

# SOIL

## Nitrogen Sources and Transformations no. 0.550

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To get the maximum benefit from nitrogen fertilization with a minimum pollution hazard, you must understand nitrogen properties and transformations.

### Quick Facts...

Nitrogen in the air is the ultimate source of all soil nitrogen.

Nitrogen may enter the soil through rainfall, plant residues, nitrogen fixation by soil organisms, animal manures and commercial fertilizers.

There is no difference between the nitrogen that enters the plant from commercial fertilizers and that from organic products.

Nitrogen may be lost from the soil by plant removal, volatilization, leaching or erosion.

Leaching of nitrate is a pollution hazard; control nitrogen losses with proper management practices.

### Nitrogen Sources

The earth's atmosphere consists of 78 percent nitrogen and is the ultimate source of nitrogen. In most areas of the world, the nitrogen found in soil minerals is negligible. Nitrogen may be added to or lost from soil by a number of processes (see Figure 1). In the soil, nitrogen can undergo a number of transformations.

Rainfall adds about 10 pounds of nitrogen to the soil per acre per year. The nitrogen oxides and ammonium that are washed to earth are formed during electrical storms, by internal combustion engines and through oxidation by sunlight. Some scientists also believe that some of the gaseous products that result from the transformation of nitrogen fertilizers may cause a depletion of the ozone (O<sub>3</sub>) layer around the earth. The extent of this possible damage has not been substantiated.

Crop residues decompose in the soil to form soil organic matter. This organic matter contains about 5 percent nitrogen. An acre-foot of soil having 2 percent organic matter would contain about 3,500 pounds of nitrogen. Generally, about 1 to 3 percent of this organic nitrogen is converted per year by micro-organisms to a form of nitrogen that plants can use.

Legumes fix atmospheric nitrogen through their symbiotic association with *Rhizobium* bacteria. If plant roots are well nodulated, the legume plant does not benefit from the addition of fertilizer nitrogen. Perennial legumes, such as alfalfa, can fix several hundred pounds of nitrogen per acre per year.

Manure contains an appreciable amount of nitrogen. Most of this nitrogen is in organic forms: protein and related compounds. Cattle manure contains about 10 to 40 pounds of nitrogen per ton. About half of this nitrogen is converted to forms available to plants during the first growing season. Lesser amounts are converted during succeeding seasons. Each ton of applied manure is equal to about 5 to 20 pounds of commercial fertilizer nitrogen.

Commercial fertilizer nitrogen comes in three basic forms: gas, liquid and dry. All forms are equally effective when properly applied. Once applied, fertilizer nitrogen is subject to the same transformations as other sources of nitrogen. There is no difference between the ammonium (NH<sub>4</sub><sup>+</sup>) or nitrate (NO<sub>3</sub><sup>-</sup>) that enters the plant from commercial fertilizer and that produced from natural products such as manure, crop residues or organic fertilizers.

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## Nitrogen Transformations

Nitrogen exists in a number of chemical forms and undergoes chemical and biological reactions. The following transformation processes are numbered to coincide with Figure 1.

### 1. Organic nitrogen to ammonium nitrogen (mineralization).

Organic nitrogen comprises over 95 percent of the nitrogen found in soil. This form of nitrogen cannot be used by plants but is gradually transformed by soil microorganisms to ammonium ( $\text{NH}_4^+$ ). Ammonium is not leached to a great extent. Since  $\text{NH}_4^+$  is a positively charged ion (cation), it is attracted to and held by the negatively charged soil clay. Ammonium is available to plants.

**2. Ammonium nitrogen to nitrate nitrogen (nitrification).** In warm, well-drained soil, ammonium transforms rapidly to nitrate ( $\text{NO}_3^-$ ). Nitrate is the principle form of nitrogen used by plants. It leaches easily, since it is a negatively charged ion (anion) and is not attracted to soil clay. The nitrate form of nitrogen is a major concern in pollution.

**3. Nitrate or ammonium nitrogen to organic nitrogen (immobilization).** Soil microorganisms use nitrate and ammonium nitrogen when decomposing plant residues. These forms are temporarily “tied-up” (incorporated into microbial tissue) in this process. This can be a major concern if crop residues are high in carbon relative to nitrogen. Examples are wheat straw, corn stalks and sawdust. The addition of 20 to 70 pounds of nitrogen per ton of these residues is needed to prevent this transformation. After the residues are decomposed, the microbial population begins to die back and processes 1 and 2 take place.

**4. Nitrate nitrogen to gaseous nitrogen (denitrification).** When soil does not have sufficient air, microorganisms use the oxygen from  $\text{NO}_3^-$  in place of that in the air and rapidly convert  $\text{NO}_3^-$  to nitrogen oxide and nitrogen gases ( $\text{N}_2$ ). These gases escape to the atmosphere and are not available to plants. This transformation can occur within two or three days in poorly aerated soil and can result in large losses of nitrate-type fertilizers.

