Site-Specific Management Guidelines

D.W. Franzen and N.R. Kitchen SSMG-5

# Developing Management Zones to Target Nitrogen Applications


## Summary

Whether the goal is to determine the level of soil nitrogen (N) or the soil yield potential, management zones for N fertilizer management can be constructed using a variety of tools, including topography, aerial photographs, satellite imagery, soil electrical conductivity sensors, yield maps, and intensive soil survey data. For the producer starting out, viewing satellite images and/or aerial photos that are relatively inexpensive to obtain and comparing them with landscape features would be a good place to start.

More than one layer of information may be necessary to determine similarities between patterns and identify nutrient management areas. Often there are logical reasons for N patterns to exist in fields, and these patterns are stable between years. Zones can be constructed and managed for N using a fraction of the number of soil samples required to reveal the same zones through grid sampling. Zone sampling results in lower sampling costs for variable-rate fertilizer application and allows precision farming to be much more practical for producers of commodity crops. Using these principles, the next step would be to develop computer models to automate the zone development process and eliminate reviewing several maps for each field by the producer in order to decide where to draw zone boundaries.


Determining the amount of N fertilizer to apply to meet crop needs is challenging. Inorganic forms of N tend to be transient in soils; N losses from the root-zone due to leaching, denitrification, and volatilization are common on agricultural soils. The amount of N mineralized from organic matter can also vary tremendously from year-to-year. Factors such as precipitation, soil temperature, and amounts and types of freshly added plant residues influence N availability from organic matter decomposition. Further, the N content of healthy crop plants and N removed in harvested grain is high. Therefore, as yield potential increases, there is a corresponding need for N to meet crop requirements.

In spite of the dynamics of N in agricultural soils, effective diagnostic tools and procedures have been developed that can help farmers make good N management decisions. Some of these same tools are now being used to help develop variable-rate N management plans within fields. New technologies are also being developed and adopted. In general, two sources of within-field variability should be considered when determining which tools and procedures are most important for developing variable-rate N management plans:

1. The variability of the soil to supply N to the crop, typically determined with some type of soil testing (e.g., soil nitrate [$NO_3$] or soil organic matter).
2. The variability of the soil to provide a suitable rooting environment for crop plants or the yield potential of the soil, typically determined by some type of soil/yield classification (e.g., soil maps, yield maps, drainage maps, and soil water storage maps).

## I. Variation in Soil Nitrogen

Site-specific sampling for soil nutrients is often conducted using grid sampling. Grid sampling is a systematic sampling that is ideally used at a scale dense enough so that existing fertility patterns and levels within these patterns are reproduced. Grid sampling is used because it is an unbiased approach that does not assume a relationship of fertility patterns with any more easily defined field attribute. Nitrogen sampling is different than sampling of phosphorus (P), potassium (K), and soil pH. Soil must be sampled each year that N is applied because of the chemical transformations it is subject to and due to N mobility in the soil. Nitrogen sampling is also usually performed to a deeper depth (from 1 to 6 feet), depending on the crop and soil region being sampling. Thus the expense of grid sampling and the time to sample is usually much higher and generally cost prohibitive when compared to sampling for nutrients needing only a 0 to 6 inch core. However, many studies have demonstrated that soil N levels are frequently related to soil type and/or

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landscape position, leading to the use of management zones to direct or target sampling. Other measurements and observations, including soil electrical conductivity sensors, yield mapping, aerial photographs, and satellite imagery, as well as detailed knowledge of soil series, can be helpful in determining management zones similar in N availability. Appropriate grouping of areas before soil sampling can reduce the number of soil samples needed and help make sampling a cost-effective tool in creating a map of N variability and in developing a variable-rate N plan.

## A. Topography

Early work in North Dakota showed that similar patterns of N appeared in successive years (**Figure 1**). This phenomena came as a surprise, but it indicated that some underlying soil property, probably landscape, was involved in directed N levels.

