USDA Natural Resources Conservation Service
Science and Technology

Conservation Webinars

Date	2017 Conservation Webinars Topics
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Aug 21	Use of LiDAR High Resolution Elevation Datasets for Engineering Efficiencies
Sep 11	Implementing Soil Health Management Systems in Vegetable Production of the Southeast US and the Tropics
Sep 18	Ephemeral Gully Erosion: What is it and how do we treat it?
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SREF

Rethinking the Nutrient Management Paradigm for Soil Health

Z. Kabir, Ph.D.

Regional Soil Health Specialist for CA, NV & Pacific Islands Area

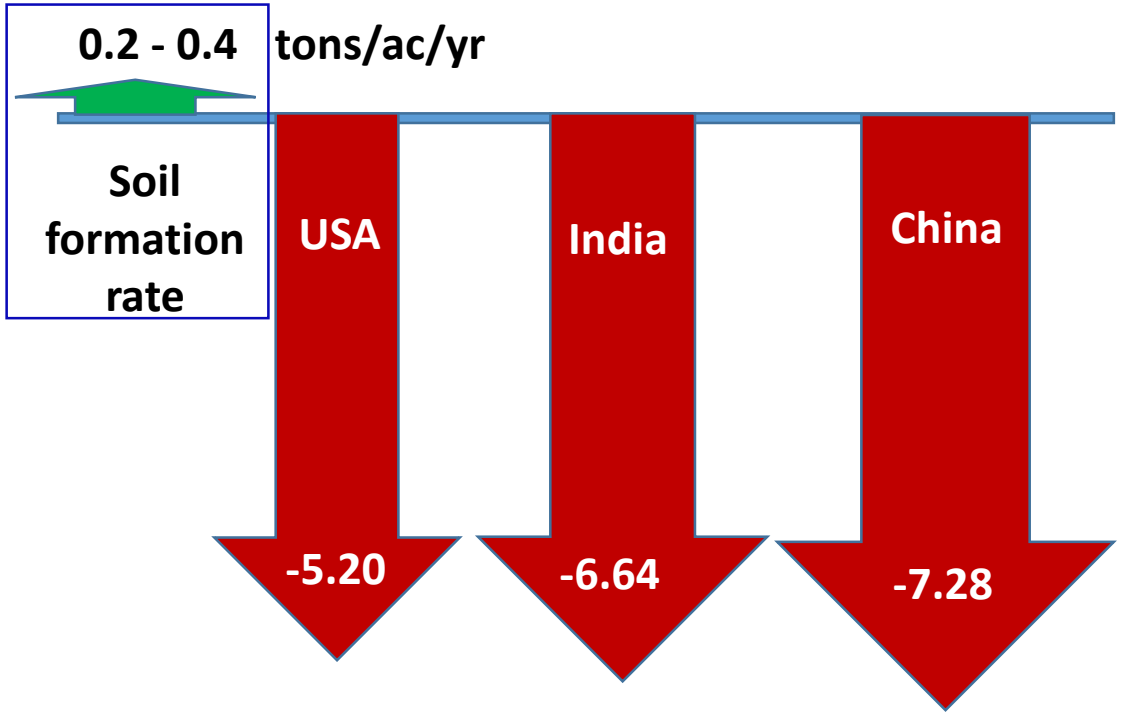
National Soil Health Division, USDA-NRCS

430 G Street, Davis, CA 95616

Outline

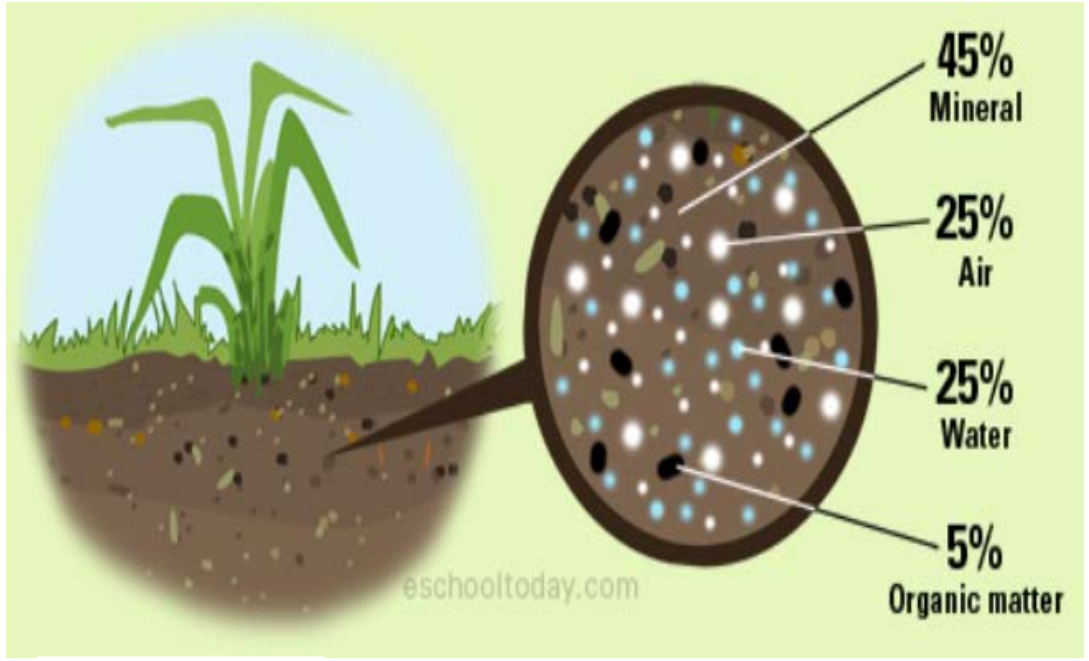
- **Soil erosion**
- **Effect of soil erosion on soil organic matter and nutrients**
- **Effect of nutrient loss on water pollution**
- **Nitrogen and phosphorus balance**
- **Dominant nutrient management paradigm**
- **4R strategies for nutrient management**
- **Holistic approach of nutrient management for soil health**

Soil Loss from Water and Wind Erosion



Adapted from D. Johnson

A Typical Soil before Degradation

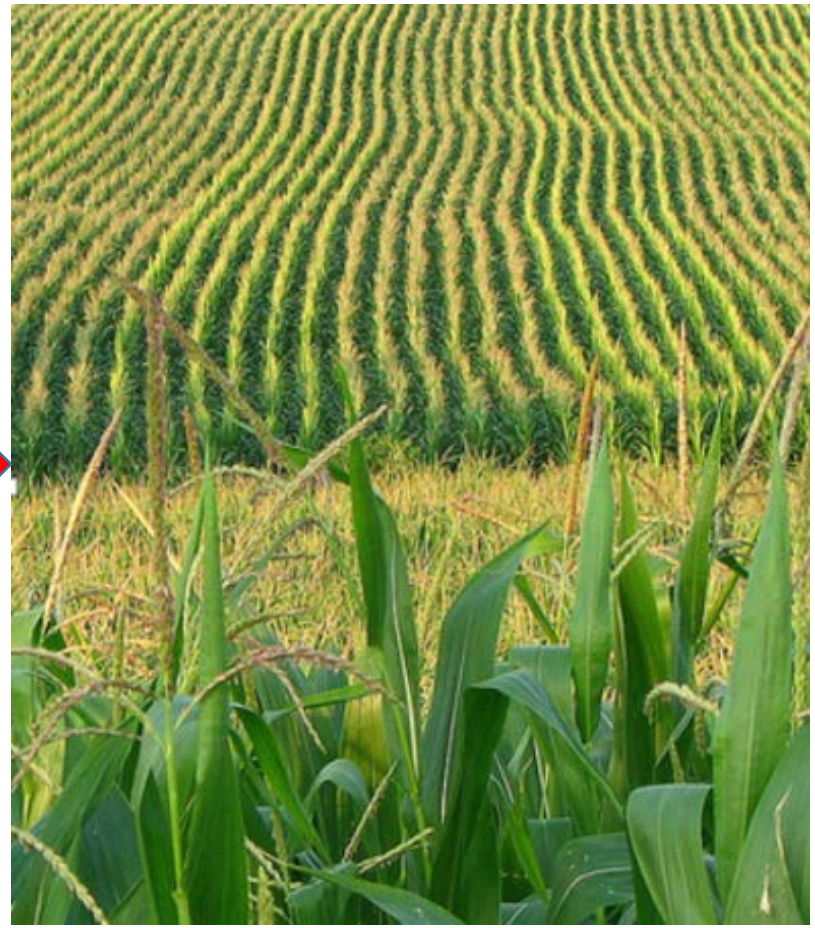


eschooltoday.com

This is an ideal soil; however, in our soil, proportions are changing by intensive Ag practices causing:

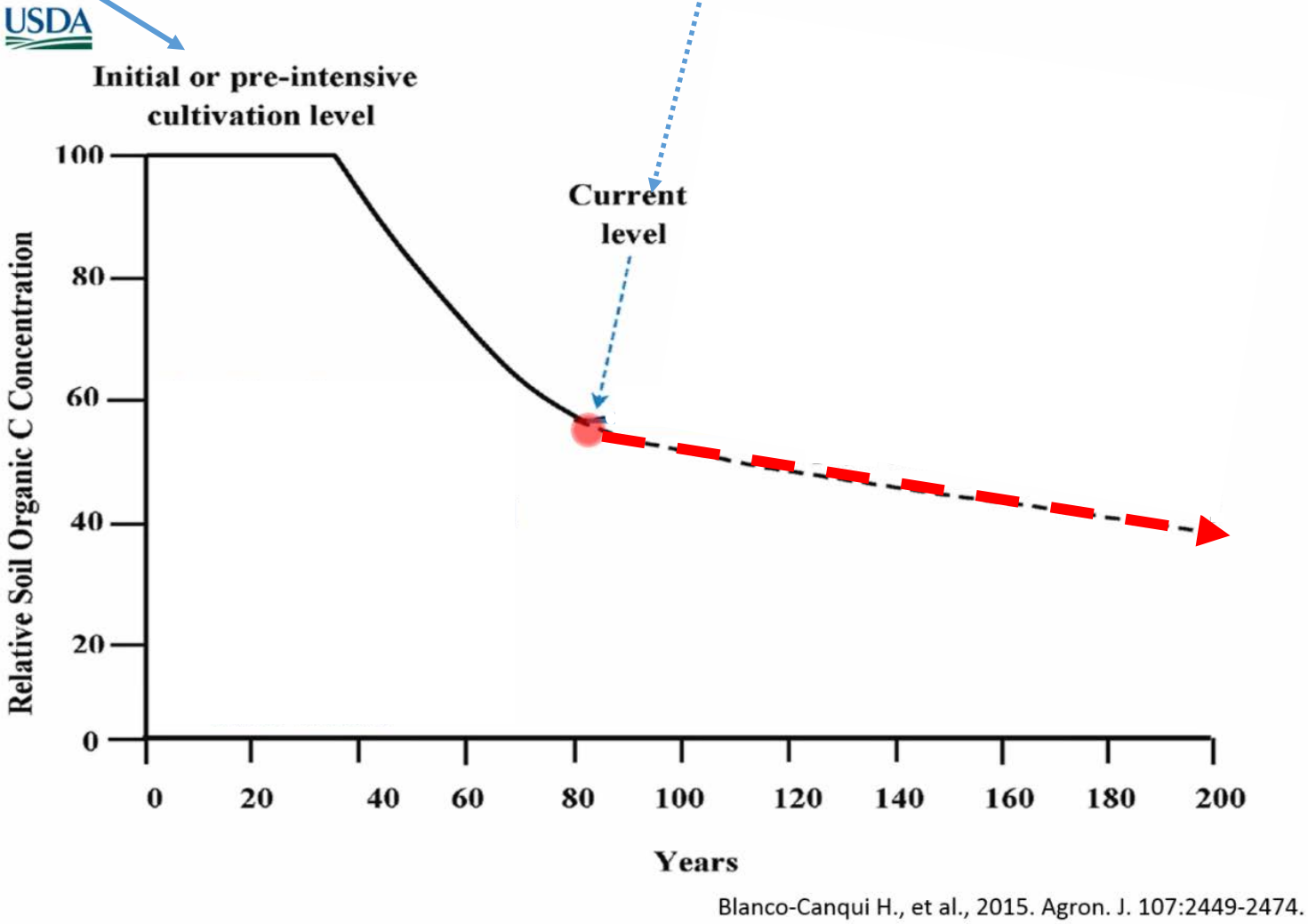
- **Organic matter depletion,**
- **Compaction**
- **Aggregate instability**
- **Disappearing soil life**

