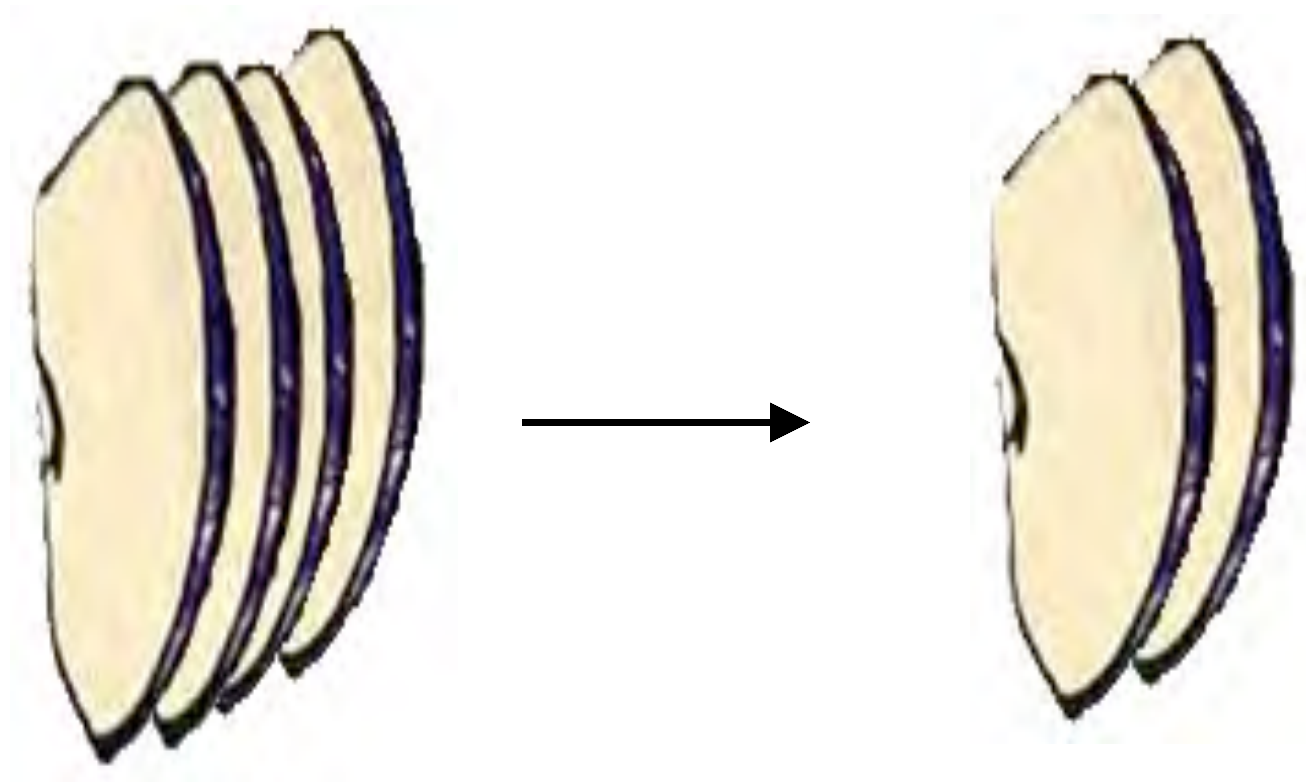
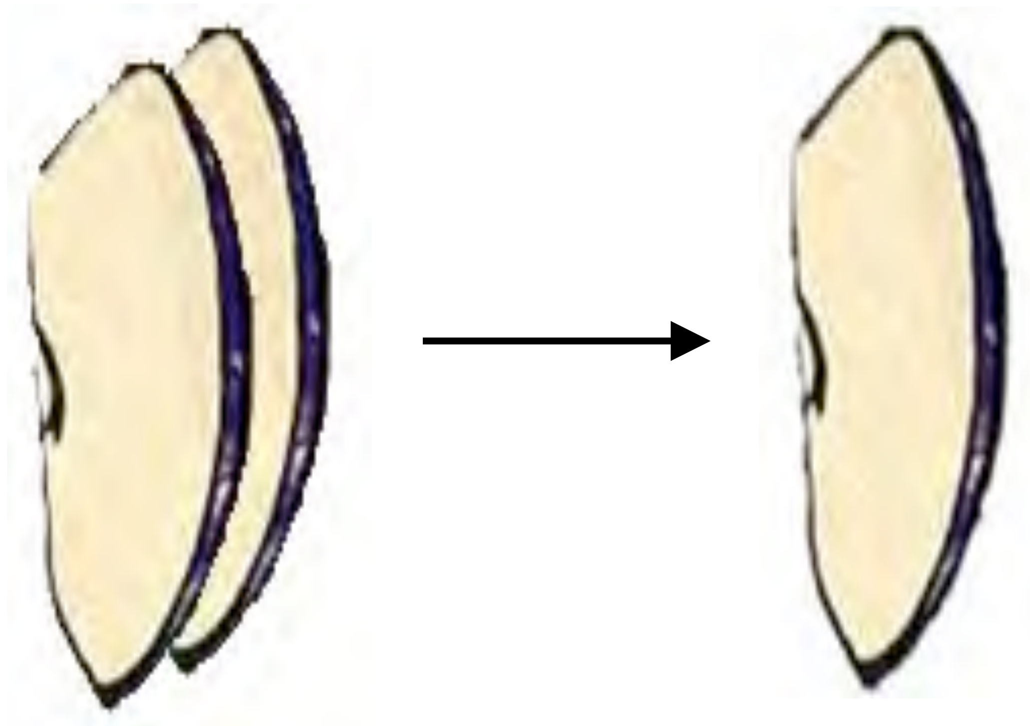


4/32 or 1/8 too cold or too dry



2/32 or 1/16 too rocky, wet, or forest covered



Where do people live?

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Soil is top 6 inches (i.e. peel) of 1/32 apple

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Soil is the Heart of the System

- Connects above and below ground
- Recycles C, N, O, P, etc.
- Drives physical, chemical, and biological processes

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Soil is the Heart of the System

- Value of soil organic matter (~$600-800 per acre) – Hoorman & Islam, OSU
- Estimated value of soil biota is $1.5 trillion globally per year - Dance, 2008

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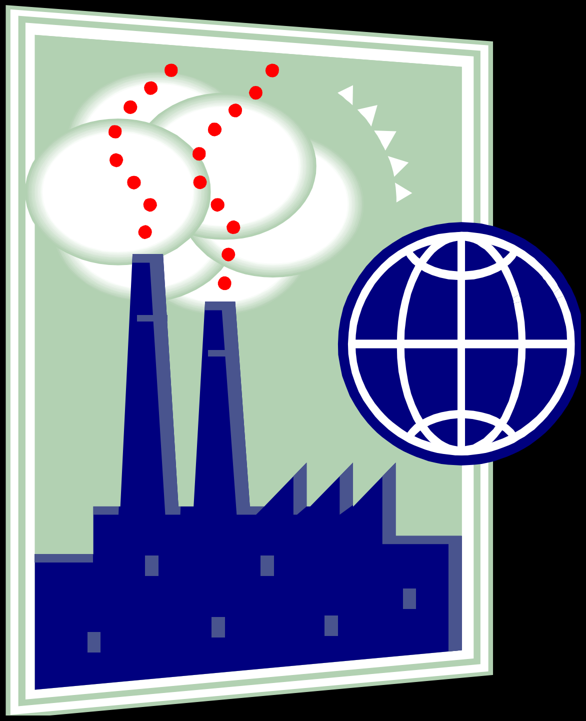
Efficient Soil Factory
What limits production?

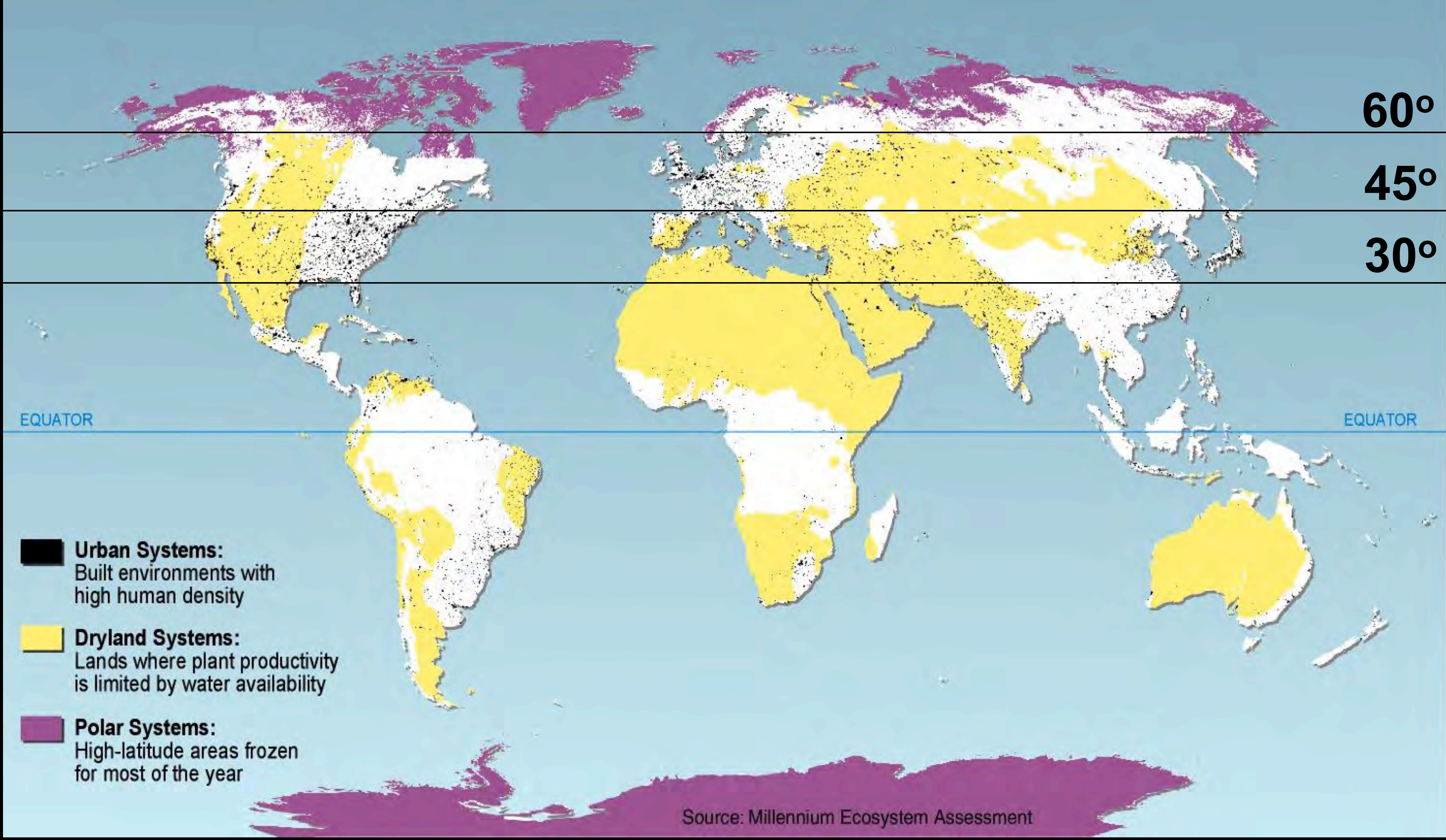
INPUTS

- Nitrogen
- Water
- Phosphate
- Potash
- Micronutrients
- Light Energy
- Carbon Dioxide



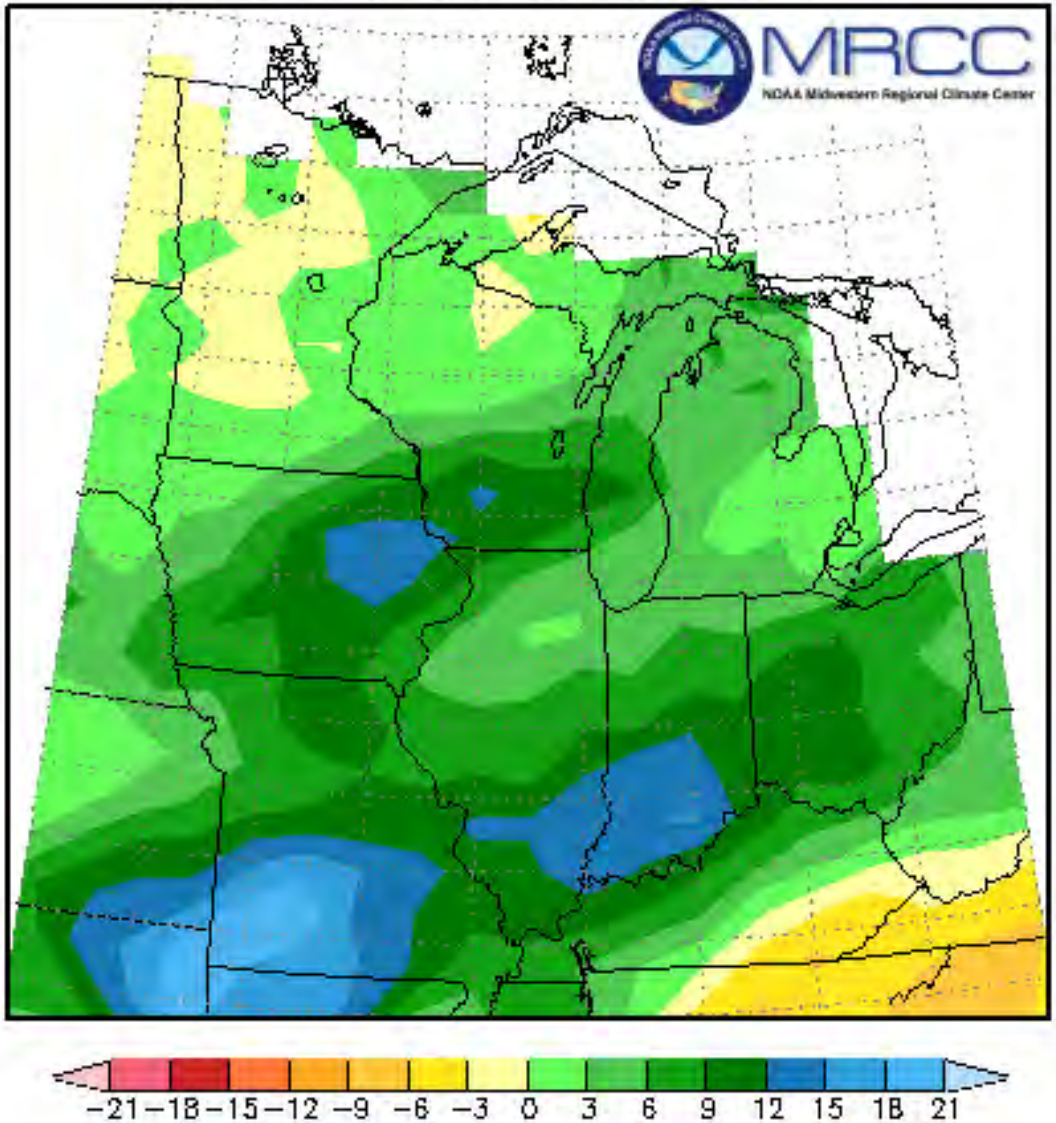
OUTPUTS

- Highest Yields
- Lowest Costs
- Highest quality
- Long-term Sustainability



- Dryland systems cover 41% of the Earth's land surface
- Almost all of the U.S. lies between 30° and 45° north latitude

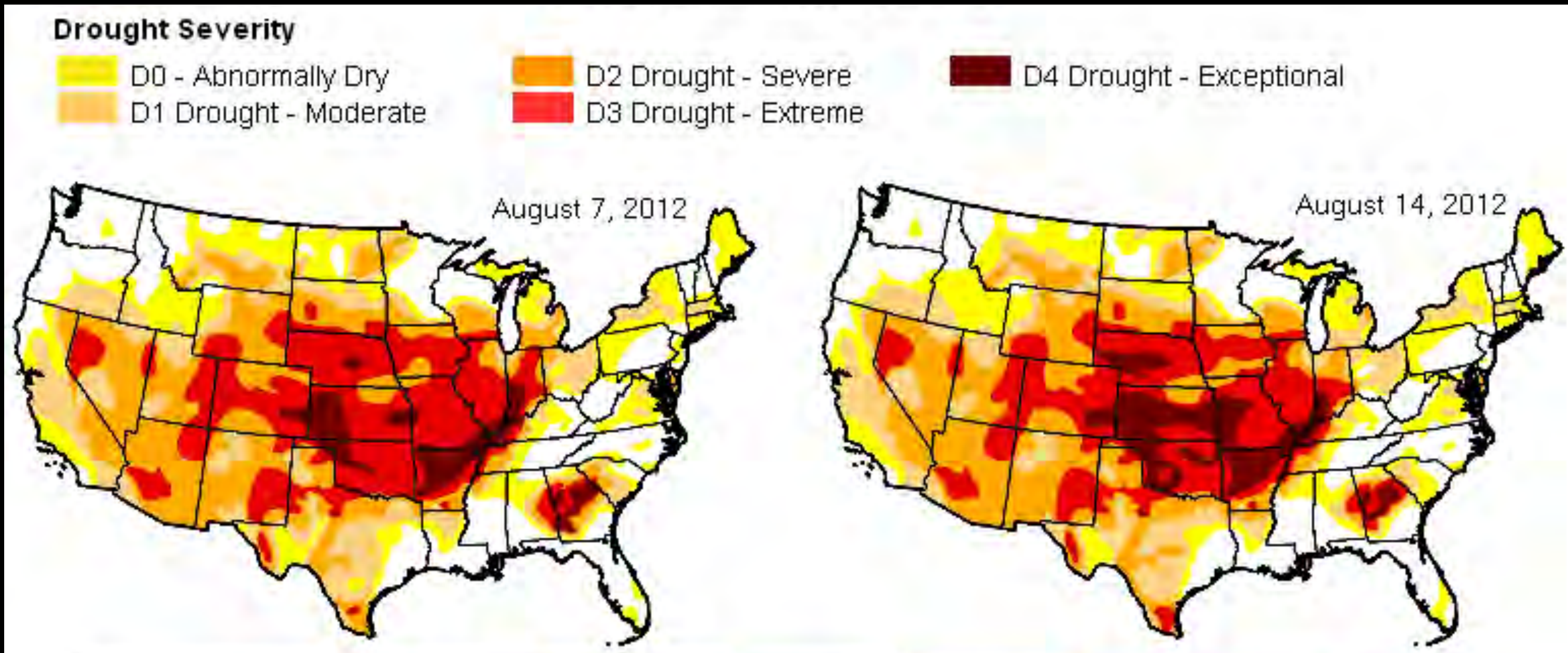
Total Precipitation Departure from Mean in Inches
January 1, 2008 to June 26, 2008



Midwest Flood 2008

Rainfall: 45-50 inches


STOP


Drought Severity
D0 - Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
August 7, 2012
August 14, 2012

Midwest Drought 2012

Rainfall: 18-23 inches

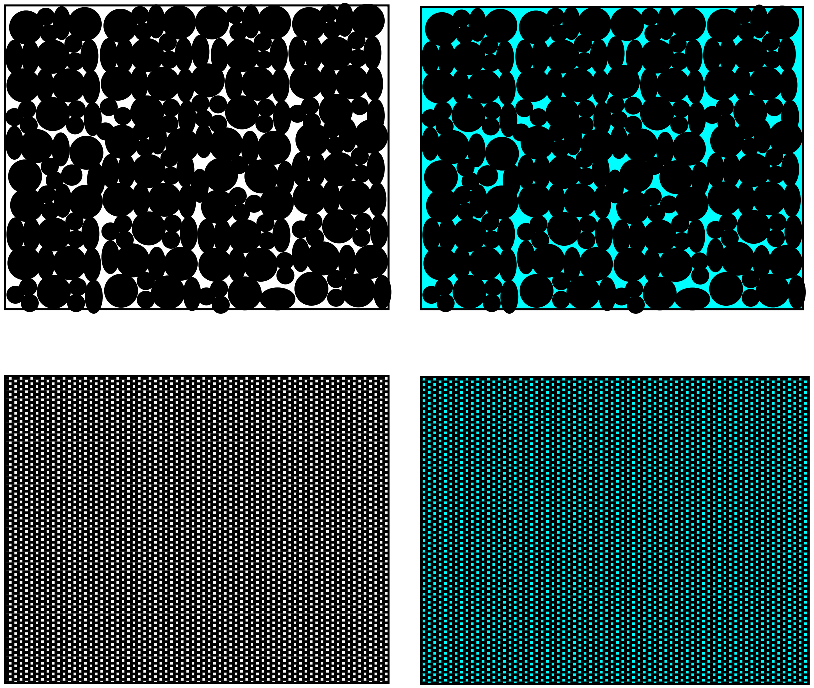
Texas Dust Storms in 1930s and 2012

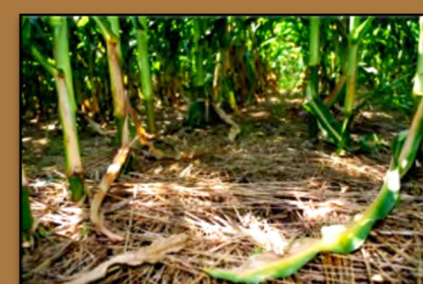

Brown Ranch, Bismarck, ND - 13 inches of rainfall in 24 hrs - 2006

Soil Architecture – Soil Aggregates Food and Habitat

Why are aggregates important?

