Professor dr. Idham A. Abed

1. Organic Matter (Nutrient Supplying Power of Soil)

CO_2 levels in the atmosphere have increased from 260 to 340 ppm in the last 150 years

Expected to rise 1.5 to 2.0 ppm per year (Wittwer, 1985)

Responsible for 0.5 °C global temp increase

Benefits associated with increased atmospheric CO_2 (increased water use efficiency, nitrogen use efficiency and production in many crops)

Can OC be increased?

No-till management practices (10 yrs no-tillage with corn, OC in surface 30 cm increased by 0.25% (Blevins et al. 1983).

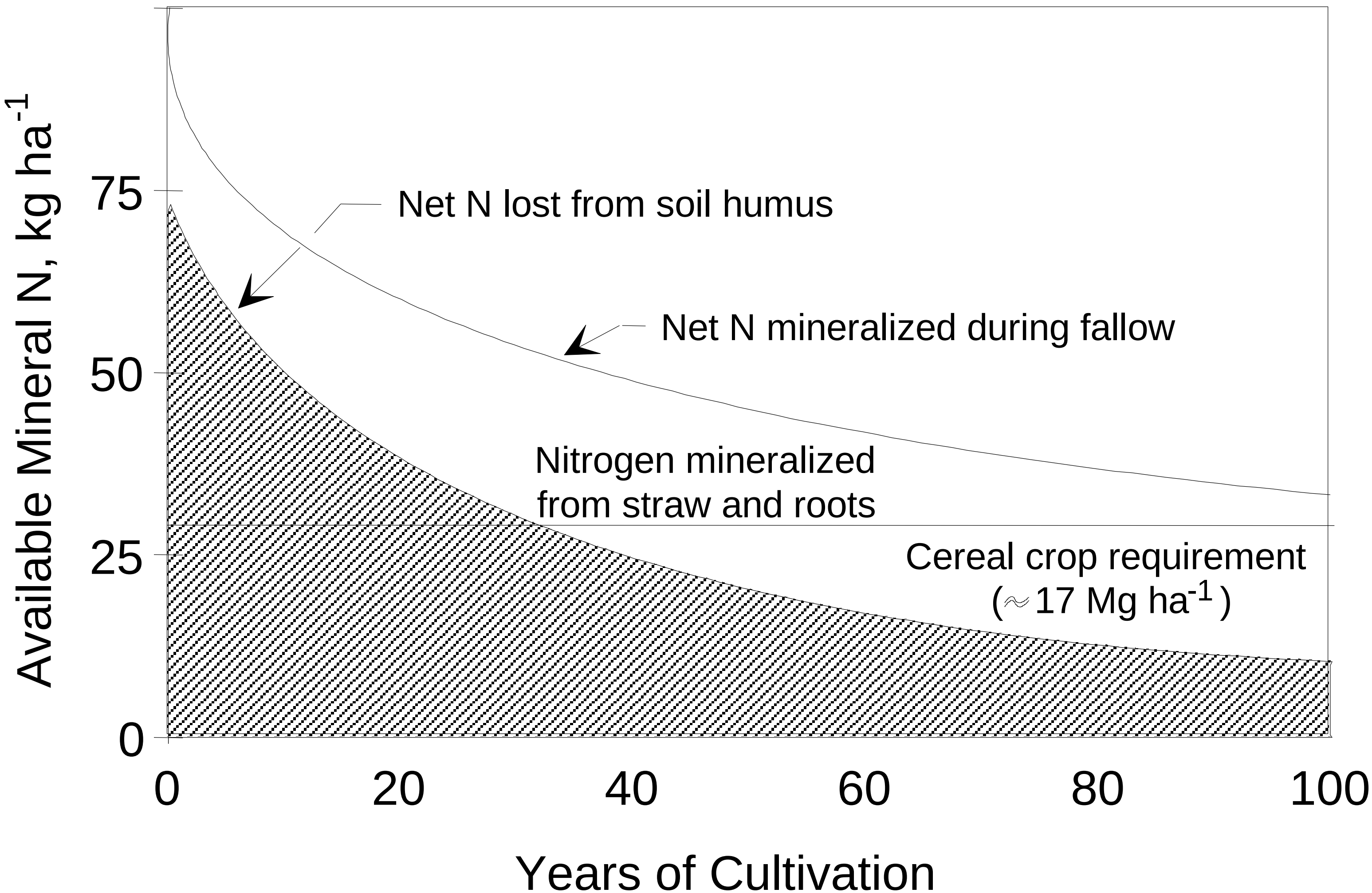
N rates in excess of that required for maximum yields result in increased biomass production (decreased harvest index values e.g., unit grain produced per unit dry matter) . Increased amounts of carbon from corn stalks, wheat stems,

