ADVANCEMENTS IN NITROGEN AND POTASSIUM FERTILIZER RECOMMENDATIONS IN NORTH DAKOTA OVER THE PAST 30 YEARS

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ABSTRACT

Beginning my career at NDSU as Extension Soil Specialist June 13, 1994, I inherited the obligation of periodically revisiting crop nutrient recommendations and determining whether adjustments were needed. The state of the state in 1994 was composite soil sampling, a dominantly wheat-based cropping system, and yield-goal-based fertilizer recommendations. First addressing site-specific soil sampling, I was surprised to find that zone soil sampling was an excellent predictor of residual nitrate and other nutrient patterns within fields, making sampling for site-specific nutrient application practical. Zone soil sampling led the realization that nutrient recommendations were poorly related to yield responses within fields, resulting in many N-rate trials in spring wheat/durum, corn, sunflower and most recently 2-row malting barley. The findings indicated that N recommendations should be relative yield-based within regions and cropping systems, not actual yield-based. Soybean is now the dominant ND crop, with wheat #2 and corn #3, canola #4. The change in rotation sapped soil potassium (K) reserves, spurring K rate trials in corn. The results indicated that soil test alone was only half predictive. Considering clay chemistry as well as K soil test resulted in a far better prediction of K need in corn.

My career began at NDSU June 13, 1994. I received my MS in soil fertility under the tutelage of Dr. Fred Welsh at the University of Illinois, then took a job (it wasn't a position) as agronomist for a retail fertilizer chain with headquarters about 20 miles north of Champaign. Being an agronomist at a retail location was unusual for the time. In addition to solving grower problems, keeping up with the latest ag-protection products, and providing support for the soil laboratory within the company I also mixed fertilizer and spray combinations, fixed things, filled ammonia tanks delivered product, tool many, many soil samples, and produced maps (pre-computer coloring pencils) for growers. Within a couple years I was managing the location, then the breadth of the locations. I had the opportunity to make a deal with the owner in 1989 to enter a PhD program under Dr. Ted Peck in a site-specific soil sampling project. I constantly told people that I was still employed, still going to school and still married during those 4 years. Graduating in May, 1993 I continued to work at the firm until the following May, but it was clear that the business would be sold. I interviewed at NDSU for their open Soil Extension Specialist position and was able to get the job. The business sold within 2 months following my move.

North Dakota soil fertility at the time was based on a composite soil test, including 2-foot nitrate-N testing usually in the fall. The major crop was spring wheat, with about 17 other crops following, with corn and soybean as minor crops, grown mostly in the southeast part of the state. My early years were spent continuing the work I conducted for my PhD; determining the grid size for site-specific nutrient application.

However, I found in the second year that nitrate-N patterns, in fact most soil nutrient patterns were stable in area from year to year. The magnitude of nitrate varied, but the patterns remained similar (Figure 1). From that revelation, I continued to develop the zone sampling system for use to direct N application to North Dakota crops, including wheats, corn, sugarbeet, sunflower, barley and others. Various tools were tested for zone delineation usefulness, including satellite imagery, aerial photography, EC sensors, EM sensors, topography and multi-year yield maps. A series of Extension circulars and a sizable number of peer-reviewed publications resulted from these investigations, as well as presentations at this conference.

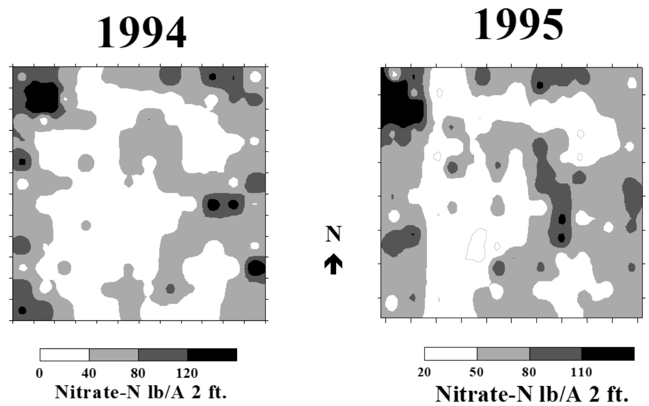

Figure 1. Similar patterns in a 40-acre field near Valley City, ND after spring wheat (left) then after sunflower (right).

