Variable Rate Fertility Management

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Fertility is the foundation of high forage and grain yields. With the large variation in soil types in many crop fields of the Northeast, variable rate fertility management is a natural step to take to improve crop yields. Defining management zones with significant differences in fertility requirements and applying the inputs most likely to respond to variable rate management are for essential success. In northwestern NY grain and forage crops will most likely respond to applying variable rates of lime, potassium, & nitrogen. Variable phosphorous and sulfur rates also have potential for inclusion in fertility programs.

Defining Management Zones

The first step in variable rate management is identifying separate areas of each field that will receive different rates of nutrients. These management zones often use some combination of traditional soil tests (grid or zone sampling), data from a Veris unit or similar machine that measures soil conductivity (and in some cases pH and organic matter), the NRCS soil type maps, satellite or aerial images, and multiple years of yield data. Currently yield maps are easiest to generate during grain harvest, while forage yield monitoring is still in its infancy. Most farms have at least three management zones (low, medium, and high yield potentials) across their farm, though it's possible to have many more.

In some cases there may not be enough difference between management zones to justify variable rate applications. For example if the fertilizer recommendations for potassium were 80 lb./acre, 90 lb./acre, & 100 lb./acre of K_2O in three different management zones in the same field variable rate management would not be very beneficial. Another field with potassium recommendations of 50 lb./acre, 100 lb./acre, and 150 lb./acre in different management zones would probably worth the effort and added expense of variable rate management. Another factor to consider before going down the road of variable rate management is what rates are possible to apply with the equipment available. Having management zones requiring 15 lb./acre difference in fertilizer does not do a farmer any good if they can only vary their application rate by 25 lb./acre increments.

Prioritizing Variable Rate Fertility Inputs

Before any variable fertilizer is applied, variations in soil pH should be determined within each management zone. Different soil types have vastly different liming requirements in order to change soil pH. A sandy soil would only need 0.5 ton/acre of lime to raise the pH from 6.0 to 7.0, while a loamy soil would need 1.5 tons/

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acre and a clay soil would need 3.0 tons/acre of lime (100% effective neutralizing value). With the cost of lime and the wide range of soil types within fields, variable rate liming will be a sound investment on many farms. While variations in soil pH have traditionally been determined by grid sampling and wet chemistry analyses, on-the-go sensors now have the ability to reasonably measure soil pH directly in the field at a much finer resolution than traditional soil sampling. These in-field units also greatly reduce analysis costs, making them an attractive option for farmers. It's important to note that in-field measurements of crop nutrients are still in the early stages of development, and targeted soil sampling within management zones will still be necessary for the foreseeable future.

While there are 16 essential plant elements for growth, the focus of fertility programs has traditionally been on the big three—nitrogen, phosphorus, & potassium**.** Crops remove higher amounts of **nitrogen** and **potassium** than other any other nutrient, *Table 1,* making them the most likely candidates for increases in yields and profits from variable rate management. Additionally the increases in nitrogen and potassium fertilizer prices in recent years have made variable rate management of these nutrients a very attractive option to farmers.

Soil types vary considerably in their ability to supply potassium to crops. When growing corn a very-low testing clay only requires ~50 lb. K_2O/acre, but a silt loam would need ~80 lb. K_2O/acre and sand ~120 lb. K_2O/acre. In addition to potassium supply differences based on soil type, crops also removed different amounts of potassium, *Table 1*. Alfalfa, soybean, corn silage, and possibly grass fields are great candidates for variable rate potassium management given their high demands for this nutrient.

Table 1: Crop Nutrient Removal

	Pounds Removed Per Acre					
Nutrient	Corn (250 Bu)	Soybeans (80 bu)	Wheat (100 bu)	Corn Silage[1] (11.6 ton DM)	Alfalfa (6 ton DM)	Orchardgrass (6 ton DM)
N	188	300	117	260	350	300
P_2O_5	50	66	34	52	40	50
K_2O	50	118	42	200	300	320
Ca	7.5	30	3.3	22	160	-
Mg	23	16	17	54	40	25
S	19	37	6.6	31	44	35
Cu	0.1	0.08	0.07	0.13	0.10	-
Mn	0.13	0.10	0.17	1.60	0.64	-
Zn	0.23	0.08	0.26	0.48	0.62	-

Source: Adapted from Table 9-1, pp. 299-300 in Soil Fertility and Fertilizers
[1]Nutrients removed from corn grain (200 bu corn at 56 lb./bu corn) plus 6 tons of corn stover.
*Note: Nutrient removal rates are **not** fertilizer recommendations. Fertilizer recommendations are based on nutrient removal rates from yield goals minus soil test levels.*

