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Chapter 12

Screening Procedure for Estimating Potentially Leachable Nitrate-Nitrogen Below the Root Zone

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Leaching of nitrate-N (NO_3-N) in soil is a complex process. Prediction of NO_3-N movement below the root zone and into groundwater supplies is difficult even though the physical and biological processes controlling N cycling in soil are well defined. The difficulty arises because of the highly variable nature of soils and processes that determine the overall fate of N in soils and also because of the limited or inaccurate site-specific data.

Procedures to assess potential NO_3-N leaching can vary in complexity and scale from simple screening procedures to complex simulation models. Selection of an assessment procedure depends on several factors including the scale of analysis, the problem to which the procedure is applied, and availability of required resource data (soils, weather, crop, and management data).

Five major categories of models, classified on the basis of time frame, can be used to assess NO_3-N leaching potential. These are long-term (equilibrium), annual, monthly, event, and short, time-step based models. In the order presented, these generally represent procedures with minimal to extensive data requirements and least to most reliable prediction. Although the more detailed models should predict the most probable amount of NO_3-N leaching, the input requirements and operational configuration requirements are often so extensive that their use by some managers and advisors in soil management may be limited by technology available to them. While not the most precise, annual models can be important tools for determining when more intensive procedures are needed to more fully assess NO_3-N leaching potential.

The purpose of this chapter is to use information contained in previous chapters and the existing knowledge base to develop a simple "hand" calcu-

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lation procedure to estimate the potential for NO_3-N leaching on an annual basis. The procedure involves calculation of an annual leaching risk potential (ALRP) that can be used to determine the NO_3-N leaching risk for given conditions. If ALRP exceeds critical limits, the user is directed to the computer model in chapter 13 by Shaffer et al. to more thoroughly evaluate the NO_3-N leaching potenital of their crop management system. An automated version of this procedure is included in chapter 13.

12-1 CALCULATION OF LEACHED NITRATE-N POTENTIAL

This procedure uses the leaching index (LI) of Williams and Kissel (chapter 4) and an estimate of NO_3-N available for leaching (NALy) which is obtained from an annual N balance to determine a leached NO_3-N potential (LNP). The Appendix gives a glossary of variables used in this chapter. Examples are given to illustrate the calculation procedure. The procedure is also illustrated in Fig. 12-1. The LI is calculated using the worksheet given in Fig. 12-2. Nitrate-N available for leaching is determined from the N balance worksheets. The procedure can be repeated to calculate leaching risk potentials for different soil, weather, and N or crop management strategies. Additional copies of worksheets in Fig. 12-2 and 12-8 that can be photocopied for use with the procedures are given in Fig. 12-11 and 12-12, respectively.

12-1.1 Calculation of Leaching Index

The procedure form in Fig. 12-2 is intended to assist in the calculation of LI by completing steps A through H. The form allows for calculating a range of LI values for low, average, and high rainfall years. For example, precipitation for an area may range from 30 to 40 in. per year and average approximately 34 in. The annual precipitation should be recorded in line A.

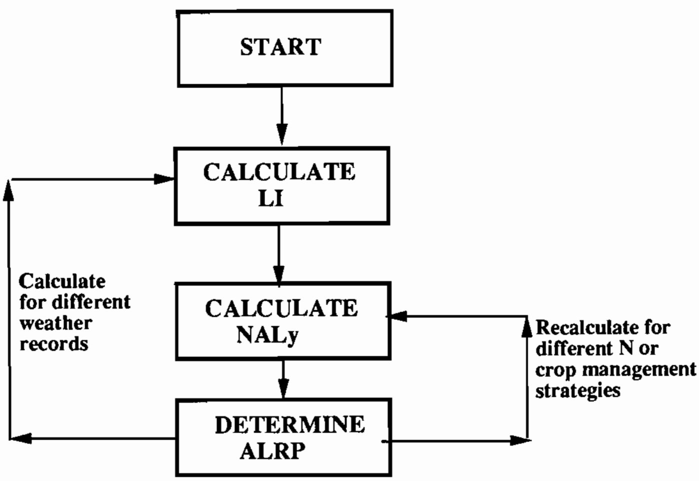

Fig. 12-1. Flow diagram illustrating the procedure for estimating leached N potential (ALRP).

The seasonal precipitation should be recorded on line B. Williams and Kissel (chapter 4) indicate that the seasonal precipitation is determined from the October through March period but it is not clear if this would be true for all regions in the USA. If seasonal precipitation is not available, move to line C and estimate the ratio (since line B is used only to determine the ratio in line C). Record the hydrologic group for your soil on line D (this can be determined from Table 8–2 in chapter 8 or can be obtained from your county soil survey report, from your local Soil Conservation Service county office, or from the appropriate regional database associated with the Nitrate Leaching and Economic Analysis Package (NLEAP) model (chapter 13). Use the nomograph in Fig. 12–3 or the equations in Table 12–1 to determine the percolation index (PI) and record on line E. Determine the seasonal index (SI) using Fig. 12–4 or Eq. 5 in Table 12–1 and record on line F. Determine the leaching index (LI) by multiplying line E (PI) times line F (SI) and record on line G (LI). Determine the severity of LI on line G from Fig. 12–5 and record on line H.

An example of the calculation of LI is given in Table 12–2 which contains precipitation and percolation data for Coshocton, OH, summarized for the April to March period for the years 1944 to 1961. The data were

Calculation of Leaching Index (LI)

Complete the following information sheet using information contained in Figures 12-3, 4, 5 and Table 12-1.

	Low	Average	High
	------	inches	------
A. Annual Precipitation	25.13	40.57	52.51
B. Seasonal Precipitation *	12.11	18.54	26.88
C. Ratio of B/A	0.48	0.46	0.51
D. Hydrologic Group (A, B, C, D)	C	C	C
E. Percolation Index, PI (from Figure 12-3 or Equations 1-4 in Table 12-1)	0.57	6.34	13.30
F. Seasonal Index, SI (from Figure 12-4 or Equation 5 in Table 12-1)	0.99	0.97	1.01
G. Leaching Index, LI = PI * SI	0.56	6.17	13.43
H. Leaching Index Severity (Figure 12-5)	L	M	H

*** For much of the United States, seasonal refers to the October to March Period.**

Fig. 12–2. Worksheet for calculation of the leaching index (LI) (Williams and Kissel, chapter 4) based on annual precipitation and hydrologic group. Data are for the Keene silt loam (fine-silty, mixed mesic Aquic Hapludalf) at Coshocton, Ohio for the weather record 1944–1961.

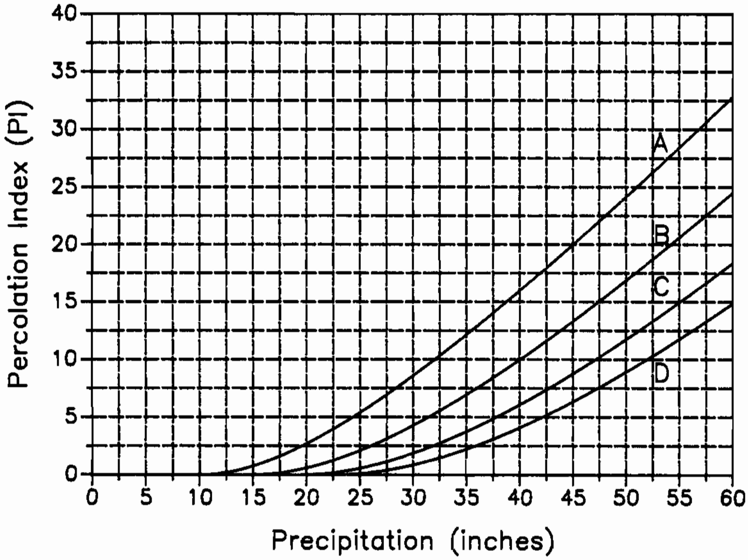

Fig. 12-3. Nomograph of percolation index (PI) vs. annual precipitation.

