REGIONAL USEFULNESS OF NITROGEN MANAGEMENT ZONE DELINEATION TOOLS

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ABSTRACT

In the Northern Plains of Montana, North Dakota and Minnesota, a number of site-specific tools have been used to delineate nitrogen management zones. A three-year study was conducted using yield mapping, elevation measurements, satellite imagery, aerial Ektochrome® photography, and soil EC to delineate nitrogen management zones and compare these zones to residual fall soil nitrate. At most of the sites, variable-rate N was applied and compared with uniform N application. The site-specific tools compared were universal in their usefulness, although some tools described zone boundaries better at some locations than at others. It was also clear in the study that present N fertilizer recommendations do not adequately account for the specific N rates required by site-specific applications.

Keywords: Nitrogen, zone nutrient management, EC, remote sensing, topography, yield mapping.

INTRODUCTION

Nitrogen (N) recommendations for many crops in the Northern Plains of the US is partially based on residual soil nitrate analysis on 60-120 cm soil cores obtained either in the fall or spring of the year prior to seeding. Zone soil sampling for residual nitrate is becoming more common in the region as farmers look for less expensive sampling methods in order to direct a site-specific variable-rate N application. The zone approach to soil sampling assumes that soil N patterns are logically linked to some inherent causal effect, either natural or man-made. A number of studies have shown that zone-based N management is a reasonable approach to site-specific N management (Franzen et al., 1998; Khosla et al., 2004).

A number of delineation methods have been examined, including topography (Franzen et al., 1996), apparent soil EC (Kitchen et al., 1999; Gangloff et al., 2004), yield mapping (Diker et al., 2002, Gangloff et al., 2004; Adams and Maling, 2004; Elbelhar et al., 2004), topography (Franzen et al., 1998), aerial imagery (Williams et al., 2002; Sripada et al., 2002), satellite imagery (Franzen, 2004; Adams and Maling, 2004; Gangloff et al., 2004), use of soil survey (Franzen et al., 2002), organic matter (Fleming and Buchleiter, 2002; Gangloff et al., 2004) and grain protein (Engel et al., 1999; Long et al., 2008).

In the Northern Plains, different researchers utilized different tools to produce zones. In North Dakota, topography was preferred (Franzen et al., 1998) except for the sugarbeet growing area in the Red River Valley (Franzen, 2004) where remote sensing was primarily used. In Montana, grain protein was preferred (Engel et al., 1999). A number of studies have proposed best predictors for determining optimal nitrogen management zones in site-specific farming (Bausch et al., 2002; Fleming and Buchleiter, 2002; Franzen and Nanna, 2002, Hendrickson and Han, 2000; Lund et al., 2002; Stenger et al., 2002). Additional studies have investigated the use of multiple tools to predict the presence of meaningful nutrient management zones (Kitchen et al., 2002; Chang et al., 2002).

The objective of this study was to investigate the use of several zone delineation tools across a large region of the Northern Plains to determine if the usefulness of a tool was local, or whether similar tools could successfully be used across the region.

MATERIALS AND METHODS

Five sites in North Dakota (Fig. 1), two in Minnesota (Fig. 2) and two in Montana (Fig.3) were established in 2000. The two Montana sites were located within one mile of each other. Elevation measurements, satellite imagery (Landsat 5/7), aerial photography using Ektochrome film nadir at 1,500 m altitude, apparent soil EC using a Veris® EC sensor, and yield maps were developed. Yield maps at most sites were developed using yield monitors, however at Crookston, barley yield was determined by grid-sampled biomass, while sugarbeet yields at both Renville and Crookston were determined by grid-sampled yields.

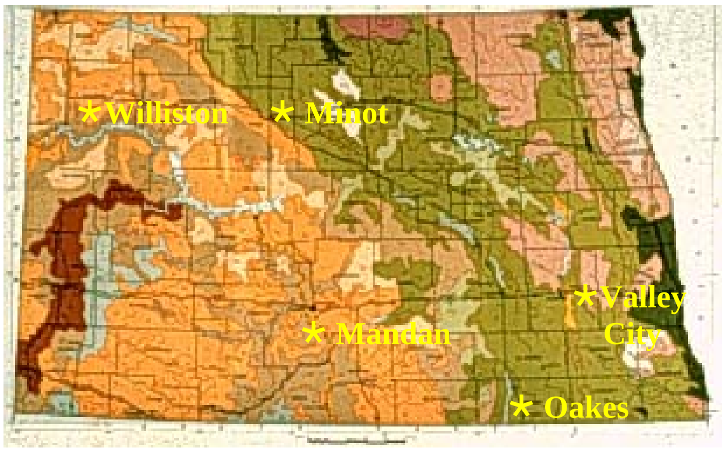

Figure 1. The five North Dakota research sites.