- ❖ **Improve Soil Structure**
  - ✓Porosity
    - Root penetration
    - Aeration
    - Water infiltration
    - Water holding capacity
  - ✓Erosion Control





Rainfall Simulator

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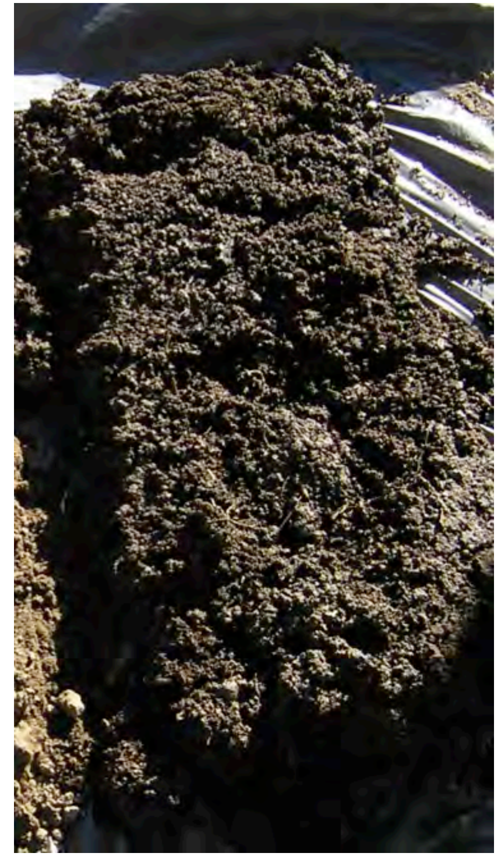
Conventional

Only a small amount of water was able to infiltrated 3” into the conventionally tilled soil.



Undisturbed

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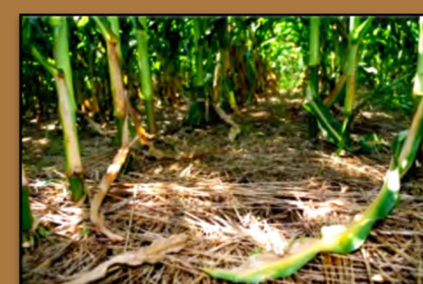

Reduced

Conventional

No-till

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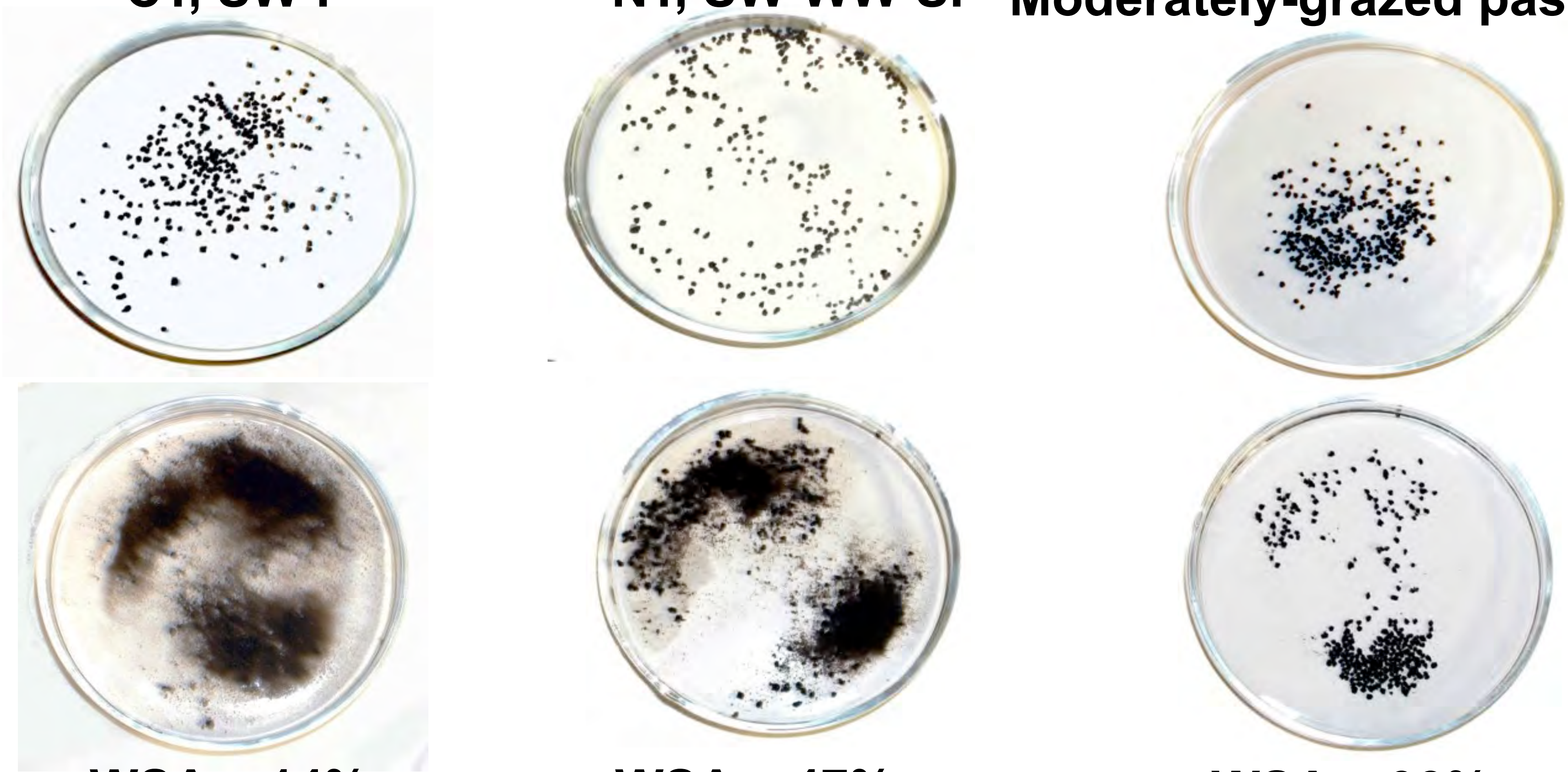
Soil Aggregate Stability

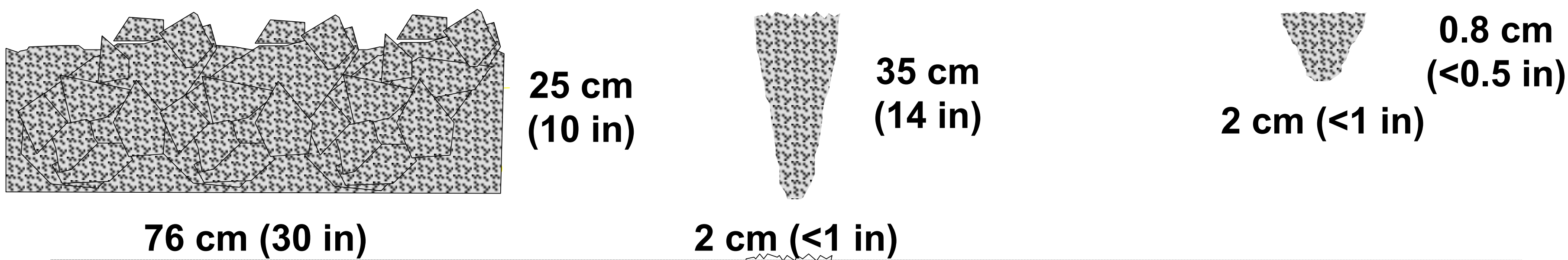
CT, SW-F | **NT, SW-WW-SF** | **Moderately-grazed pasture**



WSA = 14% | **WSA = 47%** | **WSA = 93%**

TG = 2.4 mg g^{-1} | **TG = 3.2 mg g^{-1}** | **TG = 7.9 mg g^{-1}**

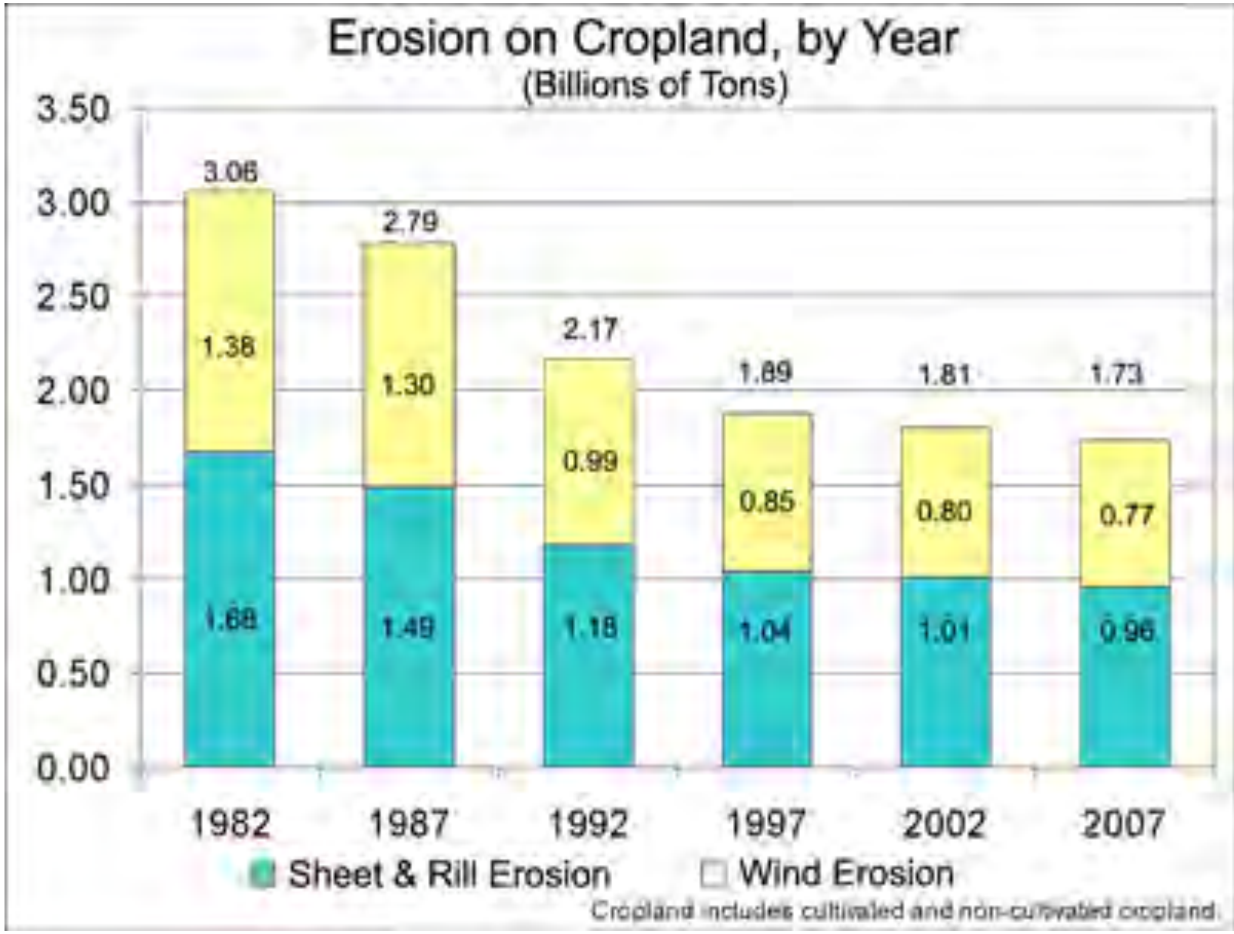
Tillage



Moldboard Plow

Subsoil Shank

No Knife
No Till Drill



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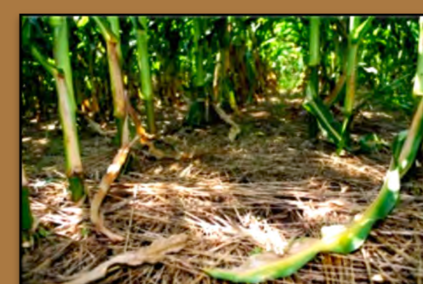
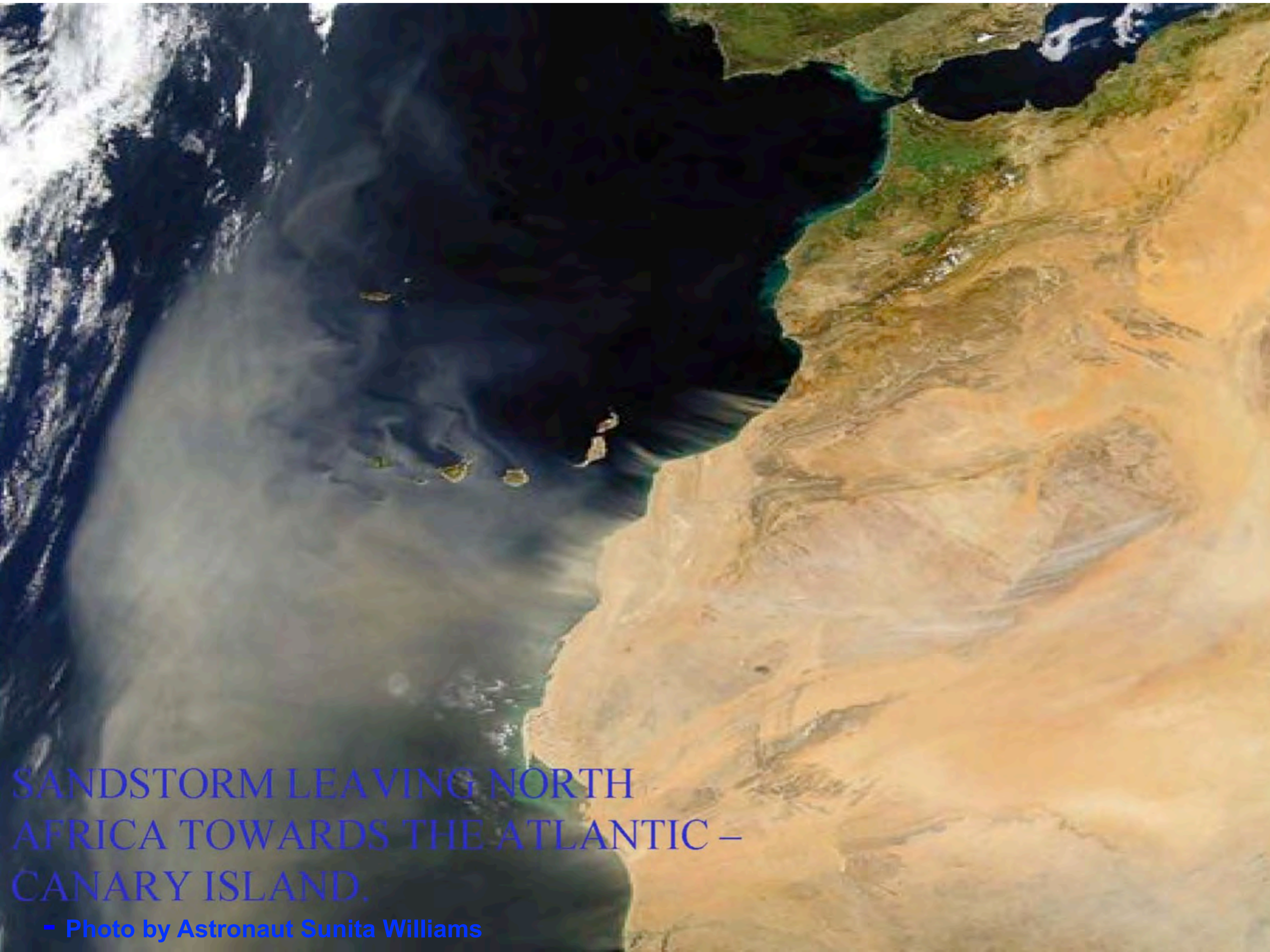
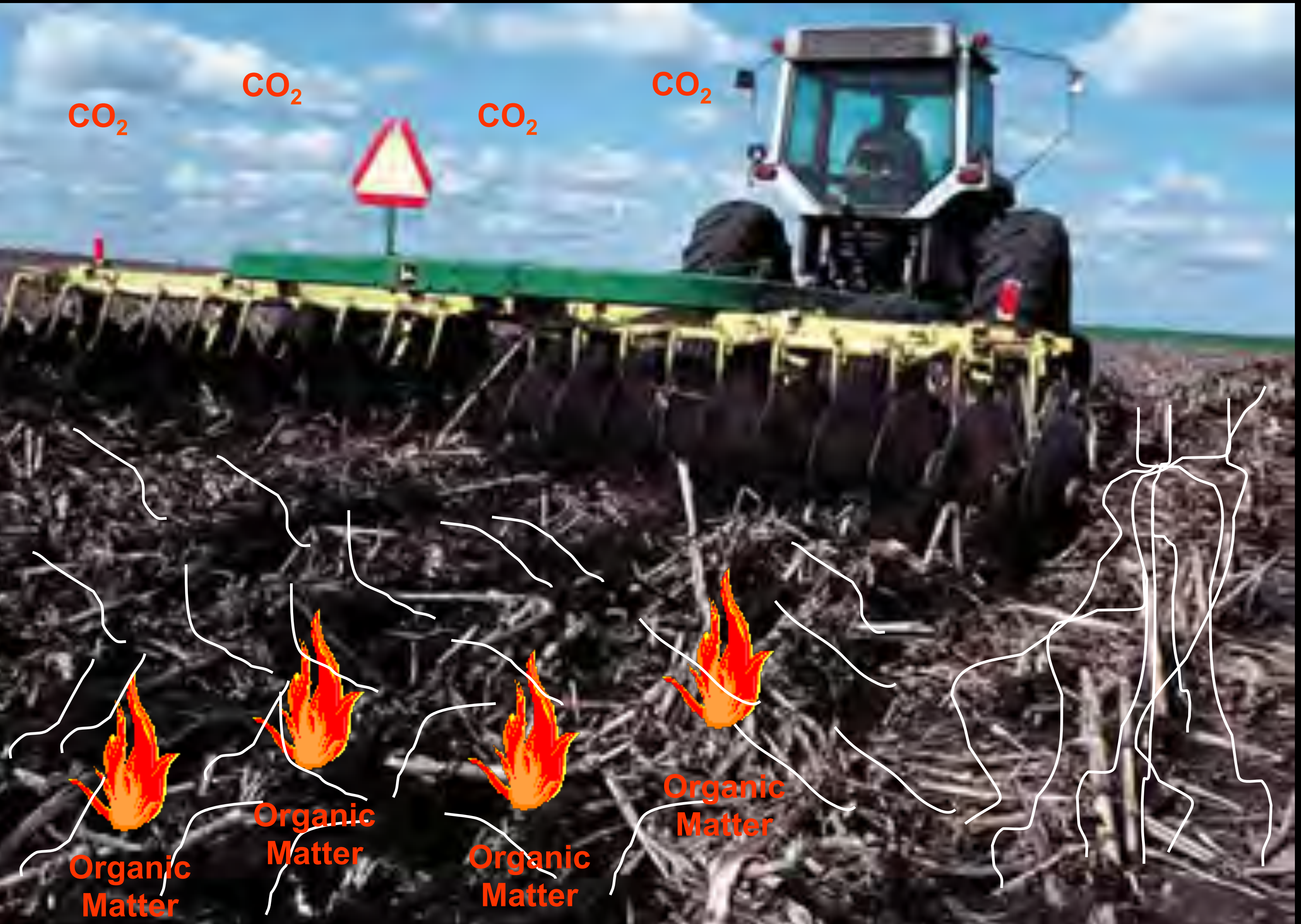
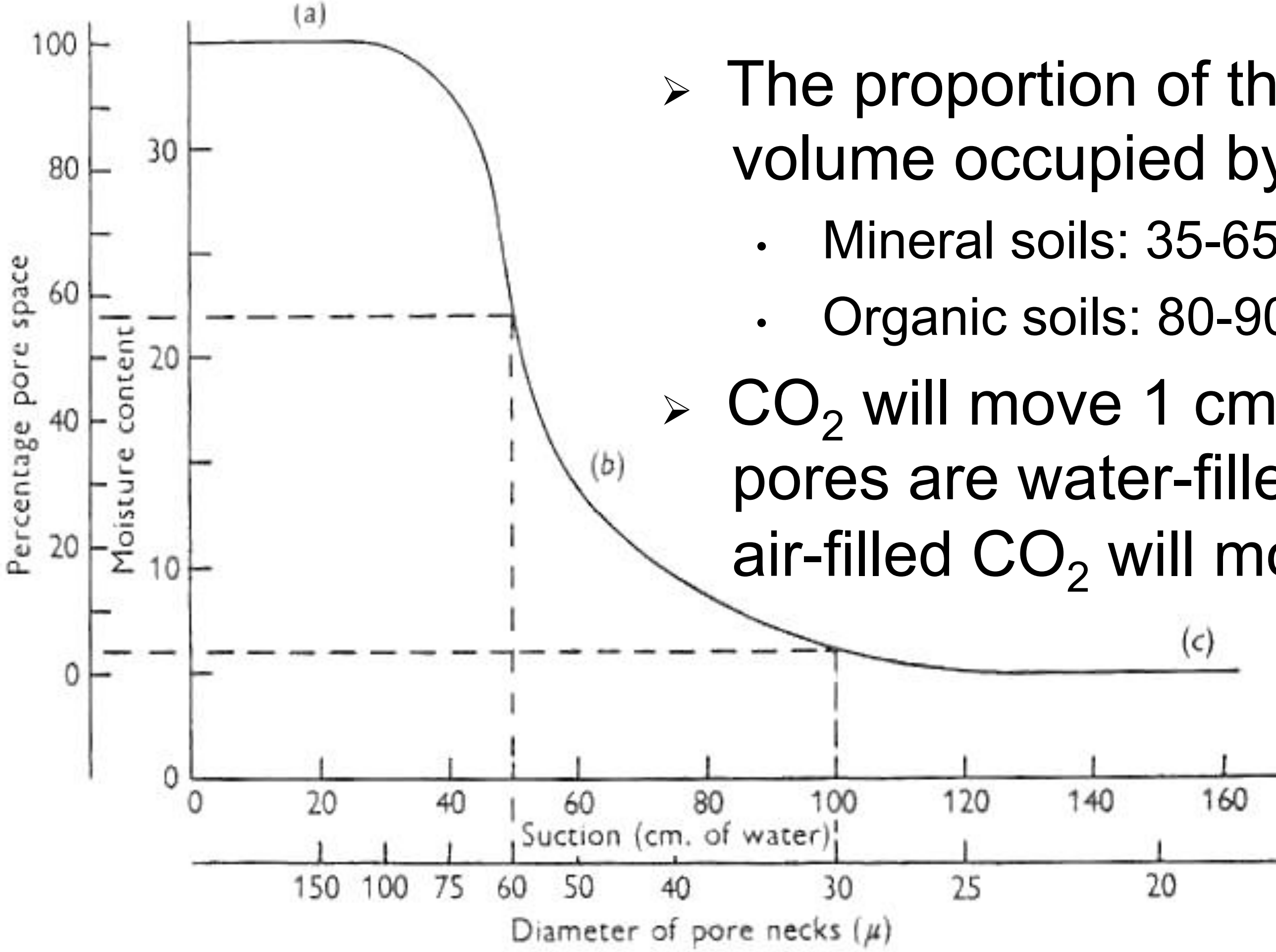
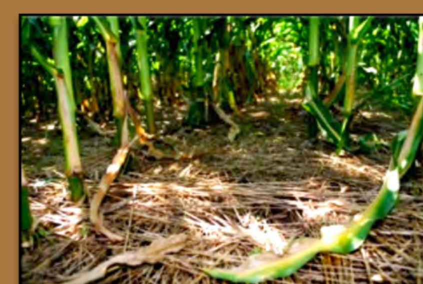


