New NLEAP for shallow and deep rooted rotations

Irrigated agriculture in the San Luis Valley of south central Colorado

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Interpretive summary

The Nitrate Leaching and Economic Analysis Package (NLEAP) is capable of providing an assessment of farm management practices on residual soil NO_3^--N. In the San Luis Valley, shallower root crops such as lettuce and potato, and deeper rooted crops such as winter cover crops or spring-planted small grains, are grown in rotation. The NLEAP computer model needed to be modified so that it could simulate the effect of crop rotations based on the root zone depth of each crop. It also needed to simulate the effect of management practices on the residual soil NO_3^--N on an identical soil depth for the whole system. A new NLEAP program, Version 1.2, was developed to conduct an assessment on how much NO_3^--N is leaching beyond the reach of the deeper rooted crops in the rotation. This version is a potential technology transfer tool that can be used by extension agents, farmers, scientists, and educators.

Key words: computer models, crop rotations, irrigation, nitrate leaching, NLEAP, root zone, water quality, winter cover crops.

*ABSTRACT: In the San Luis Valley (SLV) of south central Colorado, shallower root crops such as lettuce (*Lactuca sativa *L.) and potato (*Solanum tuberosum *L.) and deeper rooted crops such as winter cover crops or spring-planted small grains are grown in rotation. The previous NLEAP program, Version 1.10, did not account for the observed variations in maximum rooting depths of these systems. The model needed to be modified so that it could simulate the effect of crop rotations based on the root zone depth of each crop, as well as the effect of management practices on the residual soil NO_3^-–N on an identical soil depth for the whole system. NLEAP 1.2 was developed to simulate residual soil NO_3^-–N for three layers: 0 to 0.3 m (0 to 1 ft), 0.3 m (1 ft) to the bottom of the rooting depth (BRD), and BRD to a maximum soil depth desired (MSDD). The MSDD can be set from a minimum of 0.3 m (1 ft) to a maximum of 1.5 m (5 ft), by 0.03-m (0.1-ft) increments. The MSDD also can be set to be equal to the BRD of the crop with the deeper rooting system in the rotation. The 1.2 version also simulates NO_3^-–N leaching from the BRD and from the MSDD. Another new feature is that the maximum rooting depth can be entered to the nearest 0.03 m (0.1 ft), from a minimum root depth of 0.03 m (0.1 ft) to a maximum of 1.5 m (5 ft). NLEAP 1.2 has improved simulations of agricultural systems with crop rotations that have crops with varied rooting depths.*

The Nitrate Leaching and Economic Analysis Package (NLEAP) is being used by USDA-ARS and USDA-NRCS as a technology transfer tool, capable of providing an assessment of farm management practices on the transport of NO_3^--N in and out of the root zone of crops grown in the San Luis Valley of south central Colorado. In the valley, shallower root crops such as lettuce (*Lactuca sativa* L.) and potato (*Solanum tuberosum* L.) and deeper rooted crops such as winter cover crops or spring-planted small grains are grown in rotation. A typical crop rotation is potato/small grain. Average maximum rooting depth patterns for small grains and potato will also depend on varieties. For some potato varieties, average maximum rooting depth was measured at 0.45 m (1.5 ft). The previous NLEAP 1.10 version does not account for the observed variations in maximum rooting depths of these systems.

Using NLEAP 1.10, simulations were conducted for the maximum rooting zone of the modeled crop. In the case of a system with a lettuce and winter cover crop rotation, NLEAP 1.10 simulations used rooting depths, for example, of 0.3 m (1 ft) for lettuce and 0.9 m (3 ft) for the winter cover crop. This means that NO_3^--N leaching and or residual soil NO_3^--N simulations from 0.3 m (1 ft) had to be compared to 0.9-m (3-ft) depths. Additionally, NLEAP 1.10 conducted simulations for the rooting zone of a crop and entered to the nearest 0.3-m (1-ft) increment, e.g., 0.3, 0.6, 0.9, 1.2, or 1.5 m (1, 2, 3, 4, or 5 ft). For varieties that have maximum rooting depths of 0.45 m (1.5 ft), the alternative scenarios were to simulate the rooting zone to 0.3 m (1 ft) or 0.6 m (2 ft). By using the nearest 0.3 m (1 ft), the simulations of N and water budgets will be over-or under-estimated.

