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Soil Variability In Landscapes Affects N Management

Colorado researchers find topographical variability affects grain yield, soil properties, and N fertilizer response of dryland corn in VRT studies.

Summary: Corn yield varied widely along the landscapes. Corn yields of the unfertilized strips described the variations in soil properties over the landscapes. Higher yields were associated with topographically lower depositional areas having higher soil organic matter content and available N, and lower soil pH and lime contents. Soil profile NO_3-N varied 300 percent at the Sterling site and 1,200 percent at the Stratton site. The lowest residual NO_3-N levels were found on eroded sideslopes. Very high residual NO_3-N levels (up to 225 lbs/A of N) were found on the toeslopes at the Stratton site, with all other positions having low values. Soil properties were used to develop a "soil index," which identified those factors that positively and negatively impact Weld. Soil index value correlated positively with corn yield, explaining about 58 percent of the total variability in corn yields. Results of this study show promise for improving N fertilizer recommendations in dryland corn either under conventional or VRT soil fertility management. However, many factors affect crop Weld in addition to soil test parameters. The more of these that can be considered, the greater the probability of success of VRT programs.

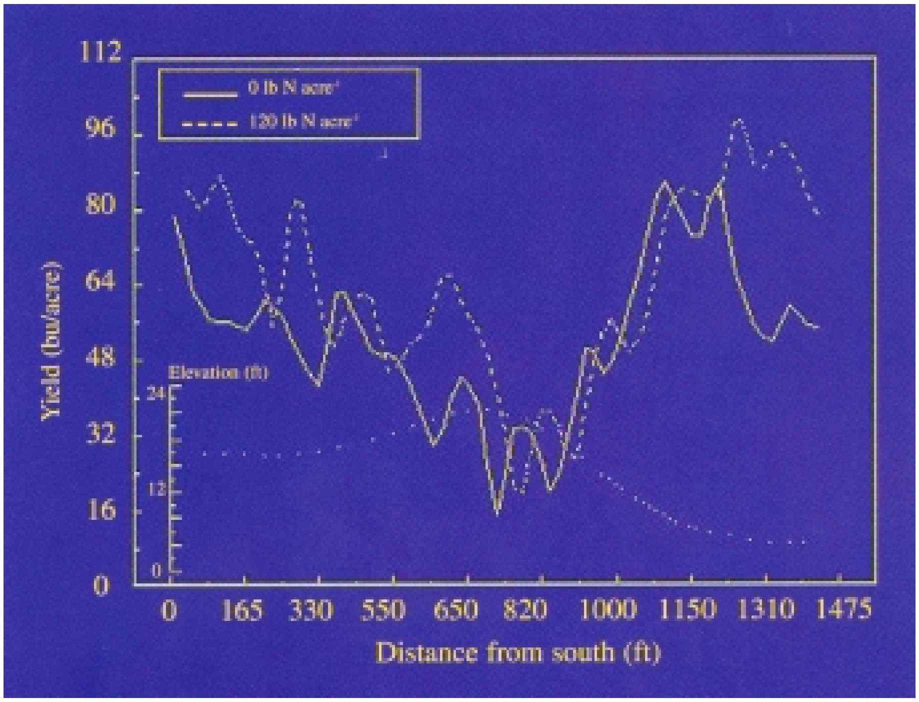

Figure 1. Spatial variability of corn grain yields of two N treatments, Sterling, CO, 1996 (30, 60 and 90 lbs/A rates are not shown due to data overlap).

Recent results from precision agriculture research have shown the yield variability within a field is much greater than we previously thought. The big question is "why do these yield variations occur and what can we do to impact them?"

Large and continuous variability in soil properties and corn yields found on typical landscapes of eastern Colorado provides an excellent opportunity to study the relationships between grain yield and soil properties affecting productivity. From this, we hope to develop guidelines for N fertilizer recommendations for dryland corn that can be used in precision agriculture or variable rate fertilizer technology (VRT).

The use of the field average for a yield goal to estimate N fertilizer needs under VRT is not an accurate method where factors other than soil-available N control yields. Yield maps obtained with a yield monitor may be able to produce "site specific" N fertilizer recommendations within a field when used with the appropriate algorithm. However, this approach assumes that yield goal is an adequate representation of spatial nutrient needs, that yield goal can reflect N fertilizer-use efficiency, and only N is the limiting growth factor.

