

Regenerative Agriculture

**What Does It Really Mean and Does It
Have Real Value for Farmers?**

Dr. Kris Nichols

KRIS Systems Education and Consultation

Kris@KRIS-systems.com

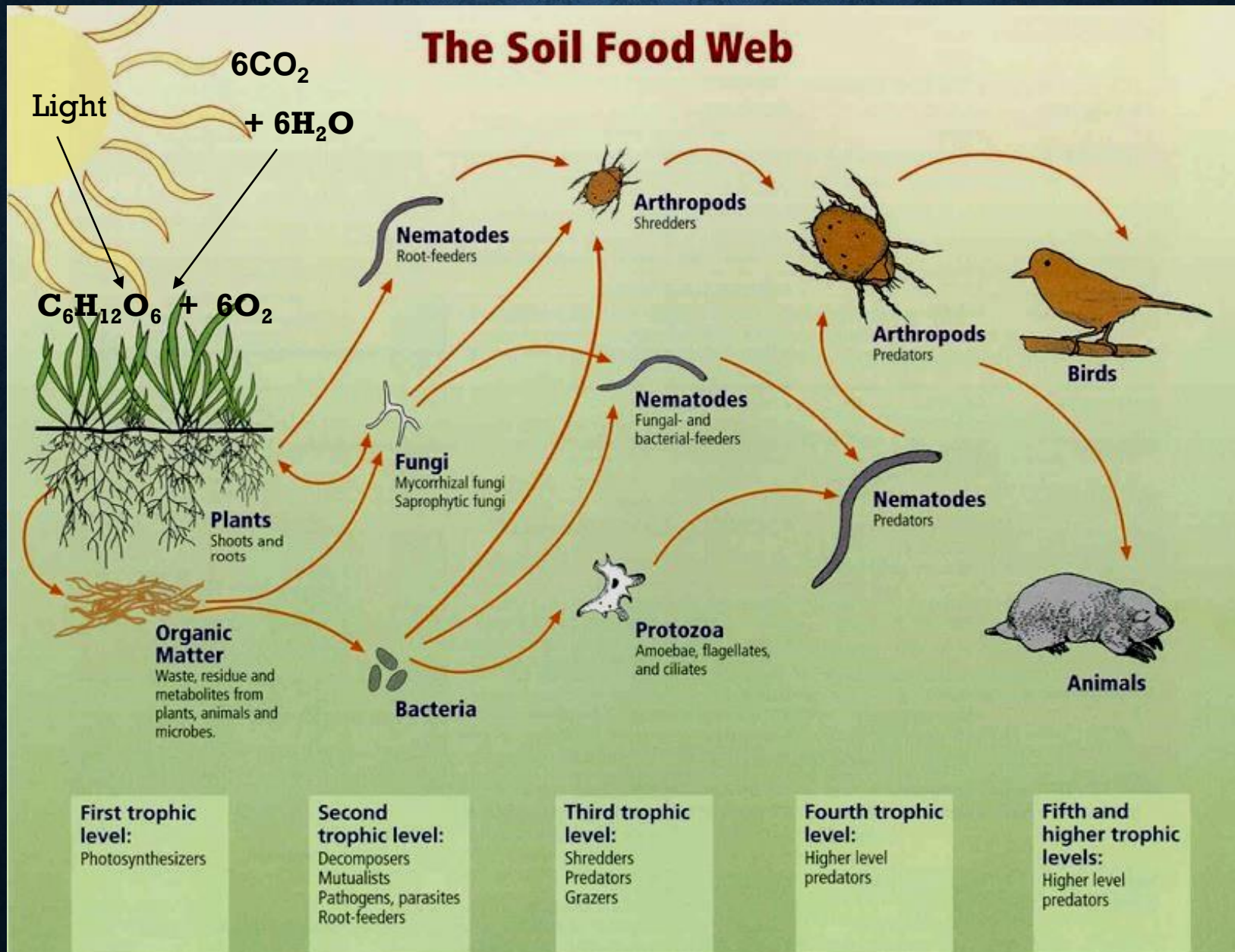


**Systems
Approach** that
starts with
Photosynthesis.

Photosynthesis –
most efficient form
of solar energy
conversion to
chemical energy in
the bonds between
carbon atoms or
carbon atoms and
other atoms.

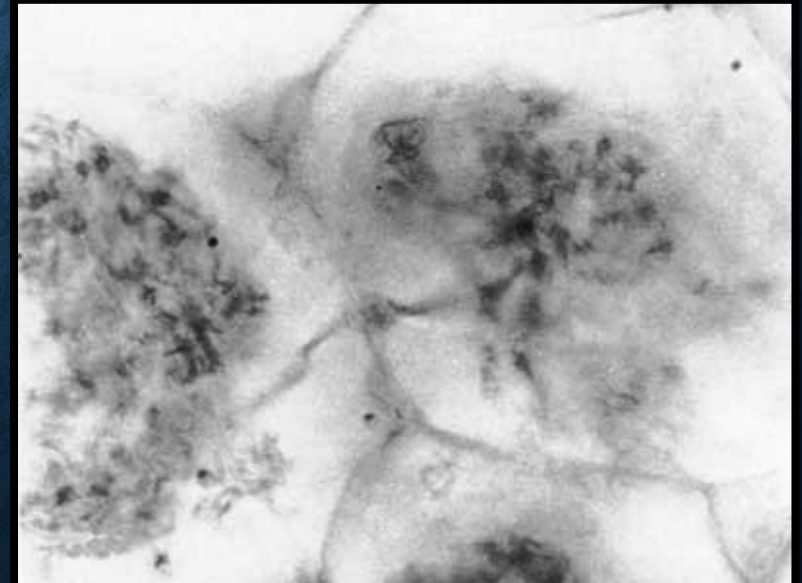
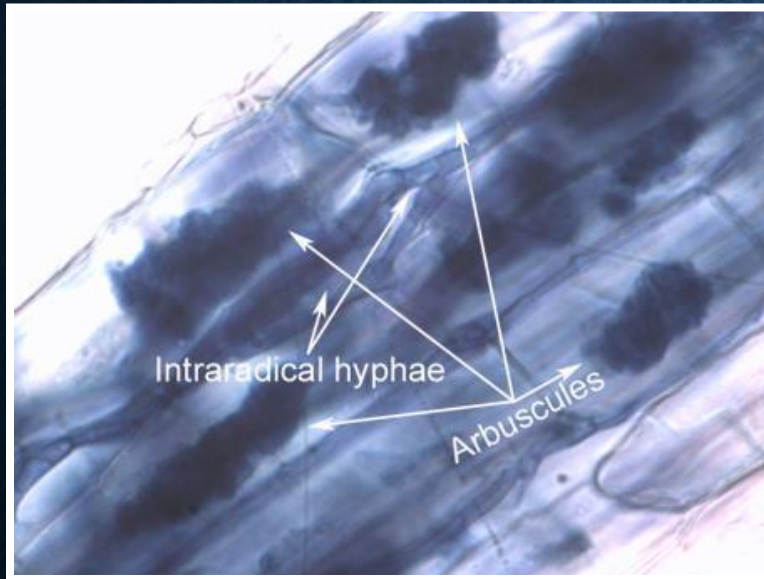
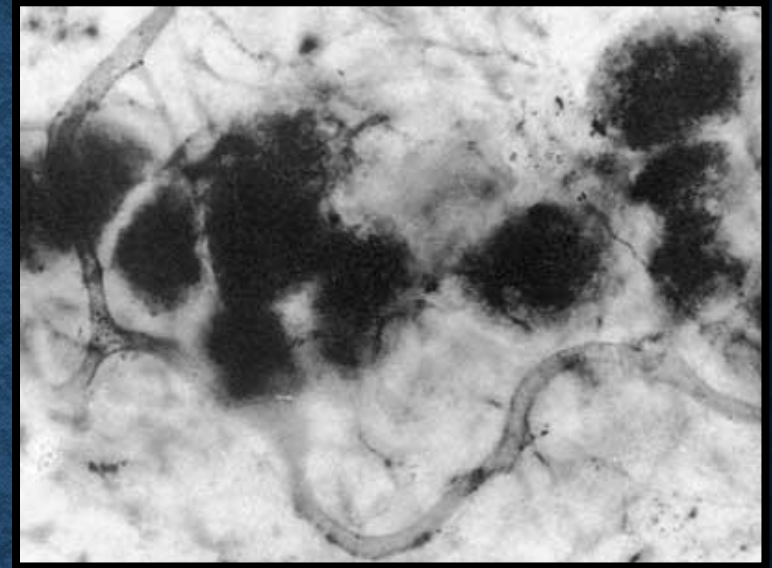


Root of the Problem is the Root of the Solution

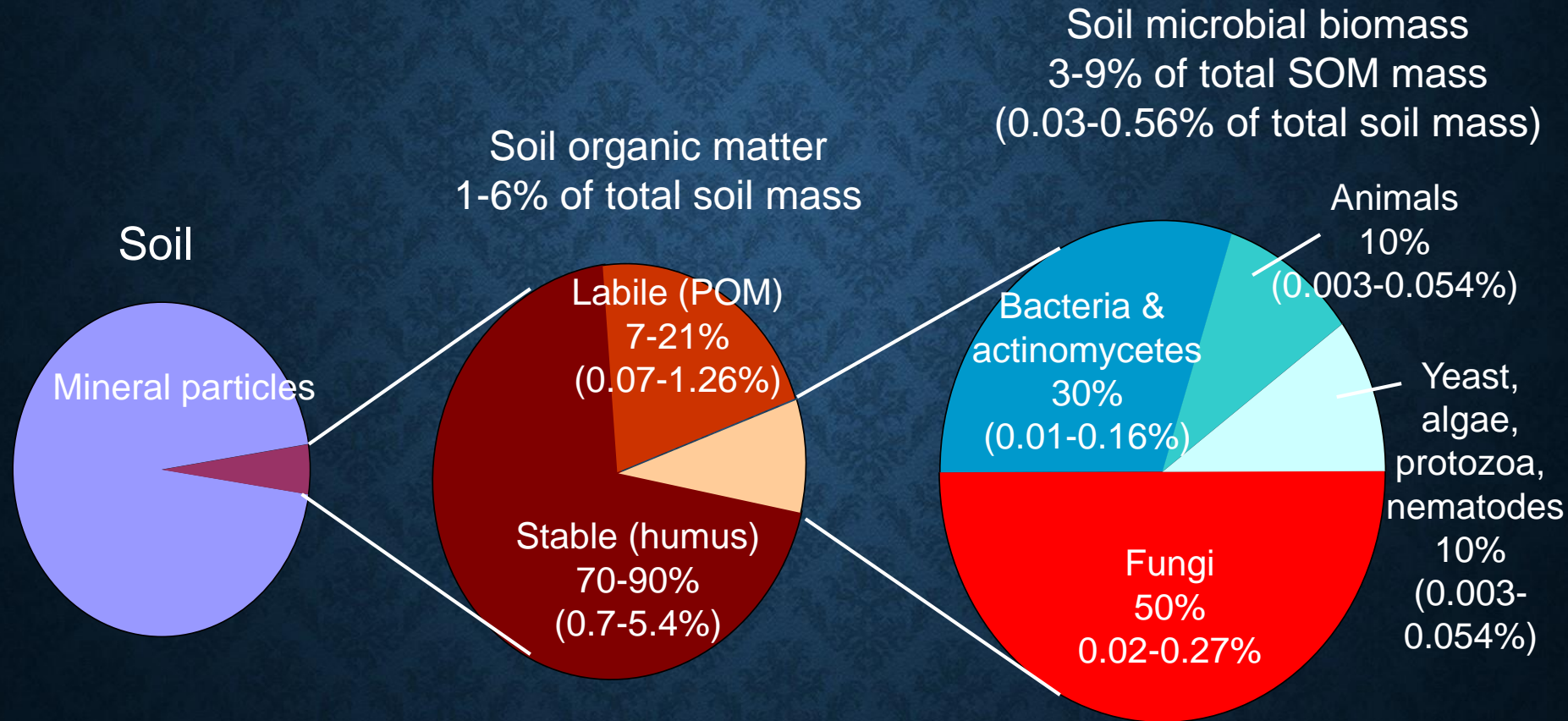


MYCORRHIZAL FUNGI MAKE SOIL

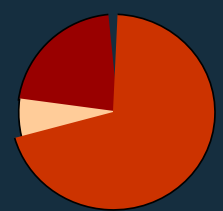
- Soil is organic – Carbon, Hydrogen, and Oxygen
- No soil without plants
- No land plants without fungi
 - Taylor et al., 1995
 - 400 – 500 Myr



