University of California

Nitrogen Management Training

for Certified Crop Advisers

MODULE 2

Nitrogen Cycling and Soil Transformations

PART 2

Volatilization, Leaching and Denitrification

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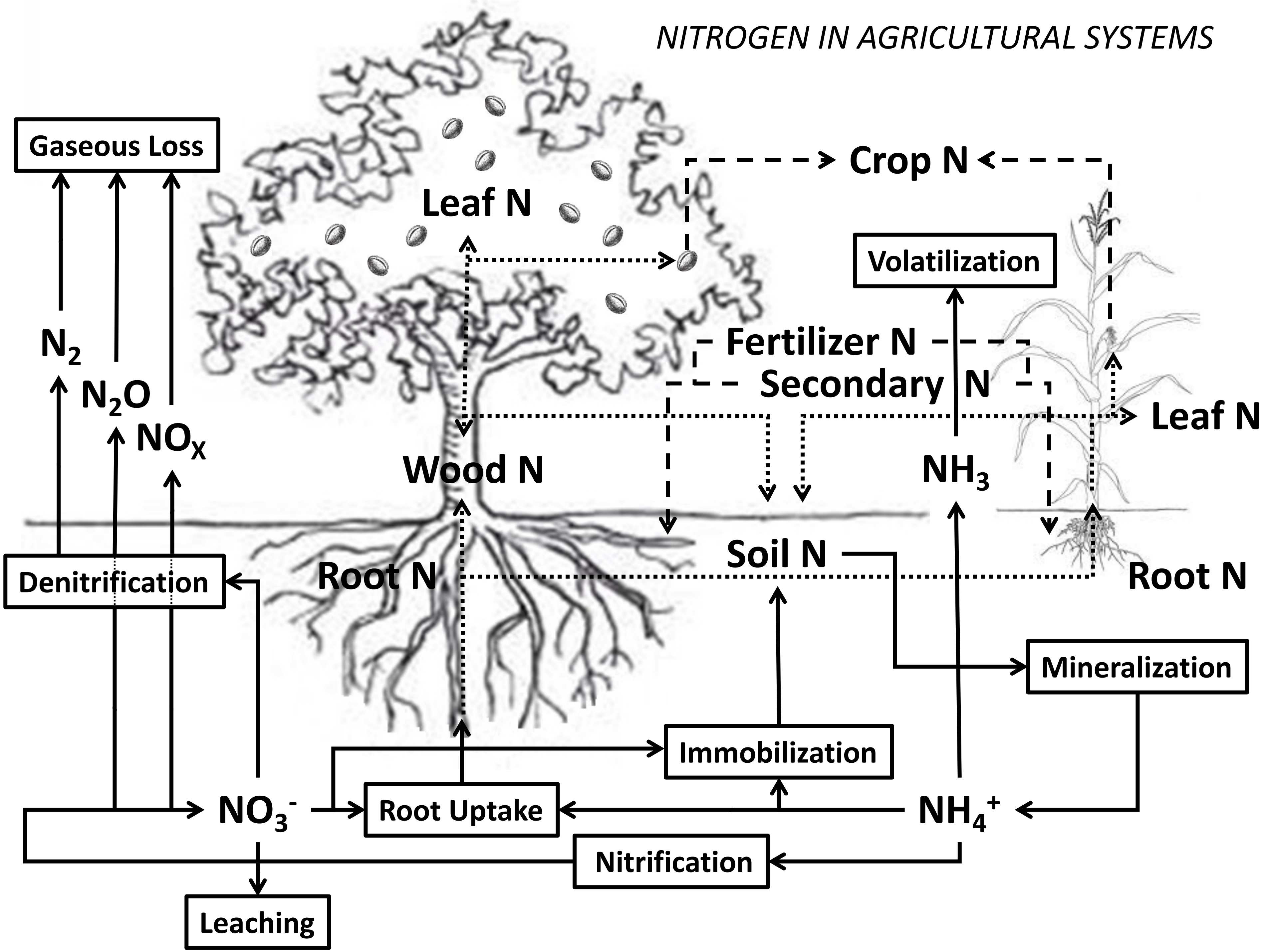
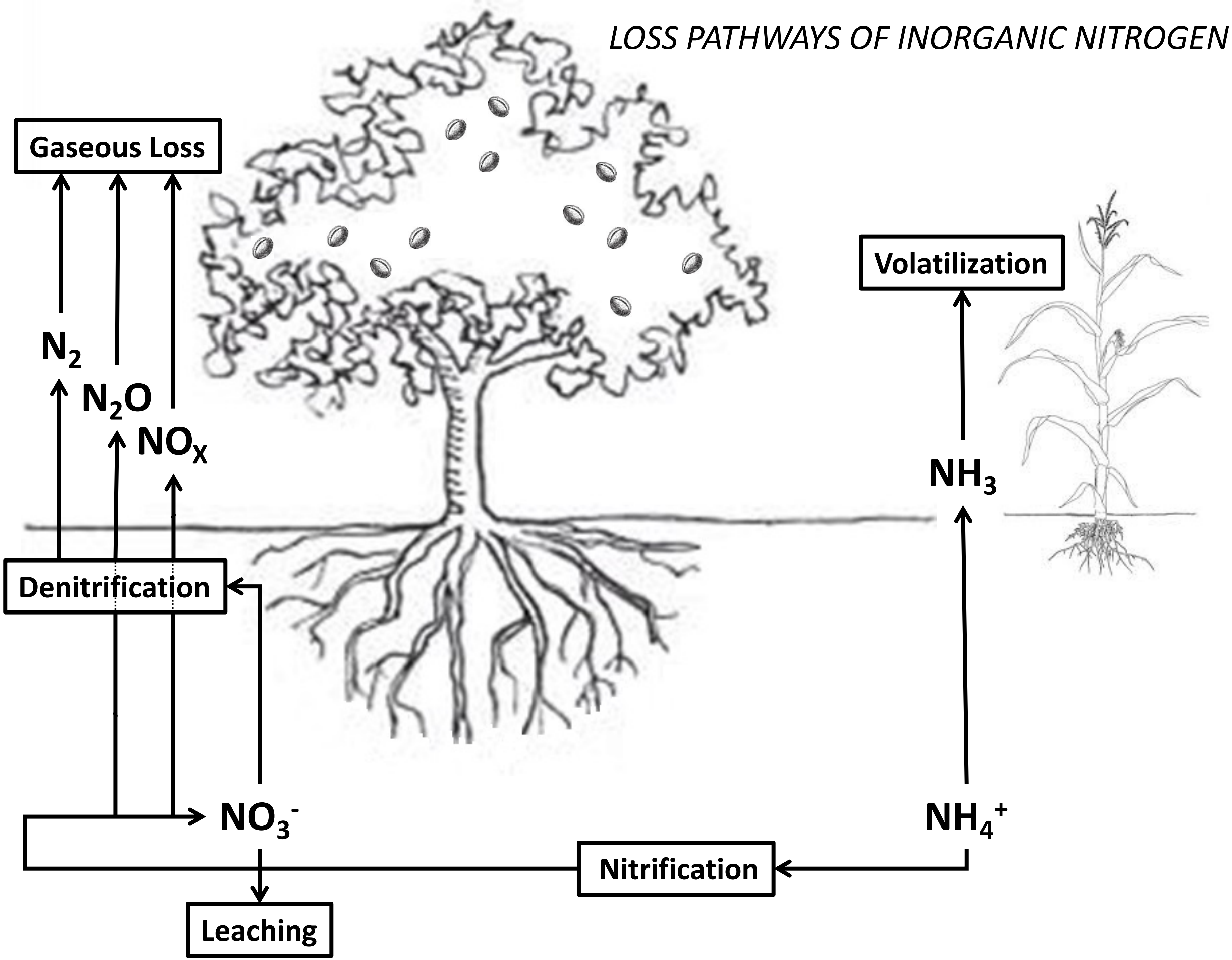


