Chapter 3

Overview of the Nitrogen Balance Approach and Guidelines for Reducing Risks of Nitrate Leaching

The objective of the Nitrogen Balance Approach for calculating biosolids application rates is to match available inorganic N with the N demand of the plant-soil system. This chapter describes the steps in the Nitrogen Balance Approach and presents guidelines for reducing risks of nitrate leaching when using the approach.

Steps in the Nitrogen Balance Approach

The Nitrogen Balance Approach consists of three steps:

Step 1. Estimate the net N requirement that allows a healthy crop (or trees and understory in a forest system) to grow at the desired yield.

Step 2. Estimate the plant-available N from the biosolids: the pool of N the plant has access to after additions and losses take place.

Step 3. Calculate the annual biosolids application rate by dividing the net plant-soil N requirement by the plant-available N from the biosolids.

Step 1. Estimate the net N requirement

The net N requirement is calculated as follows (Figure 3.1): the amount of inorganic N the plants need (plant uptake), minus the available N in the soil from other sources (N credits) and the amount of N the soil supplies—or plus the amount the soil needs (immobilizes).

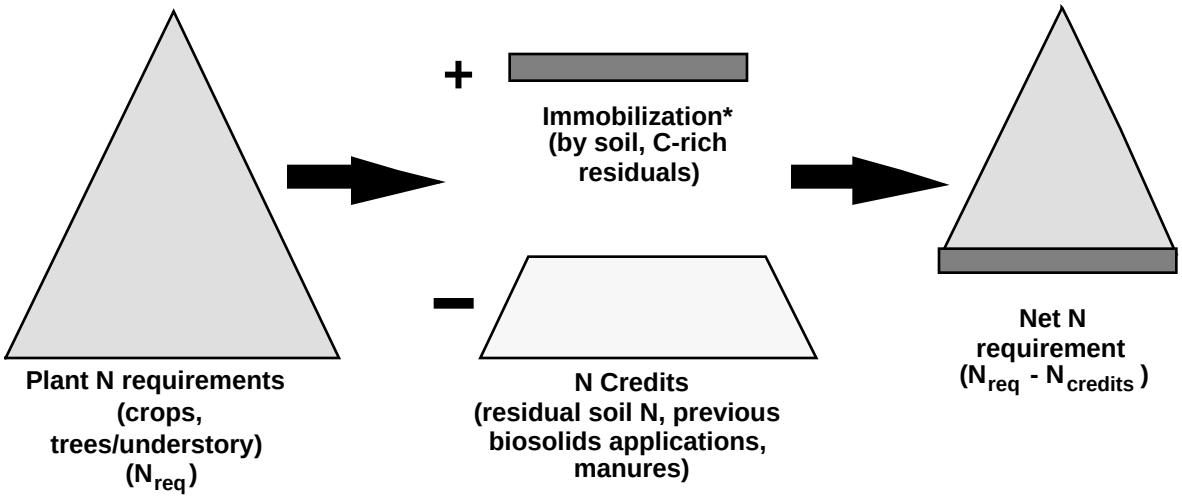

Figure 3.1. Conceptual presentation of the plant-soil nitrogen requirement. (*Immobilization occurs only in special circumstances).

N credits reduce the amount of N needed from a new biosolids application. A soil may have its own "bank of N"—residual soil nitrate, soil organic matter, and N mineralized from previous biosolids applications. The soil may also contain available N from a previous legume crop, manure or other fertilizers, and irrigation water. (See Chapters 5, 6,, and 7 for instructions on how to calculate net N requirements for application to agricultural, forest, and rangeland systems.)

Step 2. Estimate plant-available nitrogen in the biosolids

The second step in the Nitrogen Balance Approach is to estimate how much available N the biosolids will provide. The plant-available N (PAN) is the *net* amount of available inorganic N (NO_3^- and NH_4^+). It is calculated as follows (Figure 3.2): the inorganic N initially in the biosolids as NO_3-N, NH_4-N, plus the ON mineralized during the first year after application, minus the ON lost to the atmosphere by ammonia volatilization and denitrification. (See Chapter 4 for instructions on how to calculate the PAN.)

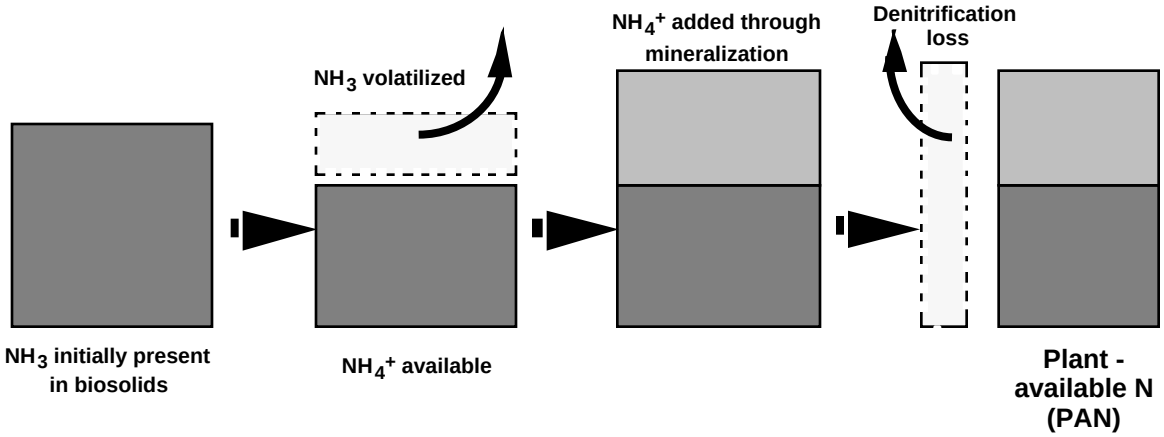

Figure 3.2 Conceptual presentation of net plant-available nitrogen.

