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Ecological Nutrient Management

Candy Thomas

Natural
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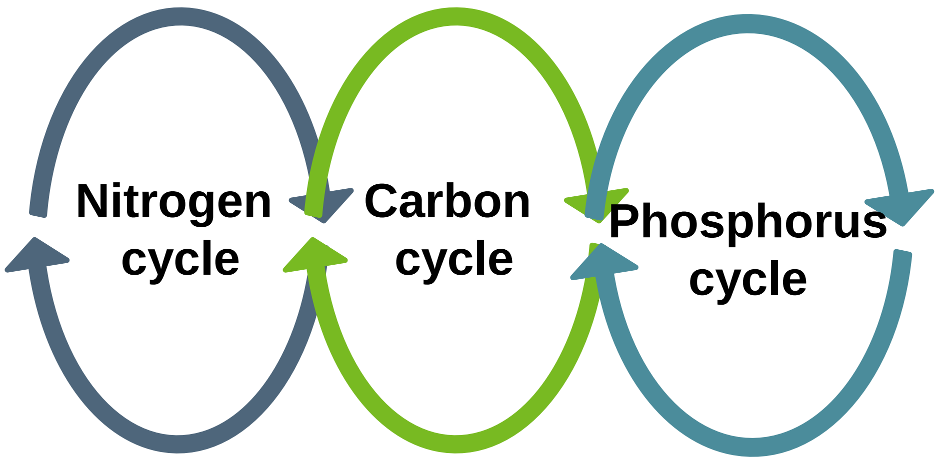
Conservation
Service

nrcs.usda.gov/

Ecological Nutrient Management

Developed by USDA-NRCS-Soil Health Division

Soil Health and Nutrient Cycling



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Factors Influencing Soil and Plant Nutrient Cycling

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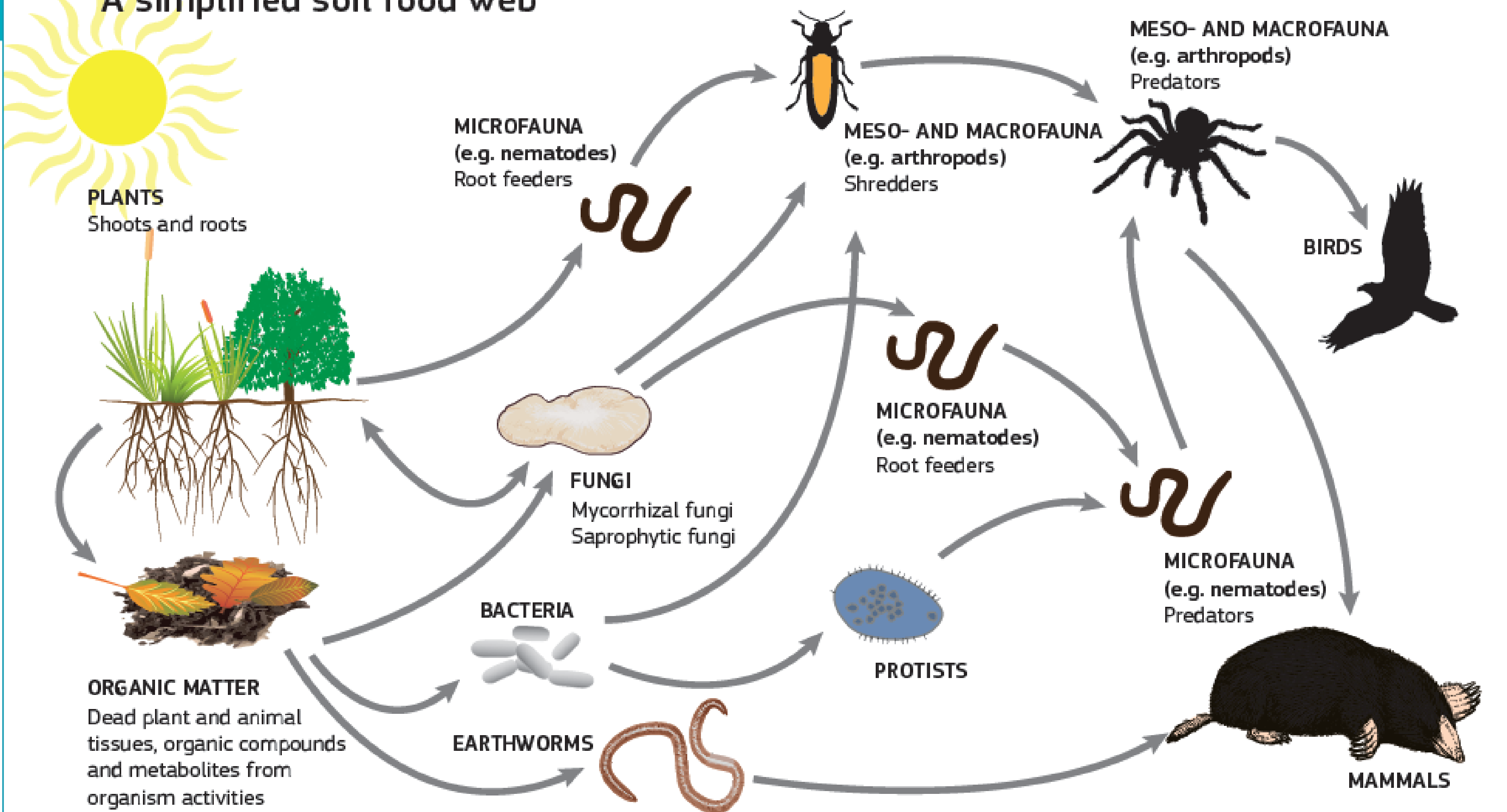
A simplified soil food web



1st TROPHIC LEVEL:	2nd TROPHIC LEVEL:	3rd TROPHIC LEVEL:	4th TROPHIC LEVEL:	5th and higher TROPHIC LEVEL:
Primary producers	Decomposers, litter and soil organic matter feeders Mutualists Pathogens and parasites Root feeders	Shredders Predators Grazers	Higher-level predators	Higher-level predators

implified soil food web represents some of the possible feeding connections in a soil ecological community. The trophic
of an organism is the position it occupies in a food web. Soil formation parallels the development of a food soil web in

Global Soil Biodiversity Atlas. 2016. Orgiazzi, Bardgett, Barrios et al. Luxembourg, European Commission, Publications Office of the European

C Cycling, Mineral Nutrient Release & SOM Formation

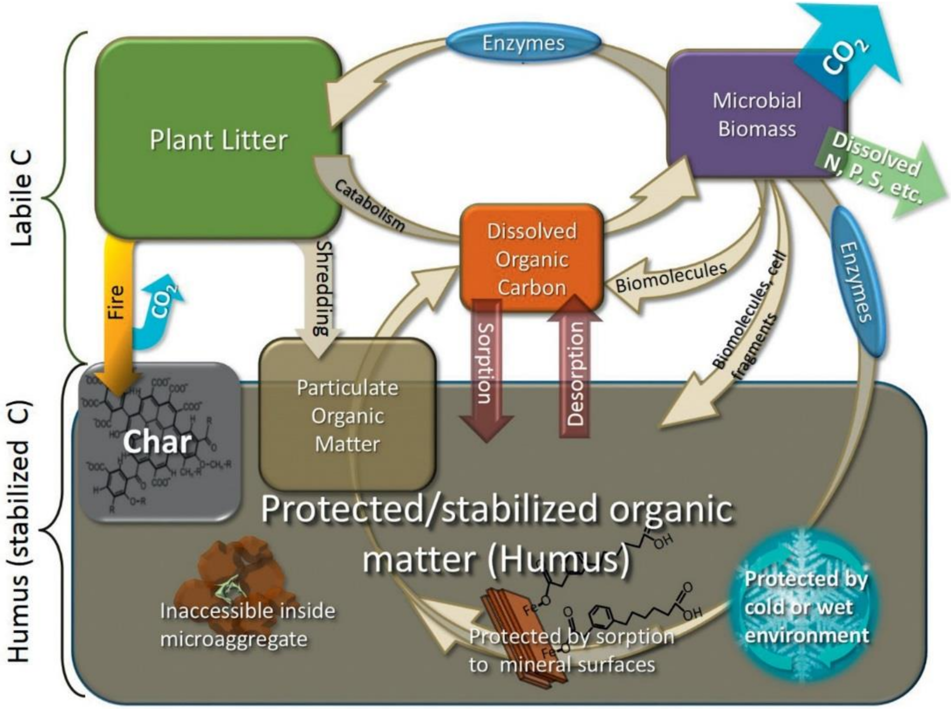
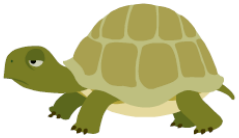