SOIL ORGANIC MATTER COMPOSITION

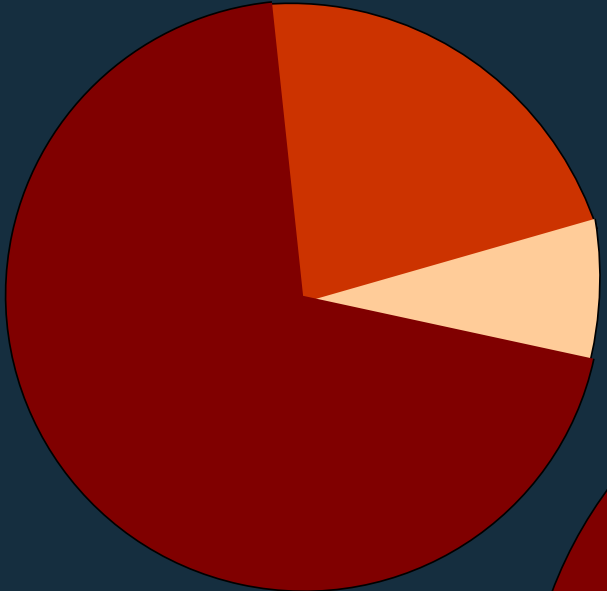


Conventional



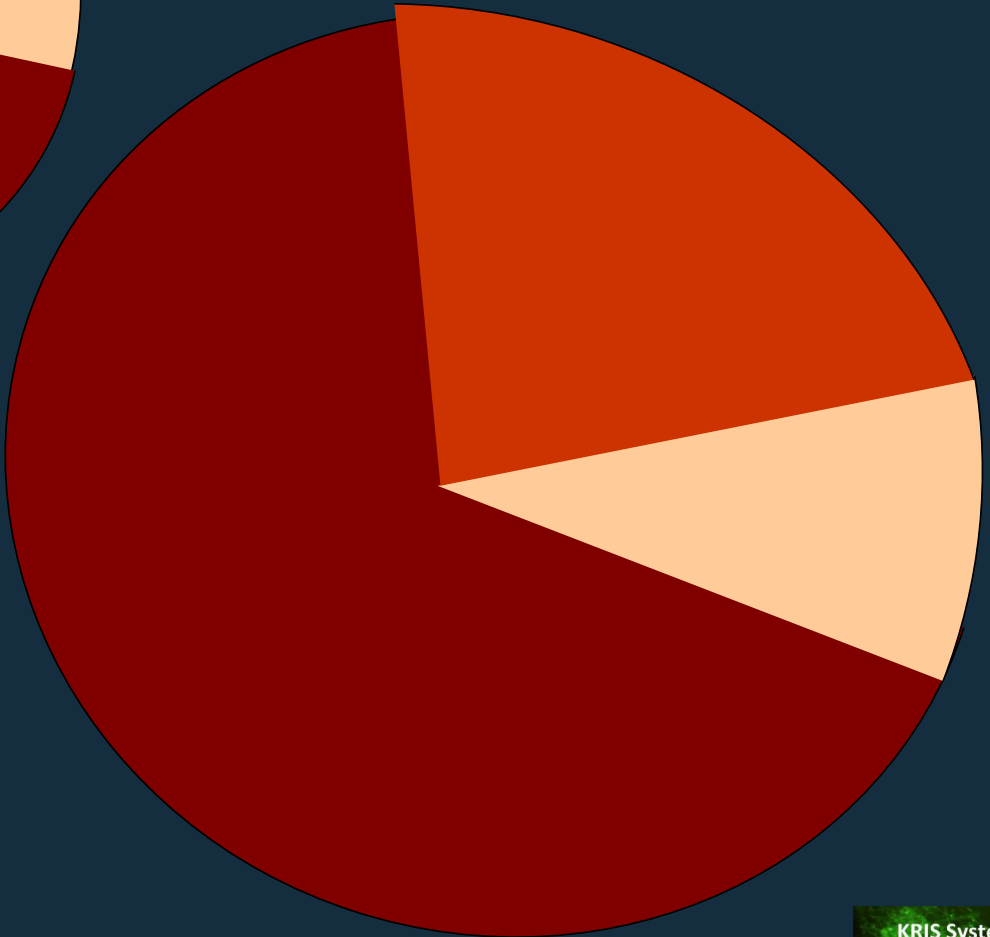
1% SOM

Transitional



3% SOM

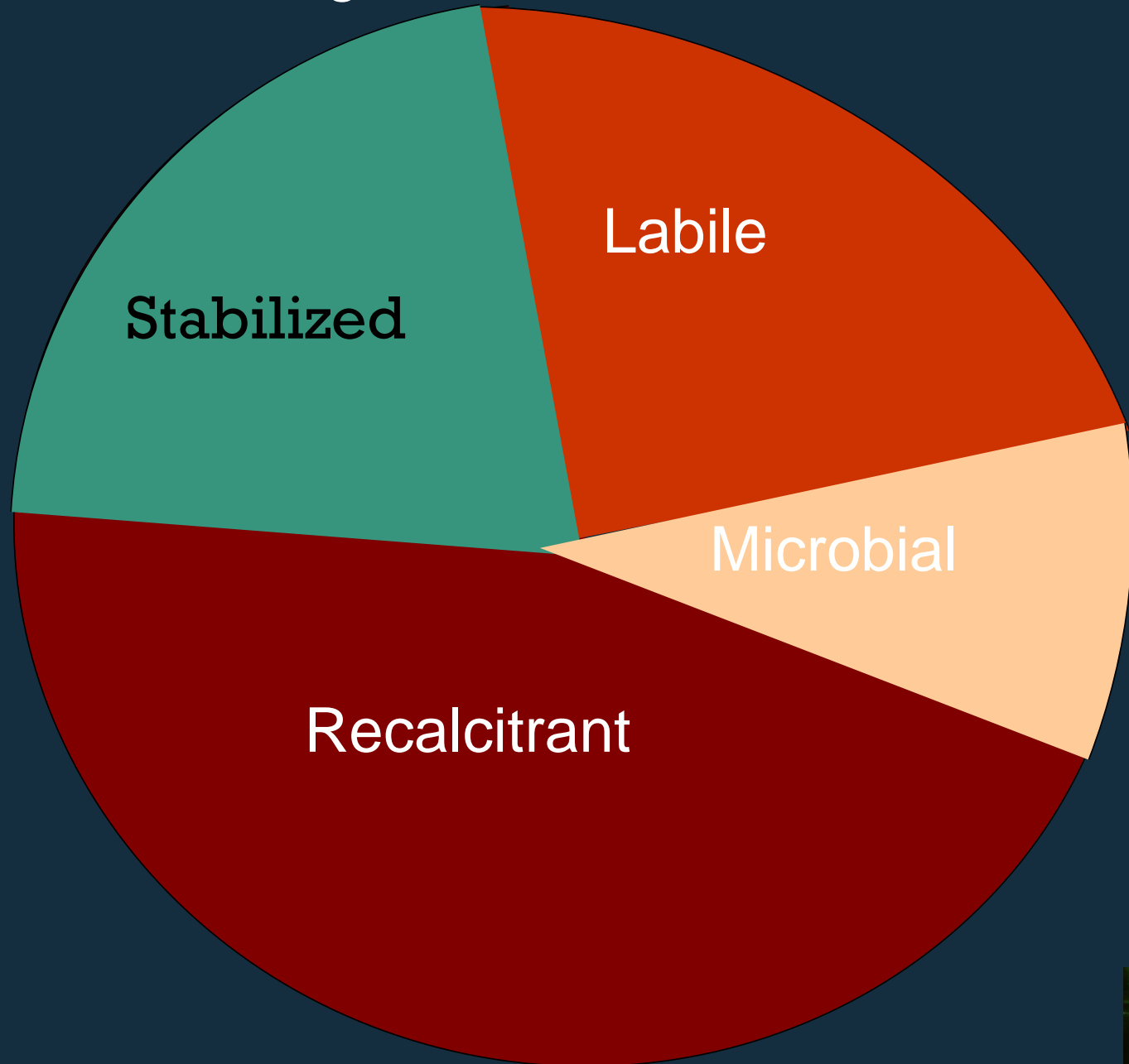
Regenerative Microbial



5% SOM

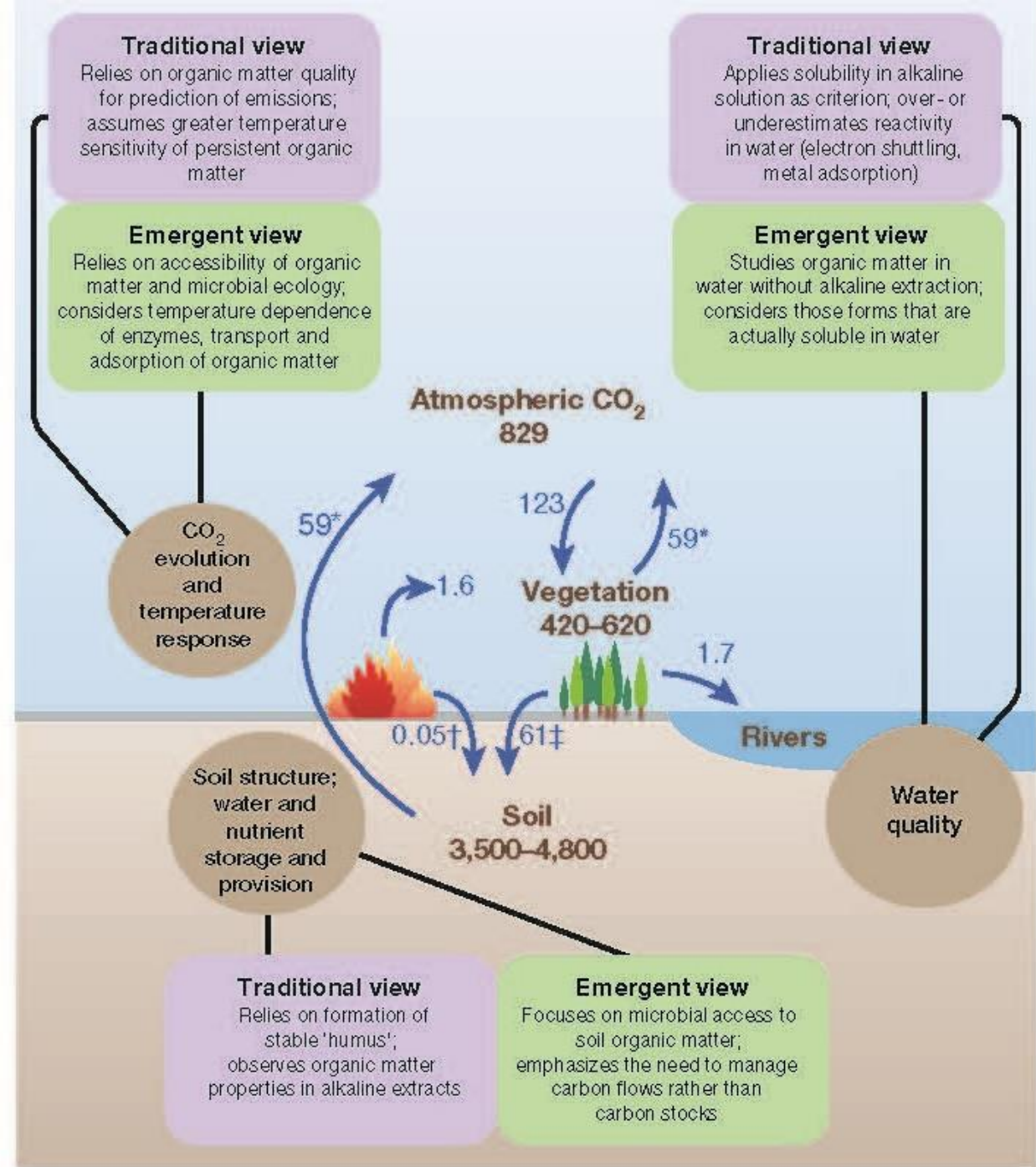
- Recalcitrant
- Labile
- Microbial

Regenerative Microbial



Emerging view of SOM supports Regenerative Ag – We can build SOM in our lifetime!

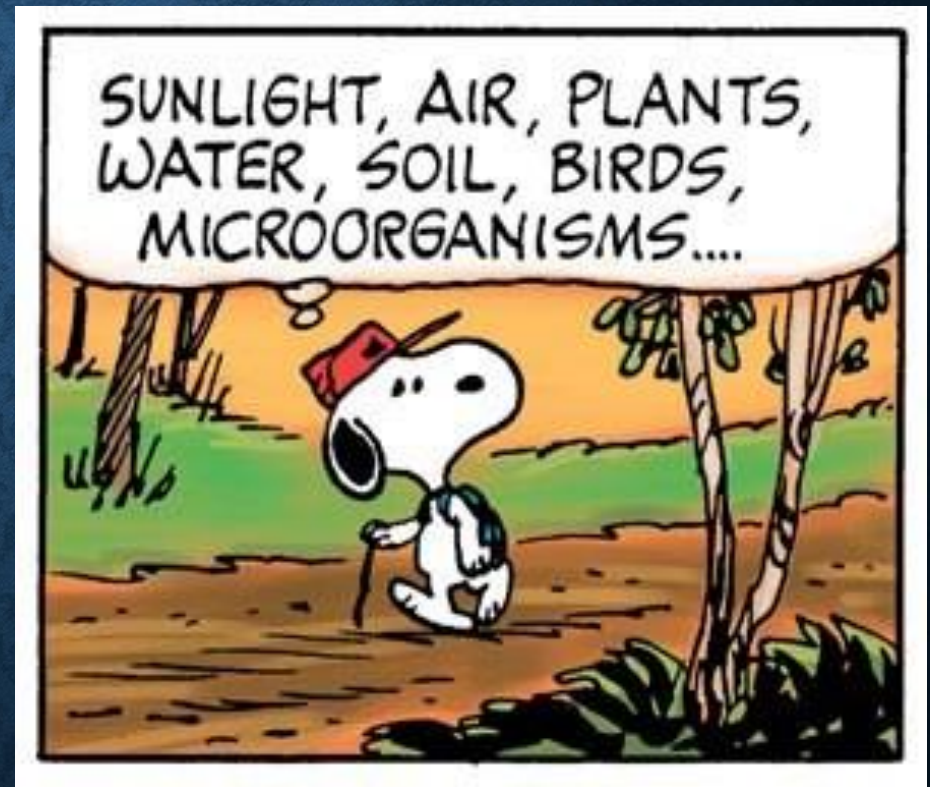
Lehmann and
Kebbler, 2015



THE BROWN REVOLUTION

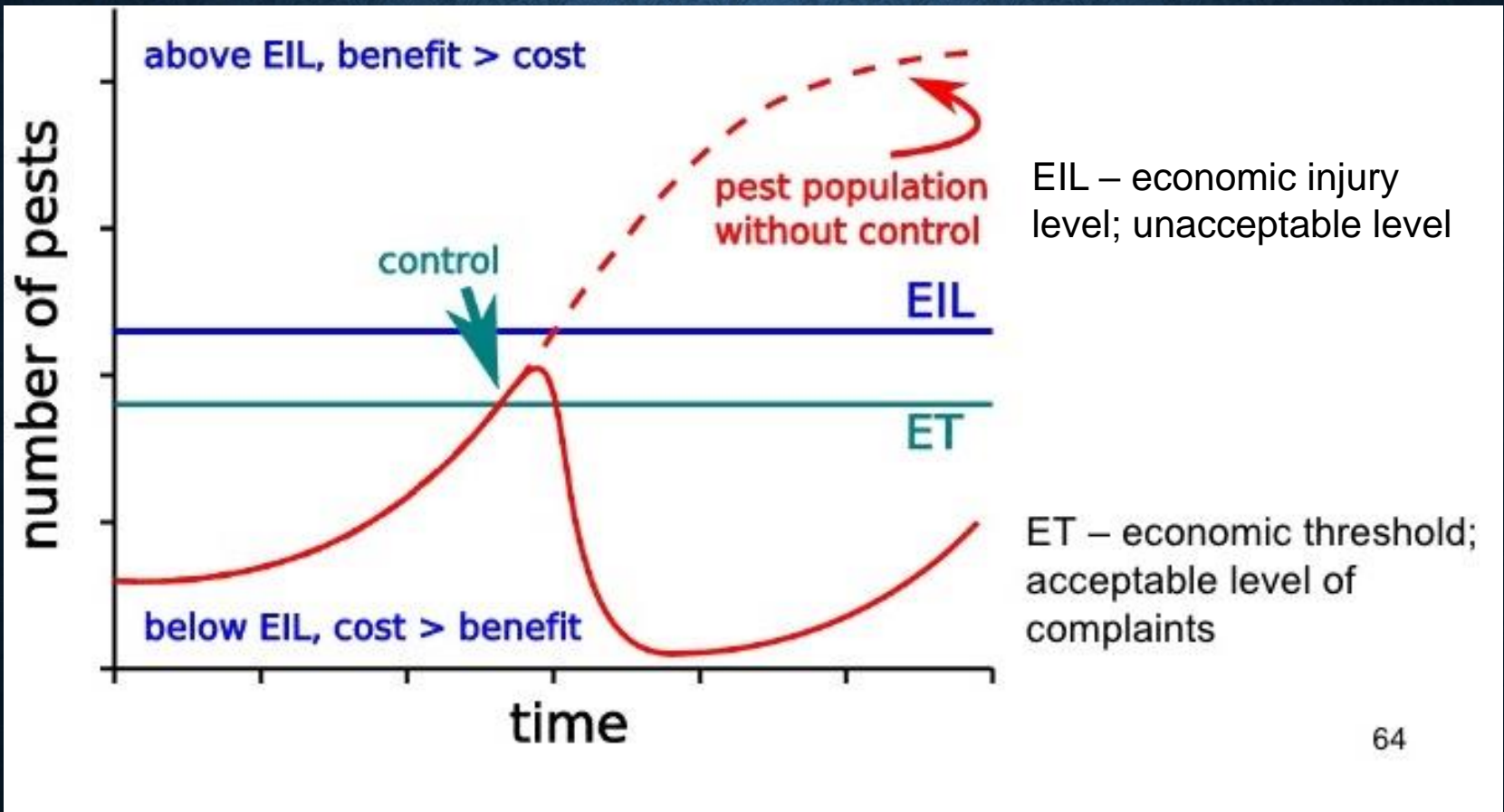
➤ Eco-Functional Intensification

- Optimize landscape use
- Maximize efficiencies
- Not more but less
- Multiple enterprises
- Everything costs
- Redistribute risk
- Nutrient density



AGROECOSYSTEM RESILIENCE

Response to pest pressures

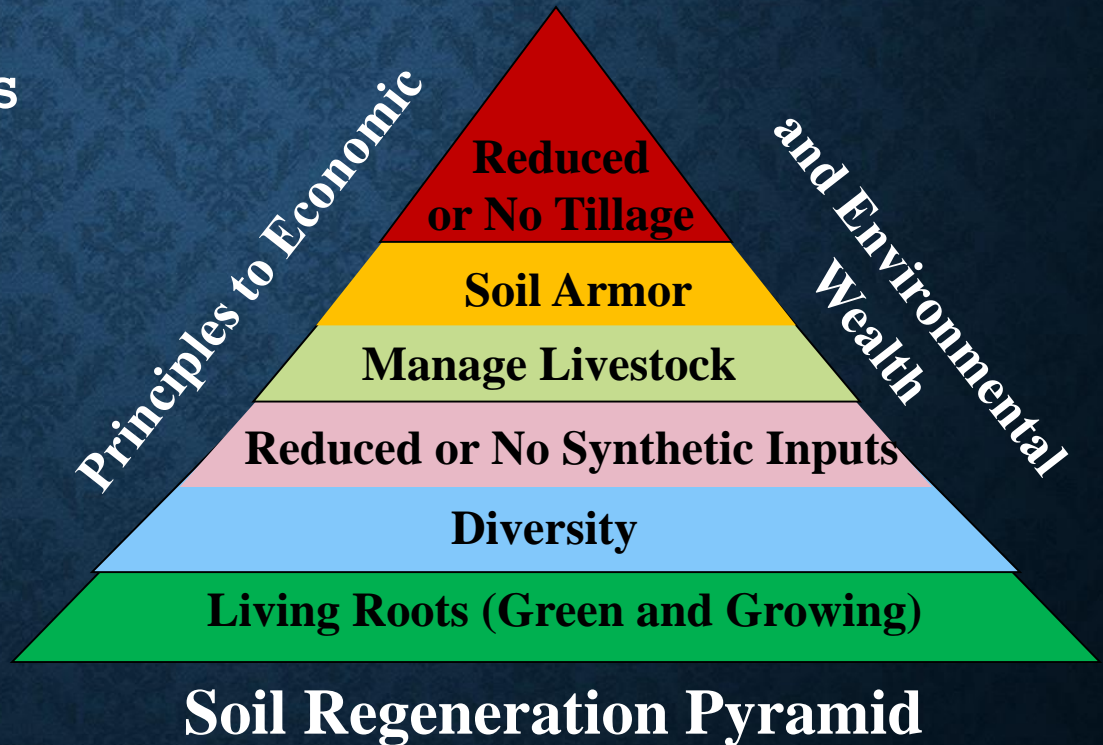


- Tracking weed community dynamics
- Measuring yield declines from weeds

THE BROWN REVOLUTION

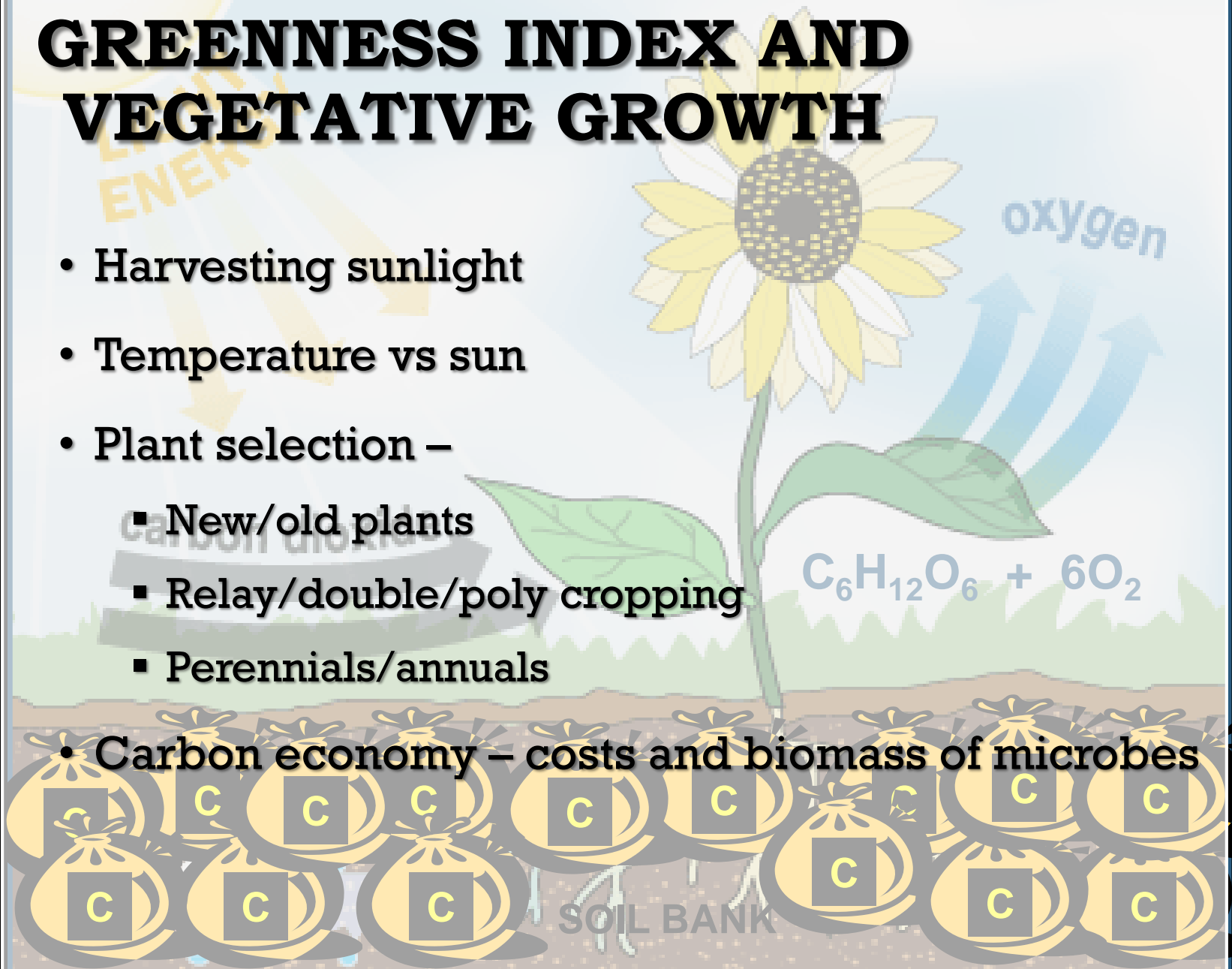
➤ Eco-Functional Intensification

- Optimize landscape use
- Maximize efficiencies
- Not more but less
- Multiple enterprises
- Everything costs
- Redistribute risk
- Nutrient density



