NLEAP facts about nitrogen management

J.A. Delgado, R.F. Follett, J.L. Sharkoff, M.K. Brodahl, and M.J. Shaffer

Interpretative summary

An extensive database containing facts from the Nitrate Leaching and Economic Analysis Package (NLEAP) about nitrogen was developed for different crops and varieties grown in the San Luis Valley of south central Colorado. This unique data set was used to develop a series of regional parameters to be used with a new 1.2 version of the NLEAP model. Version 1.2 is capable of conducting simulations on a baseline similar for different crops, varieties, management scenarios, and soil types. The development of these regional parameters and the calibration/validation of the model permits the evaluation of the effects of best management practices on residual soil NO_3^--N and transport of NO_3^--N in the soil profile for small grains and vegetable rotations. NLEAP 1.2 computer simulations suggested that the net process of NO_3^--N leaching can be reversed for coarse-textured soils and that there is potential for NO_3^--N mining when best management practices are implemented. These are important NLEAP facts that can potentially contribute to protect and improve water quality.

Key words: coarse fragments, computer models, irrigation, nitrate leaching, nitrogen use efficiency, NLEAP, potato, water quality, winter cover crops.

ABSTRACT: The use of new computer models facilitates the quick extrapolation of research results into a wide variety of different agricultural systems. However, to predict the N dynamics across different fields, local information is still needed to initially calibrate and evaluate the local effectiveness of the model. One of these new computer software packages is NLEAP, which permits a rapid evaluation of a series of best N and irrigation management practices for a site-specific farmer's field. Information from several plant parameters was used to generate simulations: soil chemical and physical properties, irrigation practices, N management practices, amount of N in irrigation water, local climatological data, and additional factors. These computer simulations have detailed information about the crop N uptake, soil N biogeochemical transformations, water budgets, and the inorganic NO_3^-–N content in the soil profile for vegetable and small grain rotations. Computer simulations with the new 1.2 version of NLEAP showed the potential to simulate residual soil NO_3^-–N and transport of NO_3^-–N in the soil profile over a wide variety of management scenarios. NLEAP 1.2 simulations suggest that the net process of NO_3^-–N leaching can be reversed for coarse-textured soils. Coarse fragments on a volume basis are an important factor related to soil quality that need to be considered when using the NLEAP model in coarse-textured soils. These are important NLEAP facts that can potentially contribute to protect and improve water quality.

Jorge A. Delgado and Ronald F. Follett are with the USDA/ARS/SPNRU, Ft. Collins, CO.; M.K. Brodahl is with the USDA/NRCS, Denver, Colo.; James L. Sharkoff is with the USDA/ARS/WMRU, Ft. Collins, CO.; and Marvin J. Shaffer is with the USDA/ARS/GPRSU, Ft. Collins, CO.

The authors thank Anita Kear, William O'Deen, Mebrat Gesese, Michael Golinski, David Wright, Robert Lober, and Kevin Lee for assistance during collection and analysis of soil and plant samples; Donald "Smokey" Barker for coordination between USDA/NRCS and USDA/NRCS/SLVWQDP personnel; the San Luis Valley Water Quality Demonstration Project (SLVWQDP) personnel for technical assistance; and the USDA-NRCS, especially Ronald Riggenbach, Lawrence Kawanabe, Richard Sparks, Linda Warsh, and Norma VanNostrand for coordinating study activities with local producers.

J. Soil and Water Cons. 53(4) 332-337

In general, natural sources of N are not adequate for optimum crop production of irrigated agricultural cropping systems where yield is very often limited by the supply of N. Since yield is a function of N availability, to sustain optimum production we need to maintain adequate levels of N in the root zone where roots can absorb it. However, when the amount of N-inputs are increased, NO_3^--N, a readily mobile form of N, can accumulate in the soil profile. This NO_3^--N has the potential to be leached out of the root zone by excessive irrigation or by large precipitation events. To reduce the leaching potential of NO_3^--N, the best N and irrigation management practices need to be implemented that reduce the movement of NO_3^--N from the root zone and increase crop N-uptake efficiency.

The use of new computer models facilitates quick extrapolation of research results into a wide variety of different agricultural systems. One new computer software package is the NLEAP model (Schaffer et al. 1991). The NLEAP model permits rapid evaluation of a series of best N and irrigation management practices for a specific site. Local information, however, is still needed to initially calibrate and evaluate the effectiveness of the model on different fields under different management practices, and to assess its capability as a predictive tool.