Tallgrass Prairies are the most productive ecosystems in USA

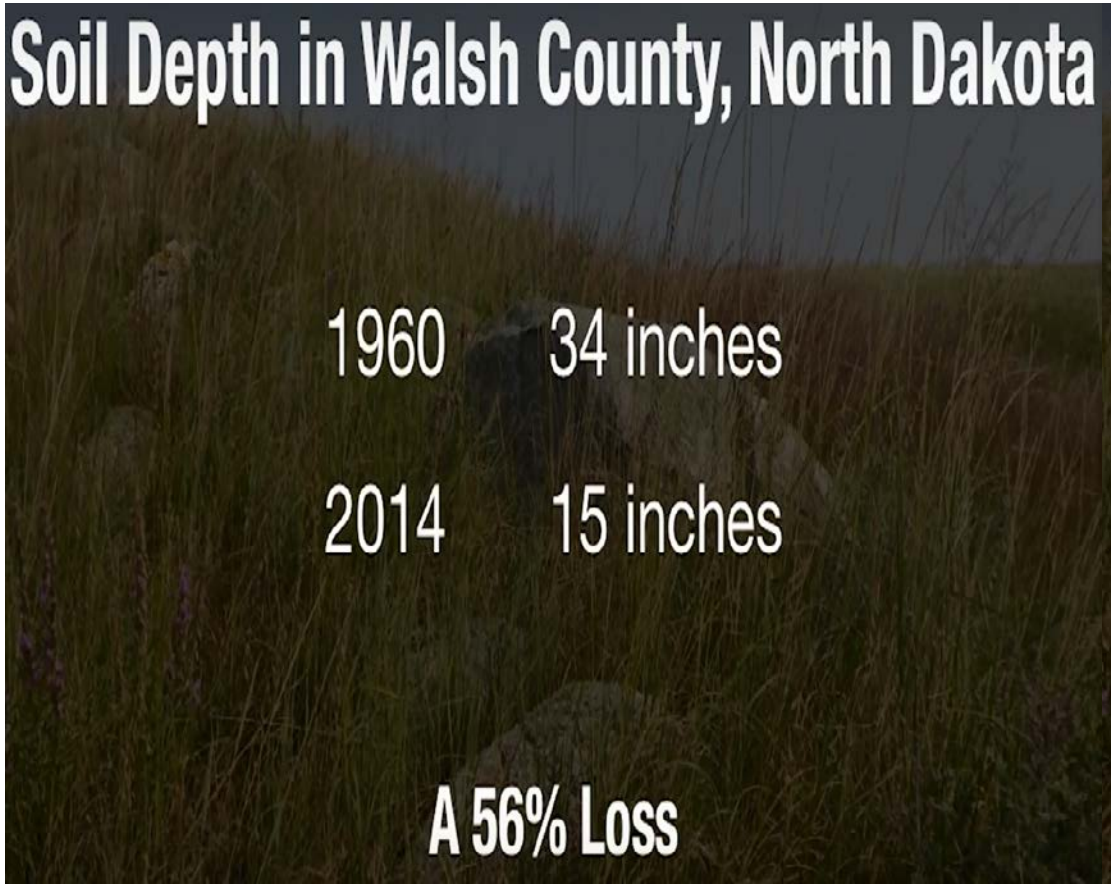


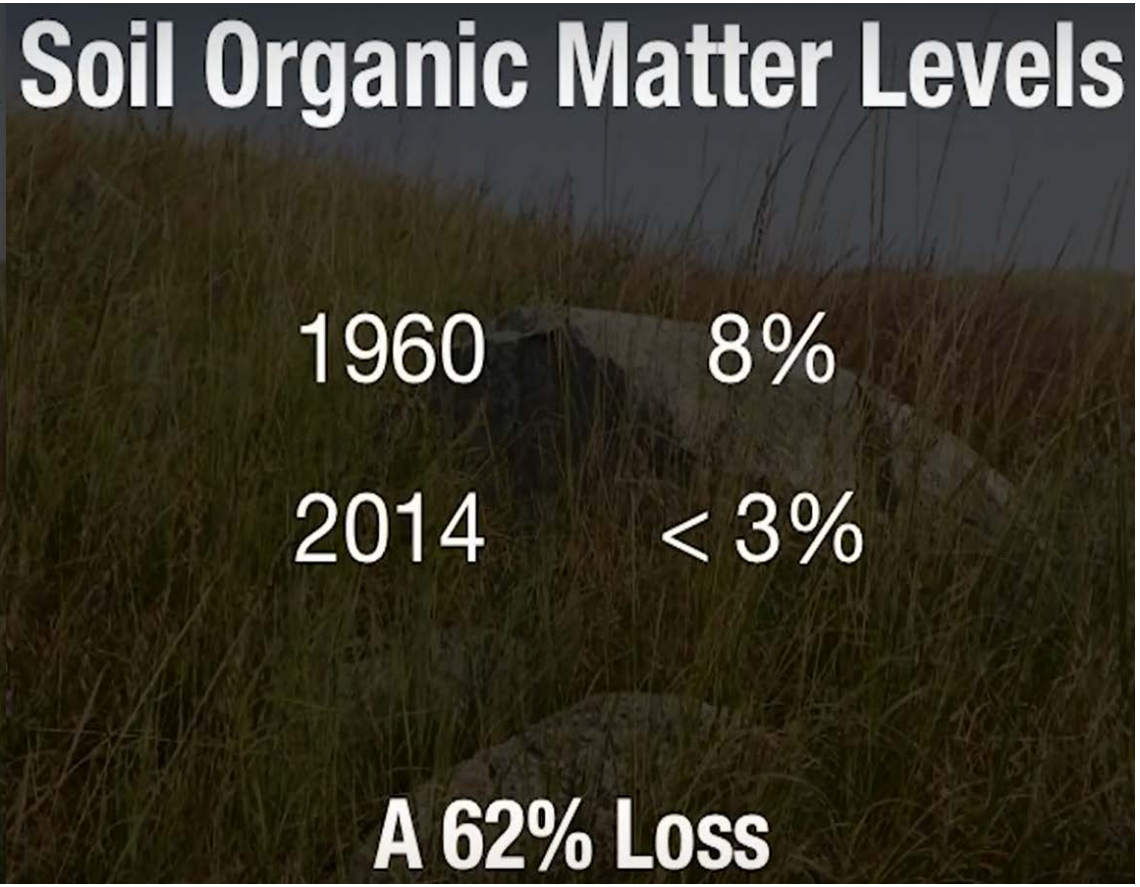
Mono Culture and Intensive Ag Practices

Tallgrass Prairies are the most productive ecosystems in USA



Blanco-Canqui H., et al., 2015. Agron. J. 107:2449-2474.





NDSU adapted from Gabe Brown

More Chemicals and Intensive Tillage

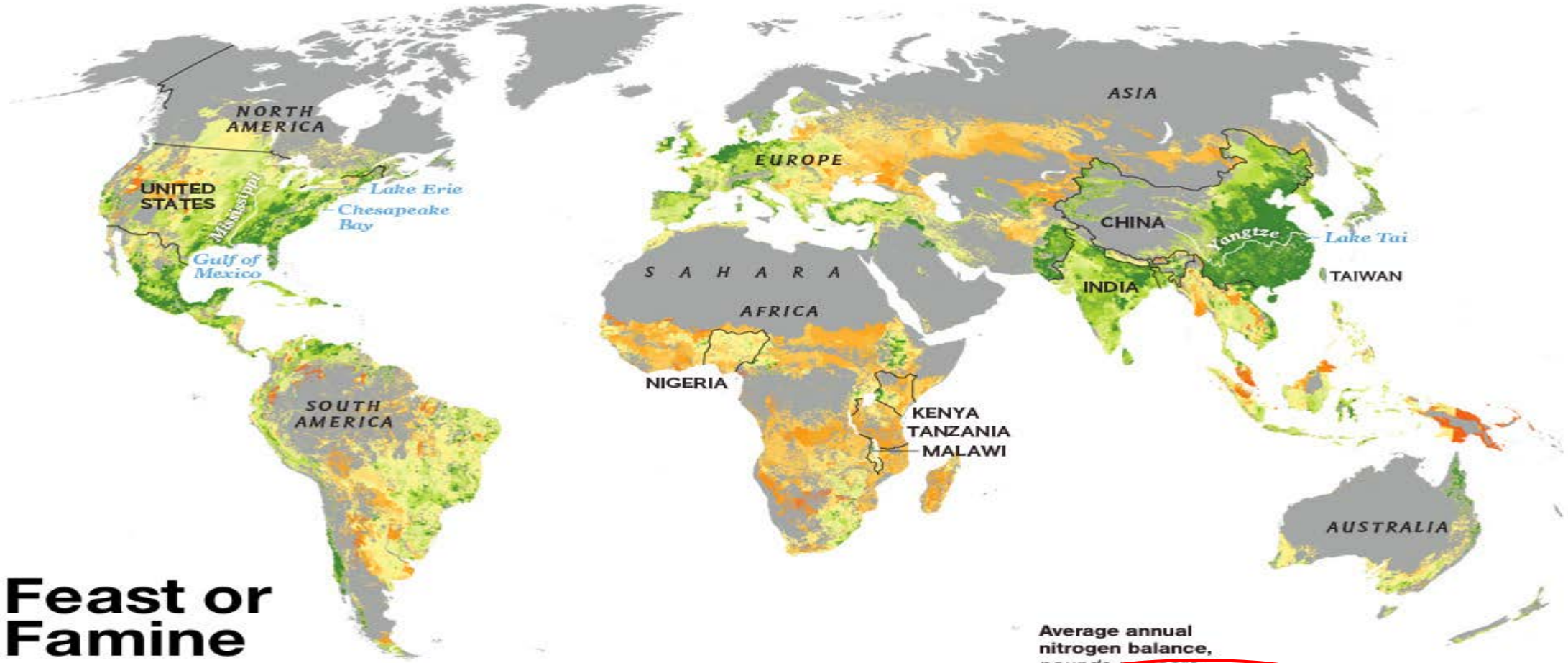
Essential Elements in Plant

Element type	Element	Conc. (%)	
Non-mineral	**Carbon** **Hydrogen** **Oxygen**	**45** **6** **45**	
Primary macro	**Nitrogen** **Phosphorus** **Potassium**	**1-5** **0.1-0.5** **0.5-1**	
Secondary macro	**Ca** **Mg** **S**	**0.1-0.5** **0.1-0.4** **0.1-0.4**	
Micro	**Cl** **Fe** **Mn** **B** **Zn** **Cu** **Mo** **Ni**	**0.01-0.1** **50-250 ppm** **20-200ppm** **6-60ppm** **25-150ppm** **5-20ppm** **0.05-0.2ppm** **0.1-1ppm**	

Nitrogen (N) and Phosphorus (P)

- **N and P are the two most limiting nutrients for biological production**
- **N and P are extensively applied for crop production**
- **Almost all nutrient related pollution is due to N & P**

Global Nitrogen Balance



Feast or Famine

Nearly half the people on the planet wouldn't be alive if not for the abundant food made possible by nitrogen fertilizer. Yet its benefits have not reached everyone. In sub-Saharan Africa, where 239 million people go hungry in a year, crops fail as soil is stripped of nutrients, and farmers can't afford to buy fertilizer. Elsewhere overuse pollutes waterways and releases greenhouse gases.

JEROME N. COOKSON AND LAWSON PARKER, NGM STAFF
SOURCE: PAUL C. WEST, INSTITUTE ON THE ENVIRONMENT, UNIVERSITY OF MINNESOTA

Average annual nitrogen balance, *pounds per acre*

Deficiency — Excess

-200 0 220

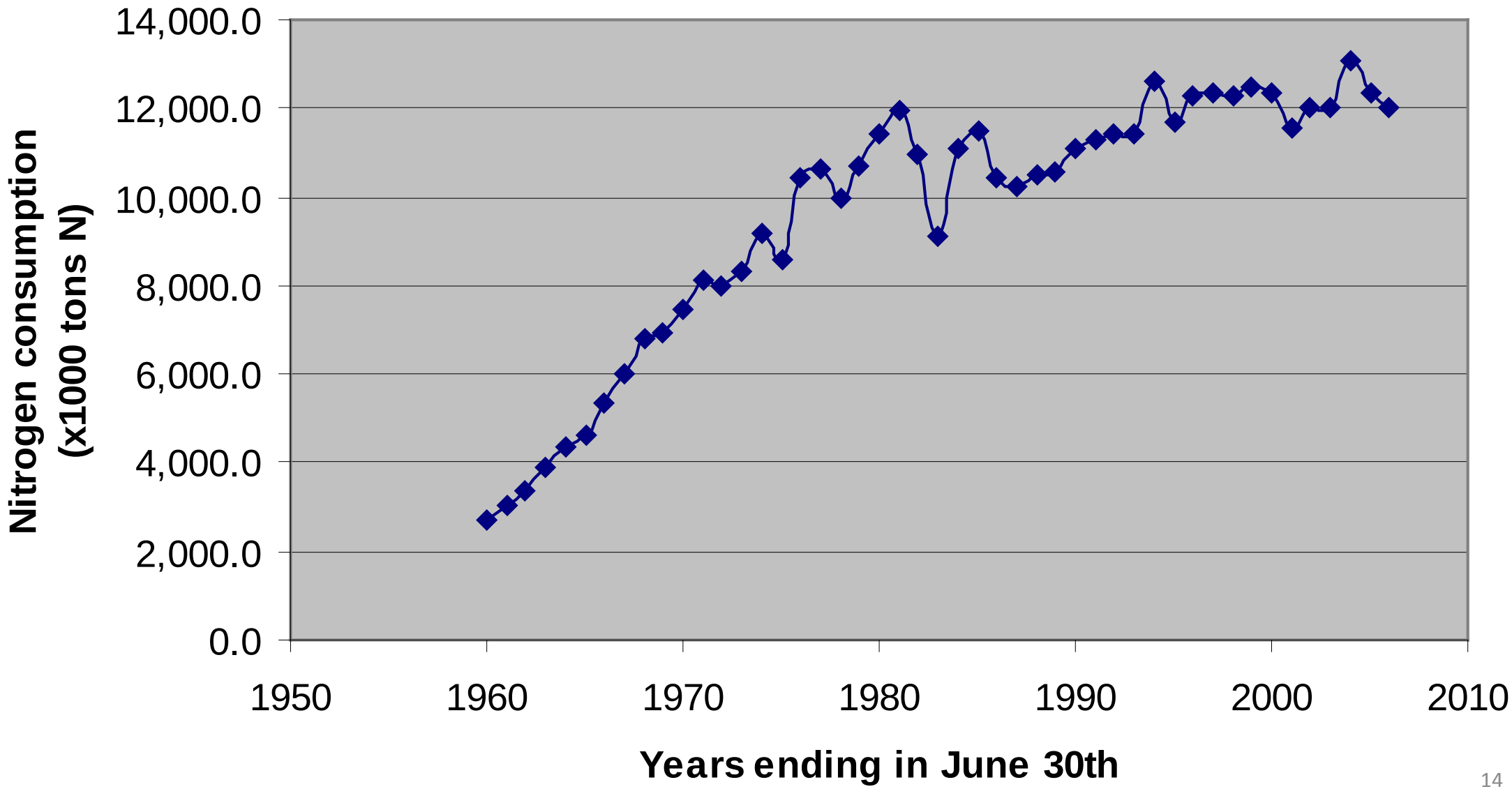
Little or no cropland

Zero means the crop used exactly the amount of nitrogen applied. The ideal range varies due to local conditions.

