NC STATE UNIVERSITY
DEPARTMENT of SOIL SCIENCE

Spatial Variability of Remote Sensing-Informed Variable-Rate and Uniform Nitrogen Management of Wheat and Corn

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Introduction

In-season, site-specific, variable-rate (SS) N management based on remote sensing (RS) via aerial color-infrared (CIR) photography may increase yield and fertilizer-use efficiency, thus improving profitability and groundwater quality. By addressing spatial variability in crop N requirements, SS N management may also reduce spatial variability of yield.

Objectives

Evaluate the spatial variability and agronomic consequences of in-season, RS-informed N management applied either on a uniform, field-average (FA) or SS basis, compared to the current uniform N-rate determination based on "Realistic Yield Expectations" (RYE) in a typical two-year southeastern U.S. coastal plain rotation: Year 1: corn (*Zea mays* L.); Year 2: winter wheat (*Triticum aestivum* L.)–double-crop soybean [*Glycine max* (L.) Merr.]. Understanding the spatial variability of N requirement and resultant yield may provide insights to help improve N management.

Materials & Methods

Experimental Setup

- 12-ha NC field with three soil map units (Fig. 1)
- Two-year corn (year 1)–winter wheat-double crop soybean (year 2) rotation
- Randomized complete block (RCB) design with three N management treatments (Fig. 1 and below) in 10 reps

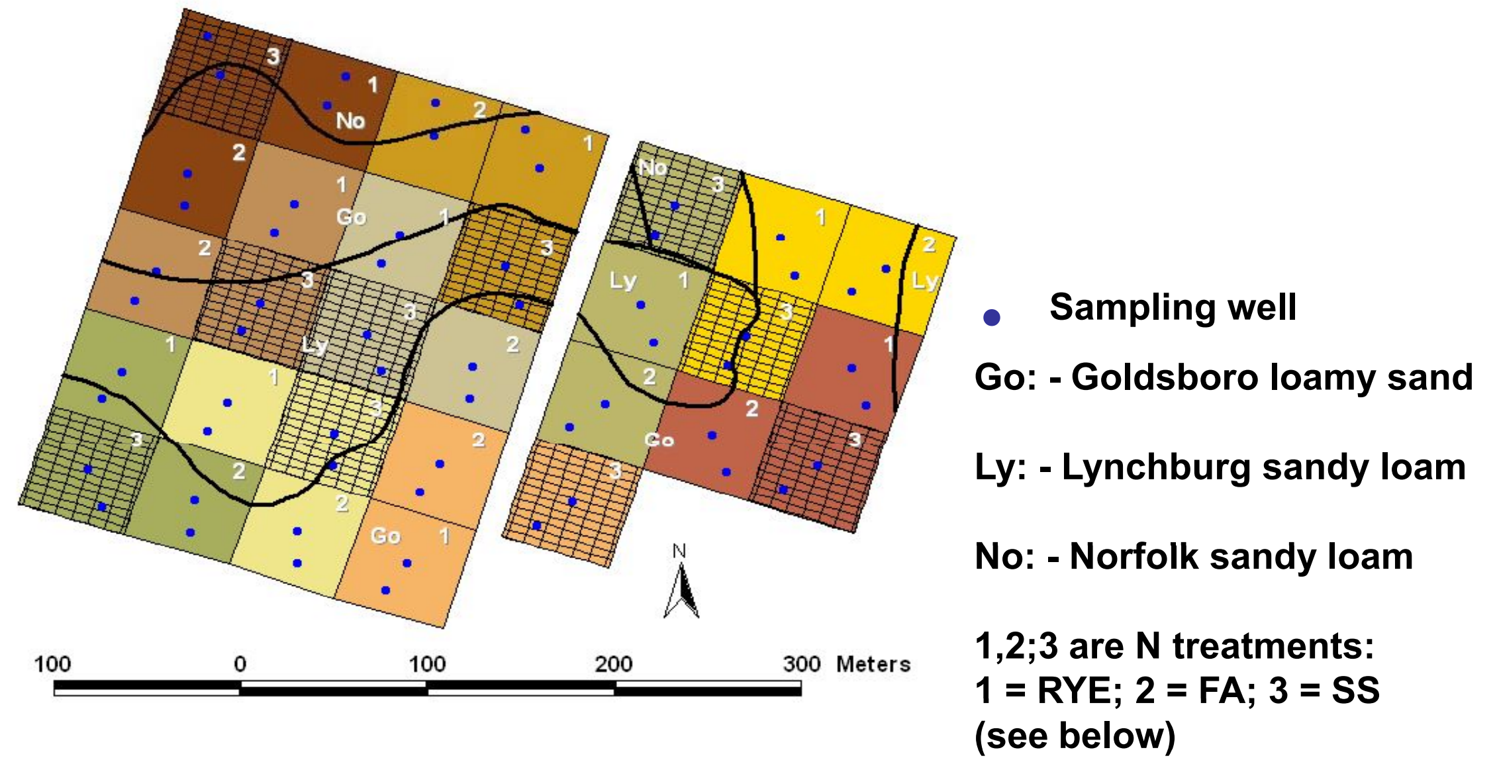

Fig. 1. Field layout of the RCB design at the Lower Coastal Plain Tobacco Research Station, Kinston, NC .