A general description of NLEAP

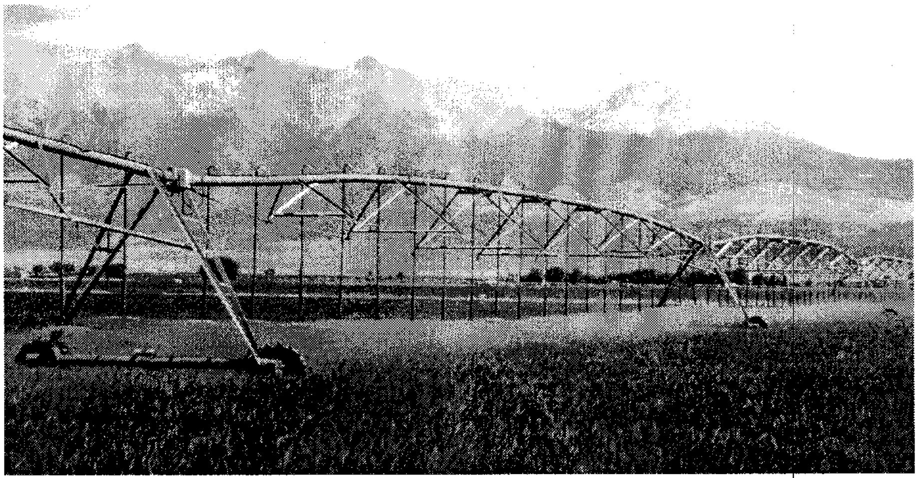
To run the NLEAP model, crop planting and harvesting dates, N-, water-, and cultural-management inputs and timing, soil and climate information, and the expected yield need to be supplied by the user. All N additions such as initial NO_3^--N content of the soil, amount and type of N fertilizer added, amount of N in the irrigation water, crop residue mass and its N content, mass and N content of other organic amendments such as manures and sewage sludges can be entered in NLEAP. The model not only accounts for all N and water inputs and outputs in the root zone, but also keeps track of how management affects N biogeochemical transformations such as nitrification, denitrification, and mineralization of N from crop residues and soil organic matter.

NLEAP can then simulate crop N uptake during the growing season and NO_3^--N leaching, if it occurs. NLEAP uses a regional configuration file that contains the crop N uptake index (NUI), a measurement of N uptake per unit of yield used to simulate total N uptake by the crop, an important N sink. The model can estimate the impact of water and N management practices on the movement of NO_3^--N out of the root zone by accounting for all N and water inputs and outputs to the root zone. For a detailed description of how NLEAP works, see Shaffer et al. (1991).

A case-study: Use of NLEAP in coarse-textured soils of the San Luis Valley

The San Luis Valley is about 105 miles long and 20 to 50 miles wide and has an average elevation of 7,700 ft (Edelmann and Buckles 1984, Hearne and Dewey 1988). This high altitude intermountain desert valley is located in south central Colorado with the Sangre de Cristo Mountains to the east and the San Juan

Mountains to the west. With an average annual precipitation of 7.1 in in Alamosa County, agriculture requires irrigation. Irrigation was first practiced in the valley by early Spanish-American settlers who diverted water from the Rio Grande (Austin 1993). Prior to 1880 irrigation was limited, but between 1880 and 1890 an intensive network of canals was constructed (Hearne and Dewey 1988). Intensive development of groundwater for irrigation began during the 1950s with the introduction of high-capacity pumps (Hearne and Dewey 1988). To improve the efficiency of groundwater use, sprinkle irrigation began to be used extensively in the 1970s, and increased from 262 wells in 1973 to more than 2,000 by



Center pivot sprinkler irrigation in the San Luis Valley of south central Colorado

Table 1. San Luis Valley soils where current N management practices are being evaluated

Soil series	Surface texture	Family or higher taxonomic class
Dunul	Cobbly sandy loam	Sandy-skeletal, mixed, frigid Typic Torriorthents
Gunbarrel	Loamy sand	Mixed, frigid Typic Psammaquents
Kerber*	Loamy sand	Coarse-loamy, mixed, frigid Aquic Natrargids
McGinty	Sandy loam	Coarse-loamy, mixed, frigid Typic Calciorthids
Mosca*	Loamy sand	Coarse-loamy, mixed, frigid Typic Natrargids
Norte*	Gravelly sandy loam	Loamy-skeletal, mixed (calcareous), frigid Aquic Ustorthents
Quamon*	Gravelly sandy loam	Sandy-skeletal, mixed, frigid Typic Ustorthents
San Arcacio	Sandy loam	Fine-loamy over sandy, or sandy-skeletal, mixed, frigid Typic Haplargids
San Luis*	Sandy loam	Fine-loamy over sandy, or sandy-skeletal, mixed, frigid Aquic Natrargids
Shawa	Loam	Fine-loamy, mixed Pachic Haploborolls
Torsido	Loam	Fine-loamy over sandy or sandy-skeletal, mixed, frigid Typic Argiaquolls