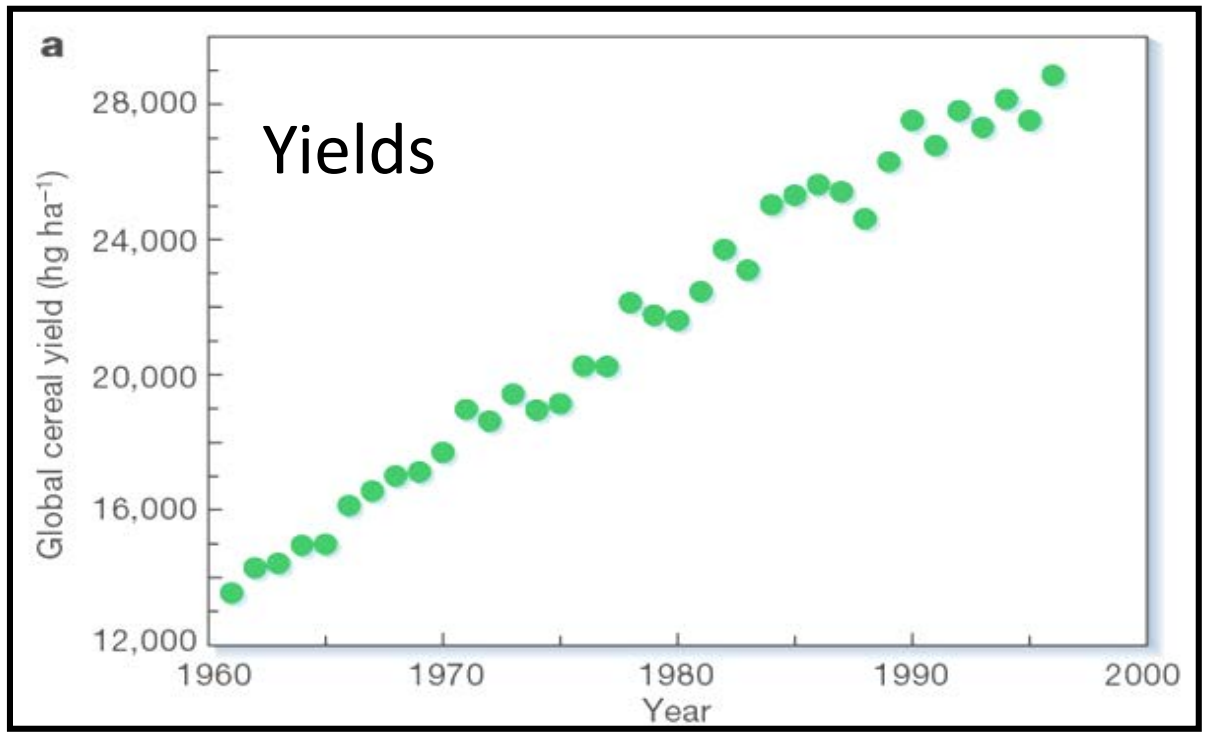
Surging Nitrate in China's Water

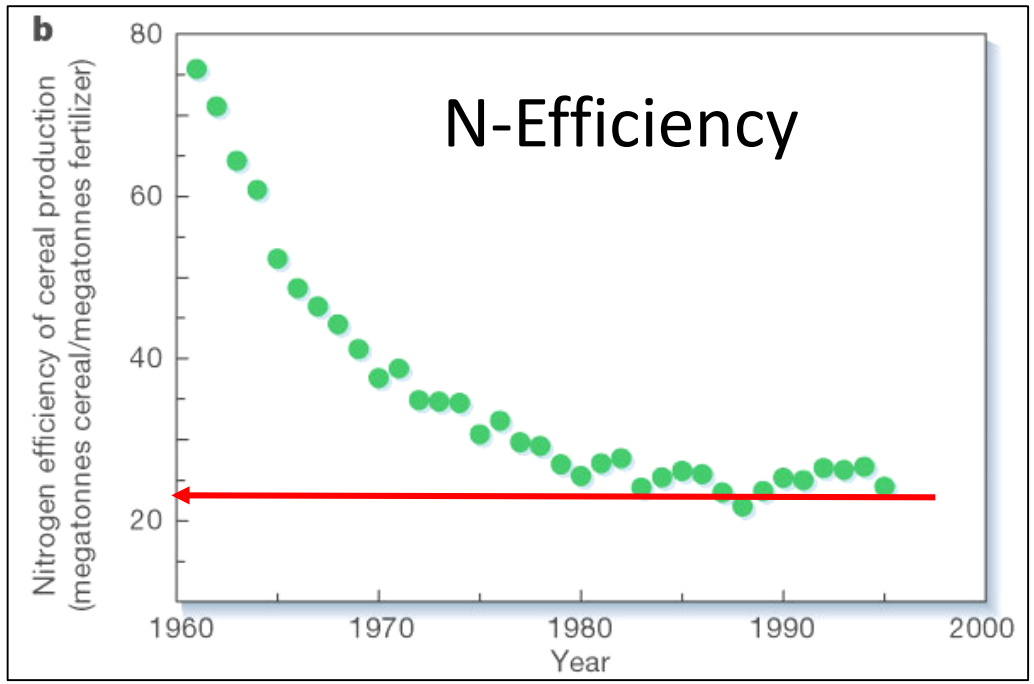
Imaginechina/Corbis

U.S. consumption of Nitrogen



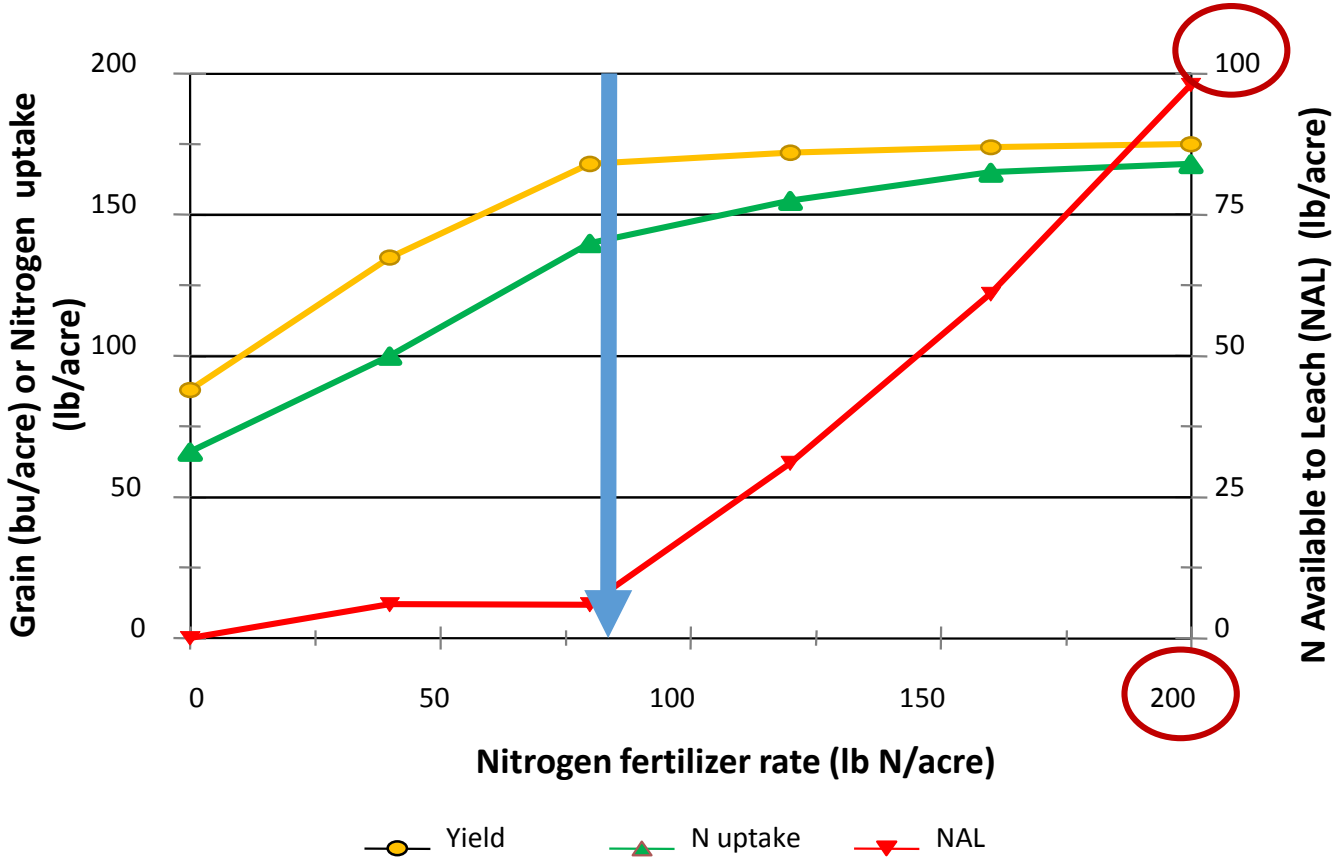
Crop Production and N Efficiency





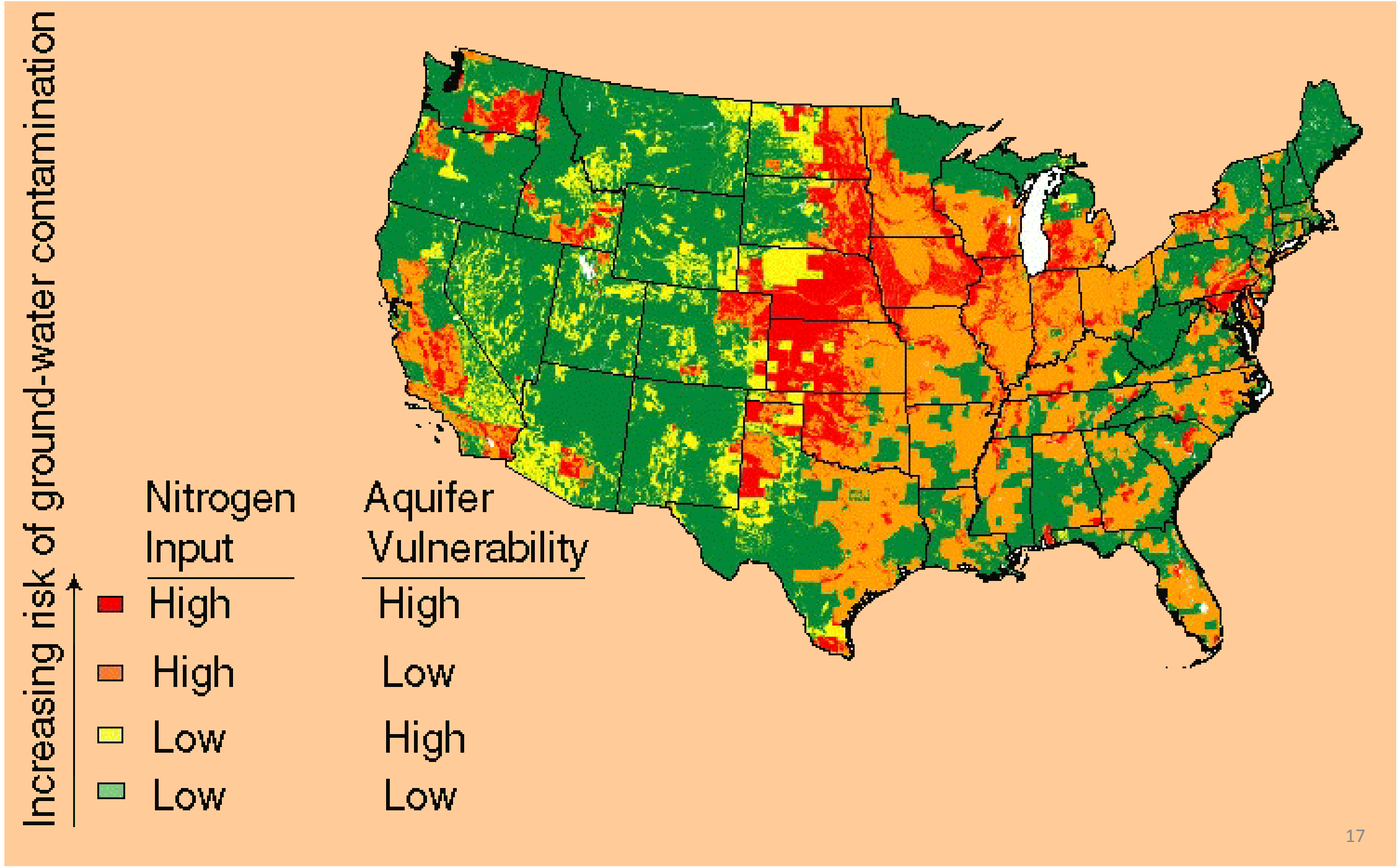
- Tilman et al., 2002

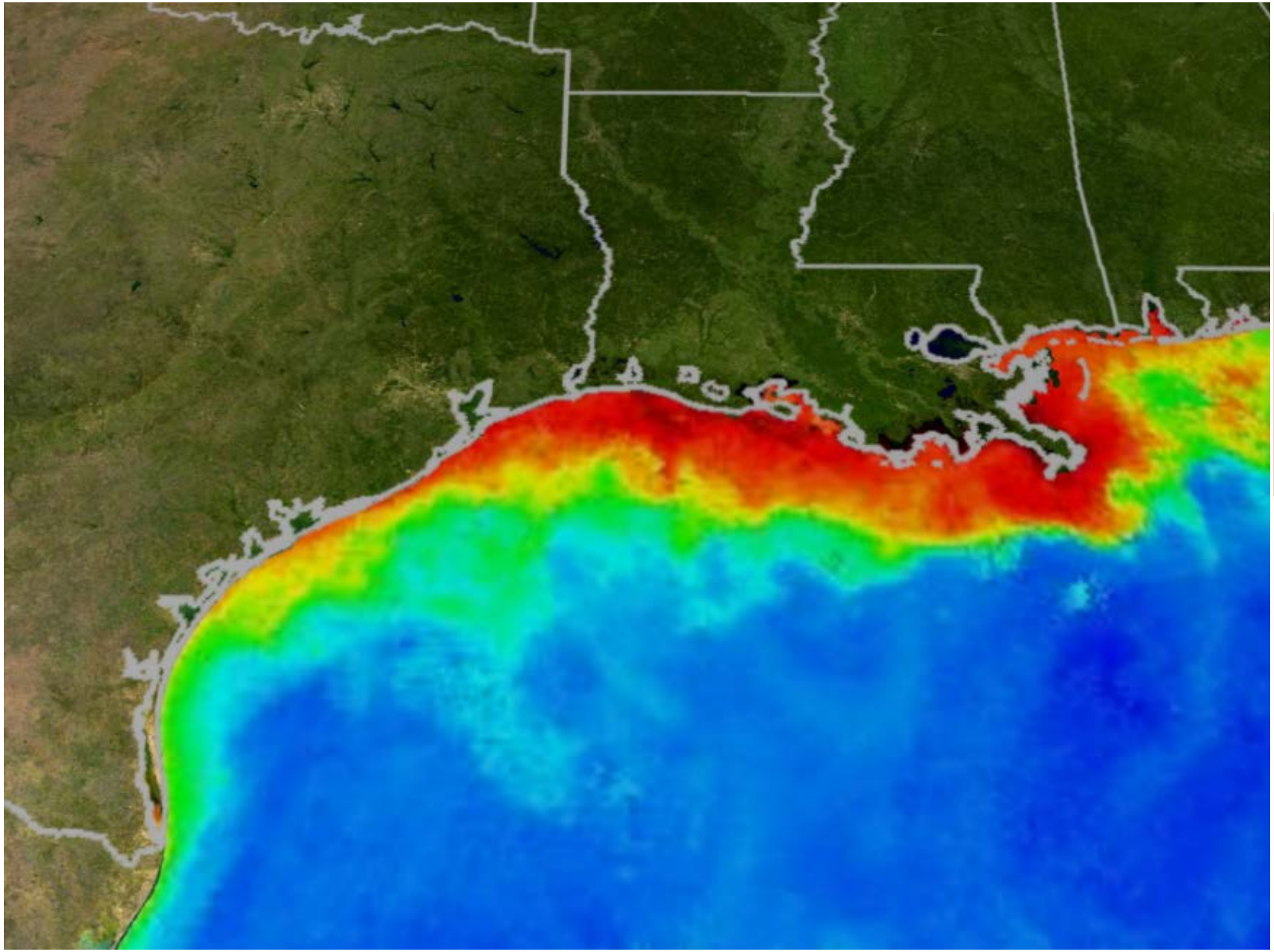
Effect of N Fertilizer Application on Yield, Crop Uptake and Nitrate Leaching Potential



Effect of N fertilizer rate applications on yield and N uptake by irrigated corn (Adapted from Bock and Hergert, 1991). Potential N available to leach (NAL) assuming major pathway for losses is leaching. The NAL was estimated as NAL = N applied – N uptake .

Delgado 2014


Increasing risk of ground-water contamination
Nitrogen Input
Aquifer Vulnerability
High
High
High
Low
Low
High
Low
Low



The Gulf of Mexico Hypoxic Zone (Dead Zone)

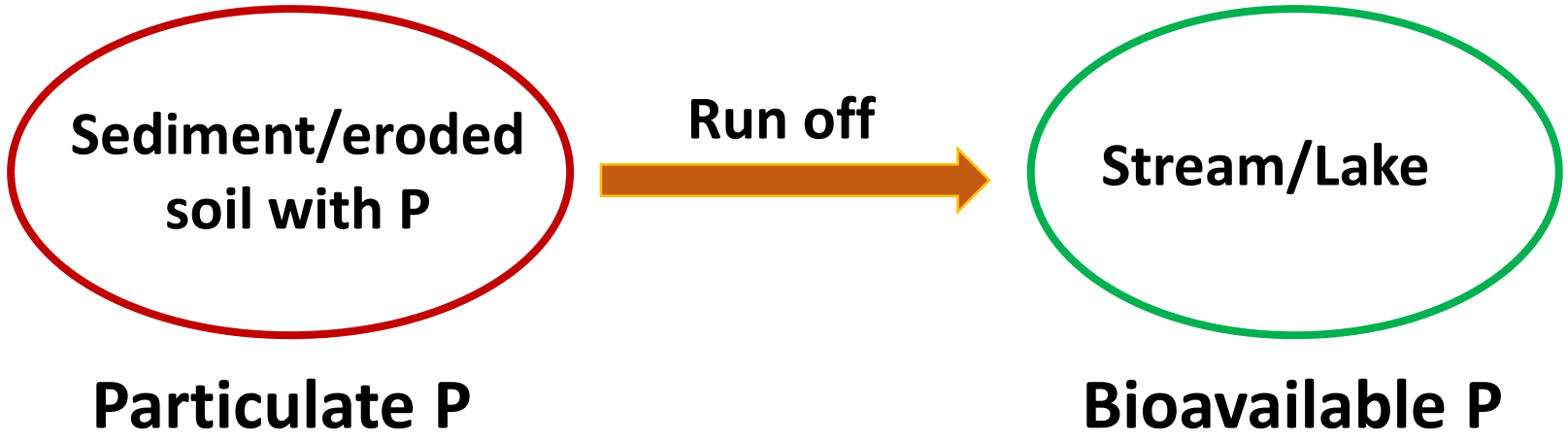
N pollution has estimated ecosystem and health damages of $157 billion/year (Sela & van Es, 2018**)**

Phosphorus

- **Phosphorus released from the weathering of rocks such as rock phosphate**
- **All living organisms need phosphorus for DNA, ATP, lipids etc.**