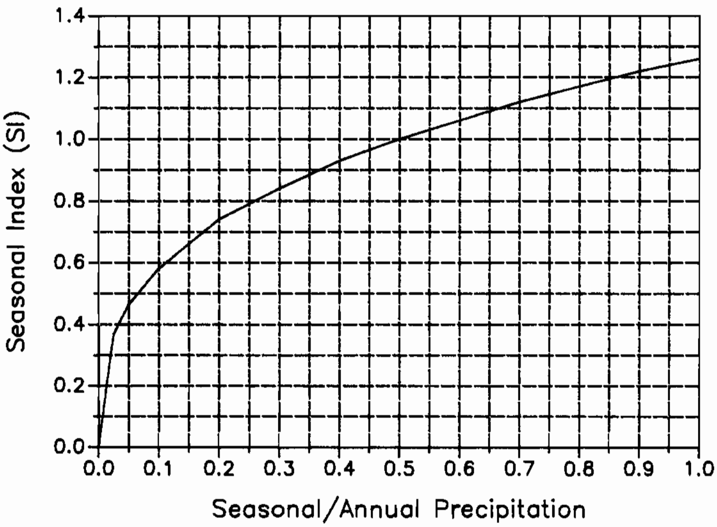

Fig. 12-4. Nomograph of season index (SI) vs. the ratio of seasonal to annual precipitation.

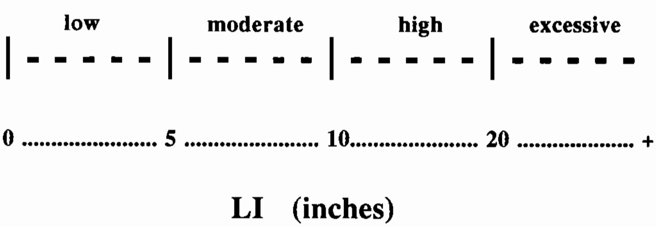

Fig. 12-5. Leaching Index Severity for values of LI. Class boundaries are examples and should be set by local expertise.

Table 12-1. Equations for use in calculation of leaching index (LI). (Derived from Williams and Kissel, chapter 4.)

Hydrologic group		Calculation of PI†
A	$PI = (P - 10.28)^2/(P + 15.43)$	[1]
B	$PI = (P - 15.05)^2/(P + 22.57)$	[2]
C	$PI = (P - 19.53)^2/(P + 29.29)$	[3]
D	$PI = (P - 22.67)^2/(P + 34.00)$	[4]
	Equation for calculation of SI	
	$SI\ (2PW/P)^{1/3}$	[5]

† PI = percolation index, SI = seasonal index.

recorded for weighing lysimeter Y103A containing an undisturbed monolith of the Keene silt loam soil (fine-silty, mixed, mesic Aquic Hapludalf) (Harrold & Dreibelbis, 1958, 1967). The parameters PI, SI, and LI were calculated for each April-March period rather than the annual January-December period because of the seasonal nature of deep percolation losses. Figure 12-6 shows that the relationship between LI and measured percolation for the Y103A lysimeter is improved when the April-March period is considered rather than the January-December period (R^2 of regression equation equal to 0.73 vs. 0.41, respectively). While using the April-March period improves correlation for the Coshocton data, it may not improve it elsewhere. Therefore, the annual precipitation values as described in chapter 4 by Williams and Kissel should be used to calculate a yearly LI since it makes no difference

Table 12-2. Calculation of leaching index (LI) for the April to March period at Coshocton, OH for the years 1944 to 1961 and comparison to measured percolation for lysimeter Y103A as reported by Harrold and Dreibelbis (1958, 1967).

Year	P†	PW	PI	SI	LI	Measured percolation
	in.	in.			in.	in.
1944	38.48	20.41	5.30	1.02	5.40	8.68
1945	43.25	16.00	7.76	0.90	7.02	8.19
1946	41.91	18.70	7.03	0.96	6.77	5.14
1947	43.35	16.78	7.81	0.92	7.17	9.53
1948	42.95	20.40	7.59	0.98	7.46	7.53
1949	45.26	20.76	8.88	0.97	8.63	8.79
1950	52.51	26.88	13.30	1.01	13.40	15.05
1951	44.40	25.48	8.39	1.05	8.79	10.74
1952	36.52	16.06	4.39	0.96	4.20	3.21
1953	32.83	14.95	2.85	0.97	2.76	1.29
1954	37.56	21.49	4.86	1.05	5.09	5.04
1955	38.94	20.60	5.52	1.02	5.63	4.11
1956	43.10	14.25	7.67	0.87	6.69	3.75
1957	44.49	14.50	844	0.87	7.32	7.74
1958	45.84	18.38	9.21	0.93	8.56	5.28
1959	46.23	23.30	9.44	1.00	9.46	5.31
1960	42.77	18.80	7.50	0.96	7.18	3.32
1961	44.89	21.40	8.67	0.98	8.53	8.25
30-yr avg.	40.57	18.54	6.34	0.97	6.17	6.72

† P = annual precipitation (in.), PW = seasonal precipitation (in.), PI = percolation index, SI = seasonal index.

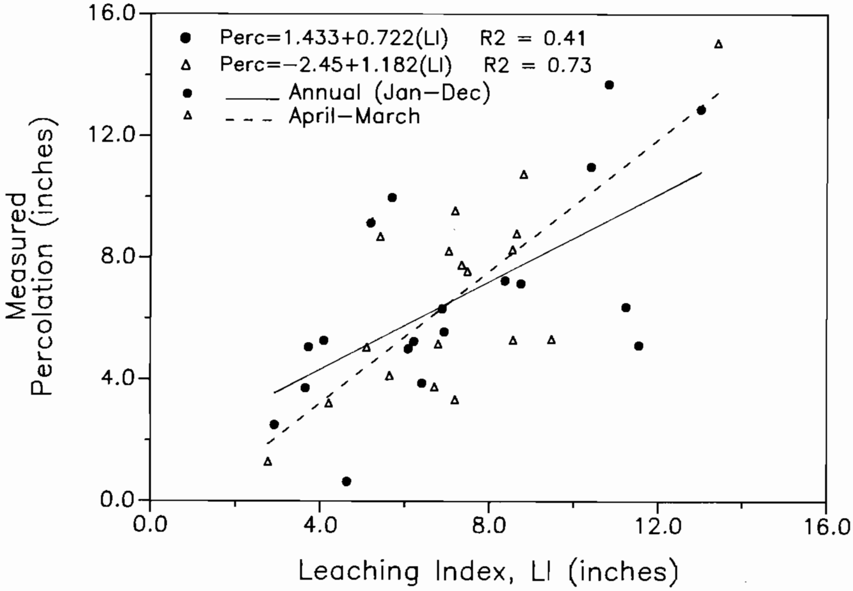

Fig. 12-6. Plot of LI vs. measured percolation (in.) for the Y103A lysimeter. (Data from Harrold and Dreibelbis, 1958, 1967.)

in the calculation of LI when using long-term (30 yr) weather records since the annual variation is eliminated in the mean value. Figure 12-7 plots the annual variation in percolation in lysimeter Y103A during the years 1944 to 1961. As indicated in Fig. 12-6, LI approximated the variability reasonably well. The LI severity for this location (Fig. 12-5) would average moderate but range from low to high depending on the year.