Step 3. Calculate the biosolids application rate

In the third step, the results of the first two steps are used to calculate the biosolids application rate that will supply a given year's N requirement (Figure 3.3). It is calculated by using the following equation:

$$B_{app} = (N_{req} - N_{credits})/PAN \quad (3.1)$$

where

B_{app} = Biosolids application rate, dt/ac
N_{req} = Plant-soil N requirement, lb/ac
$N_{credits}$ = N available from other sources, lb/ac
PAN = Net plant-available N from the biosolids, lb/t

Example: The N requirement for annual production of 25 tons of grass silage is 417 lb/ac. Credits for other N sources (soil organic matter mineralization and soil NO_3^- determined via soil testing) are 264 lb/ac. Biosolids will supply 34 lb/t of N after ammonia and denitrification loss.

Variables:

N_{req} = 417 lb/ac
$N_{credits}$ = 264 lb/ac
PAN = 34 lb/t

Result: B_{app} = (417-264)/34 = 4.5 dt/ac

(See Chapters 5, 6, and 7 for instructions on how to calculate the biosolids application rates for agricultural, forest, and rangeland systems.)

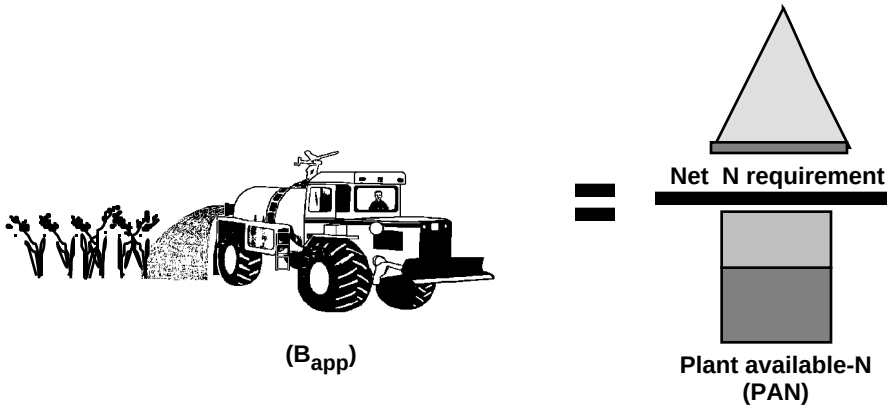

Figure 3.3 Conceptual presentation of biosolids application rate calculation.

Guidelines for reducing risks of nitrate leaching

The risk of nitrate leaching depends on several factors:

- **The site.** For example, the vulnerability of the soil to leaching, history of use of manure and other organic fertilizers, and annual precipitation
- **The crop.** For example, rooting depth and period of active N uptake
- **Quality of N testing and calculation methods.** For example, plant and soil testing, net N requirement calculations, and biosolids application rate calculations
- **Results of N tests and calculations.** For example, results of previous plant and soil tests and estimates of ammonia volatilization

Table 3.1 identifies relative risk factors for nitrate leaching at a site. If several factors are uncertain, the overall risk is compounded. Some of the identified risks can be reduced. For example, if biosolids appear to be of variable quality, more frequent analysis may be needed. If yield goals are uncertain, then harvest data can reduce uncertainty for future applications. Crop and soil N monitoring can reduce the uncertainty for a particular site/crop/management combination. Some situations with high risk may be best to avoid entirely.

Table 3.1. Factors affecting the relative risk of nitrate leaching.

Risk Factor	Relative Risk		
	Low	Medium	High
Crop N uptake efficiency			
Effective crop rooting depth	> 36 in.	12-36 in.	12 in.
Period of active N uptake by crop	> 120 days	60-120 days	< 60 days
Site potential for nitrate leaching			
Soil series vulnerability to leaching loss	Low	Medium	High
Irrigation system	Drip	Sprinkler	Furrow
Annual precipitation (non-irrigated sites)	6-12 in.	12-18 in.	> 18 in.
Impact of previous organic N inputs			
History of organic N input	None	2 out of 5 years	Annual
History of organic N application rate (previous 5 years)	0-100 lb/yr	100-300 lb/yr	Over 300 lb/yr
N testing and calculations for plants and soil			
Crop N requirement calculation	Based on previous site monitoring data and professional agronomist calculations	Based on values in a university fertilizer guide	A standard rate for all crops (for example, 5 dt/ac)
In-season soil testing	Frequent	Occasional	None
In-season plant tissue testing	Frequent	Occasional	None
Results of previous plant and soil tissue testing at the site	Low residual soil nitrate; moderate crop N concentrations	Medium residual soil nitrate; moderate crop N concentrations	High residual soil nitrate; high crop N concentrations
N testing and calculations for biosolids			
Planned vs. actual application rate	± 10% of planned	± 10-20% of planned	> ± 20% of planned
Mineralization rate estimate	Based on incubation test data **and** past site monitoring data	Based on incubation test **or** past site monitoring data	Based on book values—no track record
Ammonia (NH_3) loss estimate	NH_3 is < 5% of Total N	NH_3 is 5-30% of total N	NH_3 is > 30% of total N
Frequency of total solids testing	Daily	Weekly	Annually
Standard deviation in total N analyses (dry weight basis)	± 0.5% N	± 0.5 - 1.5% N	> ± 1.5% N