Phosphate mined on Nauru Island in the Pacific

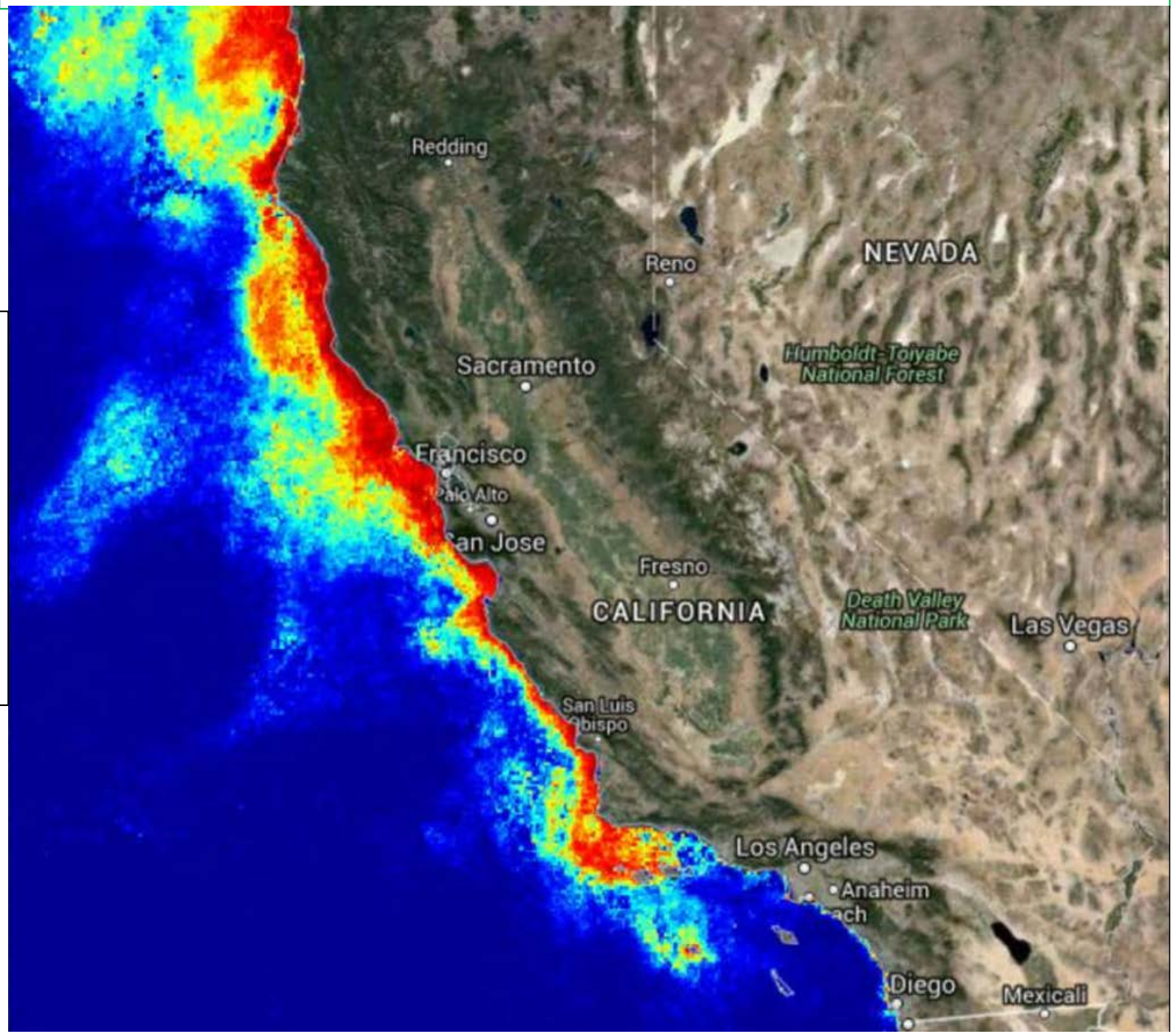
Unavailable P becomes Available



Source: NASA, 2011

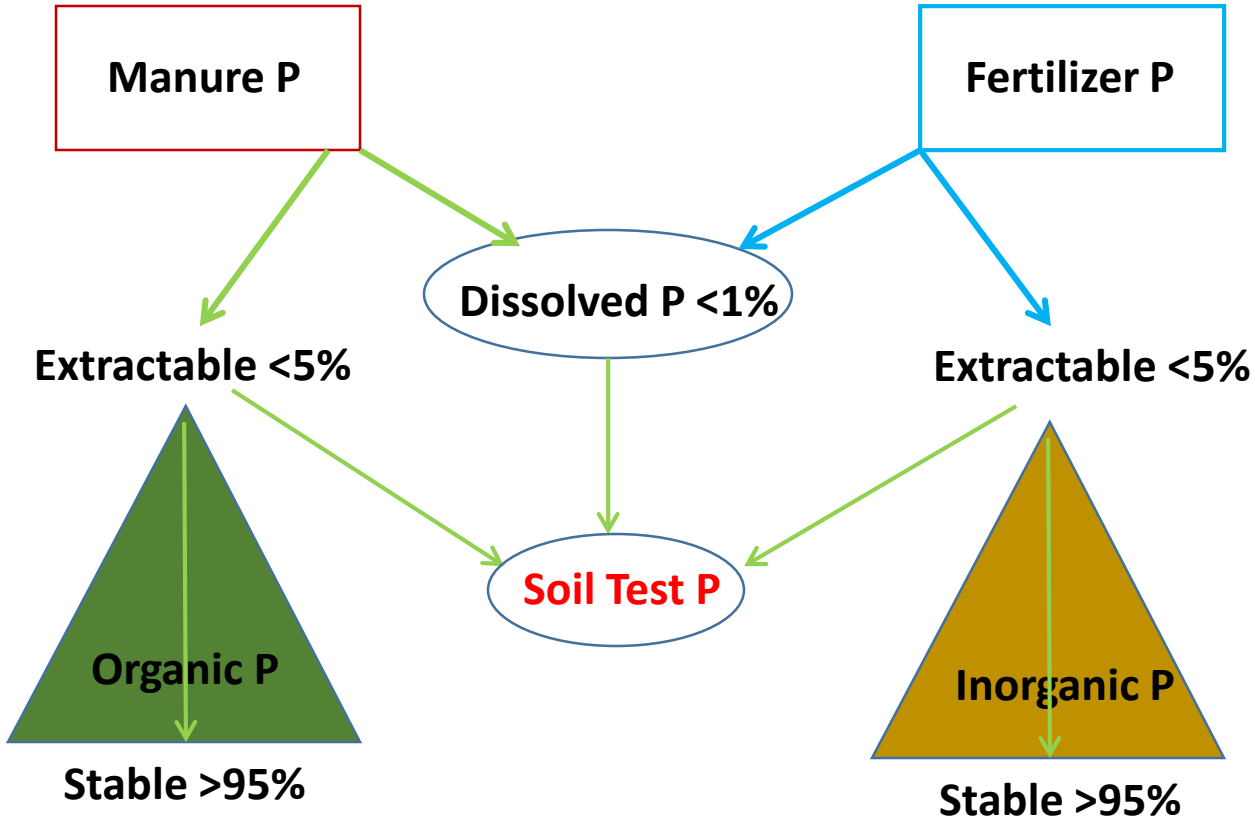
West Coast Algal Bloom

P flux to coastal oceans has nearly triple in the last 50 years, largely as a result of P applications to Ag lands (Horwath et al. 1995)



2015 Algal Bloom in CA
Raphael Kudela, UCSC

Soil Phosphorus Pools



Fertilizer Use Efficiency

For Annual Crops: N: 30-70%
P: 5-40%

For Perennial : N and P: 5-40%

Nitrogen use efficiency for cereal 30-35% (Agron. J. 91:357-363)

In tropical rice fields, as much as 50 to 70 % N can be lost (H. Kronzuccker, UOT, 2016)

Dominant Nutrient Management Paradigm

Plenty N & P are added to meet the yield goal. Soil with excess fertilizers is leaky

N gaseous loss

N and P Fertilizer

Plant and other residues

Depleting SOM & Soil life

P

N

Less N & P mineralization

Soluble N and P in Soil

P fixation

P Solubilization

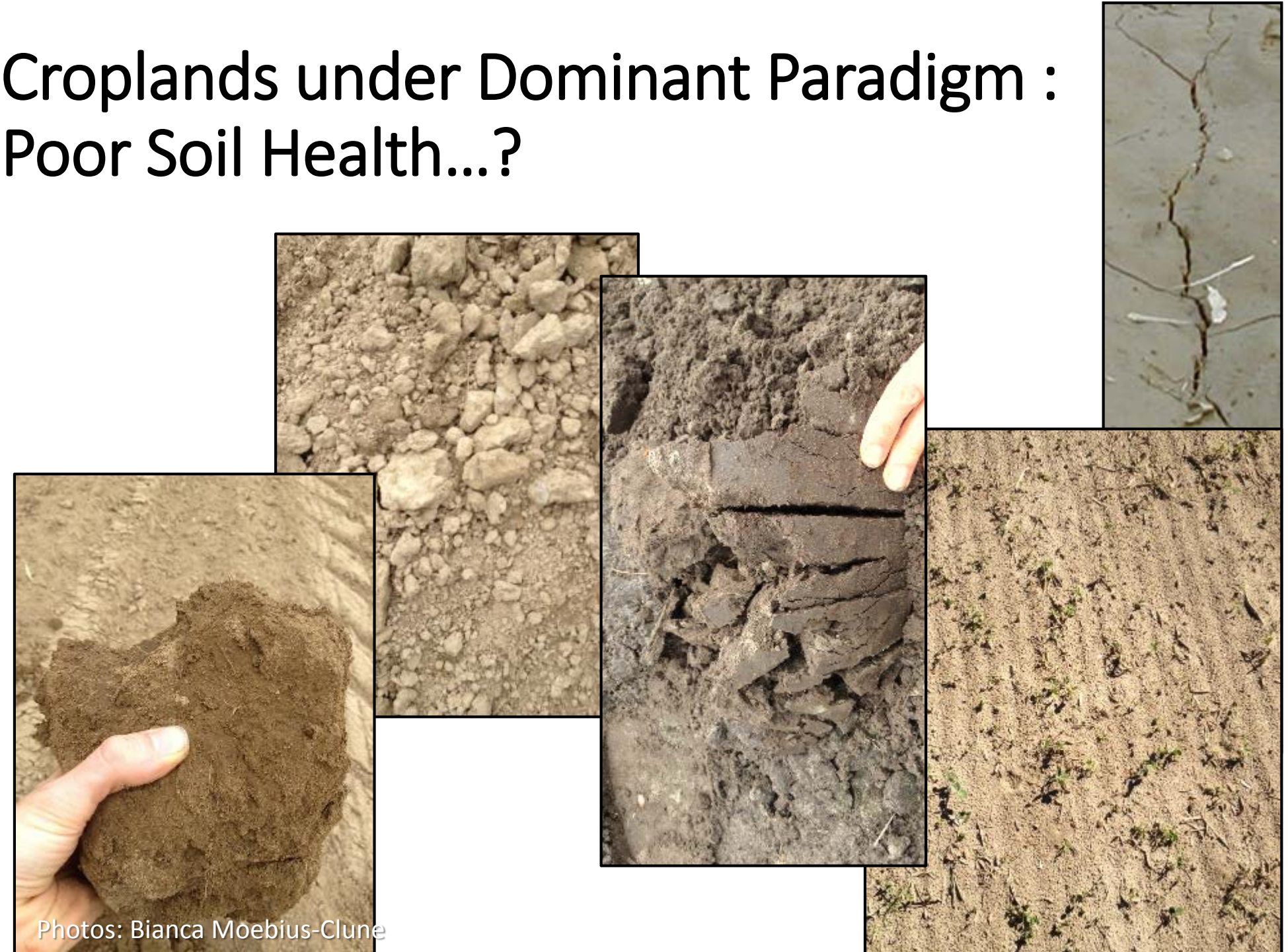
Mineral P reservoirs

Leaching & runoff

Erosion

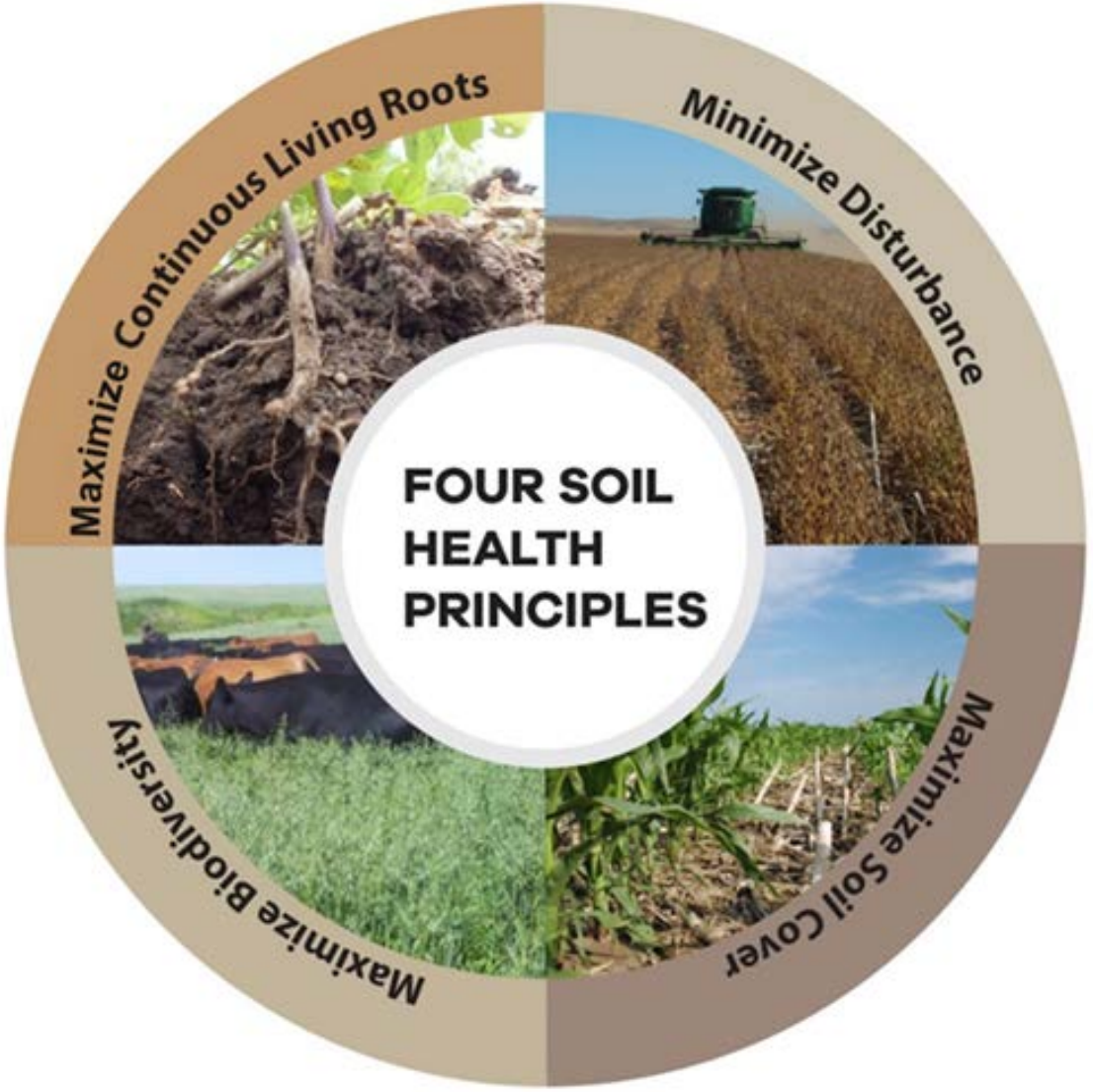
Adapted from Drinkwater & Snapp, 2007

Croplands under Dominant Paradigm : Poor Soil Health…?