Fertility of forest and grassland soils in North America has declined significantly as soil organic matter was mined by crop removal without subsequent addition of plant and animal manures (Doran and Smith, 1987).

For thousands of years, organic matter levels were allowed to increase in these native prairie soils since no cultivation was ever employed.

As soil organic matter levels declined, so too has soil productivity while surface soil erosion losses have increased. Because of this, net mineralization of soil organic nitrogen fell below that needed for sustained grain crop production (Doran and Smith, 1987).

To maintain yields with continuous cultivation, supplemental N inputs from fertilizers, animal manures or legumes are required



Influence of cultivation time on relative mineralization from soil humus and wheat residue. (From Campbell et al. (1976)). **Should the decline in years 1-5 be greater?**

Effects that management systems will have on soil organic matter and the resultant nutrient supplying power of the organic pools are well known. Various management variables and their effect on soil organic matter are listed;

Organic Matter Management	Effect
1) tillage	+/-
conventional	-
zero	+
2) soil drainage	+/-
3) crop residue placement	+/-
4) burning	-
5) use of green manures	+
6) animal wastes and composts	+
7) nutrient management	+/-
excess N	+

Composition of Organic Matter

Soil microorganisms and fauna make up a relatively small portion of total soil organic matter (1-8%).

Functions as an important catalyst for transformations of N and other nutrients

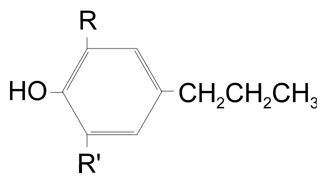
Majority of soil organic matter is contained in the nonliving component that includes plant, animal and microbial debris and soil humus.

<u>Cellulose generally accounts for the largest proportion of fresh organic material</u>

- decays rapidly
- need N for decay

<u>Lignin decomposes slowly</u>

- nutrients bound in lignin forms are not available for plant growth
- lignin is insoluble in hot water and neutral organic solvents, but it is soluble in alkali solutions
- seldom find calcareous soils with high organic matter.
- polysaccharides decompose rapidly in soils and serve as an immediate source of C for microorganisms.

Form	Formula	Decomposition	Composition
Cellulose	**$(C_6H_{10}O_5)n$**	**rapid ***	**15-50%**
Hemicellulose			**5-35%**
glucose	**$C_6H_{12}O_6$**	**moderate-slow**	
galactose			
mannose			
xylose	**$C_5H_{10}O_5$**	**moderate-slow**	
Lignin(phenyl-propane)		**slow**	**15-35%**
Crude Protein	**$RCHNH_2COOH$****	**rapid**	**1-10%**
Polysaccharides			
Chitin	**$(C_6H_9O_4.NHCOCH_3)n$**	**rapid**	
Starch	**glucose chain**	**rapid**	
Pectins	**galacturonic acid**	**rapid**	
Inulin	**fructose units**		