**5. Ammonium nitrogen to ammonia gas (ammonia volatilization).** Soils that have a high pH (pH greater than 7.5) can lose large amounts of  $\text{NH}_4^+$  by conversion to  $\text{NH}_3$  gas. To minimize these losses, incorporate solid ammonium-type fertilizers, urea and anhydrous ammonia below the surface of a moist soil.

## Nitrogen Loss

Nitrogen may be lost from the soil by plant removal, denitrification, leaching, volatilization and erosion.

The first alternative, absorption by crops, is the desired goal.

Erosion losses of N can be significant. The loss of 10 tons of soil per acre per year with 2 percent organic matter can result in a loss of 20 pounds of N.

Leaching can contribute to ground and surface water pollution problems. Loss of nitrates by leaching is undesirable from all standpoints. The loss is minimized and crop use maximized by proper management practices:

- Split the applications of nitrogen on sandy or shallow soils where leaching or erosion hazards are greatest and when heavy rates of nitrogen are required.
- Apply nitrogen during the growing season (not in the fall) on soil subject to leaching and erosion.
- Apply the proper amount of nitrogen and other plant nutrients for vigorous crop growth. Base this on a soil test.
- Use good soil conservation techniques to minimize erosion losses of topsoil.

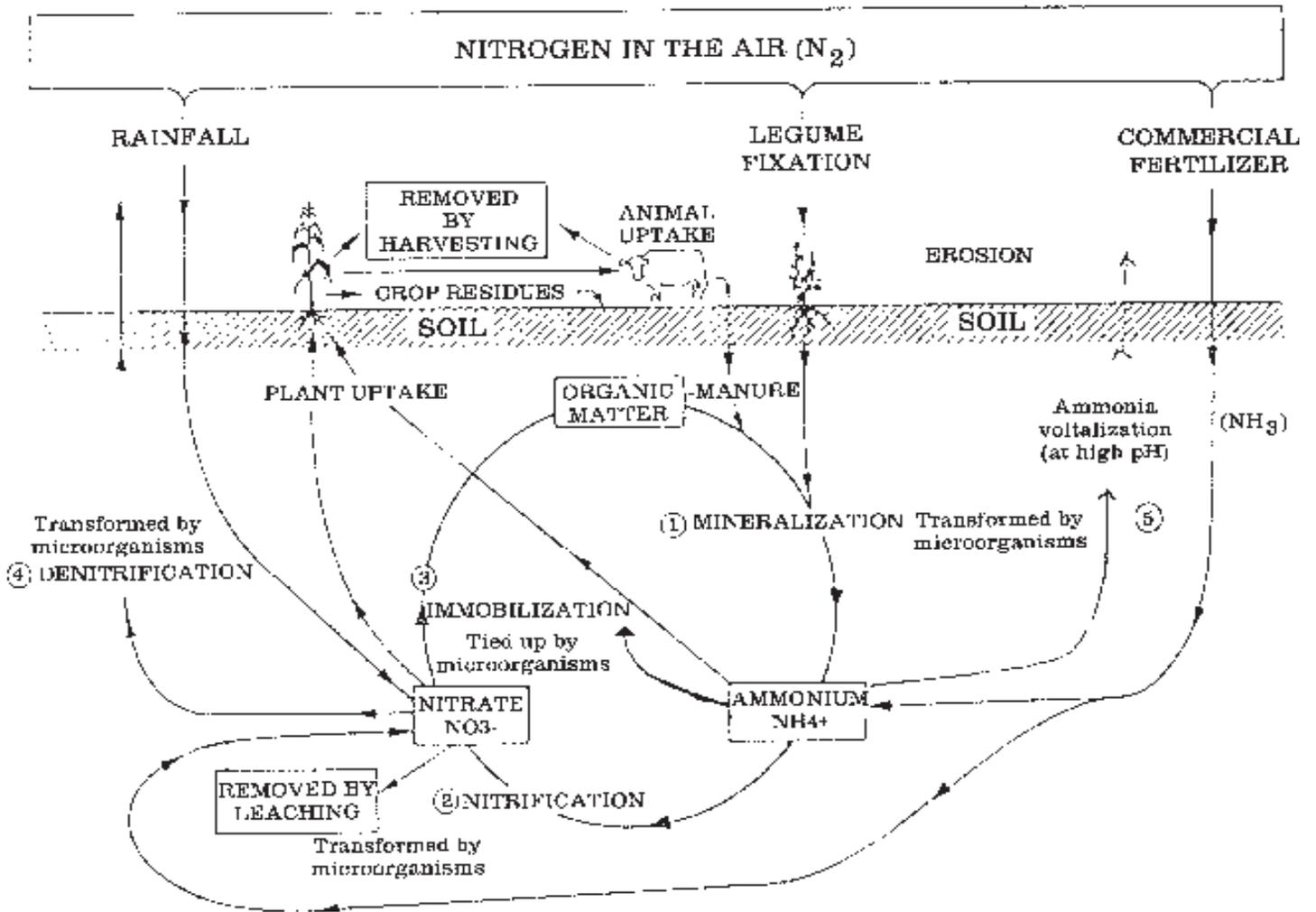


Figure 1: Nitrogen in the air is the source of all soil nitrogen.