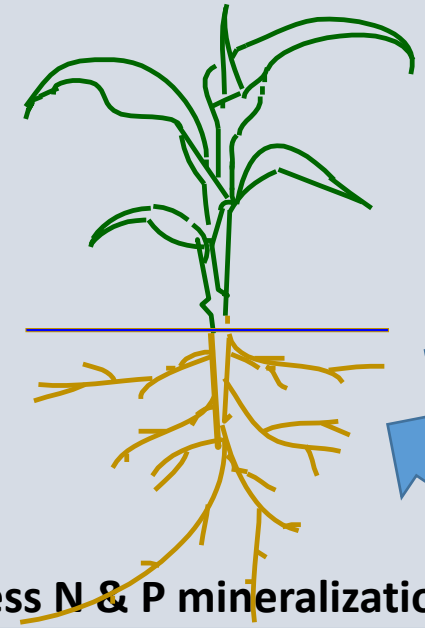


Photos: Bianca Moebius-Clune

Dominant Paradigm ≠ Soil Health Principles



The 4R Strategy to Nutrient Management



Gaseous loss

N and P Fertilizer

Side dressing, banding, fertigation, split application & nitrification inhibitors etc. increase the efficiency but do not eliminate nutrient losses

Plant and animal residues

Depleting SOM & Soil life

P

N

Soluble N and P in Soil

Less N & P mineralization

P fixation

P Solubilization

Mineral P reservoirs

Erosion

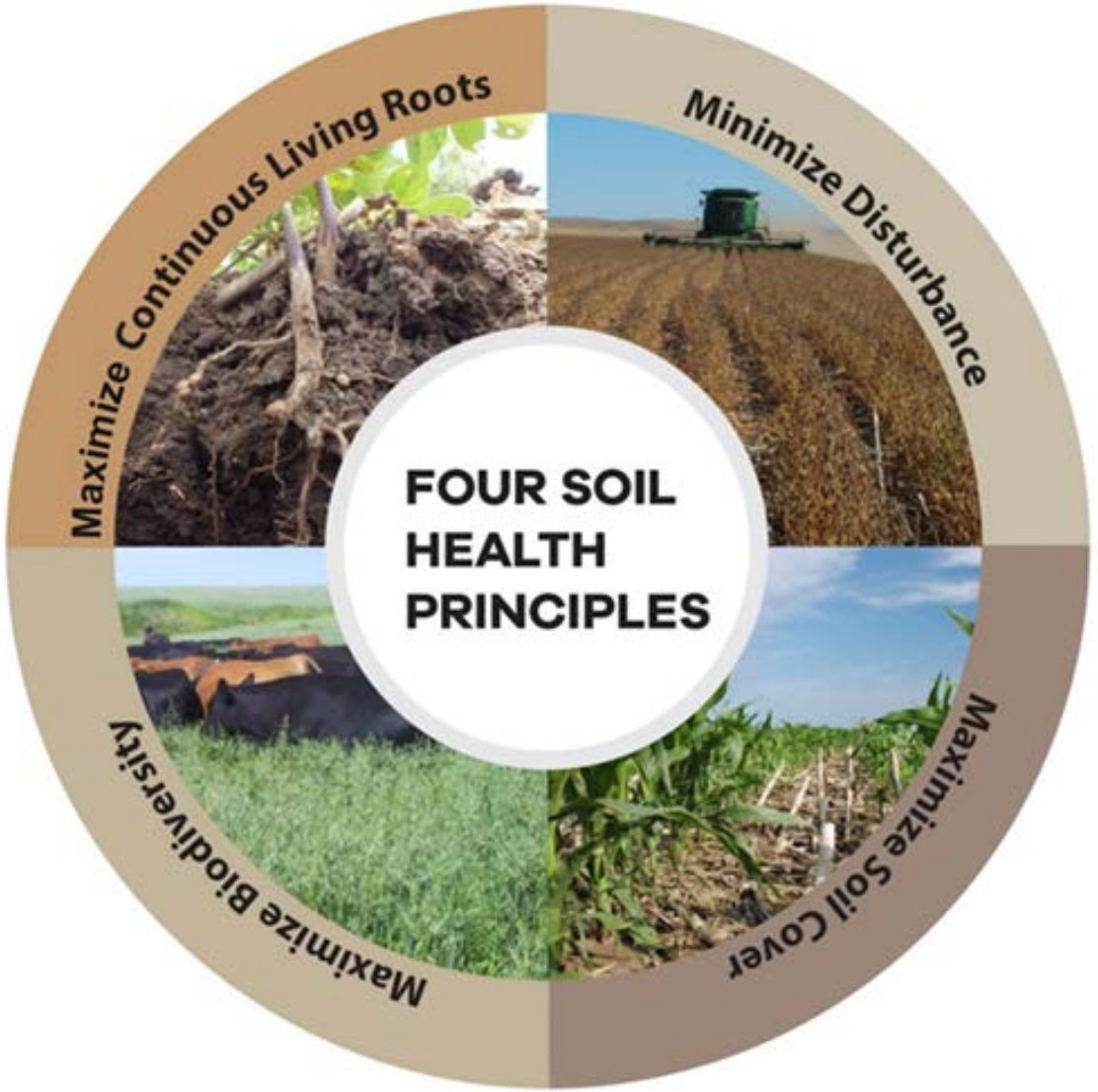
Leaching & runoff

Fallow land is maintained for 4-8 months providing limiting food for soil life

Perennial system with a bare floor is also providing limiting food for soil life

N & P fertilizer use efficiency still only 40 to 60% (Drinkwater & Snapp, 2007)

4R Strategies ≠ Soil Health Principles



Iowa State Plan - Needs Efforts Beyond 4Rs

Gulf of Mexico

- The goal is 45% reduction of N loading to Stream
- The 4Rs reduces the N loading by 11%

- To meet the goal:
  - Increase cover crops from 600K to 12M acres
  - N reducing wetlands from 81 to 7,000

We have to go beyond 4Rs and that means Soil Health

Buman, T. 2017 (www.agrentools.com)

Rethinking the Nutrient Management Paradigm

- Top soil loss
- Loss of soil organic matter
- The capacity of soil to hold water and nutrient is reduced
- Loss of soil buffering capacity
- Loss of Soil Life

Holistic Approach to Nutrient Management

Nutrients from plant and other residues,

Gaseous loss

N and P Fertilizer

Cover crops

Labile C

P

N

mineralization

Assimilation

Soluble N and P in soil

P fixation

P Solubilization

Mineral P reservoirs

Leaching & runoff

Erosion

Achieves high yields, minimizes fertilizer use, and reduces environment pollution

Soil reservoirs increase and are made more available by diverse inputs

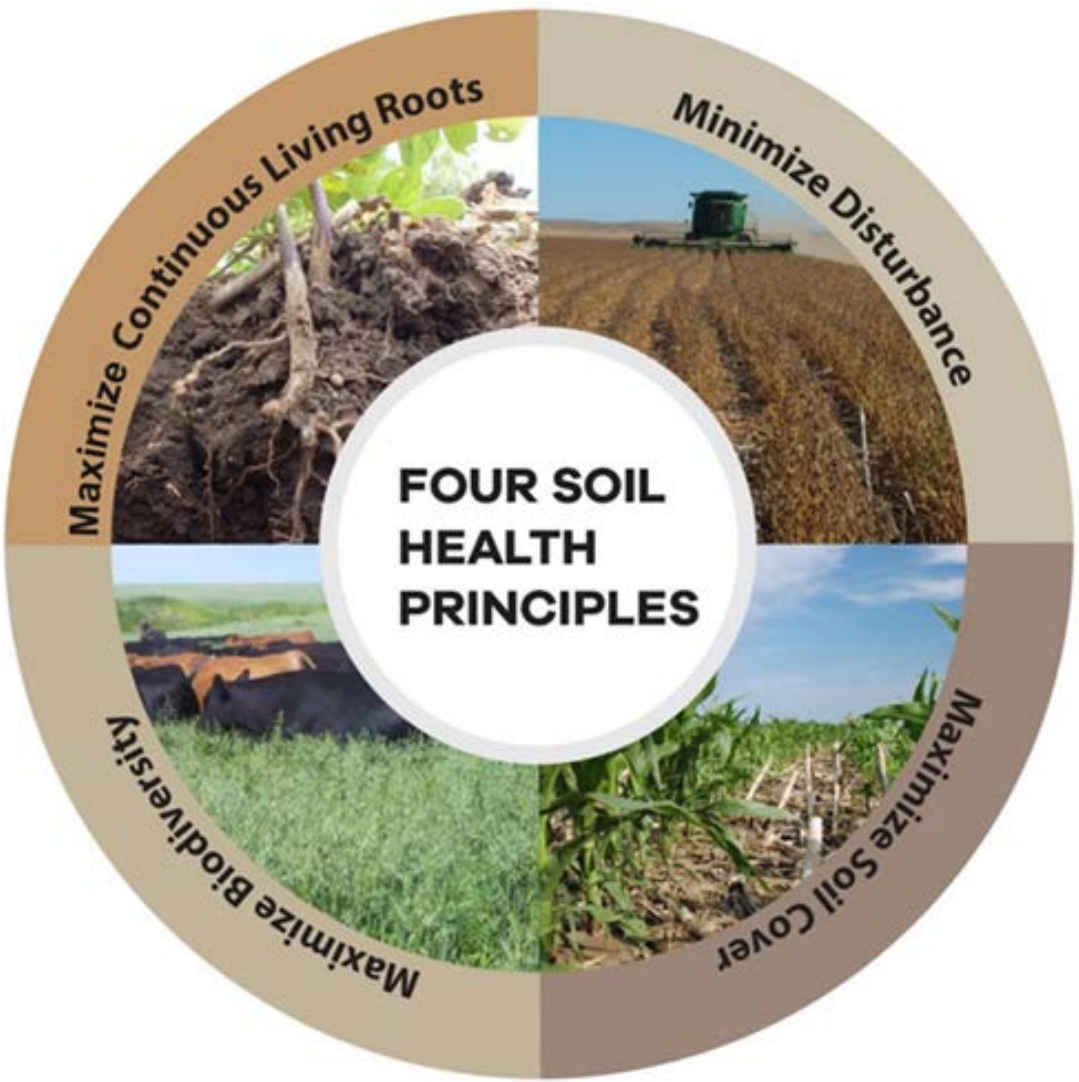
Diverse inputs are residues, compost, crop rotation, cover crops, and slow release N

Minimize tillage to preserve residues & protect soil life that recycle nutrients

Measure all pools of N & P and apply 4R strategy to maximize the nutrient efficiency

Adapted from Drinkwater & Snapp, 2007

Holistic Approach = Soil Health Principles

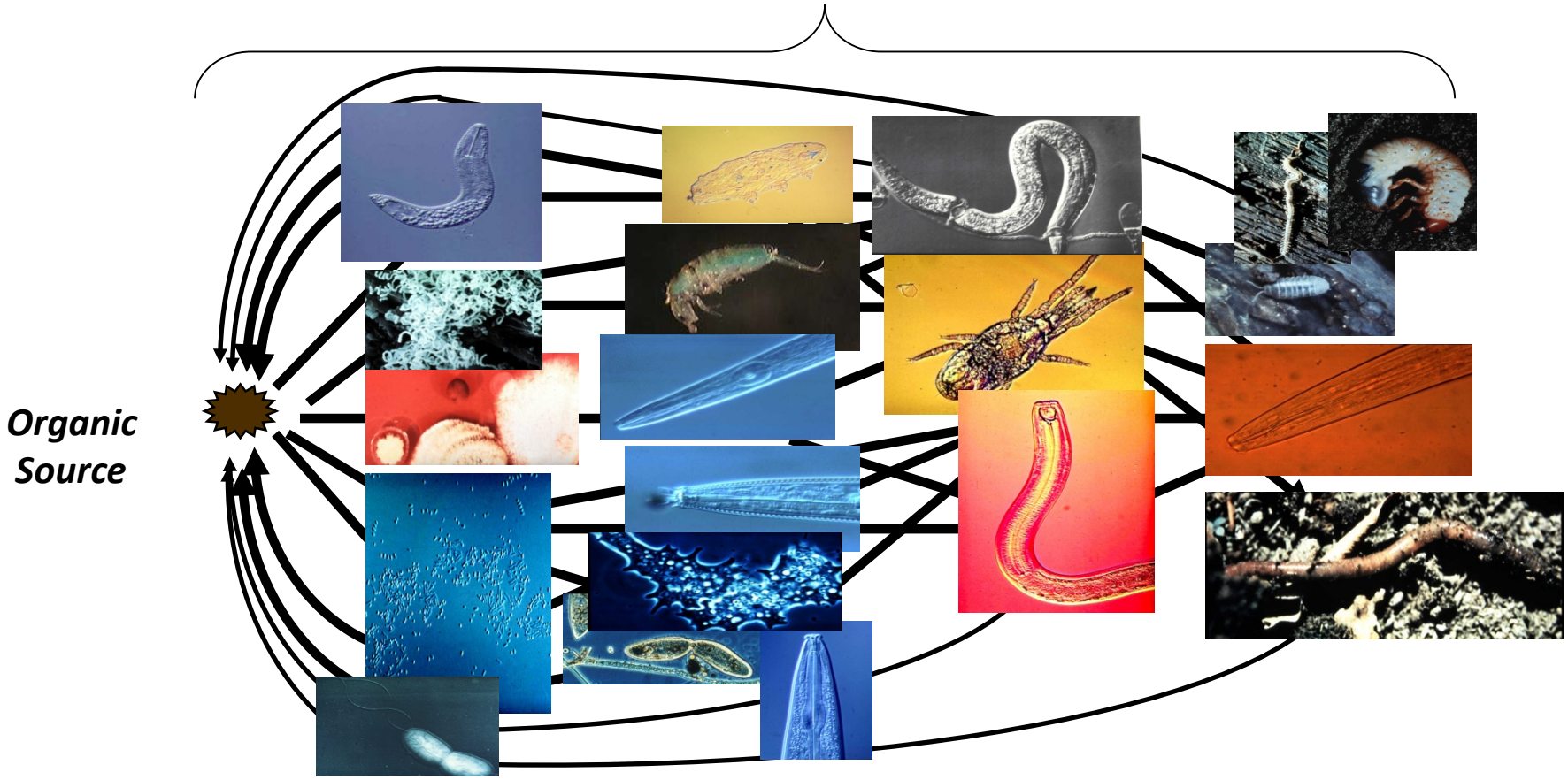


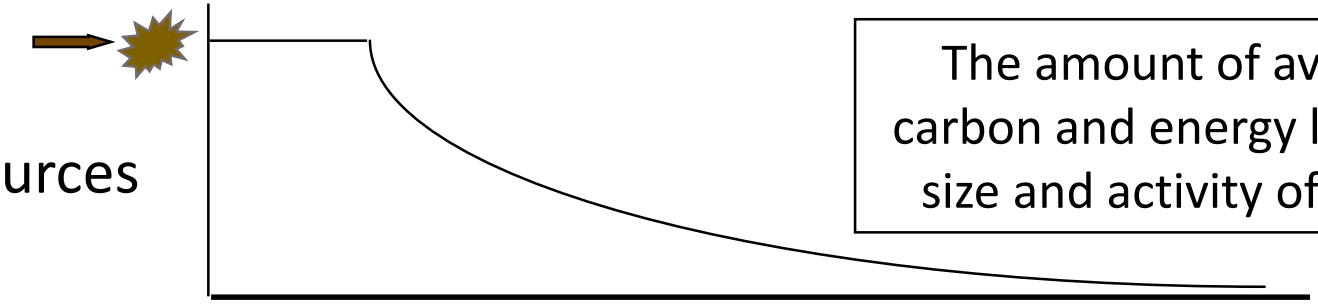
How are We going to Achieve the Holistic Approach?

- Recognize that the soil is an ecosystem
- Recognize that agriculture is an applied biology
- Recognize the long-term benefit of soil health over the short-term benefit of the dominant paradigm
- Incorporate soil health principles into nutrient management planning

Next several slides provide illustration how to apply holistic approach of nutrient management

Soil is a Living Ecosystem

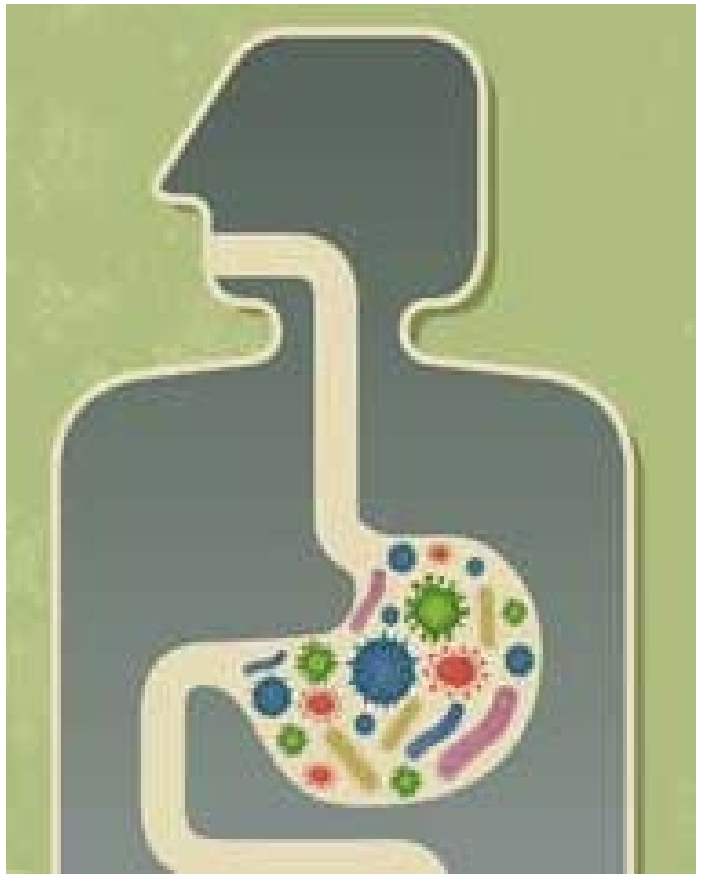


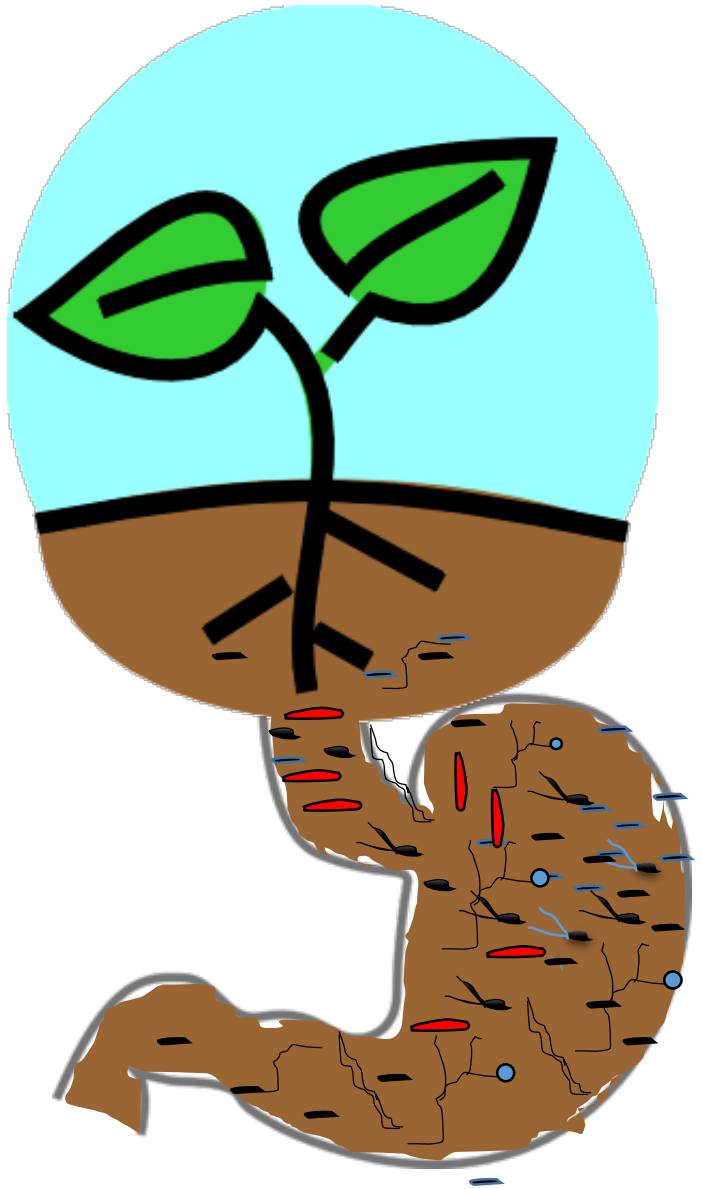


The amount of available carbon and energy limits the size and activity of soil life