NLEAP needed modifications to study the effect of management practices on agricultural systems that included rotations of shallower and deeper root systems. The NLEAP computer model had to be modified to be able to simulate the effect of crop rotations based on the root zone depth of each crop, and to simulate the effect of management practices on the residual soil NO_3^--N on an identical soil depth over an entire system. Additionally, the simulations needed to be improved to increase resolution for crops that have maximum rooting depths of 0.45 m (1.5 ft). Using data collected at 25 sites throughout the San Luis Valley, version 1.2 of the NLEAP model was developed.

The new 1.2 version can simulate residual soil NO_3^--N for three layers: 0-to-0.3 m (0-to-1 ft), 0.3 m (1 ft) to the bottom of the rooting depth (BRD), and BRD to a maximum soil depth desired (MSDD). This MSDD can be set from a minimum of 0.3 m (1.0 ft) to a maximum of 1.5 m (5 ft), by 0.03-m (0.1-ft) increments. The MSDD also can be set to be equal to the BRD of the crop with the deeper rooting system in the rotation. NLEAP 1.2 also simulates NO_3^--N leaching from the BRD and from the MSDD.

Another new feature is that maximum rooting depth can be entered to the near-

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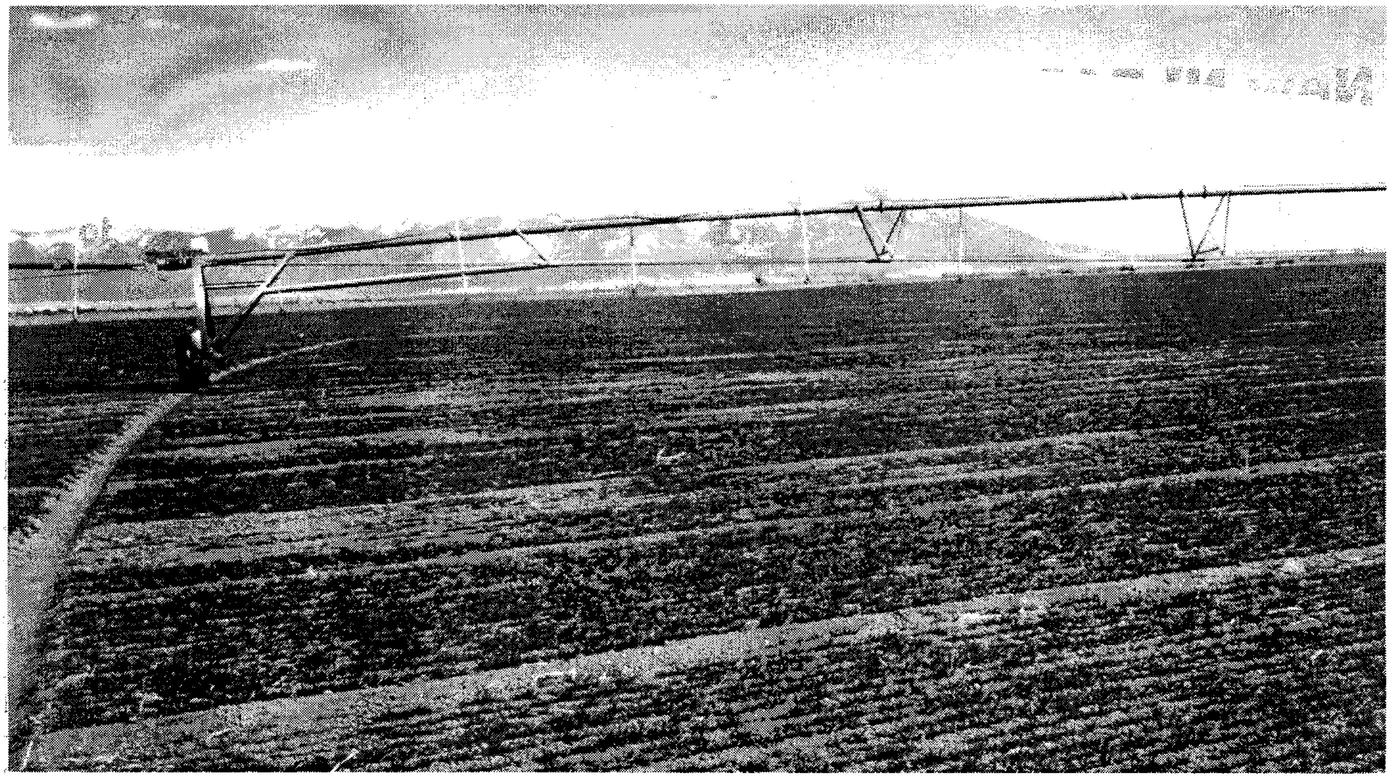
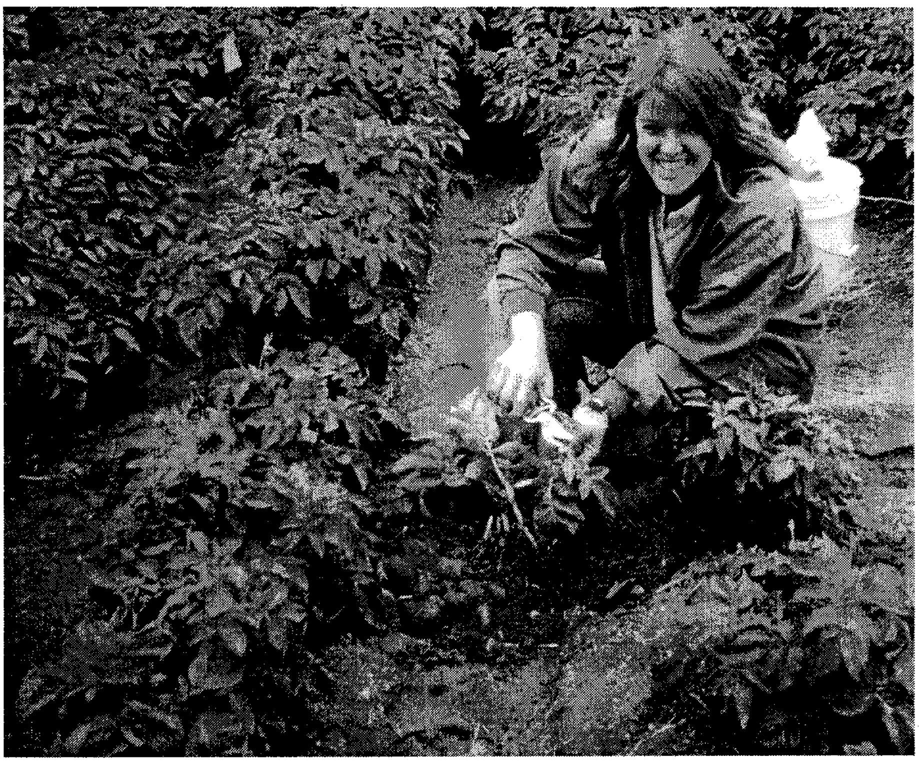