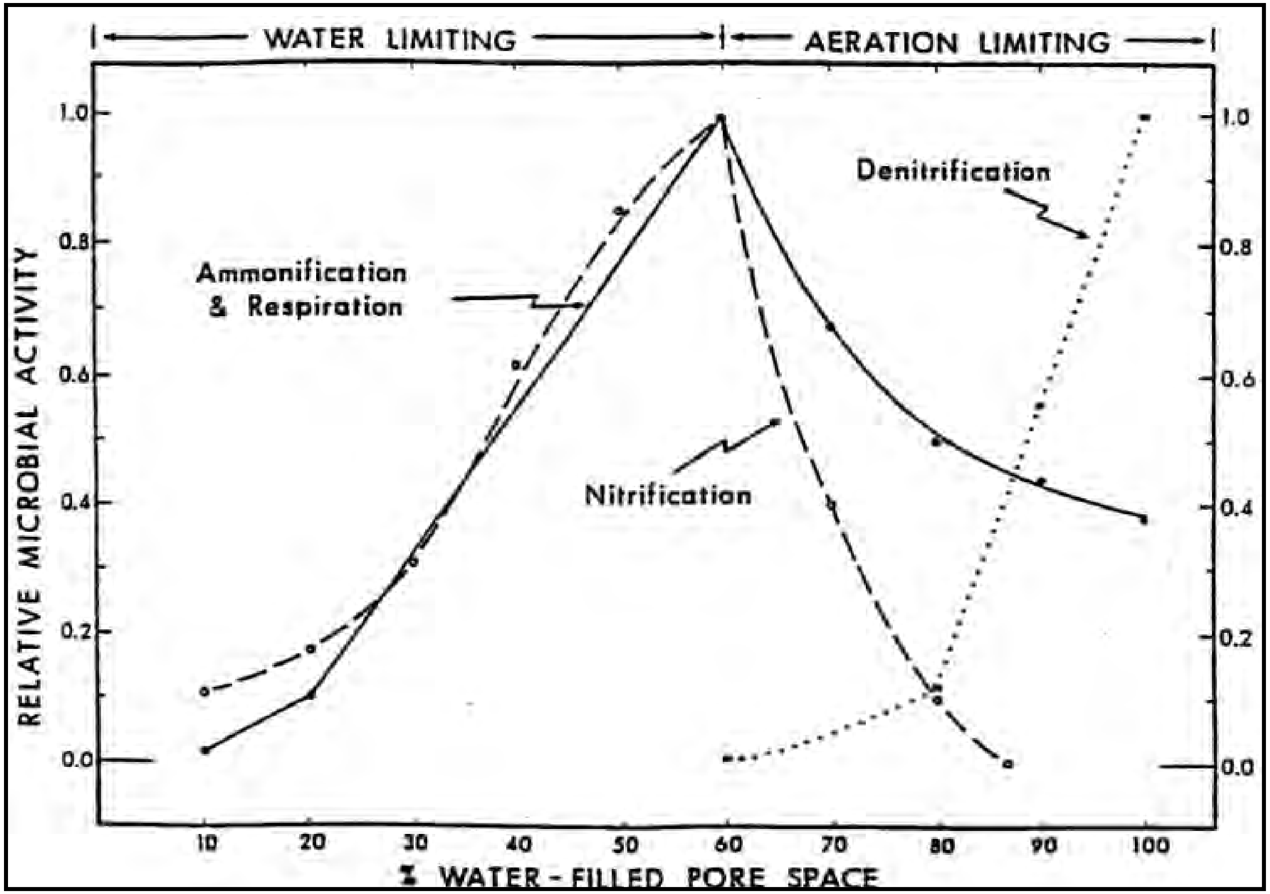

SANDSTORM LEAVING NORTH AFRICA TOWARDS THE ATLANTIC – CANARY ISLAND.
- Photo by Astronaut Sunita Williams

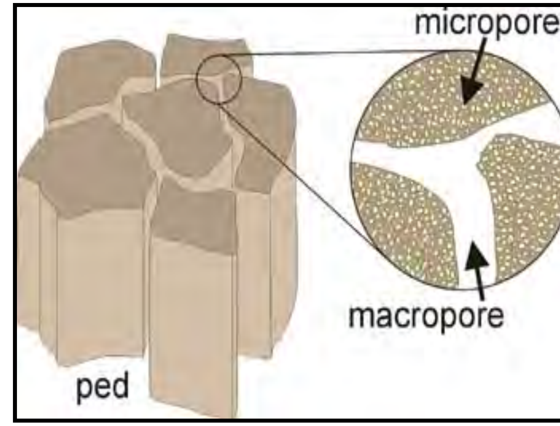

CO_2
CO_2
CO_2
CO_2
Organic Matter
Organic Matter
Organic Matter
Organic Matter



- The proportion of the total soil volume occupied by soil pores.
  - Mineral soils: 35-65%
  - Organic soils: 80-90%
- CO_2 will move 1 cm day^{-1} when pores are water-filled but when air-filled CO_2 will move 1 cm hr^{-1}







Macropores (>10 µm)

Micropores (<10 µm)

- **Linn and Doran, 1984**

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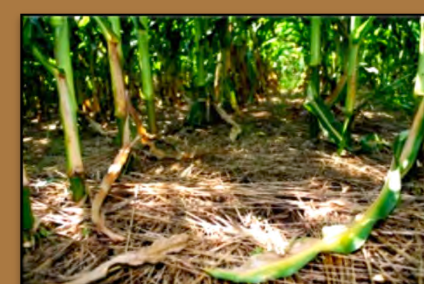

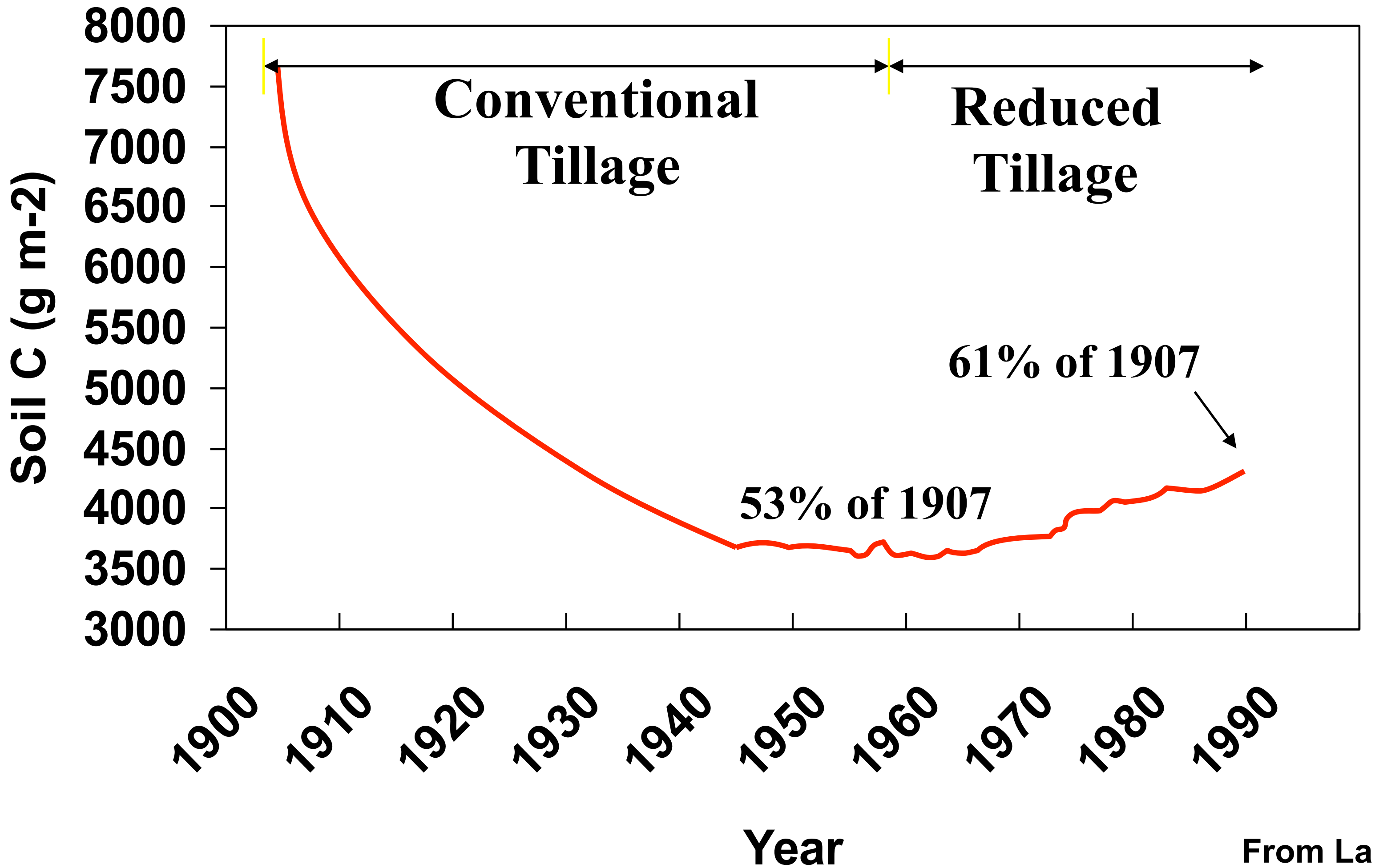

From Lal et al., 1998

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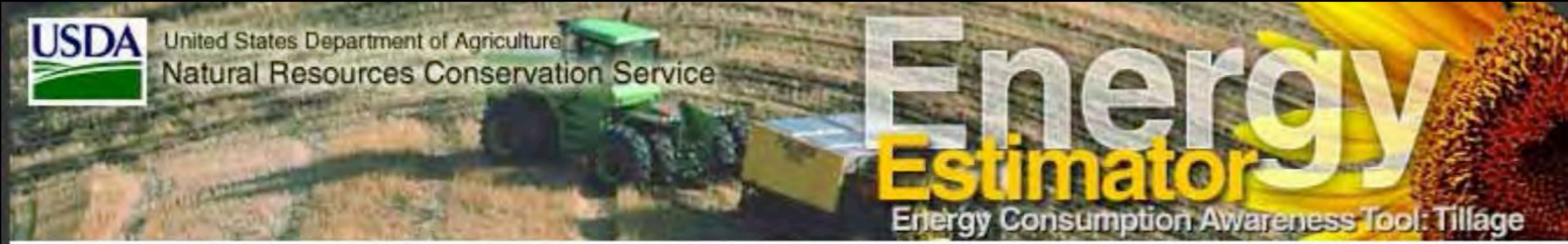
Morris, MN
2012

Glasgow, MT
11-19-13



Welcome to Energy Estimator: Tillage

Energy Estimator for Tillage is one of several tools from Natural Resources Conservation Service (NRCS) developed to increase energy awareness in agriculture. The tool estimates diesel fuel use and costs in the production of key crops in your area and compares potential energy savings between conventional tillage and alternative tillage systems. The crops covered are limited to the most prevalent crops in 78 Crop Management Zones (CMZ´s). NRCS agronomists have identified these crops and estimated typical fuel use associated with common tillage systems. Without including every crop and tillage system, the Energy Estimator gives you an idea of the magnitude of diesel fuel savings under different levels of tillage.

Step 1: ZIP code

Instructions:

1. Enter your ZIP code.
2. Click **Next** to continue.

ZIP code * :

* Required Input

Next >>

Last Modified: 11/05/2012

The Natural Resources Conservation Service (NRCS) has developed four energy tools designed to increase energy awareness in agriculture and to help farmers and ranchers identify where they can reduce their energy costs. The results generated by these tools are estimates based on NRCS models and are illustrative of the magnitude of savings. Please contact your local NRCS office for additional assistance.

Spotlights

Energy Estimator: Animal Housing

The Energy Estimator for Animal Housing tool is designed to enable you to estimate potential energy savings associated with swine, poultry or dairy cows housing operations on your farm or ranch. This tool evaluates major energy costs in lighting, ventilation and heating costs for swine and poultry. It evaluates major energy costs with lighting air circulation, milk cooling, water heating and milk harvesting costs for typical dairy. This tool does not provide site specific recommendations.

Energy Estimator: Irrigation

The Energy Estimator for Irrigation tool enables you to estimate potential energy savings associated with pumping water for irrigation. NRCS technical specialists developed this model to integrate general technical information farm-specific crops, energy prices, and pumping requirement. This tool does not provide field-specific recommendations.

Energy Estimator: Nitrogen

The Energy Estimator for Nitrogen tool enables you to calculate the potential cost-savings related to nitrogen use on your farm or ranch. NRCS agronomists developed this model to integrate general technical information on nitrogen use with farm-specific information on fertilizer types, costs, timing, and placement. This tool does not provide field-specific recommendations.