Figure 2. The two Minnesota research locations at Crookston and Renville.

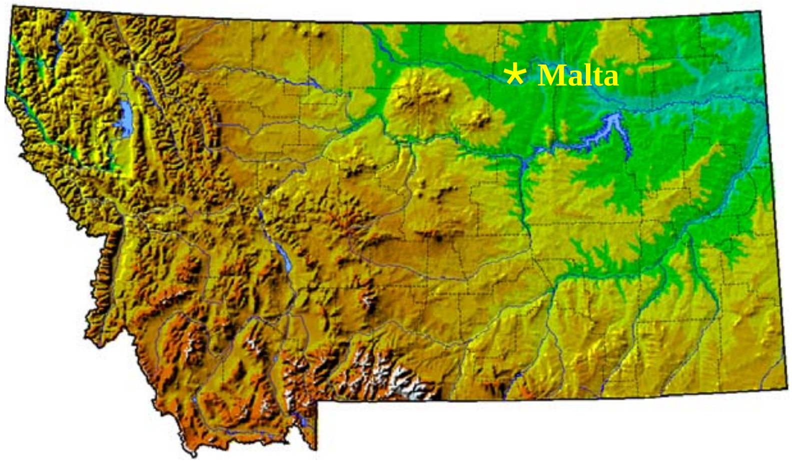

Figure 3. The Montana project research site outside of Malta.

Zones were delineated for each data set by dividing the data ranking into quintals with a relative 1-5 value. Data sets were merged onto a 0.1-ha grid representation of the field, which corresponded to the 0.1 ha grid sampling conducted prior to seeding for the 60 cm residual soil nitrate analysis. Correlations of the zone representation of nitrate were made against the 0.1 ha grid sampled residual soil nitrate for each given year.

RESULTS AND DISCUSSION

Valley City

Topography zones were most consistently correlated with 0.1 ha sampled residual nitrate compared to EC, yield frequency, aerial photograph and satellite imagery (Table 1). In some years, aerial photograph and satellite imagery were superior to topography.

Table 1. Correlation of sampling grid residual nitrate-N with various zone residual N estimates, Valley City, 2001-2004.

Year	EC	Topography	Yield frequency, 2001-2004	Aerial photograph	Satellite imagery
2001	0.28	0.39	0.27	0.43	0.39
2002	0.24	0.41	0.26	0.37	0.50
2003	0.16	0.30	0.21	0.23	0.25
2004	0.20	0.30	0.12	0.33	0.30

Combinations of zone methods were used to determine whether more than one zone represented nitrate levels better than single zones. The results suggest that more than one layer of data, especially the better correlated data with residual nitrate sampling, results in more stable and more highly correlated patterns than any single data layer. The most successful combination of layers tested was topography, satellite imagery and yield.

Table 2. Correlation values for different combinations of data subsets for 2001, 2002, and 2003.

Comparison	Correlation		
	2001	2002	2003
Topography + EC	0.44	0.40	0.32
Topography + EC +Yield	0.50	0.46	0.38
Topography + EC + Satellite	0.49	0.45	0.37
Topography + Satellite + Yield	0.52	0.48	0.40
All Data Layers*	0.54	0.37	0.42

* Includes Order 1 soil survey, topography, aerial photos, satellite, EC, and yield data.

Williston

Correlation of zone nitrate-N estimates compared with sampling grid N estimates were significant for all comparisons (Table 3). Soil EC was mostly highly correlated. Highest correlation was in 2003 with the satellite image, however, the correlation coefficient for satellite imagery in 2002 and 2004 was much lower.

Table 3. Williston, zone nitrate-N estimates compared with sampling grid nitrate-N, 2002-2004.

Year	Yield frequency, 2002-2004	Topography	Aerial photograph, 2002	Satellite image, 2002	EC
2002	0.27	0.28	0.16	0.19	0.34
2003	0.29	0.18	0.23	0.47	0.22
2004	0.21	0.22	NA	0.13	0.33

Crookston

The results (Table 4) show that zones from each delineation tool had r correlation values higher than 0.25 for all but the EC zones for the 2001 sampling. Particularly high correlations were found in the 2002 soil nitrate comparisons from the topography, EC and yield frequency zones. Higher correlations were also seen in satellite imagery and topography for all three years. Consistent correlations above an r of 0.30 were seen in all zone comparisons with the exception of soil EC.

Table4. Correlation of zone delineation method residual soil nitrate estimates with the residual soil nitrate grid sampling, Crookston, 2001-2003.