*** - decomposition more rapid in the presence of N**

**** - amino acid glycine (one of many building blocks for proteins)**

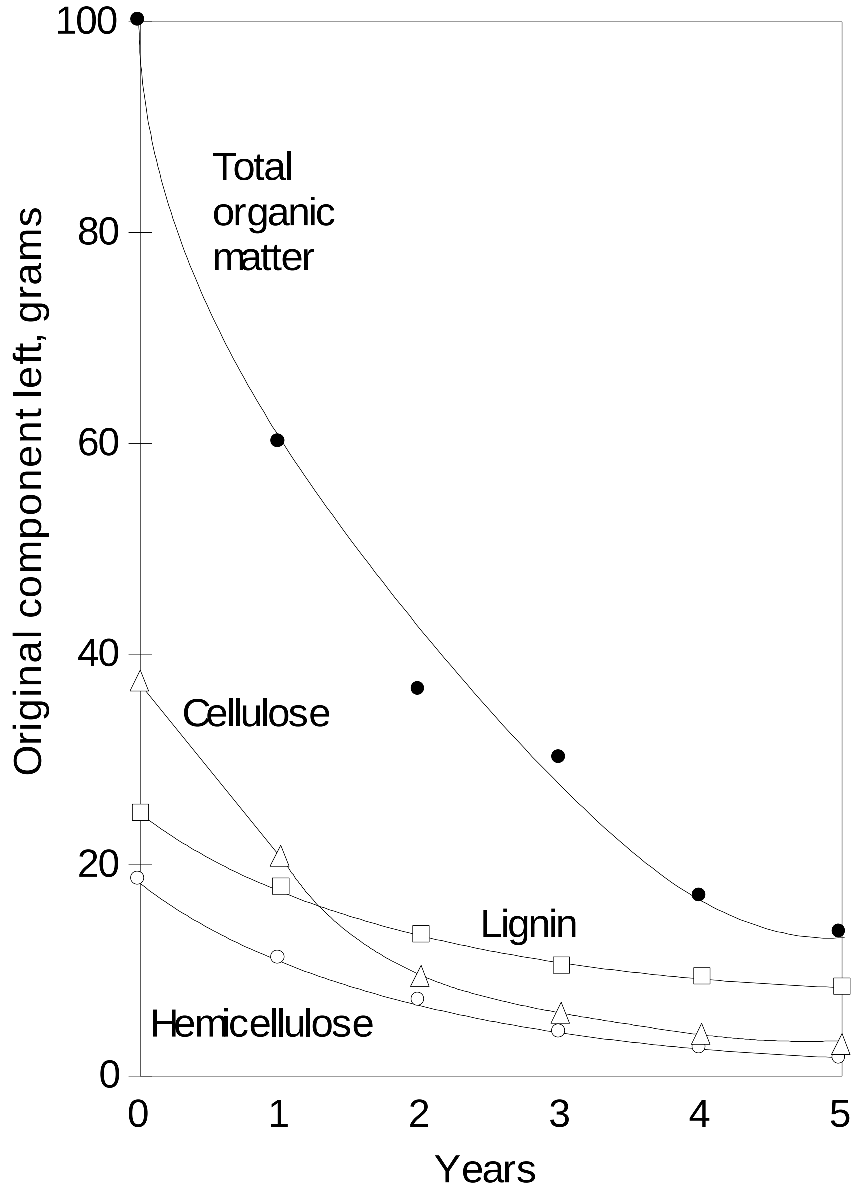


Figure 1.2. Decomposition of Miscanthus sinensis leaf litter.

Composition of mature cornstalks (*Zea mays* L.) initially and after 205 days of incubation with a mixed soil microflora, in the presence and absence of added nutrients (Tenney and Waksman, 1929)

Constituents or fraction	Initial composition %	Composition after 205 days (%) No nutrients added	Nutrients added
Ether and alcohol soluble	6	1	<1
Cold water soluble	11	3	4
Hot water soluble	4	4	5
Hemicelluloses	18	15	11
Cellulose	30	13	6
Lignins	11	23	24
Crude protein	2	9	11
Ash	7	19	26

1. As decomposition proceeds, water soluble fractions (sugars, starch, organic acids, pectins and tannins and array of nitrogen compounds) readily utilized by microflora.

2. Ether and alcohol-soluble fractions (fats, waxes, resins, oils), hemicelluloses and cellulose decrease with time as they are utilized as carbon and energy sources.