This report covers our precision agriculture research on spatial variability of soil N components and the resulting yield variability of dryland corn in a dryland winter wheat-corn-fallow cropping system. The specific objectives were to:

- quantify spatial variability of corn yields, soil N and “in-situ” net N mineralization over “typical” landscapes of eastern Colorado
- determine spatial relationships among corn yields and soil properties.

Spatial variability

Grain yield. At the Sterling site, grain yield at all N rates showed a high spatial dependence. This was measured using the Moran’s I technique[1], which varied from 0.15 to 0.35 for 30 and 120 lbs/A of N, respectively. Range for spatial dependence[2] of grain yield varied between 138 and 402 feet for 30 and 120 lbs/A of N, respectively, with most soil property values falling between 261 and 402 feet. Kriged[3] corn yields varied 720 percent, from 15 to 108 bu/A, depending on slope position and N rate. Highest yields occurred at the toeslope and summit positions while lowest-yielding areas occurred on the eroded sideslope (Figure 1). Highest nitrogen-use efficiency values (61 percent) occurred on the toeslope, although no definite pattern was observed over the landscape.

At the Stratton I site, corn yields had similar spatial dependence as shown by index values (Moran’s I) of 0.10 to 0.18 for 0 and 120 lbs/A of N, respectively. Range of spatial dependence was 74 and 122 feet for the unfertilized strip (0 lbs/A) and 120 lbs/A, respectively. Kriged corn yields varied 252 percent from 44 to 111 bu/A over the landscape, depending on position and N rate (Figure 2). Highest yields occurred at the toeslope. Yields were not normally distributed. Coefficients of variation were low (18 percent) and similar for both N treatments.

Nitrogen-use efficiency was less variable over the Stratton I landscape than at the Sterling site, yet similar values occurred at both landscapes. Higher nitrogen-use efficiency values (37 percent) occurred at the toeslope, with all other positions showing similar values.

Soil available N. Total available N (NO_3-N + NH_4-N) measured to the 4-foot soil depth varied from 28 to 71 lbs/A of

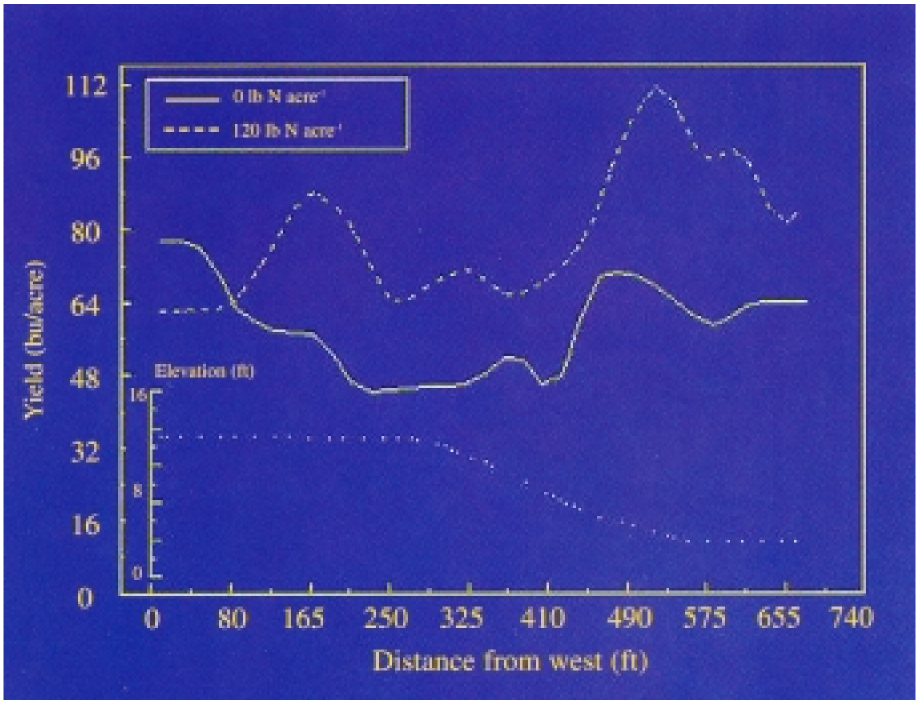

Figure 2. Spatial variability of corn grain yields of two N treatments, Stratton, CO, 1996.