Soil series listed where current N-management is being evaluated because the sites have similar particle size distribution in the soil fractions less than 0.079 inches. However, their soil chemistry has been changed as a result of irrigation and tillage. The coarse fragments of the soil surface may have changed if large cobbles were removed from the surface horizon.

Table 2. Mean crop Nitrogen content (%N), Carbon content (%C), Carbon: Nitrogen ratio (C/N), and nitrogen crop indices (NUI) for whole plant (aboveground and underground parts), for selected small grains grown in the San Luis Valley

The NUI values are adjusted for water content of the harvested grain (12%) and weights of the yield unit

Crop	Scientific name	Variety	Part*	% N† Mean	% C† Mean	C/N† Mean	Yield Unit‡	Lbs/ Yield Unit§	NUI¶ Mean Std
Barley	*Hordeum vulgare* L	Moravian 14	Grain	1.63	43.2	26.5	Bushel	48	1.00 ± 0.07
			stalk & chaff	0.53	41.6	78.4			
		Moravian III	Grain	1.74	44.0	25.3	Bushel	48	1.17 ± 0.12
			stalk & chaff	0.50	42.7	85.3			
		Triumph	Grain	1.24	41.9	33.8	Bushel	48	0.78 ± 0.03
			stalk & chaff	0.53	40.2	75.9			
Canola	*Brassica napus* L.	IMC 129	Grain	3.58	59.1	16.5	Bushel	50	3.03 ± 0.57
			stalk & chaff	0.96	54.1	56.3			
			root	0.05	41.8	83.5			
Oat	*Avena sativa* L.	Monida	Grain	1.70	47.1	27.7	Bushel	32	0.73 ± 0.02
			stalk & chaff	0.41	44.8	109.3			
Winter wheat	*Triticum aestivum* L.	Tomahawk	Grain	2.24	43.2	19.3	Bushel	60	1.76 ± 0.09
			stalk & chaff	0.66	40.9	61.9			

* Stalk & Chaff means all aboveground crop biomass minus Grain; Hay means all aboveground crop biomass
† Values are expressed on a dry weight basis
‡ Weight of the yield unit used for NLEAP
§ Amount of pounds per yield unit used for NLEAP
¶ Mean NUI ± 1 Standard Deviation (Std): Values were adjusted using the lbs/yield unit and water content of the harvested unit

Table 3. Mean crop Nitrogen content (%N), Carbon content (%C), Carbon:Nitrogen ratio (C/N) and nitrogen crop indices (NUI) for whole plant (aboveground and underground parts) ± 1 Standard Deviation (Std), for selected vegetables grown in the San Luis Valley. The

NUI values are adjusted for water content and weights of the yield unit

Crop	Scientific name	Variety	Part*	% N[†] Mean	% C[†] Mean	C/N[†] Mean	Water Content[‡] %	NUI[§] Mean	Std
Carrot	*Daucus carota*	Caropak	Top root	1.54 0.89	37.1 38.6	24.1 43.4	90	2.97	± 0.27
		Flame	Top root	1.84 1.04	38.5 39.9	20.9 38.4	90	3.72	± 0.08
Lettuce	*Lactuca sativa* L.	821	Head	3.34	36.7	11.0	94	4.16	± 0.56
		Fallgreen	Head	3.43	36.7	10.7	94	4.01	± 0.12
		Summertime	Head	3.30	37.0	11.2	94	4.05	± 0.03
Spinach	*Spinacia oleracea* L.	Tyee	Top root	4.94 4.60	35.1 36.3	7.1 7.9	90	10.39	± 0.40

* Top and Head, means all aboveground crop biomass
[†] Values are expressed on a dry weight basis
[‡] Water content for the harvested portion used for NLEAP
[§] Mean NUI ± 1 Standard Deviation (Std). The yield unit used for NLEAP is tons and the lbs/yield unit is 2,000; Values were adjusted using the lbs/yield unit and water content of the harvested unit.