Use of winter cover rye as a scavenger crop to protect soil and water quality after potato harvest

est 0.03 m (0.1 ft), from a minimum root depth of 0.3 m (1 ft) to a maximum of 1.5 m (5 ft). This allows greater resolution, especially in cases where the maximum rooting depth average is 0.45 m (1.5 ft). This new feature allows the user to allocate observed N and water budgets. For this new version of NLEAP, maximum rooting depth is located in columns 98 to 100 of the region idx computer file.

These new features in NLEAP 1.2 allow for more effective single-year simulations on two crops with different rooting depths. This allows the user to simulate a system when winter cover crops are planted after a shallower rooting crop, such as lettuce, on an identical soil depth. The user can then simulate the residual soil NO_3^--N for both rooting zones and for an identical soil profile using the MSDD. Additionally, the user can simulate NO_3^--N leaching from the shallower and deeper rooted crop zones and from a soil depth identical for both crops.

NLEAP 1.2 simulation to a maximum soil depth desired. By default independent of maximum rooting depth, NLEAP 1.2 will simulate the residual soil NO_3^--N to the 1.5-m (5-ft) soil profile. Using the maximum rooting depth identified in the regional configuration file, the model by default will simulate the following soil layers: the 0-to-0.3 m (0-to-1ft) layer, the 0.3m-to-BRD (1 ft-to-BRD) layer, and the BRD-to-1.5 m (BRD-to-5 ft) layer. The user can control the maximum soil depth simulation over the entire system by entering in the soil data input screen (1 = yes) for the ques-



Amy Kunusi, San Luis Valley farmer, shows how aboveground biomas for nontreated plots contrasting with treated plots where controlled release fertilizers had been applied (behind her)

tion: Water flow restriction? The user, after answering this question, can then indicate at which soil depth the simulation is desired between 0.3 (1 ft) and 1.5 m (5 ft) to the nearest 0.03 m (0.1 ft).

Case 1 is an example of a lettuce/winter cover crop/potato rotation. Maximum rooting depth for the rotation was set at 0.39, 0.45, and 0.90 m (1.3, 1.5, and 3 ft), respectively. In this example, the next question is answered affirmatively, and the MSDD for the depth of the deepest rooting system (0.9 m or 3 ft) is entered. The model then simulates the crop rotation with an identical soil profile for the three crops.