NITROGEN IN AGRICULTURAL SYSTEMS
Gaseous Loss
Crop N
Leaf N
Volatilization
Fertilizer N
Secondary N
Leaf N
N_2
N_2O
NO_X
Wood N
NH_3
Soil N
Root N
Denitrification
Root N
Mineralization
Immobilization
NO_3^-
Root Uptake
NH_4^+
Nitrification
Leaching



LOSS PATHWAYS OF INORGANIC NITROGEN
Gaseous Loss
N2
N2O
NOX
Denitrification
Volatilization
NH3
NO3-
NH4+
Nitrification
Leaching

Overview of Nitrogen Cycling in Soils

- Volatilization
  - Loss of ammonia gas (NH_3) from soil to the environment
  - Understanding fertilizer source and soil conditions

- Leaching
  - What reasons lead to increased potential for leaching
  - Role of soil texture and water management

- Denitrification
  - Transformation of nitrate (NO_3^-) into nitrogen gases
  - Impact of soil conditions and management

Volatilization Loss of Nitrogen

- Ammonia (NH_3) gas from soil to the environment
  - Two step reaction to ammonia (NH_3) gas
  - Can be a significant nitrogen loss based on management
  - Reacts with sulfur and nitrogen oxides to form smog

- Impact of nitrogen fertilizer source and soil conditions
  - Volatilization is most common with urea at or near the surface
  - Most likely to take place under moist and warm soil conditions
  - Alkaline soils with pH greater than 8 are especially at risk

Soil to the Environment

Conversion from urea [$CO(NH_2)_2$] into ammonia (NH_3) gas

Step 1: Urea to ammonium

$$CO(NH_2)_2 + 2H_2O \xrightarrow{urease} 2NH_4^+ + CO_3^{2-}$$

- In the presence of water urease enzyme catalyzes hydrolysis
- Rapid conversion to ammonium (NH_4^+) and carbonate (CO_3^{2-})

Step 2: Ammonium to ammonia

$$2NH_4^+ + CO_3^{2-} \longrightarrow 2NH_3 + 2OH^- + CO_2$$

- Ammonium (NH_4^+) converts to ammonia (NH_3) and carbon dioxide (CO_2)
- Complete reaction results in local region of higher pH from hydroxyls (OH^-)

Management Implications

Conversion from urea [$CO(NH_2)_2$] into ammonia (NH_3) gas

Urea granules at the soil surface

- Poor seal during soil injection of anhydrous ammonia
- Anhydrous ammonia injection into irrigation water
- Loss before nitrification but, after urea hydrolysis

Leaching Loss of Nitrogen

- Reasons for leaching losses of nitrogen specifically nitrate
  - Nitrate (NO_3^-) is an anion and not held by soil particles
  - Fertilizer applied in excess with inadequate water management
  - Timing of NO_3^- availability does not match crop demand

- Impact of soil conditions and management
  - Soil type is critical with more rapid movement in coarser soils
  - Fertilizer source also plays an important role
  - Timing fertilizer application relative to applied water is key