GREENNESS INDEX AND VEGETATIVE GROWTH

- Harvesting sunlight
- Temperature vs sun
- Plant selection –
 - New/old plants
 - Relay/double/poly cropping
 - Perennials/annuals
- Carbon economy – costs and biomass of microbes



Maximize Living Roots

Put Down Some Roots...Plant Prairie



Rhizosphere 0.5-1 inches around 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**

Kentucky Blue Grass, Lead Plant, Missouri Sycamore, Indian Grass, Compass Plant, Partridge Pea, Heath Aster, Prairie Cordgrass, Big Blue Stem, Pink Purple Cowpea, Prairie Turnip, Side Oats Gramma, False Broomrape, Switch Grass, White Wild Indigo, Little Blue Stem, Rain Weed, Purple Prairie, June Grass, Cylindrical Blowing Star, Buffalo Grass

STARVING AND HOMELESS



- Soil is organic (i.e. living)
- Billions of different organisms from millions of species
- Total weight of living organisms in the top six inches of an acre of soil can range from 5,000 to 20,000 lbs
- Soil from one spot may house a very different community from soil just a yard (meter) away

INTERACTIVE CARBON ECONOMY

- **Plants trade carbon to fungi and bacteria**
 - Mycorrhizal fungi
 - Rhizobium – N fixation
 - P-solubilization
 - Aggregate formation
 - Porosity
 - Soil structure
- **Nematodes and Protozoa eat bacteria and fungi for N**
- **Microarthropods prep residues for bacteria**



ARBUSCULAR MYCORRHIZAL FUNGI

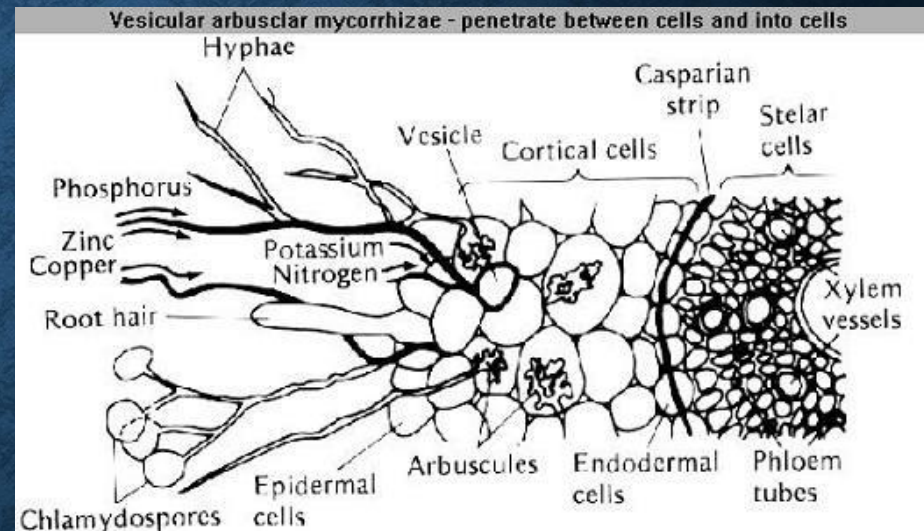
➤ Obtain nutrients (up to 90% of N and P) -

Smith and Read, 2008

- Phosphate-solubilizing bacteria – Toro and Barea, 1996
- Mixed cultures more efficient, but this was also AMF species dependent – Walder et al 2012
- Non-legume trades P for N via AMF and rhizobia activity – Chalk et al, 2014

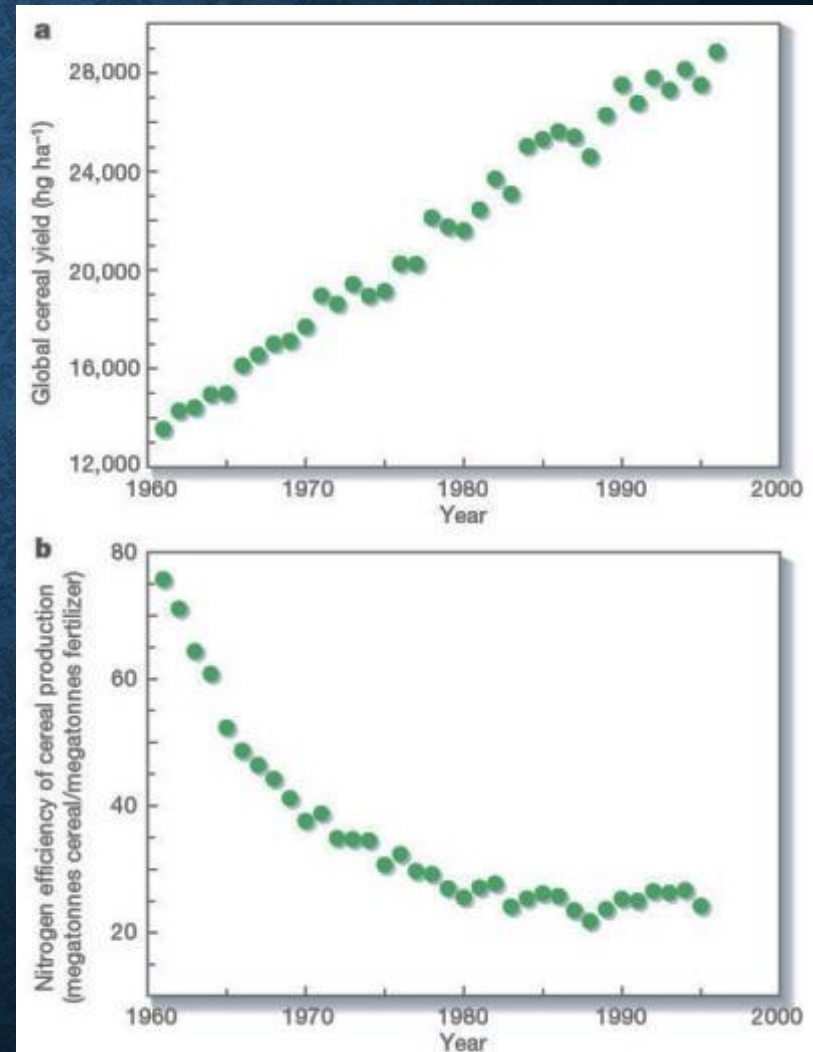
➤ Transfer water

➤ Induce antioxidants (Garcia-Sanchez et al., 2014)



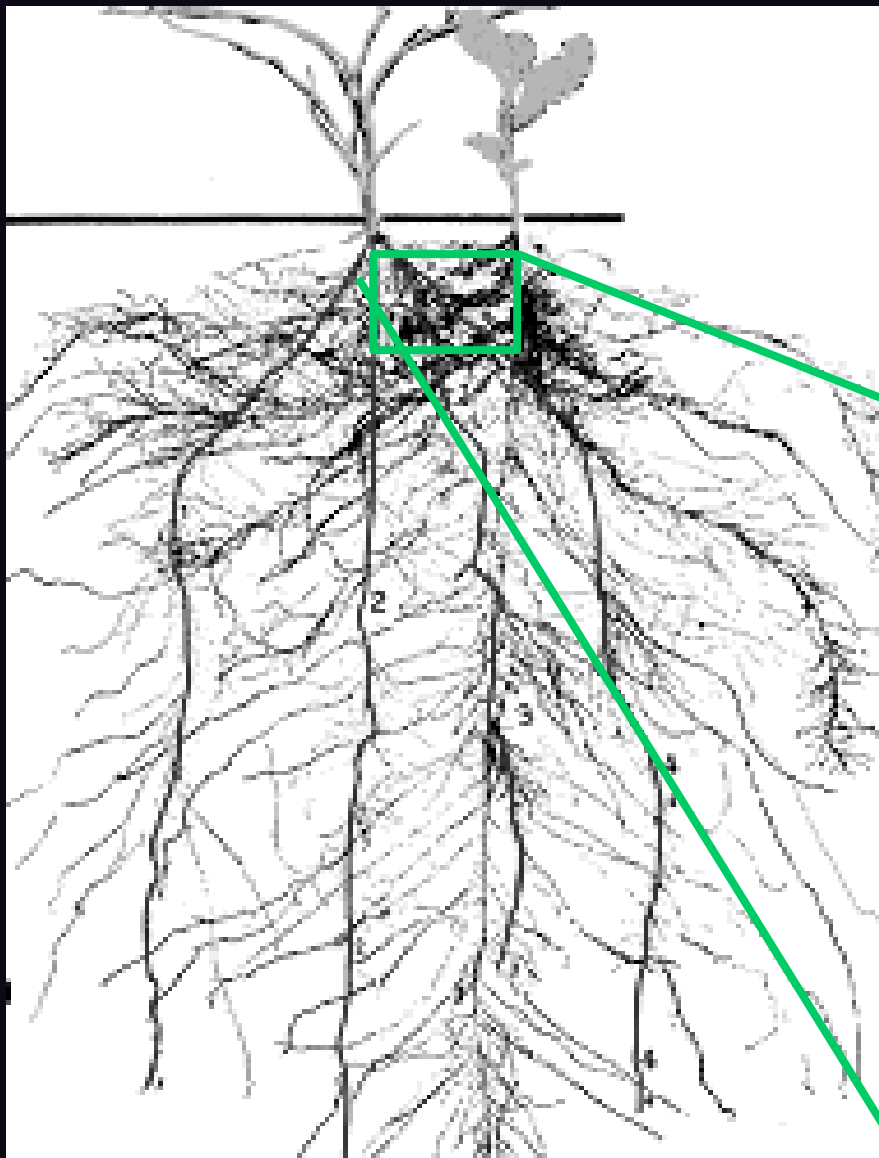
Nutrient Use Efficiency

- Plant available – synthetic vs. biologic
- 30-50% of nitrogen fertilizer is used by the plant (Hirel et al 2011)
- 30% of phosphorus is used by the plant
- Availability, timing, water, and pH