Image source: The Nature and Properties of Soils, 15e, Weil and Brady

C:N Ratio for Various Crops (Nutrient Cycling)

Material	C:N Ratio
rye straw	82:1
wheat straw	80:1
oat straw	70:1
corn stover	57:1
rye cover crop (anthesis)	37:1
pea straw	29:1
rye cover crop (vegetative)	26:1
mature alfalfa hay	25:1
Ideal Microbial Diet	**24:1**
rotted barnyard manure	20:1
legume hay	17:1
beef manure	17:1
young alfalfa hay	13:1
hairy vetch cover crop	11:1
soil microbes (average)	8:1



slower

Relative Decomposition Rate

faster

Rye
- High C:N
- Ties up N
- Compounds problem following another high C:N crop

Hairy Vetch
- Low C:N
- Release lots of N
- Decomposes Fast

Rye & Hairy Vetch Mix
- Balance C:N ratio
- Control decomposition
- Ideal cover crop mix

Microbial-Feeding Fauna Enhance Nutrient Release

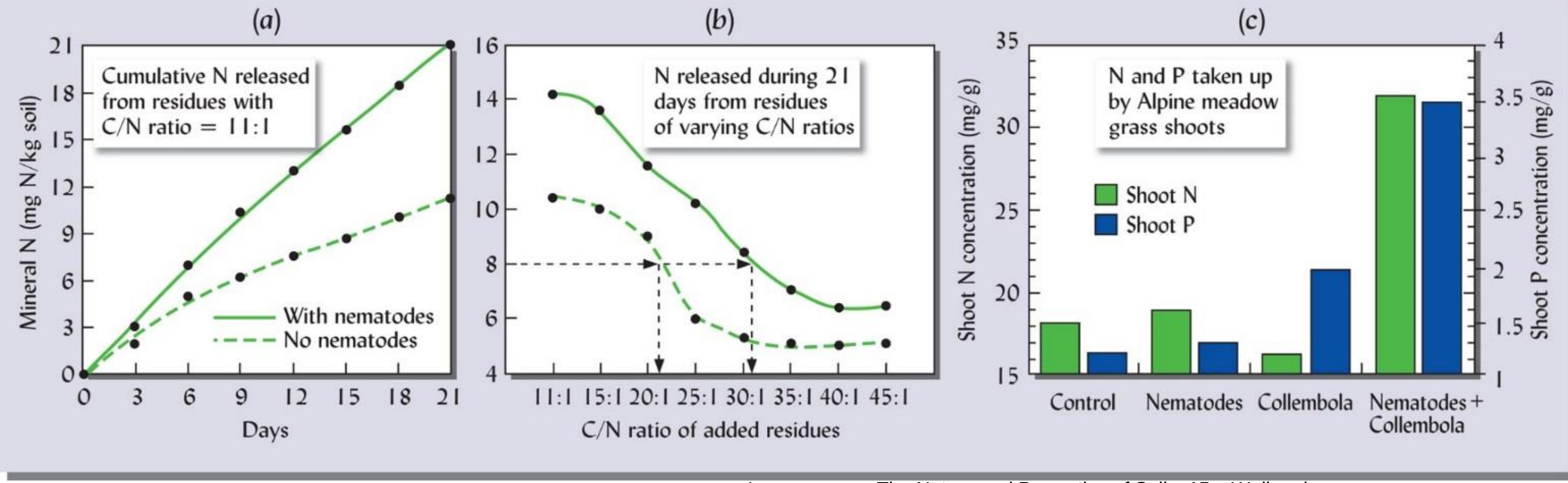
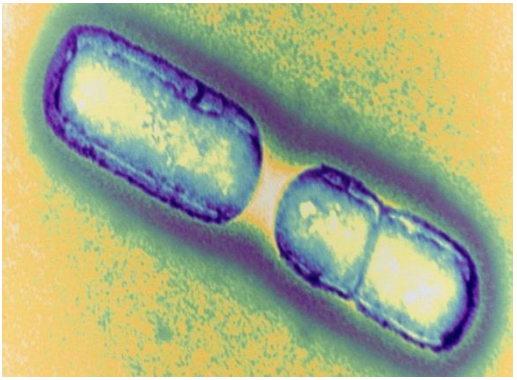


Image source: The Nature and Properties of Soils, 15e, Weil and Brady

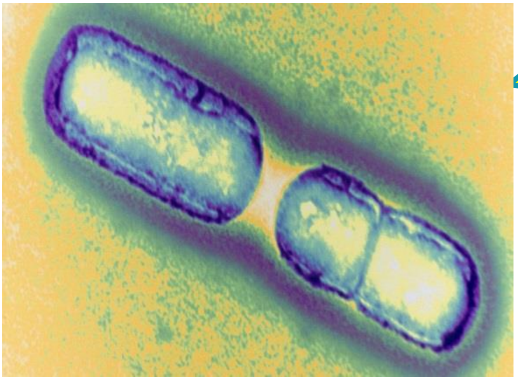
Nitrogen Mineralization



5:1

10:1

Nitrogen Mineralization



Consume two bacteria to get enough carbon for function and reproduction

Nitrogen Mineralization

Consume two bacteria to get enough carbon for function and reproduction

Only Needs 1 part N

Nitrogen Mineralization

Consume two bacteria to get enough carbon for function and reproduction

Only Needs 1 part N

Excrete 1 part N to soil solution as Plant Available N

Plant available Nitrogen, exactly what we want…right???

Cover Crop Mgt for N Retention

Cover Crop Mgt for N Retention

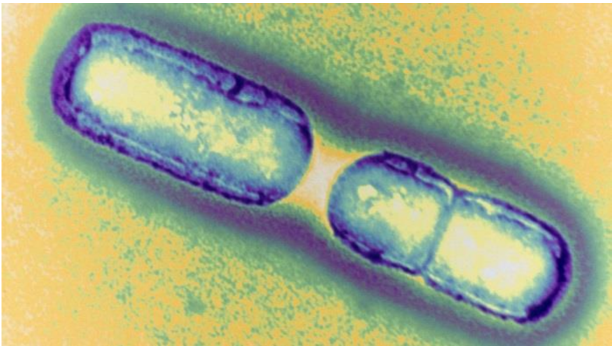
Nitrogen Immobilization

Cover Crop

C:N ratio about 40:1

Bacteria

C:N ratio about 5:1



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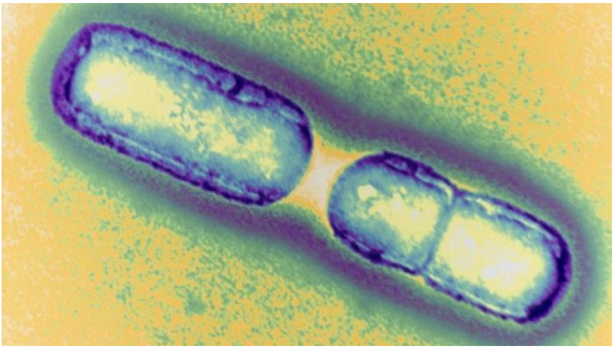

Consume enough carbon from the rye for respiration & body structure

Nitrogen Immobilization

Cover Crop

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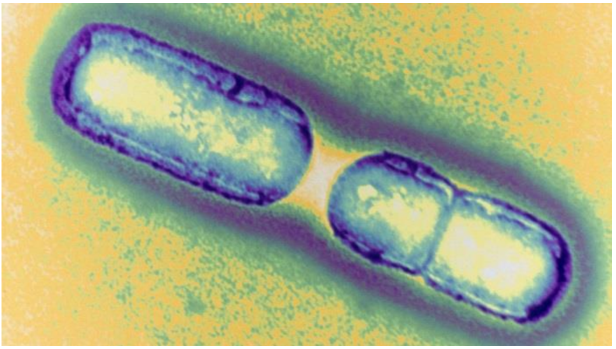
C:N ratio about 5:1



