Analysis of Spatio-Temporal Field Productivity of a Wheat Field in Southern Prairie Region

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Abstract

The site-specific management of agriculture inputs have spawned a revolution in how farmers are managing their fields with the improvement in technology involving variable rate chemical applications and geographic positioning system. No longer do fertilizer and pesticides need to be applied uniformly across a field, but now may be varied to match the soil potential as the soil type varies across the field. Success of this method of precision farming depends on being able to set application rates matching field productivity. Unfortunately, little information is available on how variable yields are across fields, what patterns of yield can be expected, and how consistent these patterns are from year to year. In this study we found that wheat yield varies across a field, but that the yield pattern is not the same each year. Overall spring soil moisture level does affect the strength of the spatial pattern.This information is important to those trying to use yield patterns for making chemical applications for precision farming. Our study indicates that several years are needed before a clear pattern of yield potential can be determined.

Introduction

Variation of the environment in which agriculture operates is effectively continuous. This influences profoundly the function of the biological system used by agriculture. One way of describing the interaction between the organism and its environment is to consider it as a system influenced by three factors: controlled; uncontrolled and noise. Controlled variation comprises manipulation of inputs such as seed, nutrition, water or chemicals. These are adjusted by managers to increase the beneficial function of the plant. Uncontrolled variation describes measurable factors of known significance, such as incident radiation, temperature, rainfall or soil condition. A third source of variation, noise, is indeterminate.

Agricultural management copes with this variation in two ways. At continental scale, it modifies the system to suit local conditions. As scale focusses on smaller area, climate becomes less significant, and other sources of variation such as geology, soil fertility or hydrology tend to predominate. At this scale, the strategy is to sub-divide the land into manageable parcels and apply a system in a way perceived to be appropriate for the conditions within it. However, most agricultural land is partitioned not on bio-physical lines but cadastres. By and large, these cut across landscape variations with the consequence that as much variation can occur within as between fields.

Temporal variation compounds this problem by causing patterns of plant growth- which reflect the interaction of spatial variation in soil condition with temporal variation of climate- to fluctuate from season to season. Even for the same crop, consistency is the exception rather than the rule, and spatial trends can reverse between seasons, so that a part of a field which yielded better than average one year may yield poorly the next.

Objectives

The primary objective of this study was to analyze in-field spatial and temporal variability for better understanding of field productivity.

Other objectives of this research was to identify factors affecting field productivity and develop a methodology to minimize the effect of temporal variability in the identifying management zones.

Materials and Methods

Description of Study Area

The study site is near highway 13, 11 Km NE of Shaunavon (NE10-09-18w3)(Figure 1) .

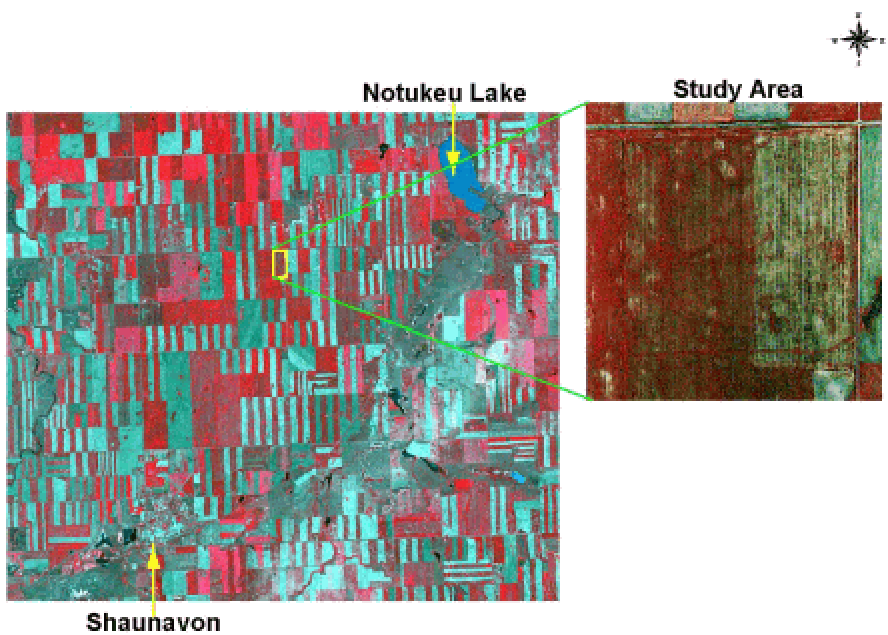


Figure 1. Location of the Study Area

Each plot inside the study area (bounded by white polygon with plot width 14.8 meters) (Figure 2) received different amount of nitrogen fertilizer from year 1997 to 1999 but in 2000 it was planted under uniform nitrogen fertilizer. Topographically the area is a typical rolling plain. The difference between highest and lowest point is 29 meters. 3D image of both study area is based on the elevation information obtained from the ground control points using geographic positioning systems(GPS).