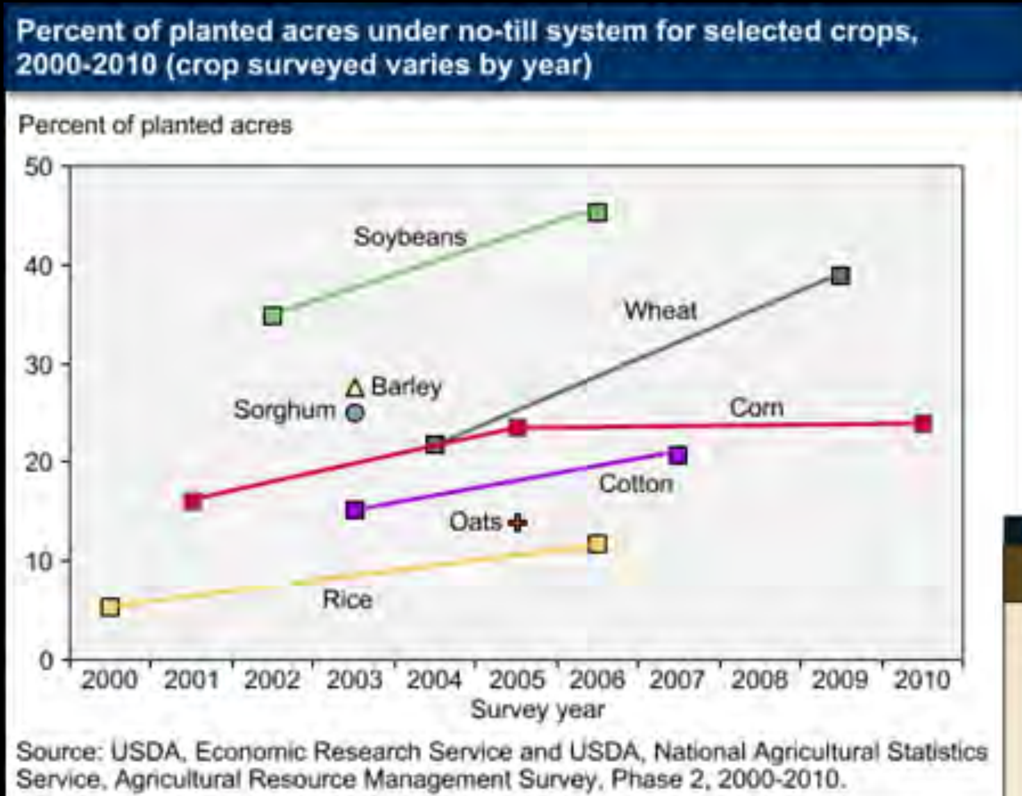
Energy Estimator: Tillage

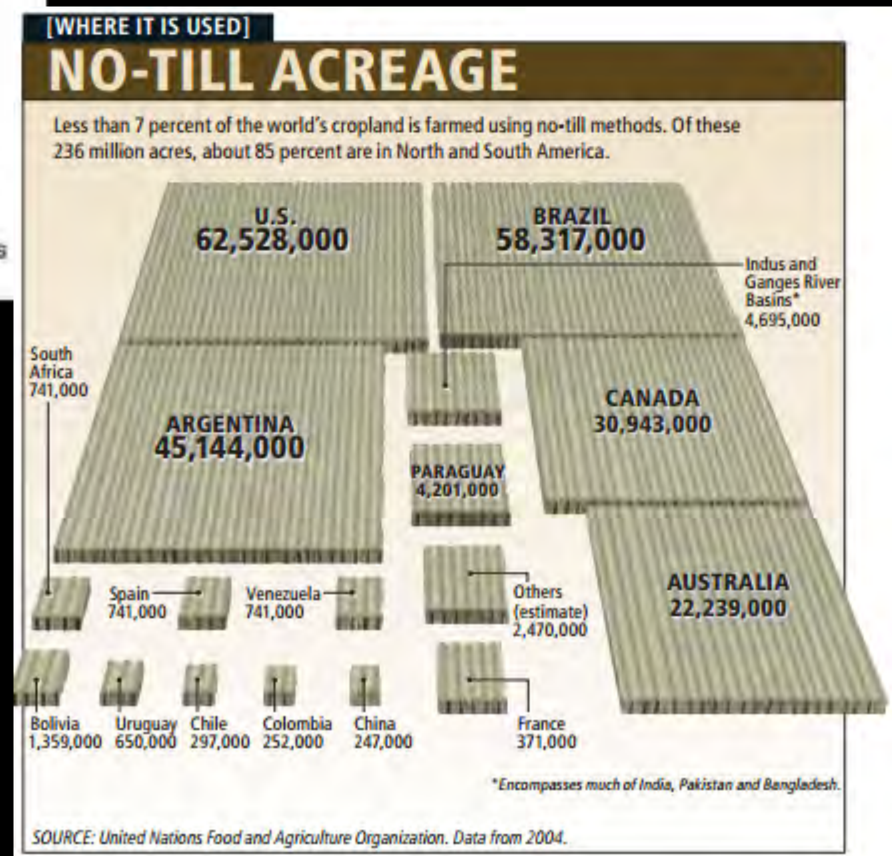
The Energy Estimator for Tillage tool estimates diesel fuel use and costs in the production of key crops in your area and compares potential energy savings between conventional tillage and alternative tillage systems. The crops covered are limited to the most predominant crops in 74 Crop Management Zones (CMZ's). NRCS agronomists have identified these crops and estimated the fuel use associated with common tillage systems. The Energy Estimator gives you an idea of the magnitude of diesel fuel savings under different levels of tillage.

NRCS Energy Tool: Tillage

Reduction in diesel fuel (gallons per acre) usage compared to Conventional Till.

	Conventional	Mulch	Ridge	No
Corn	5.40 0%	4.53 16%	4.49 17%	3.13 42%
Oats	5.19 0%	4.40 15%	NA	2.25 56%
Sorghum – grain	5.40 0%	4.53 16%	4.26 21%	3.03 44%
Soybean – wide row	5.24 0%	4.37 17%	3.46 34%	2.33 56%
Wheat – winter	5.32 0%	3.11 42%	NA	2.27 57%


Percent of planted acres under no-till system for selected crops, 2000-2010 (crop surveyed varies by year)
Percent of planted acres
50
40
30
20
10
0
Soybeans
Wheat
Barley
Sorghum
Corn
Cotton
Oats
Rice
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
Survey year
Source: USDA, Economic Research Service and USDA, National Agricultural Statistics Service, Agricultural Resource Management Survey, Phase 2, 2000-2010.


[WHERE IT IS USED]
NO-TILL ACREAGE
Less than 7 percent of the world's cropland is farmed using no-till methods. Of these 236 million acres, about 85 percent are in North and South America.
U.S. 62,528,000
BRAZIL 58,317,000
Indus and Ganges River Basins* 4,695,000
South Africa 741,000
ARGENTINA 45,144,000
CANADA 30,943,000
PARAGUAY 4,201,000
AUSTRALIA 22,239,000
Spain 741,000
Venezuela 741,000
Others (estimate) 2,470,000
Bolivia 1,359,000
Uruguay 650,000
Chile 297,000
Colombia 252,000
China 247,000
France 371,000
*Encompasses much of India, Pakistan and Bangladesh.
SOURCE: United Nations Food and Agriculture Organization. Data from 2004.

Canby, MN
2007

Jamestown, ND
June 16, 2013

Water Use Efficiency

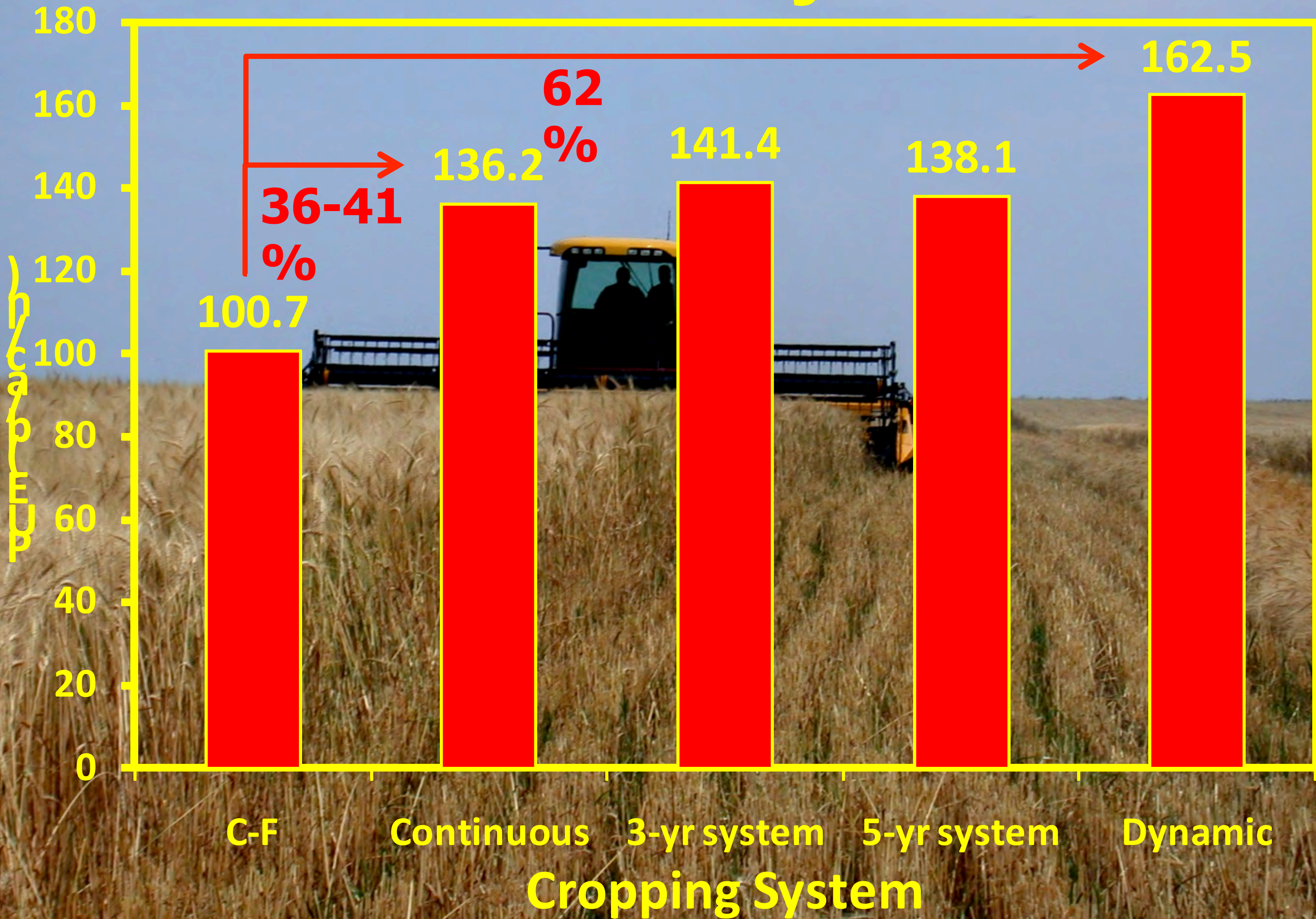
- 45% greater porosity increases infiltration rate by 167% for the first inch and 650% for the second inch - Karlen et al., 1998

- The Drought Myth - a case of plant hunger rather than thirst - unfertilized corn required 26,000 gallons of water per bushel yielded 4X less than a fertilized field receiving only 5,600 gallons of water per bushel. – W.A. Albrecht, University of Missouri, 1930-1974

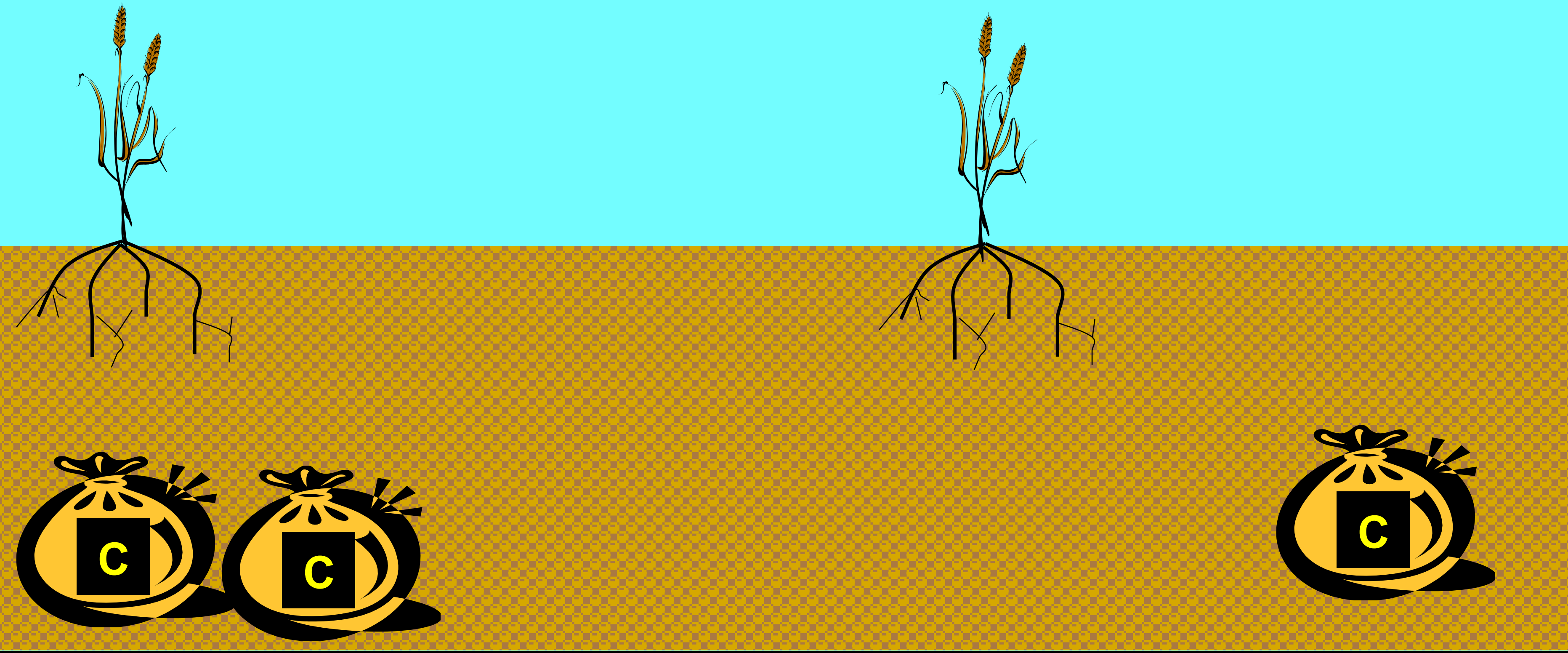
- Seven-way cover crop mix yield almost 3 times higher than of single crop on 7 in of soil moisture. Field with manure and no commercial fertilizer yielded the same as a fertilized field and plant tissues tested sufficient or high for N, P, K, and S – North Dakota, 2006

Plants use 180 to 900 kg (400 to 2000 lbs) of water for every kg (2.2 lbs) of dry matter. In a fertile soil in a moist climate where growing conditions are good, the amount of water needed is much less than in a poor soil. Approximately 5 million liters of water will transpire from a hectare of corn during one growing season.

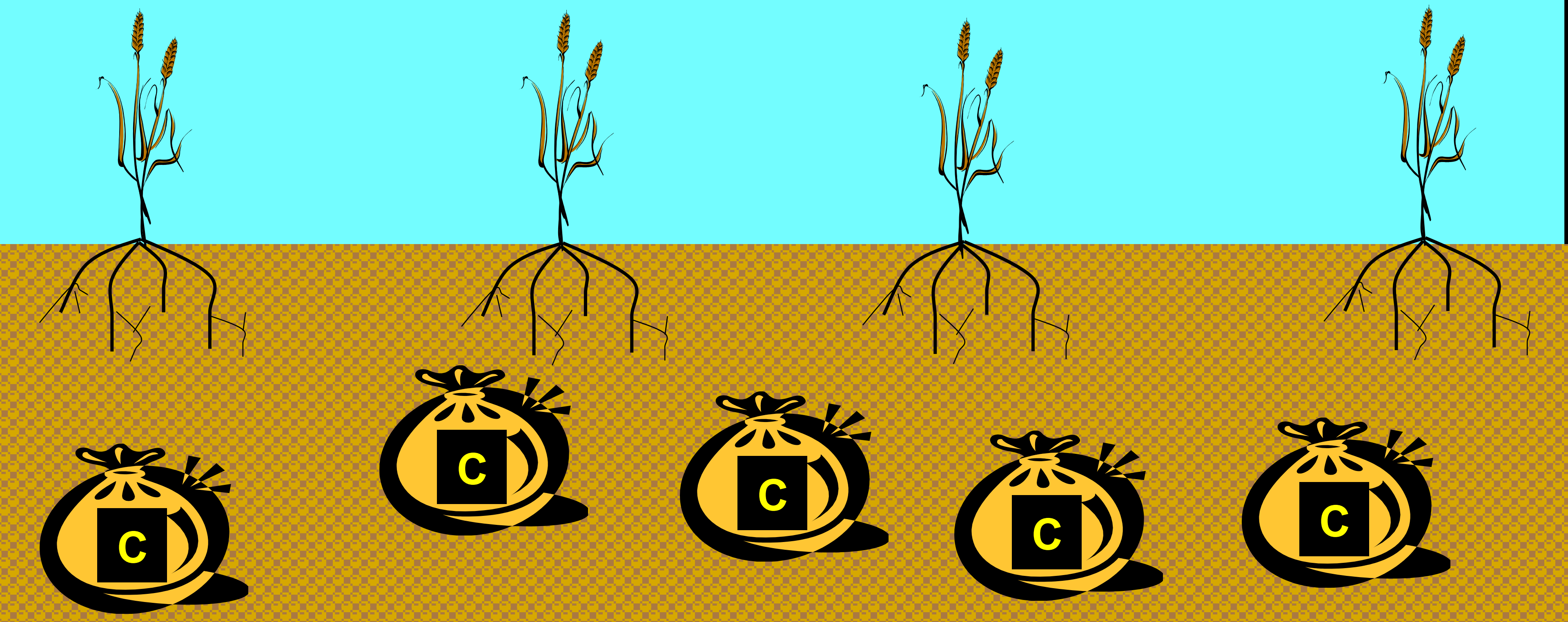
PUE of each system



Wheat - Fallow



Continuous Wheat



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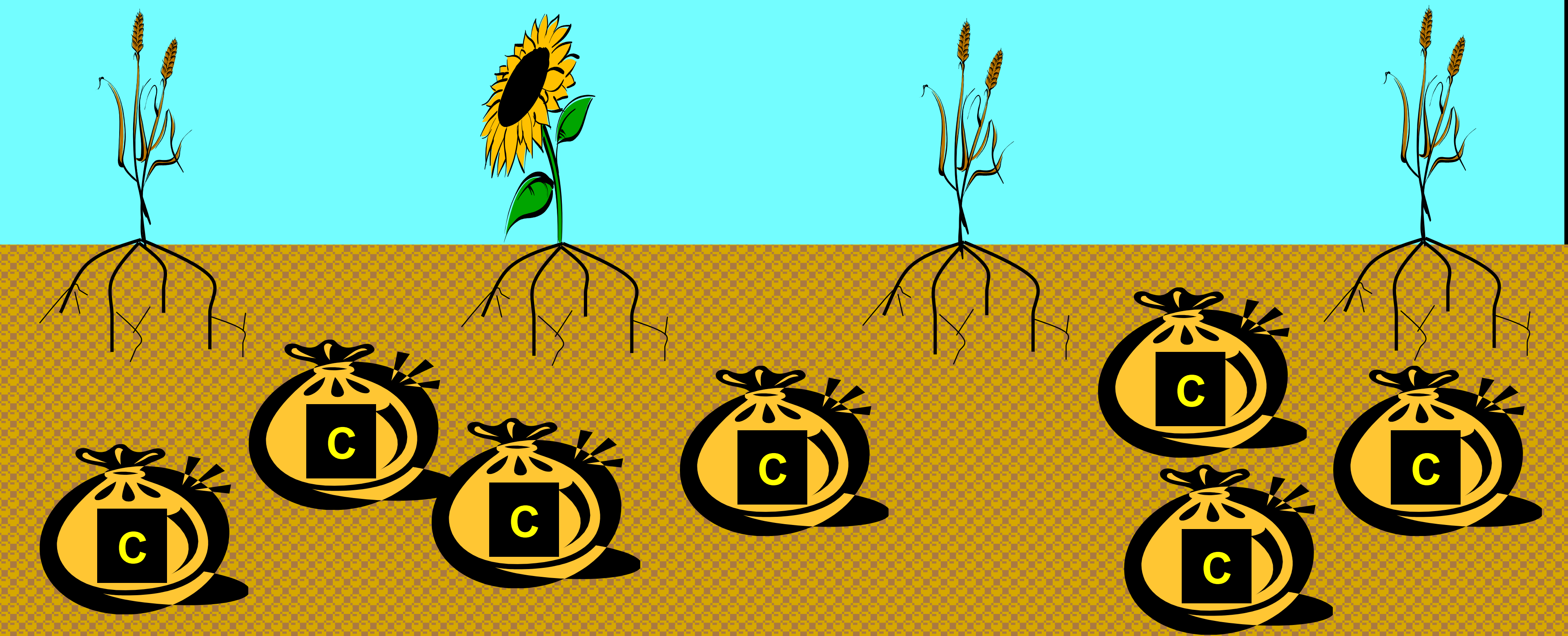
Minimum Diversity



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Maximum Diversity

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Maximum Diversity with Cover Crops
How can you not grow a cover crop during a drought?