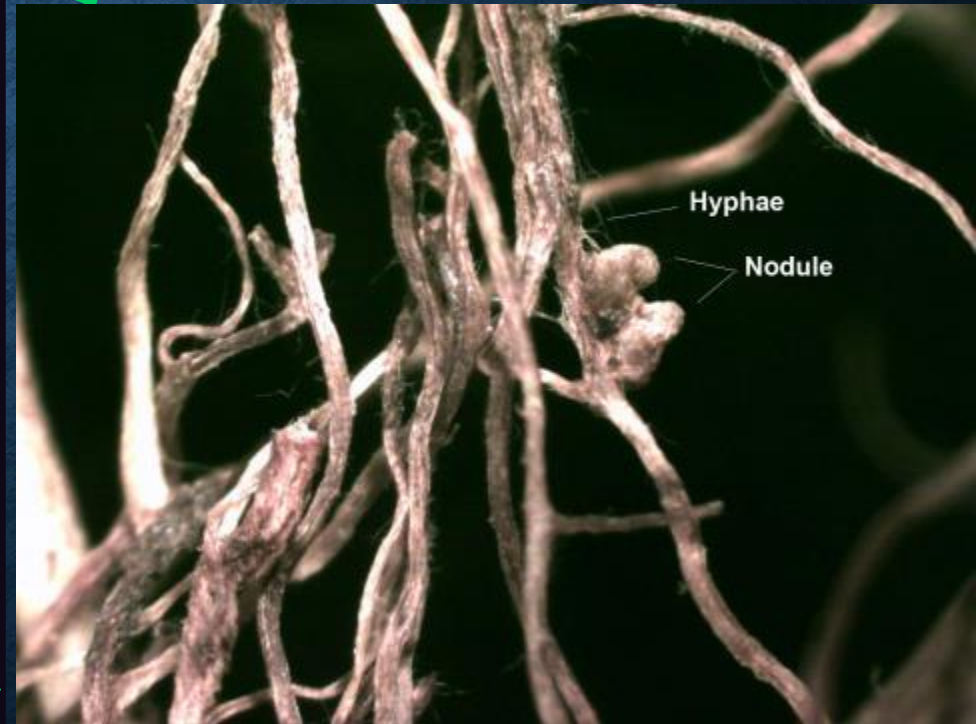
- Tilman et al., 2002

Plant to Plant Nutrient Exchange

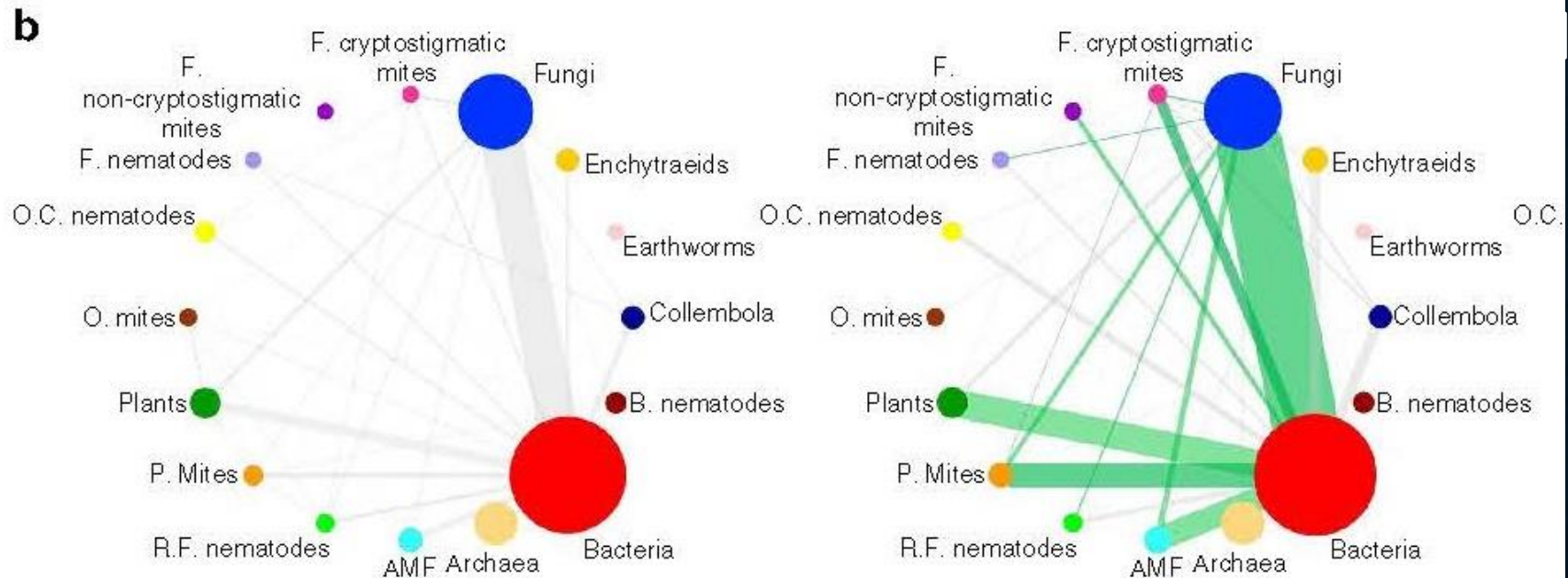


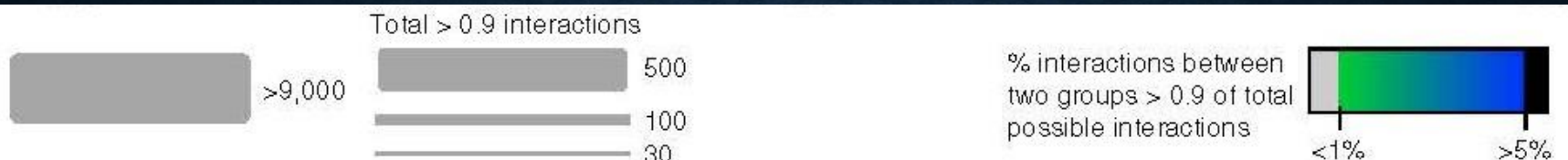
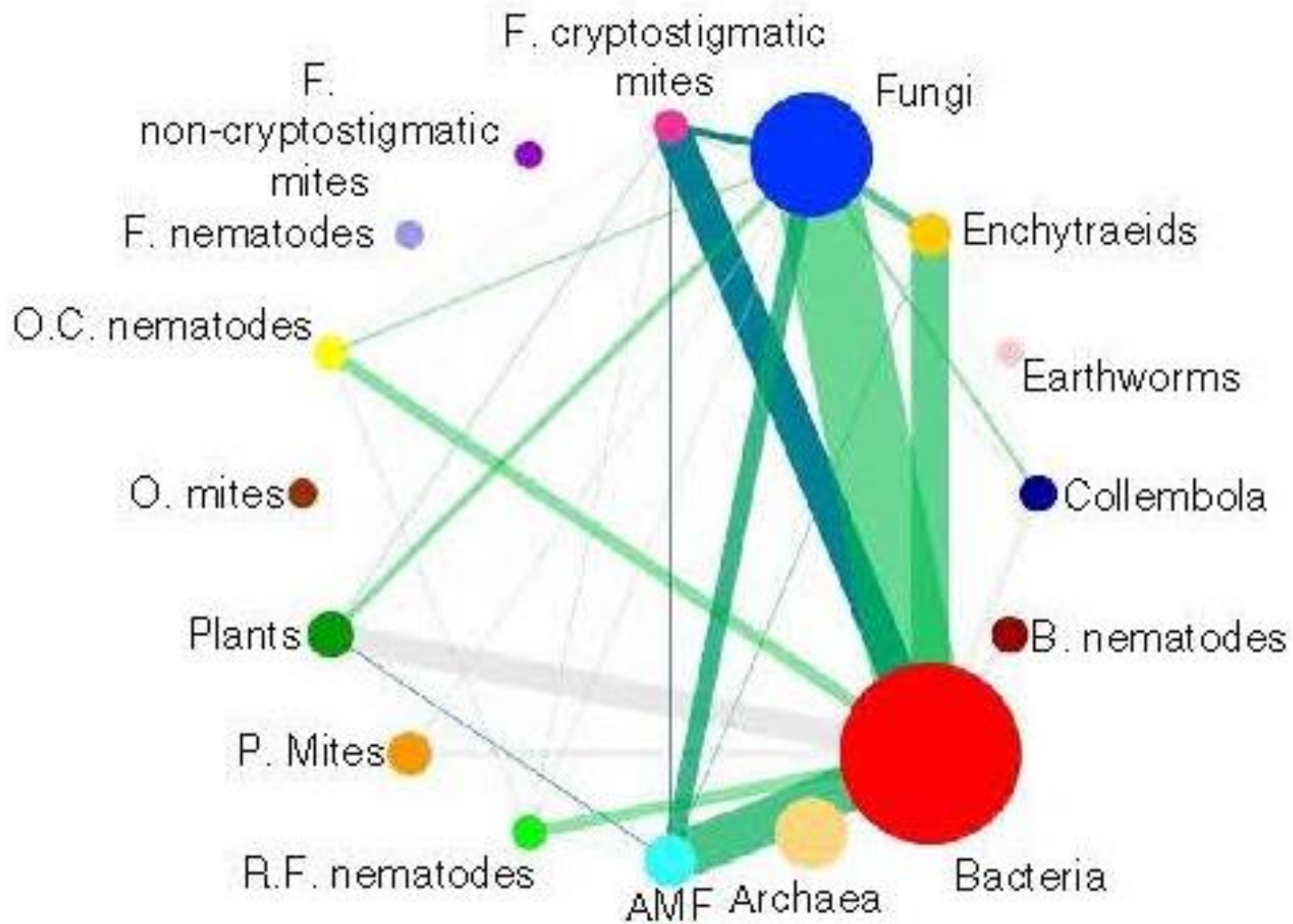
**Interplant transfer N for P
and C – Chalk et al., 2014**

**N fixation: N_2 via 32 ATP
(needs 128 P and 320 C)**



Compounding Principle of Consortia

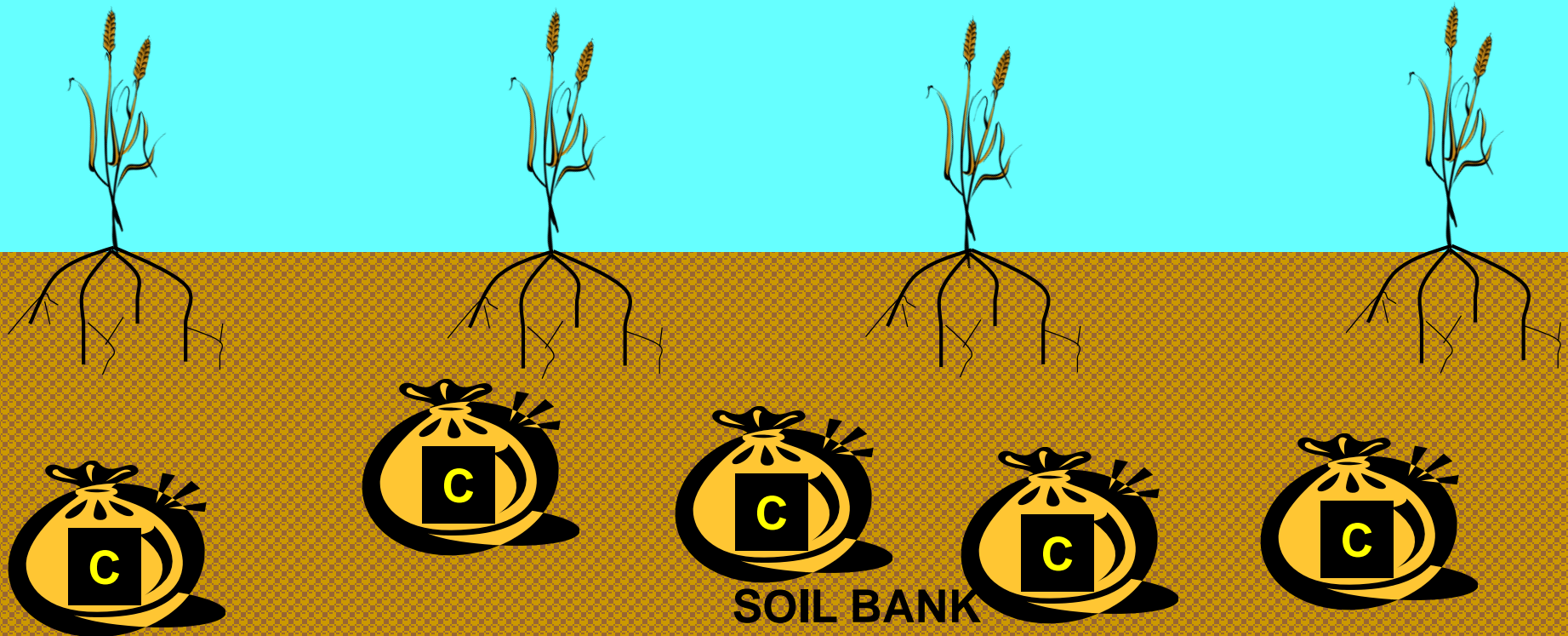




Morriën et al., 2017

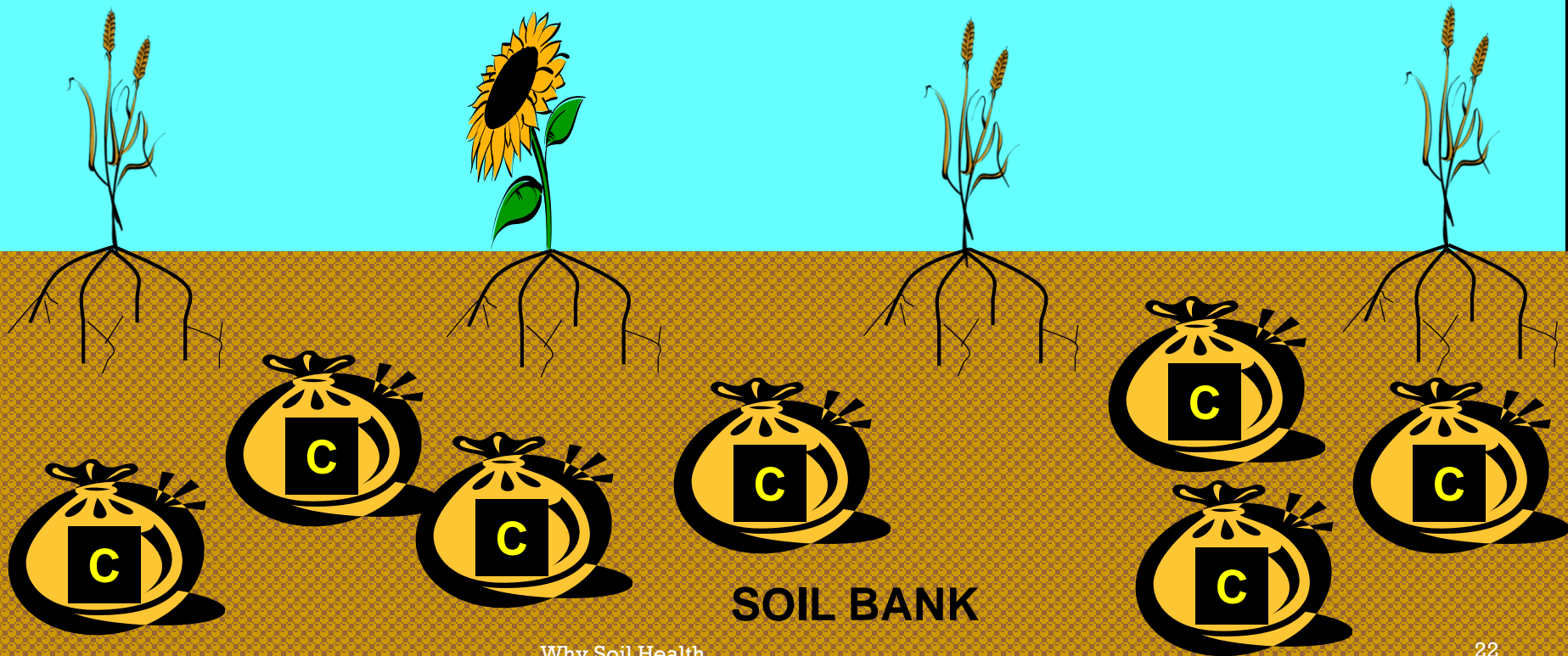
Cropping to Bank Carbon

Continuous Wheat



Cropping to Bank Carbon

Minimum Diversity



Cropping to Bank Carbon

Maximum Diversity

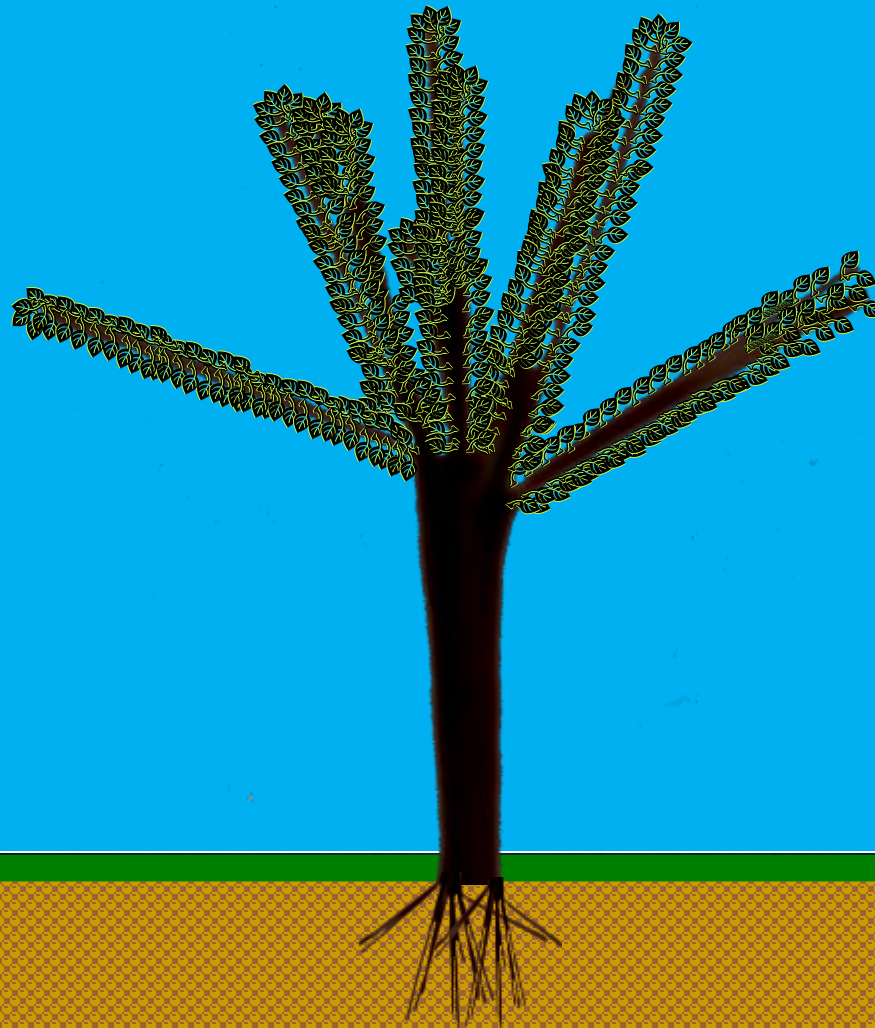
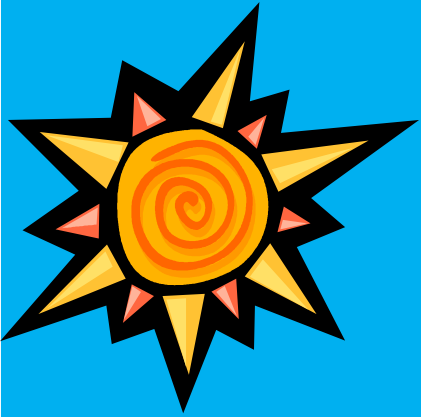