Table 4. Mean crop Nitrogen content (%N), Carbon content (%C), Carbon: Nitrogen ratio (C/N) and nitrogen crop indices (NUI) for whole plant (aboveground and underground parts), for winter cover rye (*Secale cereale* L.) and winter cover wheat (*Triticum aestivum* L.) grown in the San Luis Valley

The NUI values are adjusted for water content and weights of the yield unit

Crop*	Variety	Part[†]	% N[‡] Mean	% C[‡] Mean	C/N[‡] Mean	Water content[§] %	NUI[¶] Mean	Std
Winter rye (Planted early in fall)	Common	Shoot	2.35	38.1	16.2	50	18.79	± 2.28
Winter rye (Planted early in fall High soil NO_3-N)	Common	Shoot Crown	4.82 4.00	41.9 37.2	8.7 9.3	50	40.45	± 3.96
Winter rye (Planted late in fall)	Common	Shoot Plant	3.47 4.36	39.2 42.3	11.3 9.7	70	27.12	± 3.87
Winter wheat (Grazed cover crop planted early in fall)	Tomahawk	Plant	3.33	39.3	11.8	50	20.00	± 0.63
Winter wheat (Grazed cover crop planted late in fall)	Tomahawk	Plant	3.92	42.7	10.9	70	23.49	± 0.71

* For Crop, high soil NO_3-N content means that residual soil NO_3-N was > 600 lb N/acre for the top 5 ft.
[†] Shoot means all aboveground crop biomass; Plants means all aboveground and belowground crop biomass;
[‡] Values are expressed on a dry weight basis.
[§] Water content for the harvested portion used for NLEAP.
[¶] Mean NUI ± 1 Standard Deviation (Std). The yield unit used for NLEAP is ton and the lbs/yield unit is 2,000; Values were adjusted using the lbs/yield unit and water content of the harvested unit.

1996. Irrigated agriculture is the economic base for the majority of the residents in the valley (Eddy-Miller 1993).

It has been reported that the valley has a variety of soils; most of them are of a coarse sandy texture over a coarse-textured substratum (USDA-SCS 1973, USDA-SCS 1988). Some of these coarse-textured soils have a significant amount of coarse fragments, which usually increases with depth (USDA-SCS 1973; USDA-SCS 1988).

The area and yield of the predominant crops grown in the valley are potato, 78,000 ac (369 cwt ac^{-1}); spring wheat, 23,000 ac (89 bu ac^{-1}); barley, 61,000 ac (133.5 bu ac^{-1}); oats, 21,000 ac (88.5 bu ac^{-1}), alfalfa hay, 125,000 ac (3.0 t ac^{-1}), and other hay, 60,000 ac (1.8 t ac^{-1}) as reported by the Colorado Department of Agriculture and USDA (1997). The San Luis Valley in 1996 produced 90% of the potato, 77% of the spring wheat, 81% of the barley, 32% of the oats, and 12% of the hay produced in Colorado. Lettuce, carrot, and spinach production represents an important and viable crop production base of about 7,600 ac.

A recent study found well water NO_3^--N concentrations as high as 80 ppm in the central region of the San Luis Valley. The combination of N fertilizer use, a high water table, and sandy soils contribute to this elevated concentration of NO_3^--N in groundwater (Edelmann and Buckles 1984; Austin 1993; Eddy-Miller 1993; Agro Engineering, Inc. and Colorado State University 1995). There is a growing concern about the movement of NO_3^--N out of the root zone. In response to these concerns, the USDA Working Group for Water Quality, in cooperation with Colorado State University Cooperative Extension, has established the San Luis Valley Water Quality Demonstration Project (SLVWQDP) to promote the use of best management practices and to minimize agricultural nonpoint source pollution of water resources in the valley (SLVWQDP 1994).

The USDA-ARS, USDA-NRCS and

Table 5. Mean crop content (%N), Carbon content (%C), Carbon: Nitrogen ratio (C/N) and mean Nitrogen crop indices (NUI) for whole plant (aboveground and underground parts) ± 1 Standard Deviation (Std) for selected potato (*Solanum tuberosum* L.) varieties grown in the San Luis Valley