N Management Treatments

1. "RYE": <u>Uniform</u>, whole-field, Realistic Yield Expectation (RYE) management based on NC database RYE and crop N-use factor for the predominant soil type (Goldsboro)

2. "FA": <u>Uniform</u>, whole-field N management based on field-averaged in-season estimates of optimal N rates determined by aerial color infrared photography (CIR)

3. "SS": Site-specific VR-N management based on in-season estimates of optimal N rates determined by CIR. For SS, each plot was divided into subplots for applying VR-N (Fig.1).

Determination of Crop N Requirement and Grain Yield

- Corn: at tasseling (VT) based on Relative Green Difference Vegetation Index: (Near-Infrared [NIR] – Green)/(NIR – Green)$_{\text{high-N reference}}$ (Sripada et al., 2005) (Table 1 & Agronomy Journal cover →)
- Wheat: at Zadoks' GS-25, based on tiller density (Flowers et al., 2001) estimated via normalized NIR: NIR/(NIR + Red + Green); at GS-30 based on tissue N estimated (Flowers et al., 2003) using Green Normalized Difference Vegetation Index, (NIR – Green)/(NIR+Green), and an algorithm relating N rate to tissue N (Flowers et al., 2004). Here, we examine only GS-30 (Table 1).
- Crop grain yield estimated via a combine, yield monitor, and differential GPS; yield monitor data "cleaned" to remove outliers, plot buffers, and high-N reference strips

Table 1: Mean N rates and timing for the three N treatments by crop and year.

	N treatment (see M&M)		
CropYr & time of application	1	2	3
	------kg N ha^{-1}------		
Corn02			
Starter (early Apr)	8	8	8
V2 (late Apr)	104	53	53
VT (mid June)	0	157	83† (0 - 157)
Total	112	218	144† (61 - 218)
Wheat03			
Starter (Nov 2002)	34	34	34
GS-25 (late Feb 2003)	0	67	67
GS-30 (early Apr 2003)	119	67	65† (45 - 67)
Total	153	168	166† (146 - 168)
Corn04			
Starter (early Apr)	8	8	8
V2 (late Apr)	104	53	53
VT (late June)	0	102	102† (15 -181)
Total	112	163	163† (76 - 242)
Wheat05			
Starter (Oct 04)	34	34	34
GS-25 (late Feb 2005)	0	0	0
GS-30 (mid March 2005)	118	134	119† (101 - 134)
Total	152	168	153† (135 - 168)

† Weighted average of the variable N rates (range).

Geostatistical and Statistical Analyses

- Descriptive statistics and AOV determined using SAS v. 9.1
- Semivariograms modeled using GS+ v. 7.0
- Nugget-to-sill ratio calculated to indicate strength of spatial correlation: nugget:sill ≤ 25%, strongly spatially dependent; 25 < nugget:sill ≤ 75%, moderately spatially dependent; > 75%, weakly spatially dependent (Cambardella et al., 1994)

Descriptive Statistics and Geostatistics

Table 2. Descriptive statistics by crop, year, and treatment (CropYr_Tmt) for: A. CIR-based estimated N requirements for corn at VT and for winter wheat at Zadoks GS-30; and B. resultant grain yield. For treatment details, see Materials and Methods.

	A. CIR-based N requirement					B. Grain Yield				
CropYr_Tmt	**n**	**Min.**	**Max.**	**Mean**	**CV**	**n**	**Min.**	**Max.**	**Mean**	**CV**
		-------kg N ha^{-1}------			%		--------Mg ha^{-1}-------			%
Corn02_1	2399	0	185	54	127	895	1.5	10.4	5.5b†	25
Corn02_2	2426	0	185	96	69	816	2.3	10.2	5.7ab	16
Corn02_3	2458	0	185	84	97	829	3.1	8.7	5.8a	17
Wheat03_1	2570	47	147	105	15	829	0.7	5.0	2.3b	26
Wheat03_2	2582	41	121	73	15	838	0.9	7.8	3.3a	24
Wheat03_3	2583	42	130	74	16	825	0.7	5.3	3.2a	23
Corn04_1	2566	0	185	65	69	547	4.4	9.6	7.3a	13
Corn04_2	2577	0	185	86	70	496	4.0	9.7	7.2a	13
Corn04_3	2584	0	185	77	66	521	5.0	9.8	7.2a	12
Wheat05_1	2452	109	134	134	2	849	4.2	7.4	5.9a	9
Wheat05_2	2421	122	134	134	0.5	841	4.2	7.6	5.9a	10
Wheat05_3	2426	92	134	133	3.6	837	4.3	7.4	5.9a	9

†Means within a crop-year with the same letter are not significantly different (α=0.05).