In about 2003, I found that although the zone sampling was as useful as a 1 sample per acre grid in determining nutrient patters, and far less expensive, the fertilizer recommendations in place at NDSU did not contribute to advancement in grower profitability. From that date until about 2010, a total of 50+ N rate experiments on spring what and durum were conducted, and 50+ archived studies on spring wheat and durum from the late 1970's until present were combined with the goal of updating N recommendations. Several important principles were stumbled across during this process. The first was the presence of an N credit available against N rate for fields in 6 years or more no-till (including classic no-till, shallow one-pass seeding, and shank strip-till.

In my first winter in North Dakota, January, 1995, I was invited by the then Manitoba-North Dakota Zero-Tillage Conference to speak. I remember it because it was the coldest day I ever spent in my life (45^{o} below zero F), but also because they asked me up to the committee room at the hotel to visit afterwards. After the pleasantries, they stated that they did not follow NDSU N recommendations anymore. They explained that once they were in no-till for a period of years (some had been in no-till for over 20 years by then) that they could shave their N rates without penalty. They had kept on shaving them back enough that their profitable N rates did not resemble NDSU recommendations anymore, so they ignored them. I thanked them, didn't argue (I was from Illinois corn and soybean country, what do I know?) but I remembered.

When it was time to put pen to recommendation in 2010 I remembered the conversation and divided out the long-term no-till sites from conventional sites and they were correct. It took 50 pounds N per acre less N to produce at least the same yield and at least the same wheat protein as it did in conventional till. So it became part of the NDSU recommendations, later part of the N-calculator for spring wheat/durum. When it came time to evaluate N rate in corn, then sunflower, then 2-row malting barley, I deliberately included many sites of long-term no-till with those of conventional tillage and the principle held. The long-term no-till N credit is a part of all of those recommendations.

The second principle was the lack of relationship between yield and N rate. Bill Raun at Oklahoma State University was one of the first to recognize this principle as part of his work with active-optical sensors. It also became apparent to me in my studies that relative yield was far more important than actual yield. Environment is the yield driver. There just needs to be enough N present either in the soil or in supplements to cover basic needs. If environment favors greater yield, it also favors N release from soil and the greater efficiency of uptake by the crop due to favorable moisture conditions.

Support for this principle can be found in Figures 2a of actual spring wheat/durum yield with N rate and Figure 2b of relative spring wheat/durum yield with N rate. Use of relative yield instead of actual yield always resulted in greater regression coefficients, sometimes greater than 3-fold the value of actual yield vs N rate (Table 1).