Consume enough carbon from the rye for respiration & body structure

N N

N N N N N N N

How C:N is Impacted by Microbes

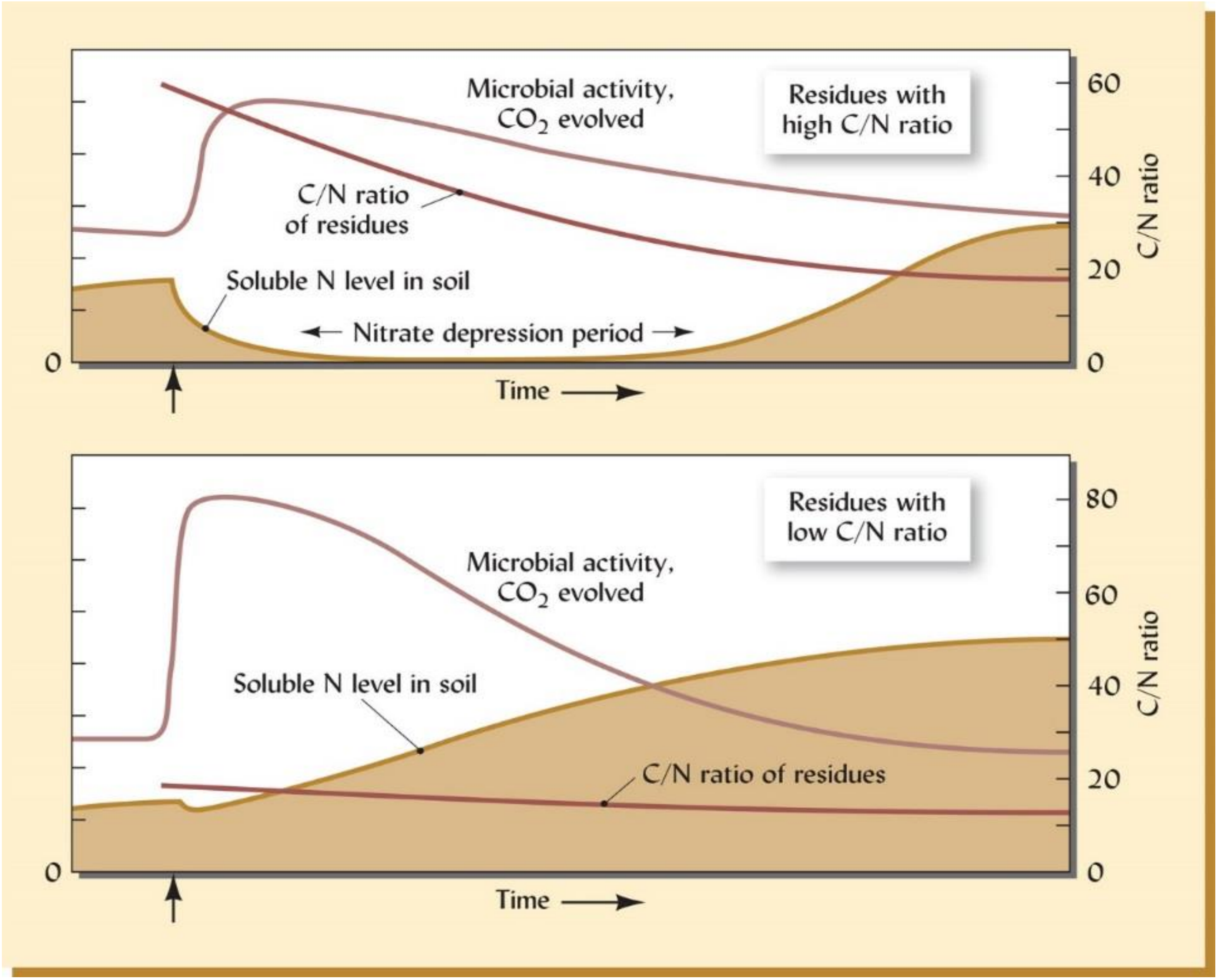


Image source: The Nature and Properties of Soils, 15e, Weil and Brady

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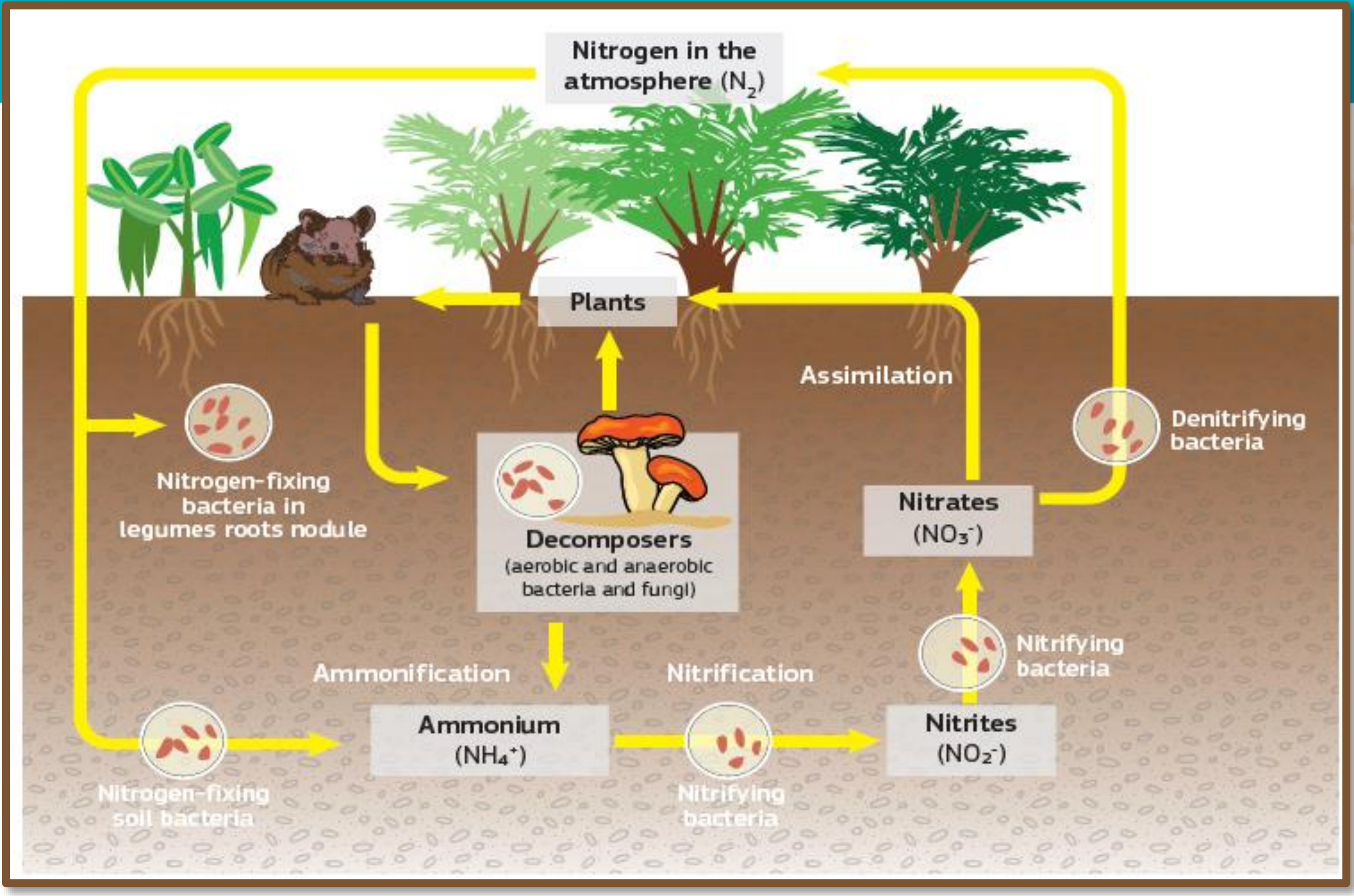
Biological N Fixation

Image source: The Nature and Properties of Soils, 15e, Weil and Brady



Microbes are Involved in All Steps of Soil N Cycle

N-fixation: N_2 → Organic N

Ammonification: Organic N → NH_4^+

Nitrification: NH_4^+ → NO_2^- → NO_3^-

Denitrification: NO_3^- → → N_2O → N_2

Large amount of fertilizer, NO MATTER WHAT INITIAL FORM, goes through microbes before plant gets it.

