A list of definitions to consider when using the NLEAP model to evaluate N management practices in soils containing coarse fragments

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Introduction

In irrigated agricultural cropping systems, yield is very often limited by the supply of N in the root zone. In general, natural sources of N are not adequate for optimum crop production. Since yield is a function of N availability, we need to maintain adequate levels of N in the root zone, where roots can absorb it. However, when we increase the amount of N-inputs, NO_3-N can accumulate in the soil profile. This form of N is readily mobile and 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, we need to implement N and irrigation management practices 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 the quick extrapolation of research results into a wide variety of different farmers' fields. One of these new computer software packages is the NLEAP (Nitrate Leaching and Economic Analysis Package) model. The NLEAP model permits a rapid evaluation of a series of best N and irrigation management practices for a site-specific farmer's field. However, in order to predict the N dynamics, across different fields or management practices, local information is still needed to initially calibrate and evaluate the local effectiveness of the model and its capability as a predictive tool. The purpose of this publication is to present a series of definitions that need to be considered when using the NLEAP model to evaluate N and irrigation management practices in coarse textured soils.

A general description of NLEAP

To run the NLEAP model, the user supplies the crop planting and harvesting dates, N-, water-, and cultural-management inputs and timing, soil and climate information, and the expected yield. NLEAP can then simulate crop N uptake during the growing season and NO_3-N leaching, if it occurs. The percentage of soil coarse fragments greater than 0.079 inches (2 mm) and the soil bulk density are also part of the model inputs. The model simulations are conducted on a soil volume basis. All N additions are accounted for as inputs in the model. Inputs 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, it also keeps track of how the management of the system affects N biogeochemical transformations such as

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nitrification, denitrification, and mineralization of N from crop residues and soil organic matter, that occur in the root zone. For a detailed description of how NLEAP works see Chapter 13 in "Managing Nitrogen for Groundwater Quality and Farm Profitability" 1991. Soil Science Society of America, Inc, Madison, WI, USA (R. F. Follett, D.R. Keeney, and R.M. Cruse, Eds.).

A case-study: use of NLEAP in coarse textured soils of the San Luis Valley of south central Colorado

The San Luis Valley, with an average elevation of 7,700 ft, is a high altitude intermountain desert valley located in south central Colorado. With an average annual precipitation of 7.1 inches in Alamosa County, agriculture requires irrigation. Although the Valley has a variety of soils, most of them are of a coarse sandy texture over a coarse textured substratum. Some of these soils have a significant amount of coarse fragments, which usually increases with greater depth.

A recent study found groundwater NO_3-N concentrations as high as 80 ppm, north of the town of Center in the Valley. The combination of N fertilizer use with irrigated agriculture, a high water table and coarse textured sandy soils are factors that contributed to this elevated concentration of NO_3-N in groundwater.

The USDA Working Group for Water Quality in Cooperation with Colorado State University Cooperative Extension authorized the San Luis Valley Water Quality Demonstration Project (SLVWQDP) in 1991. The mission of the SLVWQDP is to promote the use of best management practices in the Valley to minimize agricultural non-point source pollution. The NLEAP model is being used by USDA-ARS, USDA-NRCS and the SLVWQDP to evaluate the effects of agricultural management practices on N and water budgets. Agricultural management practices and soil, crop, and irrigation data have been collected for 35 field scale sites to evaluate the status of current N management practices. When completed, a unique data set, consisting of about 80 site-years of information will be used to test NLEAP across different cropping systems and various coarse textured soils (Tables 1 and 2).

Table 1. Selected crops grown in the San Luis Valley.

Crop description or common name	Scientific name
Alfalfa	*Medicago sativa* L.
Barley	*Hordeum vulgare* L.
Canola	*Brassica napus* L.
Carrot	*Daucus carota*
Lettuce	*Lactuca sativa* L.
Oat	*Avena sativa* L.
Potato	*Solanum tuberosum* L.
Rye	*Secale cereale* L.
Spinach	*Spinacia oleracea* L.
Wheat	*Triticum aestivum* L.