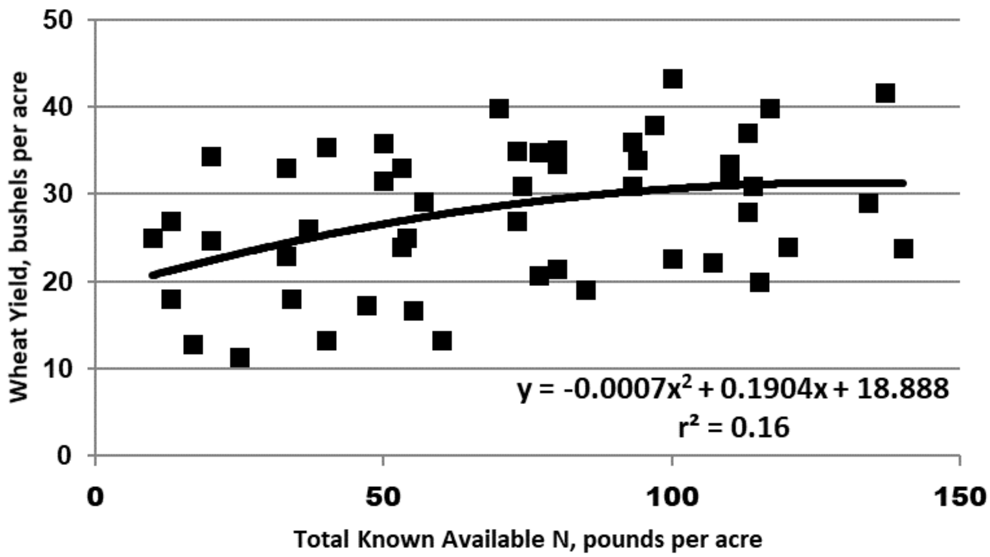

Figure 2a. North Dakota spring wheat/durum yields, west of the Missouri River, compared with total known available N, conventional tillage.

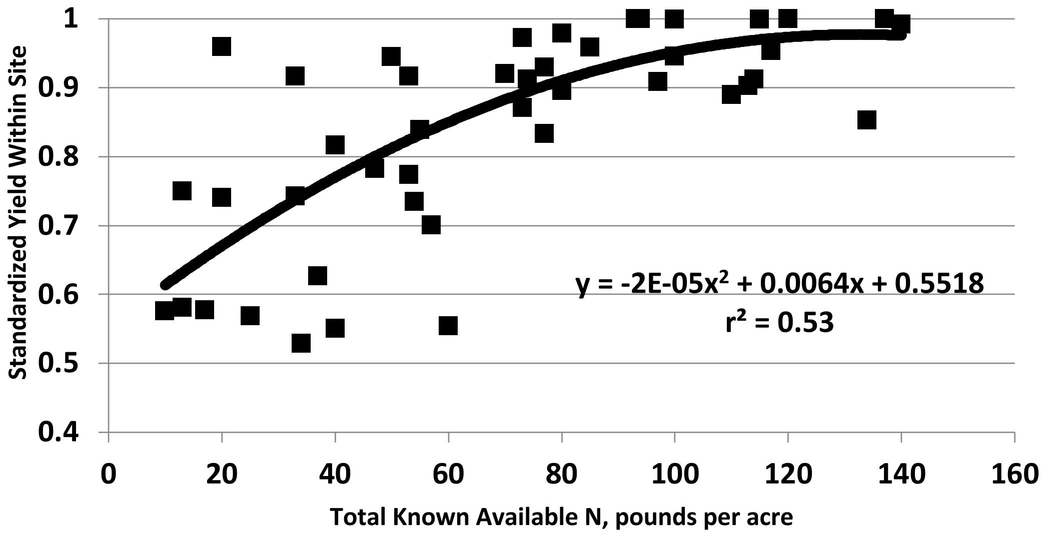

Figure 2b. North Dakota standardized spring wheat/durum yields, west of the Missouri River, compared with total known available N, conventional tillage.

Table 1. Regression of spring wheat/durum, corn, sunflower and 2-row malting barley yields vs total known available N using raw yield and standardized yield.

Comparison			**r^2 with total known available N**	
Crop	**Region**	**Tillage**	**Raw Yield**	**Standardized Yield**
SW/Durum	West	CT	0.16	0.53
SW/Durum	West	NT	0.19	0.62
SW/Durum	East	CT	0.32	0.39
SW/Durum	East	NT	0.26	0.45
Corn	West	NT	0.35	0.68
Corn	East HClay	Ct	0.22	0.47
Corn	East Med Tx	CT	0.29	0.50
Corn	East NT	NT	0.20	0.68
Sunflower	West	NT	0.27	0.47
Sunflower	East	CT	0.14	0.41
Sunflower	East	NT	0.16	0.30
2-row MB	East	NA	0.01	0.55

SW = Spring wheat; MB=malting barley; CT = conventional tillage; NT = no-tillage at least 6 years continuous. HClay are sites with >40% clay; Med Tx are sites with <40% clay.