3. Lignin, persists and can accumulate in the decaying biomass because of its resistance to microbial decomposition.

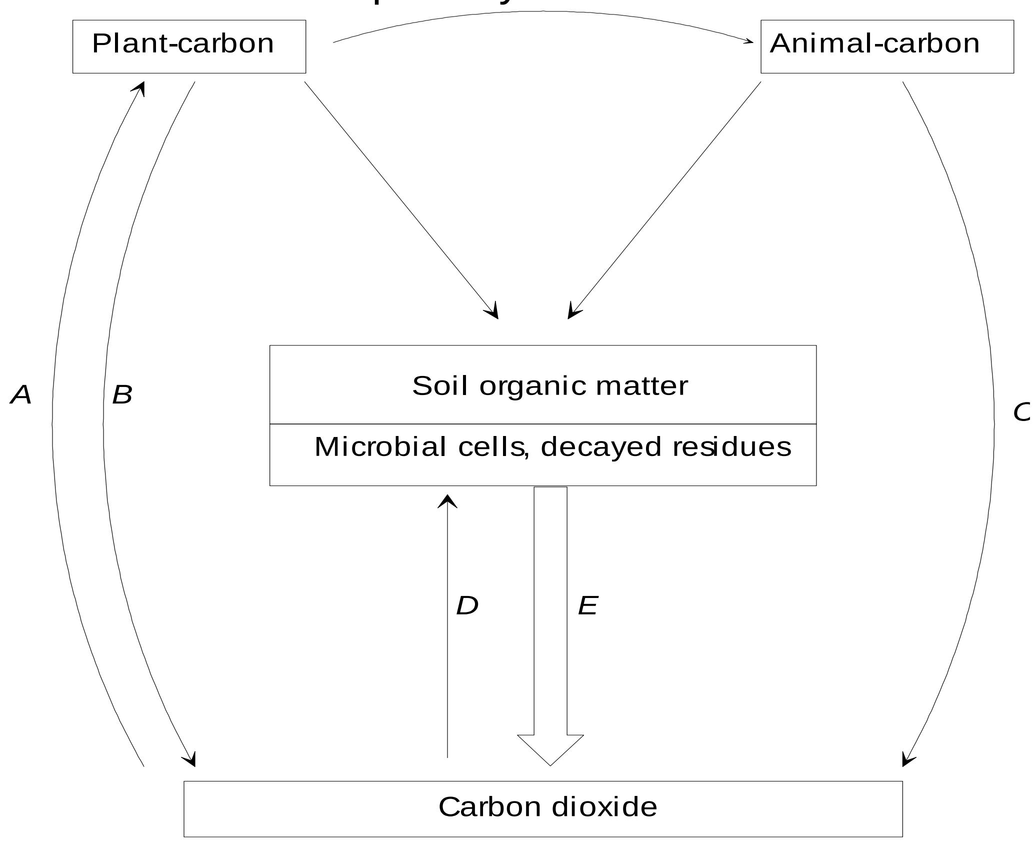
4. Decomposition rates of crop residues are often proportional to their lignin content and some researchers have suggested that the lignin content may be a more reliable parameter for predicting residue decomposition rates than the C:N ratio.

5. Vigil and Kissel (1991) included the lignin-to-N ratio and total soil N concentration (in g/kg) as independent variables to predict potential N mineralization in soil. They also noted that the break point between net N mineralization and net immobilization was calculated to be at a C/N ratio of 40.

The carbon cycle revolves around CO_2, its fixation and regeneration.

Chlorophyll-containing plants utilize CO_2 as their sole carbon source and the carbonaceous matter synthesized serves to supply the animal world with preformed organic carbon.

Without the microbial pool, more carbon would be fixed than is released, CO_2 concentrations in the atmosphere would decrease and photosynthesis rates would decrease.



A. Photosynthesis
B. Respiration, plant
C. Respiration, animal
D. Autotropic microorganisms
E. Respiration, microbial

The carbon cycle

C:N Ratios as Related to Organic Matter Decomposition

In general, the following C:N ratios are considered to be a general rule of thumb in terms of what is expected for immobilization and mineralization.

C:N Ratio	Effect
30:1	immobilization
<20:1	mineralization
20-30:1	immobilization = mineralization

1. C:N ratios say nothing about the availability of carbon or nitrogen to microorganisms
2. Why? What makes up the carbon (C) component
3. In tropical soils, significantly higher proportions of lignin will be present in the organic matter
4. Even though the percent N within the organic matter may be the same, it would be present in highly stable forms that were resistant to decomposition.
5. Therefore, mineralization rates in organic matter that contain high proportions of lignin will be much smaller
6. C:N ratios discussed were generally developed from data obtained in temperate climates.
7. Therefore their applicability to tropical soils is at best minimal.