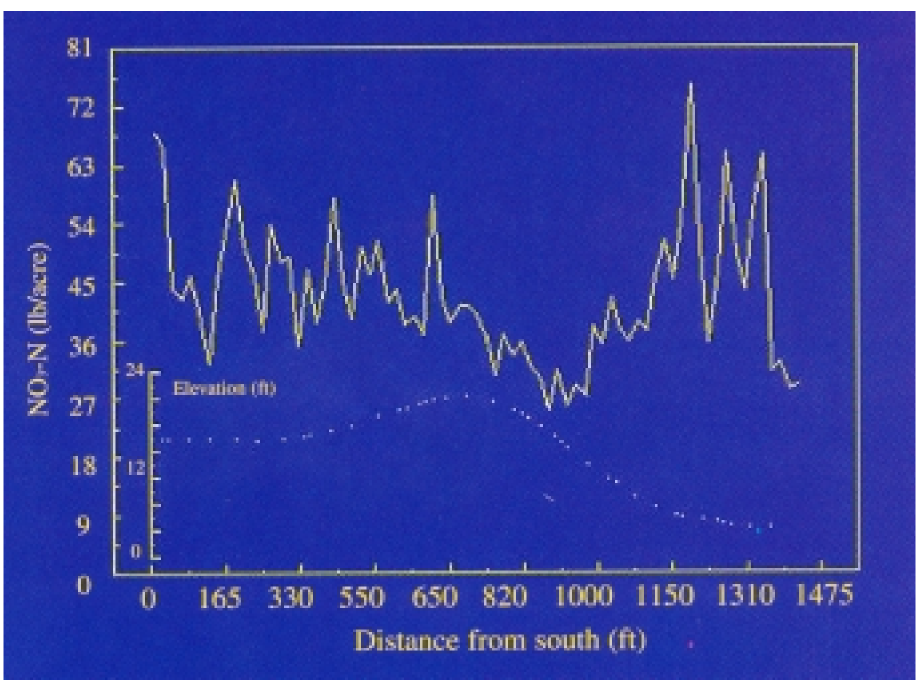

Figure 3. Spatial variability of soil profile (4-ft depth) NO_3-N, Sterling, CO, 1996.

N along the Sterling landscape. Soil NO_3-N ranged from 25 to 75 lbs/A of N (Figure 3). The 4-foot profile for NO_3-N was spatially independent at the 22 sampling positions. This means that the soil NO_3-N level at one location was not related to the soil NO_3-N level 20 feet away at Sterling. These results are very disturbing because the whole theory of VRT is that soil parameters are spatially dependent – i.e., the soil test level at point “A” is related to the soil test level of its close neighbors (point “B”, “C,” etc.). We are continuing to investigate this finding. In general, residual NO_3-N was low over this landscape, which is expected in fields that have not been overfertilized during the previous season.

At the Stratton I site. NO_3-N at the 4-foot depth showed strong spatial dependence. A range of spatial dependence was 74. Residual NO_3-N in the soil profile varied 1,200 percent from 19 to 222 lbs/A of N. On the summit and sideslopes, NO_3-N content was low (approximately 35 lbs/A of N). However, NO_3-N soil level was as high as 225 lbs/A of N on toeslopes.

N mineralization. Kriged daily N mineralization rates varied from 0.23 to 0.96 lbs/A of N per day, depending on position along the Sterling landscape.

At the Stratton 1 site, N mineralization rates varied from 0.19 to 1.6 lbs/A of N per day. Highest N mineralization rates occurred on the toeslopes, the most favorable environment in the landscape due to highest organic matter content and available soil water throughout the season.

For both the Sterling and Stratton I landscapes, average daily N mineralization rates were 0.5 and 0.57 lbs/A of N, respectively. This means that these soils were producing (mineralizing) about 0.5-0.6 lbs/A of N that is available for plant use.

N fertilizer response

Sterling. N fertilizer applications increased corn grain yields at 53 percent of the positions along the landscape. No effect of applied N was observed at 33 percent of the positions, while the remaining 14 percent suffered reductions in yield (Figure 1). Yield response to N fertilizer was linear, meaning that under these conditions maximum yield was not achieved at the N rates used in this study, which was high (120 lbs/A of N).

Stratton 1. Positive yield response to N fertilization occurred at 76 percent of the positions along the landscape. No response occurred at 1 8 percent of the positions, while only 6 percent showed reduced yields (Figure 2).

Stratton 2. A quadratic yield response to N fertilization was observed on the landscape. N rate for maximum yield was 104 lbs/A of N.