It was important to develop recommendations within regions. The state division between east of the Missouri River and west of the river are intuitive, because of the age of soil sediment west (residual materials about 60+ million years old) compared to recent glacial materials east of the river less than 12,000 years old. However, the area in the north, at the Canadian border was identified first by the lower N rate required to produce yield compared to the rest of the eastern North Dakota region. The reason was determined to be the high amount of small shale pieces in the soil material, which contain significant mineralizable N from ancient non-exchangeable ammonium sources within their original clay constituents.

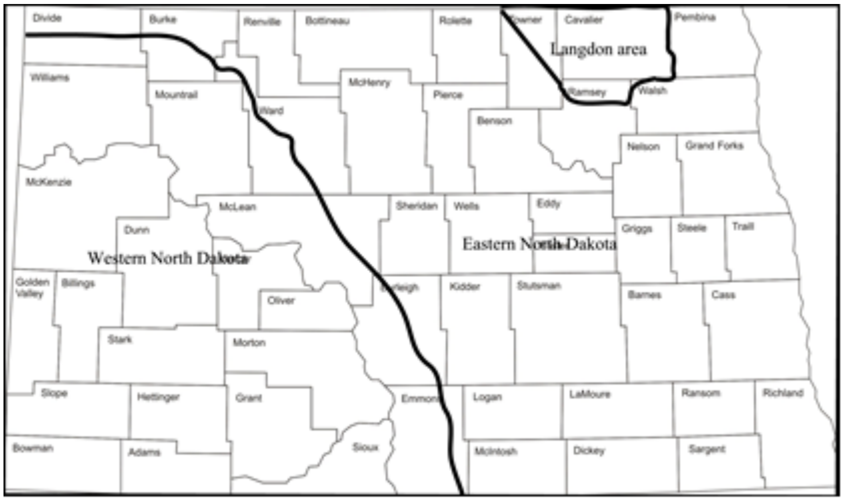

Figure 3. N recommendation regions for spring wheat/durum.

In corn, the high-clay soils of the Red River Valley- the roughly 30-mile-wide area on the very eastern boundary with Minnesota, formerly Glacial Lake Agassiz- is easily saturated by spring rains. Just to the west of these high-clay soils are a series of deep, sandy low organic matter ridges, beach ridges, that are relics of different extents of the glacial lake. Both of those conditions favor loss of preplant/at planting N by leaching in sands, and denitrification in the clays. Corn N rate studies in these soils indicate that loss of over 100 pounds per acre of N during a wet May is not uncommon. Therefore, eastern North Dakota in the corn N-rate recommendation structure is divided into a narrow, Valley encompassing eastern region, while to the west is the Central region, with drier, more forgiving soils.

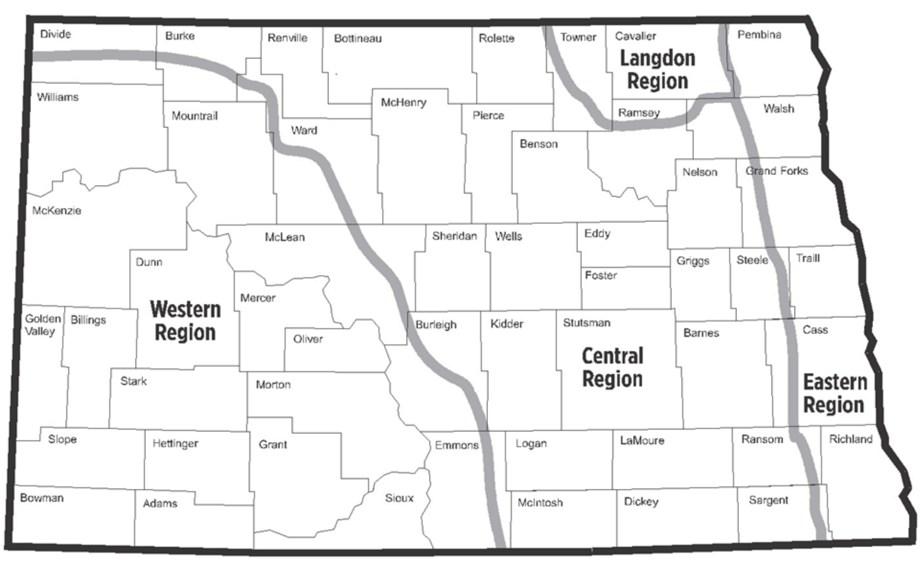

Figure 4. Regions of importance for corn N recommendation in North Dakota.