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Long-term Cropping System Study

USDA-ARS, Mandan, ND, 1983-1996

Results for 0-6” depth

	ton C ac^{-1} yr^{-1}		
Cropping System	**CT**	**MT**	**NT**
SW-F	**- 0.12**	**- 0.07**	**-0.14**
SW-WW-SF	**- 0.06**	**0.01**	**0.10**

From Halvorson et al. (2002)

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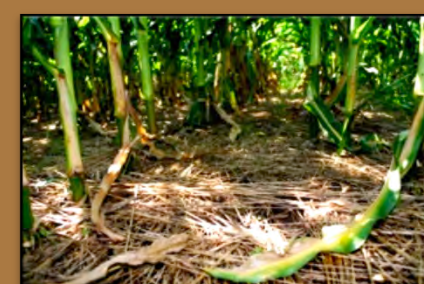
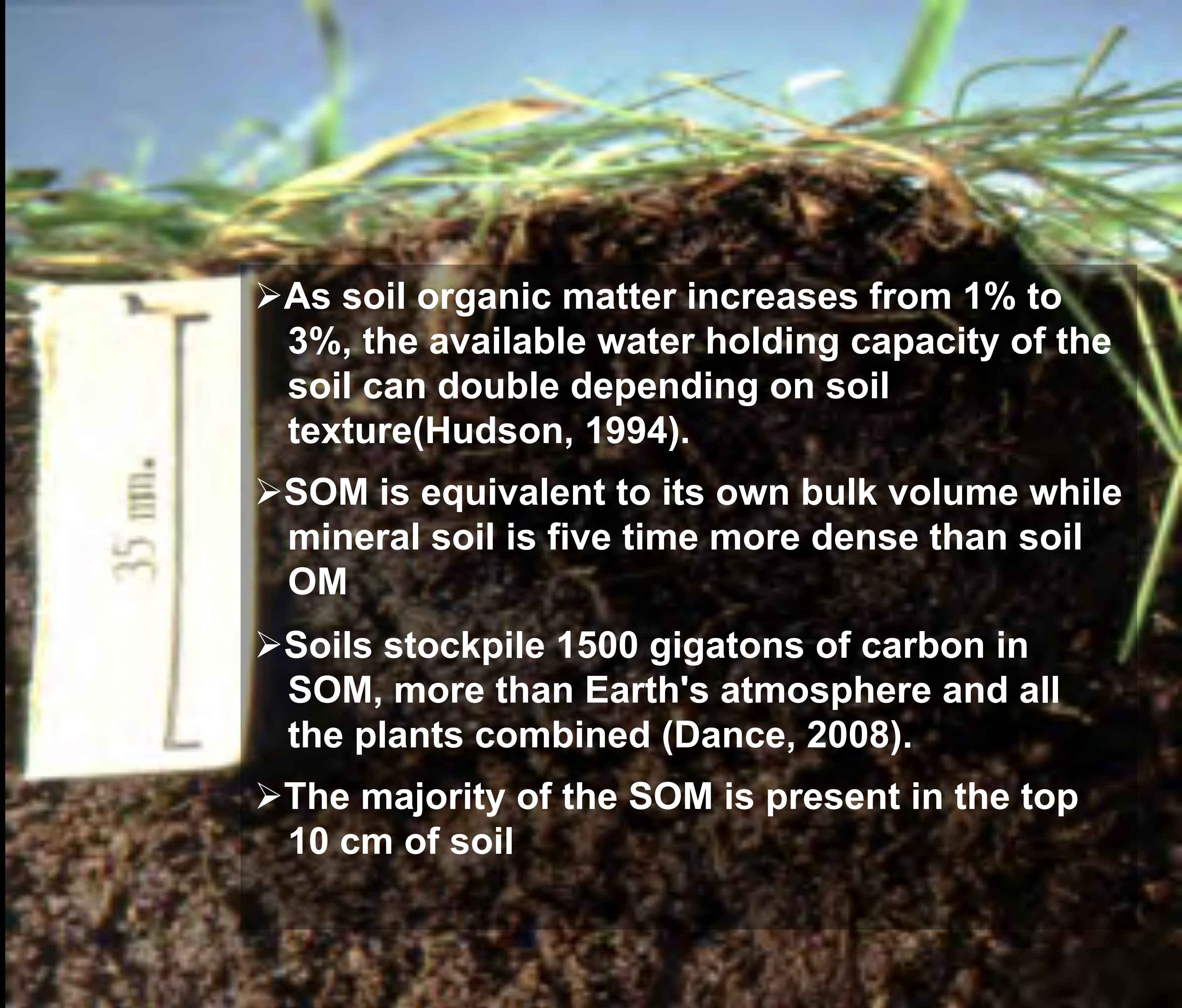


- ➢Soil organic matter (SOM) is <6% of soil by weight but controls >90% of the function
- ➢SOM is mostly negatively charged, but binds both cations and anions

Figure 2. Components that relate to nutrient availability in the soil-rhizosphere system



- As soil organic matter increases from 1% to 3%, the available water holding capacity of the soil can double depending on soil texture(Hudson, 1994).
- SOM is equivalent to its own bulk volume while mineral soil is five time more dense than soil OM
- Soils stockpile 1500 gigatons of carbon in SOM, more than Earth's atmosphere and all the plants combined (Dance, 2008).
- The majority of the SOM is present in the top 10 cm of soil

Plant Diversity = Food Diversity

Crop	C:N Ratio
Cereals	80:1 – 100:1
Corn	60:1
Peas	25:1 – 30:1
Soil OM	10:1 – 12:1

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- Hartman - 1999

- **Treasure**
  - Erosion control
  - Nutrients
  - Organic matter and soil quality
  - Soil moisture conservation
  - Weed control
- **Trash**
  - Seeding issues
  - Crop issues

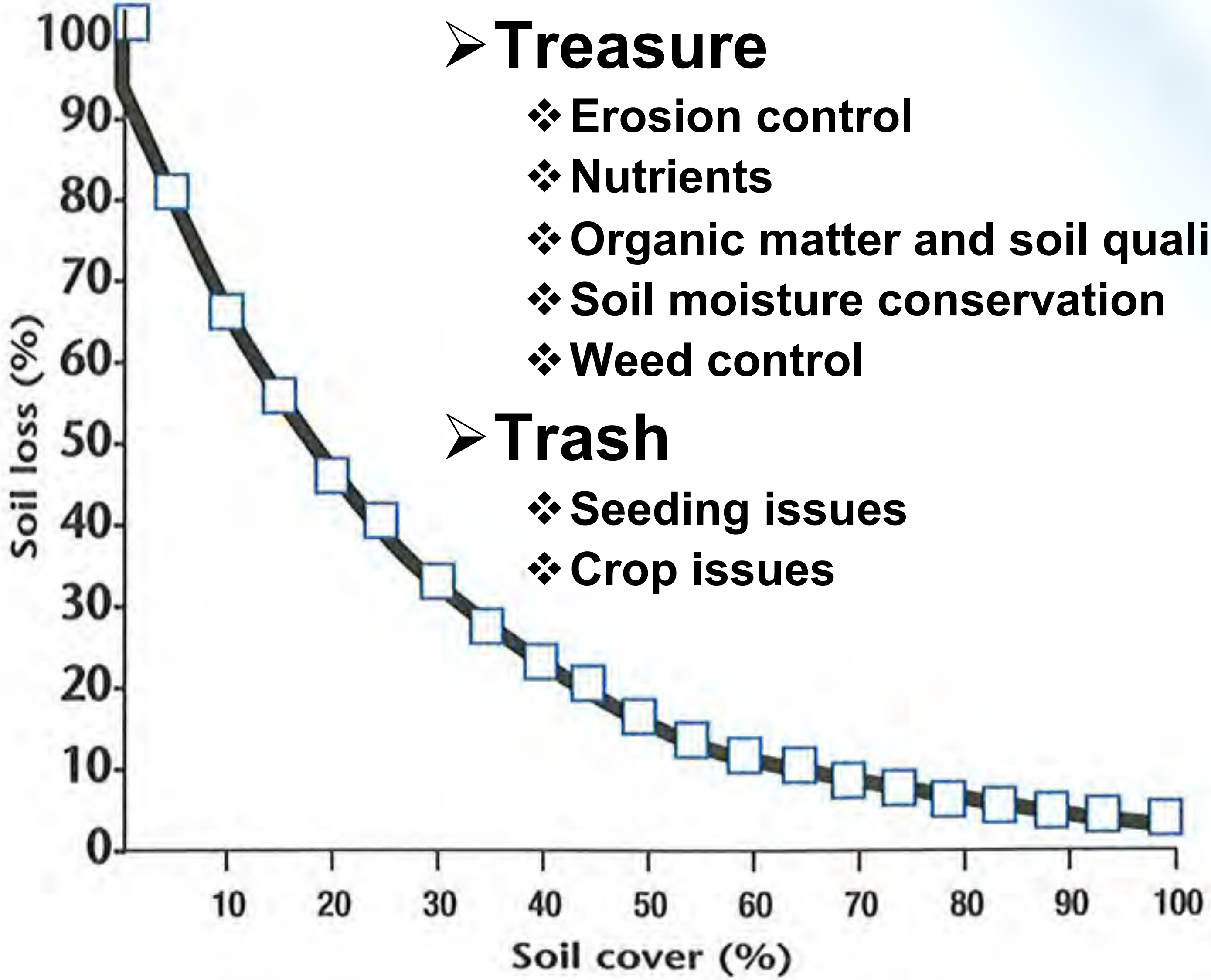
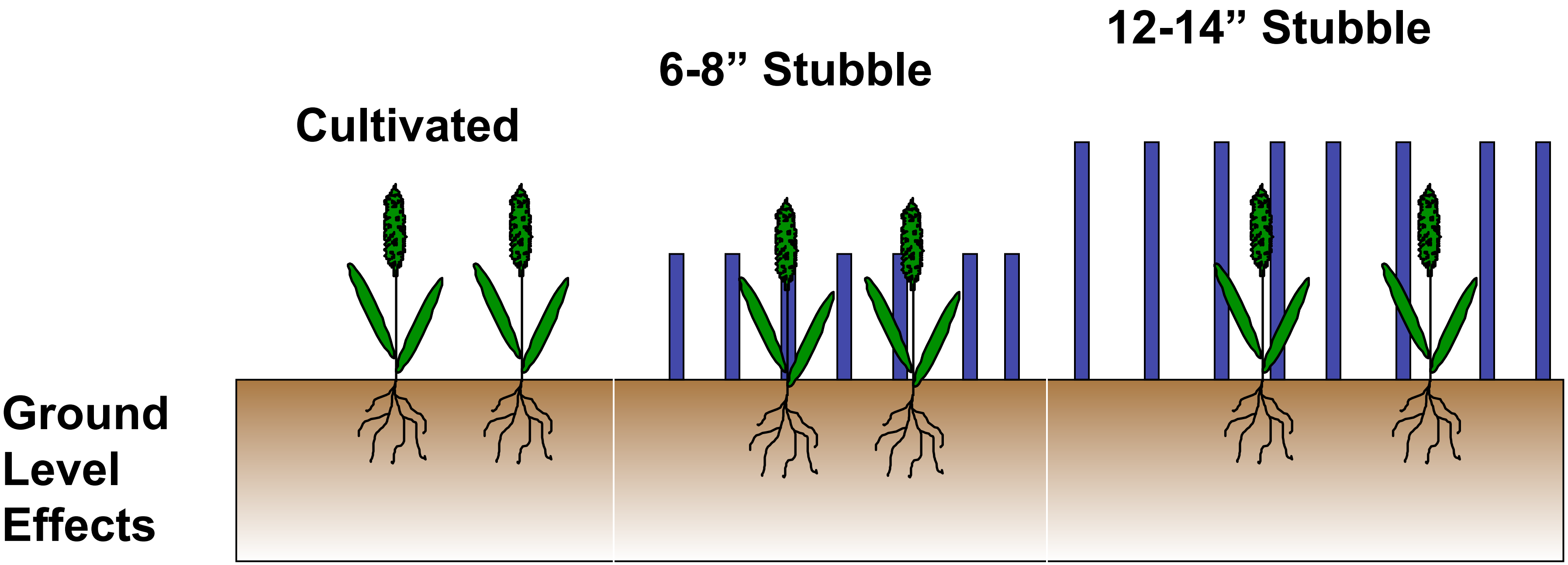


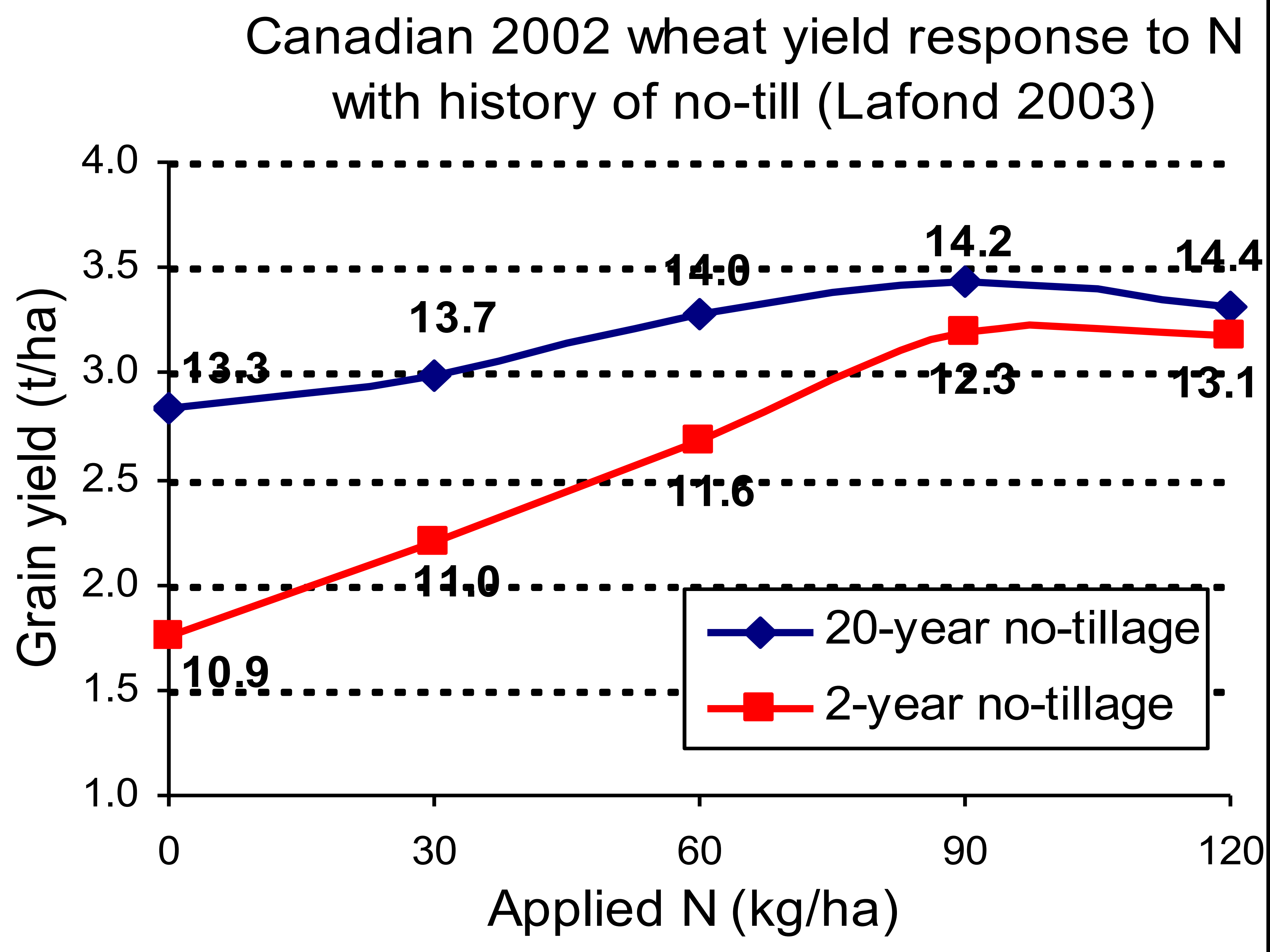
FIGURE 6. Residue cover – relative soil loss relationship. With 30% residue cover, soil loss is reduced 70%.

No Till and Residue Management Combine to Produce Stubble which Impacts Evaporation

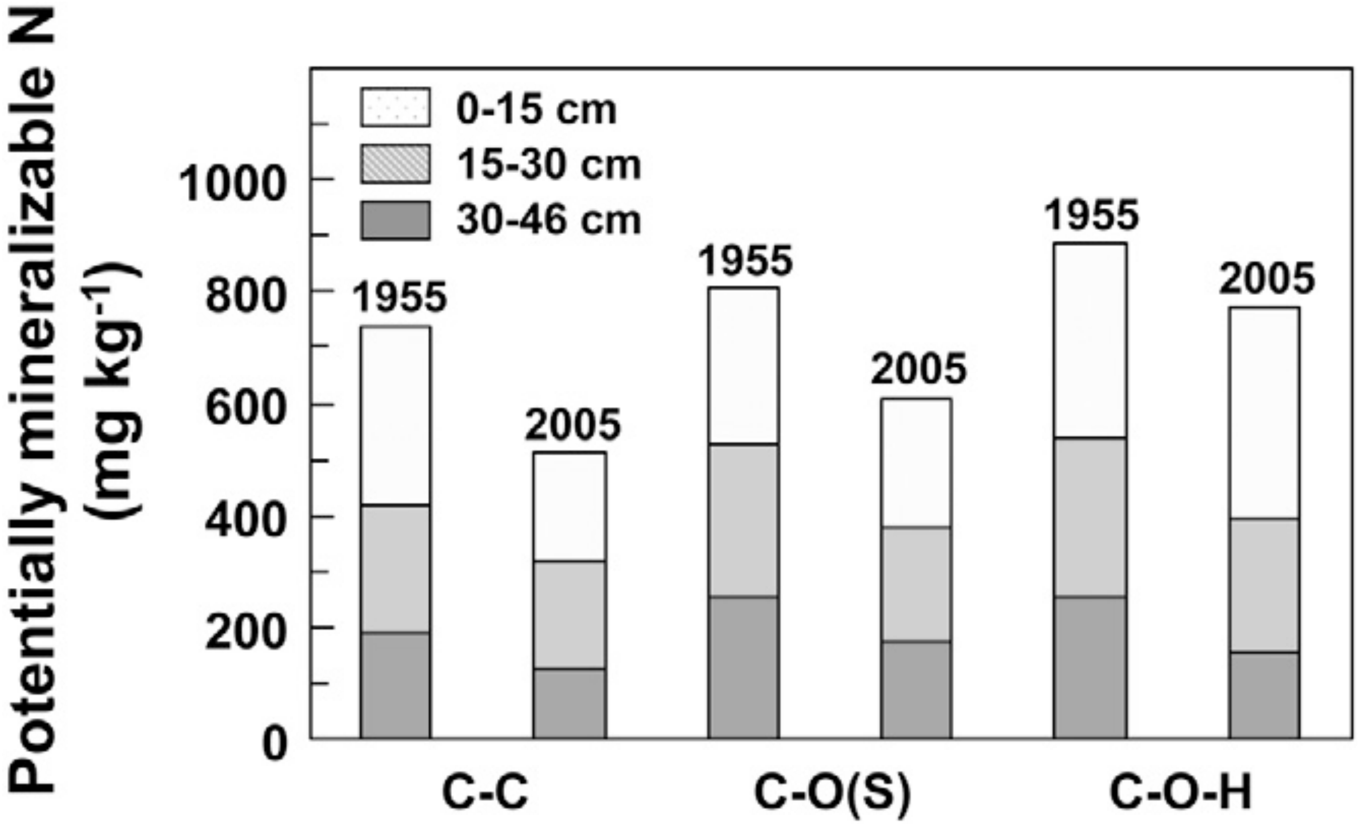


	Cultivated	6-8" Stubble	12-14" Stubble
Wind:	100%	85%	32%
Evap. Demand:	100%	95%	70%

- Cutforth and McConkey, 1995



Canadian 2002 wheat yield response to N
with history of no-till (Lafond 2003)
Grain yield (t/ha)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
30
60
90
120
Applied N (kg/ha)
13.3
13.7
14.0
14.2
14.4
10.9
11.0
11.6
12.3
13.1
20-year no-tillage
2-year no-tillage



- Mulvaney et al., 2009

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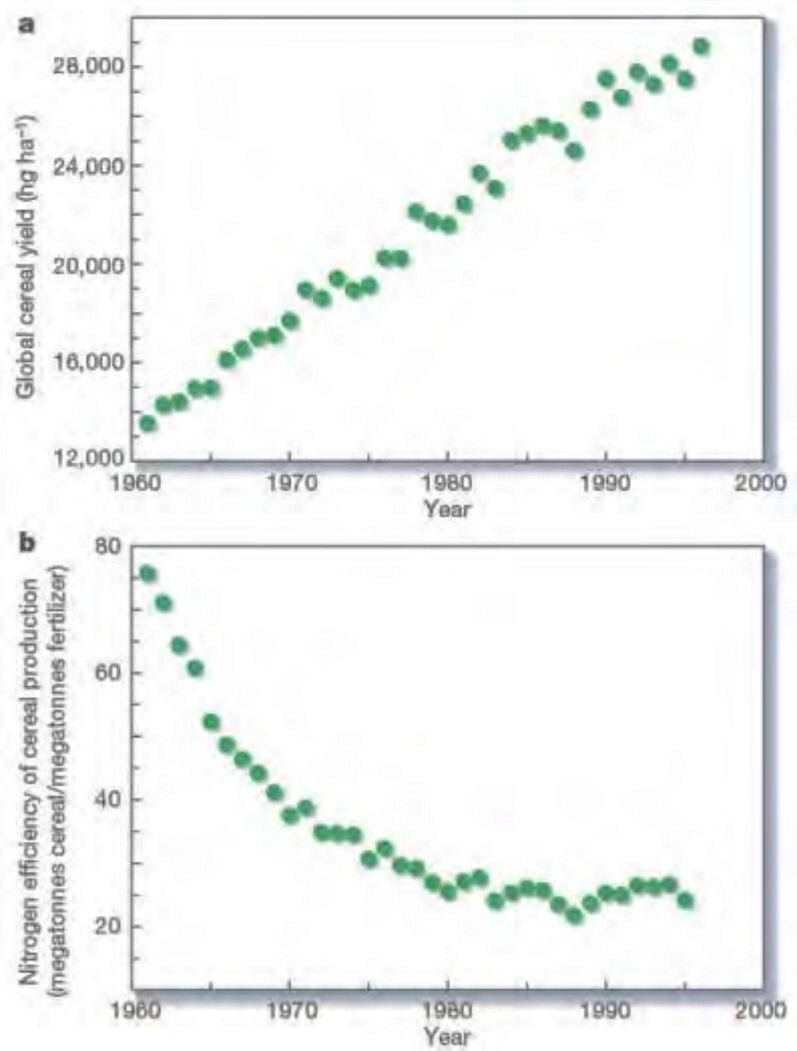
Nutrient Use Efficiency

- ➢Plant available – synthetic vs. biologic
- ➢30-50% of nitrogen fertilizer is used by the plant
- ➢30% of phosphorus is used by the plant
- ➢Fertility and water
- ➢Availability, timing, water, and pH



- Tilman et al., 2002

Resource-intensive food production systems vs. biological systems.