Leaching

% N applied by Depth

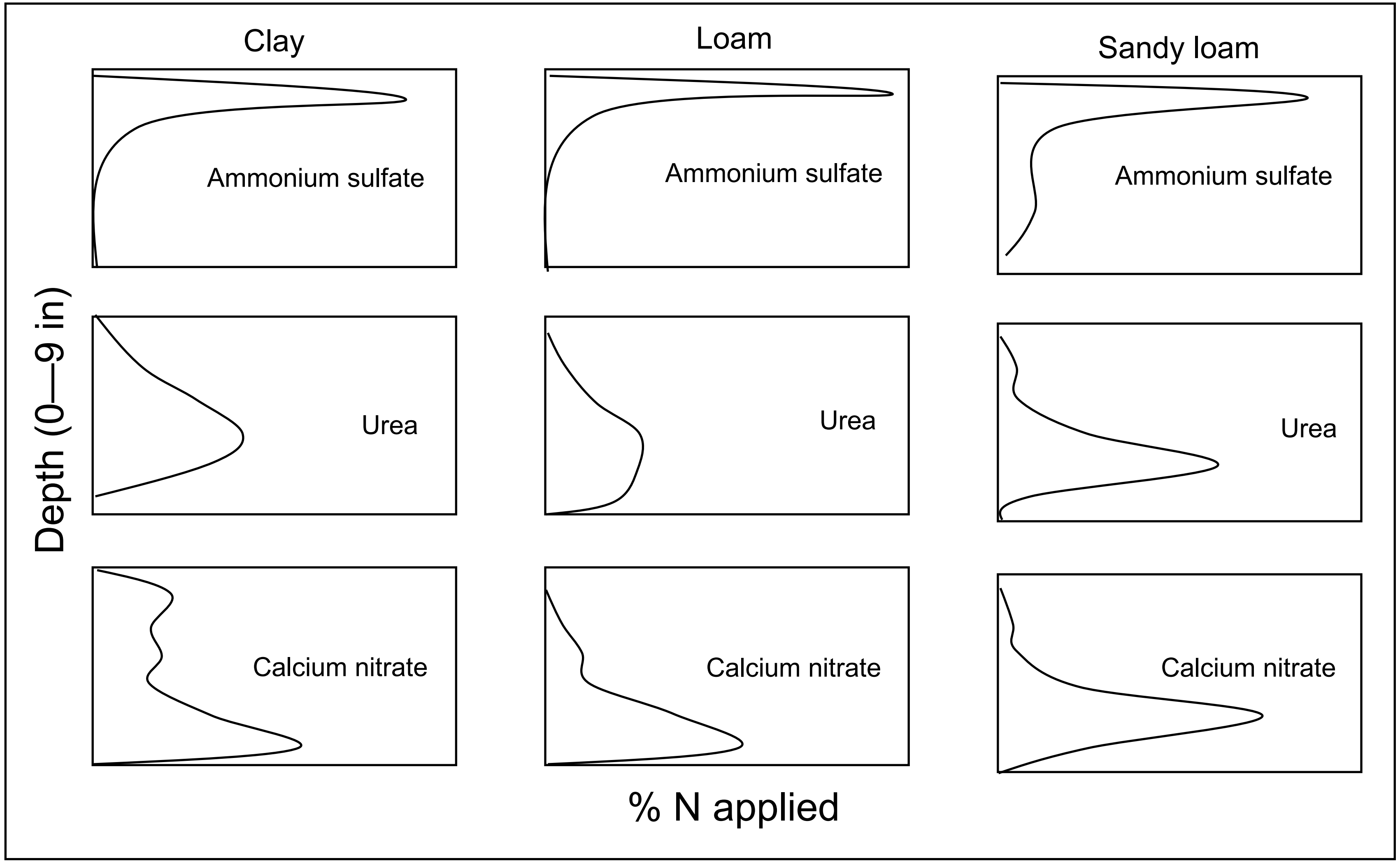
The x-axis of each figure shows the location by depth of applied N fertilizer. The area under each curve is equal to 100%.

Soil Texture

The clay, loam and sandy loam soils are displayed with increasing sand content leading to more rapid movement of water and nitrate.

Fertilizer Source

Ammonium is positively charged, urea is neutral before hydrolysis and nitrate is negatively charged.