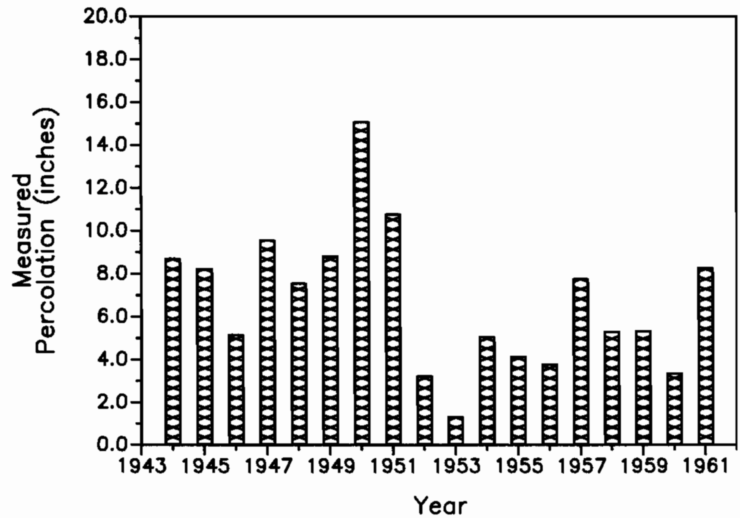

Fig. 12-7. Annual frequency of measured percolation for the Y103A lysimeter at Coshocton, OH for the April to March period from 1943-1961. (Data from Harrold and Dreibelbis, 1958, 1967.)

12-1.2 Calculation of Nitrate-Nitrogen Available for Leaching

This procedure uses both the N mass balance concepts described by Meisinger and Randall in chapter 5 and the efficiency factor concept described by Bock and Hergert in chapter 7. The user can estimate NALy by using a mass balance method alone or using a procedure that combines both mass balance and N-efficiency methods into a single procedure. The second method is designed to evaluate whether sufficient N is available to the plant based on the yield goal supplied by the user. The worksheets in Fig. 12-8 and 12-9 will facilitate calculation of NALy. Once determined, Fig. 12-10 is used to estimate the relative severity of NALy.

	1972	1973	1974
		lbs N/acre	
A. Mineralized N	62	62	62
B. Crop Residue N	62	56	30
C. Residual Soil Nitrate-N	233	216	120
D. Fertilizer N	300	0	150
E. Organic N Wastes (manures, etc.)	0	0	0
F. Symbiotic N Fixation	0	0	0
G. Precipitation N	5	5	5
H. Irrigation N	0	0	0
I. Other N (seed, non-symbiotic N)	0	0	0
J. Total N inputs (Sum Column)	682	339	367
K. Crop Uptake (Harvested Portion)	122	71	130
L. Crop Uptake (Unharvested Portion)	75	40	82
M. Total Plant Uptake (YG = K+L)	197	111	212
N. Potentially Leachable N, PLN = H - L	485	228	155
O. PLN Adjustments			
01 Runoff and Erosion	2	3	1
02 Ammonium Volitalization	0	0	0
03 Denitrification	68	28	34
04 Other (gaseous losses)	0	0	0
Total PLN Adjustments	70	31	35
P. Nitrogen Available for Leaching (NALy) = N - O	395	197	120
Q. Relative Nitrate-N Leaching Severity (Figure 12-10)	H	H	H

Fig. 12-8. Worksheet for the calculation of N available for leaching (NALy) for Keene silt loam soil for the Chichester (1977) and Chichester and Smith (1978) N lysimeter studies. See Table 12-5 for notes on parameter estimation.

	N Source lbs/acre	Efficiency Factor	Potentially Available N lbs/acre
A. Mineralized N	____	____	____
B. Crop Residue N	____	____	____
C. Residual Soil Nitrate-N	____	____	____
D. Fertilizer N	____	____	____
E. Organic N Wastes (manures, etc.)	____	____	____
F. Symbiotic N Fixation	____	____	____
G. Precipitation N	____	____	____
H. Irrigation N	____	____	____
I. Other N (seed, non-symbiotic N)	____	____	____
J. Total N inputs (Sum Column)	____		
K. Total Potentially Plant Available N			____
L. Potentially Leachable N, PLN = J - K			____
M. PLN Adjustments			
M1 Runoff and Erosion	____		
M2 Ammonium Volitalization	____		
M3 Denitrification	____		
M4 Other (gaseous losses)	____		
Total PLN Adjustments			____
P. Nitrogen Available for Leaching (NALy) = L - M			____
Q. Relative Nitrate-N Leaching Severity (Figure 12-10)			____

Fig. 12-9. Worksheet for the calculation of N available for leaching (NALy) using Method II.

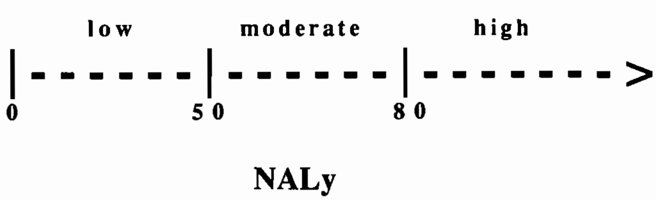

Fig. 12-10. Assessment of leachable N severity based on annual NALy.

Complete the following information sheet using information contained in Figures 12-3, 4, 5 and Table 12-1.

	Low	Average	High
	------	inches	------
A. Annual Precipitation	_____	_____	_____
B. Seasonal Precipitation *	_____	_____	_____
C. Ratio of B/A	_____	_____	_____
D. Hydrologic Group (A, B, C, D)	_____	_____	_____
E. Percolation Index, PI (from Figure 12-3 or Equations 1-4 in Table 12-1)	_____	_____	_____
F. Seasonal Index, SI (from Figure 12-4 or Equation 5 in Table 12-1)	_____	_____	_____
G. Leaching Index, LI = PI * SI	_____	_____	_____
H. Leaching Index Severity (Figure 12-5)	_____	_____	_____

* For much of the United States, seasonal refers to the October to March Period.

Fig. 12-11. Additional worksheet for calculation of the leaching index (LI) based on annual precipitation and hydrologic group.

12-1.2.1 Method I for Calculating NALy

The mass balance approach calculates NALy as follows:

$$\text{NALy} = (\text{N}_{\text{inputs}} - \text{N}_{\text{outputs}}) \quad [1]$$

where NALy is determined from the inorganic N balance. N_{inputs} include inorganic N from all sources: N mineralized from soil organic matter (net mineralization), added organic wastes, crop residues, fertilizer N, residual NO_3-N in the soil profile, N in precipitation and irrigation water, fixed N, and other minor inorganic N sources (see Fig. 12–8). Inorganic $N_{outputs}$ include runoff and erosion losses and gaseous losses through volatilization and denitrification (immobilization of inorganic N in soil organic matter is accounted for in "net" mineralization on the input side of Eq. [1]). A procedure to calculate annual N balance is outlined below.