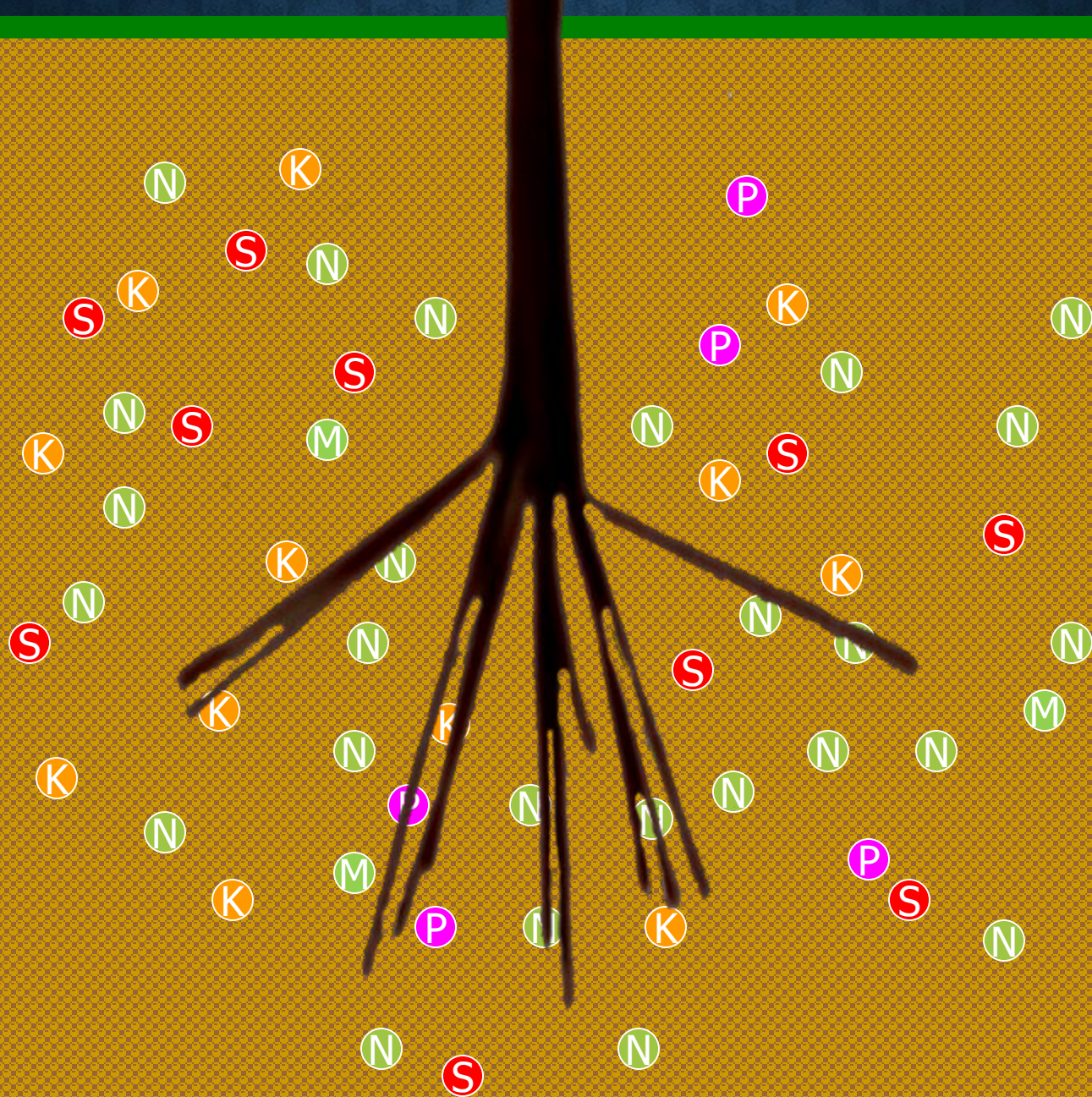
Cropping to Bank Carbon

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

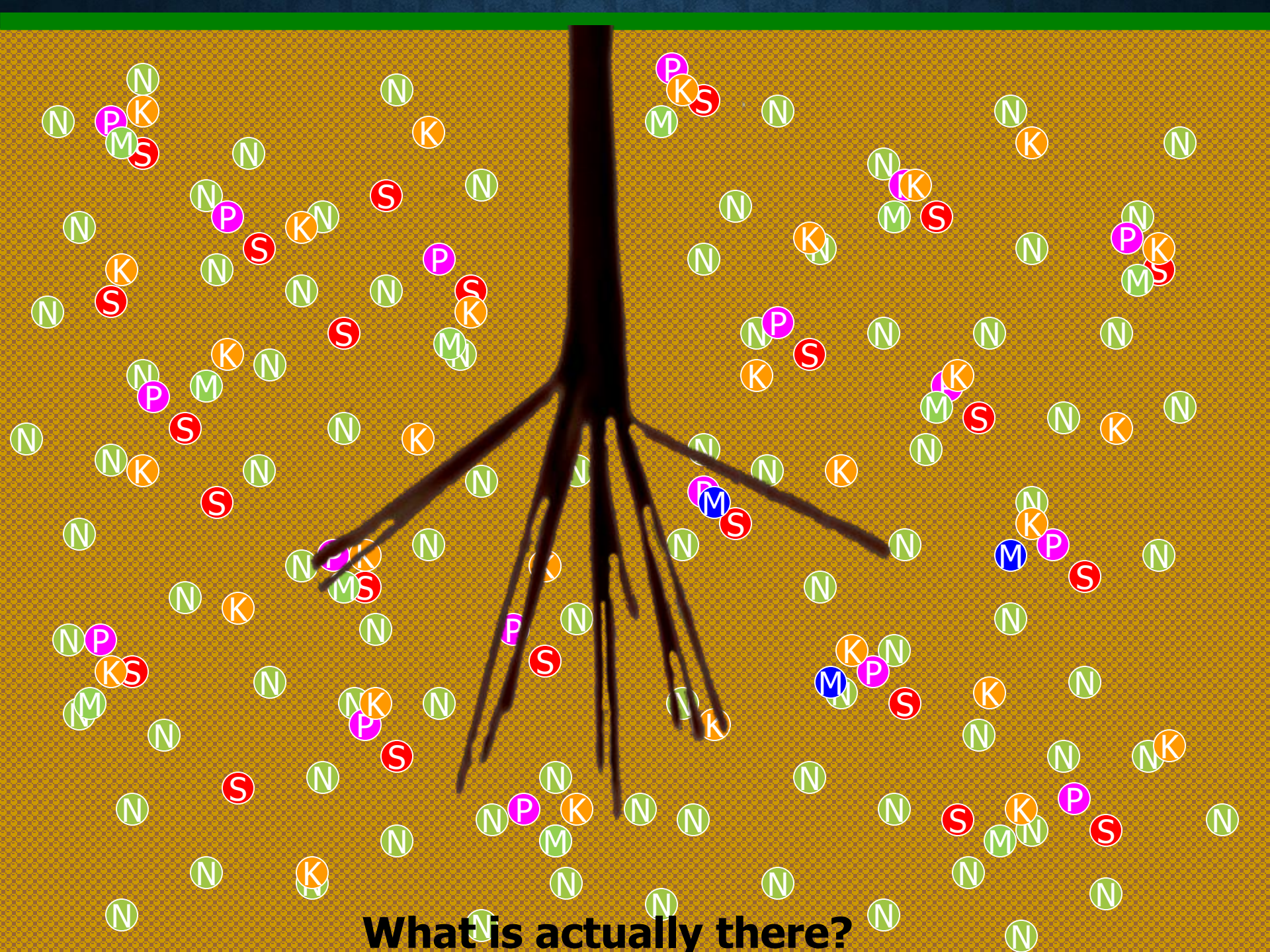


Efficiency

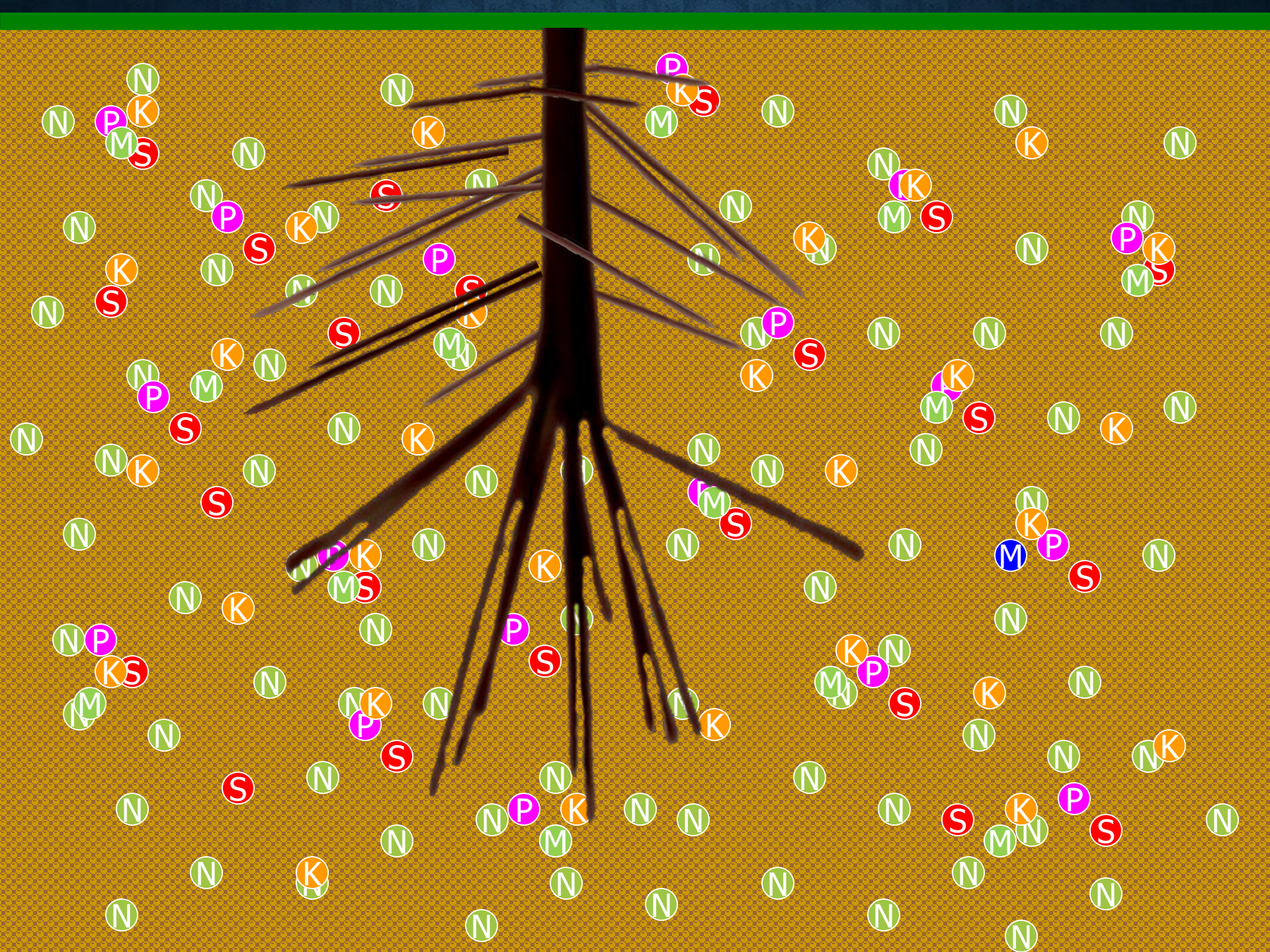


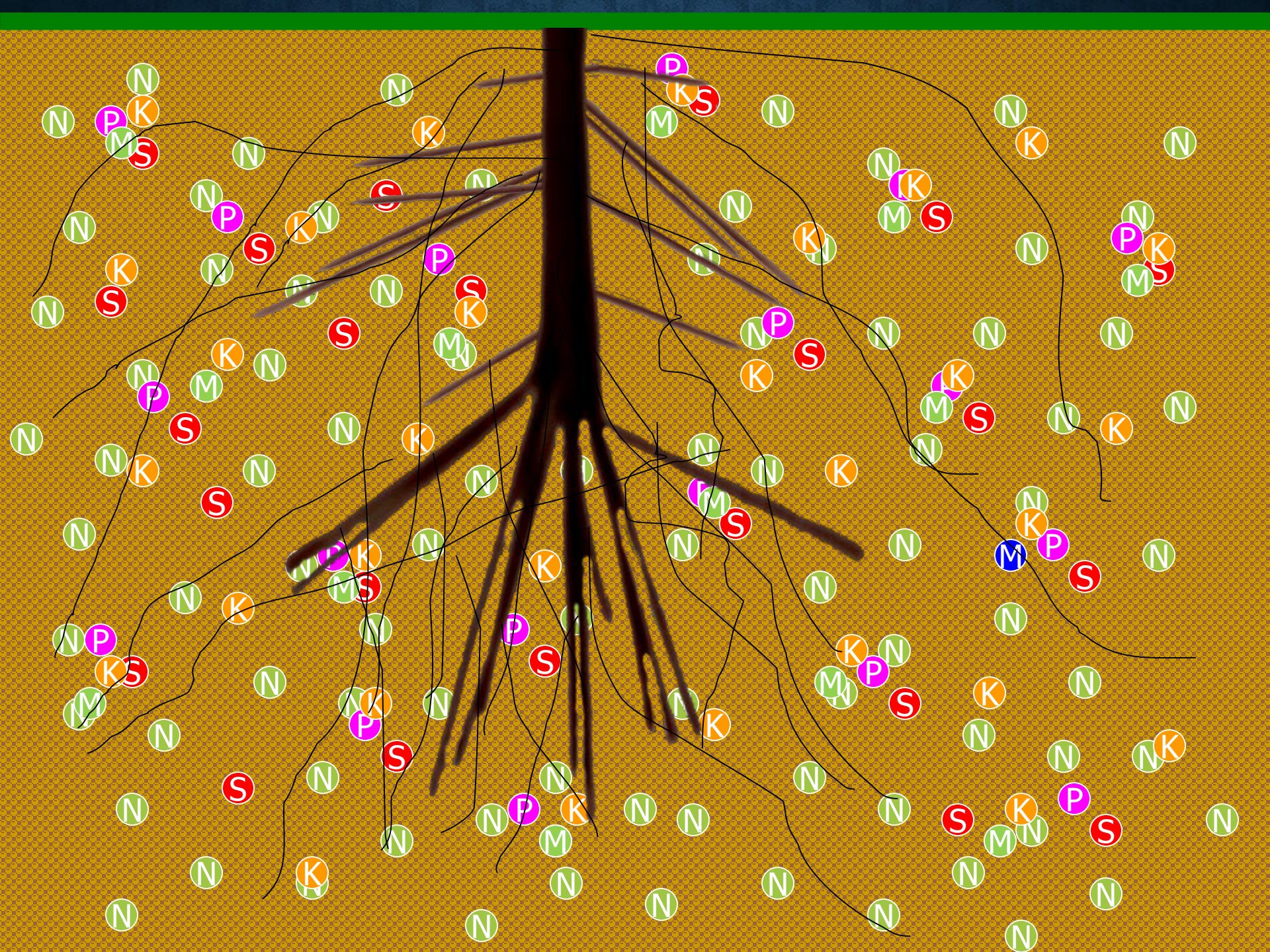


What the plant can access alone?

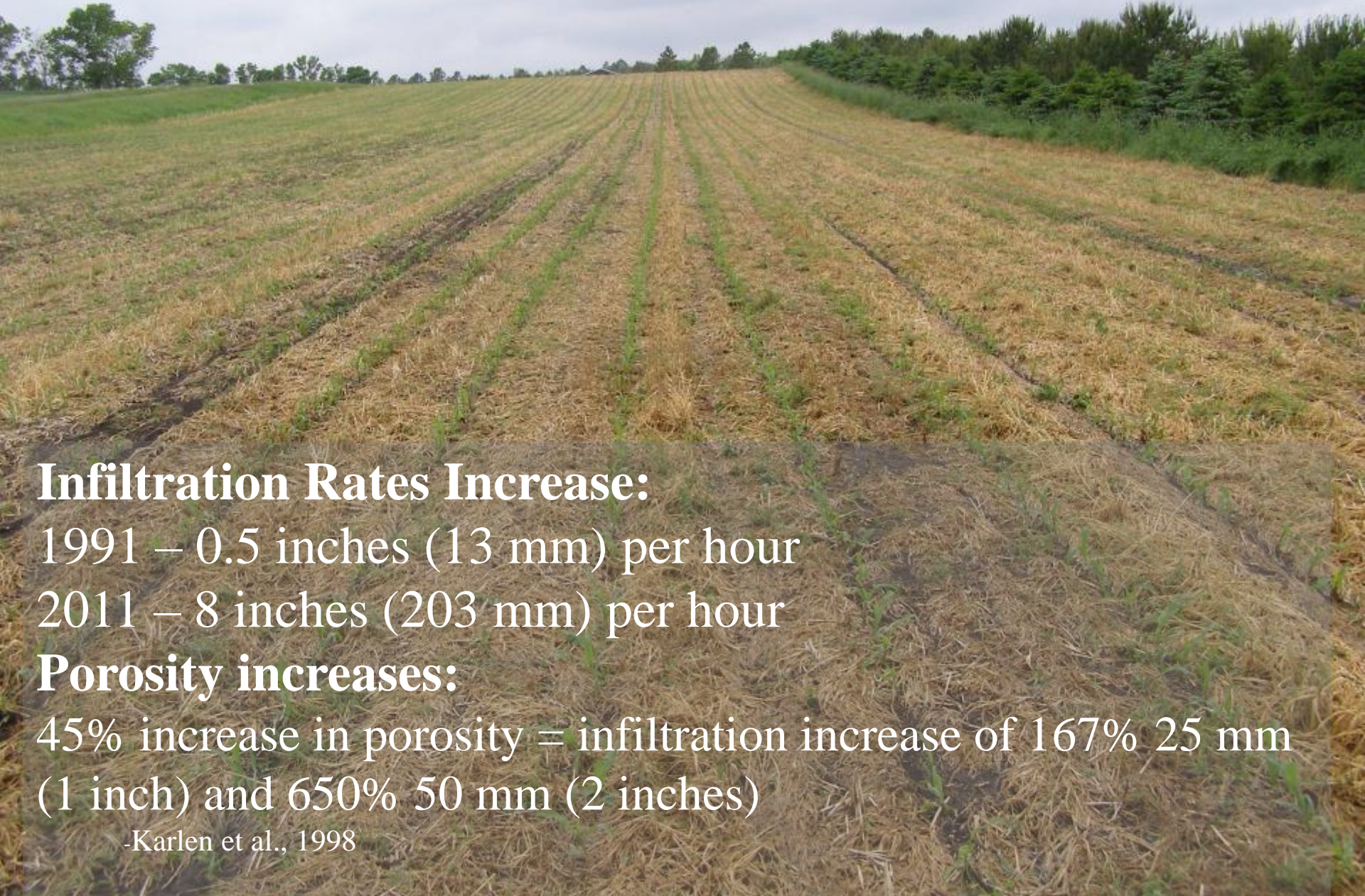


What is actually there?





Brown Ranch near Bismarck, ND after 13.6 inches (330 mm) of rainfall in 24 hrs in June 15, 2009



Infiltration Rates Increase:

1991 – 0.5 inches (13 mm) per hour

2011 – 8 inches (203 mm) per hour

Porosity increases:

45% increase in porosity = infiltration increase of 167% 25 mm (1 inch) and 650% 50 mm (2 inches)