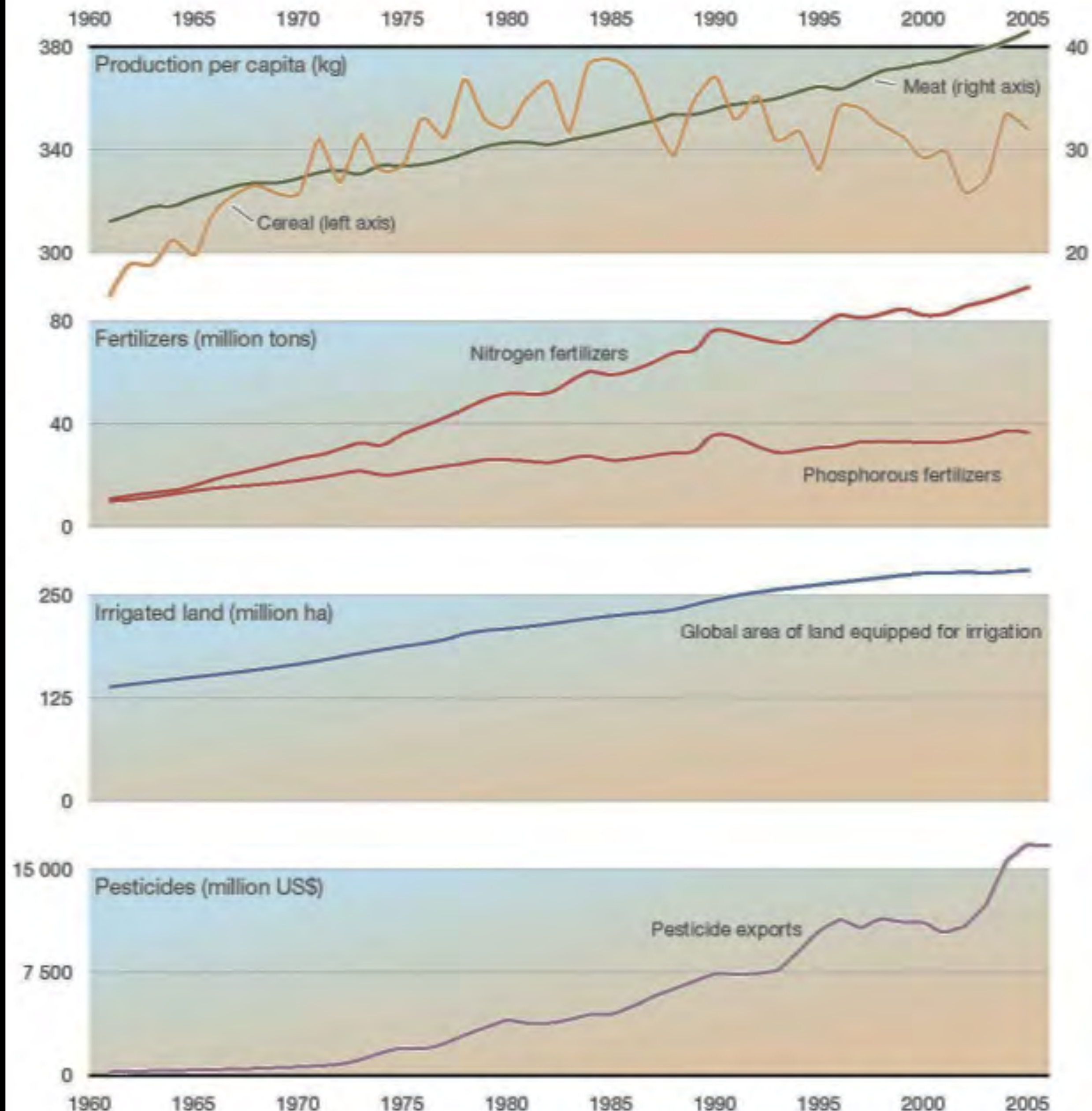
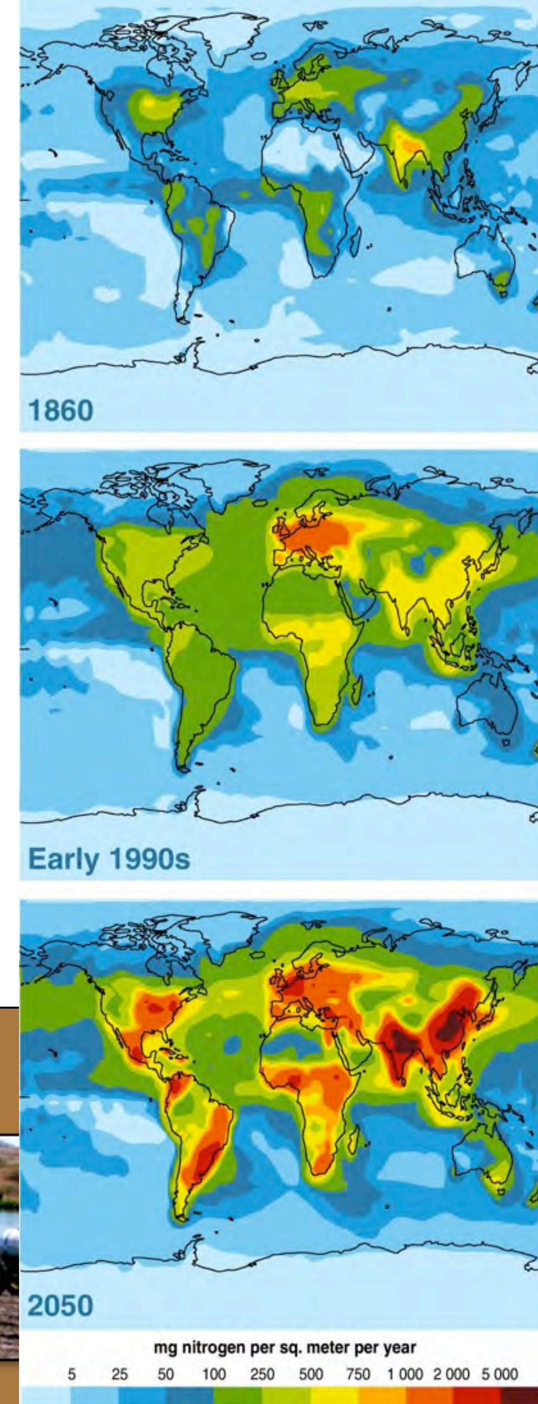


Figure 8: Global trends (1960–2005) in cereal and meat production, use of fertilizer, irrigation and pesticides. (Source: Tilman, 2002; FAO, 2003; International Fertilizer Association, 2008; FAOSTAT, 2009).

Nutrient loading

- Humans have doubled N and may increase by 2/3 by 2050
- Eutrophication leads to changes in plant community composition and loss of grassland species diversity, hypoxia in aquatic systems, and increased levels of NO3 in drinking water
- Microbes control the chemical form of N through various N transformations:.
  - NH4+, which readily binds to soil surfaces, NO3– of nitrification, carried out by bacteria, and is very prone to being lost from soil because of its negative charge.
  - NO3 is the precursor of denitrification, and its availability strongly controls denitrification rates, causing N loss from soil as N2 O and N2 semi-arid and forest soils, fuelled by mineralization of proteins.
  - Finally, microbes control soil N availability through their ability to immobilize N; fungi are a stronger sink for N than are bacteria.



Source: Galloway et al. 2004

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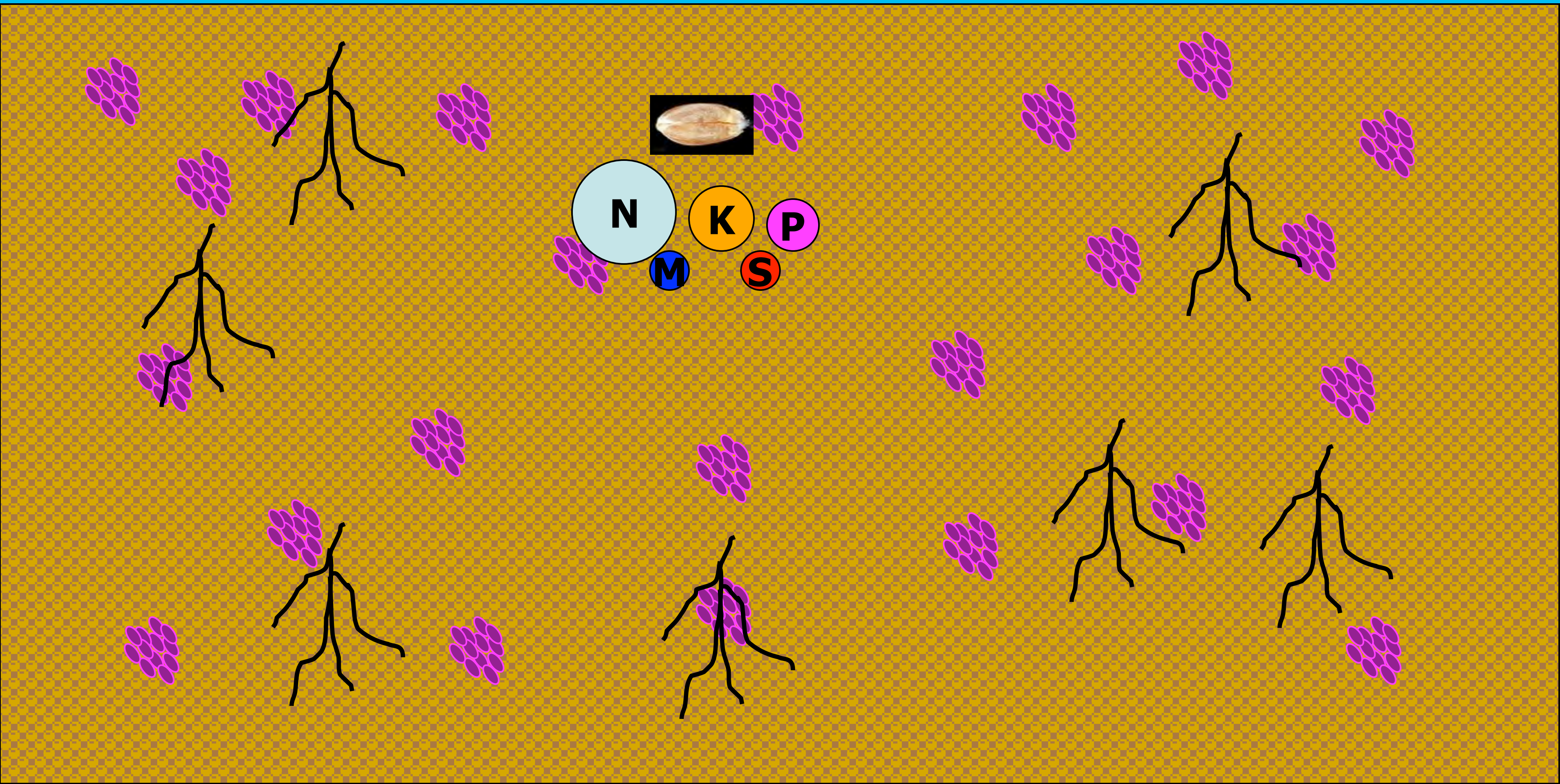
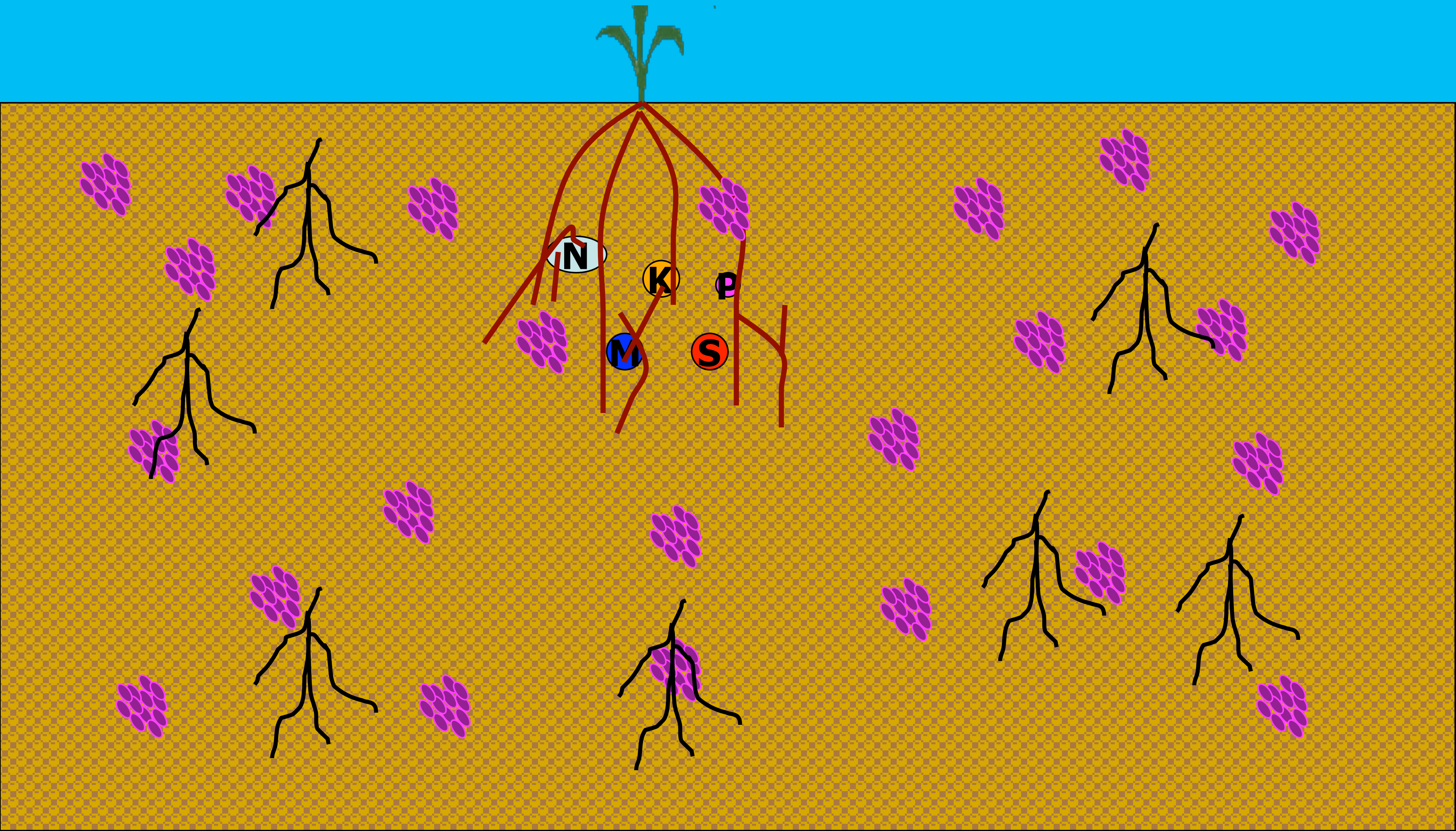
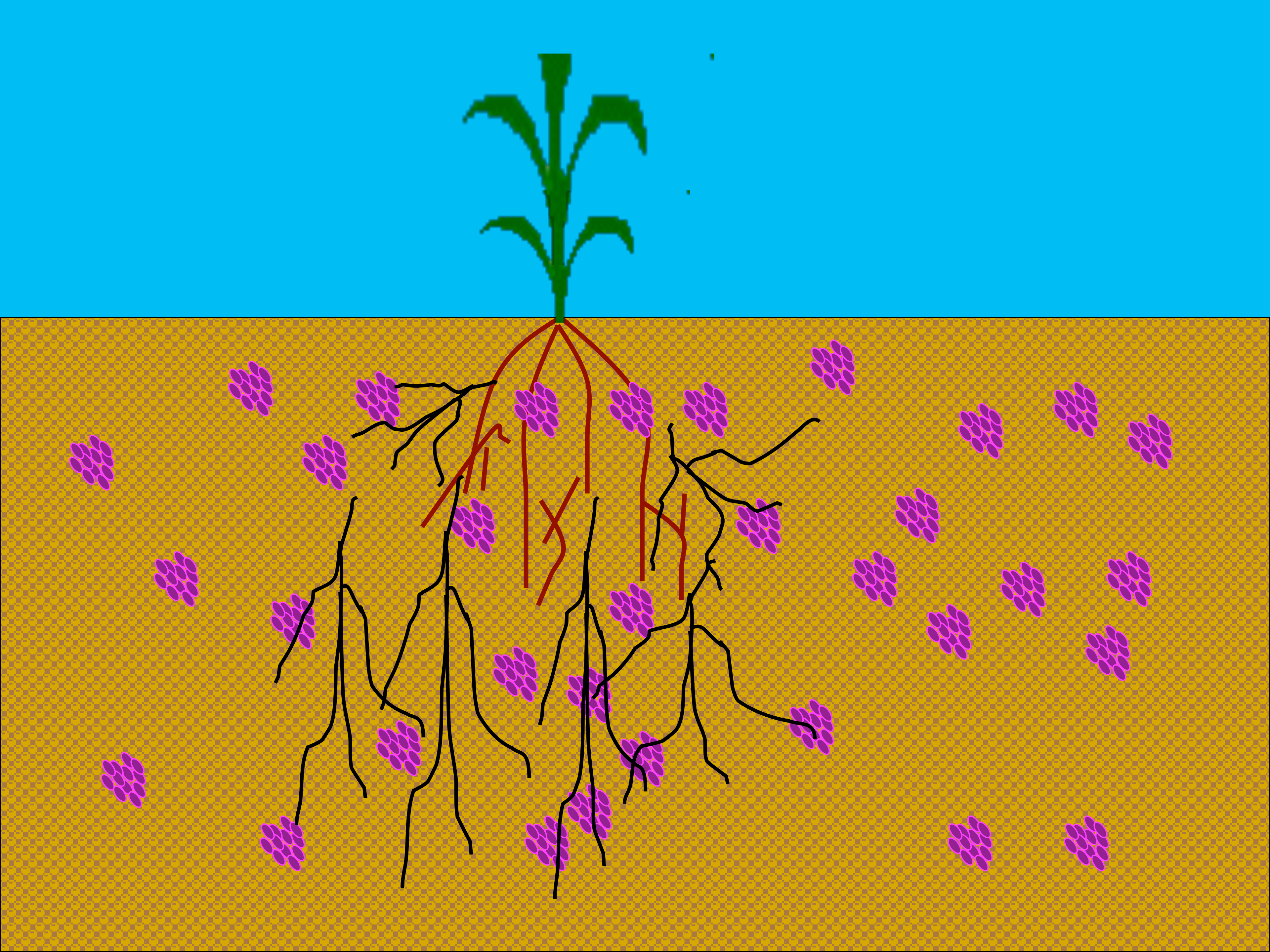
Seeding and Fertilizing