CALCULATION OF ANNUAL NITROGEN BALANCE

A worksheet is given in Fig. 12–8 to facilitate the calculation of the annual soil inorganic N balance for a given annual crop or a sequence of crops. Use the information contained in chapters 5, 6, and 7 to assist in estimation

	Year 1	Year 2	Year 3
		lbs N/acre	
A. Mineralized N	______	______	______
B. Crop Residue N	______	______	______
C. Residual Soil Nitrate-N	______	______	______
D. Fertilizer N	______	______	______
E. Organic N Wastes (manures, etc.)	______	______	______
F. Symbiotic N Fixation	______	______	______
G. Precipitation N	______	______	______
H. Irrigation N	______	______	______
I. Other N (seed, non-symbiotic N)	______	______	______
J. Total N inputs (Sum Column)	______	______	______
K. Crop Uptake (Harvested Portion)	______	______	______
L. Crop Uptake (Unharvested Portion)	______	______	______
M. Total Plant Uptake (YG = K+L)	______	______	______
N. Potentially Leachable N, PLN = J - M	______	______	______
O. Pln Adjustments			
01 Runoff and Erosion	______	______	______
02 Ammonium Volitalization	______	______	______
03 Denitrification	______	______	______
04 Other (gaseous losses)	______	______	______
Total PLN Adjustments	______	______	______
P. Nitrogen Available for Leaching (NALy) = N - O	______	______	______
Q. Relative Nitrate-N Leaching Severity (Figure 12-10)	______	______	______

Fig. 12-12. Additional worksheet for the calculation of N available for leaching (NALy).

of values to be used in these calculations. Estimates of inorganic N inputs and outputs should be determined and recorded in the worksheet in Fig. 12-8. Users are encouraged to use local and site-specific values when available for each parameter in the worksheet. Estimates for each parameter can be obtained using state and regional estimation procedures often found in extension publications. The following guidelines for estimation of inorganic N inputs and outputs are provided for the user when local sources of information are not available.

I. Nitrogen Estimation Procedures

A. Nitrogen Mineralization (line A, Fig. 12–8).

Annual quantity of N mineralized from soil organic matter (Nminy) is approximated as a percent of the organic N content of soil in the surface layer (see chapter 6). This is estimated as follows:

$$\text{Nminy} = [\text{OMR}/(100 \times \text{Cf} \times \text{CN})] \times \text{Wsoil} \times \text{ON}/100 \qquad [2]$$

where
OMR = soil organic matter (%)
Cf = factor to convert OMR to carbon (C)
= 1.724 (assumes C content of OMR is 58%)
CN = carbon to nitrogen ratio in soil = 10
Wsoil = weight of soil to a depth of 1 ft in lb/acre
= approximately 4 000 000 lb/acre-ft
= 226 512 × bulk density (g/cm^3) × layer thickness (in.)
ON = percent of organic N mineralized annually
= 1 to 2 (see chapter 6)

Assuming default values above then,

$$\text{for ON} = 2,\ \text{Nminy} = \text{OMR} \times 45.5 \qquad [3]$$

$$\text{for ON} = 1,\ \text{Nminy} = \text{OMR} \times 22.7 \qquad [4]$$

B. Crop Residue N (line B, Fig. 12–8).

The mineralization of N from the residue of the previous crop is estimated in a manner similar to organic wastes (chapters 5 and 6) as follows:

$$\text{Crop residue N} = \text{kresy} \times \text{Npres} \qquad [5]$$

where
kresy = fraction of crop residues mineralized each year
Npres = N content of plant residues lb/acre

Values Npres can be determined using Table 5–4 in chapter 5.

C. Residual Soil Nitrate-N (line C, Fig. 12–8).

Residual NO_3-N in soil should be determined by testing the soil to at least 2 ft (see chapter 8) but preferably to the depth of rooting. Determine residual soil NO_3-N in lb/acre for the entire sampling depth.

D. Fertilizer N (line D, Fig. 12–8).

Fertilizer is often a major source of N for agricultural production. Record the total quantity of fertilizer N applied to each crop. A list of common N fertilizers and their composition is given in Table 5–2 in chapter 5. Values in Table 5–2 can be used to convert fertilizer material applied to actual N applied.

E. Nitrogen in Manures and Organic Wastes (line E, Fig. 12–8).

Animal manures and other organic wastes can supply large quantities of inorganic N to soils but the fate of organic wastes applied to land is complex. As indicated in other chapters in this book, N contribution from organic wastes is difficult to determine because these wastes are subject to a number of loss mechanisms, land applications are not uniform, and N concentrations are variable.

The amount of N mineralized from organic wastes (Now) is determined as the sum of N waste applied annually (less volatilization losses) plus N residual from various waste applications expressed as follows:

$$\text{Now} = [(\text{Wt}/2000) \times (\text{dm}/100) \times \text{Nw} \times \text{Mn}] \times \text{Vret}/100 \qquad [6]$$

where

Wt = tons organic waste applied (wet wt.),
dm = Dry matter content of the waste %,
Nw = N content of waste [lb N/lb waste (dry wt. basis)],
Mn = mineralization coefficient for that waste [declines each year after application (see chapter 6, Table 6–4)],
Vret = ammonia volatilization correction expressed as percent N retained from land applied organic waste (values for manure can be obtained from Table 5–6.2 in chapter 5 or local values).

F. Symbiotic Dinitrogen Fixation by Legumes (Line F, Fig. 12–8).

Section 5–3.4 in chapter 5 gives a discussion of estimating symbiotic N_2 fixation inputs. The procedure to calculate N_2 fixation (Nfx) as discussed by Meisinger and Randall requires legume yield (YLD), percent N content (Ny), the proportion of N in plant derived from N_2 fixation (PN), and the amount of N in the nonharvested portion of the plant. Nitrogen content of the harvested portion of the legume can be estimated by direct chemical analysis or using the default values given in Table 5–4. The proportion of N in the legume derived from N_2 fixation is determined from Table 5–5 which is based on N availability to the legume. Nitrogen fixed is calculated using Eq. [7]:

$$\text{Nfx} = \text{YLD} \times (\text{Ny}) \times \text{PN} \quad [7]$$

The amount of N fixed in the unharvested portion of the plant is equal to 50% of the harvested portion. Therefore, the total N fixed by the plant is Nfx times 1.5.

G. Precipitation N (line G, Fig. 12–8).

Figure 6–2 and Table 6–6 in chapter 6 give annual N contributions from rainfall dry deposition for the continental USA. The user should record annual N content from a known data source or interpolate from the map in Fig. 6–2.

H. Irrigation N (line H, Fig. 12–8).

If irrigation water is applied, calculate annual N amounts in irrigation water as follows:

$$\text{NI} = \text{base NI} \times \text{Ia} \times 0.226 \quad [7]$$

where

Ia = annual irrigation amount (acre-in./yr),
base NI = average annual irrigation water N concentration (ppm),
NI = annual lb N/(acre yr) in irrigation water application, and
0.226 = conversion factor from ppm to lb N/acre

I. Other N Inputs (line I, Fig. 12–8).

This includes other sources of N including seed and nonsymbiotic N_2 fixation obtained from local estimates.

J. Total Inputs (line J, Fig. 12–8).

Sum of all N inputs in lines A through I.

II. Nitrogen Output Estimation Procedures

A. Crop Uptake (harvested portion) (line K, Fig. 12–8).

Uptake of N in harvested crop is calculated as follows:

$$\text{CNh} = (\text{YG} \times \text{Ny}) \quad [8]$$

where

CNh = crop N uptake lb/(acre yr),
YG = yield goal units of yield/(acre yr), and
Ny = N content of harvestable crop in lb/harvest unit (see values and footnotes from Table 5–4 in chapter 5).

Determination of a realistic yield goal is important and procedures to determine a yield goal are presented by Bock and Hergert in chapter 7. Local and regional yield goal determination procedures are available in many fertilizer recommendations publications. Often yield goal is estimated as the 5-yr average plus 5% (see chapter 7).

