

100 713 Land Resources and
Environment in
Sustainable Agriculture

Soil fertility

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Soil fertility studies

Soil fertility is the study of soils as a source of plant nutrients. The objectives of studying soil fertility is to learn about 'behaviour' of plant nutrients in soils, and how soils supply nutrients to plants. To achieve the above objectives, two major concepts are employed.

Concepts employed for soil fertility study:

- Soil is a colloidal system.
- The availability concept:
Available forms of nutrients and
nutrient availability.

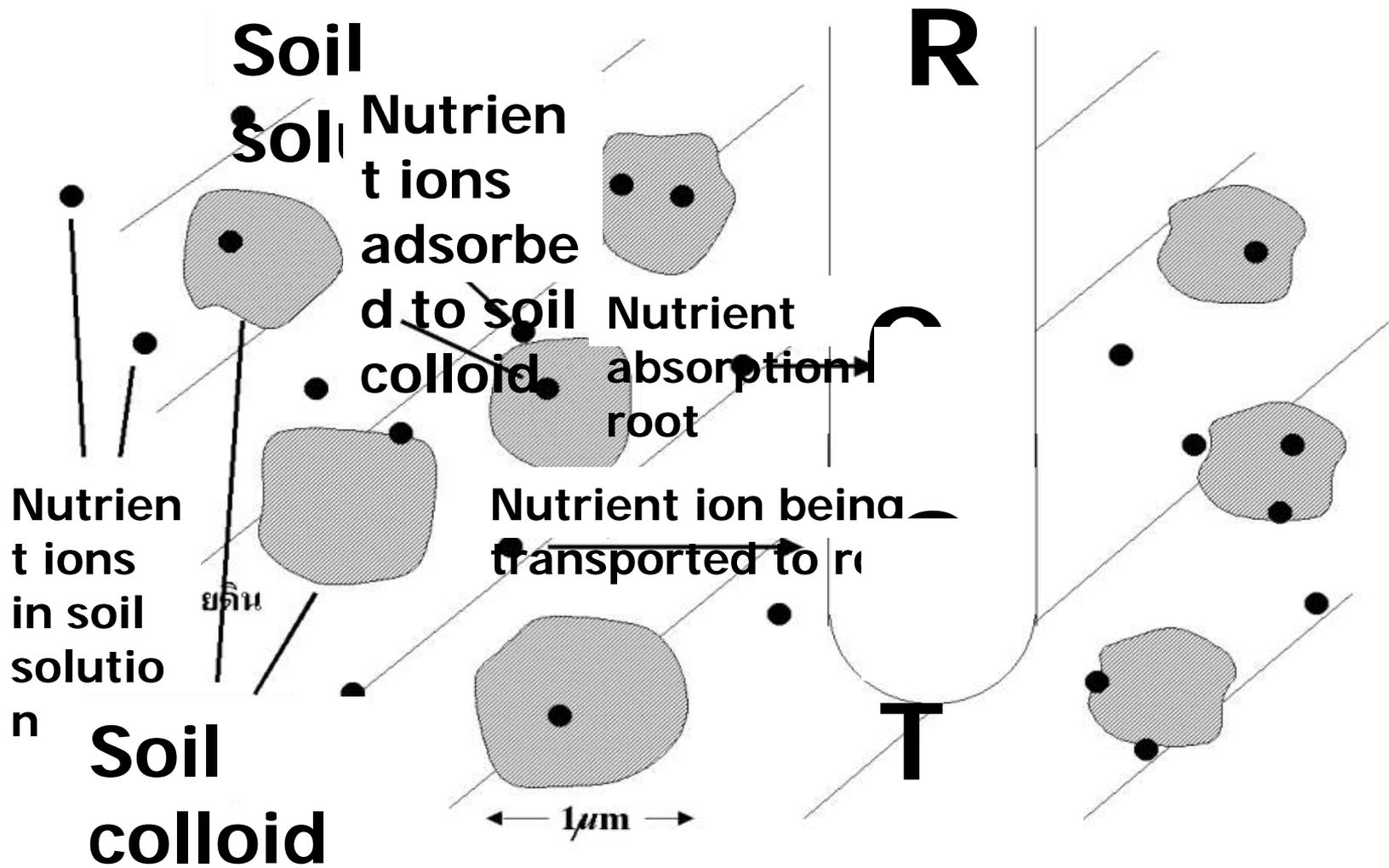


Figure 1. Profile of soil colloidal system as related to soil nutrients and their absorption by roots

The availability concept

The words used most commonly to describe the supply the plant nutrients in soil are *available* and *availability*.

Available means susceptible to absorption by plants.

Availability means effective quantity (Black, 1993)

Available forms of nutrients

Nutrients exist in soils in different forms, such as water soluble, adsorbed, and fixed forms. These nutrients become available to plants to different degrees but with time it can be said that all will become available. However, the most readily available form is those in soil solution (water soluble form).

Availability factors

- The ability of soils to supply nutrients to plants is affected by the following factors:
 - Intensity
 - Quantity
 - Buffering capacity
 - Mobility

Further reading on the availability concept

- Black, C.A. 1993. Soil fertility evaluation and control. Lewis Publishers. 746 p.

Nitrogen in soils

Table 1. Distribution of N in atmosphere, geosphere and biosphere.