All sites. Considering the landscapes, a significant yield response to N fertilizer occurred at both the Sterling and Stratton sites. If it is assumed that N fertilizer-use efficiency is 50 percent, N requirement for dryland corn will vary between 1.12 and 1.6 lbs N/bu of total plant uptake or 0.9 and 1.23 lbs N/bu of grain uptake. These values agree with current N recommendation algorithms that are being used in this region.

Soil productivity index

When all soil parameters were evaluated, yields were higher where the profile NO_3-N, surface organic matter, soil organic N, and mineralization rates were high, and lower in positions with high pH and lime content. The problem is that several soil properties that vary along the landscape contributed to variation in grain yield, either positively or negatively. One way to isolate the “cause and effect” relationship is by using a “soil index” that represents all soil properties of interest. This was calculated by principal component analysis, which identifies those factors contributing positively or negatively to corn yield. When considering the impact of soil

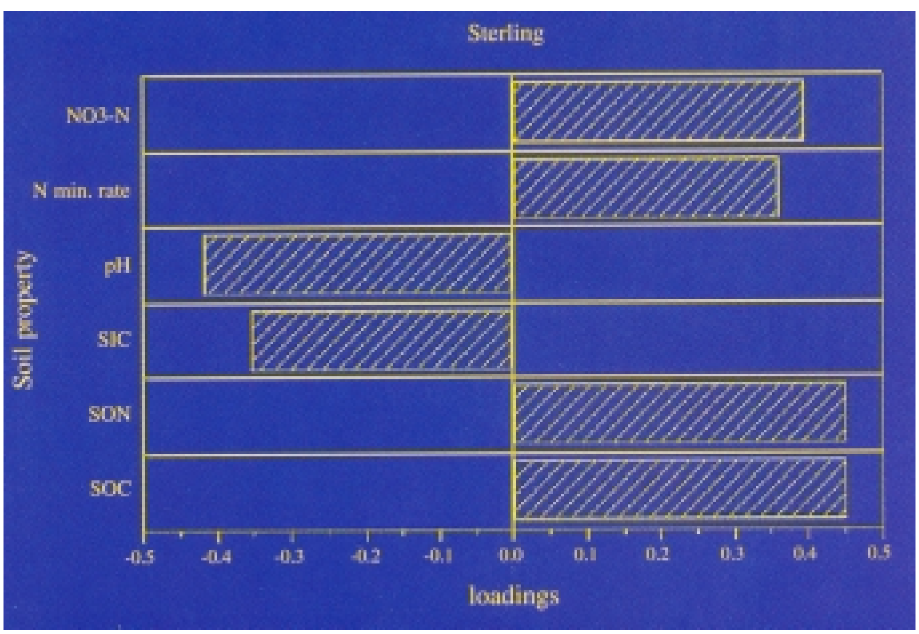

Figure 4. Loading of the different soil properties on the value of Principal Component used to predict corn yield.

organic matter, soil organic N, lime content, pH, N mineralization rate, and profile NO_3-N on yield, about 58 percent of total yield among variance positions was explained. Soil index values and corn yields were positively affected by soil organic matter, soil organic N, profile NO_3-N, and N mineralization rates, and negatively affected by lime content and pH (Figure 4).

These results show that using only one soil test parameter to predict yield response to applied fertilizer has limited effectiveness. A multi variate approach to fertilizer application is required since yields and yield response to fertilizer are dependent not only on nutrient level in the soil but also on several other factors.

Procedure

Selected landscapes were near Sterling and Stratton in eastern Colorado, varying 220 to 1,300 feet in length. Corn was planted no-till in a wheat-corn-fallow cropping system. Composite soil samples to a 4-foot depth in 12-inch increments were taken along each transect. Hybrids were NK 4242 and Pioneer brand 3752. N was banded at 30, 60, 90 and 120 lbs/A at Sterling and Stratton 2 sites. At Stratton 1, rates were 0 and 120 lbs/A. N was dribbled as UAN over the row at planting. P_2O_5 was applied at 15 lbs/A to all treatments.

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[1]Moran's I is a dimensionless statistic that ranges from –1 to +1. It determines spatial relationship of measured parameters. A large Moran's I (+/-1) indicates a strong relationship between measured parameters, while zero indicates complete independence among parameters.

[2]Range for spatial dependency means properties within these distances are spatially dependent or related, while properties at greater distances are not related to each other.

[3]Kriging is a statistical technique used to interpolate values across an x,y coordinate system based on the value of the surrounding parameter. In this case, trends in yields over the landscape are interpolated from data at the point of interest as influenced by surrounding yield values.