B. Crop Uptake (unharvested portion) (line L, Fig. 12–8).

$$CNu = Bmu \times Ns \text{ or}$$

$$CNu = (YG/HI) \times Ns \qquad [9]$$

where

CNu = crop N uptake (lb/[acre yr]) in unharvested portion,
Bmu = total unharvested biomass units/(acre yr),
HI = harvest index (harvested portion/total above-ground biomass), and
Ns = N content of unharvested plant portion lb N/unit (values obtained from Table 5–4 in chapter 5, where unit is based upon both YG and HI).

(Root N can be estimated as 20% of the aboveground N uptake. It can be included in this calculation by multiplying CNu by 1.20.)

C. Total Crop N Uptake (line M, Fig. 12–8).

Sum of values in lines K and L.

III. Calculation of Potentially Leachable N (line N, Fig. 12–8).

The PLN is calculated as the difference between total N inputs and N uptake in the above-ground plant biomass. PLN is then adjusted for N losses to calculate the NALy. Therefore, calculate PLN as

$$PLN = N_{inputs} - \text{Total N Uptake}. \qquad [10]$$

Then adjust PLN for N losses from runoff, erosion, ammonium volatilization, and denitrification using the following procedures.

PLN adjustments: (line O, Fig. 12–8).

Nitrate-N in soil is subject to loss mechanisms that reduce the amount of inorganic N in the soil and therefore reduce the quantity of potential leachable NO_3-N. These mechanisms also reduce the efficiency of N utilization. Major mechanisms for loss of N from the soil include runoff, soil erosion, and gaseous losses through volatilization and denitrification.

Nitrogen losses through any of these mechanisms will reduce PLN. What follows are procedures to estimate quantities of N lost through these mechanisms. Be advised that quantitative estimates are difficult to obtain and highly variable at best (refer to chapters 5 and 6).

A. Runoff and Erosion N Losses (line O1, Fig. 12-8).

Runoff and erosion losses of inorganic N can be significant if runoff occurs soon after fertilizer or organic waste applications to the soil surface. Otherwise, annual runoff and erosion losses of inorganic N are small and need not be included in the annual N budget. If runoff and erosion loss estimates are desirable, these can be calculated as follows:

$$RN = RT \times Nr \times 0.226 \qquad [11]$$

where

RN = N losses in runoff lb N/(acre yr),
RT = total runoff in./(acre yr),
Nr = average N concentration of runoff water (ppm), and
0.226 = conversion factor to convert to lb N/acre.

$$EN = E \times Ne \qquad [12]$$

where

EN = N loss in eroded sediment lb N/(acre yr),
E = soil erosion rate tons/(acre yr), and
Ne = average inorganic N content of eroded soil (lb N/ton).

B. Ammonium Volatilization (line O2, Fig. 12-8).

Ammonia volatilization ($N_{NH3}y$) occurs at the soil surface when fertilizers or organic wastes are surface applied. If these materials are incorporated soon after application, $N_{NH3}y$ is assumed to be zero. Corrections for volatilization losses from organic wastes should have been made when calculating N inputs from organic wastes above.

For $N_{NH3}y$ losses from fertilizer applications, obtain a value of percent loss of applied fertilizer (F1) from Table 5-6.1 in chapter 5. Then calculate fertilizer N volatilization loss ($N_{NH3}fy$) as follows:

$$N_{NH3}fy = FN \times F1/100 \qquad [13]$$

where

$N_{NH3}fy$ = fertilizer N volatilization losses, lb N/(acre yr),
FN = fertilizer N applied lb/(acre yr), and
F1 = percent loss of applied fertilizer (%) (Table 5-6.1).

C. Denitrification (line O3, Fig. 12-8).

Denitrification (Dn) is also difficult to assess. Familiarize yourself with the discussion in chapter 5 on denitrification. Then use Table 5-7 with the following procedure to obtain an annual estimate of Dn. Dn = 0 when any of the following are true:

Soil Organic Matter (OMR) $<1\%$
Topographic position is summit or side slope
Slope is $\geq 5\%$
LPy <0

Calculate Dn as a fraction of total NO_3-N in the surface soil layer as follows:

1. Select drainage class:
   I = Well drained
   II = Moderately well drained
   III = Somewhat poorly drained
   VI = Poorly drained
2. Identify climate: SC = arid, semiarid and HC = humid, irrigated
3. Adjust drainage class:
   a. If tile drained, use one class drier
   b. If no-tillage management, use one class wetter
   c. If compacted, use one class wetter
4. Determine Dn percentage from Table 5–7
5. Multiply total N inputs (line J) by Dn/100

Calculate the NALy by subtracting the sum of the PLN adjustments (line O) from PLN in line N.

Relative leaching severity of NALy is determined from Fig. 12–10. Because some inorganic N remains in the soil profile after harvest in all crop production and natural ecosystems, some level of NALy is rated as low. Therefore, the NO_3-N leaching risk potential is low for NALy values below some base level. A value of 50 is used in Fig. 12–10 as the base level. However, the level of NALy used to determine boundaries of risk categories should be determined by local expertise. For illustration purposes, we have arbitrarily chosen the NALy level for each class boundary.

Table 12–3. The relative leached N potential (LNP) determined from the annual budget analysis.

LI†	NAL	LNP	Action
L	L	L	I
	M	L	I
	H	M	II
M	L	L	I
	M	M	II
	H	H	III
H	L	H	III
	M	E	III
	H	E	III
E	L	E	III
	M	E	III
	H	E	III

† LI = leaching index; L = low, M = medium, H = high, E = excessive; NALy = N available for leaching; LNP = leached NO_3-N potential; I = complete event based analysis if desired; II = evaluate management practices and complete event based analysis; III = change management practices and complete event based analysis.

The LNP is determined from the relative LI and NALy determined above using Table 12–3. Low LNP ratings indicate that leaching of NO_3-N should not be a major problem for the environmental conditions input by the user. When LNP values are medium to excessive, it is strongly suggested that the user complete the event-based analysis (chapter 13) to further evaluate NO_3-N leaching potential if computers are available. High and excessive ratings indicate a need to reevaluate and consider alternatives to their current N management strategies, tillage systems, and cropping sequence decisions, among other things.

Data reported by Chichester (1977) and Chichester and Smith (1978) for fertilizer studies on the Coshocton, OH lysimeter Y103A provide an example for the calculation of annual NALy. Chemical characteristics of the Keene silt loam obtained prior to the initiation of the study in 1972 are given in Table 12–4. The calculations of NALy are given in Fig. 12–8 for each year of the duration of the study, 1972 to 1974. Notes on the calculation for this example are given in Table 12–5. The reader is encouraged to work through this example to become familiar with this calculation procedure. Note, that for this example, NALy values, and consequently LNP values, for each year of the study are high.

12–1.2.2 Method II for Calculating NALy

Method II combines mass balance and N-use efficiency concepts to produce an estimate of NALy. The N-use efficiency calculation procedure calculates potentially plant-available N as the sum of an efficiency factor times available N from each N source using the following equation:

$$\begin{aligned} \mathrm{Npa} = {} & (e_f \times N_f) + (e_{om} \times \mathrm{Nom}) + (e_{pres} \times \mathrm{Npres}) \\ & + (e_{rsd} \times \mathrm{Nrsd}) + (e_{fx} \times \mathrm{Nfx}) + (e_{ow} \times \mathrm{Now}) \\ & + (e_{prec} \times \mathrm{Nprec}) + (e_I \times \mathrm{NI}) \end{aligned} \qquad [14]$$

Table 12–4. Chemical characteristics of the Keene soil in lysimeter Y103A sampled in April 1972. (From Chichester and Smith, 1978.)