Table 2. San Luis Valley soils where current N management practices are being evaluated

Soil series	Surface texture
Dunul	*Cobbly sandy loam*
Gunbarrel	*Loamy sand*
Kerber*	*Loamy sand*
McGinty	*Sandy loam*
Mosca*	*Loamy sand*
Norte*	*Gravelly sandy loam*
Quamon*	*Gravelly sandy loam*
San Arcacio	*Sandy loam*
San Luis*	*Sandy loam*
Shawa	*loam*
Torsido	*loam*

* *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 (2mm). 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.*

Collection of soil samples

To determine the residual soil NO_3-N content in a uniform field, soil samples need to be collected and analyzed in a laboratory for NO_3-N. For each major soil series in a farmer's field, usually 20 soil cores are taken at random through the field. The sampling depth for the soil cores will depend on the rooting depth of the crop to be planted. For our example of soil coarse fragments volume determination, two depths are sampled, 0-1 and 1-3 ft. The 20 cores for the 0-1 depth are composited, mixed, and subsampled. The same procedure is repeated for the 1-3 ft depth, samples are air dried and sent to the laboratory.

Example of coarse fragment by volume determination

To determine the % coarse fragments on a volume basis (%CFV), the soil sample including coarse fragments needs to be weighed. In the laboratory, samples are processed and the cobbles (fraction that is greater than 3 inches) and the gravel (fraction that is smaller than 3 inches but greater than 0.079 inches) are removed by sieveing. The chemical analyses for NO_3-N content are conducted in the soil fraction that is smaller than 0.079 inches. The weights of the cobbles and gravel are recorded (Table 3). The %CFV will be the percentage of soil sample on a volume basis greater than 0.079 inches. NLEAP takes into account the soil coarse fragments, greater than 0.079 inches, and the effects that this fraction has on the N and water budget.

Table 3. 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 (g)	Gravel (g)	< 0.079 (g)	NO_3-N ppm
0 - 1	1.45	0	350	650	33.0
1 - 3	1.60	0	670	330	14.6

* Weights for cobbles, gravel, and < 0.079 inches soil fractions are in grams (g).

¶ Bulk density expressed as the dry weight of the soil fraction < 0.079 inches over the moist volume at ⅓ bar of the soil fraction < 0.079 inches. The moist volume at ⅓ bar includes the air and water pore space volume of the soil.

Using the gravimetric weights from table 3 and equation 1, we can determine the % weight of the coarse fragments (%RFW) greater than 0.079 inches. For our example, the %RFW for the 0-1 and 1-3 ft depths are 35 and 67%, respectively.

Using the %RFW and the bulk density (BD) values from table 3, and equation 2, we can calculate the %CFV. The 0-1 and 1-3 ft depths have a %CFV of 22.8 and 55.1%, respectively. The %CFV are the values that need to be entered into the NLEAP soils data screen. These %CFV values are lower than the calculated %RFW of 35 and 67%, respectively. These %CFV values are lower because they include the % air space in the soil.

$$\%RFW = \frac{Wt.\ cobble + Wt.\ gravel}{Wt.\ total} * 100 \qquad (1)$$

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

$$\%CFV = \left(\left(\frac{\%RFW}{2.65}\right) \div \left(\frac{100 - \%RFW}{BD} + \frac{\%RFW}{2.65}\right)\right) * 100 \qquad (2)$$

%CFV = *Percent coarse fragments by volume*
BD = *Bulk Density of the soil fraction < 0.07874 inches*

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 (Table 4). Other chemical and physical characteristics are also entered on this screen. When working with NLEAP and coarse textured soils, it is important to know if the soil organic matter and the initial soil NO_3-N results received from the laboratory are based on the fraction smaller than 0.079 inches or if they have been adjusted with the %CFV to reflect the actual field value.

The initial soil NO_3-N content and soil organic matter entered in the NLEAP soil data screen must be based on the soil fraction smaller than 0.079 inches. The model will use the %CFV to adjust this initial soil NO_3-N content to reflect the actual field value. For example, using table 3 we found 33.0 and 14.6 ppm of initial soil NO_3-N for the 0-1 and 1-3 ft soil depths, respectively. Using a conversion factor, the BD, and the depth in ft that the sample represents (Example: 1-3 ft = 2 ft horizon), we can convert these ppm into lb NO_3-N/acre (equation 3). The initial soil NO_3-N content based on the soil fraction smaller than 0.079 inches are 130 and 127 lb NO_3-N/acre for the 0-1 and 1-3 soil depths, respectively. Although these NO_3-N values are not adjusted for the %CFV, these are the values that need to be entered into the NLEAP soils data screen (Table 4). NLEAP will use the volumetric coarse fragments of 22.8 and 55.1%, to adjust the values based on the soil fraction smaller than 0.079 inches to reflect the initial field soil NO_3-N content, 100 and 57 lb NO_3-N/acre. A similar reduction for the soil organic content will be expected.