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The story is a little more complicated for nitrogen variable rate management compared to potassium. Given the dynamic nature of nitrogen, methods that include in field measurements of organic matter, NDVI, and crop biomass are being adopted to fine tune nitrogen application rates beyond simple management zone assignment. There is some debate how much nitrogen to apply to the low, medium, & high testing areas of the field. Should the low yielding areas be pushed with more fertilizer? Should the high areas be given an extra boost? According Josh McGrath of the University of Maryland when discussing variable rate nitrogen management in corn, *"When we side-dress corn at V6-V8 using NDVI and reference strips (a strip with more than sufficient N applied at planting and a strip with no N applied before side-dress) we can apply based on responsiveness and yield goal, applying the lowest rate to the low yield potential areas, medium rates to the highest yielding, highly responsive areas, and the highest rates to the areas that have high yield potential, but perhaps less soil supply. This approach accounts for yield potential and N responsiveness."* We will be evaluating Professor McGrath's method during the 2014 season and are currently seeking farms to participate. Besides corn, variable nitrogen management is a great fit in small grain fields and potentially pure grass stands. However fields with long-term manure histories may not be as responsive to variable rate nitrogen applications compared to those without manure due to the long-term build-up of nitrogen from the manure's organic matter. However manure fields have not always received uniform levels of application, presenting another opportunity for variable rate management.

Responses to variable rate management are also common for phosphorous in grain crops, but fertilizer placement is as important as the rate of phosphorus fertilizer applied. Work from Ontario has shown a larger yield response from placing MAP near the wheat seed compared to broadcasting 4 times as much MAP on the surface. Similar to nitrogen, fields with a history of manure applications may be less likely to respond to variable phosphorus rates.

Prior to the Clean Air Act, the sulfur in the acid rain across the Northeast also supplied most, it not all, of the sulfur needs of the crops in the region. Now most crops respond to sulfur applications in the 15-25 lb./acre range. While less work has been done with variable rate sulfur fertility than other crops, using soil organic matter levels to define low, medium, and high management zones is a good place to start if the field does not have long-term manure history. It may difficult to vary sulfur applications due the relatively low levels of application and the type of application equipment available.

Variable rates of lime based on correcting soil pH will likely supply the variable rate calcium and magnesium needed by crops that is not already supplied by the soil. All liming materials contain very high levels of calcium (and some supply magnesium), many Northeast soils contain high amounts of calcium and magnesium, and crop removal of calcium and magnesium is relatively low compared to other nutrients for most crops, *Table 1.* If soil Mg tests are low, dolomitic lime should be instead of a $CaCO_3$ (high calcium) lime to replace the Mg removed by the crops. However balancing soil for Ca:Mg:K ratios has not been demonstrated to consistently improved crop yields, quality, or other parameters in University research trials. Additionally it is difficult to document a change in soil base saturation independent of soil pH. Variable rate liming to manage soil pH with a high calcium lime or dolomitic lime (if soil Mg is low) will supply the needed calcium and magnesium needed by the crops commonly grown in NY in most, if not all, situations.

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The likelihood of micro-nutrients responding to variable rate management is very low. In most cases uniform application will provide the needed nutrient across the entire field. Zinc applications are becoming more common in corn, manganese in soybeans, and boron in a variety of crops. Additionally applying very small variable rates of micro-nutrients will likely be more difficult than other nutrients applied at much higher rates. If foliar applications at variable or uniform rates of these or other micro-nutrients are attempted they should be based on tissue tests. Sandy & muck soils, soils without manure history, and soils with extreme pH levels (<6.0 or >7.0) are most likely to respond to micro-nutrients.

Making multiple applications of nitrogen and potassium will also improve fertilizer crop uptake and yield on many farms. Nitrogen losses can be greatly decreased with multiple applications to corn, wheat, and grass fields. Applying all of the nitrogen at the beginning of the season greatly increases the risk of nitrogen loss due to yearly spring rains. As potassium application rates increase on haylage fields spreading the total fertilizer application across multiple cuttings becomes necessary to keep forage K at desirable levels while allowing for more efficient use of potassium throughout the growing season.

In order to have success with variable rate fertility management zones must have differences in fertilizer and lime rates that are worth the investment of variable rate management. The application equipment also needs to be able to apply the desired rates. Money spent on variable rate fertility should be prioritized to the inputs used at the highest levels (lime, potassium, & nitrogen), followed by those with a reasonable chance of a response (phosphorus & sulfur), and only then the micro-nutrients (zinc, manganese, boron, copper, etc.).

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