Basic Physical, Chemical, and Biological Factors Affecting N Transport in Soils

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• Summary
Nitrogen Sources

- **Global extent**—introduction to terrestrial system from atmosphere: symbiotic fixation, lightening, commercial fertilizer.

- **Site specific**—all of above, animal waste, inherent soil sources.
Nitrogen Transformation

- **Mineralization:**
  - organic to mineral form: Org-N to \( \text{NH}_4^+ \) (weeks to years)

- **Nitrification:**
  - From \( \text{NH}_4^+ \) to \( \text{NO}_3^- \) (rapid, days)
  - Done by selective bacteria in presence of oxygen
Nitrogen Transformation

• Denitrification
  – $\text{NO}_3^- \rightarrow \text{NO}_2 \rightarrow \text{N}_2\text{O} \uparrow \rightarrow \text{N}_2 \uparrow$ (rapid, days)
  – Need bacteria done in absence of oxygen

• Immobilization
  – $\text{NH}_4^+$ or $\text{NO}_3^-$ to plant
Nitrogen Transformation

• Ammonia volatilization
  – $\text{NH}_3 \uparrow$ from animal waste
  – $\text{NH}_4^+$ in alkaline solution $\rightarrow \text{NH}_3 \uparrow$

• Emission from combustion engines and transformed in the atmosphere.
Nitrogen Transport in Soil & Water

- **Organic**: not very mobile
- **NH\textsubscript{4}^+**: not very mobile, electrostatic attraction to soil
- **NO\textsubscript{3}^-**: very mobile, repelled by negative surfaces, soluble in water $R \approx 1$. 
N Transport to Roots

- **Convection** – N moves to root surface through water flux (driven by ET).

- **Diffusion** – When N supply by convection is not sufficient, N concentration at the root surface is lower than the soil solution, concentration gradient develops.
N Management Goal

The rate of plant available N supply to be equal to the rate of plant uptake.
Org-N release rate (not on scale)
N Sources and Release Rates

• Consider all N input sources:
  - Soil N
  - Atmosphere
  - Irrigation
  - Fertilizers

• N Release
  – Typically, Org-N releases fastest when incorporated into soil and tends to decrease exponentially.
  – Slow release N fertilizers behave similarly to org-N, but with higher release rates.
Nitrate Leaching

- **Leaching**: \( \text{NO}_3^- \text{ (lb)} = C \text{ (lb/Ac-in)} \times \text{Deep Percolation (Ac-in)} \)

- **Nitrate concentration**: Higher conc., greater potential for leaching.

- **Water Management**: Excess water moving out of the root zone

- Excess water, N supply > crop demand, lower water holding capacity promotes nitrate leaching!
Irrigation Management

- $ET_0$ (climate based)
- Water application rate according to soil infiltration capacity
- Timing and frequency vs. soil water holding capacity
- Uniformity
Irrigation Uniformity & Water Management

• Higher uniformity reduces water application and leaching potential

• Irrigation based on CIMIS
  \[ ET_a = K_c \times E_To \]
  – Generic, ignore specific conditions such as N deficiency and high salinity
Irrigation uniformity affects leaching

Root depth
Percolation right below the root zone as influenced by DU

- **Percolation (cm)**
- **DU**
  - 0.25
  - 0.45
  - 0.65
  - 0.85
  - 1.05

**Soils:**
- Sand
- Sandy loam
- Silty clay loam
Effect of Plant Growth on Leaching

- Less nitrogen
  - More N leaching
  - More deep percolation
- Less plant growth
  - Less ET

- Less ET
Effect of soil on leaching: Water retention capacity

Water Content (v/v)

Available Water

Field capacity

Residual water content

Tension (Bar)
# Ranges of available water for three soil textural groups

<table>
<thead>
<tr>
<th>Textural group</th>
<th>Available water (in./ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse (sand, loamy sand, sandy loam)</td>
<td>¼ to ½</td>
</tr>
<tr>
<td>Medium (fine sandy loam, loam, silt loam)</td>
<td>1 to 2</td>
</tr>
<tr>
<td>Fine (clay loam, silty clay loam, clay)</td>
<td>1½ to 3</td>
</tr>
</tbody>
</table>

* Allowable depletion
Summary: Fertilizer Application

- Try to match N supply to N demand as much as possible.
- Applying less fertilizer but more frequently, especially in soils of high leaching potential (sandy soils).
- Use new technologies to improve N utilization rate.
Summary: Irrigation Management

• Improve irrigation uniformity
• Avoid applying excess water to generate deep percolation
• If leaching is necessary to control soil salinity, leach the soil while soil residual N is low.
• Upgrade irrigation system.
Summary

To reduce nitrate leaching potential, one should consider:

– soil conditions,
– plant characteristics, and
– irrigation practices.