The NUI values are adjusted for water content and weights of the yield unit

Variety*	Part†	% N‡ Mean	% C‡ Mean	C/N‡ Mean	NUI§ Mean	NUI§ Std
Burbank	Stem & Leaf	2.11	30.4	14.4	10.03	± 0.70
	Tuber	1.88	41.9	22.3		
Centennial	Stem & Leaf	2.87	34.4	12.0	9.30	± 1.66
	Tuber	1.53	41.3	27.0		
Century	Stem & Leaf	2.31	30.3	13.1	6.88	± 1.24
	Tuber	1.28	37.1	29.0		
Frontier (*Low N*)	Stem & Leaf	2.38	28.3	11.9	6.92	± 0.85
	Tuber	1.33	41.9	31.5		
Nugget	Stem & Leaf	2.46	43.1	17.5	9.30	± 2.22
	Tuber	1.68	42.7	25.4		
Nugget (*Low N*)	Stem & Leaf	2.01	40.6	42.2	6.25	± 0.69
	Tuber	1.13	20.2	37.3		
Norkota	Stem & Leaf	1.35	23.6	17.5	8.54	± 0.34
	Tuber	1.91	40.9	21.4		
Sangre	Stem & Leaf	1.30	40.6	31.2	9.45	± 0.89
	Tuber	1.88	33.3	17.7		

* Low indicates low N inputs.
† Stem & Leaf means all aboveground crop biomass.
‡ Values are expressed on a dry weight basis.
§ Mean NUI ± 1 Standard Deviation (Std). The yield unit used for NLEAP is ton and the lbs/yield unit is 2,000; Values were adjusted using the lbs/yield unit and water content of the harvested unit.

Table 6. Example of weights* for different soil fractions, bulk density and NO_3-N content of two different soil depths on a Norte gravelly sandy loam

Depth (ft)	Bulk† Density (g/cc)	Cobbles (lb)	Gravel (lb)	< 0.079 (lb)	NO_3-N ppm	NO_3-N‡ lb/acre non-adjusted	NO_3-N§ lb/acre adjusted
0 - 1	1.45	0	3.5	6.5	14.6	130	100
1 - 3	1.60	0	6.7	3.3	33.0	127	57

* Weights for cobbles, gravel, and < 0.079 inches soil fractions are in lb.
† Bulk density expressed as the dry weight of the soil fraction < 0.079 inches over the moist volume at 1/3 bar of the soil fraction < 0.079 inches. The moist volume at 1/3 bar includes the air and water pore space volume of the soil.
‡ The NO_3-N content non-adjusted for the coarse fragments content.
§ The NO_3-N content adjusted for the percentage coarse fragments by volume.

SLVWQDP are using NLEAP, a computer software package capable of providing a rapid and efficient evaluation of farm management practices on soil N and water budgets and their impact on NO_3^--N movement out of the root zone. NLEAP also can generate computer outputs to identify areas where irrigation water and N management practices create NO_3^--N leaching problems. By identifying problem areas, managers can develop alternatives that reduce the amount of NO_3^--N leaching, protect water quality, and increase water-and N-use efficiency. The potential also exists to implement agricultural best management practices to mine NO_3^--N from underground well water in the San Luis Valley if the amount of background NO_3^--N added to the field with irrigation during the growing season is higher than the NO_3^--N that leaches from the field (Delgado 1998a).

Agricultural management practices and soil, crop, and irrigation data have been collected on more than 25 cooperating farms to evaluate the status of current N management practices on soil N transformations and their impact on residual soil NO_3^--N available to leach. A unique data set consisting of about 80 site-years of information is being used to test a new version of NLEAP (Delgado et al. 1998a) across different cropping systems (Delgado 1998a, b).

Approach. Harvesting procedures, N analyses and collection of soil samples

From 1993 to 1998, plots were established at a series of farmers' fields with different soil types (Table 1); some plots were sampled sequentially over two or three years. At other farmers' fields, plant samples for various crops were collected randomly from the plots. Plant material was analyzed for total N and C using a Carlo Erba automated C/N analyzer. Statistical analyses were performed using the SAS software for data analysis for microcomputers (SAS 1988).

The sum of the total crop N content in all plant parts and yields was used to estimate the crop N uptake per unit of yield, or NUI, with yield being the harvested crop production for that particular growing season. Equation 1 (Tables 2, 3, 4, and 5) was used to calculate NUI. All NUIs were adjusted for water content of the harvested unit and weight per unit of yield used in the NLEAP model.

$$NUI = \frac{\text{Crop N uptake (lbs N/acre)}}{\text{Yield (tons or bushels/acre)}} \quad (1)$$

To determine the percentage of coarse fragments on a volume basis (%CFV), the soil sample and coarse fragments were weighed. Soil samples were processed, removing all cobbles (fragments greater than 3 in) and gravel (fragments smaller than 3 in but greater than 0.079 in) with a sieve. Percentage coarse fragments on a weight (%RFW) and volume basis (%CFV) were measured with Equations 2 and 3, respectively. Chemical analyses for NO_3^--N content and NH_4^+-N were determined colorimetrically by automated flow injection analysis.