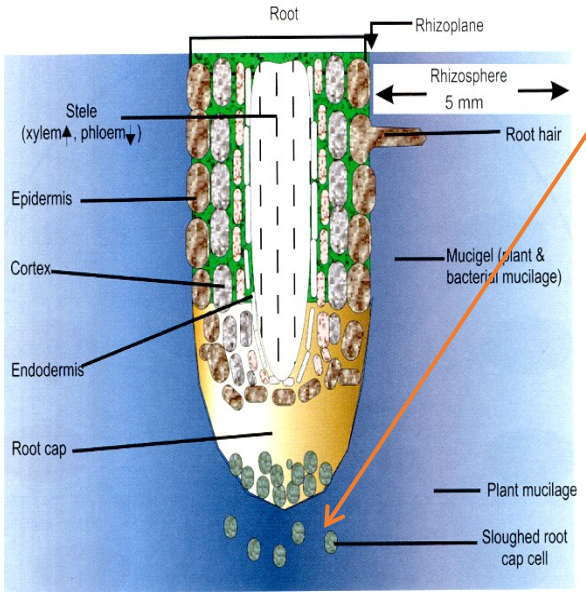
H. Ferris, UCD

Soil serve as the “Gut” for Plants

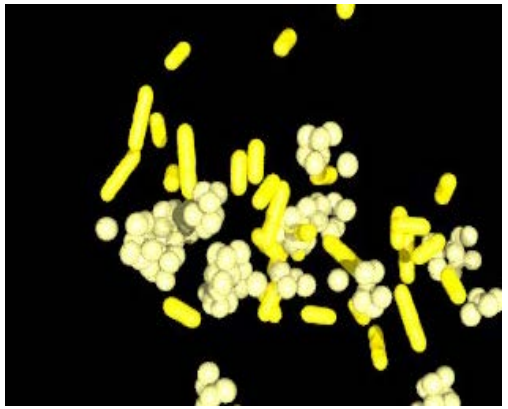


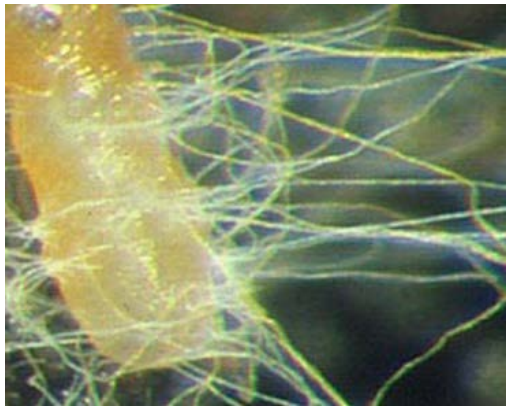


Microbes and Plant Roots Interaction



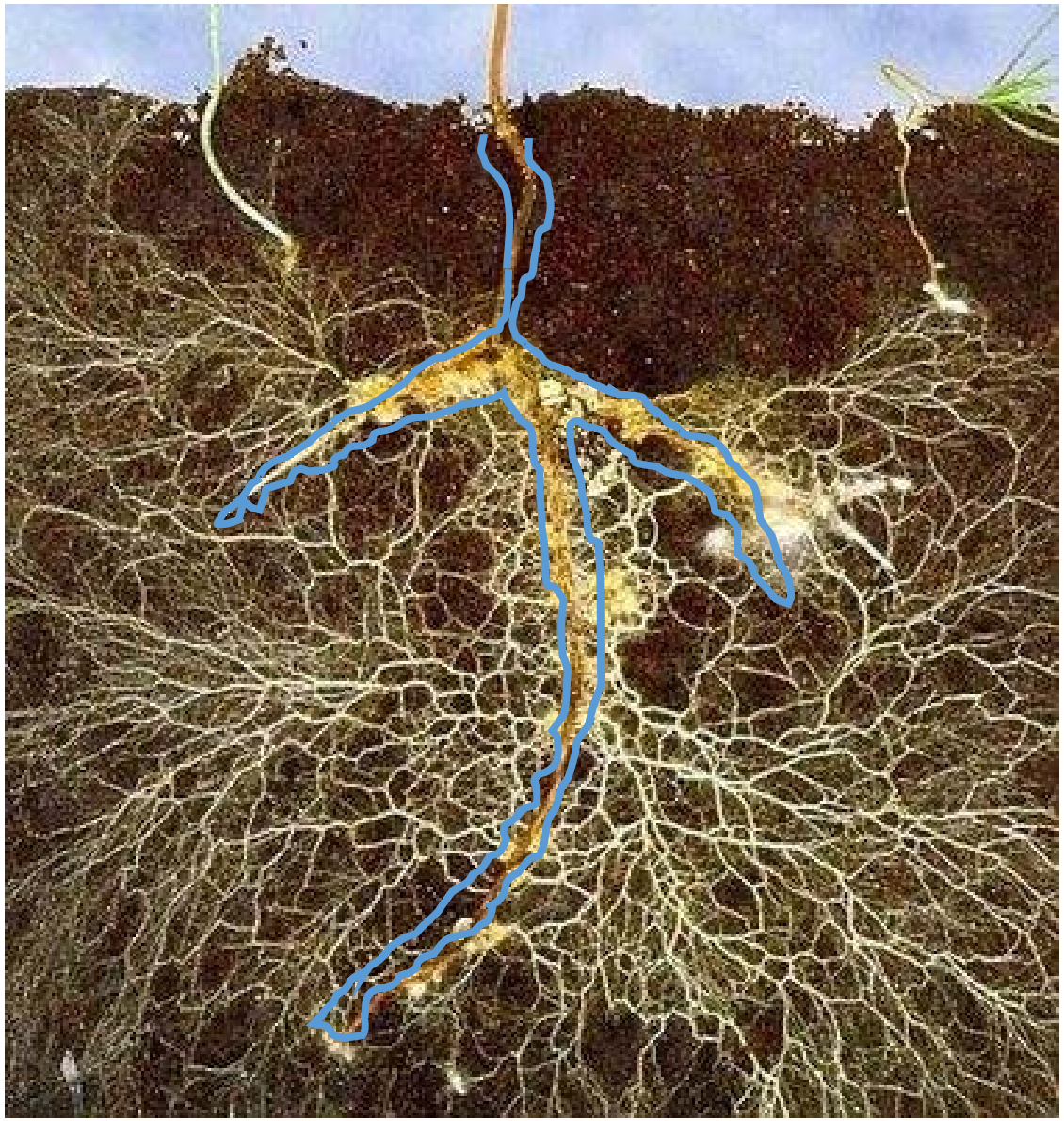
Exudates: carbohydrates and proteins secreted by roots; attract bacteria, fungi, nematodes, protozoa





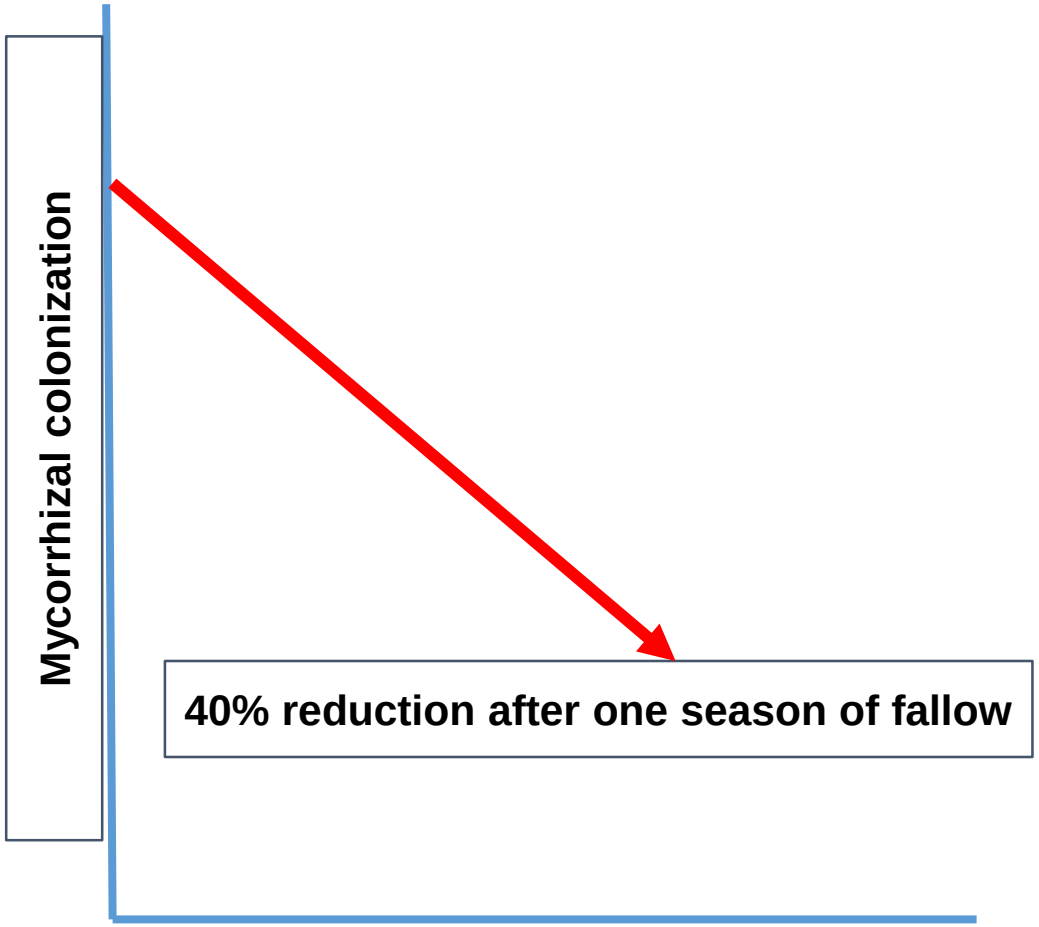
Bacteria and fungi are like little fertilizer bags

Nematodes and protozoa eat bacteria and exudates and excrete nutrients



Read, 1997

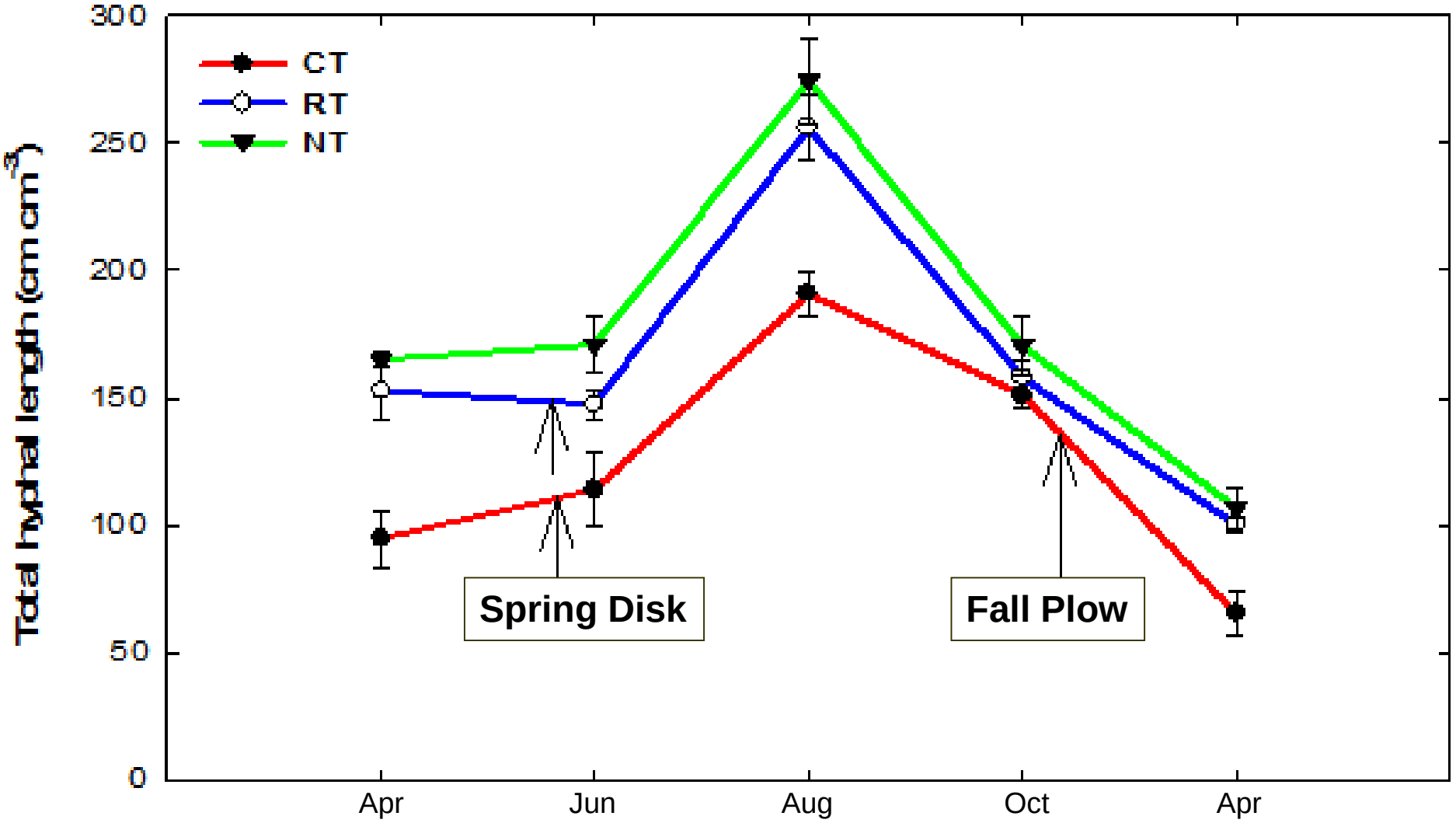
Effects of Fallow on Mycorrhizal Fungi



Harinikumar and Bagyaraj

Mycorrhizal colonization, P, Zn uptake, yields of various crops are inversely related to the duration of the fallow.

Seasonal Changes of Mycorrhizal Hyphae in Tillage Systems



CT= Conventional Tillage, RT = Spring Disk only, NT= No-till

Kabir et al.