$$lb\ NO_3\text{-}N/acre = 2.719 * BD * soil\ NO_3\text{-}N\ ppm * Depth\ ft \qquad (3)$$

How to use the % coarse fragments by volume method in estimating plant available soil water content.

NLEAP uses soil physical characteristics such as soil plant available water holding capacity, and soil water content at 15 bar in the calculation of the water budgets. The user needs to input the soil water holding characteristics adjusted for the %CFV. The user could utilize a field measured value or an estimation of these values that represents the field soil water holding characteristics. NLEAP will not use the %CFV entered in the soil data screen to adjust the input of these soil water holding properties.

There are different methodologies on how to measure these physical parameters, "*in situ*" or in the laboratory. If the soil water holding properties are measured "*in situ*", they will account for the effect of the %CFV. These soil parameters can also be estimated using the USDA-SCS National Soils Handbook. With the USDA-SCS method the soil texture is used to estimate the soil water holding characteristics. The USDA-SCS texture method, when working with coarse textured soils, uses an adjustment for the %CFV to reflect the field water holding properties (USDA-SCS National Soils Handbook). For a cobbly sandy loam, available water holding capacity was estimated as 0.12 and 0.10 in/in for the 0-1 and 1-3 ft depths, respectively. Using the 24.5 and 55.1%CFV, the plant available water holding capacity is adjusted to 0.09 and 0.05 in/in for the 0-1 and 1-3 ft respectively. These are the values to enter in the NLEAP soils data screen (Table 4).

How to use the % coarse fragments by volume method in interpreting the NLEAP simulated outputs

When interpreting NLEAP simulated outputs with coarse textured soils, the %CFV needs to be considered. All the NLEAP simulated outputs are on a volume basis and are adjusted for %CFV. If the user wants to correlate how well NLEAP has simulated residual soil NO_3-N for the root zone, another set of samples for the 0-1 and 1-3 ft depths needs to be collected at the end of the growing season. The same procedure described in the collection of soil samples is used. If the laboratory reports the values based on the fraction smaller than 0.079 inches, the user needs to use equation 3 to convert ppm to lb NO_3-N acre and then adjust these values with the %CFV. These adjusted values for the %CFV are the ones to be used in evaluating how well NLEAP has simulated residual soil NO_3-N.

Definitions to consider when entering inputs

Soils data screen

Cation Exchange Capacity (CEC) in meq/100g: The user needs to enter the CEC for the soil fraction smaller than 0.079 inches. The CEC of the % soil organic matter needs to be accounted for. The user should not use the %CFV to adjust the CEC in meq/100g.

% of Organic matter: The percentage of soil organic matter entered in NLEAP should be based on the soil fraction smaller than 0.079 inches. NLEAP will use the %CFV to adjust this value.

Percentage coarse fragments (volume): Percentage coarse fragments on a volume basis (%CFV), fraction greater than 0.079 inches needs to be entered. The model uses the %CFV to adjust the initial NO_3-N, and organic mater content inputs.

NO_3-N- initial: The initial soil NO_3 -N content entered in NLEAP should be based on the soil fraction smaller than 0.079 inches. NLEAP will use the %CFV to adjust this value.

Bulk Density: The user needs to enter the bulk density of the soil fraction smaller than 0.079 inches (grams/cubic centimeter).

Plant available water holding capacity: The user must enter the soil measured or estimated plant available water holding capacity which accounts for the presence (if any) of coarse fragments. NLEAP will not use the %CFV to adjust this value.

Soil water content at the start of the run: The user needs to enter the measured or estimated soil water content at the start of the run which accounts for the presence (if any) of coarse fragments. NLEAP will not use the %CFV to adjust this value.

Soil water content @ 15 Bar: The user needs to enter the measured or estimated soil water content at 15 bar which accounts for the presence (if any) of coarse fragments. NLEAP will not use the %CFV to adjust this value.