The area is in dark brown soil zone and the soils of the area consist of clay loam glacial till

(Amulet Association) and silty loessial over till (Wymak Association) (Saskatchewan Soil Survey 1988). For most part, soils of the Amulet Association are expressed on the tops of the knolls, while soils of Wymark Association are expressed in the mid- and lower-slope positions. Slopes are ranged from 2 to 15 percent and there is the expression of calcareous soils on the tops of the knolls (Meinert 1996).

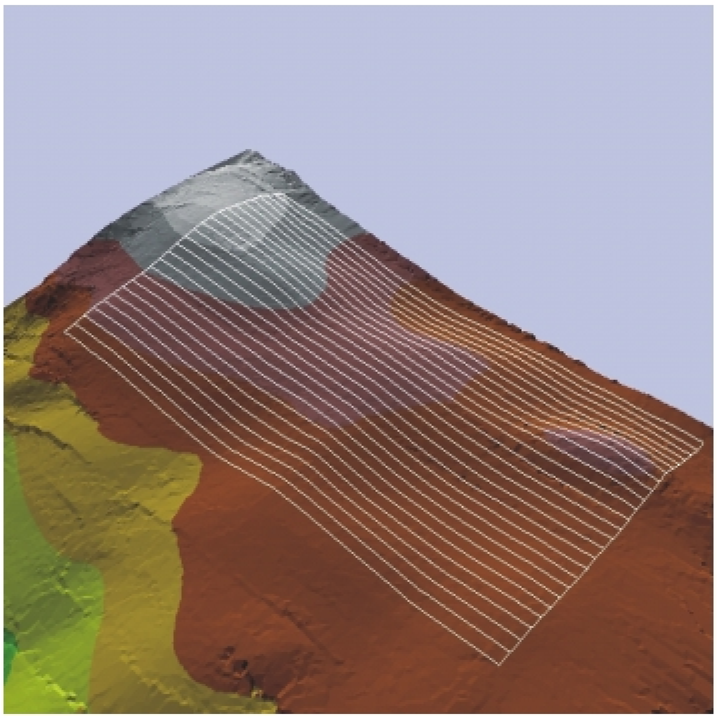


Figure 2. Topography of the Study Area

Water and N are the primary factors determining stubble crop yields in the Dark Brown soil zones (Cambell and others 1997). Hence, we have analyzed these factors in terms of their spatial as well as temporal variability. In this process we have used both spatial statistics and geographic information systems (GIS) in order to extract better information from the soil and crop information collected. Soil moisture and nitrate information were extracted from the soil samples collected during spring season before planting and yield information were collected using a plot combine representing all slope position. These point observations were used to create surface covering the study area using kriging interpolation. In order to analyze temporal variation we have used one plot which has received no fertilizer during 1997 to 1999.

Results and Discussion

Results from this study indicate the temporal variation in spring soil N and moisture level, which has resulted in the variation in the grain yield spatially. The difference in crop yield pattern spatially year to year is the result of availability of yield limiting factors (moisture and N etc.) In that year. Here in Figure 3 and Figure 4 we have shown such variation in the check plot, which has received no-fertilizer in 1997, 1998, and 1999. Figure 5 shows the consequences of temporal variation on grain yield. This type of temporal variation will created problem in developing strategies to manage a field unless we find a way to minimize such effect.