The N recommendations for corn, spring wheat/durum, sunflower and 2-row malting barley are imbedded within the interaction North Dakota N calculator (Figure 5). The calculator is accessible from my website and contains the sites for all four of these crops.

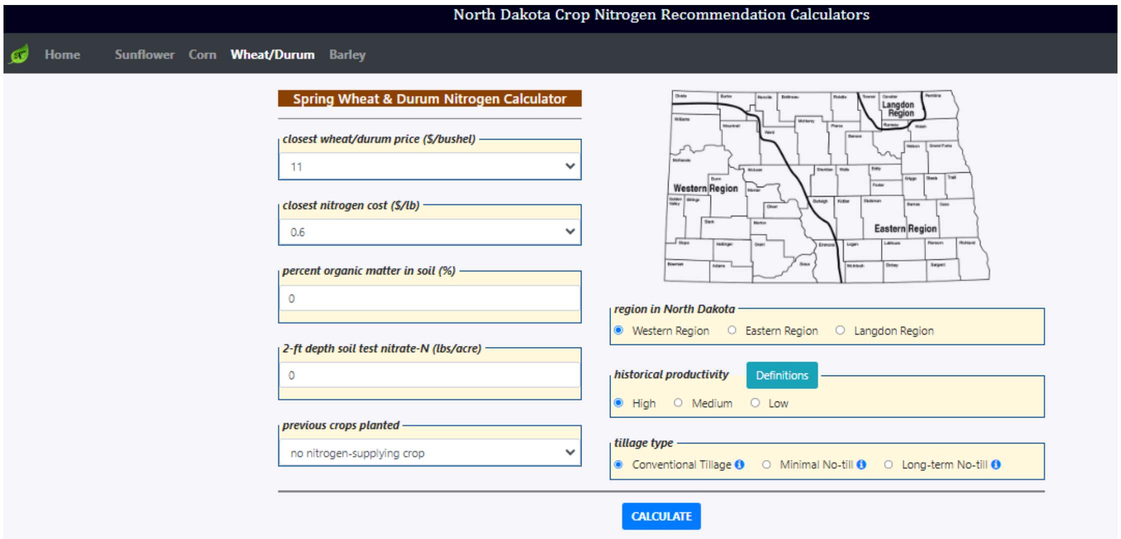

Figure 5. N calculator for spring wheat/durum, sunflower, corn and 2-row malting barley.

Advances in Potassium

I began working in potassium (K) in 2014. By that year, North Dakota was one of the top soybean producers in terms of acreage in the USA and had several million acres of corn as well. In the southeast of North Dakota, corn and soybean had been grown for 30 years in many fields, and the K soil tests were showing drastic declines from their values in the 1970's. I decided it would be a simple matter to have multiple years of multiple K rates in the area, then determine whether 150 ppm was the critical value of not. In the middle of the studies, it was alarming that only half of the sites were diagnosed correctly by the K soil test criteria in place at the time. Some of the studies were responsive with K tests greater than 150 ppm, while other sites with K tests less than 100 ppm showed no yield increase with K fertilizer (Figure 6).