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Schematic representation of the main flows of nitrogen (N) through the terrestrial environment. The importance of soil bacteria and fungi in the cycle is immediately recognized as being a key element, providing different forms of N compounds assimilable by higher organisms, such as plants. (JJB, FVI, NLA, NRCS)

Importance of Soil Biology: Release Plant-Available Nutrients

Soil Function

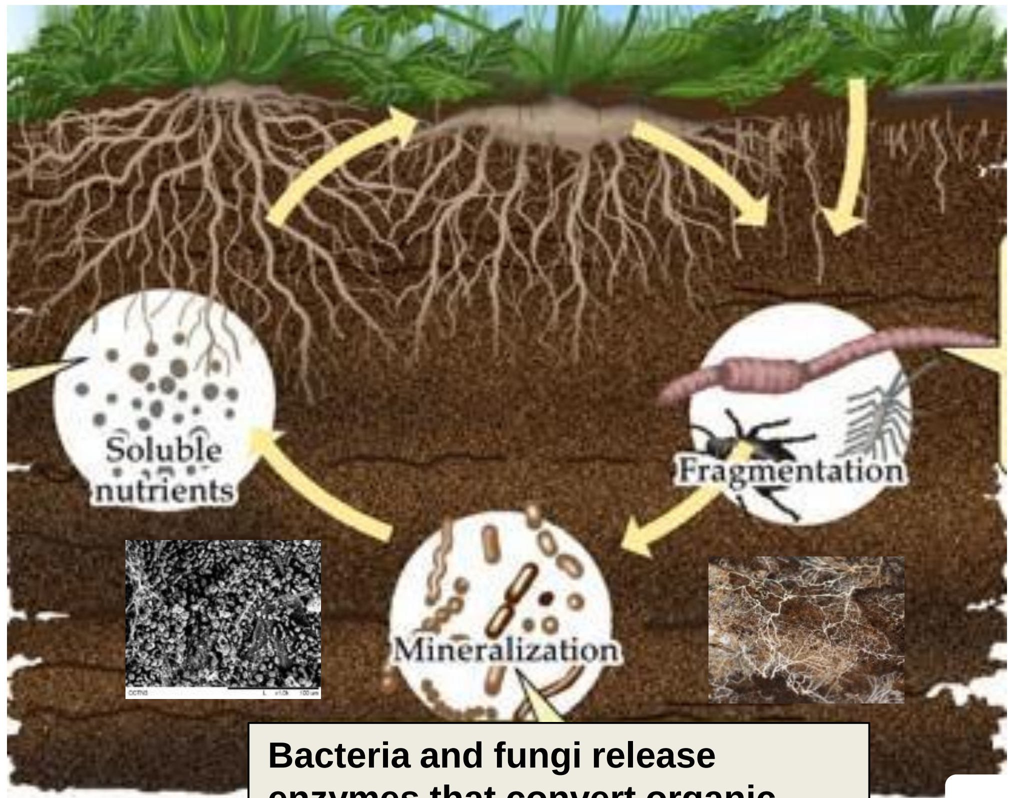
Nitrogen mineralization

↓

Plant-available N release

↓

Reduction in fertilizer needs



Bacteria and fungi release enzymes that convert organic molecules from residues into soluble nutrients (N, P, S)

Importance of Soil Biology: Release Plant-Available Nutrients

Soil Function

Nitrogen fixation

↓

'Free' N fertilizer factories

↓

Reduction in fertilizer needs

Fava Bean; Moore-Kucera, 2016

Symbiosis between soil bacteria associated with some plant roots supply:
25-75 lb/ac in natural systems
100-200 lb/ac in cropland

Soil Biology and Nutrient Cycling

Majority of fertilizer, *no matter what initial form*, goes through microbes before it is used by the plant.

Soil microbial biomass accounts for:

- 1-5% of total organic C
- 2-6% of total organic N
- ~3% of total organic P in arable soils
- 5-24% of total organic P in grassland soils

Paul, 1984, Plant and Soil 76:275-285;
Brookes et al., 1984. Soil Biol Biochem, 16:169-175

Plant Available Nitrogen (PAN)

- **Depends upon the crop**
- **Termination stage**
- **Typical cover crop 60 percent is lost as CO2 and 40% moved to Soil organic matter**

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Plant Available Nitrogen (PAN)

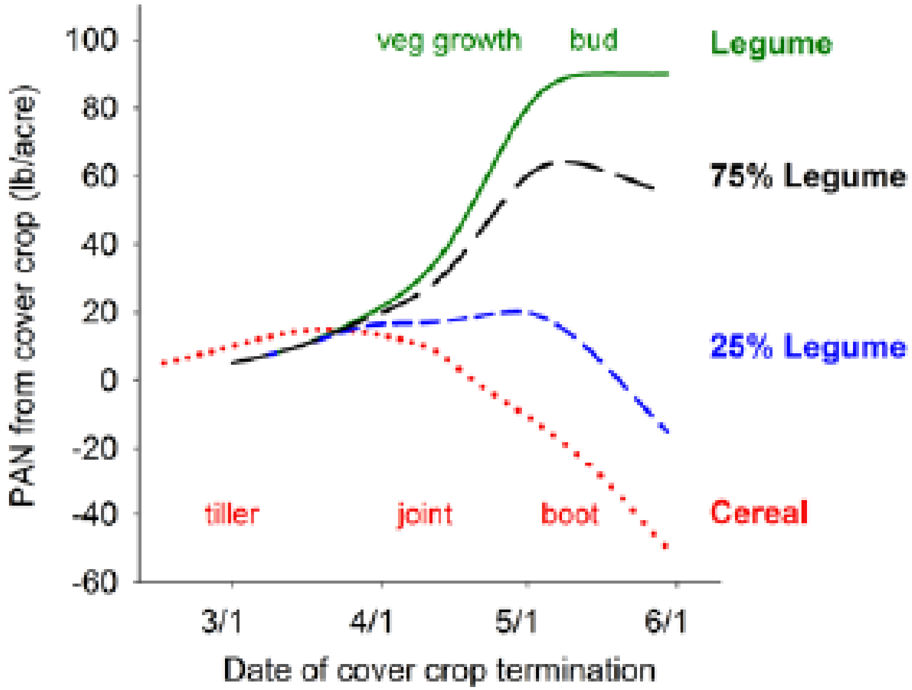

Figure 4.—Effect of kill date on typical plant-available N (PAN) release from cereal, legume, or mixed stands. Based on compilation of field data from Willamette Valley cover crop trials. Source: D. Sullivan.

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Site Specific PAN

- Accuracy of cover crop N “credits” is improved, and N fertilization practices can be fine tuned.
- Accuracy of this method has been documented extensively for winter cover crops harvested from March through May in the Willamette Valley.
- A site-specific method is especially useful for mixed cover crop stands.

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SHORTCUT METHOD

If you prefer to forego lab analysis, you can harvest and measure cover crop biomass (see steps 2–4 on pages 6–8) and use typical values for cover crop DM and %N to estimate PAN. Values below are typical for cover crops collected in mid-April in the Willamette Valley:

Biomass dry matter:
- Common vetch = 12 to 18 percent
- Cereals = 15 to 20 percent
- 50/50 vetch/cereal mix = 15 percent

%N in DM:
- Common vetch = 3 to 4 percent
- Cereals = 1.5 to 2.5 percent
- 50/50 vetch/cereal mix = 2.5 to 3 percent

The %N in cereals varies with field history. Fields that have a history of manure/compost application and/or legumes in rotation have higher %N in cereal than do fields with history of only mineral N fertilizer application.

We always recommend cutting and weighing cover crop biomass to estimate PAN. Visual estimates of cover crop biomass are not very accurate, especially for multi-species cover crop mixes.

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Determining Dry Matter for Estimation

Cool Season Legumes- first 4”=140 lbs with an additional 250 lbs. for each inch there after

Warm Season covers – first 4”= 1275 lbs with additional 200 lbs. for each in there after

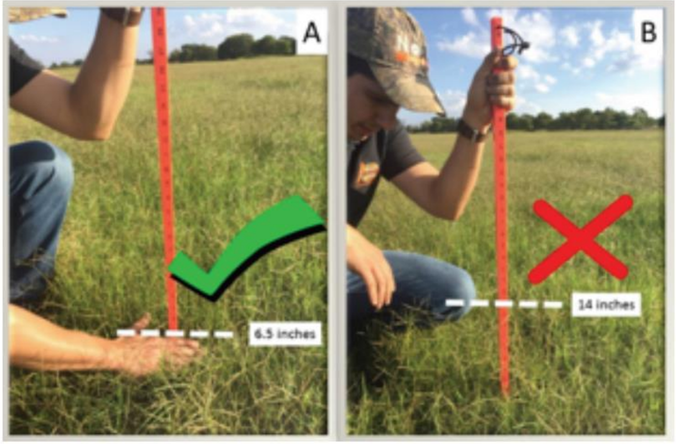


Figure 1: Proper (A): average forage leaves height. Improper (B): highest plant or shoot. Focus in measuring the height where leaves are found if the forage already has an elongated seed head.

Clip, weigh, dry and weigh again, for acclimating eye for estimation

Table 1. Generalized estimates of N contribution to current or subsequent plantings as a result of plowing down a group of legume species growing in several different environments.