Profile depth	Inorganic N	Total N	Total C	pH
cm	lb/acre		%	
0–15	19	2913	1.55	6.45
15–30	12	1363	0.68	6.60
30–45	13	1082	0.36	6.55
45–60	16	808	0.21	5.25
60–75	43	1033	0.18	4.40
75–90	38	1160	0.17	4.30
90–105	27	1024	0.15	4.50
105–120	22	880	0.18	4.50
120–135	22	1108	0.19	4.80
135–150	22	1146	0.19	5.05

Table 12-5. Notes on N budget calculations for Table 12-2 for the Keene silt loam soil in lysimeter Y103A at the Coshocton Experiment Station reported by Chichester (1977) and Chichester and Smith (1978).

A. Mineralized N	Based on organic C content of 1.55% (Table 12-4), a C/N ratio of 10, a 6-in. plow layer = 2 000 000 lb soil and 2% of the total N mineralized annually
B. Crop residue	This is assumed to be equal to 75% of the N contained in the roots and stover. Stover N was given by Chichester (1977) and root N was calculated as 20% of the aboveground N uptake (stover + grain).
C. Residual soil NO_3-N	Chichester and Smith (1978) reported 233 lb inorganic N/acre in the 150-in. soil profile in lysimeter Y103A in April 1972 at the start of the experiment. For 1973 and 19744, 200 and 132 lb N/acre, respectively, were reported in percolate water leached from lysimeter Y103A. This was subtracted from NAL (line P) to obtain residual soil NO_3-N for these 2 yr.
D. Fertilizer N	300 lb N/acre was added to lysimeter Y103A in 1972, none in 1973 and 150 lb N/acre in1974 in this experiment
E. Organic wastes	None added
F. Symbiotic N_2 fixation	Corn grown all 3 yr—none
G. Precipitation N	Estimated at 5 lb/(acre yr)
H. Irrigation	None
I. Other	None
K. Crop uptake (grain)	Reported by Chichester and Smith (1978)
L. Crop uptake (unharvested)	= stover N uptake reported by Chichester and Smith (1978) + root N (= 20% of aboveground uptake)
O. PLN adjustments	
Runoff and erosion	Reported by Chichester and Smith (1978)
Ammonium volatilization	None
Denitrification	Using Table 5-6, SOM = 2.67 (1.55% C), moderately well-drained soil (Hydrologic group C), the estimated denitrification rate selected was 10% and would be equal to 0.10 × line J
Other losses	None

where N refers to nitrogen (lb N/acre), e refers to N-use efficiency values and subscripts refer to N sources as follows:

pa = plant available,
f = fertilizer,
om = soil organic matter mineralized,
pres = crop residues mineralized,
rsd = residual N in soil profile,
fx = fixation,
ow = organic wastes mineralized (including manures),
prec = precipitation, and
I = irrigation.

The quantity of N contributed from each source (Fig. 12-9, lines A through I) is input by the user or determined from procedures outlined in the mass balance procedure and recorded in the first column marked "N

Source" on the appropriate line in Fig. 12-9. Nitrogen-use efficiency factors, e, are estimated locally or determined from Table 7-3 (chapter 7) and recorded for each N source in the column marked "Efficiency Factor." B. Bock (personal communication) and Bock and Hergert (chapter 7) recommend the use of e factor values at high relative efficiencies in Table 7-3 for nonfertilizer N sources. The efficiency factors are variable and difficult to determine and care should be taken when selecting appropriate e values. Local estimates of e factors are preferred because values given in Table 7-3 are gross estimates. Where reliable values of e factors are not available, the mass balance approach to plant N uptake and NALy should be used.

Potentially available N is calculated for each N source by multiplying the quantity of N from a given source times the N-use efficiency factor for that N pool (columns one and two in Fig. 12-9) and recording the result in the third column marked "Potentially Available N." Total potentially available plant N is calculated by summing the potentially available N from all N sources in the third column in Fig. 12-9 and recording the sum on line K. Potentially leachable N is calculated as the difference between total inorganic N inputs (line J) and plant uptake (line K). The PLN is adjusted by accounting for N losses on line M using local estimates of runoff and erosion, ammonium volatilization, and denitrification or estimates of these values using procedures described earlier. The NALy is calculated as the difference between PLN and the PLN adjustments (line L − line M). Relative leaching severity and leached N potentials are determined as discussed for Method I, the mass balance approach.

12-2 ANALYSIS OF LEACHING RISK

The purpose of this screening procedure is to quantify potential NO_3-N leaching below the root zone associated with present management practices and to demonstrate the effect of alternative management strategies on reducing those potentials. While important, this is only one phase of the total NO_3-N leaching problem (see chapter 11).

Assessments of risk associated with different quantities of leached N must incorporate details on location, geometry, and vulnerability of the aquifer, local hydrology, characteristics of the vadose zone, expert opinion on the fate of leached NO_3-N and perceived impacts on regional groundwater quality. Risk associated with NO_3-N leached below the root zone (annual leaching risk potential, ALRP) should consider four important parameters: the quantity of NO_3-N leached from the root zone (NLy), the position of the aquifer (PA), the travel time to reach the aquifer (TT) (a function of conductivity of the vadose zone, the magnitude of LI, and the distance to the aquifer), and the vulnerability of the aquifer (VA). This is expressed functionally as:

$$\text{ALRP} = f\,(\text{NLy, TT, PA, VA}). \qquad [15]$$

Pionke (chapter 11) discusses this problem and Shaffer et al. (chapter 13) describe an approach to quantify ALRP that provides a quantitative risk assessment. However, the paucity of quantitative data on the physical and chemical properties of geologic materials in the vadose zone and aquifer properties restricts quantitative assessments. A more qualitative assessment can be made by categorizing the parameters in Eq. [15] and determining relative ratings to ALRP categories. An example of an assessment table is given in Table 12-6 that can serve as a guide in the development of regional or national qualitative guidelines. A scheme for calculating ALRP is proposed as follows.

The first step is to estimate the quantity of NO_3-N leached from the root zone (NLy). An estimate of NLy can be obtained from a relationship between NALy, LI, and the porosity of the root zone (POR) (see chapter 13 by Schaffer et al.):

Table 12-6. Assessment of annual leaching risk potentials (ALRPs) based on NLy, travel time (TT), the position of the aquifer (PA), and the vulnerability of the aquifer (VA).