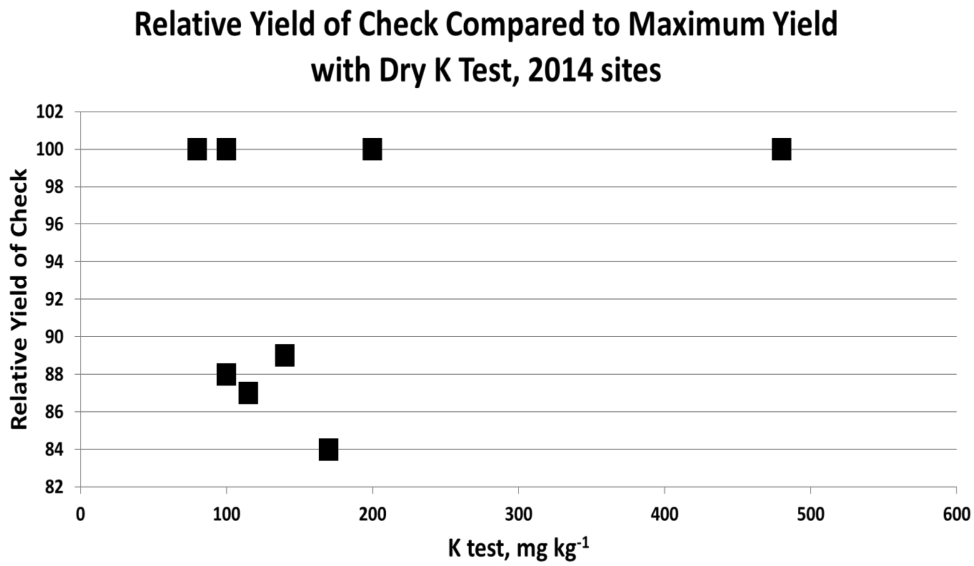

Figure 6. Relationship of soil test K with relative yield of check. Some sites were non-responsive with K tests less than 100 ppm, while some sites were responsive with K tests greater than 150 ppm.

After attending a sobering seminar with Dr. Don Sparks of the University of Delaware, it because apparent that I didn't know anything about K. Because there was a lack of anything but assumptions about North Dakota clay species and potassium feldspar mineralogy, the soil samples from several years of the K rate study were analyzed for clay species. The results indicated that the ratio of smectite to illite clays within a soil helped explain most of the response data (Figure 7; Figure 8).

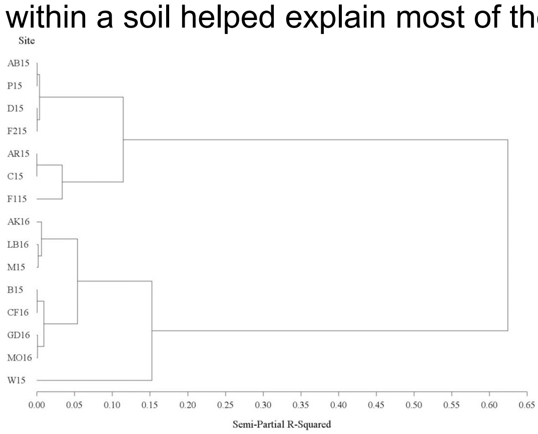

Figure 7. Cluster analysis of K sites by clay species ratio.

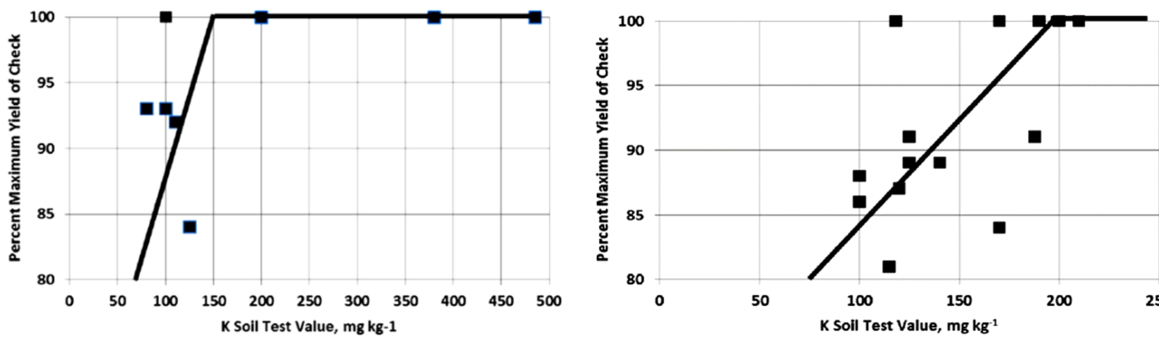

Figure 8. K soil test vs % max yield of check for sites with smectite:illite ration of > 3.5 (left) and <3.5 (right).