$$\%RFW = \frac{\text{Wt. cobble} + \text{Wt. gravel}}{\text{Wt. total}} \cdot 100 \quad (2)$$

%RFW = Percent coarse fragments by weight
Wt. gravel = Dry weight of gravels
Wt. cobble = Dry weight of cobble
Wt. total = Dry weight of soil sample (fine soil plus all coarse fragments)

$$\%CFV = \left[\left(\frac{\%RFW}{2.65} \div \frac{100-\%RFW}{BD} + \frac{\%RFW}{2.65}\right)\right] \cdot 100 \quad (3)$$

%CFV = Percent coarse fragments by

volume
BD = Bulk density of the soil fraction < 0.07874 in

Definitions to consider when using the NLEAP model in soils containing coarse fragments

To determine the volume of soil coarse fragments, two depths were sampled: 0 to 1 and 1 to 3 ft. Using gravimetric weights from Table 6 and Equation 2, the %RFW for the 0-to-1 and 1-to-3 ft depths are 35 and 67, respectively. Using the %RFW and the bulk density (BD) values from Table 6 and Equation 3, the 0-to-1 and 1-to-3 ft depths have a %CFV of 22.8 and 55.1, respectively. The %CFV was then entered into the NLEAP soils data screen.

Use of coarse fragments by volume with NLEAP

In the NLEAP model, the soil data entry screen is where the user needs to input the %CFV, soil bulk density, and the initial soil NO_3^--N content of the surface and subsoil horizons. Other chemical and physical characteristics also are entered on this screen.

When working with NLEAP and coarse-textured soils, it is important to know if the laboratory results for the soil organic matter and soil NO_3^--N are based on the fraction smaller than 0.079 in, or if they have been adjusted with the %CFV to reflect actual field values. The initial soil NO_3^--N and soil organic matter values entered in the NLEAP soil data screen must be based on the soil fraction smaller than 0.079 in. The model uses the %CFV to adjust this initial soil NO_3^--N content to reflect the actual field value.

Table 6 was used to determine 33.0 and 14.6 ppm of initial soil NO_3^--N for the 0-to-1 and 1-to-3 ft soil depths, respectively. Using a conversion factor and the BD, the initial soil NO_3^--N content, based on the soil fraction smaller than 0.079 in, is 130 and 127 lb NO_3^--N ac^{-1} for the 0-to-1 and 1-to-3 ft soil depths, respectively. These non-adjusted NO_3^--N values are then entered in the NLEAP soils data screen. NLEAP will use the %CFV of 22.8 and 55.1 to calculate the initial field soil NO_3^--N content, 100 and 57 lb NO_3^--N ac^{-1}.

A similar reduction for the soil organic matter content will be expected for the 0-to-1 ft soil depth. The percentage of soil organic matter entered in NLEAP should be based on the soil fraction smaller than 0.079 in. NLEAP will use the %CFV to adjust the soil organic matter. The user needs to enter the Cation Exchange Capacity (CEC) in meq 100 g-1 for the soil fraction smaller than 0.079 in. The model will not adjust this value.

The NLEAP model uses soil physical characteristics such as plant-available water-holding capacity, and water content at 15 bar in the calculation of the water budgets. The user needs to input these soil water-holding characteristics adjusted for the %CFV. The model will not use the %CFV entered in the soil data screen to adjust the input of these soil water-holding properties.

How to use %CFV when interpreting NLEAP simulated outputs

When interpreting NLEAP-simulated outputs with coarse-textured soils, the user needs to consider that all NLEAP-simulated outputs are on a volume basis and are adjusted for %CFV. If the residual soil NO_3^--N values received from the laboratory are based on the fraction smaller than 0.079 in, the user needs to convert ppm to lb NO_3^--N ac^{-1} and then adjust these values with the %CFV. These adjusted values for the %CFV are the ones to be used to correlate how well NLEAP has simulated residual soil NO_3^--N for the root zone.

NLEAP facts about simulations for coarse-textured soils

For the coarse-textured soils of the San Luis Valley, NLEAP simulations show a potential to account for the effect of management on N budgets in the root zone (Delgado 1998a). Studies about the effect of N management practices on these agricultural systems show that rotations of small grains with vegetables increase N use efficiency and protect water quality (Delgado and Follett 1997a). Studies about the effects of management practices on the compartmentalization of N in the soil organic matter found that rotation with small grains helps to protect soil quality in the valley (Delgado and Sparks 1998). Results also show that winter cover crops conserve N, reduce soil erosion, return organic C and N to the surface soil, and protect soil and water quality (Delgado et al. 1998b). Additionally, preliminary studies showed that controlled release fertilizers have the potential to increase N use efficiency, reduce NO_3^--N leaching, and protect water quality in these sandy soils of the valley (Delgado et al. 1998c).