Pools of N	Total mass (x 10 ¹⁹)	% total N mass
Atmosphere (N gas)	390	1.9
Hydrosphere (soluble N)	2.3	0.01
Lithosphere	19,085	>98
Igneous rock	19,000	
Biosphere		0.2
0.001		
Terrestrial ecosys (N in soil, plants)	0.0682	
Marine ecosystem	0.1314	

Adapted from Haynes (1986a), Stevenson (1986)

Global Fluxes of Nitrogen into and out of the Terrestrial Biosphere

Process	(Tg N yr ⁻¹)
Wet and dry deposition (NH ₃)	90-200
Wet and dry deposition (NO _x)	80-100
Atmospheric (organic nitrogen)	10-15
Biogenic (lightning)	100-150
Industrial fixation (fertilizers)	200

Process
rate
(g N yr^{-1})

Out	yr^{-1})
Ammonia	36-
Denitrification	250
Nitrogen fixation	150
Production	10-
Respiration (CO_2)	20-
Leaching and runoff	5-20
Leaching and runoff (organic)	5-20

Source: Haynes (1986)

Table 2. Distribution of N in a nutrient-poor Amazonian rain forest, an oak-hickory forest, a short grass prairie, and a wet meadow

	Amazonian rain forest		Oak-hickory forest		Short grass prairie		Wet meadow	
Nitrogen	kg N	%	kg N	%	kg N	%	kg N	%
Total	7	56	2	8.	6	1.	2	1.
Vegetation	9	.2	357	4	15	9	0.24	0
ground	336	16	135	6.	51	0.	0.68	0.
Roots	843	.2	1	1	4	4	3	3
Little	274	40	2	2.	76	1.	0.10	0.
Soil	132	.0	508	3	337	5	91	7
(sampling	785	6.	0	4.	4	2.	(20	0.
depth in cm)	(75	3	(60	7	(30	1	cm)	1
pot)	cm)		cm)		cm)			
Source: Haynes (1986)	37		86		96		92	98
	209	.7	584	.9	351	.0		.9

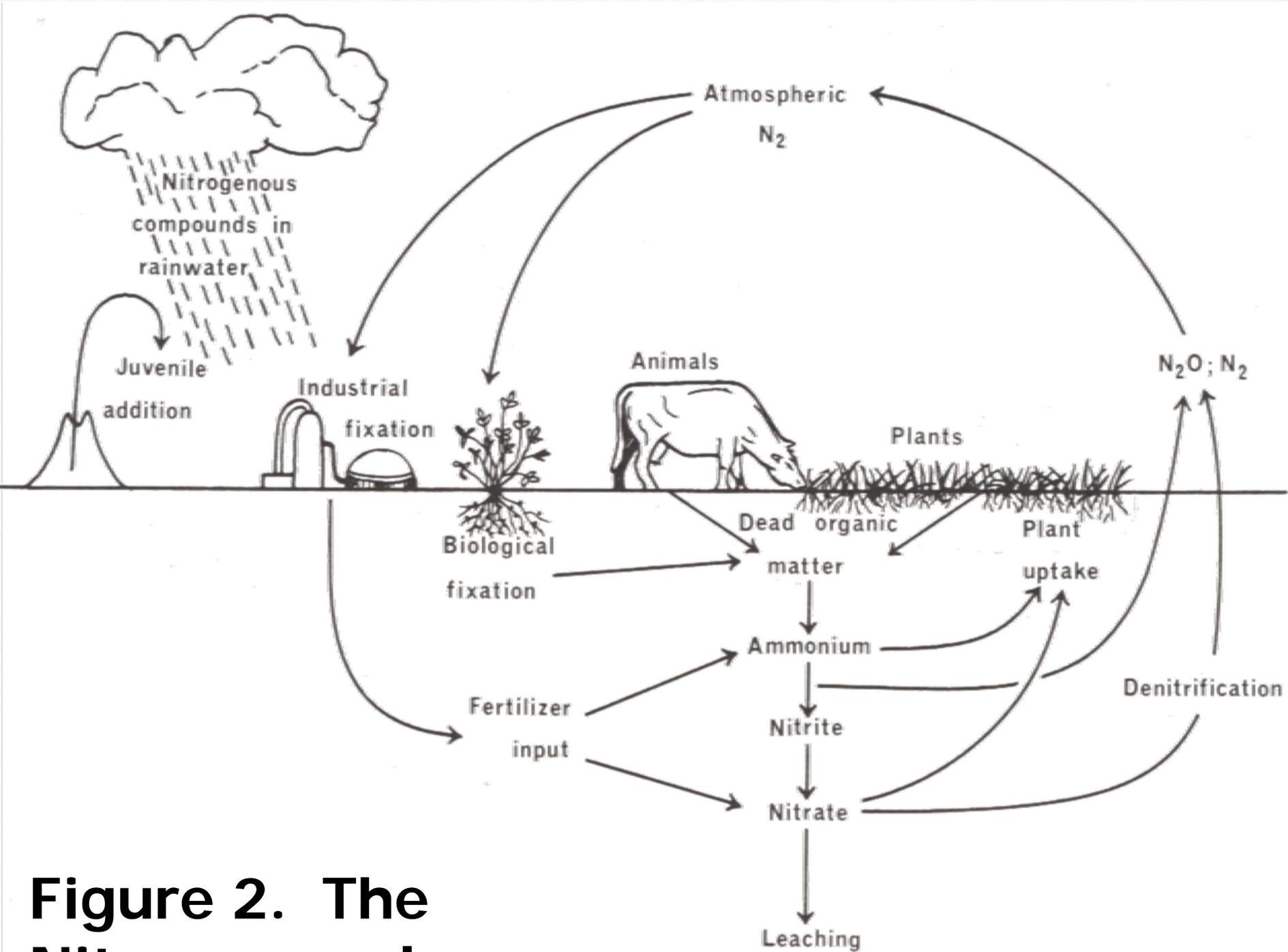


Figure 2. The Nitrogen cycle

Table 3. Global fluxes of nitrogen into and out of the terrestrial biosphere.