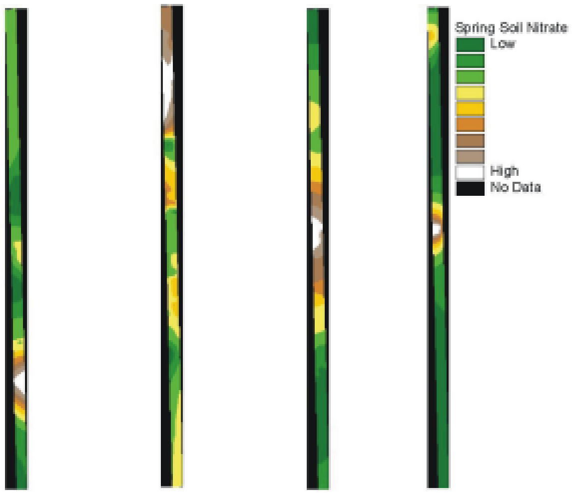


Figure 3. Soil N in Check plot

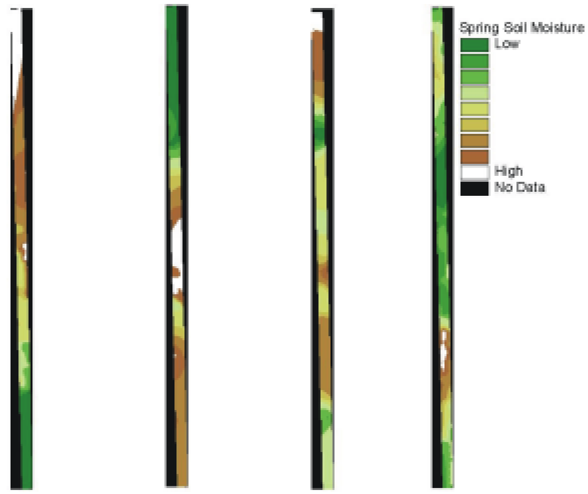


Figure 4. Soil Moisture in Check plot

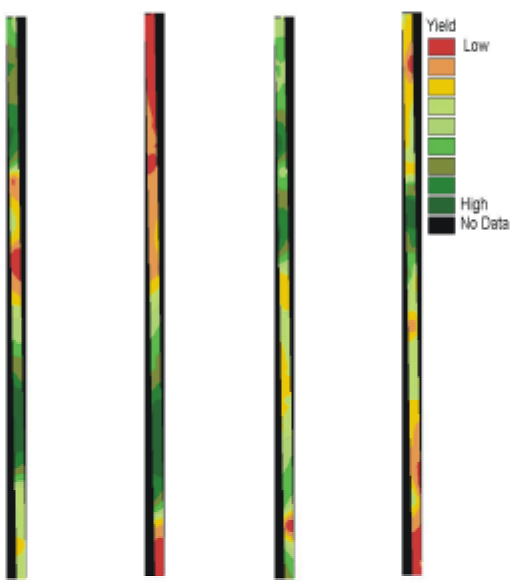
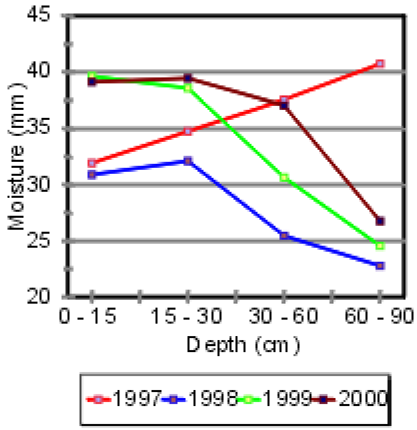


Figure 5. Grain Yield in Check Plot

Figure 6, 7, 8, and 9 show the spatial variability of two important yield limiting factors in the study area. Based on the variability of these factors along soil depth, soil moisture pattern were similar in 1998, 1999 and in the year 2000. In the year 1997 spring soil moisture was showing different patterns. In 1997 and 2000 variation in soil N along soil depth follows the similar pattern where as in 1998 and 1999 they are different. The spatial variability observed here are the result of variation in the climatic condition as well as mineralization. Variation of these factors with respect to landscape position show a similar pattern for soil moisture, but soil N is not showing similar pattern temporally.



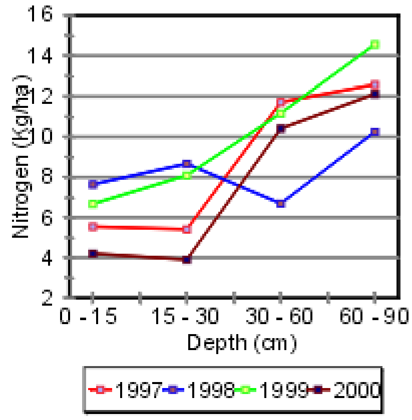
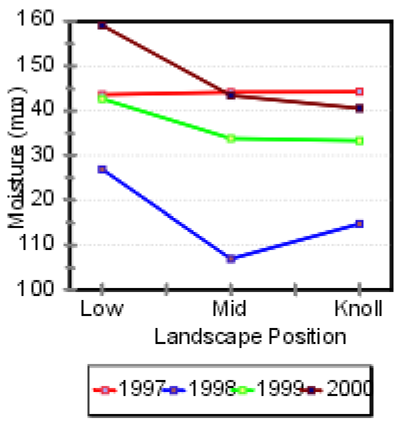