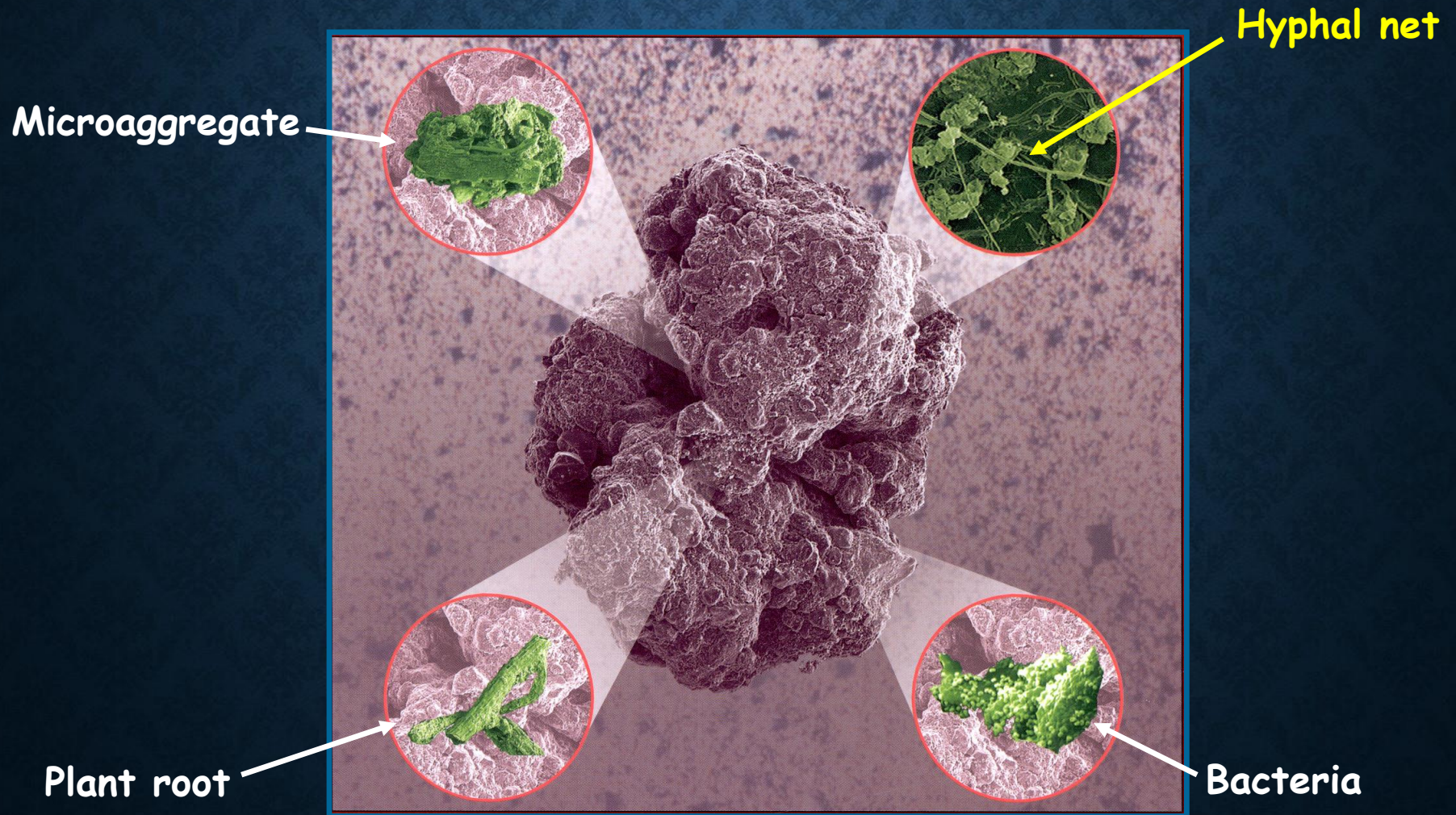
-Karlen et al., 1998

Water Use Efficiency

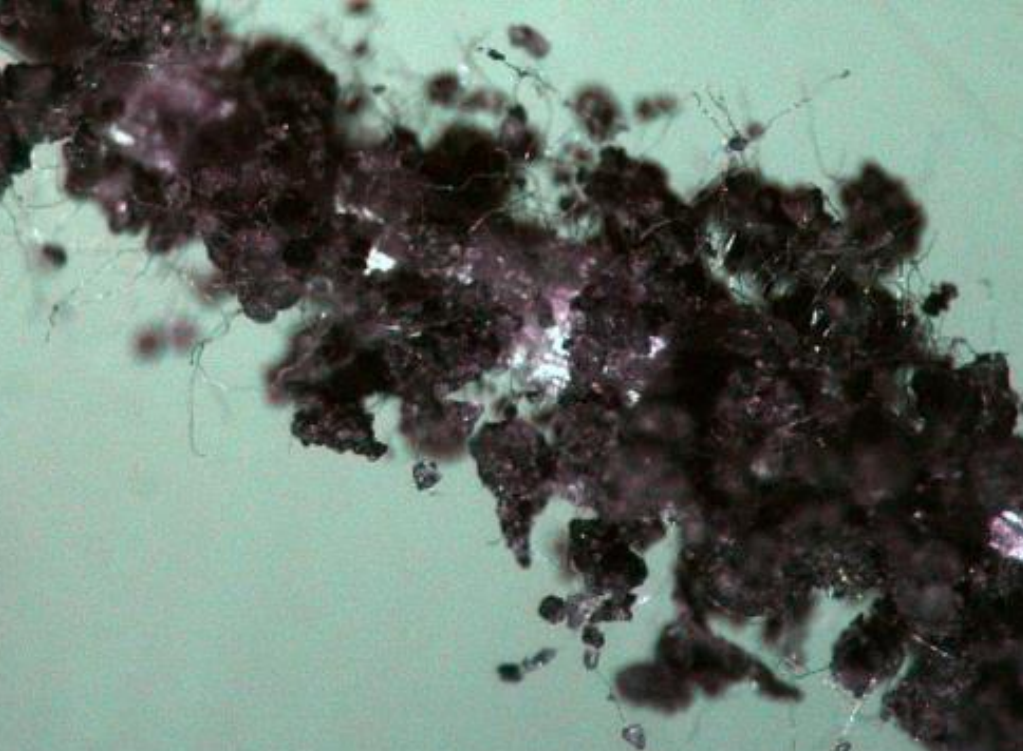
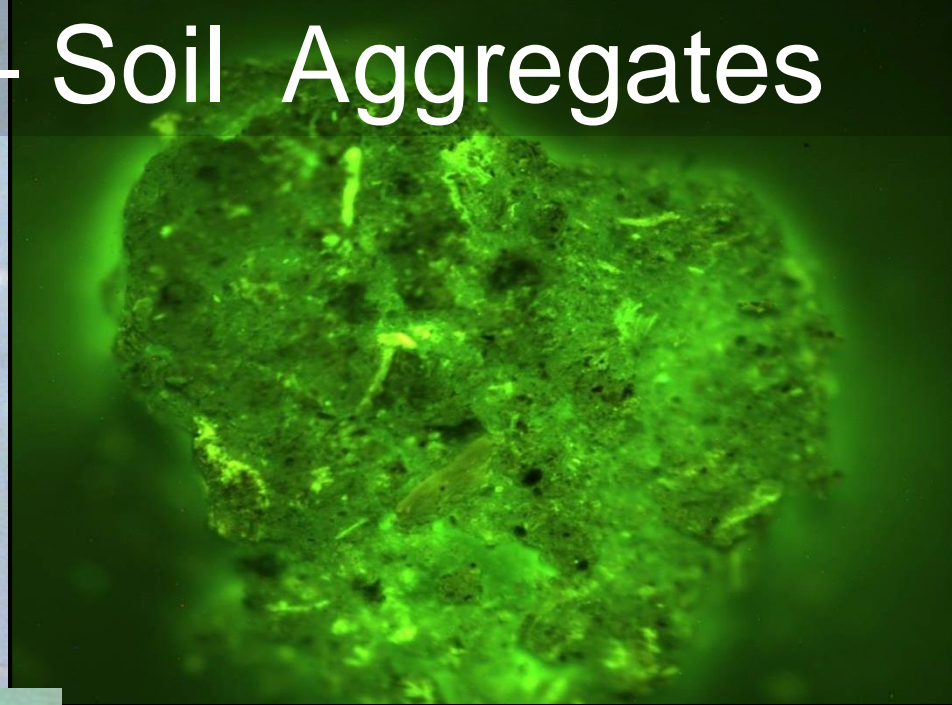
- The Drought Myth - a case of plant hunger rather than thirst - unfertilized corn required 26,000 gallons of water per bushel yielded 4X less than a fertilized field receiving only 5,600 gallons of water per bushel. – W.A. Albrecht, 2000
- Seven-way cover crop mix yield almost 3 times higher than of 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
- 45% greater porosity increases infiltration rate by 167% for the first inch and 650% for the second inch - Karlen et al., 1998
- Loose soil has a slower rate of drying compared to packed soil, because the water films are discontinuous and moisture is not readily conducted to the surface.



AGGREGATE STRUCTURE



Soil Architecture – Soil Aggregates



WHAT MAKES SOIL AGGREGATES?

Chemistry, Biology, and Physics Collide

Biological Components



Plant roots



Mycorrhizal hyphae



Organic matter (Humics)



Polysaccharides



Glomalin



Particulate Organic Matter



Bacterial Colony

Chemical Components



Clay minerals



Sand



Cations – Fe, Al, Ca

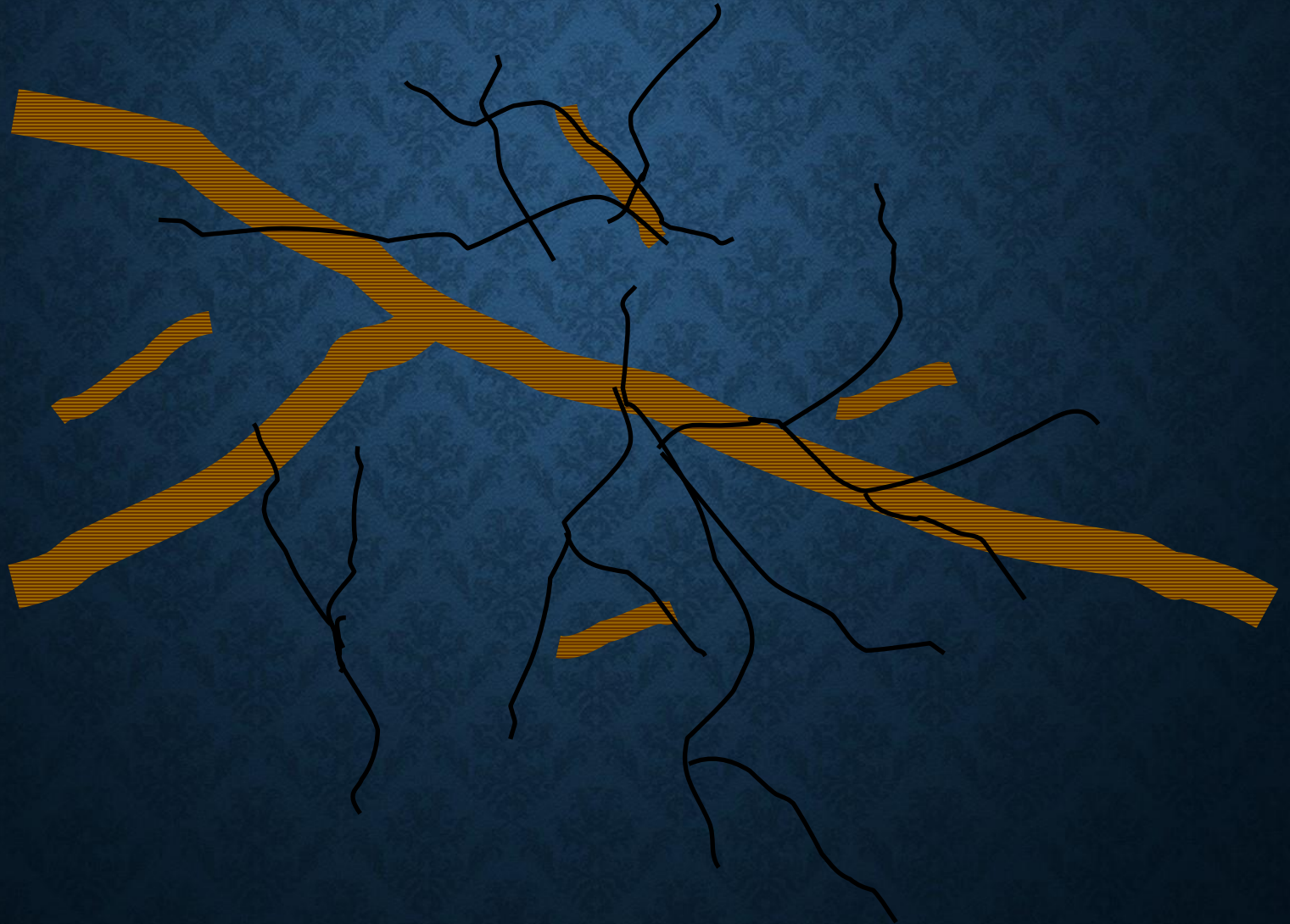


Silt



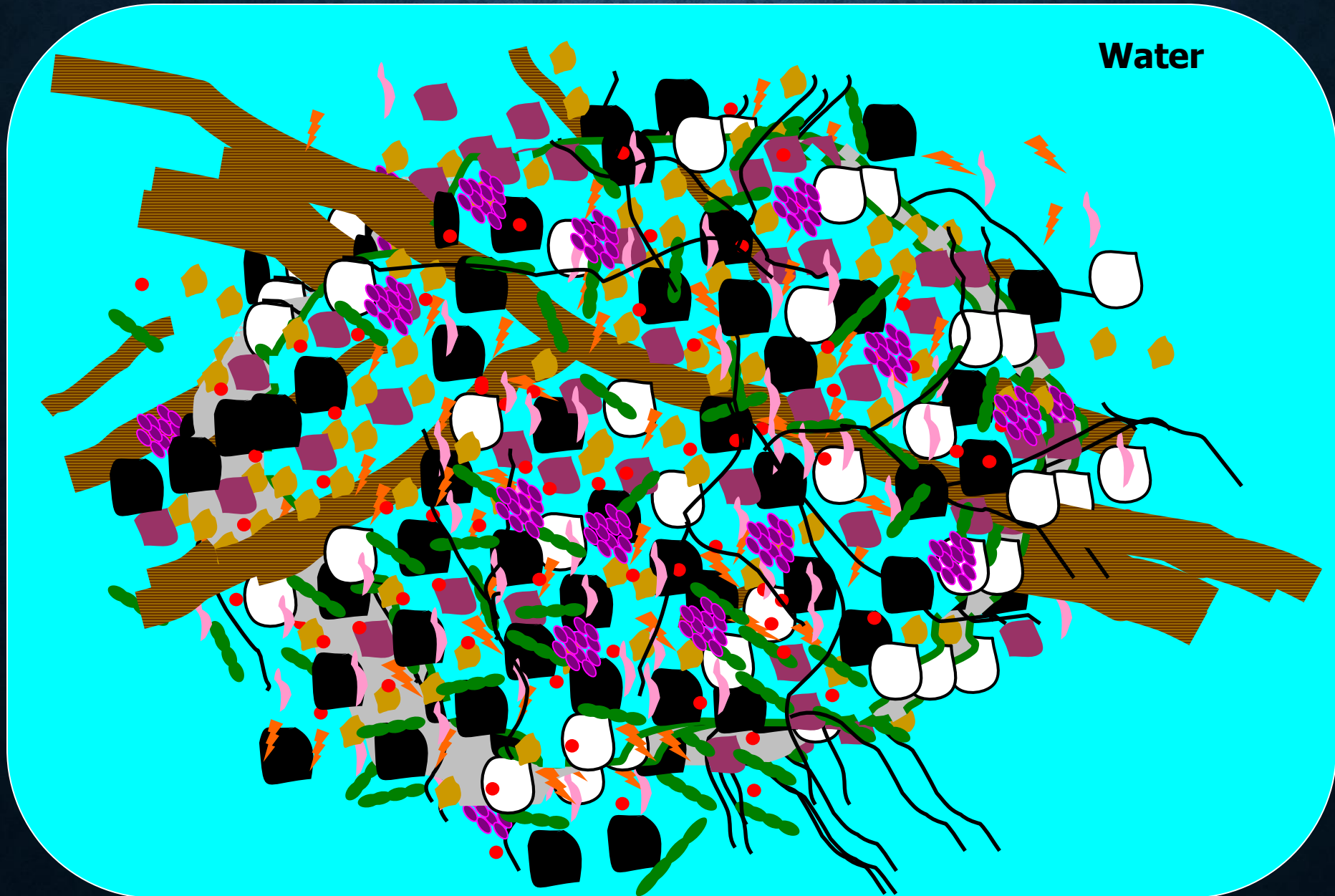
Pore Space

Microbial Engineering





AGGREGATE STABILIZATION MODEL



Aggregate Stability



WSA = 14%

CT, SW-F



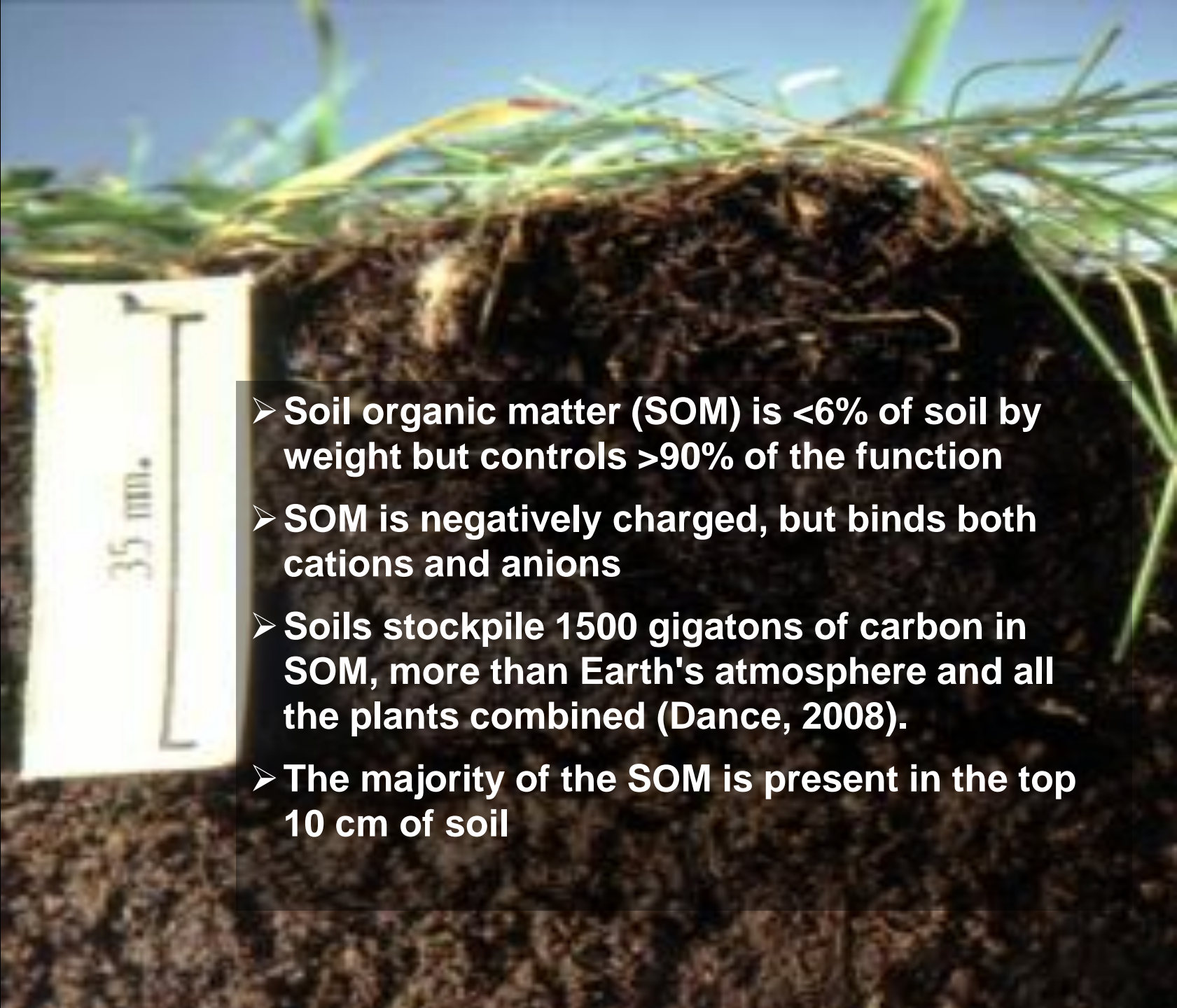
WSA = 47%

NT, SW-WW-SF



WSA = 93%

**Moderately-grazed
pasture**



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

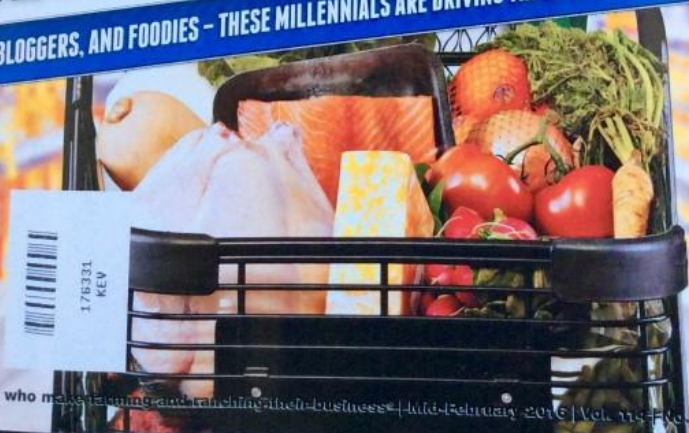
INSIDE: WHY IT'S CRITICAL THAT FARMERS SHOULD INVEST IN SOIL HEALTH. P.4

Successful Farming



MEET YOUR NEW BOSS

MOMS, BLOGGERS, AND FOODIES - THESE MILLENNIALS ARE DRIVING THE NEW FOOD AND AG ECONOMY.