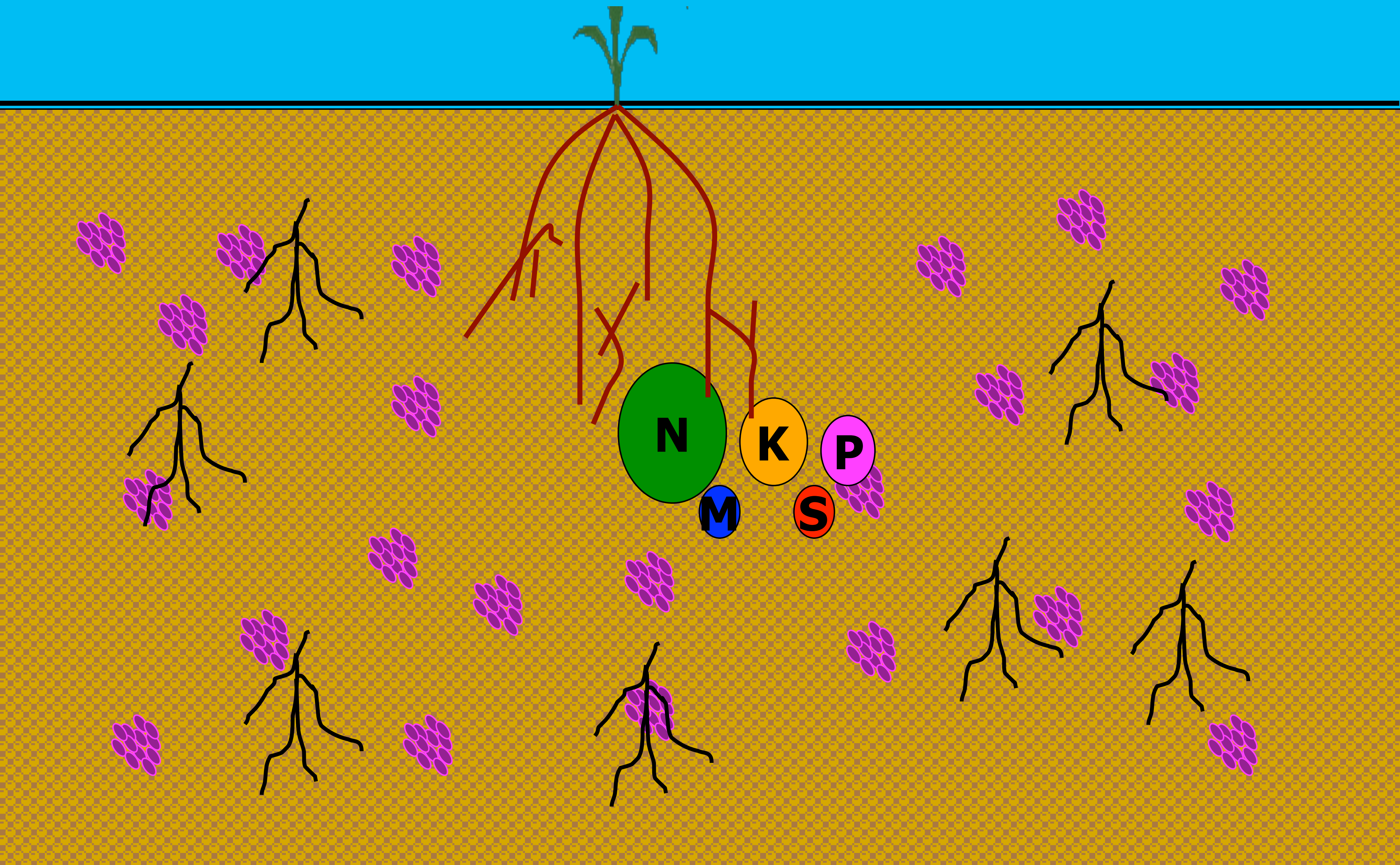


Seedling Germinates and Starts Consuming Nutrients

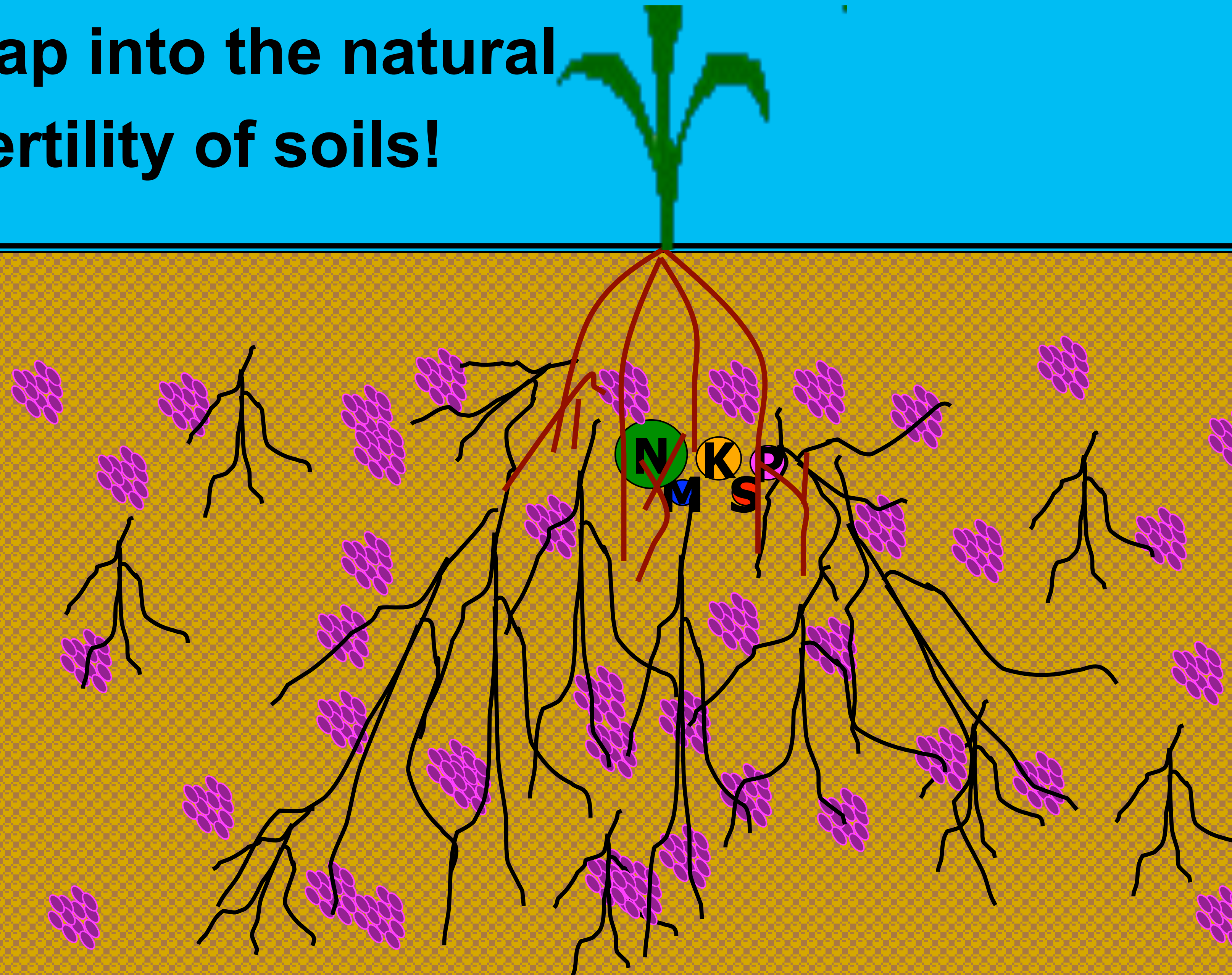




Big Buffet Dries the Microbes Away.



Tap into the natural fertility of soils!

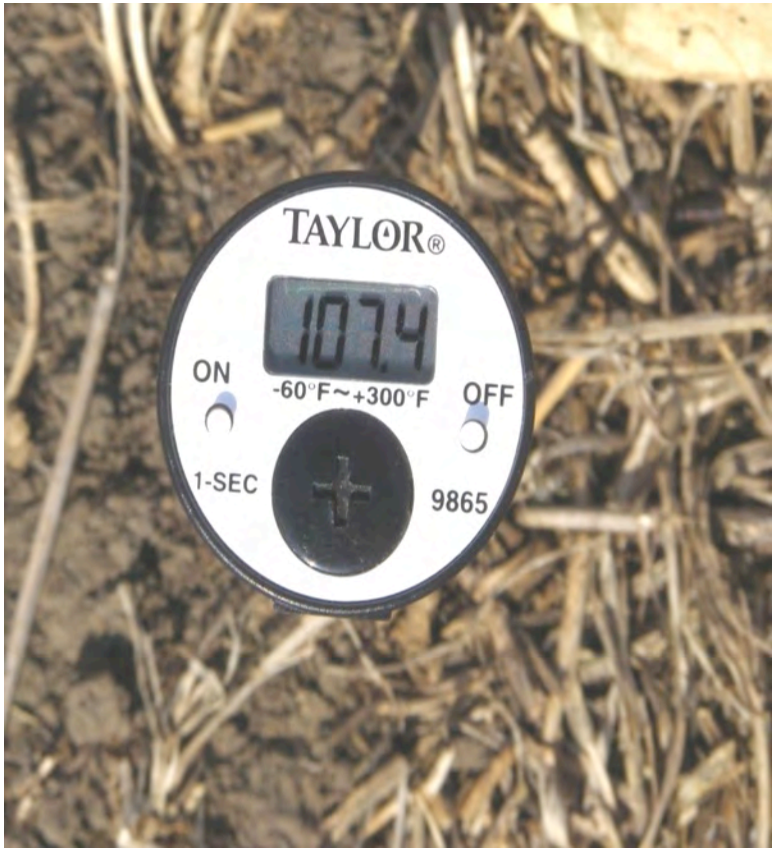


Cover Crop Enhancement
Burleigh County SCD Demo Farm, 2006

Cocktail

Cocktail

Radish



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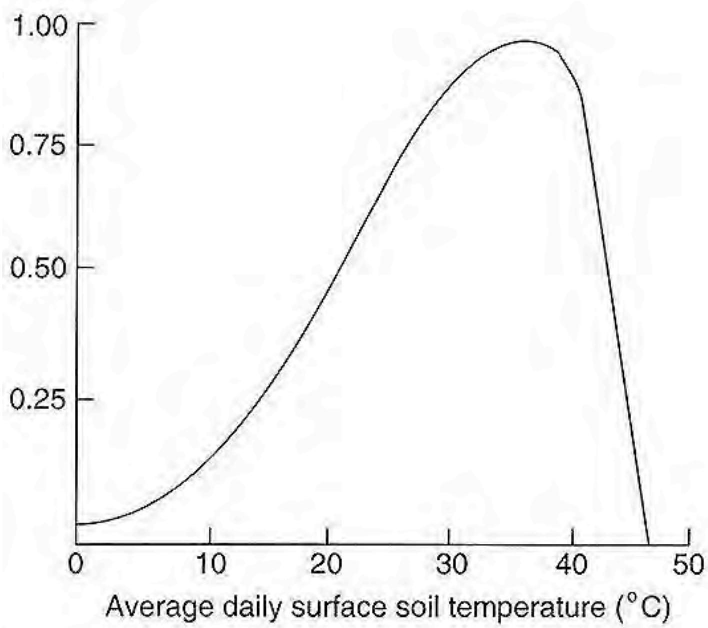
Soil Temperature

- Soil microorganisms possess three cardinal temperatures:
  - Minimum
  - Optimum
    - 28-45°C (about 80-110°F)
  - Maximum
    - 40-48°C (100-115°F)

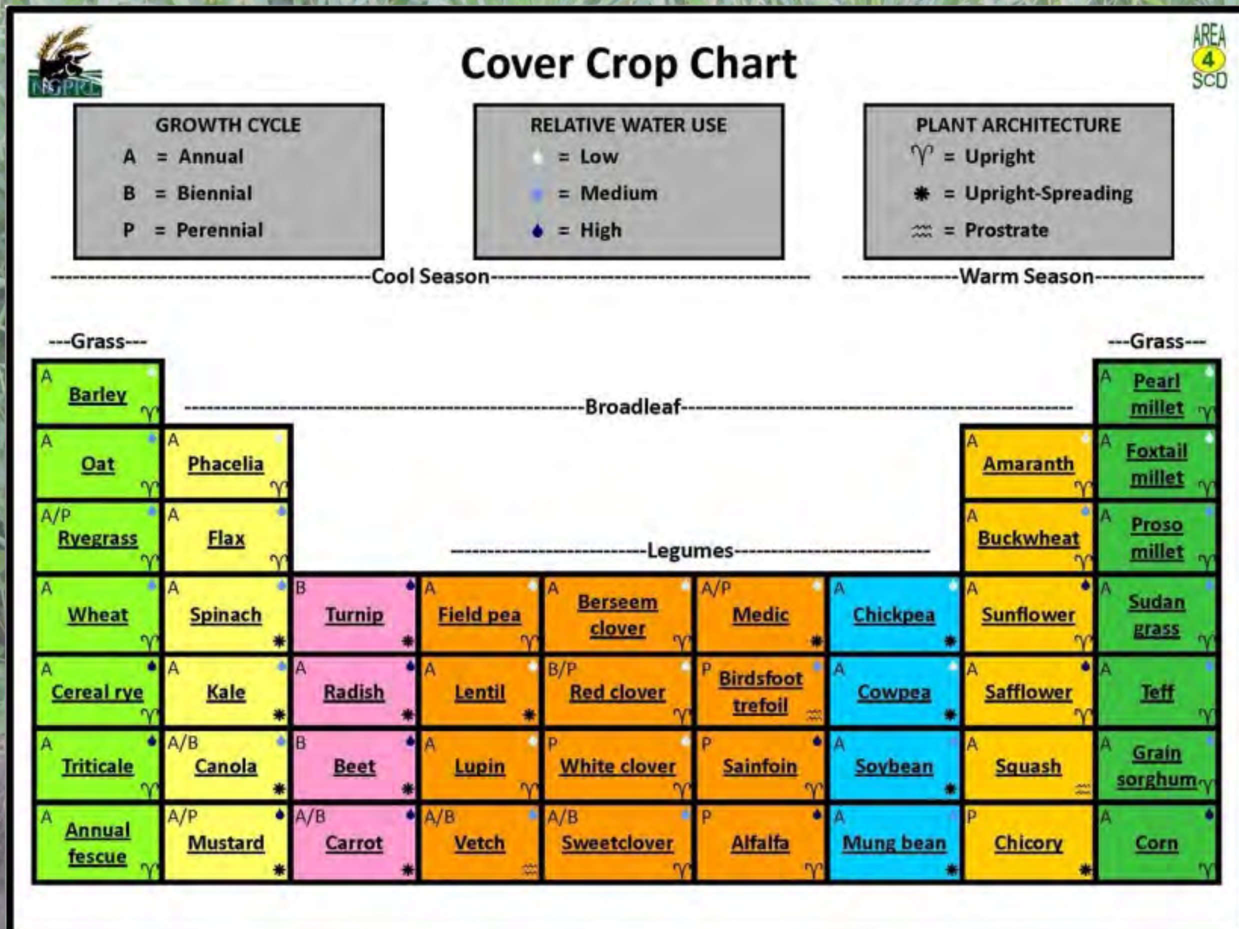


Corn with white clover, pantain, turnip, crimson clover, cosmos, and marigold planted May 7, 2011 with 2.25” rain on it .
- Gail Fuller Emporia, KS

Same field, one week later with air temps above100ºF daily.

Cover Crop Outreach Tool

www.mandan.ars.usda.gov



USDA-ARS, Northern Great Plains Research Laboratory

Cover Crop Chart

GROWTH CYCLE	RELATIVE WATER USE	PLANT ARCHITECTURE
A = Annual	(light drop) = Low	♈ = Upright
B = Biennial	(medium drop) = Medium	✱ = Upright-Spreading
P = Perennial	(dark drop) = High	(wavy lines) = Prostrate

Season	Group	Crop	Growth cycle	Relative water use	Plant architecture
Cool Season	Grass	Barley	A	Low	Upright
Cool Season	Grass	Oat	A	Medium	Upright
Cool Season	Grass	Ryegrass	A/P	Medium	Upright
Cool Season	Grass	Wheat	A	Medium	Upright
Cool Season	Grass	Cereal rye	A	High	Upright
Cool Season	Grass	Triticale	A	High	Upright
Cool Season	Grass	Annual fescue	A		Upright
Cool Season	Broadleaf	Phacelia	A	Low	Upright
Cool Season	Broadleaf	Flax	A	Medium	Upright
Cool Season	Broadleaf	Spinach	A	Medium	Upright-Spreading
Cool Season	Broadleaf	Kale	A	Medium	Upright-Spreading
Cool Season	Broadleaf	Canola	A/B	Medium	Upright-Spreading
Cool Season	Broadleaf	Mustard	A/P	High	Upright-Spreading
Cool Season	Broadleaf	Turnip	B	High	Upright-Spreading
Cool Season	Broadleaf	Radish	A	High	Upright-Spreading
Cool Season	Broadleaf	Beet	B	High	Upright-Spreading
Cool Season	Broadleaf	Carrot	A/B	High	Upright-Spreading
Cool Season	Legumes	Field pea	A	Low	Upright
Cool Season	Legumes	Lentil	A	Low	Upright-Spreading
Cool Season	Legumes	Lupin	A	Low	Upright
Cool Season	Legumes	Vetch	A/B	Medium	Prostrate
Cool Season	Legumes	Berseem clover	A	Low	Upright
Cool Season	Legumes	Red clover	B/P	Low	Upright
Cool Season	Legumes	White clover	P	Low	Upright
Cool Season	Legumes	Sweetclover	A/B	Medium	Upright
Cool Season	Legumes	Medic	A/P	Low	Upright-Spreading
Cool Season	Legumes	Birdsfoot trefoil	P	Medium	Prostrate
Cool Season	Legumes	Sainfoin	P	High	Upright
Cool Season	Legumes	Alfalfa	P	High	Upright
Warm Season	Legumes	Chickpea	A	Low	Upright-Spreading
Warm Season	Legumes	Cowpea	A	Low	Upright-Spreading
Warm Season	Legumes	Soybean	A	Medium	Upright-Spreading
Warm Season	Legumes	Mung bean	A	Medium	Upright-Spreading
Warm Season	Broadleaf	Amaranth	A	Low	Upright
Warm Season	Broadleaf	Buckwheat	A	Medium	Upright
Warm Season	Broadleaf	Sunflower	A	High	Upright
Warm Season	Broadleaf	Safflower	A	High	Upright
Warm Season	Broadleaf	Squash	A		Prostrate
Warm Season	Broadleaf	Chicory	P		Upright-Spreading
Warm Season	Grass	Pearl millet	A	Low	Upright
Warm Season	Grass	Foxtail millet	A	Low	Upright
Warm Season	Grass	Proso millet	A	Medium	Upright
Warm Season	Grass	Sudan grass	A	Medium	Upright
Warm Season	Grass	Teff	A	Medium	Upright
Warm Season	Grass	Grain sorghum	A	Medium	Upright
Warm Season	Grass	Corn	A	High	Upright

V 1.0. June 2010

◈Additional Information

Sunflower (*Helianthus annuus* L.)