Decomposition of Organic Matter (Mineralization)

1. **percent organic matter**
2. **organic matter composition**
3. **cultivation (crop, tillage, burning)**
4. **climate (moisture, temperature)**
5. **soil pH**
6. **N management (fertilization)**
7. **soil aeration**

Rapid increase in the number of heterotrophic organisms accompanied by the evolution of CO_2 (initial stages)

Wide C:N ratio of fresh material is wide = net N immobilization

As decay proceeds, C:N ratio narrows & energy supply of C diminishes.

Addition of materials with >1.5 to 1.7% N need no supplemental fertilizer N or soil N to meet demands of microorganisms during decomposition

'**Demands of the microorganisms'** discussed first, disregarding plant N needs

Adding large amounts of oxidizable carbon from residues with less than 1.5% N creates a microbiological demand for N, immobilize residue N and inorganic soil N

Addition of fertilizer N to low N residues accelerates rate of decomposition (Parr and Papendick, 1978).

•1000+yrs prior to the time cultivation was initiated, C and N had built up in native prairie soils.

•C:N ratio was wide, reflecting conditions for immobilization of N.

•Combined influence of tillage and the application of additional organic materials (easily decomposable wheat straw and/or corn stalks)

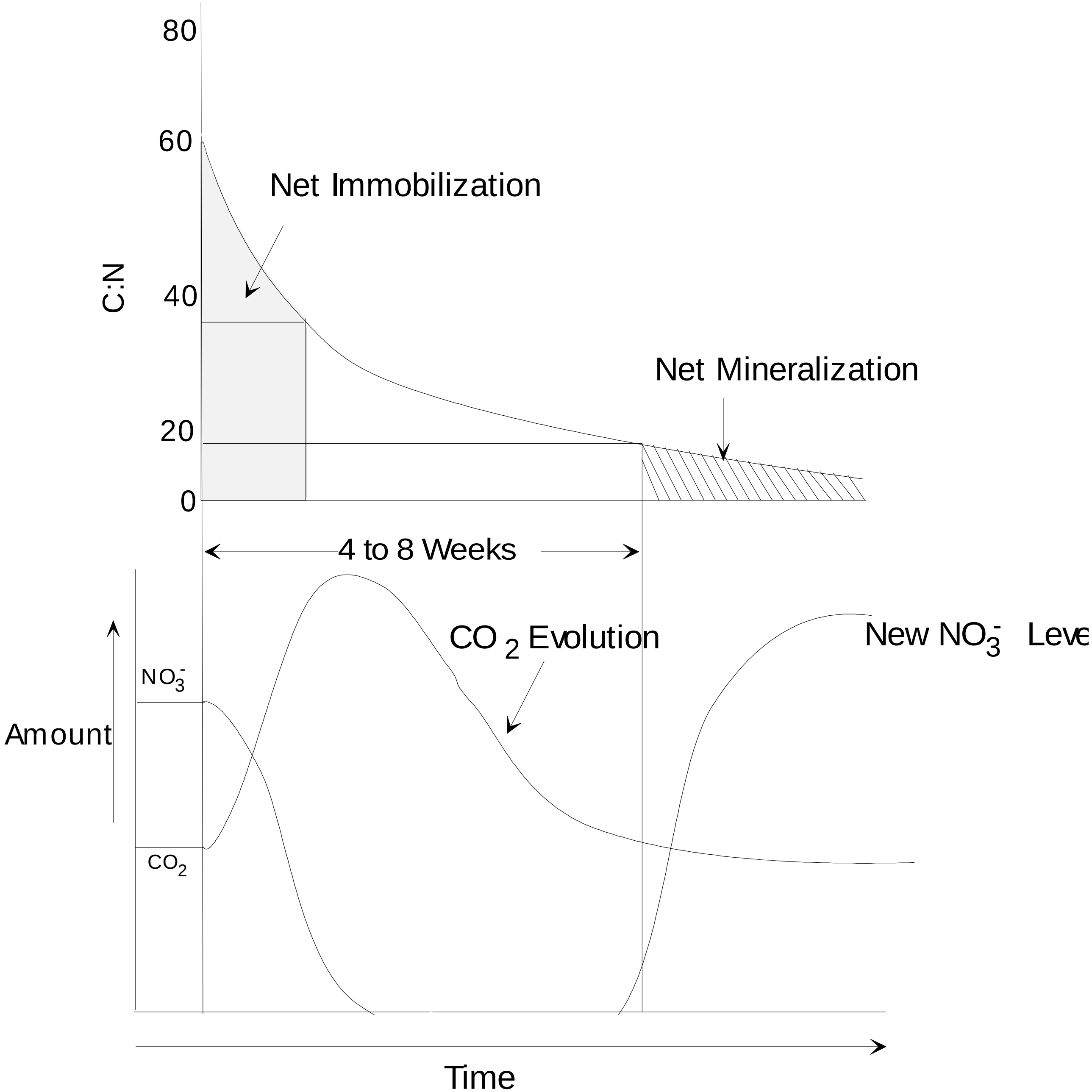
•Cultivation alone unleashed a radical decomposition of the 4% organic matter in Oklahoma soils.