	Process	rate (Tg N yr ⁻¹)
Input		
s	Wet and dry deposition (NH ₃) / NH ₄ ⁺	100-200
	Wet and dry deposition (NO _x)	30-80
	Wet and dry deposition (NO _x)	10-
	Atmospheric fixation (lightning)	0.5-300
	Biological fixation	100-200
	Industrial fixation (fertilizers)	6
Outputs		
	Ammonia volatilization	36-250
	Denitrification (N ₂ + N ₂ O)	40-350
	Biogenic NO _x production	1-15
	Fossil fuel burning (NO _x)	10-20
	Fires (NO _x)	10-20
	Leaching and runoff (inorganic)	5-20
	Leaching and runoff (organic)	5-20

Nitrogen cycling in different ecosystems

- Natural ecosystems, e.g. forest
- Agricultural ecosystems

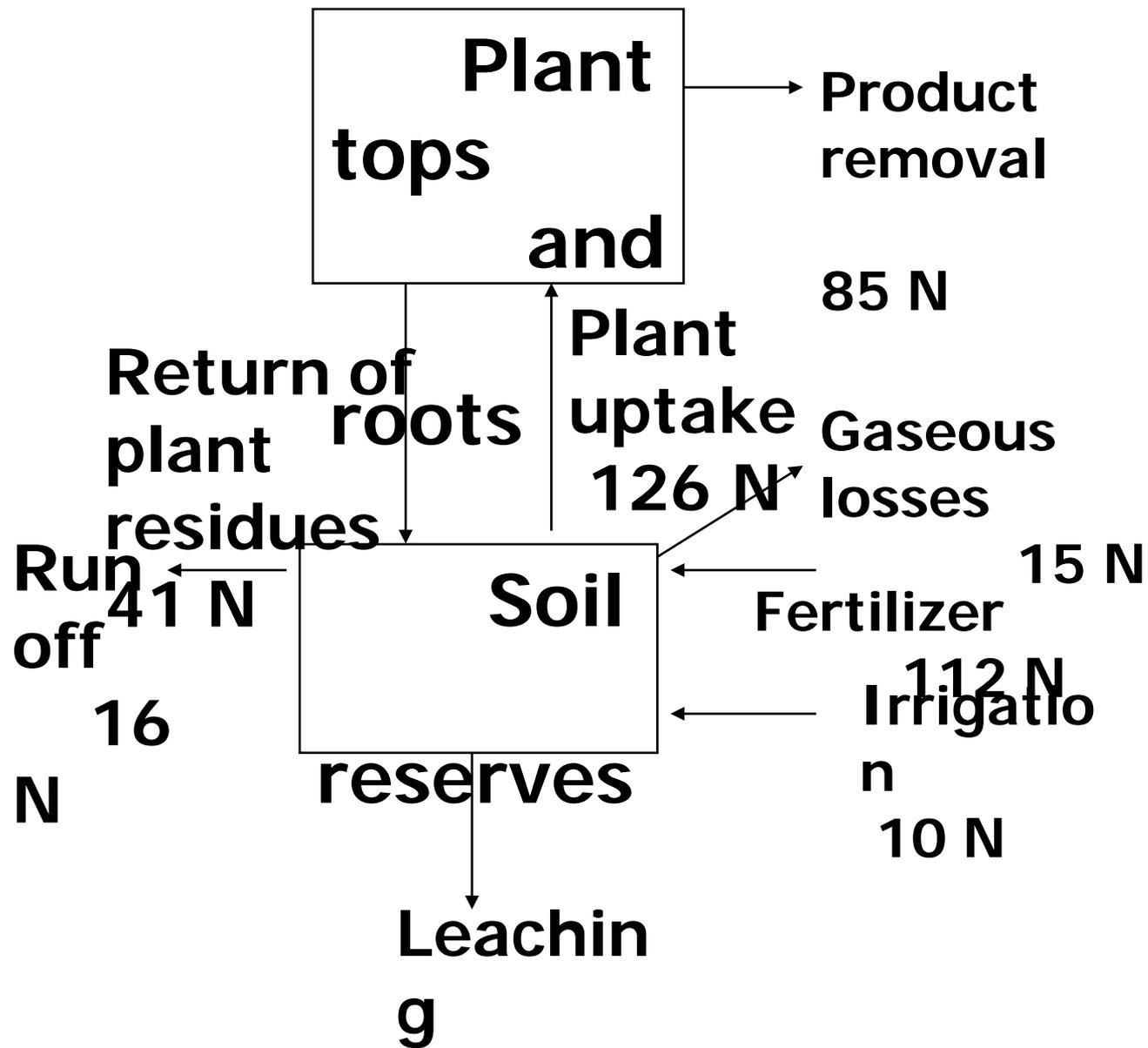


Figure 3. N cycle in a corn crop in USA (values in kg N/ha) (Haynes 1986)

Forms of N in soils

- Organic nitrogen: More than 90% of total N in soils is organic N.
- Inorganic nitrogen:
Major forms:
 NH_4^+ (soluble, exchangeable, non-exchangeable)
 NO_3^- (soluble, and exchangeable)