In Case 1, NLEAP simulates three layers for lettuce: 0-to-0.3 m (0-to-1 ft), 0.3-to-0.39 m (1-to-1.3 ft), and 0.39-to-0.9 m (1.3-to-3 ft) during the first-year simulation. Then during the first year, after lettuce harvest, the model will simulate two layers for the winter cover crop: 0-to-0.3 m (0-to-1 ft), and 0.3-to-0.9 m (1-to-3 ft). During the second year the model will simulate three layers for potato: 0-to-0.3 m (0-to-1 ft), 0.3-to-0.45 m (1-to-1.5 ft), and 0.45-to-0.9 m (1.5-to-3 ft).

NLEAP 1.2 outputs of the system. The residual soil NO_3^--N for each one of these different soil layers of the lettuce(winter cover crop/potato rotation and the NO_3^--N leaching from the bottom of the root zone and the bottom of the MSDD can be found in the output screens described in NLEAP. The "Nitrogen sources (lb/a)" screen is where the residual soil NO_3^--N for the 0-to-0.3 m (0-to-1 ft) and 0.3 m-to-BRD (1 ft-to-BRD) layers are located. The "Summary of Nitrogen Sinks, NO_3^--N and NAL" screen is where the residual soil NO_3^--N for the rooting zone (0-to-BRD) will be found. This residual soil NO_3^--N also will be equal to the sum of the residual soil NO_3^--N for the 0-to-0.3 m (0-to-1 ft) and 0.3 m-to-BRD (1 ft-to-BRD ft) layers. The "Water and Nitrogen Summary" screen is where the NO_3^--N leached from the bottom of the rooting zone of each crop will be located. The last output screen will be the "Soil Profile Summary" screen, which has the residual soil NO_3^--N for the soil profile and NL from the same MSDD [in this case, 0-to-0.9 m (0 to3 ft)]. In the case of lettuce and potato the residual, soil NO_3^--N for the BRD to the MSDD can be obtained by subtraction: Residual soil NO_3^--N for BRD to MSDD = (Residual soil NO_3^--N in soil profile – Residual soil NO_3^--N in root zone).

Limitations of NLEAP 1.2 for a system. One limitation of NLEAP 1.2 is that users must enter the average description of the 0.3-m (1-ft) depth to an identical soil depth for the system. The model only allows the user to enter the physical and chemical characteristics of the 0-to-0.3 m (0-to1 ft) and the 0.3 m-to-MSDD. In the case of three layers, the average properties are used for the 0-to-0.3 m (0-to-1 ft) and 0.3 m-to-MSDD. If necessary, the user can conduct sensitivity analyses by changing the average physical and chemical characteristics of the 0.3 m-to-MSDD layer.

There also are some limitations for sequential simulations and simulations for a single year with two crops of different rooting depths. In the case of a sequential simulation, a depth-weighted average for the 0.3 m-to-MSDD depth will be redistributed after each simulation on the soil NO_3^--N and water budgets. The user should consider what impact this redistribution has with respect to possible differences from the 0.3 m-to-BRD (1 ft-to-BRD) layer, and the BRD-to-MSDD layer at the end of each simulation. This situation also will occur when two crops with different rooting depths are simulated during a single year.

Improvement and validation of the new NLEAP 1.2 version. NLEAP 1.2 has improved simulations of agricultural systems with crop rotations that have crops with varied rooting depths. The capability of simulating NO_3^--N leaching from each rooting zone and from the MSDD at 0-to-0.9 m (0-to-1 ft) can help in the evaluation of an entire agricultural system. This NLEAP version can help users assess how crop rotations can protect water quality. It allows the user to interpret how much NO_3^--N leached from shallower-rooted crops, can be recovered and scavenged by deeper-rooted crops (e.g., a winter cover crop). The model also allows users to interpret how much NO_3^--N that leached from a shallower root system is actually moving beyond the reach of the deeper-rooted crop in the rotation.

This new version has been validated for agricultural systems in the San Luis Valley (Delgado 1998; Delgado et al. 1998). These results agree with other scientists who have found that NLEAP can be used to evaluate the effects of management practices with other crops such as corn and wheat (Shaffer et al. 1991; Khakural and Robert 1993; Beckie et al. 1994; Follett et al. 1994; Shaffer et al. 1995). Since NLEAP has been used by other authors across different ecosystems, these results suggest that NLEAP 1.2 has the potential to be applied to other national and international agricultural systems. NLEAP 1.2 is a potential technology transfer tool capable of evaluating the effects of management practices on movement of NO_3^--N in the soil profile that can be used by extension agents, farmers, and educators.

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