Due to the successful relationship of clay species ratio, a survey of North Dakota was conducted, with at least 2, often 3 sites per county sampled and clay species analyzed. The results of this survey was condensed into Figure 9, with areas greater or less than smectite:illite ratio identified.

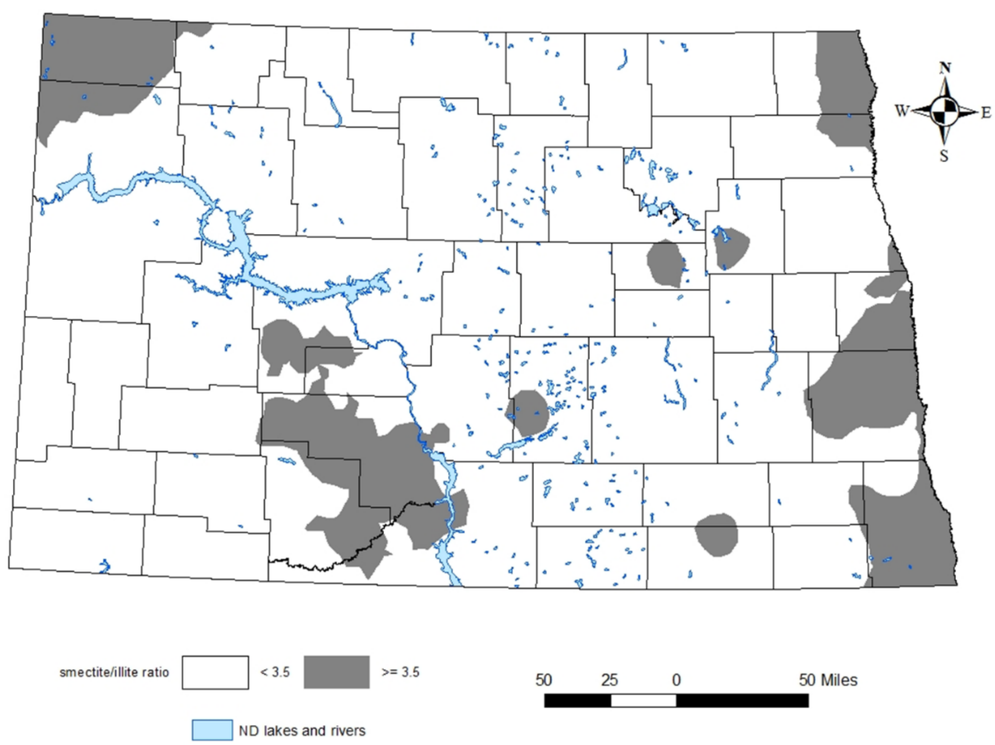

Figure 9. Map of smectite:illite ratio in North Dakota for use in determining K fertilization need.

North Dakota K recommendations are now based on clay chemistry.

For corn, alfalfa:

- Smectite/illite > 3.5, critical soil test value is 200 ppm
- Smectite/illite < 3.5, critical soil test value is 150 ppm

For sugarbeet

- Smectite/illite > 3.5, critical soil test value is 150 ppm
- Smectite/illite < 3.5, critical soil test value is 120 ppm

For spring wheat/durum/winter wheat

- Smectite/illite > 3.5, critical soil test value is 150 ppm
- Smectite/illite < 3.5, critical soil test value is 100 ppm

There are many questions which remain unanswered. Nitrogen and potassium are crop nutrients that are not explained simply. Nitrogen is very biologically and environmentally sensitive, with a little physical chemistry thrown in. Potassium is very physical chemistry-related, with some biology and environmental influence thrown in. My hope is that my contributions and those of my students and colleagues have advanced the science and made farming more profitable and more environmentally sensitive than practices used in the past.

REFERENCES

A host of references may be found at https://www.ndsu.edu/snrs/people/faculty/dave_franzen/