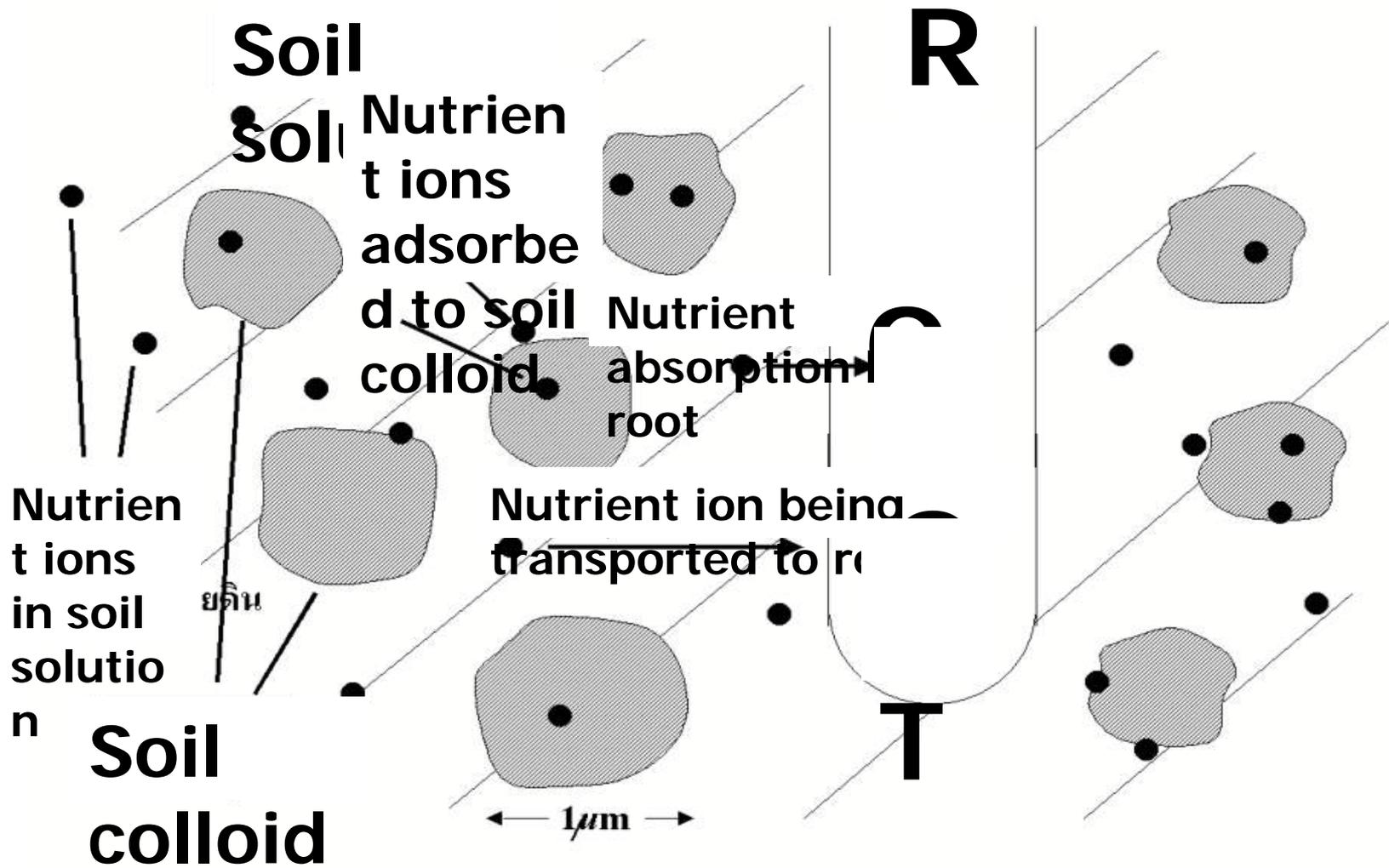


Figure 1. Profile of soil colloidal system as related to soil nutrients and their absorption by roots

Table 4. Pools of soil organic N as chemically separated by acid hydrolysis.

Soil N	Quantity
Acid-insoluble or acid-hydrolysa	20
Acid-hydrolysable	35
bl-NA ₃ amino	35
bl-NA ₃ amino	55
bl-NA ₃ amino	10
unknown-N or HUN	20

Source: Stevenson
(1982)