Growing Environment	*Legume Species*	*Size and/or Density*	*Legume Dry Matter Yield (approx. lb/acre)*	*N Contribution (lb N/acre)*
General				
September through March for fall plantings, April through May for spring plantings	Small Seeded Forage Legumes	Seedlings, 1 to 6 in. tall with few branches	10 to 100	0 to 10 [1]
Legumes interseeded with grass or small grains				
Good conditions, adequate water, P, K, and pH	Alfalfa, Clover[2], Vetch, Hop Clover, Ladino clover, Annual Lespedeza	Scattered (1 legume plant/yd^2)	100	1 to 5 [3]
	Hop Clover, Annual Lespedeza	Thick stand, 1 ft. tall	1,000	15 to 30 [3]
	Alfalfa, Clovers[2]	1 legume plant/ft^2, 12 to 15 in. tall	1,000	20 to 30 [3]
	Alfalfa, Clovers[2]	1 legume plant/ft^2, 15 to 24 in. tall,	1,500	30 to 60 [3]
	Clovers[2], Vetch	Thick stand, 3 legume plants/ft^2, 20 to 30 in. tall	2,000	40 to 60 [3]

OK State Forage and Legumes N Content http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-3101/PSS-2590web%20color.pdf

Growing Environment	*Legume Species*	*Size and/or Density*	*Legume Dry Matter Yield (approx. lb/acre)*	*N Contribution (lb N/acre)*
Monoculture Legumes				
Droughty, low P, K, and/or pH	Cowpea or Austrian Winter Pea with pods	Poor stand (1 legume plant/yd^2)	500 to 1,000	15 to 30[4]
	White Clover	Full stand, 3 to 4 in. tall	500 to 1,000	15 to 40 [5]
Good conditions, adequate water, P, K, and pH	Soybean (without beans), Peanut (after nuts harvested)	Full stand	1,000 to 2,000	20 to 60 [6]
	Cowpea, Austrian Winter Pea with pods	Full Stand	2,000 to 3,000	50 to 95 [6]
	Alfalfa, Clovers [2]	Full stand, 24 to 36 in. tall	4,000 to 5,000	100 to 150 [6]

1 Plow down N could be negative because seedlings required N from soil before fixation begins.
2 Clovers include any of several upright-growing clovers including red, arrowleaf, and crimson.
3 Additional N from roots that will eventually become available may be estimated at as little as10 lb N/acre for short-lived annuals to 90 lb N/acre for perennials with well developed root systems.
4 Little additional N will be available from roots with a poor stand growing under poor conditions.
5 Ladino clover plants tend to be short-lived and roots are relatively shallow, resulting in little N (10 to 20 lb/acre) from roots.
6 Contributions from roots may be estimated in the range of 20 lb N/acre, for crimson clover, to 60 lb N/acre for 2- to 3-year-old alfalfa stands.

OK State Forage and Legumes N Content http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-3101/PSS-2590web%20color.pdf

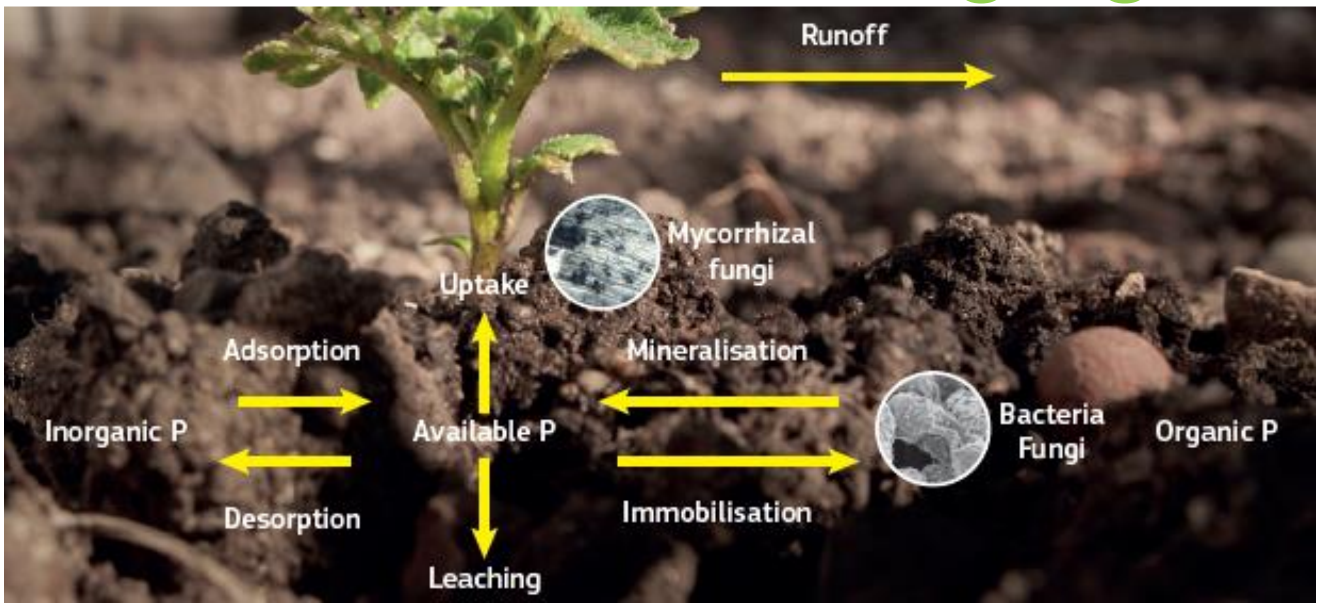
Sources of Variation in N Availability and Crop Needs

- Organic amendments (manure, compost, etc.)
- Crop rotations
- Soil type differences
- Soil organic matter content and quality
- Soil and crop management (tillage, cover crops, planting date, amendment timing, etc.)
- Weather—Temperature & Precipitation

Interactions are Complex & Nonlinear!

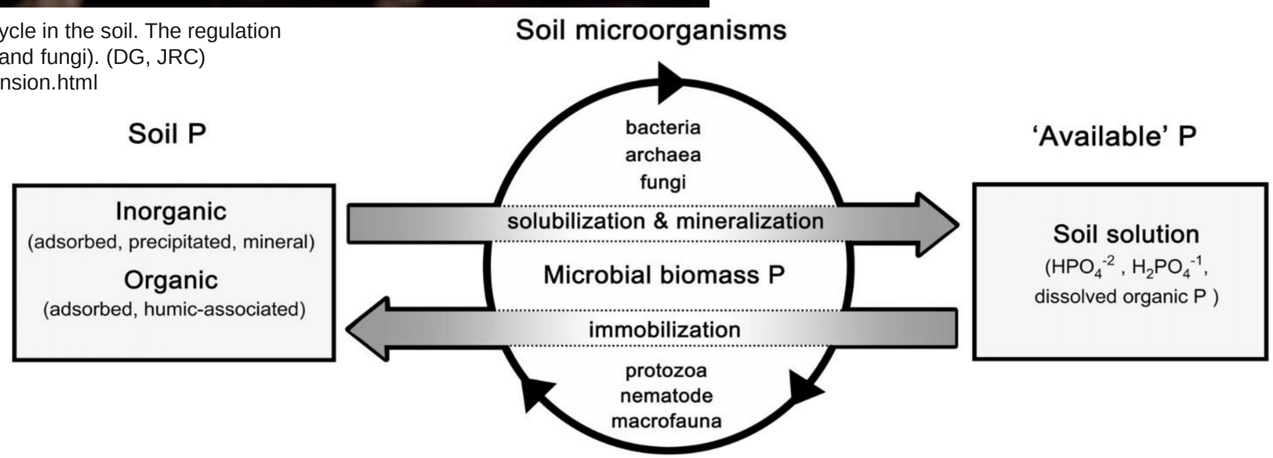
Slide adapted from van Es and Moebius-Clune, 2014

Nutrient Cycling: Managing the P Cycle Means Managing Biology



- P sources mainly from ancient rocks and deposits
- Soil pH and minerals affect availability
- Plant-microbe interactions release stored org-P and mineral-P

Top: Global Soil Biodiversity Atlas: Simplified phosphorus (P) cycle in the soil. The regulation of soil P cycling is influenced by microorganisms (e.g. bacteria and fungi). (DG, JRC)
Bottom: http://www.plantphysiol.org/content/156/3/989/F1.expansion.html