NLy, lb/ (acre yr)	NLy score	TT	TT score	PA	PA score	VA	VA score	Score product	ALRP	ALRP rating
<40	1	Long	1	Deep/Conf	1	Cls III	1	1	0	vlow
<40	1	Long	1	Deep/Conf	1	Cls IIB	2	2	1	vlow
<40	1	Long	1	Deep/Conf	1	Cls I,IIA	4	4	2	vlow
<40	1	Long	1	Medium	2	Cls III	1	2	1	vlow
<40	1	Long	1	Medium	2	Cls IIB	2	4	2	vlow
<40	1	Long	1	Medium	2	Cls I,IIA	4	8	3	low
<40	1	Long	1	Shal/Krst	4	Cls III	1	4	2	vlow
<40	1	Long	1	Shal/Krst	4	Cls IIB	2	8	3	low
<40	1	Long	1	Shal/Krst	4	Cls I,IIA	4	16	4	high‡
<40	1	Moder	2	Deep/Conf	1	Cls III	1	2	1	vlow
<40	1	Moder	2	Deep/Conf	1	Cls IIB	2	4	2	vlow
<40	1	Moder	2	Deep/Conf	1	Cls I,IIA	4	8	3	vlow†
<40	1	Moder	2	Medium	2	Cls III	1	4	2	vlow
<40	1	Moder	2	Medium	2	Cls IIB	2	8	3	low
<40	1	Moder	2	Medium	2	Cls I,IIA	4	16	4	mod
<40	1	Moder	2	Shal/Krst	4	Cls III	1	8	3	low
<40	1	Moder	2	Shal/Krst	4	Cls IIB	2	16	4	mod
<40	1	Moder	2	Shal/Krst	4	Cls I,IIA	4	32	5	high
<40	1	Short	4	Deep/Conf	1	Cls III	1	4	2	vlow
<40	1	Short	4	Deep/Conf	1	Cls IIB	2	8	3	vlow*
<40	1	Short	4	Deep/Conf	1	Cls I,IIA	4	16	4	vlow*
<40	1	Short	4	Medium	2	Cls III	1	8	3	low
<40	1	Short	4	Medium	2	Cls IIB	2	16	4	mod
<40	1	Short	4	Medium	2	Cls I,IIA	4	32	5	high
<40	1	Short	4	Shal/Krst	4	Cls III	1	16	4	mod
<40	1	Short	4	Shal/Krst	4	Cls IIB	2	32	5	high
<40	1	Short	4	Shal/Krst	4	Cls I,IIA	4	64	6	vhigh
40-<80	2	Long	1	Deep/Conf	1	Cls III	1	2	1	vlow
40-<80	2	Long	1	Deep/Conf	1	Cls IIB	2	4	2	vlow
40-<80	2	long	1	Deep/Conf	1	Cls I,IIA	4	8	3	low
40-<80	2	Long	1	Medium	2	Cls III	1	4	2	vlow
40-<80	2	Long	1	Medium	2	Cls IIB	2	8	3	low
40-<80	2	Long	1	Medium	2	Cls I,IIA	4	16	4	mod
40-<80	2	Long	1	Shal/Krst	4	Cls III	1	8	3	low
40-<80	2	Long	1	Shal/Krst	4	Cls IIB	2	16	4	mod

(continued on next page)

Table 12-6. Continued.

NLy, lb/ (acre yr)	NLy score	TT	TT score	PA	PA score	VA	VA score	Score product	ALRP	ALRP rating
40-<80	2	Long	1	Shal/Krst	4	Cls I,IIA	4	32	5	vhigh‡
40-<80	2	Moder	2	Deep/Conf	1	Cls III	1	4	2	vlow
40-<80	2	Moder	2	Deep/Conf	1	Cls IIB	2	8	3	low
40-<80	2	Moder	2	Deep/Conf	1	Cls I,IIA	4	16	4	low†
40-<80	2	Moder	2	Medium	2	Cls III	1	8	3	low
40-<80	2	Moder	2	Medium	2	Cls IIB	2	16	4	mod
40-<80	2	Moder	2	Medium	2	Cls I,IIA	4	32	5	high
40-<80	2	Moder	2	Shal/Krst	4	Cls III	1	16	4	mod
40-<80	2	Moder	2	Shal/Krst	4	Cls IIB	2	32	5	high
40-<80	2	Moder	2	Shal/Krst	4	Cls I,IIA	4	64	6	vhigh
40-<80	2	Short	4	Deep/Conf	1	Cls III	1	8	3	low
40-<80	2	Short	4	Deep/Conf	1	Cls IIB	2	16	4	low†
40-<80	2	Short	4	Deep/Conf	1	Cls I,IIA	4	32	5	low†
40-<80	2	Short	4	Medium	2	Cls III	1	16	4	mod
40-<80	2	Short	4	Medium	2	Cls IIB	2	32	5	high
40-<80	2	Short	4	Medium	2	Cls I,IIA	4	64	6	vhigh
40-<80	2	Short	4	Shal/Krst	4	Cls III	1	32	5	high
40-<80	2	Short	4	Shal/Krst	4	Cls IIB	2	64	6	vhigh
40-<80	2	Short	4	Shal/Krst	4	Cls I,IIA	4	128	7	extreme
>80	4	Long	1	Deep/Conf	1	Cls III	1	4	2	vlow
>80	4	Logn	1	Deep/Conf	1	Cls IIB	2	8	3	low
>80	4	Long	1	Deep/Conf	1	Cls I,IIA	4	16	4	mod
>80	4	Long	1	Medium	2	Cls III	1	8	3	low
>80	4	Long	1	Medium	2	Cls IIB	2	16	4	mod
>80	4	Long	1	Medium	2	Cls I,IIA	4	32	5	high
>80	4	Long	1	Shal/Krst	4	Cls III	1	16	4	mod
>80	4	Long	1	Shal/Krst	4	Cls IIB	2	32	5	high
>80	4	Long	1	Shal/Krst	4	Cls I,IIA	4	64	6	extreme‡
>80	4	Moder	2	Deep/Conf	1	Cls III	1	8	3	low
>80	4	Moder	2	Deep/Conf	1	Cls IIB	2	16	4	mod
>80	4	Moder	2	Deep/Conf	1	Cls I,IIA	4	32	5	mod†
>80	4	Moder	2	Medium	2	Cls III	2	16	4	mod
>80	4	Moder	2	Medium	2	Cls IIB	2	32	5	high
>80	4	Moder	2	Medium	2	Cls I,IIA	4	64	6	vhigh
>80	4	Moder	2	Shal/Krst	4	Cls III	1	32	5	high
>80	4	Moder	2	Shal/Krst	4	Cls IIB	2	64	6	vhigh
>80	4	Moder	2	Shal/Krst	4	Cls I,IIA	4	128	7	extreme
>80	4	Short	4	Deep/Conf	1	Cls III	1	16	4	mod
>80	4	Short	4	Deep/Conf	1	Cls IIB	2	32	5	mod†
>80	4	Short	4	Deep/Conf	1	Cls I,IIA	4	64	6	mod†
>80	4	Short	4	Medium	2	Cls III	1	32	5	high
>80	4	Short	4	Medium	2	Cls IIB	2	64	6	vhigh
>80	4	Short	4	Medium	2	Cls I,IIA	4	128	7	extreme
>80	4	Short	4	Shal/Krst	4	Cls III	1	64	6	vhigh
>80	4	Short	4	Shal/Krst	4	Cls IIB	2	128	7	extreme
>80	4	Short	4	Shal/Krst	4	Cls I,IIA	4	256	8	vextreme

Special cases:

† If: PA score = 1 and NLy score = 1; then, maximum ALRP = very low.
  If: PA score = 1 and NLy score = 2; then, maximum ALRP = low.
  If: PA score = 1 and NLy score = 4; then, maximum ALRP = moderate.

‡ If: PA score = 4, VA score = 4, and NLy score = 1; then, minimum ALRP = high.
  If: PA score = 4, VA score = 4, and NLy score = 2; then, minimum ALRP = very high.
  If: PA score = 4, VA score = 4, and NLy score = 4; then, minimum ALRP = extreme.

$$\text{NLy} = \text{NALy} \times [1 - \exp(-1.2 \times \text{LI/POR})]. \qquad [16]$$

The POR of a soil can be estimated from the average bulk density (BD) and particle density (PD) of the root zone as follows:

$$\text{POR} = (1 - \text{BD/PD}) \times [\text{root zone depth (in.)} \times \text{unit area (in.)}]. \qquad [17]$$

For mineral soils, an average value of PD is 2.65 g cm^{-3}. Values for BD vary with soil texture, organic matter content, and soil management and can be obtained from soil surveys, research reports (e.g., see Jones, 1983), and the U.S. Soil Conservation Service (SCS), National Soil Survey Laboratory (NSSL) soils databases. The computer version of this procedure (NLEAP, chapter 13) contains a SCS soils database which contains estimates of bulk density.