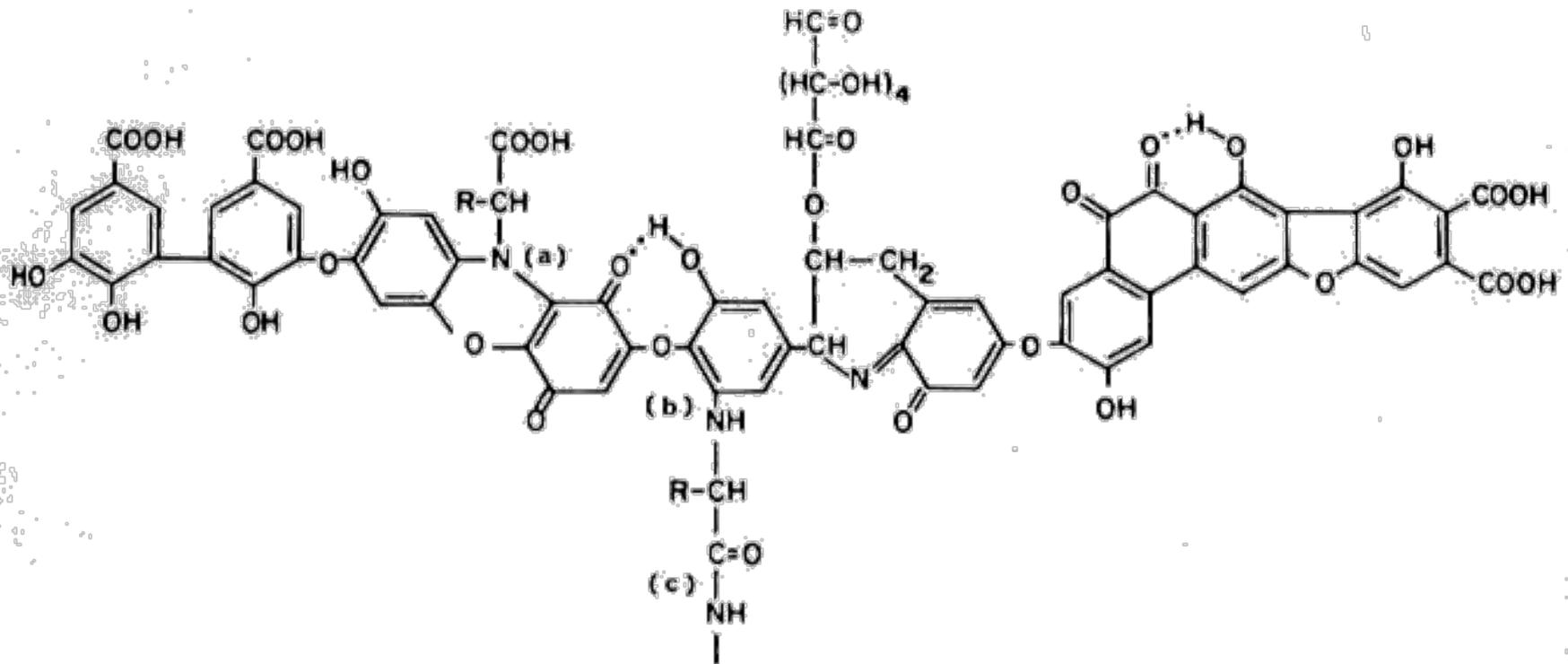


Fig Hypothetical structure of humic acid. Nitrogen is incorporating into the humic acid in three ways: (a) as a bridge unit, (b) in the form of N – phenylamino acid, (c) in the

Soil processes which transform organic N to inorganic N

- N mineralization : organic N is transformed to inorganic N.
- N immobilization: inorganic N is transformed to organic N.

Both are microbially mediated.

Mineralization \rightleftharpoons
Immobilization

Nitrogen mineralization and immobilization occurs simultaneously in soils but in opposite directions. Higher N mineralization relative to N immobilization results in *net N mineralization* and vice versa. This is affected by the relationships between energy and nutrient nitrogen in decomposing organic materials.

Carbon to nitrogen ratio

The C/N ratio is used as an indicator of the likelihood of net N mineralization or net N immobilization taking place upon decomposition of organic materials or soil organic matter in question.

The C/N ratio estimates the energy/N ratio of organic materials.