Year	Aerial zone	Satellite zone	Yield frequency zone	Soil zone	EC	Topography zone
	----------	----------	r	----------	----------	----------
2001	0.32	0.53	0.32	0.10		0.53
2002	0.38	0.26	0.73	0.78		0.76
2003	0.31	0.61	0.31	0.26		0.44

Oakes

Deep EC and shallow EC zones were most correlated with grid soil nitrate (Table 5). This was a sandy site with a narrow range of residual nitrate levels in both 2002 and 2004. Topography, aerial photograph and satellite image were useful in 2002, but not as much in 2004. Shallow EC was consistent in both years, although the zone map developed from SEC was not as highly correlated as DEC. A more in-depth study of the Oakes site with respect to zone delineation methods is published (Derby et al., 2007).

Table5. Oakes, zone nitrate-N estimates compared with sampling grid coil nitrate, 2002 and 2004.

Year	Yield 2002 map	Topography	Aerial photograph, 2002	Satellite image, 2002	SEC	DEC
2002	0.12	0.43	0.24	0.37	0.34	0.46
2004	0.06	0.23	0.16	0.13	0.33	0.43

Renville

A correlation of delineation tool zones with residual soil nitrate was only possible in 2002. The yield frequency, topography, satellite image and EC tools were similar in the zone nitrate estimate correlation with grid-sampled residual nitrate (Table 6).

Table 6. Renville, zone nitrate-N estimates compared with sampling grid nitrate-N, 2002.

Year	Yield frequency 2001-2003	Topography	Aerial photograph, 2002	Satellite image, 2002	EC
	----------	----------	r	----------	----------
2002	0.26	0.21	0.16	0.25	0.21

Montana

The correlation of zone nitrate-N estimates in Montana compared with the nitrate-N (Table 7) measurement in the plots was generally lower than most other locations. Yield frequency zones, topography, satellite imagery and soil EC measurements were more highly correlated compared to the aerial photograph. 2002 was the only year that residual nitrate was available for comparisons.

The residual nitrate in both 2001 and 2002 were very low compared with most other sites. The range of residual nitrate results was between 22 to 33 kg ha^{-1} for the 0-90 cm depth. Therefore, the correlation of zone estimates with the grid sample results was very low. In the west field, topography zones were most highly correlated with residual nitrate grid samples. IKONOS satellite imagery zones were least correlated. Soil EC and yield frequency zones from 2002 and 2004 yield maps were similar in correlation.

Table 7. Correlation of zone residual soil nitrate with the grid sample results, Montana sites, 2001 and 2002.

Site	EC*	Topo	YFZ	Aerial photo	IKONOS satellite	Topo-EC-YFZ	Topo -EC
West, 2001	0.04	0.17	0.05	0.10	0.01	0.06	0.11
East, 2002	0.12	0.17	0.12	0.03	NA	----	----

*EC = shallow EC, Topo = topography, YFZ = yield frequency zones.

In contrast to Valley City, where correlations between zone estimates and residual nitrate sample results were higher than Montana, combining zone data did not result in higher correlations. The result tended to be more of an average of the correlation values from the zones used.

Mandan

At Mandan In 2001, yield frequency maps were most highly correlated with grid sample results, with topography, satellite image (Landsat 7) and shallow EC also highly correlated (Table 8). In 2002, topography was most highly correlated. In 2003, aerial imagery was better correlated than other zone estimates, but topography, satellite image and EC were also highly correlated with grid sample results. Topography was most consistently the zone that had the highest degree of correlation.

Table 8. Mandan correlation of residual nitrate estimates from zones following winter wheat compared with grid sample results.

Year/Field	Yield frequency map	Topography	Aerial photograph, 2002	Satellite image, 2002	SEC
2001/I4	0.82	0.47	0.18	0.78	0.51

2002/I6	0.21	0.37	0.13	0.25	0.16
2003/I5	0.11	0.44	0.51	0.39	0.41

Minot

In 2001, all zone delineation residual nitrate estimates were highly correlated with the grid sample nitrate results. In 2002, EC and topography were most highly correlated. In 2003, satellite imagery and topography were most highly correlated. Topography was most consistently correlated at a high level with grid sample nitrate results.

Table 9. Correlation of zone delineation residual nitrate estimates with grid sampling from 2001, 2002 and 2005 at Minot.

Year	Yield	Topography	EC	Aerial photo	Satellite image
2001	0.61	0.47	0.32	0.43	0.49
2002	0.20	0.43	0.61	0.16	0.27
2003	0.39	0.58	0.29	0.16	0.74

CONCLUSIONS

1. Zone management appears to be a useful tool in managing nitrogen throughout the 3-state region.
2. Topography was one of the most useful zone delineation data sets throughout the region.
3. In the drier west, soil EC and yield frequency maps generally resulted in zones with a higher correlation to soil residual nitrate levels than imagery.
4. In the east, imagery was more useful in developing zones.
5. Use of multiple sources of data within a site (i.e. yield frequency maps, soil EC, topography) generally resulted in higher correlation with soil residual nitrate levels than each individual data source alone.

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