•Easily decomposable organic materials added back to a cultivated soil, increases CO_2 evolution and NO_3 is initially immobilized.

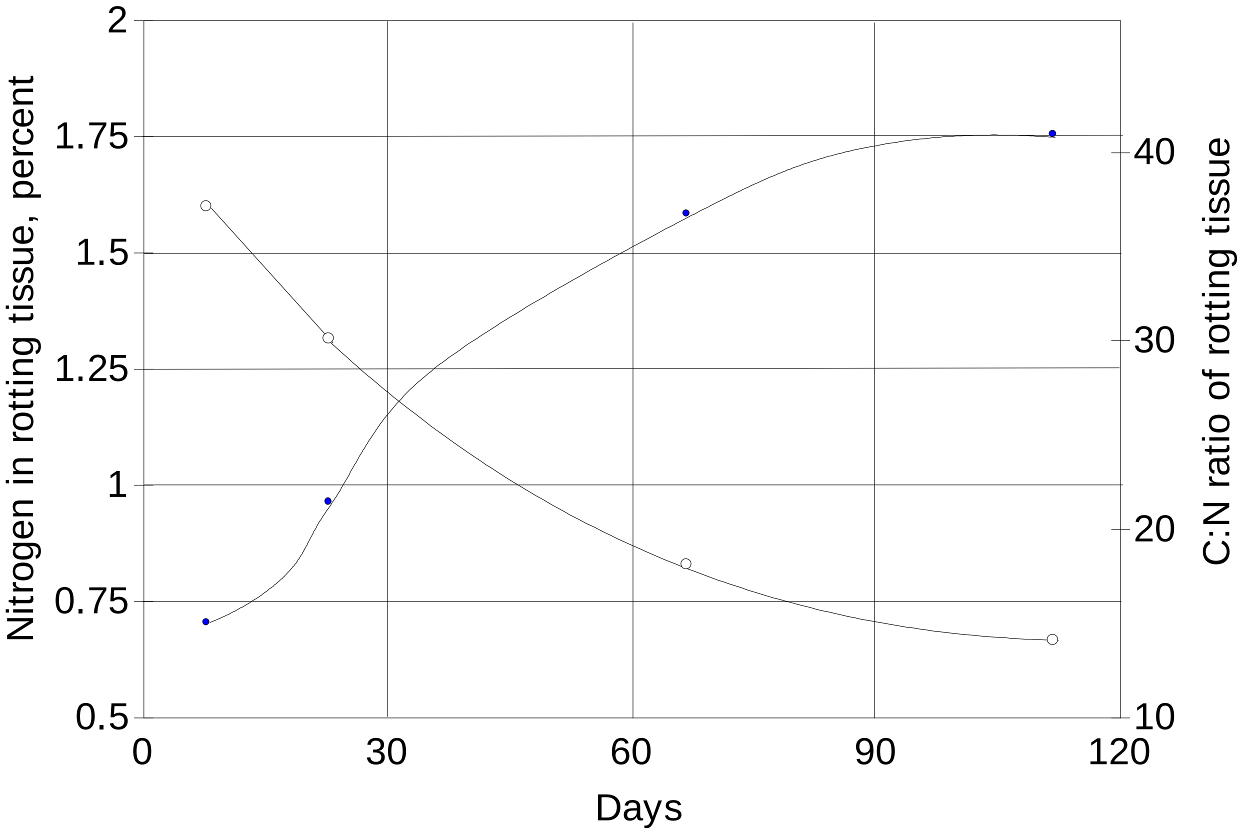
•Within one yearly cycle in a temperate climate, net increase in NO_3 is reflected via mineralization of freshly added straw/stalks and native organic matter pools.