Mycorrhizal Root Colonization and Effective Root Volume

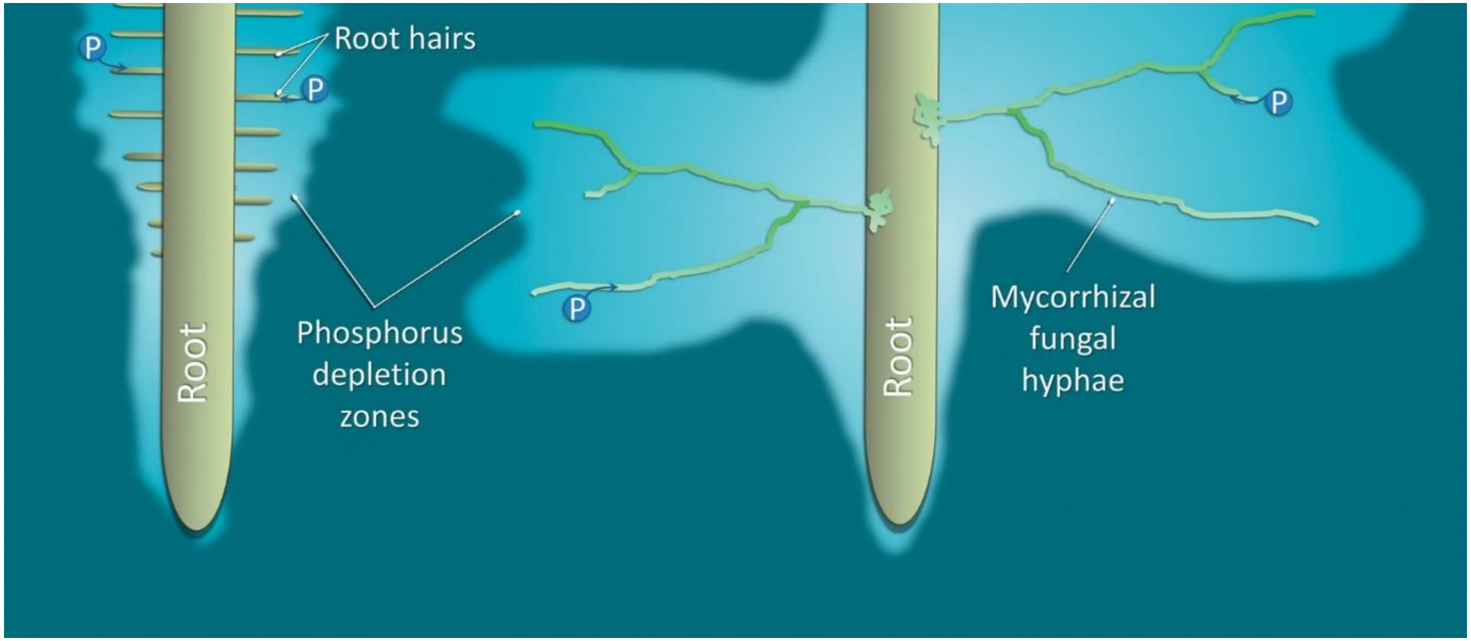


Image source: The Nature and Properties of Soils, 15e, Weil and Brady

Microbes Release P from Minerals

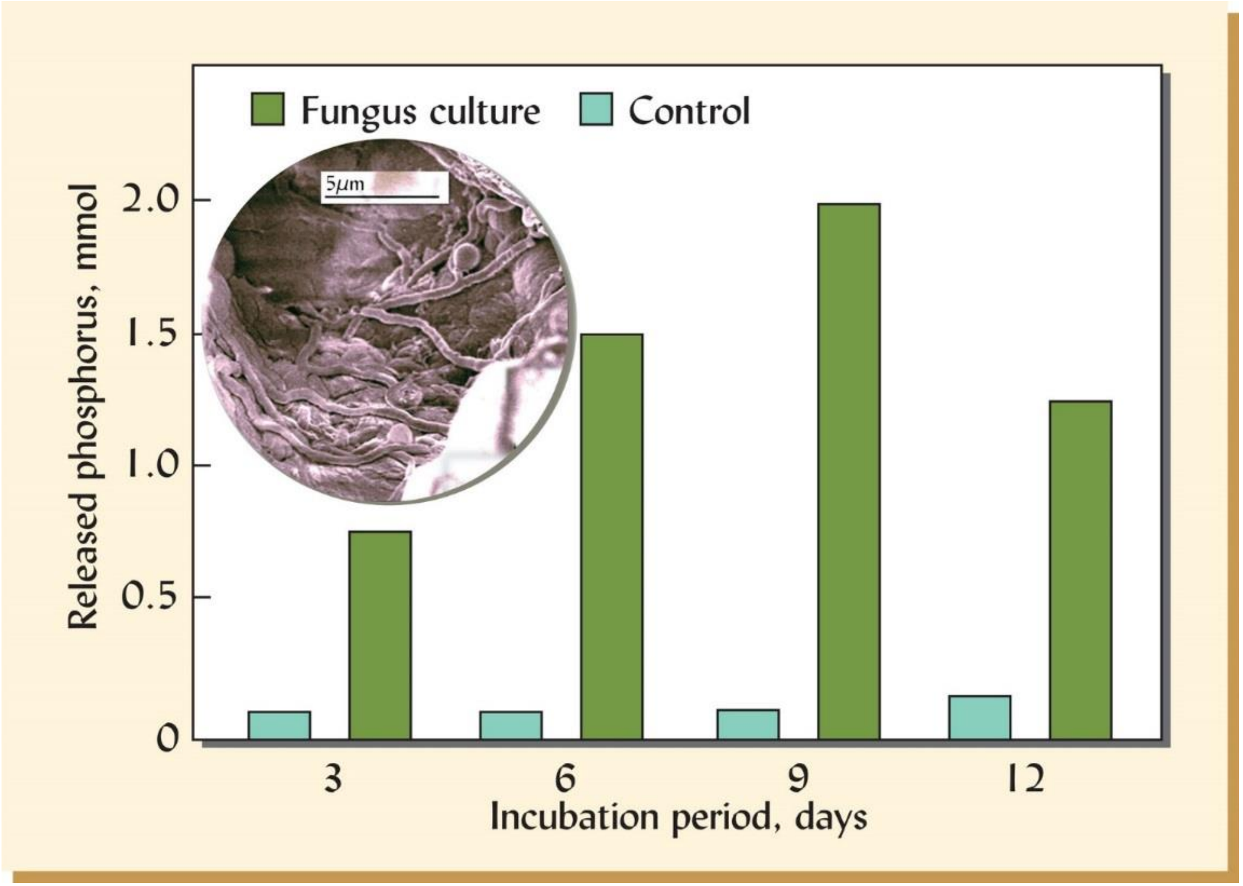


Image source: The Nature and Properties of Soils, 15e, Weil and Brady

Cover Crops for Absorbing Soluble P

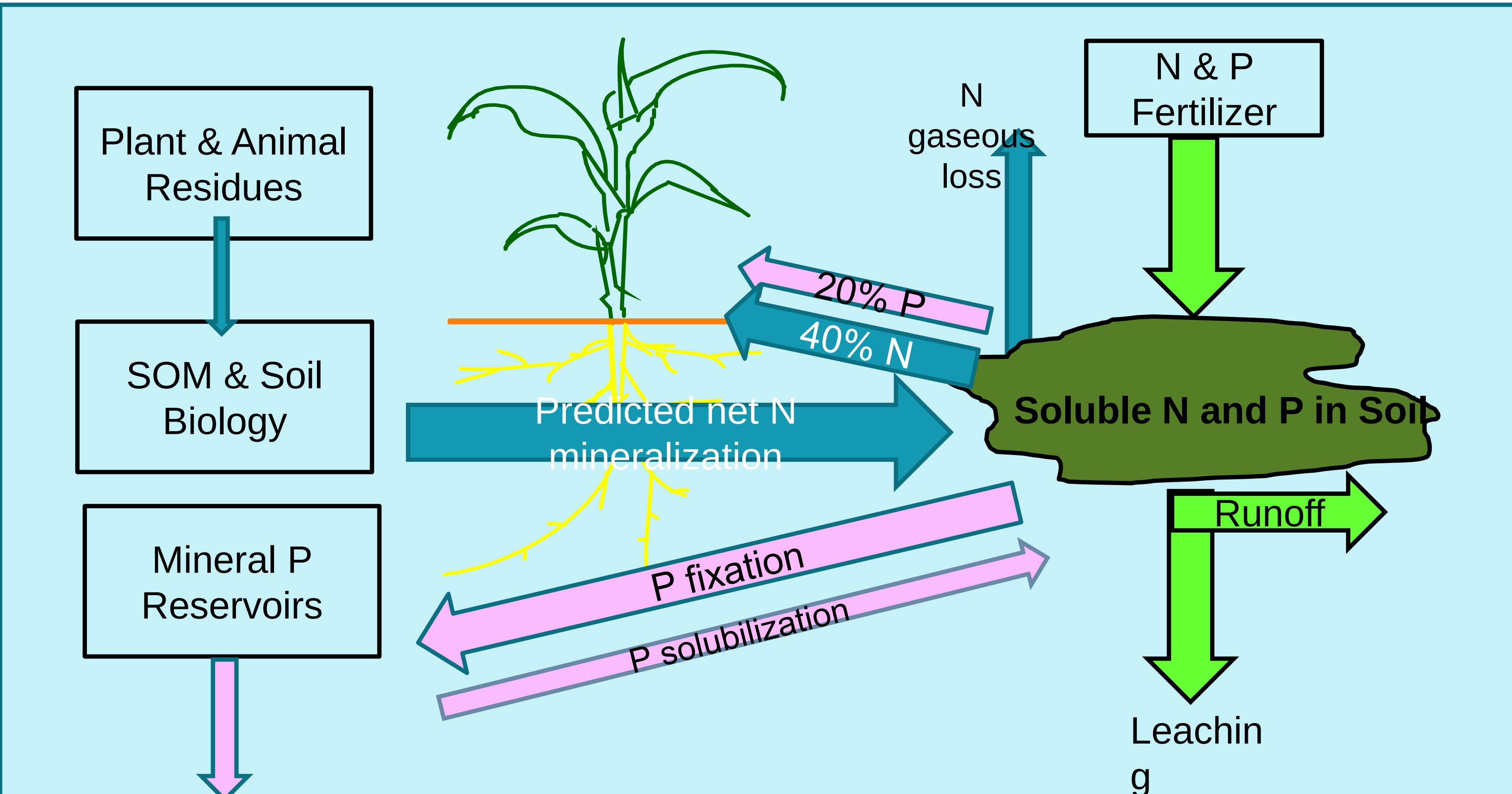
Good Cover Crops
Cereal rye
Annual Ryegrass
Triticale
Barley
Wheat