NLEAP 1.2 simulated the effect of management practices such as date of planting of winter cover crops (Delgado 1998a); vegetable and small grain rotations (Delgado and Follett 1998b), and effect of controlled release fertilizers (Delgado and Mosier 1998). NLEAP 1.2 has the potential of being a technology transfer tool capable of evaluating effects of precision management practices on residual NO_3^--N (Delgado 1998b). The 1.2 version of NLEAP has higher resolution and accounts for observed variations in maximum rooting depths. These modifications were needed to evaluate rotations that included shallower and deeper root systems (Delgado et al. 1998a).

Sequential NLEAP simulations were used to evaluate the effect of winter cover crops on nitrogen dynamics (Delgado 1998a). Background NO_3^--N applied in the irrigation well water for the whole loamy sand area (121 ac) under center-pivot irrigation was 2,807 lb NO_3^--N ac^{-1} y^{-1}. The NLEAP-simulated NO_3^--N leaching from the 0-to-3 ft baseline for the potato crop grown after the winter cover crop was 97 lb NO_3^--N ac^{-1} y^{-1}. Although there will be a significant spatial variability in soil properties and water application across the irrigated loamy sand, computer simulations showed a potential benefit of mining 1.4 tons of NO_3^--N ac^{-1} y^{-1} at this site when best irrigation and management practices are applied.

These results agree with other researchers who found that with proper water and fertilizer management practices NO_3^--N leaching can be kept very small in irrigated sandy soils (Smika et al. 1977; Hergert 1986; Westerman et al. 1988; Schepers et al. 1995; Thompson and Doerge 1996a, b). NLEAP computer simulations suggested that this net process of NO_3^--N leaching in the valley can be reversed for these coarse-textured soils and that there is potential for NO_3^--N mining when best management practices are implemented (Delgado 1998a). These are important NLEAP facts that can potentially contribute to protect and improve water quality.

Summary

The mean crop N content (%), C/N ratios, and NUI for the harvested and unharvested plant parts, for small grains, potato, vegetables, and for winter cover crops are presented (Tables 2, 3, 4, and 5). This data set of plant parameters is being used with the respective soil chemical and physical information, irrigation practices, N management practices, and amount of N in the irrigation water as inputs into NLEAP. Local climatological data also is being used to generate simulations of the crop N uptake and soil N transformations to calculate N and water budgets for each cropping system. NLEAP simulations include other soil transformations and dynamics such as NO_3^--N leaching and the soil inorganic NO_3^--N content in the soil profile. The NLEAP model is a tool that is being used to evaluate N management practices in these systems. The model can be used by extension agents, farmers, and educators and is a potential technology transfer tool. Coarse fragments by volume is an important factor related to soil quality that needs to be considered when using the NLEAP model in coarse-textured soils.

REFERENCES CITED

Agro Engineering, Inc. and Colorado State University. 1995. Field Scale Ground Water Monitoring to Evaluate Nitrogen Best Management Practices in the San Luis Valley. San Luis Valley, CO.

Austin, B. 1993. Report to the Commissioner of Agriculture, Colorado Department of Agriculture, Groundwater monitoring activities San Luis Valley Unconfined Aquifer. Colorado Department of Public Health and Environment. Denver, CO.

CDA and USDA. 1997. (Colorado Department of Agriculture and United States Department of Agriculture) 1997. Colorado Agricultural Statistics. Colorado Agricultural Statistics Service. Lakewood, CO.

Delgado, J.A. 1998a. Sequential NLEAP simulations to examine effect of early and late planted winter cover crops on nitrogen dynamics. Journal of Soil and Water Conservation 53(3):241-244.

Delgado, J.A. 1998b. NLEAP simulation of soil type effects on residual NO_3^--N and potential use for precision agriculture. In: Proceedings of the 4th International Conference on Precision Agriculture. St Paul, MN (in press).

Delgado, J.A., and A.R. Mosier. 1998. NLEAP simulation of controlled release fertilizer use for conservation of water quality in south central Colorado. Agronomy Abstracts 90:232.

Delgado, J.A., and R.T. Sparks. 1998. Use of crop management practices as a potential tool to protect soil quality of sandy soils of the San Luis Valley of south central Colorado. Journal of Soil and Water Conservation 53(2):159.