•Percent N in added organic material increases while the C:N ratio decreases

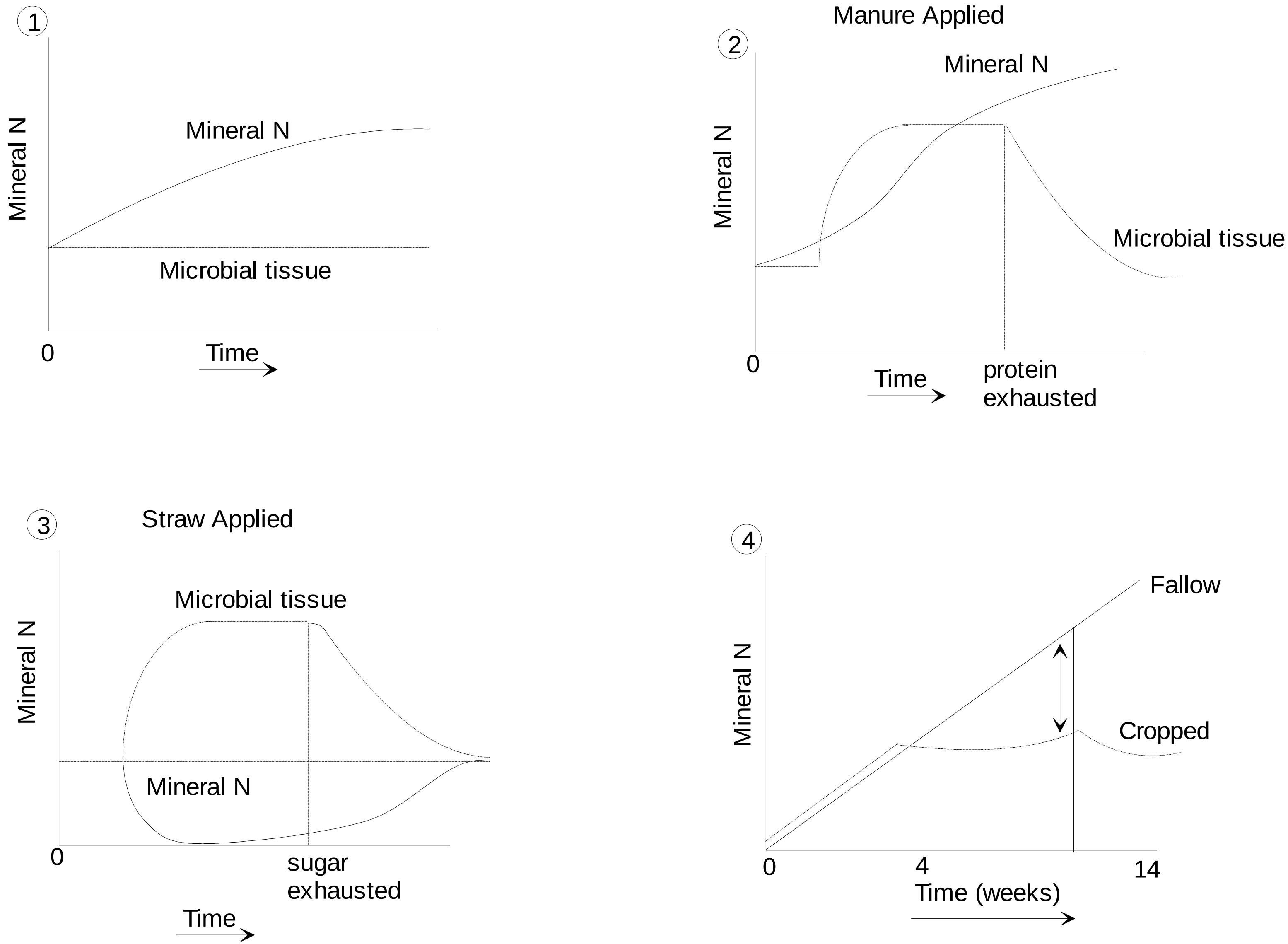
•In order for this to happen, some form of carbon must be lost from the system. In this case CO_2 is being evolved via the microbial decomposition of organic matter.