For families who make farming and ranching their business | Mid-February 2016 | Vol. 114 | No. 3 | Agriculture

GLEANNINGS

Compiled by Gene Johnston

YOUR NEW BOSS: THE CONSUMER

What consumers, primarily women, say and do regarding food and food trends.

ABOUT GMOs

66% support mandatory labeling

40% reduce or avoid GMO ingredients (up 10% since 2010)

48% say GMO-free is important in food decisions

ABOUT PAYING MORE

25% is how much extra they will pay for food they see as fresher, healthier, and more nutritious

ABOUT THE INTERNET

45% use it for recipe information

ABOUT ORGANICS

73% buy at least occasionally (up from 55% in 2000)

SODA SALES HAVE DROPPED 25% SINCE 1998, replaced mostly by bottled water

AND THOSE DARN MILLENNIALS (UNDER 35):

76% buy local foods (up 20% in two years)

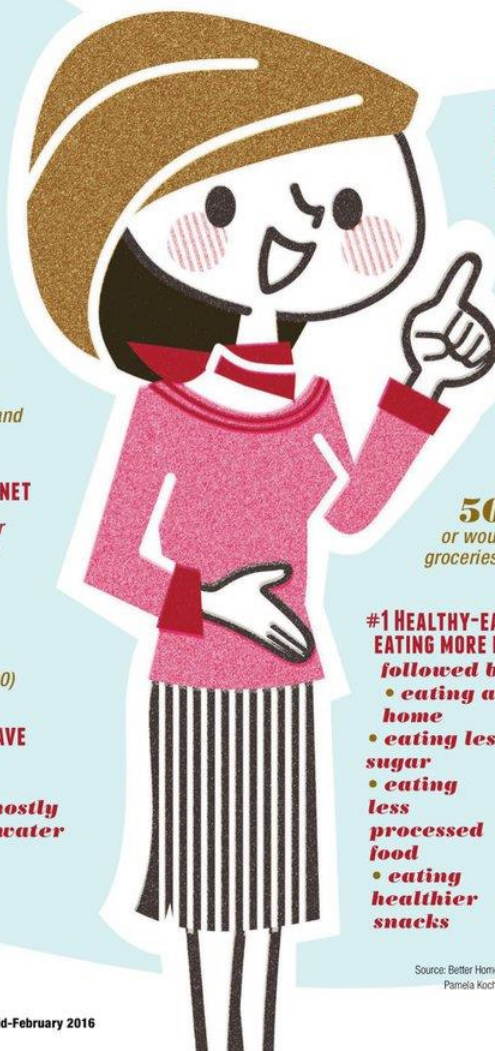
81% are willing to pay a premium for foods with a health benefit

50% have or would buy groceries online

#1 HEALTHY-EATING STRATEGY IS EATING MORE FRUITS AND VEGGIES

- followed by
- eating at home
 - eating less sugar
 - eating less processed food
 - eating healthier snacks

For more on the rapidly changing food trends, see "Meet Your New Boss" starting on page 26.



Source: Better Homes and Gardens®, The Hartman Group, Mintel Group, Pamela Koch with Columbia University, and The Nielsen Company

YOUR NEW BOSS: THE CONSUMER

What consumers, primarily women, say and do regarding food and food trends.

ABOUT GMOs

66% support mandatory labeling

40% reduce or avoid GMO ingredients (up 10% since 2010)

48% say GMO-free is important in food decisions

ABOUT PAYING MORE

25% is how much extra they will pay for food they see as fresher, healthier, and more nutritious

ABOUT THE INTERNET

45% use it for recipe information

ABOUT ORGANICS

73% buy at least occasionally (up from 55% in 2000)

AND THOSE DARN MILLENNIALS (UNDER 35):

76% buy local foods (up 20% in two years)

81% are willing to pay a premium for foods with a health benefit

50% have or would buy groceries online

#1 HEALTHY-EATING STRATEGY IS EATING MORE FRUITS AND VEGGIES followed by
• eating at



2019 Canadian Food Guide

Have plenty of
vegetables and fruits

Eat protein foods

Make water
your drink
of choice



Choose
whole grain
foods

Have plenty of
vegetables and fruits

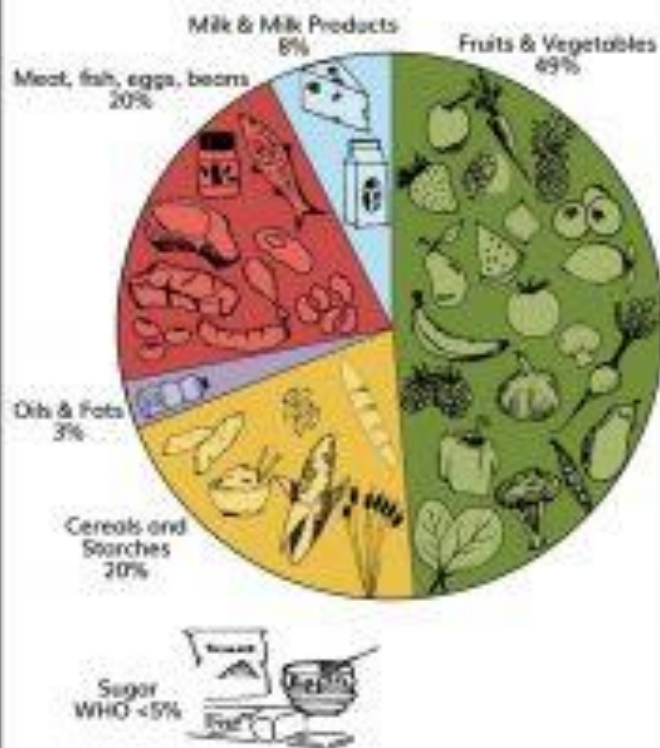
Eat protein foods

Make water
your drink
of choice

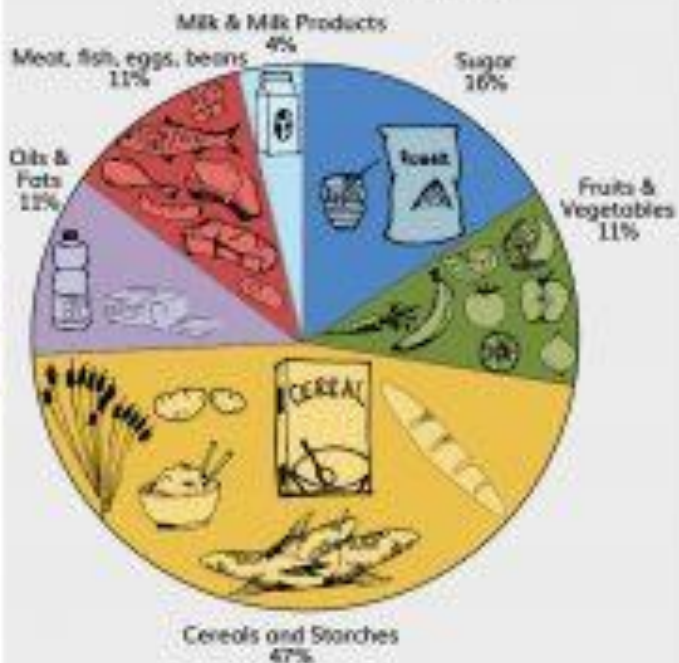


Or
whole

What we should be eating
(Harvard's Healthy Eating Plate Model)



What we are actually producing
(According to 2011 FAO)



Evan Fraser, Guelph,
FBS analysis, 2015

How Healthy Is the American Diet?



59

The Healthy Eating Index Score

shows that Americans do not align their eating choices with the Dietary Guidelines.
(on a scale from 0-100)

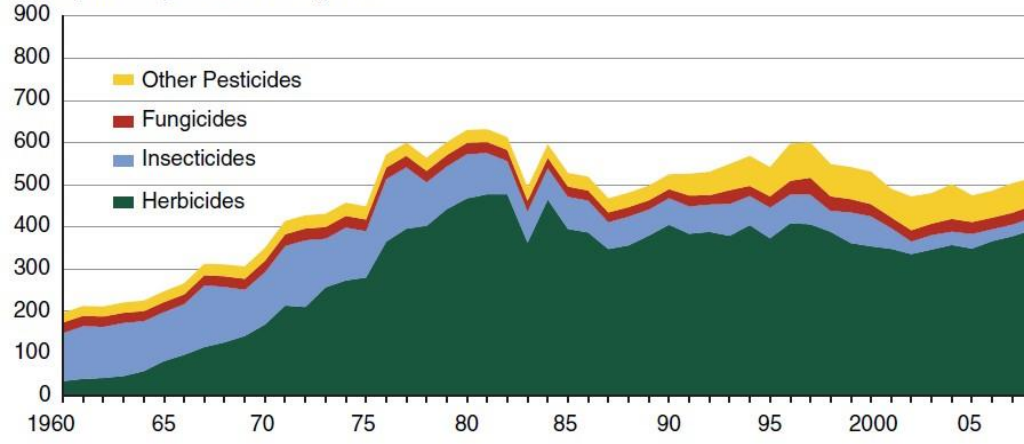


Data source for Healthy Eating Index scores: What We Eat in America, National Health and Nutrition Examination Survey (undated data are from 2013-2014).

HUMAN HEALTH

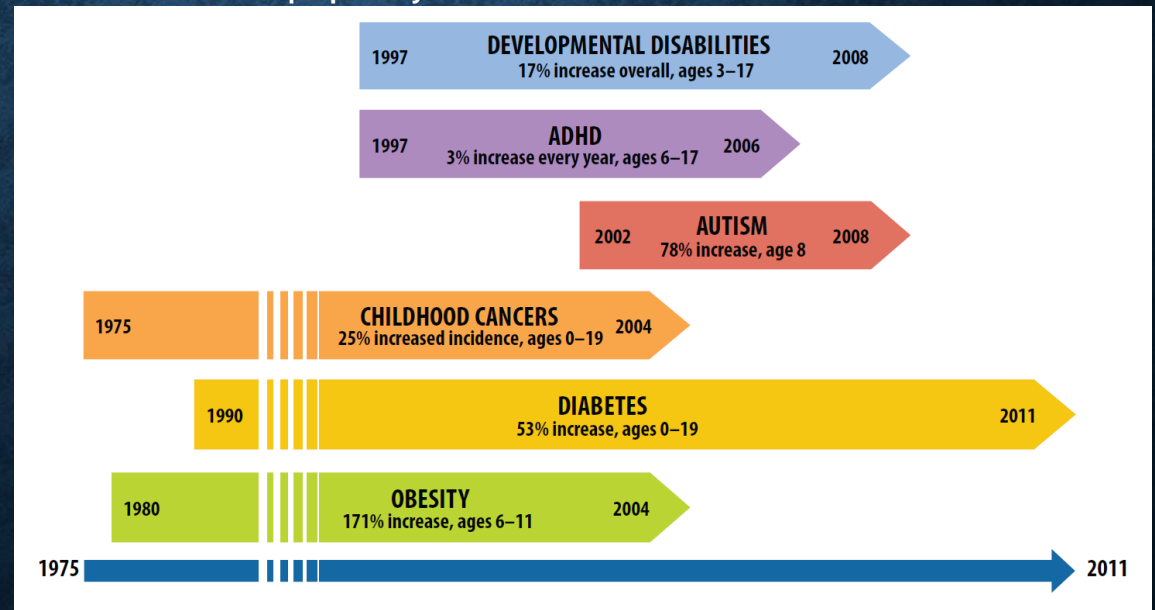
Figure 1
Pesticide use in U.S. agriculture, 21 selected crops, 1960-2008

Million pounds of pesticide active ingredient



Source: Economic Research Service with USDA and proprietary data

Average person spends about 20-25% on out of pocket healthcare.



Pesticide Action Network North America 2012

Soil Health = Plant Health = Human Health

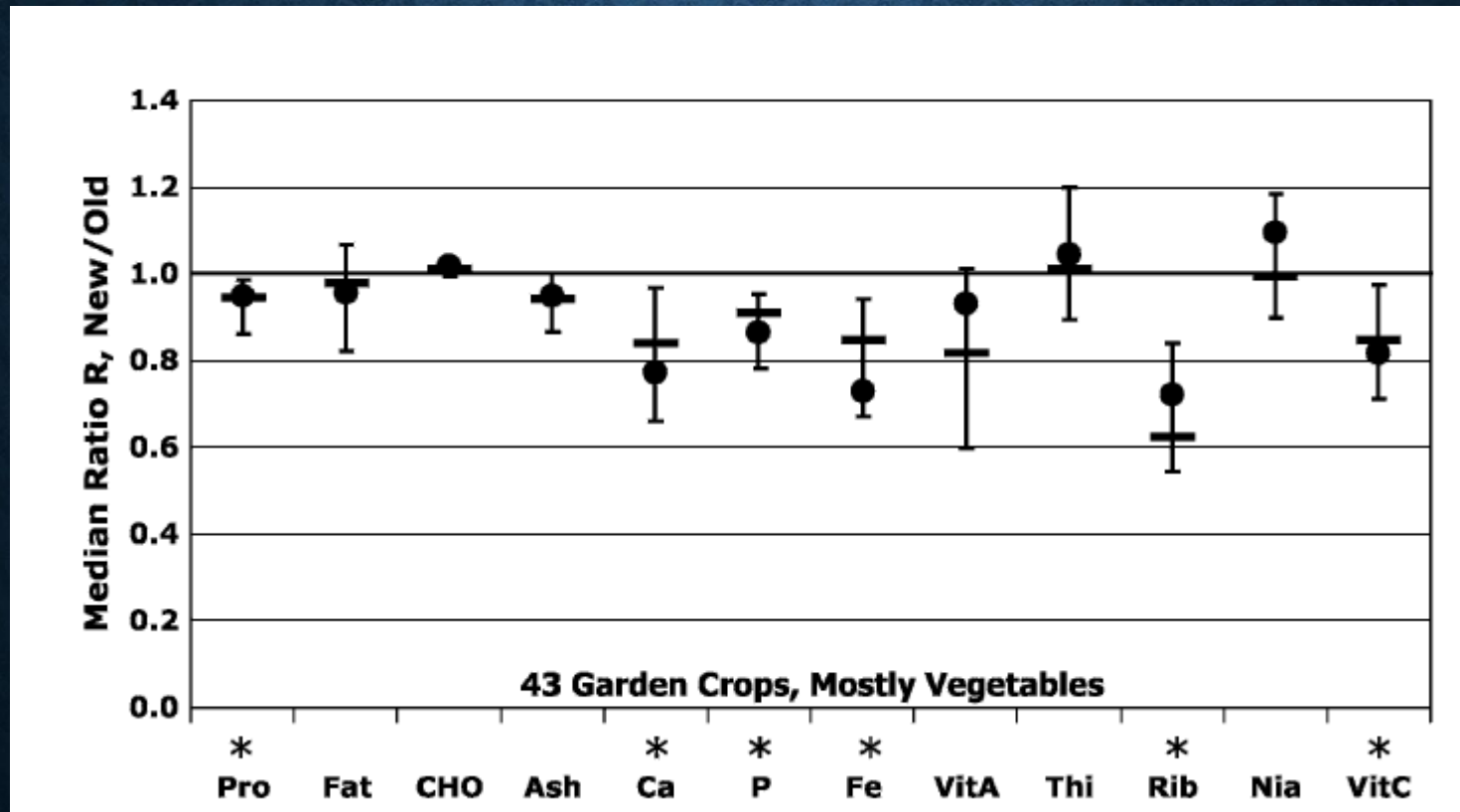


POLYCULTURE SYSTEM – MICROBES AND CROPS

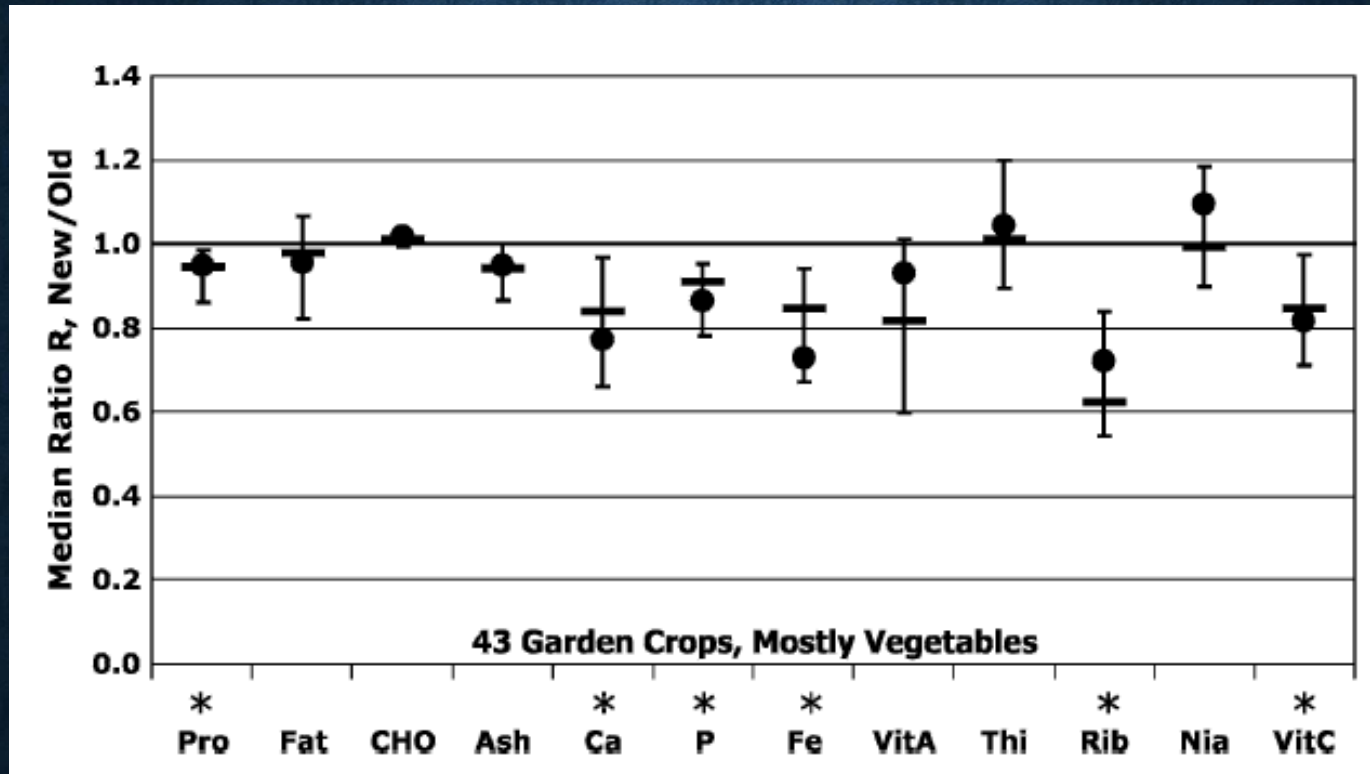


NUTRIENTS AND HEALTH

Change in fruit and vegetable nutrient status from tests in 1950 and 1999.