Delgado, J.A., M. Shaffer, and M.K. Brodahl. 1998a. Potential use of a new version of NLEAP for evaluating effects of shallower and deeper rooted crop rotations on residual soil NO_3^--N and NO_3^--N leaching from different agricultural systems. Journal of Soil and Water Conservation 53(4):338-340.

Delgado, J.A., R.T. Sparks, R.F. Follett, J.L. Sharkoff, and R.R. Riggenbach. 1998b. Use of winter cover crops to conserve soil and water quality in the San Luis Valley of south central Colorado. In: R. Lal (ed) Soil Quality and Soil Erosion. CRC Press. Boca Raton, FL pp 125-142.

Delgado, J.A., A.R. Mosier, A. Kunugi, and L. Kawanabe. 1998c. Potential use of controlled release fertilizers for conservation of water quality in the San Luis Valley of Colorado. In: A.J. Schlegel (ed). Proceedings of the Great Plains Soil Fertility Conference, Denver, Colorado. pp 151-156. Kansas State University. Manhattan, KS.

Delgado, J.A., and R.F. Follett. 1997a. Use of a sequential NLEAP model to assess the effects of a potato-grain cropping sequence on residual soil NO3—N and N use efficiency. Journal of Soil and Water Conservation 52(4):284.

Delgado, J.A., and R.F. Follett. 1997b. NLEAP, a management tool to assess effects of crop rotations on N use efficiency. Agronomy Abstracts 89:22.

Eddy-Miller, C.A. 1993. Evaluation of shallow ground water wells as a method of monitoring nitrate leaching in the San Luis Valley. M.S. Thesis. Dept. of Agricultural and Chemical Engineering. Colorado State University.

Edelmann, P., and D.R. Buckles. 1984. Quality of ground water in agricultural areas of the San Luis Valley, south central Colorado. Water-Resources Investigations Report 83-4281. U.S. Geological Survey.

Hearne, G.A., and J.D. Dewey. 1988. Hydrologic analysis of the Rio Grande Basin north of Embudc, New Mexico, Colorado and New Mexico. Water-Resources Investigations Report 86-4113. U.S. Geological Survey.

Hergert, G.W. 1986. Nitrate leaching through sandy soil as affected by sprinkler irrigation management. Journal of Environmental Quality 15:272-278.

SLVWQDP (San Luis Valley Water Quality Demonstration Project). 1994. Best management practices for nutrient and irrigation management in the San Luis Valley. Colorado State University Cooperative Extension. Fort Collins, CO.

SAS Institute Inc. (Statistical Analysis System). 1988. SAS/STAT Users Guide Version 6.03, 3rd Edition. SAS Institute. Cary, NC.

Schepers, J.S., G.E. Varvel, and D.G. Watts. 1995. Nitrogen and water management strategies to reduce nitrate leaching under irrigated maize. Journal of Contaminant Hydrology. 20:227-239.

Shaffer, M.J., A.D. Halvorson, and F.J. Pierce. 1991. Nitrate leaching and economic analysis package (NLEAP): Model description and application. In: R.F. Follett, D.R. Keeney and R.M. Cruse (eds). Managing Nitrogen for Groundwater Quality and Farm Profitability. pp 285-322. Soil Science Society of America. Madison, WI.

Smika, D.E., D.F. Heermann, H.R. Duke, and A.R. Bathelder. 1977. Nitrate-N percolation through irrigated sandy soil as affected by water management. Agronomy Journal 69:623-626.

Thompson, T.L., and T.A. Doerge. 1996a. Nitrogen and water interactions in subsurface trickle-irrigated leaf lettuce I. Plant response. Soil Science Society of America Journal 60:163-168.

Thompson, T.L., and T.A. Doerge. 1996b. Nitrogen and water interactions in subsurface trickle-irrigated leaf lettuce II. Agronomic, economic and environmental outcomes. Soil Science Society of America Journal 60:168-173.

USDA-SCS (U.S. Dept. of Agriculture Soil Conservation Service). 1973. Soil Survey of Alamosa Area, Colorado. USDA-SCS. Washington, DC.

USDA-SCS (U.S. Dept. of Agriculture Soil Conservation Service). 1988. National Agronomy Manual. 2nd Edition. Washington, DC.

Westermann, D.T., G.E. Kleinkopf, and L.K. Porter. 1988. Nitrogen fertilizer efficiencies on potatoes. American Potato Journal 65:377-386.