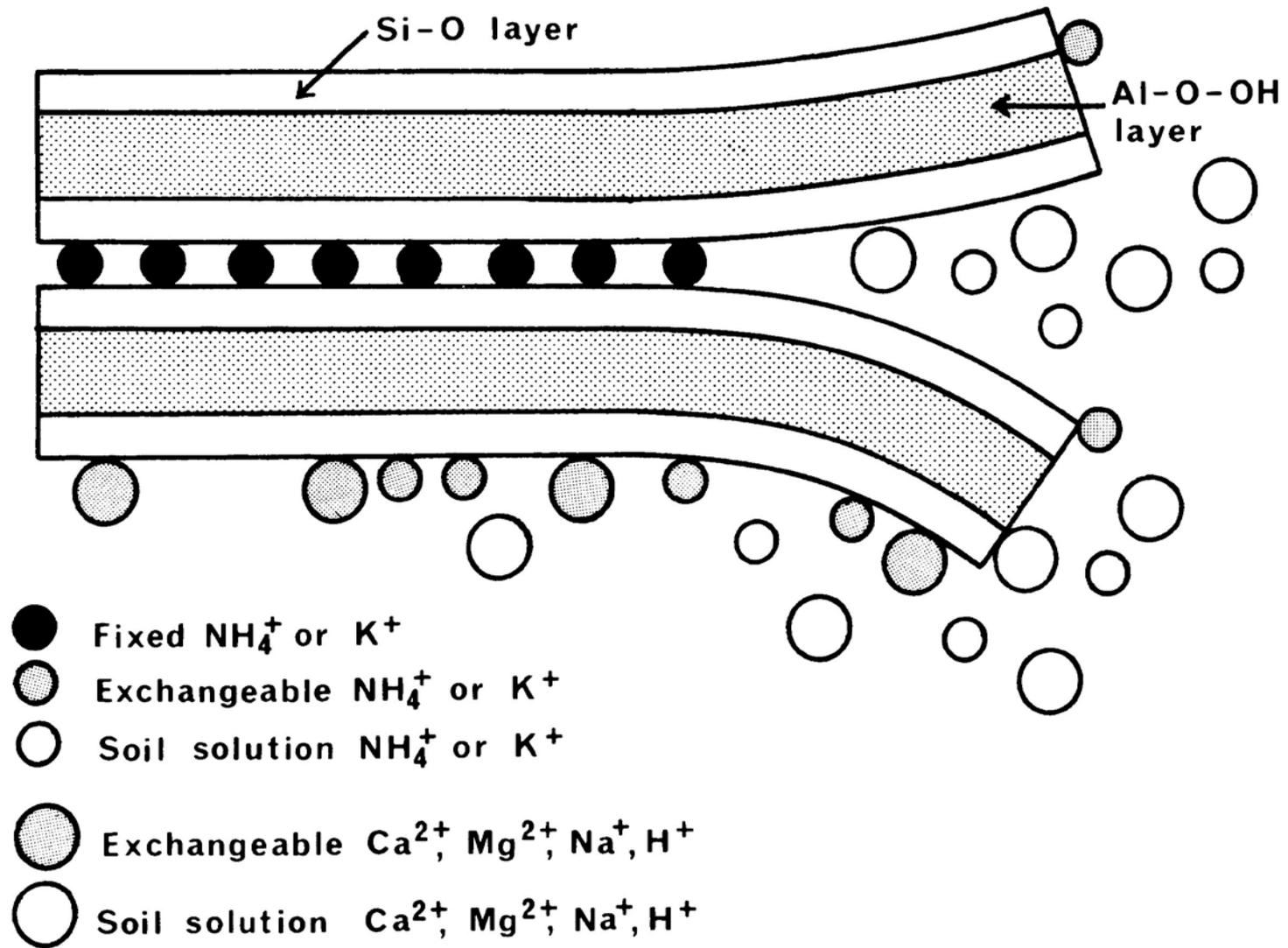


Figure 4. Schematic diagram of the different forms of cations associated with a 2:1 clay mineral.

Loss of nitrogen from soils

This can occur through different processes:

- Ammonia volatilization (Sherlock, 1986)
- Denitrification
- Leaching (especially of nitrate) (Cameron and Haynes, 1986)