The second step is to establish categories (refer to Table 12-6) for each parameter in Eq. [15]. Three classes were established for each parameter: low (<40 lb N/[acre yr]), medium (>40 but <80 lb N/[acre yr]), and high (≥80 lb N/[acre yr]) for NLy; long (>15 yr), medium (5-15 yr), and short (<5 yr) for TT; deep/confined, medium and shallow/karst for PA, and for VA, we adopted a procedure that uses EPA's three-tiered groundwater classification system (see chapter 2, Fletcher) — class I (irreplaceable source of drinking water to substantial population or as ecologically vital), class II (A—current source of drinking water or B—potential source of drinking water), and class III (unlikely to be used as drinking water). Our first category includes class I and IIA (current domestic water supplies), the second includes class IIB, and the third class III.

The third step is to assign a relative score to each parameter. We used a base of 2 for scoring the three categories for each parameter, that is, each category received a relative score of 1, 2, or 4. The higher the number, the higher the potential for significant problems with groundwater contamination.

The last step is to calculate ALRP. The products of the scores of the four parameters in Eq. [15] are each a power of 2 and leads to a clear separation of the possible combinations of the four parameters (Table 12-6). The log base 2 of the possible products yields an integer value from 0 to 8 (Table 12-7). Therefore, we define ALRP as the log base 2 of the product of the parameter scores and assign a risk description to ALRP from very low (vlow) to very extreme (vextreme) as shown in Table 12-7. Special cases were added to refine the rating scheme to better reflect field observations for certain conditions as follows. For cases in Table 12-6 where the PA score is 1 (the aquifer is deep/confined), the maximum ALRP allowed is *very low* if the the NLy score is 1, *low* if the NLy score is 2, and *moderate* if the NLy score is 4. For cases where the PA score is 4 (the aquifer is shallow/karst), and the VA score is 4 (class I and IIA), the minimum ALRP allowed is *high* when the NLy score is 1, *very high* when the NLy score is 2, and *extreme* when the NLy score is 4.

Table 12-7. Rating scheme for calculation of annual leaching risk potentials (ALRPs) for NO_3-N leaching.

ALRP rating	Score product	ALRP†
vlow	1	0
vlow	2	1
vlow	4	2
low	8	3
mod	16	4
high	32	5
vhigh	64	6
extreme	128	7
vextreme	256	8

† ALRP = log base 2 of the score product.

The rating scheme given in Tables 12-6 and 12-7 provide a reasonable method to delineate NO_3-N leaching potential on the basis of risk that considers both soil management within the root zone and the nature of the regional groundwater. This would assist land owners in selecting appropriate land uses and cultural practices that are compatible with environmental risks. It would also provide policy makers with a tool to target programs to environmentally sensitive areas.

12-3 CONCLUSION

A procedure is described to estimate NO_3-N leaching risk potentials in agricultural production. The procedures are limited by the complexity of the processes involved in water movement and N cycling and imprecise data available as input for calculations. Therefore, this procedure should be viewed as a guide to screening N-leaching potentials of various soil, climate, and management conditions. Beyond this, the assessment of risks associated with various leaching potentials needs to be fully explored by regional and national experts.

It is hoped that this procedure provides a framework for N-leaching assessment. The nature of a "hand" calculation procedure is recognized. Therefore, a computerized version of these procedures is included in the computer software described in chapter 13.

APPENDIX

Glossary of variables used in the calculation procedure.

Variable	Description
ALRP	Annual leaching risk potential
baseNI	Average N concentration of irrigation water, ppm
BD	Average bulk density of the root zone, g/cm^3
Bmu	Total unharvested biomass, lb/(acre yr)

(continued on next page)

Appendix continued.

Variable	Description
Cf	Conversion factor carbon to OMR
CN	Carbon to nitrogen ratio of crop residues, manure, and other organic wastes
CNu	Crop N uptake of unharvested biomass, lb/(acre yr)
CNh	Crop N uptake of harvested biomass, lb/(acre yr)
dm	Dry matter content of waste, %
Dn	Nitrogen loss by denitrification, lb/(acre yr)
E	Soil erosion rate, tons/(acre yr)
e	Nitrogen-use efficiency factor
EN	Inorganic N loss in eroded soil, lb/(acre yr)
Fl	Percent volatilization loss of applied fertilizer
HC	Humid, irrigated climate
HI	Harvest index (harvest portion/total aboveground biomass)
Ia	Annual irrigation application, acre-in./yr
kresy	Fraction of crop residue N mineralized each year
LI	Leaching index, in. water
LNP	Leached N potential
Mn	Annual mineralization coefficient for waste
NALy	Nitrate-N available for leaching from the root zone, lb/(acre yr)
Ne	Average inorganic N content of eroded soil, lb/ton
N_f	Fertilizer N applied, lb/(acre yr)
Nfx	Symbiotic N_2 fixation, lb/(acre yr)
NI	Nitrogen applied in irrigation water, lb/(acre yr)
NLy	Nitrate-N leached from the root zone, lb/(acre yr)
Nminy	Net N mineralized from soil organic matter, lb/(acre yr)
$N_{NH3}y$	Nitrogen loss by ammonium volatilization, lb/(acre yr)
$N_{NH3}fy$	Fertilizer N loss by ammonium volatilization, lb/(acre yr)
Nrsd	Residual soil NO_3-N and ammonium N, lb/(acre yr)
Nom	Nitrogen in soil organic matter, lb/(acre yr)
Now	Net N mineralized from organic wastes, lb/(acre yr)
Npa	Plant-available N, lb/(acre yr)
Nprec	Inorganic N contained in precipitation, lb/(acre yr)
Npres	Nitrogen content in plant residues, lb/acre
Nr	Average N concentration in runoff, ppm
Ns	Nitrogen content of unharvested biomass, lb/unit
Nw	Nitrogen content of organic waste, lb/unit of waste
Ny	Nitrogen content of harvested crop, lb/unit of yield
OMR	Soil organic matter, %
ON	Organic N mineralized annually, %
P	Annual precipitation, in.
PA	Position of aquifer
PD	Average particle density of soil in rooting zone, g/cm^3
PI	Percolation index
PLN	Potentially leachable NO_3-N (i.e., the difference between N inputs and plant N uptake)
PN	Portion of N in plant derived from N_2 fixation
POR	Total porosity of root zone, acre in.

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Appendix continued.

Variable	Description
PW	Seasonal precipitation, in.
RN	Nitrate- + Ammonium-N loss in runoff, lb/(acre yr)
RT	Total annual runoff, acre-in./yr
SC	Arid, semiarid climate
SI	Seasonal index
TT	Travel time for N to reach aquifer. (Short = <5 yr; Medium = 5–15 yr; and Long = ≥ 15 yr)
VA	Vulnerability of aquifer
Vret	Ammonia volatilization correction factor for land-applied manure, %
Wsoil	Weight of acre furrow slice, lb/acre
Wt	Total organic waste applied, tons/(acre yr)
YG	Yield goal or maximum yield, units of yield/(acre yr)
YLD	Yield (units of yield/[acre yr])

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