Mixtures/Minimize*
Radish*
Oats
Legumes

Other Issues
Short pasture
Alfalfa hay

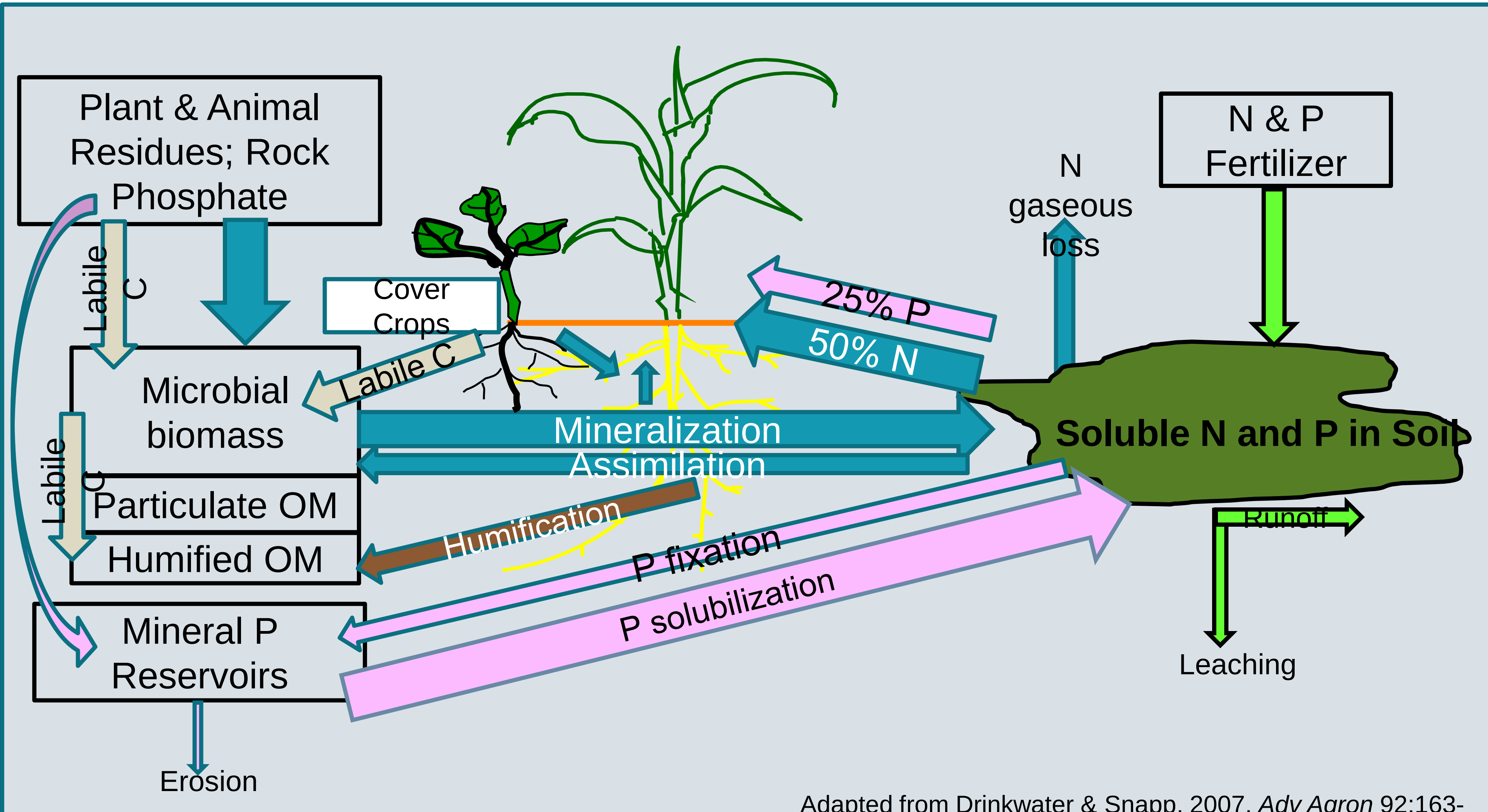
When are the Cover Crops Terminated?

Dominant Nutrient Management Paradigm



Adapted from Drinkwater & Snapp, 2007, *Adv Agron* 92:163-186.

Ecological Approach to Nutrient Management



Adapted from Drinkwater & Snapp, 2007, *Adv Agron* 92:163-186.

Options for Optimal Ecological Nutrient Cycling

- Increase microbial biomass w/carbon inputs
- Enhance mycorrhizal fungal uptake of nutrients
- Promote members higher in food web to graze on microbes and release plant nutrients

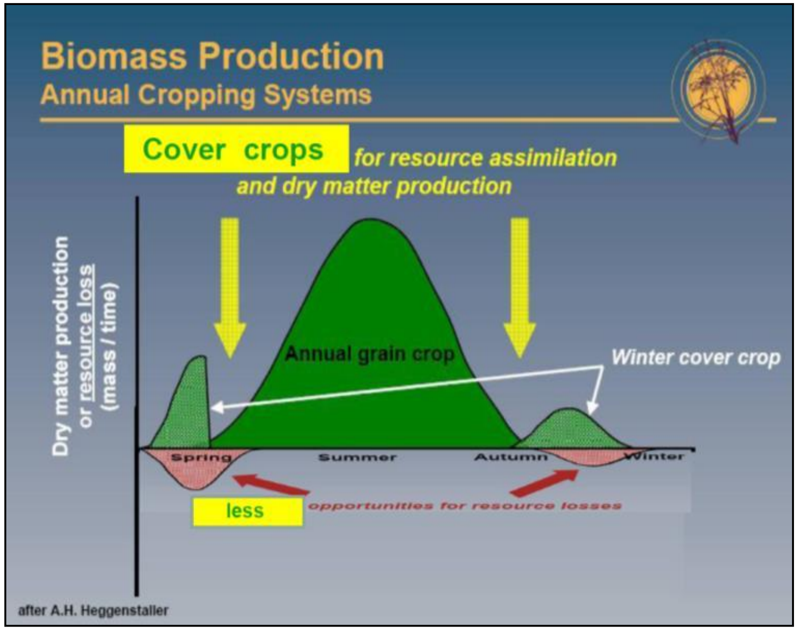
Continued. . .

Options for Optimal Ecological Nutrient Cycling

- Incorporate leguminous crops that team up with bacteria to make N fertilizer from atmosphere
- Decrease nitrification (inhibitors?) to prevent conversion of organic N to leaky NO_3^-

Cover Cropping Considerations

- **Cover crops maintain high infiltration rates**
- **Continuous living roots**
  - Take up water and nutrients in the 'off season'
  - Improve field conditions
  - Prevent losses
  - 'Filter' drainage water together with microbes
  - Release nutrients to next crop



Continued. . .