Cultivation and addition of straw, N immobilization & mineralization of N, evolution of CO_2



Changes in the nitrogen content of decomposing barley straw (From Alexander, 1977).



Changes in soil mineral N as a function of time, and addition of manure and straw.

	Oklahoma		Tropical Soil	
	min	max	min	max
1 ha (0-15cm), kg	2241653	2241653	2241653	2241653 (P_b = 1.47)
Organic, matter, kg	22416	44833	89666	268998
% N in OM	0.05	0.05	0.05	0.05
(5%)				
kg N in OM (Total)	1120.8	2241.6	4483.3	13449.9
% N mineralized/yr	0.03	0.03	0.03	0.03
(3%)				
TOTAL (kg N/ha/yr)	33.6	67.2	134.4 ?	403.5 ?

P_b= Mass of dry soil/volume of solids and voids

2000000 pounds/afs
ft^3*0.02832 = m^3
0.4535 lb/kg
1 ha = 2.471ac
1 ha = 10000m^2
1 ac = 4047m^2

2000000 lb = 907184.74 kg = 907.184 Mg
43560 ft^2 * 0.5 ft = 21780 ft^3 = 616.80m^3
907.184Mg/616.80m3 = P_b 1.4707

10000m^2 * 0.15m = 1500 m^3
2241653 kg /1000 = 2241.6 Mg
2241.6/1500 = P_b 1.49 (g/cm^3 = Mg/m^3)

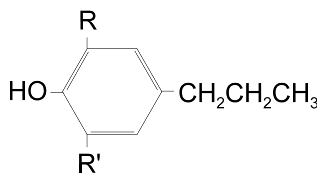
What will happen if

a) bulk density is changed?

b) % N in organic matter?

c) % N mineralized per year?

Organic Matter = 0.35 + 1.80 * (organic carbon)
Ranney (1969)

Form	Formula	Decomposition	Composition
Cellulose	$(C_6H_{10}O_5)n$	rapid *	15-50%
Hemicellulose			5-35%
glucose	$C_6H_{12}O_6$	moderate-slow	
galactose			
mannose			
xylose	$C_5H_{10}O_5$	moderate-slow	
Lignin(phenyl-propane)		slow	15-35%
Crude Protein	$RCHNH_2COOH$**	rapid	1-10%
Polysaccharides			
Chitin	$(C_6H_9O_4.NHCOCH_3)n$	rapid	
Starch	glucose chain	rapid	
Pectins	galacturonic acid	rapid	
Inulin	fructose units		

* - decomposition more rapid in the presence of N

** - amino acid glycine (one of many building blocks for proteins)

Microorganisms

Most important function is the breakdown of organic materials, a process by which the **limited** supply of CO_2 available for photosynthesis is replenished (Alexander, 1977).

Five major groups of microorganisms in the soil are:

1. Bacteria
2. Actinomycetes
3. Fungi
4. Algae
5. Protozoa

Soil Bacteria: 10^8 to 10^{10} / g of soil

Heterotroph: (chemoorganotrophic) require preformed organic nutrients to serve as sources of energy and carbon

1. Fungi
2. Protozoa
3. Most Bacteria

Autotroph: (lithotrophic) obtain their energy from sunlight or by the oxidation of inorganic compounds and their carbon by the assimilation of CO_2

Photoautotroph: energy derived from sunlight

1. Algae (blue-green, cyanobacteria)
2. Higher Plants
3. Some Bacteria

Chemoautotroph: energy for growth obtained by the oxidation of inorganic materials.

1. Few Bacterial species (agronomic importance)

a. nitrobacter, nitrosomonas and thiobacillus

Discussion

Optimum pH range for rapid decomposition of various organic wastes and crop residues is 6.5 to 8.5. Bacteria and actinomycetes have pH optima near neutrality and, thus do not compete effectively for nutrients under acidic conditions. This explains why soil fungi often become dominant in acid soils.

Decomposition rates of crop residues are often proportional to their lignin content (Parr and Papendick)

Lignin content may be a more reliable parameter for predicting residue decomposition rates than the C:N ratio (Alexander)

Addition of materials with >1.5 to 1.7% N need no supplemental fertilizer N or soil N to meet demands of microorganisms during decomposition

Increased OM, increased requirement for ____________ (nutrients, herbicides?)