Irrigation, N management, and climate screens

Crop residue and or manure and or organic waste (ton/acre): The user needs to enter the dry weight of crop residue and or manure and or organic waste in tons/acre, method of application, and date applied.

Fertilizer N : The user needs to enter the lb N/acre of fertilizer applied, source of N, method of application and date applied.

Fertilizer N in irrigation water: The user needs to enter the lb N/acre of fertilizer applied in irrigation water, source of N, and date of application. The background N content of the irrigation water could be calculated using equation 4 (assuming density of water is one gram/cubic centimeter). The N content of the irrigation water needs to be entered for each irrigation event.

$$lb\ NO_3\text{-}N/acre = 0.2266 * inches\ of\ H_2O * H_2O\ NO_3\text{-}N\ ppm \qquad (4)$$

How to handle residual NH_4-N

In the event that a significant initial residual NH_4-N is measured, the user can utilize the daily climate input data screen to enter this value. The residual NH_4-N/acre needs to be adjusted first for the %CFV. The user could enter the adjusted initial residual NH_4-N by entering a small value such as 0.0001 inches of irrigation water and the lb NH_4-N/acre as one of the following sources listed in the NLEAP model, urea, ammonium sulfate (NH_4SO_4), anhydrous/aqua ammonia, diammonium phosphate, monoammonium phosphate, and ammonium polyphosphate. This amount of NH_4-N should be entered on the day that the soil sample was collected. By entering 0.0001 inches of irrigation we will not be significantly affecting the water budget. The NLEAP model will not use the added SO_4 or sources of phosphorous to interact with the N budgets or N biogeochemical transformation. A high residual NH_4-N/acre may be due to a fertilizer application just prior to soil sampling. If this application is accounted for in the NLEAP model run, the residual soil NH_4-N/acre does not need to be entered. The user also needs to be aware to not enter any amount of lb of NH_4-N/acre fixed by the clay. When working with coarse textured sandy soils, such as those in the San Luis Valley, this value is expected to be low; however the user needs to decide if there is a significant initial soil NH_4-N.

Definitions to consider when interpreting outputs

After NLEAP uses these inputs with the irrigation and management practices and climate, the model simulates crop N uptake and soil N transformations. The simulation provides a summary of the soil inorganic NO_3-N content in the soil profile which can be compared with the measured values at the end of the growing season. The water and nitrogen output screen, nitrogen sinks screen, and the nitrogen sources screen have all of their soil NO_3-N values adjusted for the %CFV. The user needs to compare these simulated values with laboratory values that have been adjusted for the %CFV.

On the nitrogen sinks screen, total crop N uptake and potential crop N uptake includes N in the root compartment.

On the nitrogen sources screen, the simulation of the N mineralized from the soil organic matter, organic waste, and crop residues only covers the 0-1 ft depth.

On the crop N uptake efficiency screen, the uptake efficiency for crop residue, manure N and other organic waste ($\%CNUE_{CRMOOW}$) are based on the total amounts of N sources that were added into the system (equation 5). However, the soil organic matter crop N uptake efficiency ($\%CNUE_{SOM}$) is based on the total amount of N that was mineralized from the soil organic matter (equation 6).

$$\%CNUE_{CRMOOW} = \frac{Total\ crop\ N\ uptake\ from\ pool}{Total\ N\ added\ to\ soil} * 100 \qquad (5)$$

$$\%CNUE_{SOM} = \frac{Total\ crop\ N\ uptake\ from\ pool}{Total\ N\ mineralized\ from\ pool} * 100 \qquad (6)$$

Table 4. Example of soil data to be entered in the NLEAP soils data screen.

Soil Data	0 - 1 ft depth	1 - bottom root depth ft.
% Organic matter	1.1	
Soil pH	7.2	
Cation exchange capacity (meq/100 g)	11	
Bulk density (g/cc)	1.45	1.60
% Coarse fragments by volume	22.8	55.1
Soil NO_3-N at start of the run (lb/acre)	130	127
Plant available water holding capacity (in/in)	0.09	0.05
Soil water content at the start of the run (in/in)	0.10	0.05
Soil water content at 15 bar (permanent wilting) (in/in)	0.08	0.06