Denitrification Loss of Nitrogen

- Transformation of nitrate (NO_3^-) into differ nitrogen gases
  - Catalyzes under anaerobic conditions and available carbon
  - Energy required where nitrate is terminal electron acceptor
  - Multiple forms of nitrogen gas loss from reactive to benign

- Impact of soil conditions and management
  - Water-filled pore space drives from of nitrogen gas loss
  - Potential linked to fertilizer practices and irrigation/precipitation
  - Losses can be minimal despite large environmental impact

Biochemical Dynamics

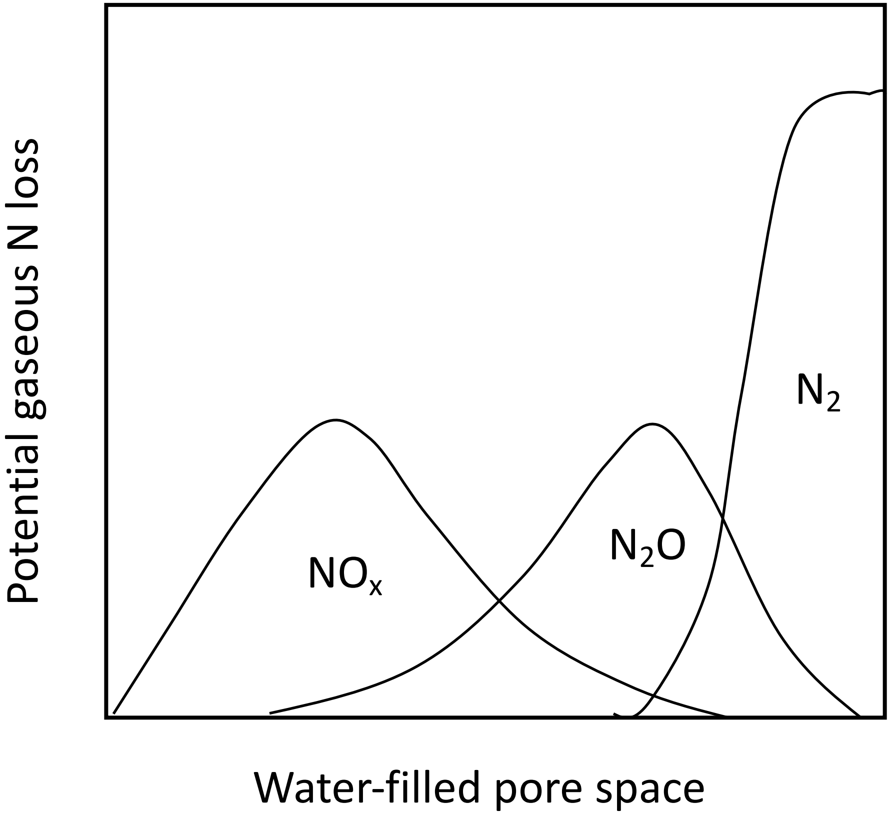
Conversion from nitrate (NO_3^-) to dinitrogen gas (N_2)

Stepwise : Nitrate to dinitrogen gas

$$\underset{\substack{Nitrate \\ (+5)}}{2NO_3^-} \xrightarrow{-2O} \underset{\substack{Nitrite \\ (+3)}}{2NO_2^-} \xrightarrow{-2O} \underset{\substack{Nitric\ oxide, gas \\ (+2)}}{2NO\uparrow} \xrightarrow{-O} \underset{\substack{Nitrous\ oxide, gas \\ (+1)}}{N_2O\uparrow} \xrightarrow{-O} \underset{\substack{Dinitrogen\ gas \\ (0)}}{N_2\uparrow}$$

- Nitrate (NO_3^-) is at risk for loss when in excess
- Nitrite (NO_2^-) does not readily accumulate
- Nitrogen oxides (NO, NO_2) are precursors to smog
- Nitrous oxide (N_2O) is a potent greenhouse gas
- Dinitrogen gas (N_2) is 80% of our atmosphere