Sripada, R., R.W. Heiniger, J.G. White, and R. Weisz. 2005. Aerial color infrared photography for determining late-season nitrogen requirements in corn. Agron. J. 95:1443-1451

Table 3. Semivariogram model parameters by crop, year, and treatment (CropYr_Tmt) for: A. CIR-based estimated N requirements for corn at VT and for winter wheat at Zadoks GS-30; and B. resultant grain yield. For treatment details, see Materials and Methods.

	A. CIR-based N requirement						A. Grain Yield					
CropYr_Tmt	**Model**	**Nugget**	**Sill**	**Range†**	**Nugget: sill**	**r^2**	**Model**	**Nugget**	**Sill**	**Range†**	**Nugget: sill**	**r^2**
		---kg^2 ha^{-2}---		m	%			---Mg^2 ha^{-2}---		m	%	
Corn02_1	spherical	150	4869	69	3	0.82	spherical	0.55	2.05	100	27	0.86
Corn02_2	spherical	610	4792	57	13	0.89	spherical	0.28	0.90	44	31	0.98
Corn02_3	spherical	560	6216	99	9	0.95	spherical	0.27	0.86	74	32	0.99
Wheat03_1	spherical	52.9	276	94	19	0.86	spherical	0.15	0.40	153	38	0.91
Wheat03_2	exponential	26.4	131	69	20	0.98	spherical	0.23	0.64	136	35	0.94
Wheat03_3	exponential	19.7	149	71	13	0.94	spherical	0.27	0.61	139	44	0.91
Corn04_1	spherical	723	2163	58	33	0.93	spherical	0.19	0.72	72	27	0.80
Corn04_2	exponential	740	4028	167	18	0.94	spherical	0.27	0.89	131	30	0.89
Corn04_3	exponential	1029	2963	199	35	0.98	gaussian	0.35	0.76	177	46	0.83
Wheat05_1	spherical	0.01	5.7	48	1	0.44	spherical	0.14	0.28	66	50	0.88
Wheat05_2	spherical	0.072	0.6	48	12	0.48	spherical	0.17	0.46	121	36	0.96
Wheat05_3	exponential	2.2	40.1	445	4	0.66	spherical	0.14	0.28	53	48	0.96

† Effective range

Results & Discussion

CIR-Based N Requirement:

- Means and CV similar among treatments within crop-years (Table 1), except for:
  - 1) Corn02 Tmt1<Tmt3<Tmt2: Tmt 1 received N at V2, reducing N need at VT. High variability may reflect spatial variability in fertilizer N-use efficiency due to leaching and denitrification
  - 2) Wheat03 Tmt 1, which needed more N than Tmt 2 & 3, which had received N at GS-25 to promote tillering
- CV for Wheat < Corn. Corn at VT may have greater potential for spatially variable N management compared to wheat at GS-30 in similar coastal plain environments.
- Wheat05: No GS-25 N was applied due to adequate tiller numbers, and the field had exceptionally uniform high N requirement, which translated to uniform and high yield.
- Strong spatial dependence (Table 3) for all crops & treatments except Corn04 Tmts 1 & 3, which had moderate spatial dependence
- Spatial correlation range similar to size of experimental plots (61 X 61 m), except for Corn04 Tmt 2 & 3, and Wheat05 Tmt3, where it was greater (167 – 445 m)

Grain Yield

- Excepting Wheat03, there was little or no difference in mean yield among treatments
- CV ranged from 9 to 26% (Table 1)
- CV similar among treatments within crop-years except Corn02 where CV Tmt1>Tmt 2 & 3. Consistent with the high CV of N requirement of Tmt 1 and the fact that Tmt 2 & 3 received N at VT, reducing yield variability due to spatially variable N needs
- Moderate spatial dependence (Table 1): nugget:sill = 27 to 50%. Nugget-to-sill ratios sometimes appeared to be affected by treatment, but with no consistent trend.
- Spatial correlation ranges varied from 44 to 176 m and appeared to be affected by treatment, but with no consistent treatment trends within crops or among years.
- Despite substantial spatial variability in CIR-based estimates of N requirement in some years, site-specific N management had little effect on yield. In-season N management was effective for corn in 2002 and wheat in 2003.

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