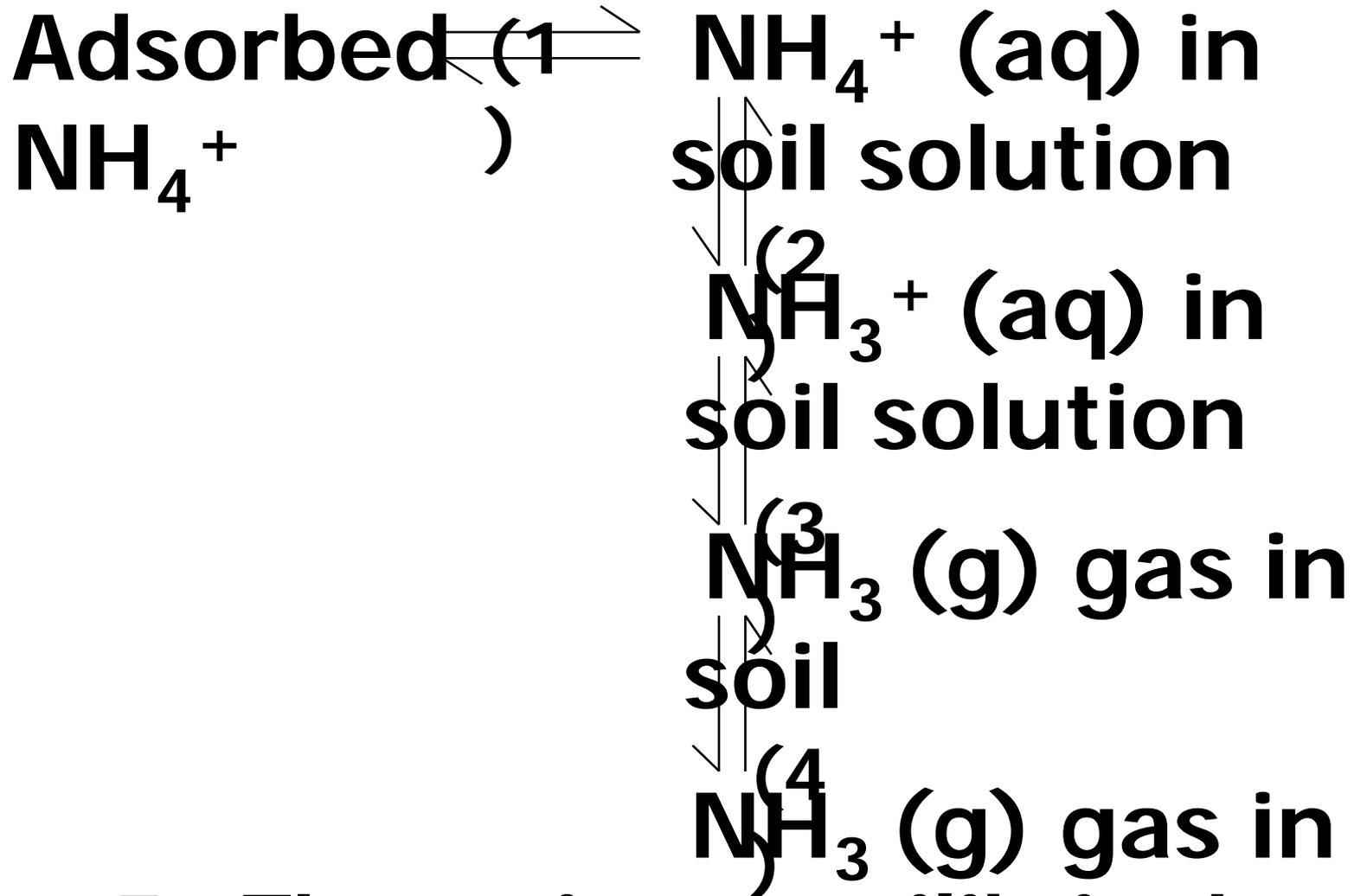


Fig. 5. The various equilibria that govern ammonia loss from soils

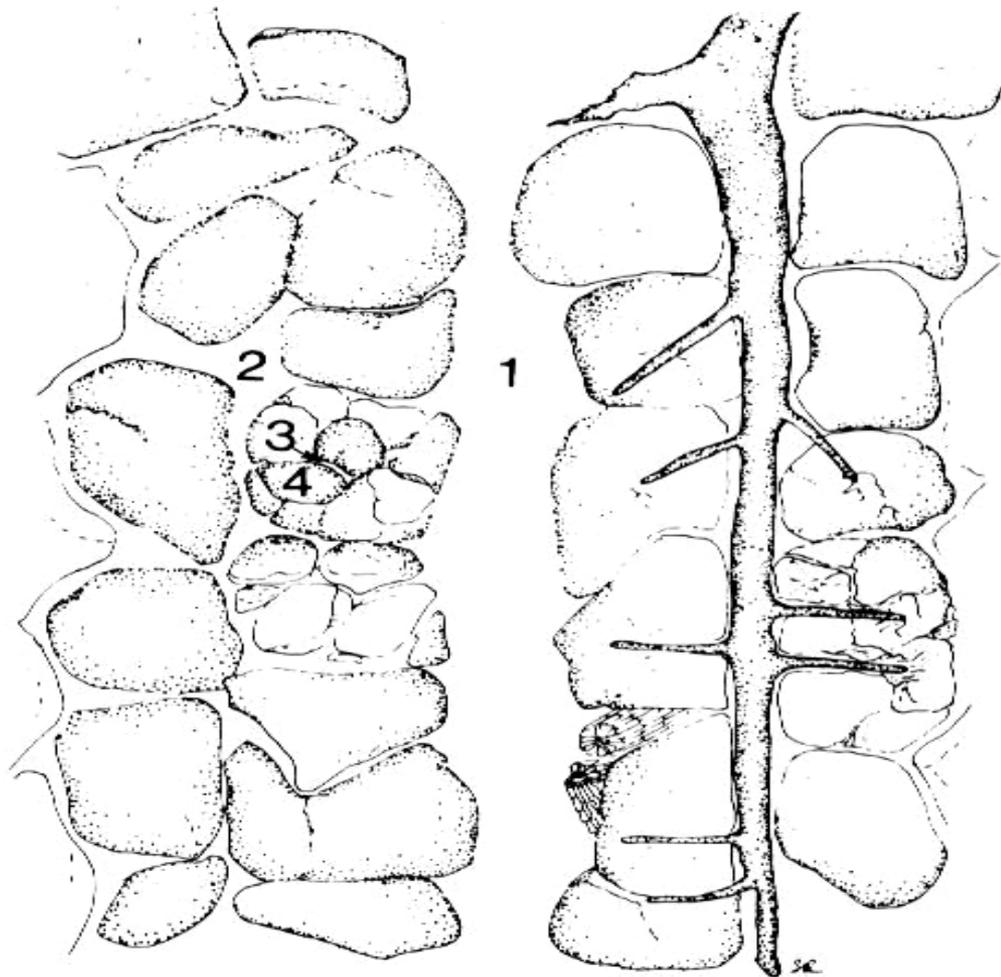


Fig 2. Hierarchical class of soil pore space according to Elliott and Coleman(1988).