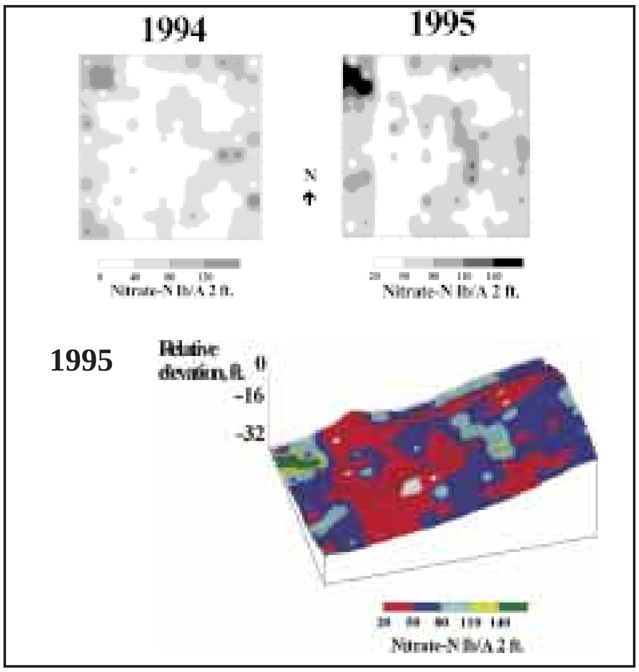


**Figure 1. Similar patterns of $NO_3$-N in two successive crop years, fall samplings, and the 1995 $NO_3$-N map superimposed over topography (each field is a square 40 acres in size).**

The reason for N to be highly related to topography is based on internal and surface movement of water in soils. Nitrate-N is mobile in the soil and appears to move to the same places each year. The relationship of soil nutrients with landscape is not a new concept and has been researched by several Canadian scientists for a number of years. **Figure 2** illustrates how water moves in relation to divergent and convergent landscape positions.

Basing N management zones on topography is attractive because the data gathered from these zones contain the needed information at a fraction of the cost of grid sampling. However, determining exactly where to fit the N level boundaries may not be clear. Where does the hilltop end and slope begin? Where does the slope end and the depression begin? Other measurements and observation may be used to help define boundaries.

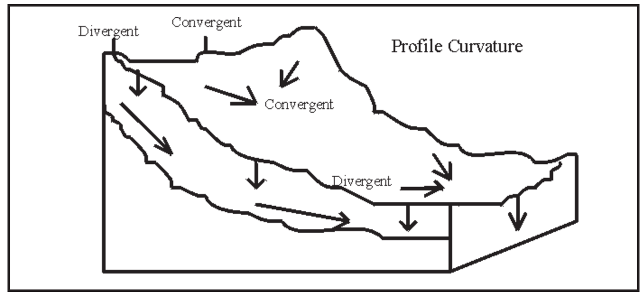


**Figure 2. Concept of surface and subsurface water movement in divergent and convergent landscape positions.**

## B. Yield maps

Yield maps are attractive to some for zone definition because they are readily available to many growers. However, numerous factors other than soil N can potentially cause yield variability. In North Dakota research, yield maps were only useful to define areas that were low in yield each year. Yield differences from other factors not related to N, such as insects or weeds, discount using yield maps to define N management boundaries.

## C. Aerial photography and satellite imagery

Aerial photography and satellite imagery were useful in potato, sugarbeet, corn, and wheat to define management zones. The management zones defined were very closely related to landscape features (**Figure 3**).

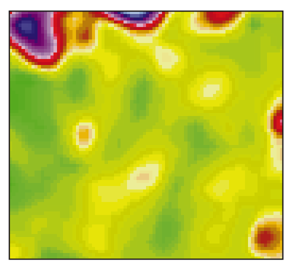

**Figure 3. The 40 acre Valley City wheat field, SPOT satellite image, 1998. Patterns are similar to topography (Figure 1), EC (Figure 4), $NO_3$ (Figure 1) and other soil fertility features (not shown).**

## D. Soil electrical conductivity

Soil electrical conductivity (EC) sensors, either by rolling electrodes (e.g., Veris Tech.)[1] or by electromagnetic induction (e.g., Geonics Ltd. model EM-38), can help define management zones. Establishing the relationship of soil EC to various soil properties is important for helping make correct interpretations. For example, in North Dakota, soil EC was not directly related to N levels. The high conductivity zone was related to elevated N levels, but the lowest conductivity areas were actually medium in N, and the medium conductivity areas were lowest in N (**Figure 4**).