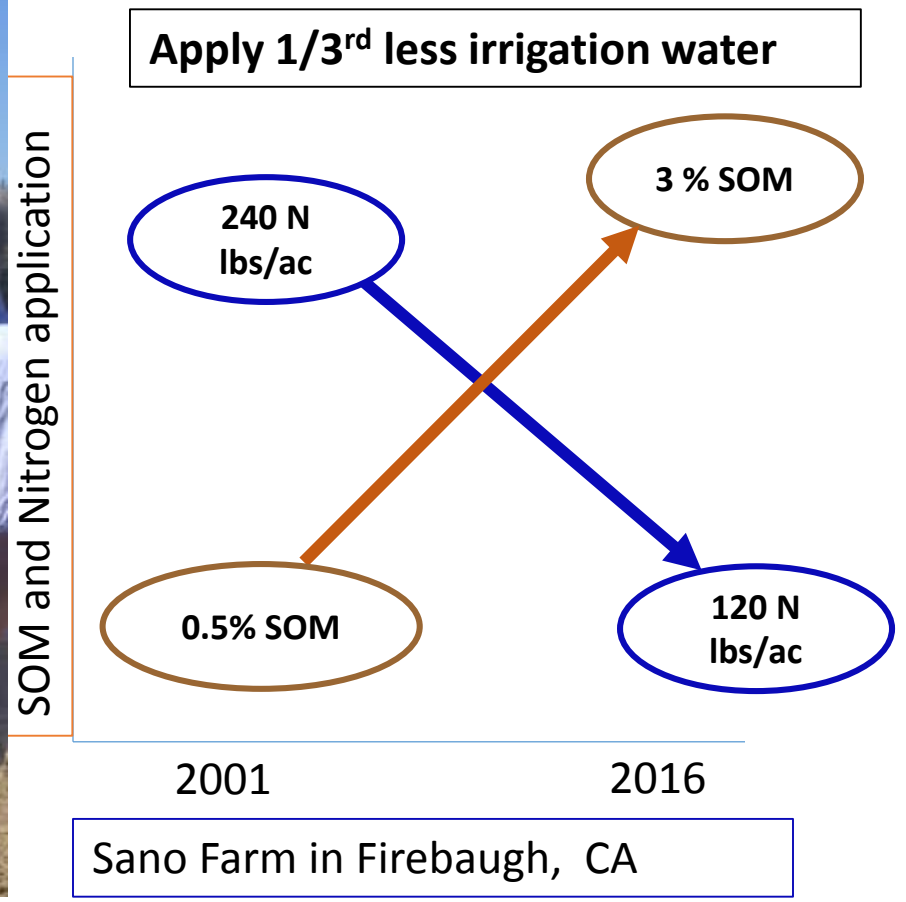
Suitable Crop Rotation for Mycorrhizal Benefits

Corn following Soybean
(Mycotrophic)

Corn following Canola
(Non-mycotrophic)

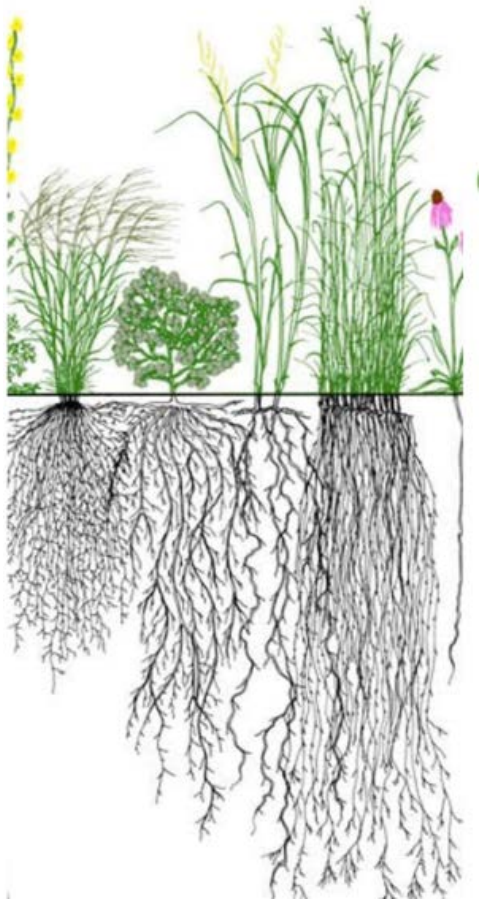
Koide, BYU

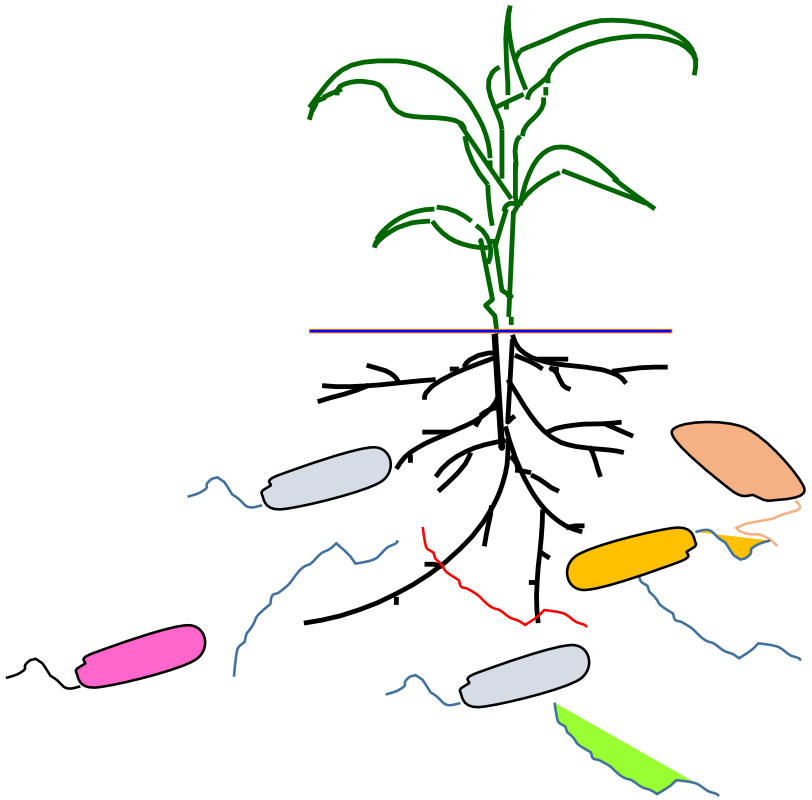
Example: Holistic Approach to Nutrient Management