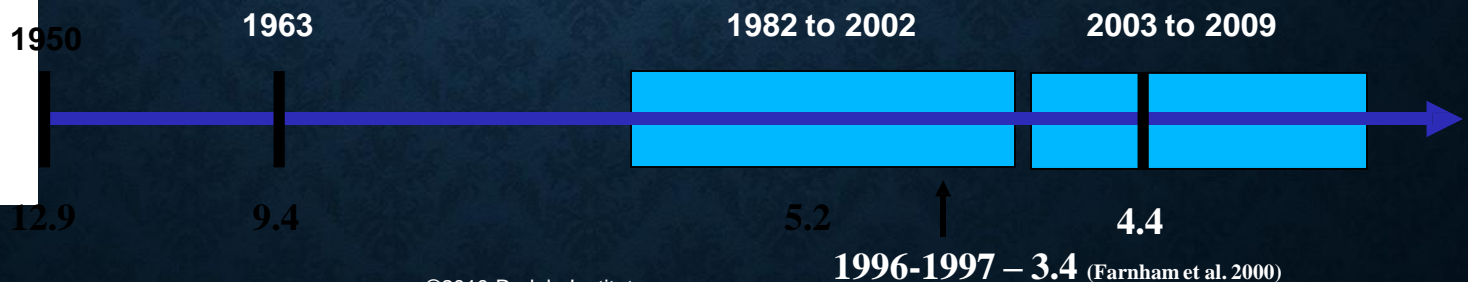
Nutrients and Health



Davis et al. 2004, USDA data, Old-1950:New-1999, from Davis. 2009

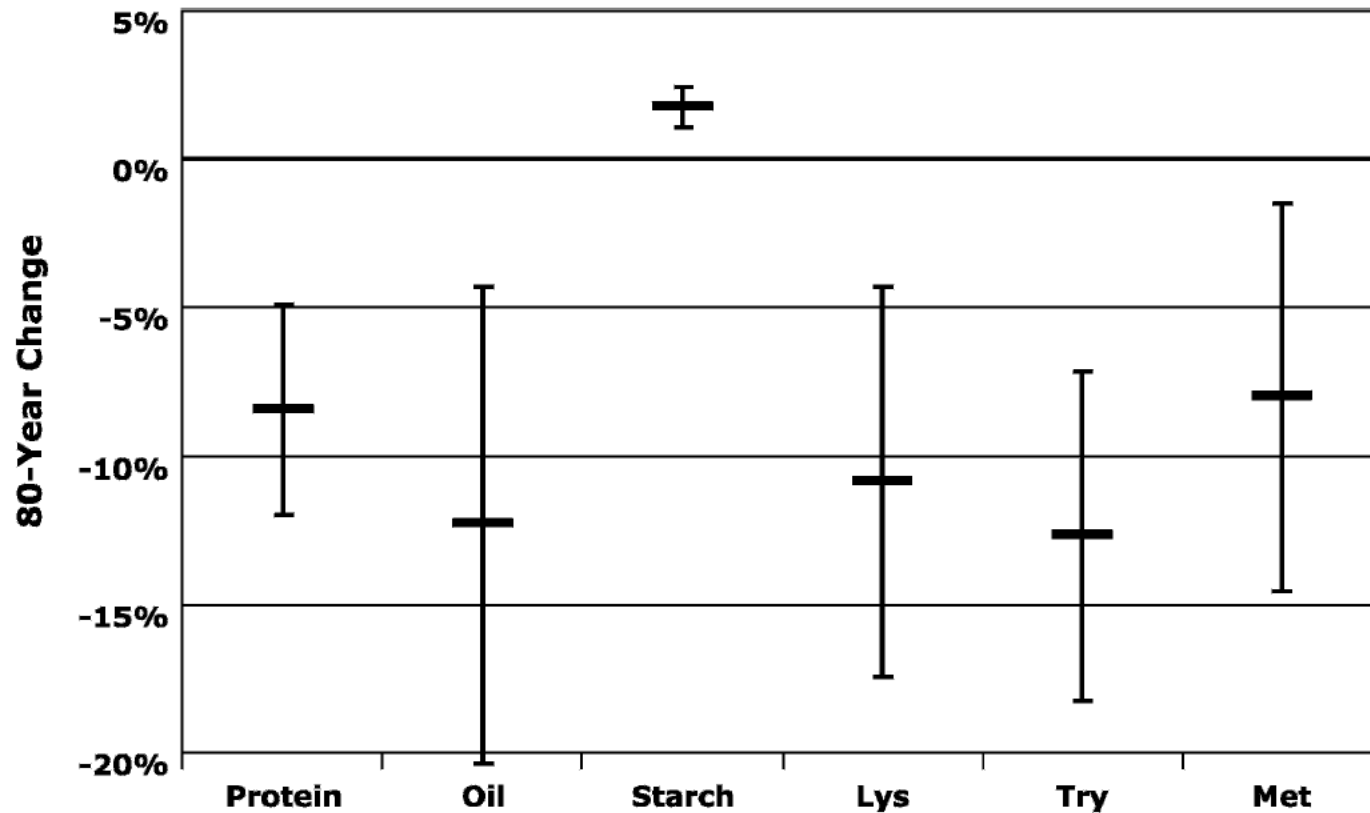


Calcium concentrations in Broccoli (mg/g)



NUTRIENTS AND HEALTH

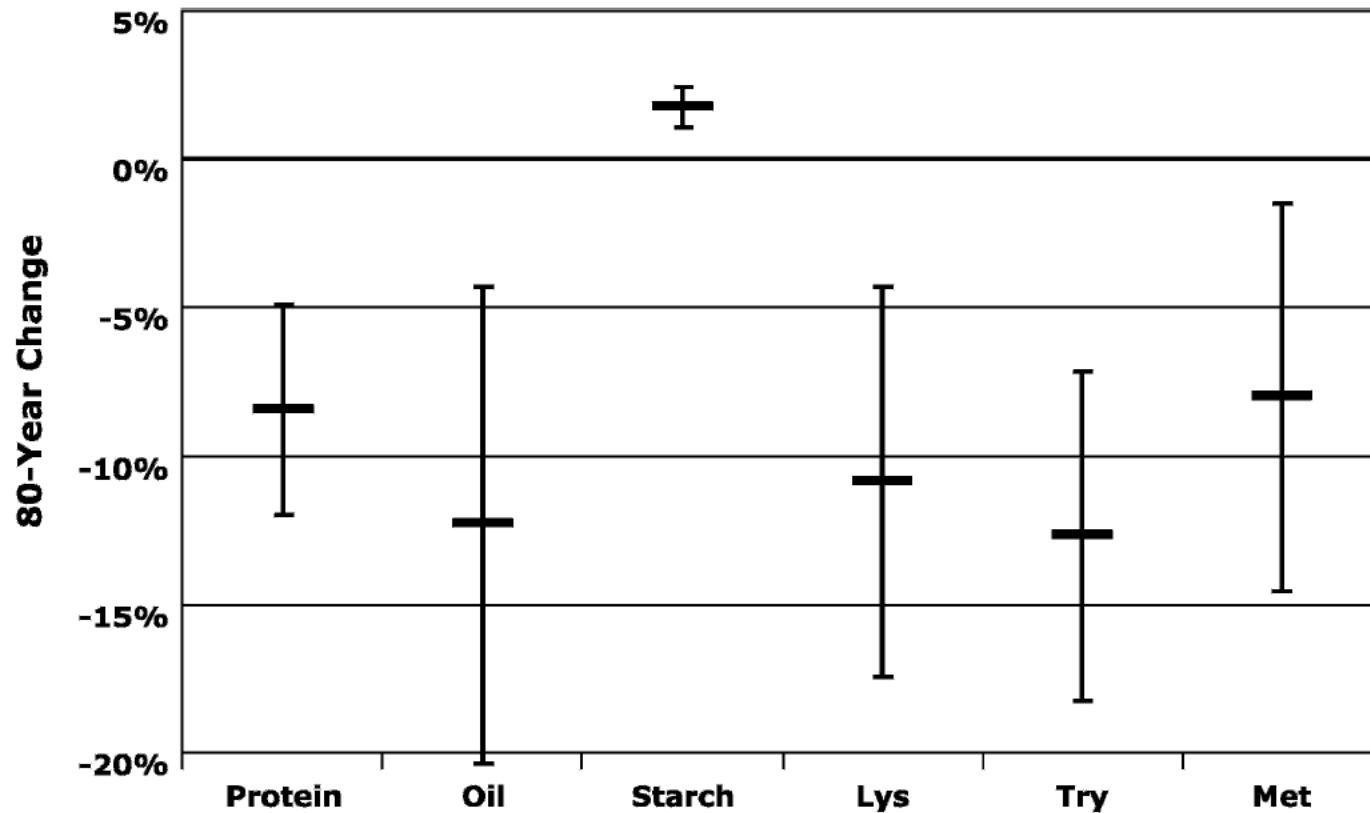
80 year changes in maize nutrient content in 45 varieties released between 1920 and 2001



Davis 2009

NUTRIENTS AND HEALTH

80 year changes in maize nutrient content in 45 varieties released between 1920 and 2001



Davis 2009

GRAZING AND CARBONOMICS





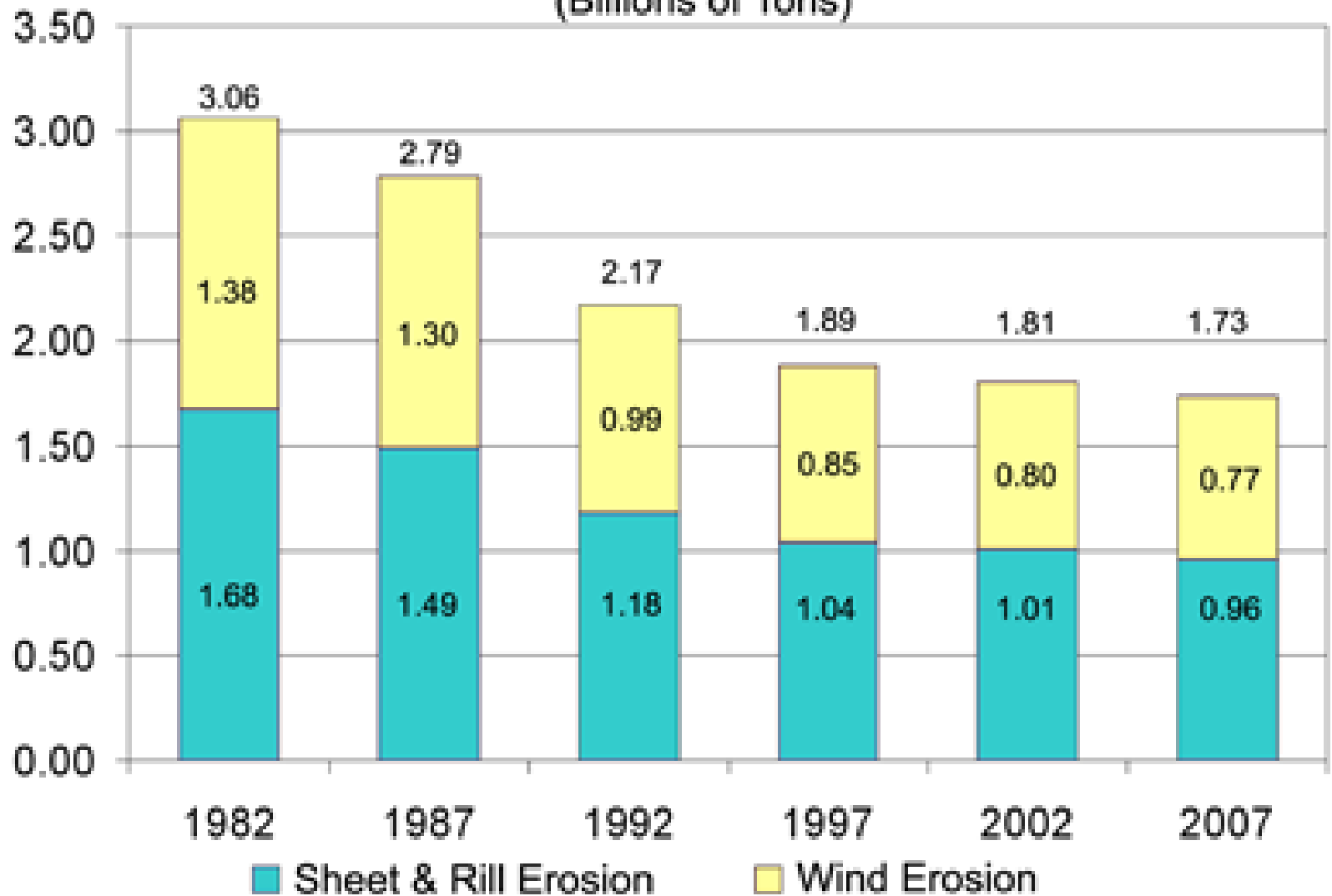


Texas Dust Storms in the 1930's and 2012 – Which is Which?



Erosion on Cropland, by Year

(Billions of Tons)



Cropland includes cultivated and non-cultivated cropland.

Salinity and Sodicity Increasing



**North Dakota
June 16, 2013**



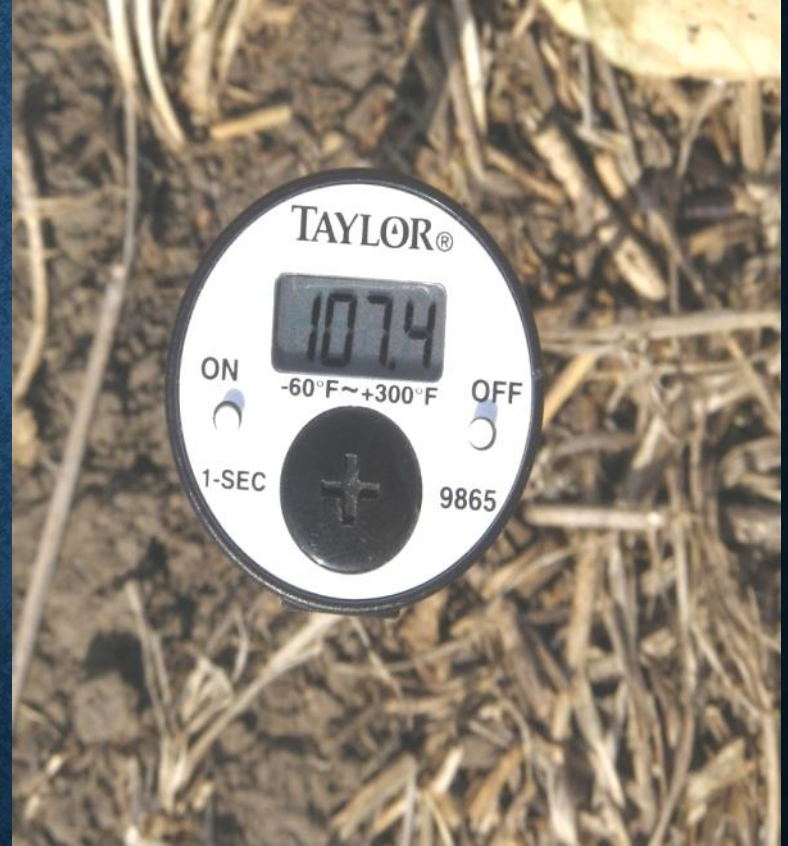
Heat, Evaporation, and Life

Life



93°

Death



112°

Moderate Temperature, Evaporation, and Microbial Health

**It really boils down to this: that all life is interrelated.
We are all caught in an inescapable network of
mutuality, tied into a single garment of destiny.
Whatever affects one destiny, affects all indirectly.**

Martin Luther King Jr., Christmas Eve Serman, 1967



**Dr. Kris Nichols
Soil Microbiologist
Founder and Principal Scientist
KRIS Education and Consultation**

www.KRIS-Systems.com

**Kris@KRIS-Systems.com
glomalin1972@gmail.com**