Variable Rate Nitrogen Fertilization in the Black Soil Zone of Saskatchewan

M.P. Solohub, D.J. Pennock, and C. van Kessel

The feasibility of variable rate N fertilization was assessed during a single growing season at Birch Hills, Saskatchewan, Canada (105° 2' W, 53" 3'10 N). The experiment was carried out across a 120 m x 620 m wheat field, which was divided into twelve 10 m x 620 m strips. Each strip was further broken down into 10 m x 10 m grid cells. Each of these grid cells was assigned to one of three possible management units based on their topographical characteristics. Prior to fertilization, initial soil testing was carried out; ten surface soil samples from each management unit were collected and analyzed for available N and P. The spring nutrient data, along with two separate growing season precipitation scenarios, were used to develop the fertilizer recommendations. At seeding each of the strips was fertilized in accordance to one of the two growing season precipitation scenarios or at a constant, or conventional, rate. Soil mineral N and available moisture was measured at ninety benchmark sites prior to seeding, weekly through the crop vegetative state, and following harvest. These benchmark sites were evenly distributed among management units and fertilizer rates. Crop yield was also measured at each of the ninety benchmark sites. Preliminary results indicate that fertilizer responses varied between management units. These observations suggest that fertilizer application can be manipulated on the basis of landscape - scale management units to minimize inputs, while maintaining yield.

1.0 Introduction

The ability to vary inputs spatially across a given field, has received a lot of attention in the last few years. In the literature this technology is referred to by a number of different names. Commonly used phrases include Variable Rate Fertilization (V.R.F.), Variable Rate Technology (V.R.T.), Farming by Foot, Best Management Practices (B.M.P.'s), Farming by Soils, and Prescription Farming. For the purposes of this paper this practice will be referred to as Variable Rate Fertilization.

Farmers are interested in maximizing fertilizer use efficiency, thus allowing them to realize their maximum economic yield. This may be achieved through the implementation of Variable Rate Fertilization, the practice of varying fertilizer rates across a field in response to nutrient requirements. Conventional allocation of inputs, or constant rate fertilization, does not allow the operator to do this.

1.1 The Premise Behind Variable Rate Fertilization

In order to implement Variable Rate Fertilization (that is to vary inputs in response to changes in soil properties) the spatial variability within a given field must be assessed. Assessment of soil variability across a landscape is possible since changes in soil properties are predictable and have a large non - random component (Hall and Olson, 1991). This concept of systematic spatial variability was first widely proposed by Milne in 1936. Milne suggested that soils along a landscape are related much the same as links in a chain.

Soils at one location influence the surrounding soils by influencing drainage conditions, erosion and deposition, leaching, and translocation and redeposition of chemical constituents. This early work is the background of the catena concept (Milne 1936). Since the conception of Milne's catena concept several authors have improved upon it by attempting to model water movement both along and across the catena (Aandahll948, Hugget 1975, Pennock et al.1987). By understanding the effect landscape position has on soil physical processes it is possible for researchers to make accurate predictions about soil physical, chemical and hydrologic properties, which in turn can be used to make predications about variability in soil productivity across a landscape.

1.2 Implementation of Variable Rate Fertilization

Thier are three different approaches to Variable Rate Fertilization; the low - ***tech approach,*** the ***medium - tech approach,*** and the ***high - tech approach. The*** low - tech approach has been implemented by farmers for many years. With this approach the farmer simply makes a double pass across certain portions of the field during fertilization, or manure is selectively spread across certain portions of the field. With the medium - tech approach the rate at which fertilizer is administered can be adjusted from the cab of the tractor. Given that the operator is aware of differences in nutrient requirements across a field he or she can adjust the fertilizer rates on the go. The medium - tech approach was utilized in this research. The high - tech approach incorporates geographical informational systems, global positioning systems, and computer activated fertilizer spreaders. Soil data and historical yield data are incorporated to produce a fertilizer rate map. This fertilizer rate map, which is tagged to G.P.S. coordinates, is subsequently downloaded into a tractor mounted computer. From here the fertilizer rate is automatically adjusted in accordance to the digital rate map.

2.0 **The Variable Rate Experience at Birch Hills**

The focus of this paper is an experience with Variable Rate Fertilization at Birch Hills, Saskatchewan (105" 2'W, 53" 3'10 N). This site is within Blaine Lake - Hamlin Association; the soils are Black Chemozems developed on a rolling lacustrine landscape. The research was conducted at the landscape - scale, nitrogen fertilizer rates were varied across the landscape and nutrient and moisture status were monitored throughout the growing season. Finally yields were measured across the landscape and the economic advantages of variable rate fertilization were assessed.