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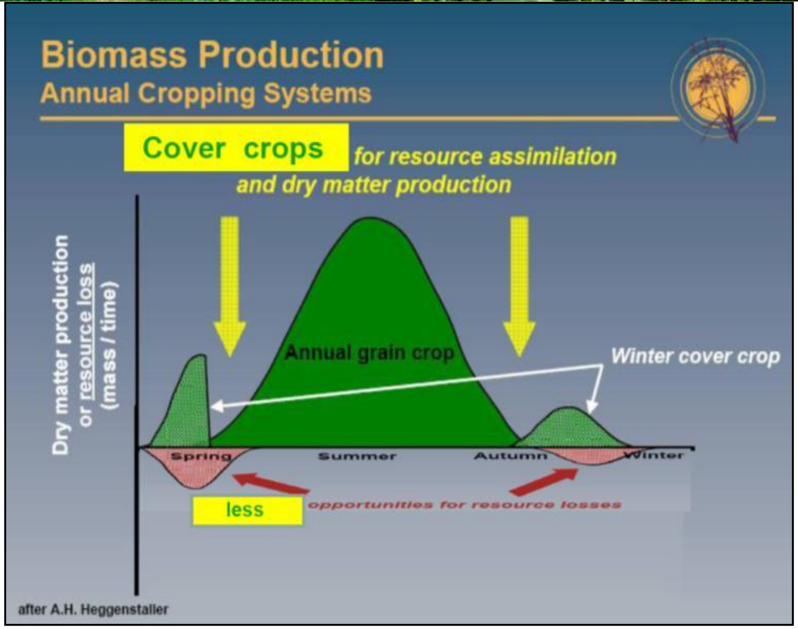
Cover Cropping Considerations

- **Different cover crops address different needs, are adapted to different main crops**
- **Use new technologies**
- **May need to avoid:**
  - Large tap roots (with tile drain)
  - Covers that winter kill



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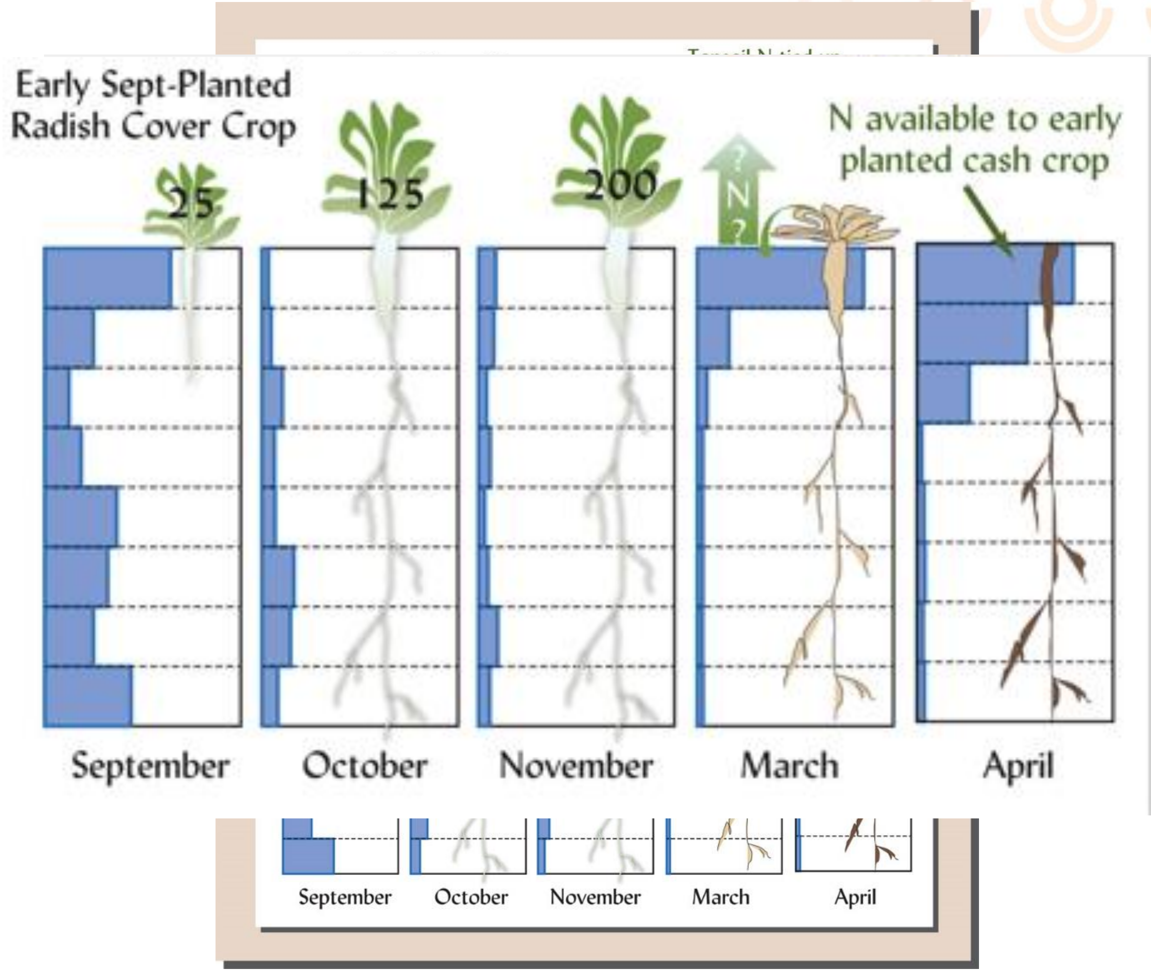

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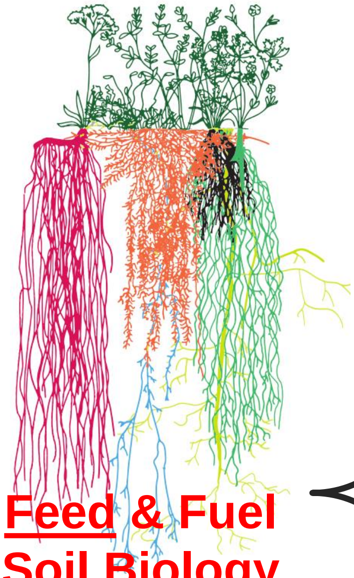
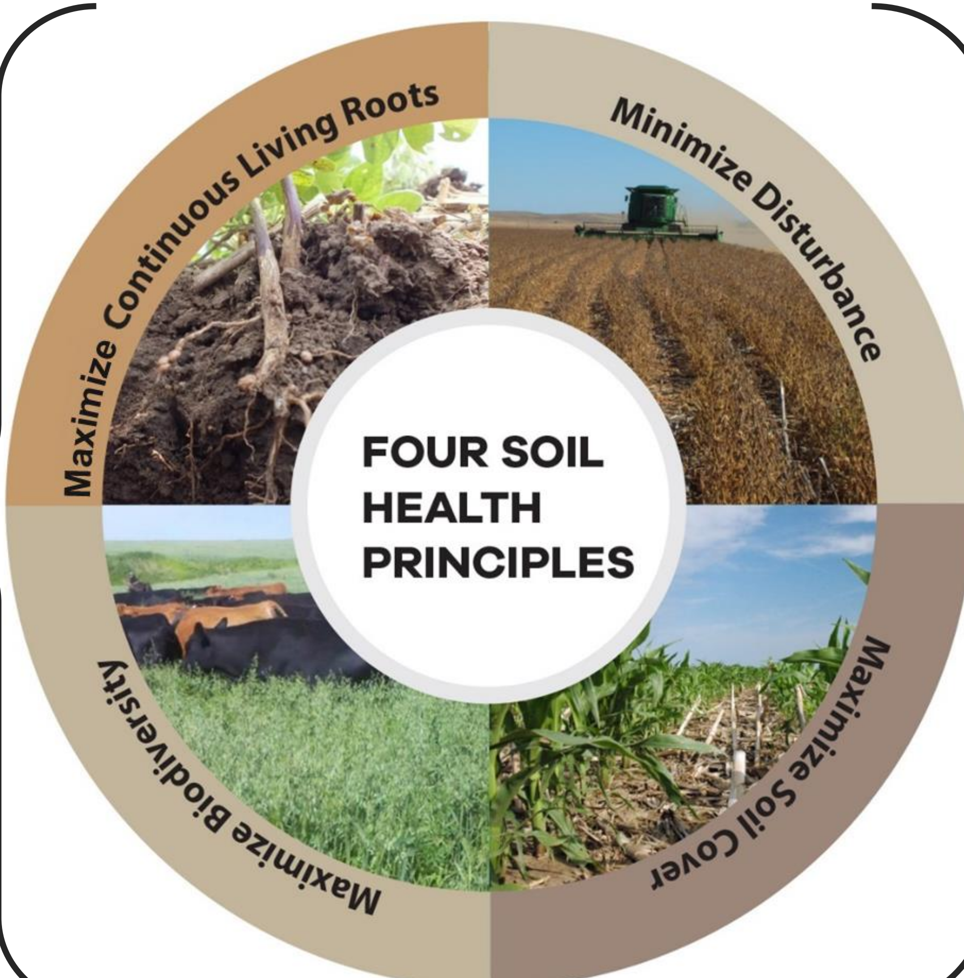
Four Soil Health Principles With Universal Applications



Feed & Fuel Soil Biology



Protect Soil Aggregates & Organic Matter

Soil Health Management Systems

Crop Rotation
Cover Crops
Relay Crops
Forage & Biomass Plantings
Perennial Crops

Reduced Tillage
Controlled Traffic
Avoid Tillage when Wet
No-Till

Crop Rotation
Cover Crop
Rotational Grazing
IPM
Pollinator Planting

Cover Crop
Surface Manage Crop Residues
Mulching
Reduced Tillage
Forage & Biomass Plantings

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(2) fax: (202) 690-7442; or

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