1= macropores, 2= pore between macroaggregates

Nitrogen requirement of plants

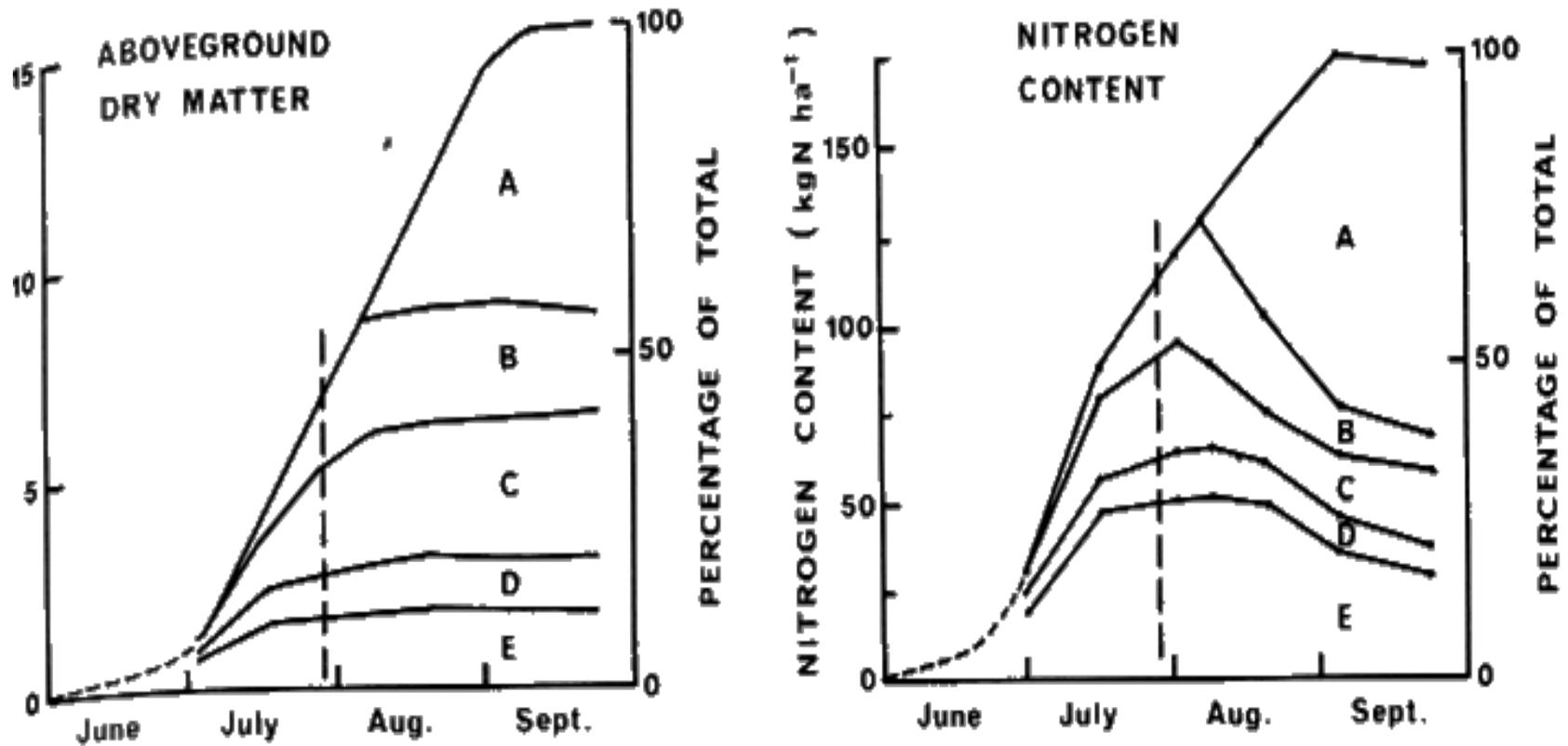


Figure 6. Accumulation and distribution of aboveground biomass and N in different parts of corn: A. seed, B. cobs, C. tassels, D. leaf sheath, and E. leaves (Goh and Haynes, 1986)

Evaluation of nitrogen availability

2 types of soil analysis for this purpose:

- Evaluation of residual nitrogen in soils,
- Evaluation of nitrogen mineralization potential

(Goh and Haynes, 1986)

Table 2.10 Chemical extraction methods to determine soil available N

Extraction method	Temperature (°C)	Time (hr)	N Fraction
Water	100°	1	Total N
0.01 M CaCl ₂	100°	6	Total or NH ₄ ⁺ N
0.01 M CaCl ₂	121°	4 ¹	Total N or UV
0.01 M CaCl ₂	Room	0.2	Total N or UV
NaHCO ₃	100°	5	Absorbance
2 M KCl	80°C	20	NH ₄ ⁺ and NO ₃ ⁻
0.01 M CaCl ₂	121°	16	Soluble NO ₃ ⁻ N
0.01 M CaCl ₂	Room	0.	Soluble carbohydrate
Ba(OH) ₂	Room	5	Soluble carbohydrate

Source: Goh and

Extraction Intermediate	Temp. (°C)	Time (hr)	Yield (%)
Alkalis	100°	0.	NH ⁺
NaOH	100°	25	NH ⁺
Neutral 0.5 N	100°	6	NH ⁺
Na ₂ CO ₃	100°	0.	NH ⁺
PH Na	100°	5.	NH ⁺
PH H	100°	26	NH ⁺
PH H ₂ SO ₄	100°	1	NH ⁺
	m		4 ⁻ N

Source: Goh and Haynes (1986)

Extraction	Temp	(hr)	N
Intensive extraction	Ro	2	NH ₄ ⁺
8 W 4.5% Na	NaOH	8	NH ₄ ⁺
0.2% Cr ₂ O ₇ + H ₂ SO ₄	distillation walkley black oxid ⁿ		NH ₄ ⁺ -N

Source: Goh and
Haynes (1984)

Further reading on soil nitrogen

- Haynes, R.J. (ed.). 1986. Mineral nitrogen in plant-soil system. Academic Press. New York, London.
- Stevenson, F.J. (ed.). 1982. Nitrogen in agricultural soils. American Society of Agronomy, Madison, Wisconsin, USA.
- Stevenson, F.J. 1986. Cycles of soil: Carbon, nitrogen, phosphorus, sulfur, micronutrients. Wiley, New York, 380 p.

Soil Organic Matter (SOM)

Table 3.1 Classification of SOM into living and non-living components.

SOM	Components of SOM	Quantities	
		% of living component	% total C ₁₀
Living	Rotting	5-	04
	Macro-organisms	15-	
	Micro-organisms	80-	1-3
non-living	Particulates	80	98
	Humus		10-
			30-
			90

Table 1. Pools of SOM and nutrients, generalized turnover rates, and

Hypothesized pool size	primary turnover time	controls of pool size
<u>Unprotected</u> Biomass (labile)	2. yr+, 0.2 yr+, humid temperate tropics	Substrate availability Residue inputs,
<u>Protected</u> GO (colloidal POM protection)	100 yr 0	Soil mineralogy, Tillage and texture, aggregate formation, particle size distribution
(structural protection)	Depends on physical disturbance	