Denitrification

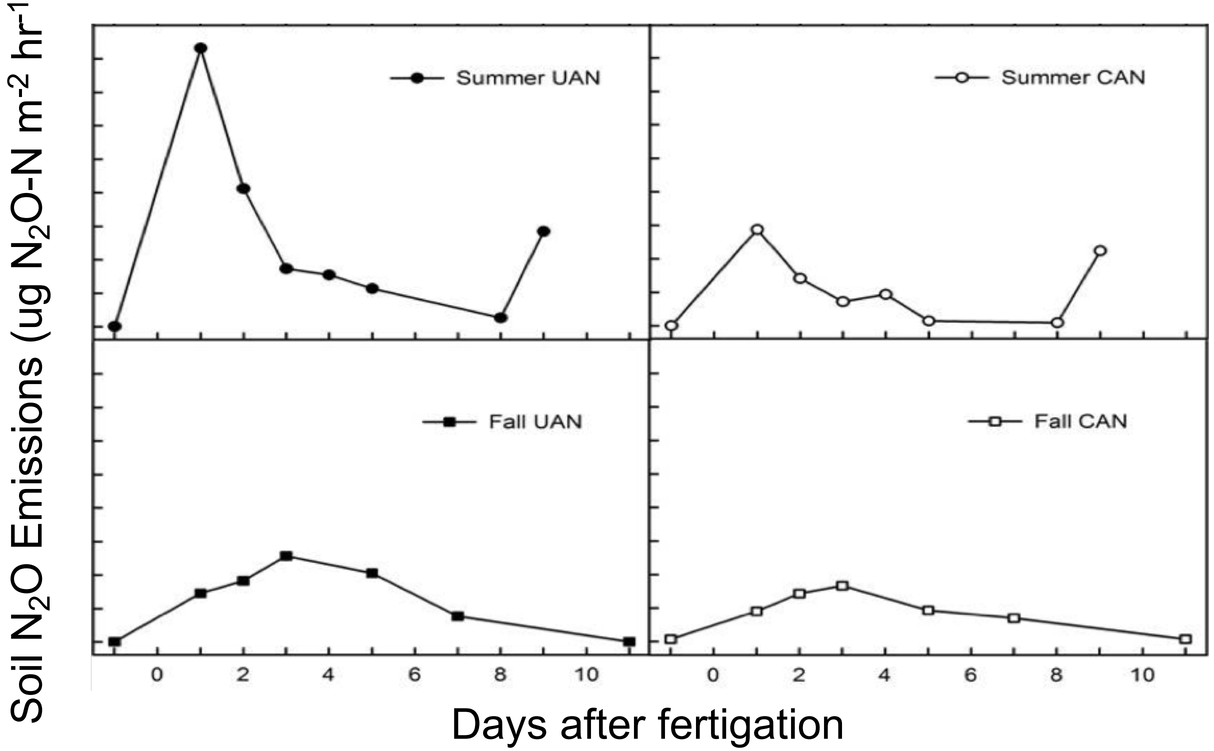


Denitrification by soil moisture

As water-filled pore space increases from field capacity to 100% (saturated conditions) gaseous N loss moves from NO_X to N_2O to N_2

Nitrous oxide emissions

Amounting to less than 1% of fertilizer N rates, N_2O emissions are episodic and can be dynamic based on season and fertilizer source.



UAN = urea ammonium nitrate 32

CAN = calcium ammonium nitrate 17

Review of Nitrogen Cycling in Soils

- Volatilization
  - Ammonia (NH_3) gas lost from soil to the environment
  - Most susceptible for surface applied urea on high pH soils
- Leaching
  - Movement of nitrate (NO_3^-) below the crop rooting zone
  - Most susceptible for coarse soils and improper water management
- Denitrification
  - Transformation of nitrate (NO_3^-) into differ nitrogen gases
  - Favored under anaerobic conditions of high water-filled pore space

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Course materials available at:

ciwr.ucanr.edu/NitrogenManagement

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