2.1 Landscape - Scale Research

The research conducted at Birch Hills is a departure from the traditional small plot work which has characterized agricultural research. The experimental site occupied a 620 m x 120 m area within the farmers field. After a detailed topographic survey was conducted a management unit map of the area was developed based on its topographic characteristics. This map is an assemblage of 10 mx 10 m grid cells, where each grid cell is defined by its topographic characteristics. This map was superimposed onto the research area prior to fertilization (figure 1).

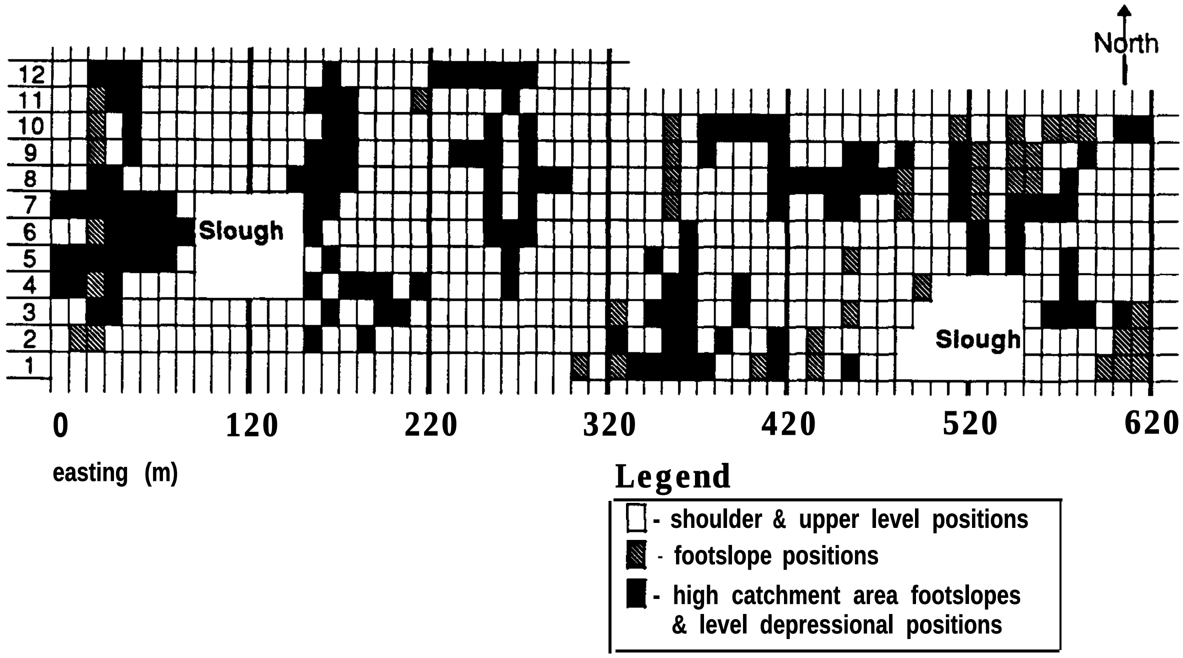

Figure 1: Management Unit Map at Birch Hills, Saskatchewan; the squares are the 10 m x 10 m grid cells.

2.2 Variable Nitrogen Rates

The two premises that Variable Rate Fertilization were based on at this site are: 1) productivity varies across landscapes, and 2) these differences in productivity are controlled by differences in soil nitrogen (N) and soil moisture across a landscape. It was also reasoned that nutrient requirements would depend on growing season precipitation. This uncertainty in growing season precipitation resulted in the development of two fertilizer scenarios, referred to as the "wet " year scenario and the "dry" year scenario.

In the "wet" year scenario it was reasoned that growing conditions would be optimal at the shoulder positions, and that excess moisture in the lower depressional positions would limit crop growth. In this scenario 90 kg/ha of actual N was applied to the shoulder positions and 30 kg/ha of actual N was applied to the lower depressional areas in the field. In the "dry" year scenario the converse was assumed to be true, that is crop growth would be limited by moisture at the shoulder positions and crop growth would be optimal in the depressional positions. In this scenario 30 kg/ha of actual N was applied to the shoulder positions and 90 kg/ha of actual N was applied to the depressional positions. Both of these scenarios were compared to a constant, or conventional, fertilizer rate. In the conventional treatment the field was fertilized at a constant rate of 60 kg/ha, regardless of landscape position.