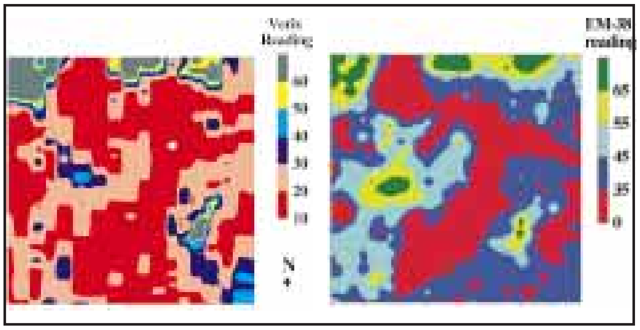


**Figure 4. Soil electrical conductivity at the 40 acre Valley City site, Veris and EM-38.**

However, the soil EC maps related very well to management zones that were originally identified using topography mapping. Soil EC appears to be a pattern detector that can help to define management zones where landscape features may not provide obvious boundaries or provide confidence that management zone boundaries are where they should be.

## E. Soil survey

Most published soil surveys are Order 2 surveys and are too coarse in resolution to allow site-specific management at the scale suggested by nutrient levels. At a site near Colfax, North Dakota, the published survey identified only two soil series, while a more detailed soil survey (Order 1) identifies important zones related to nitrogen levels (**Figure 5**).

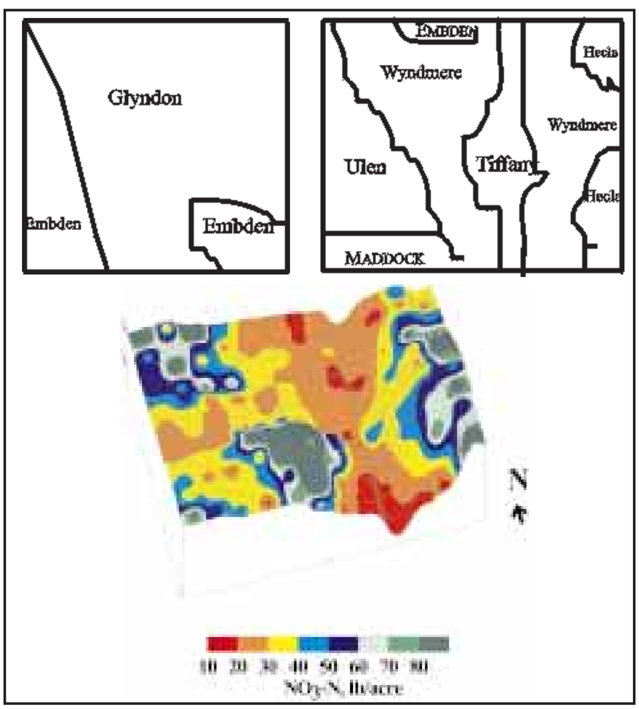


**Figure 5. Published Order 2 soil survey (top left), detailed soil survey Order 1 (top right), and topography overlain with $NO_3$-N concentrations (bottom) for a square, 40 acre field near Colfax, North Dakota.**

In some regions the emphasis has not been on measuring the inorganic N in the soil, but on measuring the soil organic matter content and using that to estimate the amount of N that will be available to crops during a growing season. Soil organic matter is an expression of historic biomass production of the soil, which is mostly a function of the hydrologic properties of the soil and landscape. Therefore, the same observations discussed above for grouping like areas of a field for inorganic-N sampling may also be effective tools in determining like management areas based on soil organic matter. For example, bare soil aerial photography and satellite images have been shown to correspond well to variations in organic matter content in Minnesota.

## II. Variations in Yield Potential

A soil characteristic often causing variability in crop production is the soil's ability to store water for plant growth. Some of the same tools mentioned above for targeting soil sampling have been successfully used for defining within-field zones of varying yield potential.

## A. Soil survey

Traditional soil surveys often provide information on crop productivity by soil mapping units. In the U.S., county soil surveys report the average grain yield of major crops by soil series. However, as illustrated earlier, the resolution of these published maps often doesn't provide the detail needed to effectively define different productivity management zones.

## B. Topography

Slope position and landform (such as shown in **Figure 2**) are topographic features that also have been used to explain water and crop productivity relationships for agricultural soils worldwide. Generally, footslope positions out-yield upslope positions unless poor drainage causes ponding.