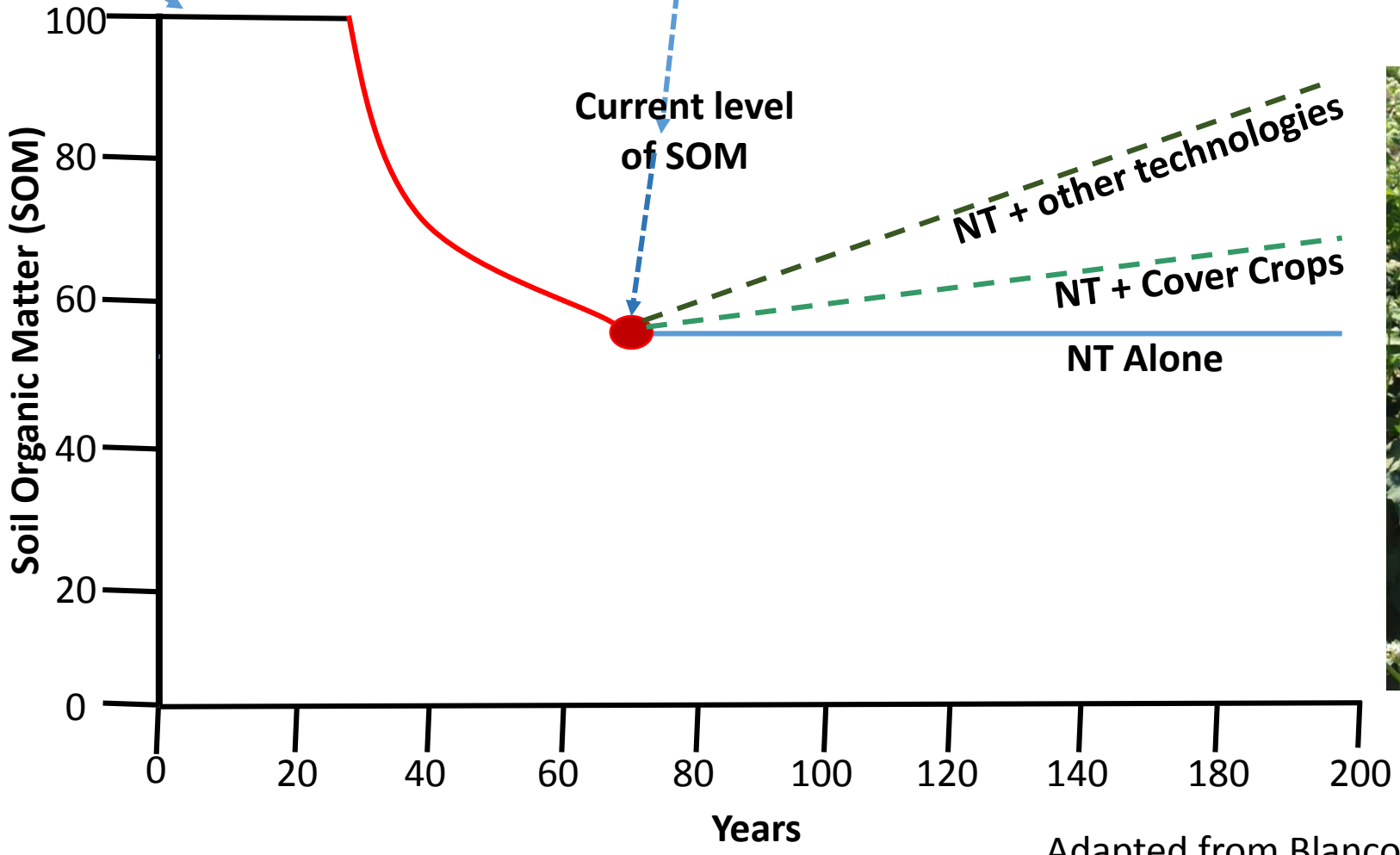
Sano Farm in Firebaugh, CA

Diversity Improves Soil Capacity



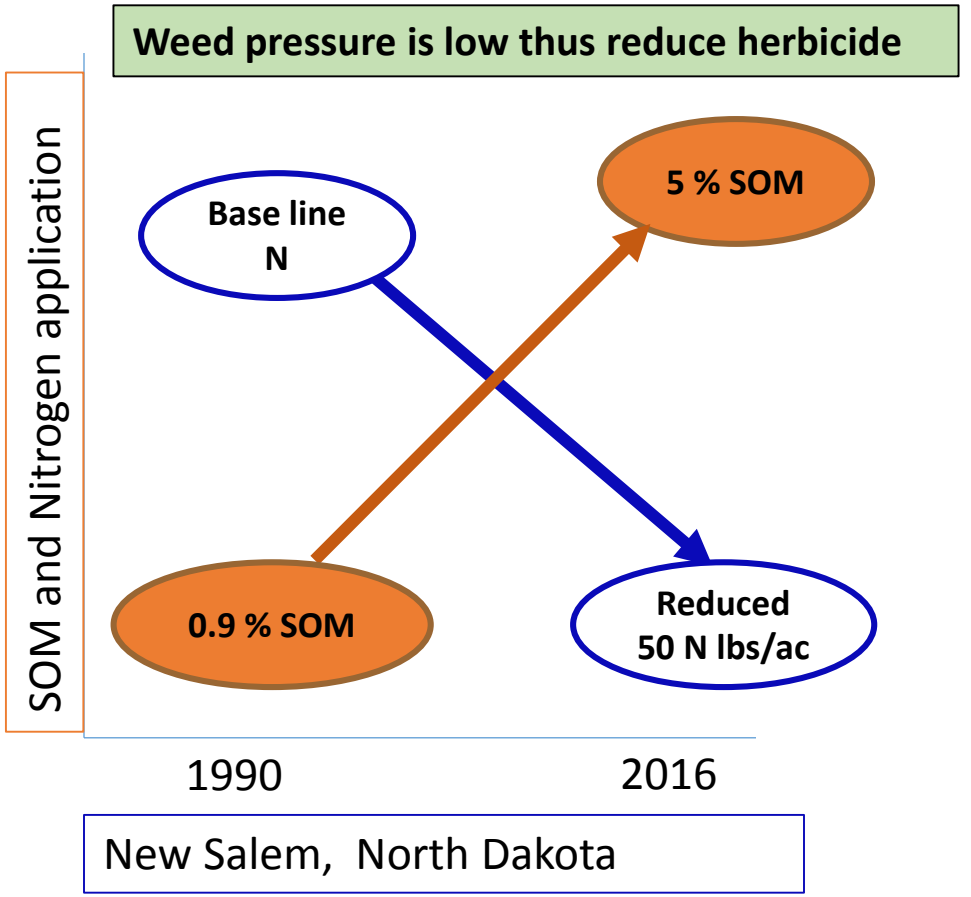


Tallgrass Prairies are the most productive ecosystems in USA

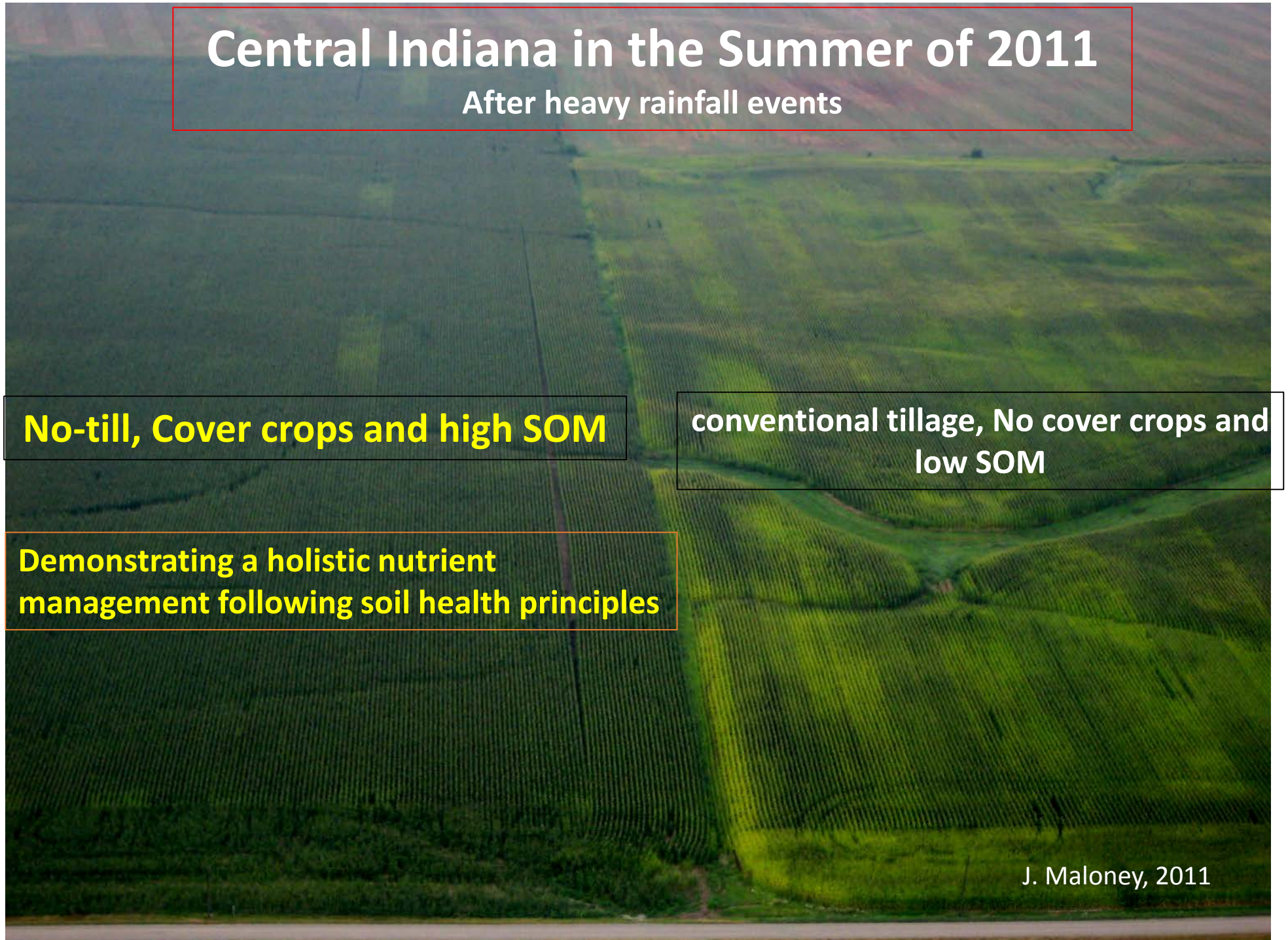


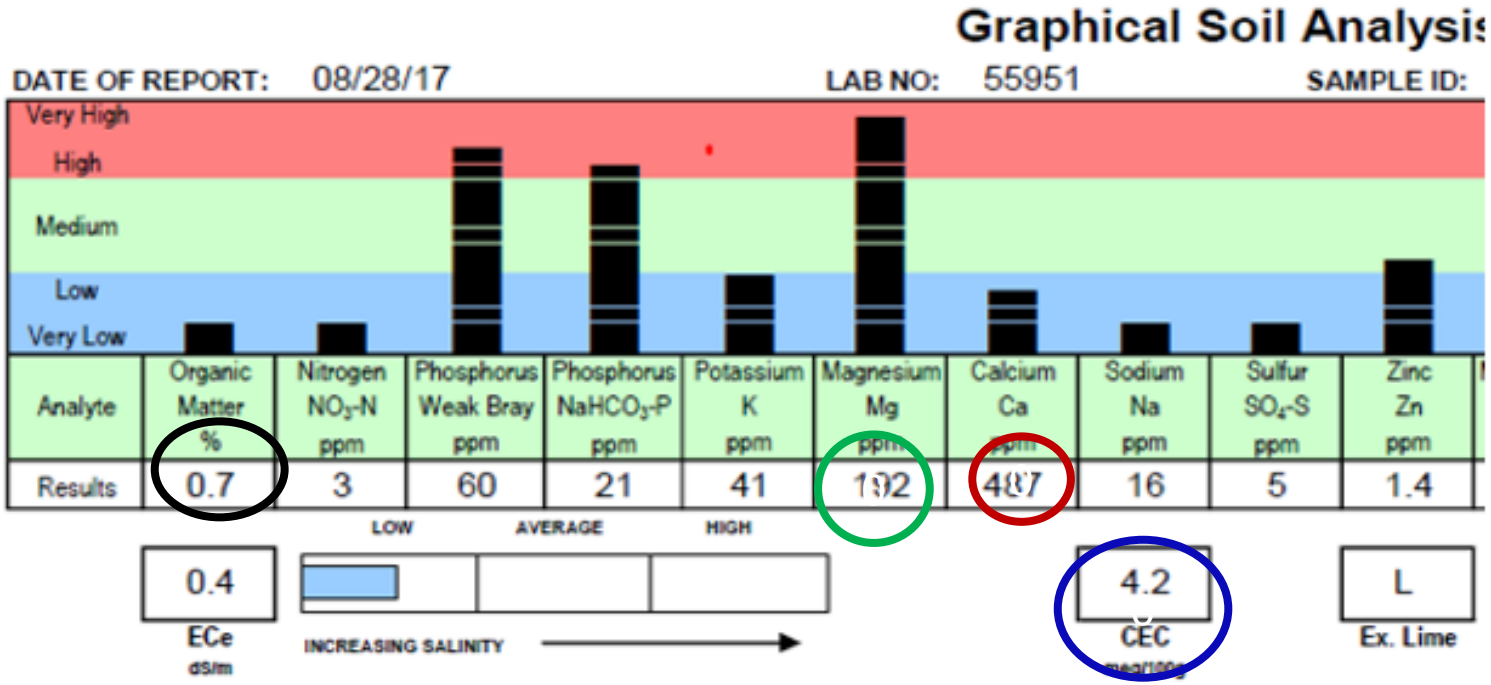
Adapted from Blanco-Canqui, H. et al. 2015

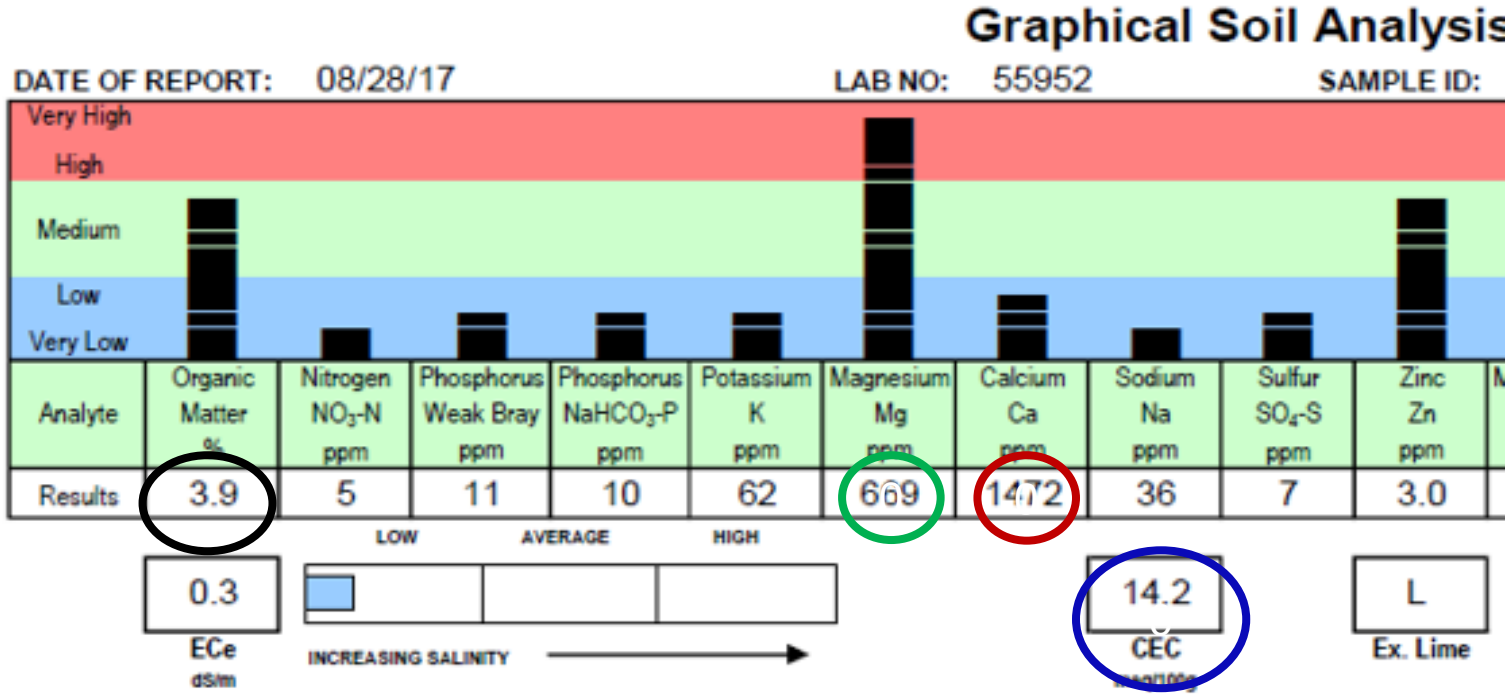
Example: Holistic Approach to Nutrient Management in Dryland Cropping System in ND



New Salem, North Dakota

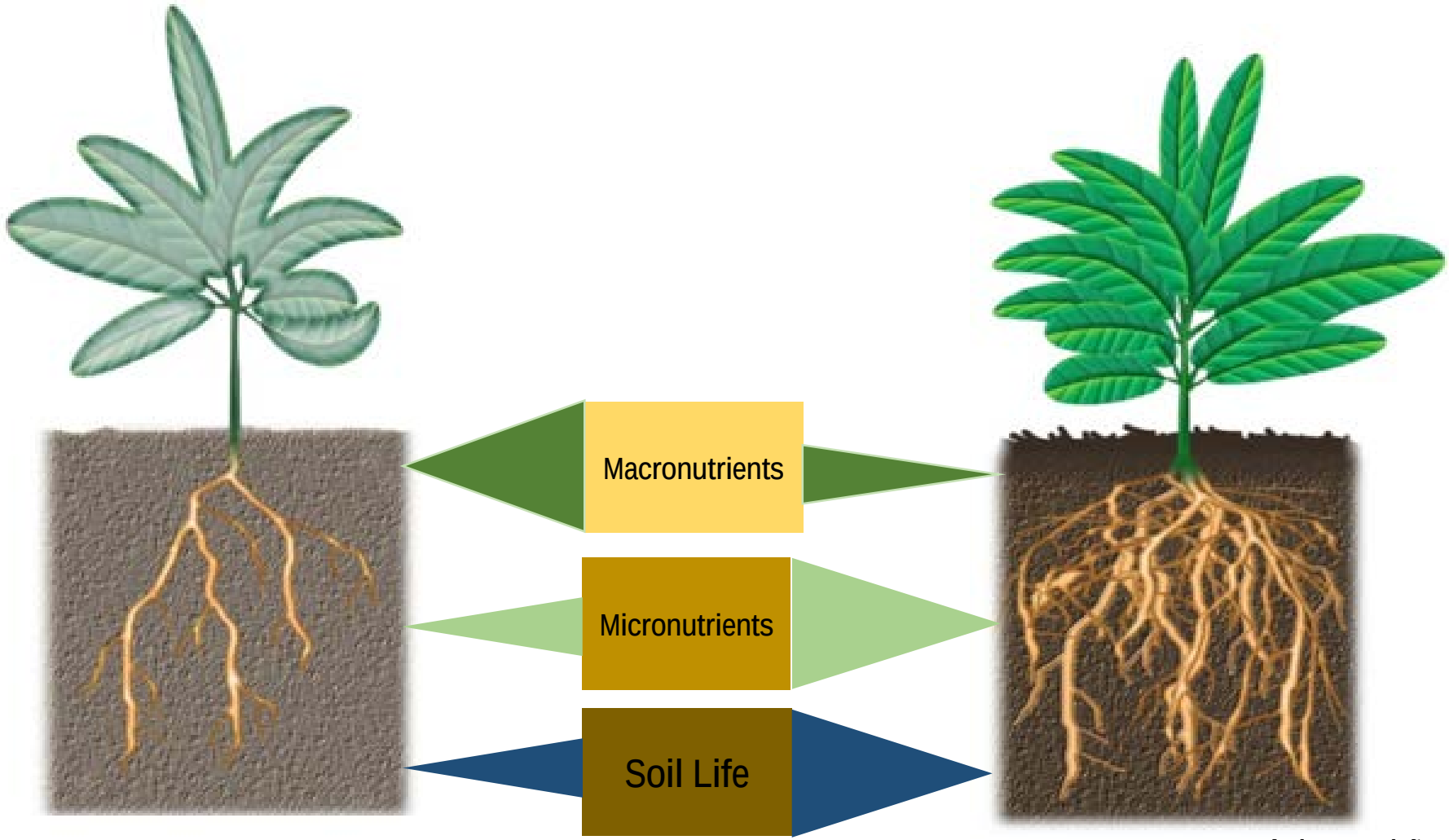

Central Indiana in the Summer of 2011
After heavy rainfall events
No-till, Cover crops and high SOM
conventional tillage, No cover crops and low SOM
Demonstrating a holistic nutrient management following soil health principles
J. Maloney, 2011


Graphical Soil Analysis
DATE OF REPORT: 08/28/17
LAB NO: 55951
SAMPLE ID:
Very High
High
Medium
Low
Very Low
Analyte
Organic Matter %
Nitrogen NO_3-N ppm
Phosphorus Weak Bray ppm
Phosphorus $NaHCO_3$-P ppm
Potassium K ppm
Magnesium Mg ppm
Calcium Ca ppm
Sodium Na ppm
Sulfur SO_4-S ppm
Zinc Zn ppm
Results
0.7
3
60
21
41
192
487
16
5
1.4
LOW
AVERAGE
HIGH
0.4
ECe
dS/m
INCREASING SALINITY
4.2
CEC
L
Ex. Lime


Graphical Soil Analysis
DATE OF REPORT: 08/28/17
LAB NO: 55952
SAMPLE ID:
Very High
High
Medium
Low
Very Low
Analyte
Organic Matter %
Nitrogen NO_3-N ppm
Phosphorus Weak Bray ppm
Phosphorus $NaHCO_3$-P ppm
Potassium K ppm
Magnesium Mg ppm
Calcium Ca ppm
Sodium Na ppm
Sulfur SO_4-S ppm
Zinc Zn ppm
Results
3.9
5
11
10
62
669
1472
36
7
3.0
LOW
AVERAGE
HIGH
0.3
ECe
dS/m
INCREASING SALINITY
14.2
CEC
L
Ex. Lime

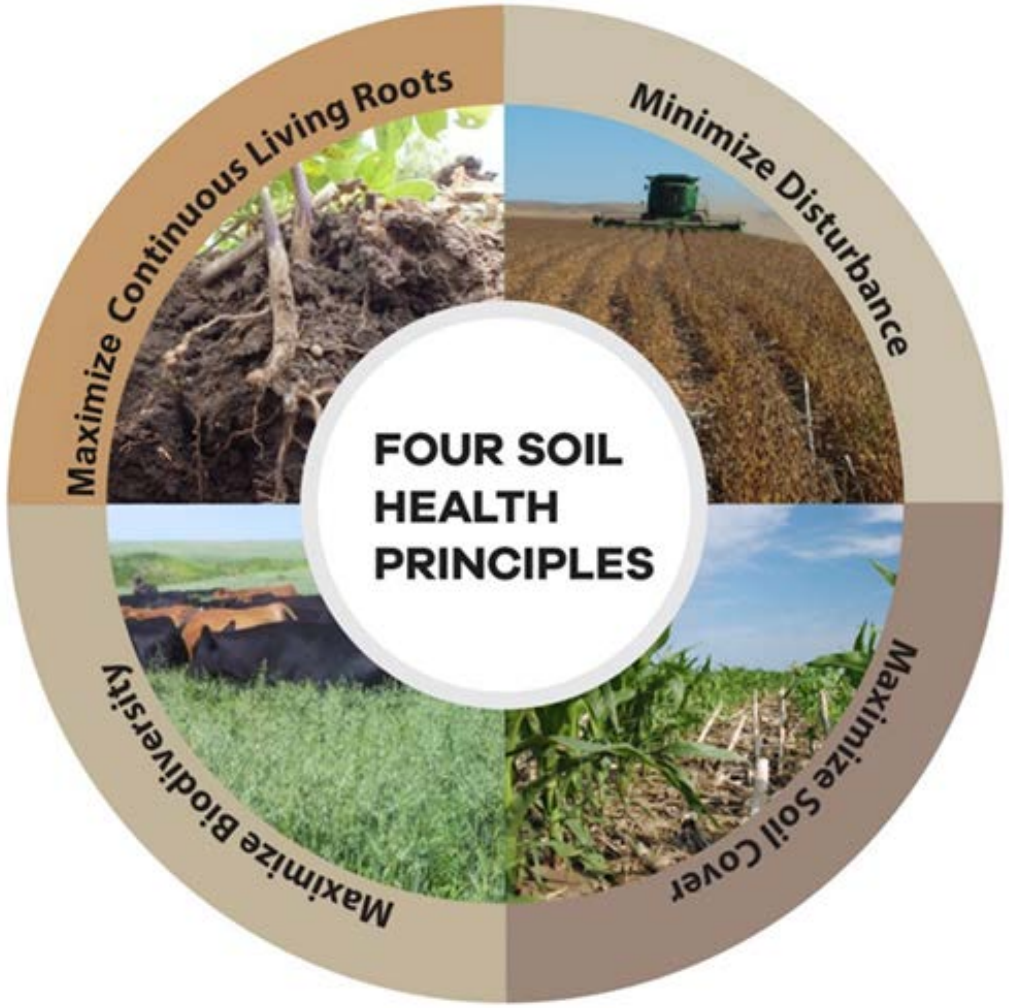
Fertilizer Diet

Soil Life Diet



Adapted from D. Montgomery

Holistic Approach to Nutrient Management



- **Living roots: cover crops & soil biology**
- **Minimize disturbance : soil biology-AMF**
- **Maximize soil cover: crop residues**
- **Maximize biodiversity: nutrient cycling & reserve**

Thank You

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Any Question?