The field was seeded and fertilized with a 10 m wide air seeder. The implement traveled in an east - west direction, for this reason the fertilizer treatments were imposed onto the management unit map in an east - west direction. As a result, the research plot was comprised of twelve 10 m x 620 m strips. Each of these strips was seeded in accordance to either a “wet” year scenario, a “dry” year scenario, or at a “conventional” rate. (figure 2).

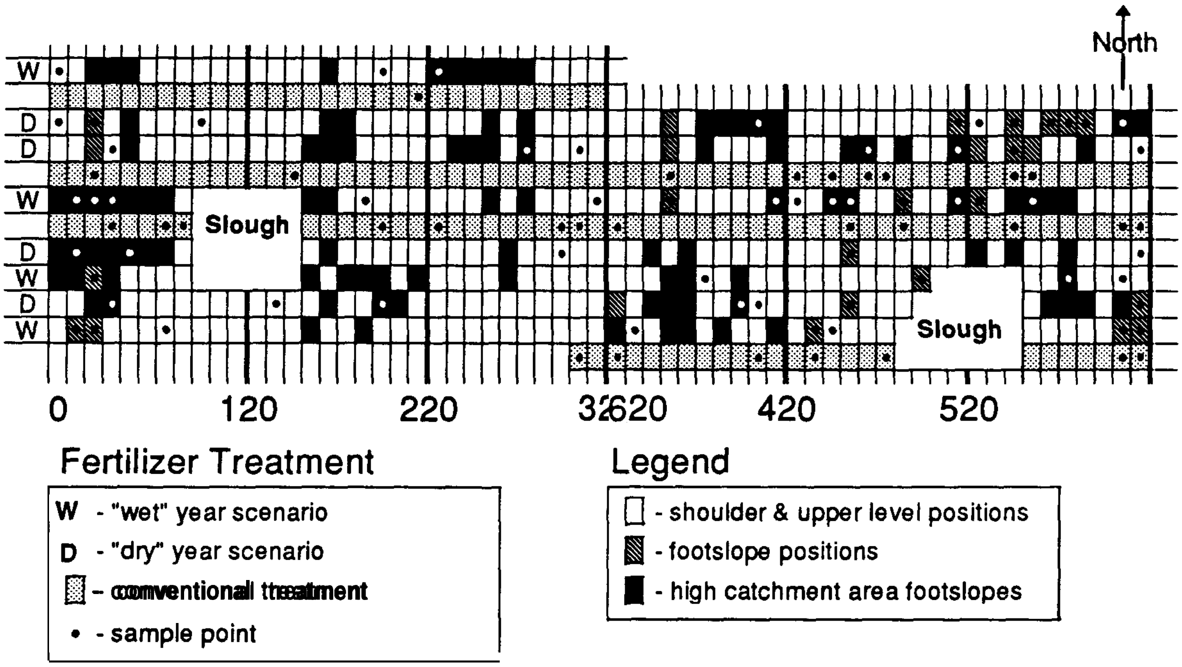

Figure 2: Management Unit / Treatment Map

3.0 Nutrient and Moisture Status throughout the Growing Season

Soil nutrient status and soil moisture were monitored at 90 sampling points, which were laid out prior to seeding and fertilization (figure 2). These 90 sampling points were distributed equally among the different management unit /fertilizer treatment combinations. Surface samples (0 - 15 cm) were obtained at ten randomly selected replicates from each of the management units prior to fertilization. These samples were analyzed for Sodium Bicarbonate extractable Phosphorus, and soil moisture. Mineral N and soil moisture was determined at each of the ninety sampling points prior to fertilization, weekly through the growing season, and in the fall. Each sampling point was sampled to 90 cm (0 - 15 cm, 15 - 30 cm, 30 - 60 cm, and 60 - 90 cm) in the spring and fall, and to 30 cm (0 - 15 cm and 15 - 30 cm) throughout the growing season.

Pre - seeding Sodium Bicarbonate extractable Phosphorus showed a significant landscape effect (Kruskal- Wallis H test, a = 0.05). The Phosphorus levels were highest in the lower level and depressional positions followed by the footslopes; the shoulder positions contained the least Sodium bicarbonate extractable Phosphorus (figure 3). Based on this data, especially the low Phosphorus levels in the shoulder positions, a rate of 25 kg/ha of seed - placed Phosphorus was applied across the field.