- Warm season growth characteristics, broadleaf
- Annual
- Upright plant architecture
- High water use
- Fair salinity tolerance
- Deep rooted.
- Effective at ‘mining’ mobile nutrients deep in the soil profile
- Crude protein: silage 11-12%; grain 20-28%
- Will form arbuscular mycorrhizal associations
- Flowers attract pollinators

USDA-ARS, NGPRL

GAP Photos

Back to Cover Crop Chart

Turnip (*Brassica rapa* L. var. *rapa*)

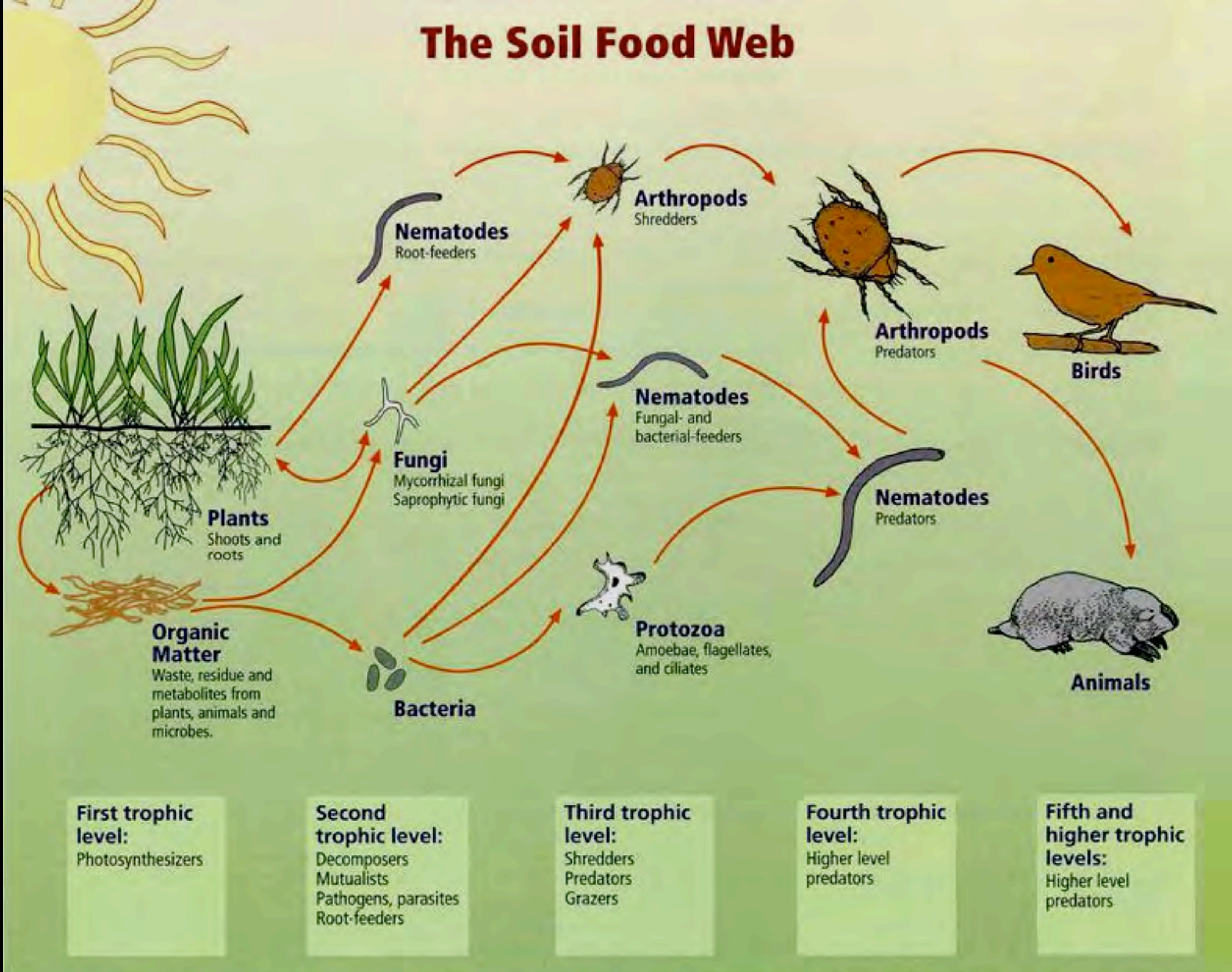
- Cool Season, broadleaf
- Biennial
- Root crop
- High water use
- Poor salinity tolerance
- Crude protein: tops 16%; root 12-14%
- Closely related to rutabagas
- Does not form arbuscular mycorrhizal associations
- Rated 'good' at scavenging nitrogen from the soil
- Flowers attract pollinators

Back to Cover Crop Chart

Bonnie Plants

AMPAC Seed Company

Mas du Diable, January 2009



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Soil Biology

- Total weight of living organisms in the top six inches of a healthy soil ranges from 5,000 to 20,000 pounds per acre

- Soil from one spot may house a very different community from soil just a yard (meter) away,

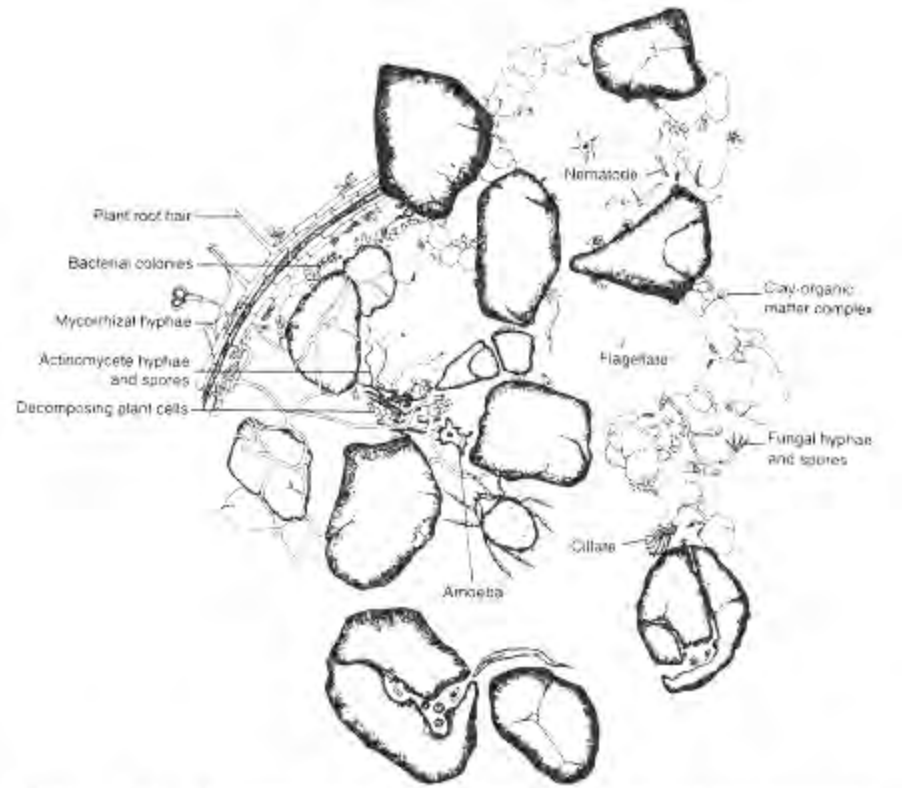


FIGURE 5.2 Diagrammatic representation of a plant root and associated biota approximately 1 cm^2 of a surface grassland horizon associated with a plant root. (Adapted from S. Rose and T. Elliott, personal communication.)

It's all about the food!

- Where does it come from?
- What type of food is it?
- How consistent is the source?

FOOD = CARBON = ENERGY

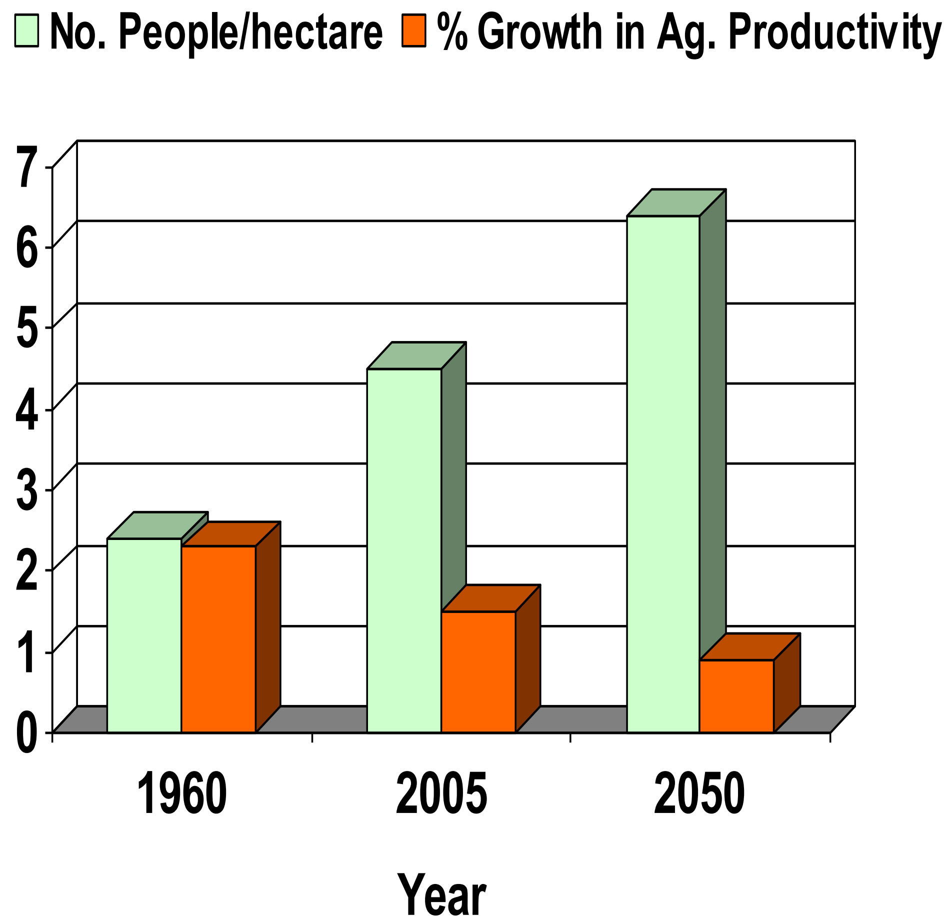
Root of the problem is the root of the solution.

The Rhizosphere is the area:

- **Immediately surrounding (0.5-1 inches) the plant roots**
- **Twice the number of microbes**
- **Highest biological activity due to photosynthetically-derived carbon (approx. 70%) – Juma, 1993**
- **Greatest impact on soil structure**
- **Majority of the nutrient cycling activity**
- **Most impacted by aboveground management**

On a global scale, arable land will need to produce more food, feed, fiber, and biofuel to meet future needs.

Sustainable, soil-building practices are more critical than ever.



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What is the monetary value of:

- 1 ton of top soil
- 1 inch of water
- 1 ton of residue
- 1-2% increase in OM
- 9 billion microorganisms in one tsp of healthy soil
- Clean water and air
- Plant, human, and animal health

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BOTTOM LINE

Using no-tillage and a diversified crop rotation with continuous cover (via residue management and/or living plants) is necessary to fix the carbon limitation problem, reduce input costs and maintain profitability by providing food and habitats for soil biota.

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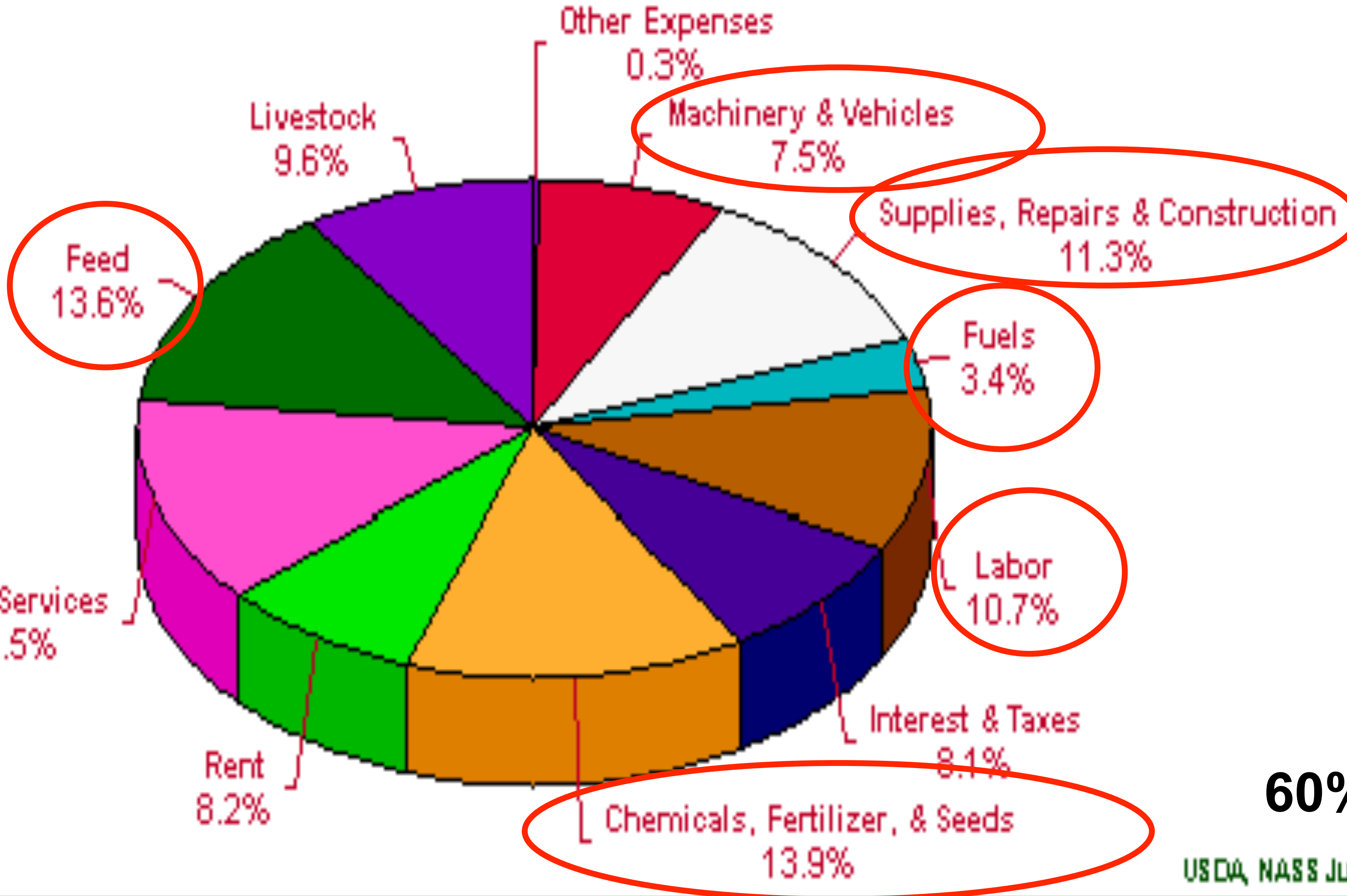
Farm Production Expenditures
Major Input Items By Percent of Total
United States, 2003

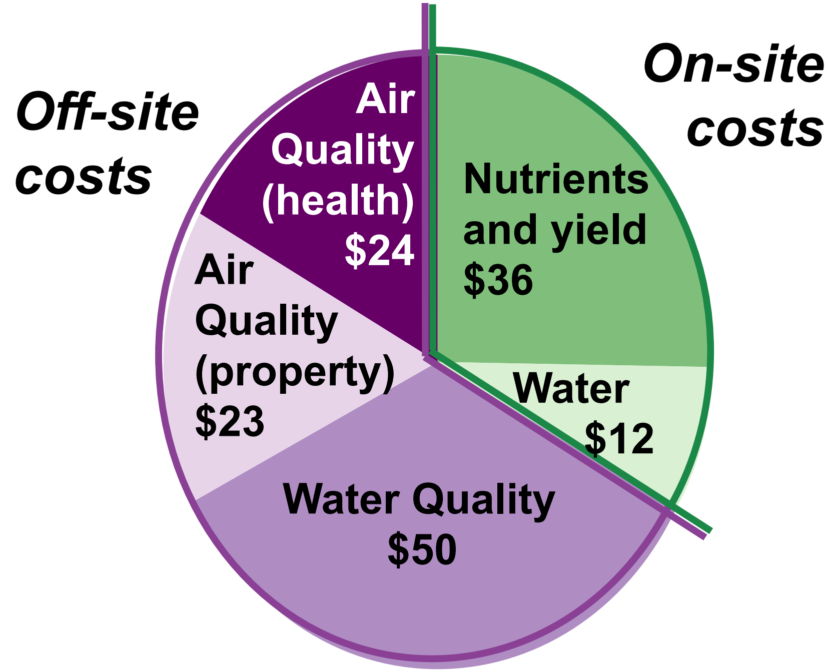


60%

USDA, NASS Jul 2004

Water & wind erosion:

- Soil loss 7.6 t/ac/yr
- $40/ac in nutrients
- $17/ac/yr to replace soil water
- Total cost of soil and water lost annually in U.S. > $27 billion/yr
- World-wide costs are more than $400 billion/yr



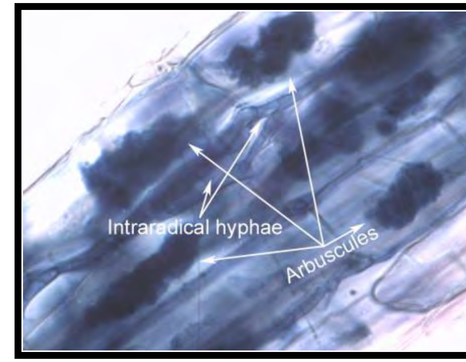
$145 per acre or $19 per ton soil

Soil Quality Institute, 2003

New GREEN REVOLUTION is a BROWN (SOIL) REVOLUTION

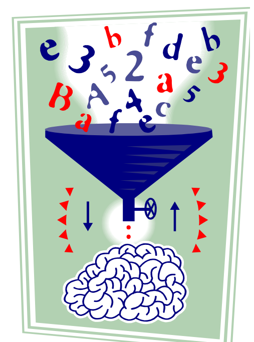
- **Designing for what you don't have!**
  - Pest management - Diversity
  - Specific C/N ratios (residue management) – Diversity, continuous cropping, and reduction in tillage
  - Soil armor – leaf size, placement, and strength – Diversity, continuous cropping, and reduction in tillage
  - Efficient use of water and nutrient resources – Diversity, continuous cropping, and reduction in tillage

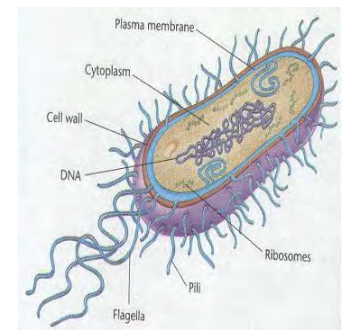
New GREEN REVOLUTION is a BROWN (SOIL) REVOLUTION



➢ Utilize:

- **Most Efficient Processes**
- **Best Tools in Agriculture**





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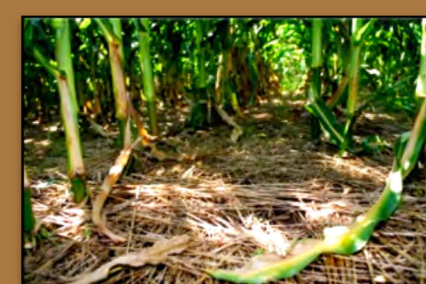

To be a successful farmer one must first know the nature of the soil.
- Xenophon, Oeconomicus, 400 B.C.

Thank You!

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Kristine.nichols@ars.usda.gov
http://www.mandan.ars.usda.gov/

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