Figure 6. Soil Moisture in Spring

Figure 7. Average Soil(0 to 90 cm) N By Landscape Position



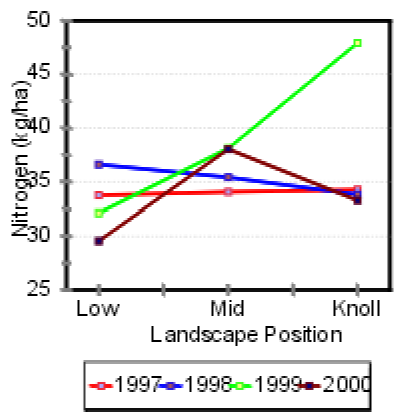


Figure 8. Average Soil(0 to 90 cm) Moisture By Landscape Position

Figure 9. Average Soil(0 to 90 cm) N By Landscape Position

Figure 10 shows the spatial variation of grain yield. There is a similar pattern in case of grain yield in 1997 and 200, only difference is in the magnitude, whereas grain yield in 1998 and 1999 are showing a different pattern. This is due to the temporal variation in the yield limiting factors. Table 1, 2 and 3 show the grain yield response to the N-fertilization rate and landscape position. There is clearly a variation in the grain yield based on the landscape position. Low slope position have higher productivity and shows more response to higher fertilization rate whereas mid slope response to fertilization rate high initially but culminates when fertilization rate exceed beyond 50 kg/ha. Knoll also shows the similar response usually lower than the mid slope position. Hence, we concluded that there is no yield rationale to adding more N fertilizer rates on Knoll or Mid slope position than low slope position. This information can serve as a starting point in the variable rate fertilizer management.

The response to varying fertilization rate can also help us in the fertilization rate prescription for the each management zone identified based on crop and soil information or vegetation index information extracted using remote sensing information.

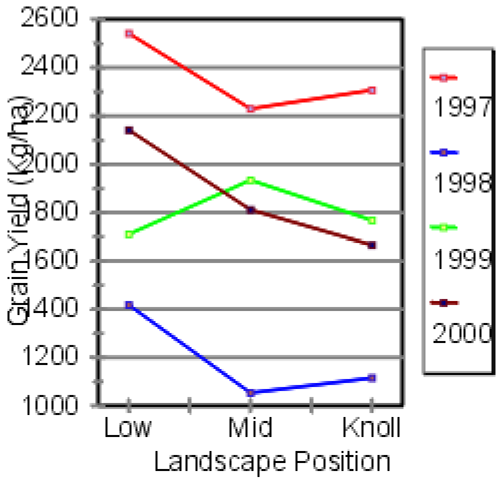


Figure 10. Grain Yield by Slope Position

Table 1 . Grain Yield (kg/ha) 1997.

Landscape Position	N-Fertilization Rate (kg/ha)									
	0		28		56		84		112	
	Yield	Protein %	Yield	Protein %	Yield	Protein %	Yield	Protein %	Yield	Protein %
Low	1761	13	2287	12	2542	14	2764	15	2566	18
Mid	1336	13	1837	12	2306	14	2185	16	2375	17
Knoll	1711	14	1818	13	2229	15	2108	16	2293	16

Table 2 . Grain Yield (kg/ha) 1998.

Landscape Position	N-Fertilization Rate (kg/ha)					
	0		45		90	
	Yield	Protein %	Yield	Protein %	Yield	Protein %
Low	1366	11	1862	13	1663	14
Mid	1597	14	1951	14	2093	15
Knoll	1270	12	1774	14	2049	15

Table 3 . Grain Yield (kg/ha) 1999.

Landscape Position	N-Fertilization Rate (kg/ha)					
	0		45		90	
	Yield	Protein %	Yield	Protein %	Yield	Protein %
Low	1197	13	1455	14	1580	16
Mid	868	13	1114	14	1107	17
Knoll	1048	14	1120	15	1194	16

Conclusions

Temporal variation introduces uncertainty to the spatial response of field productivity which will have a negative impact in the identification of management units behaving consistently. Spatial variability of the yield limiting factors can explain the temporal behavior which can be used in minimizing temporal fluctuation to address this problem for a better site-specific management.

Acknowledgments:
Thanks to Dave Gutenberg and PFRA for topographical survey.
Thanks also to Sue Dormer, Elizabeth Chan, Marty Peru and Janelle Appleyard for data Collection.

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