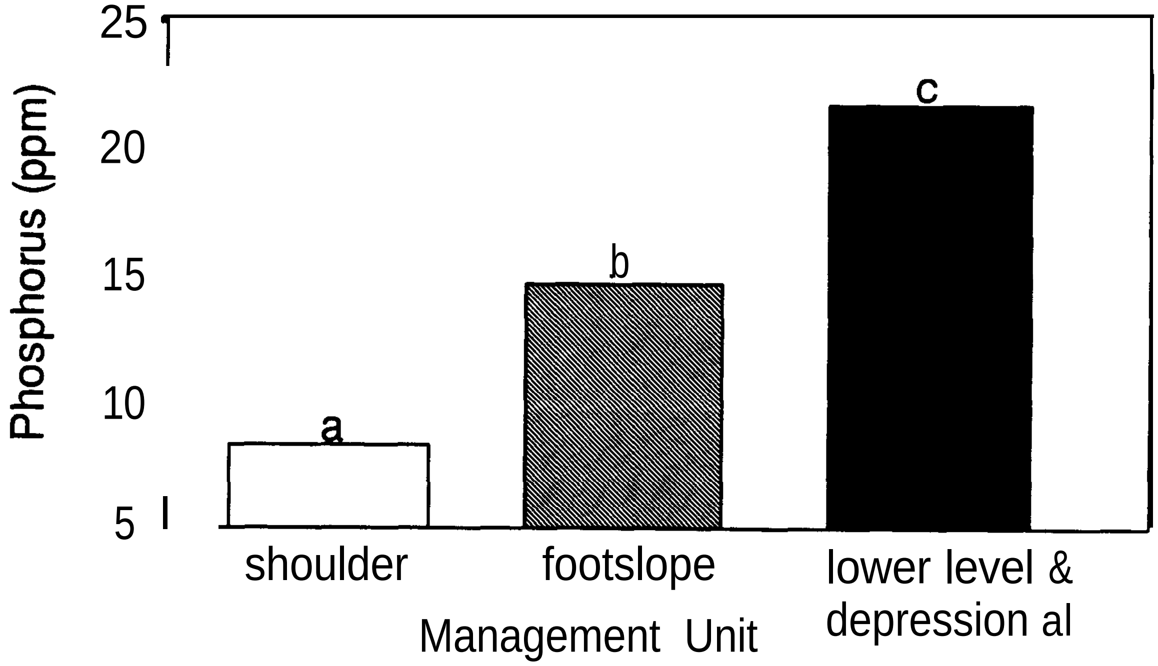

Figure 3: $NaHCO_3$ Extractable Phosphorus vs. Management Unit

Soil organic carbon levels did not appear to be related to landscape position. No significant differences between soil organic carbon levels at the management unit level were detected (Kruskal - Wallis H test, $\alpha = 0.05$). The relatively high levels of organic carbon indicates that these are good quality soils (figure 4). Also, the lack of significant differences across the landscape indicates that this field is homogeneous with respect to soil organic carbon.

Soil moisture varied both spatially and temporally throughout the growing season. The shoulder positions contained significantly more soil moisture than did the lower level and depressional positions, regardless of sampling date (Kruskal - Wallis H test, a = 0.05). Precipitation was considered to be slightly below normal and soil moisture stores were being depleted to a greater extent in the shoulder positions through the month of July. It is possible that crops in the shoulder positions may have experienced more moisture stress, as compared to those in the lower level and depressional positions, through this time period (figure 5).

A significant difference in soil mineral N across the landscape was not detected at the 95% confidence level (Kruskal - Wallis H test). There did, however, appear to be a temporal trend in soil mineral N levels. Mineral N levels increased following the June 1st seeding and fertilization operation to a maximum on June 25th , following June 25th the levels of mineral N decreased slowly over time (figure 6). This increase in soil mineral N over the 25 days following fertilization was likely due to an increase in soil temperatures, and thus, a resultant increase in the net mineralization rate. The decrease in mineral N throughout the remainder of the growing season was likely due to crop use and non - crop N losses.