## C. Yield maps

Direct measurement of variability in crop productivity by yield monitoring and mapping is another way to infer soil variability. As discussed, yield maps are confounded by many potential causes of yield variability as well as potential error sources. Averaging multiple years of yield maps has been suggested as one way of establishing stable yield productivity patterns related to soil water. However, in some regions, high producing areas of a field during "dry" years can be low producing areas of the same field in "wet" years. Averaging yield maps may neutralize the information needed to better understand the interaction between soil/landscape properties and climate for crop production.

## D. Soil electrical conductivity

Soil EC can be affected by several different soil chemical and physical properties. Soil EC measurements are especially affected by soil texture, particularly clay content and root-zone distribution of clay. As such, soil EC can provide a measure of the within-field differences of water-related properties. For example, on claypan soils in Missouri and Illinois, soil EC variations are strongly related to topsoil

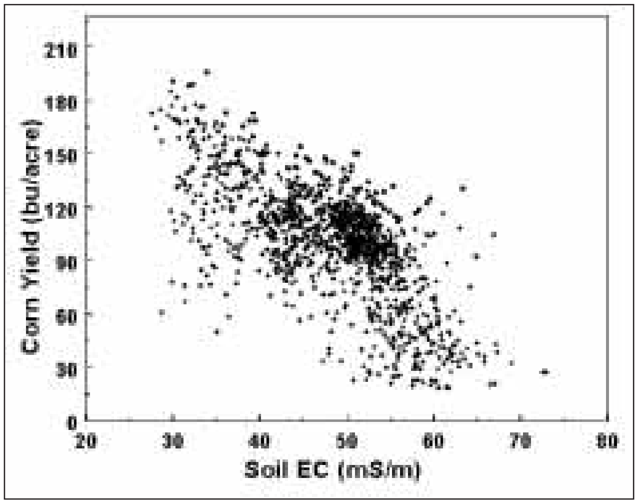


**Figure 6.** **Soil EC helps explain yield variability on claypan soil fields, especially for dry years. Yield decreased as soil EC increased, or yield decreased as topsoil thickness decreased.**

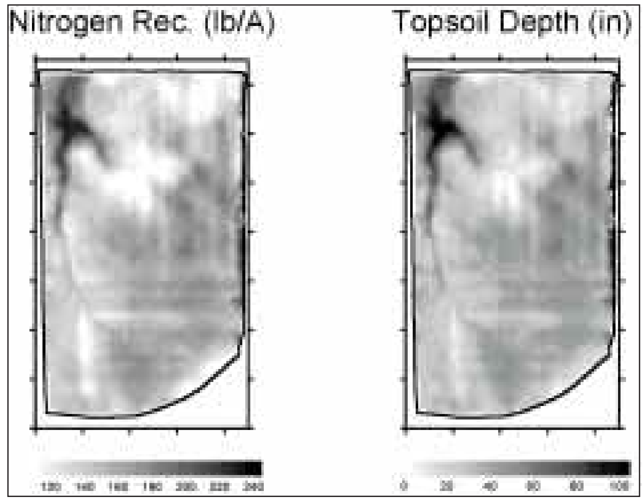


**Figure 7.** **Using soil EC to determine topsoil depth (right map), N fertilizer was applied variably (left map) to match yield potential on this 70 acre field near Centralia, Missouri.**

thickness to the high-clay Bt horizon. This topsoil thickness feature reflects landscape water flow and soil-water storage variability of these soils, the very properties that affect yield potential.

With soil EC measurements determining topsoil thickness, yield potential can be estimated and used to employ a variable-rate N fertilizer. This approach for N management has been tested and found to be effective (**Figure 7**). ■

[1] Names are necessary to report factually on available data; however, the authors or USDA neither guarantees nor warrants the standard of the product, and the use of the name implies no approval of the product to the exclusion of others that may also be suitable.

**This Site-Specific Management Guideline was prepared by:**

**Dr. D.W. Franzen**
Extension Soils Specialist
North Dakota State University
Soil Science Department
229 Walster Hall
Fargo, ND 58105
Phone: (701) 231-8884
E-mail: dfranzen@ndsuext.nodak.edu

**Dr. N.R. Kitchen**
Soil Scientist
USDA-ARS
University of Missouri–Columbia
240 Agricultural Engineering Building
Columbia, MO 65211
Phone: (573) 882-1135
Fax: (573) 882-1115



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