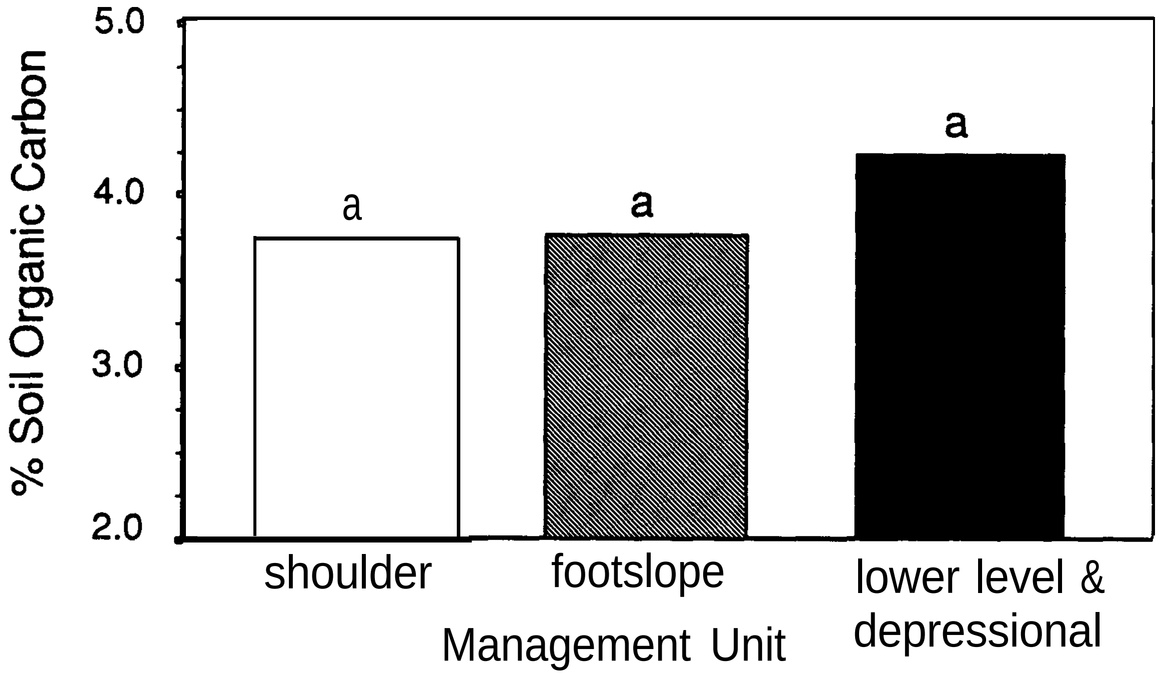

Figure 4: Soil Organic Carbon vs. Management Unit

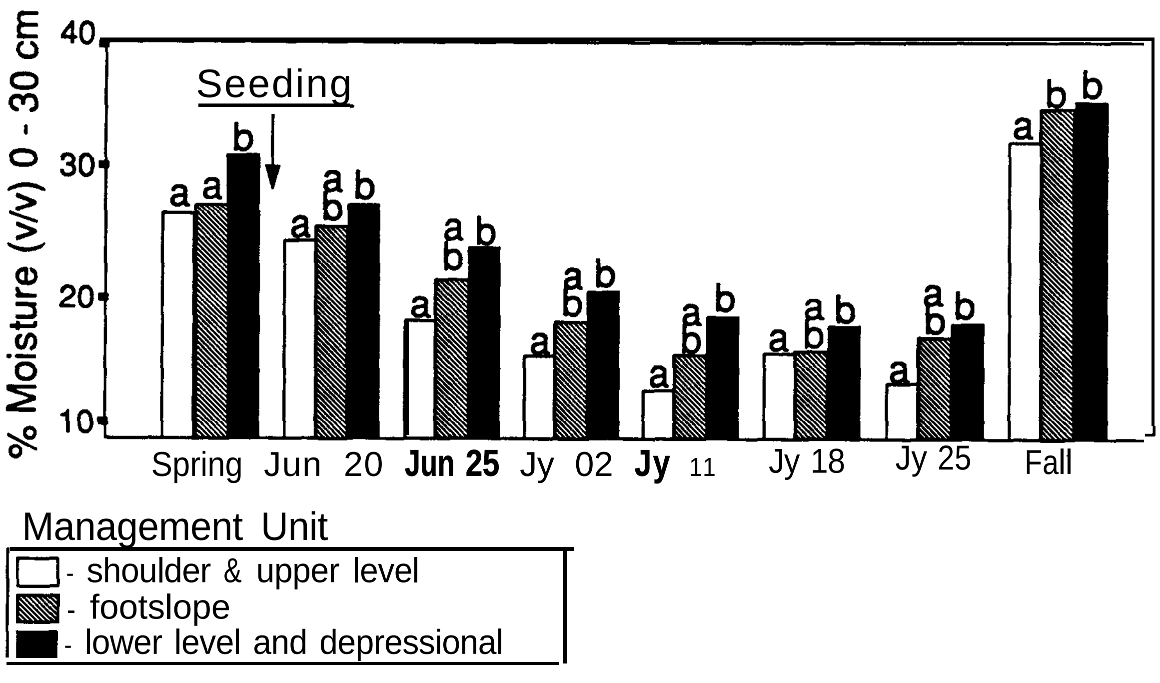

Figure 5: Spatial and Temporal Variations in Soil Moisture

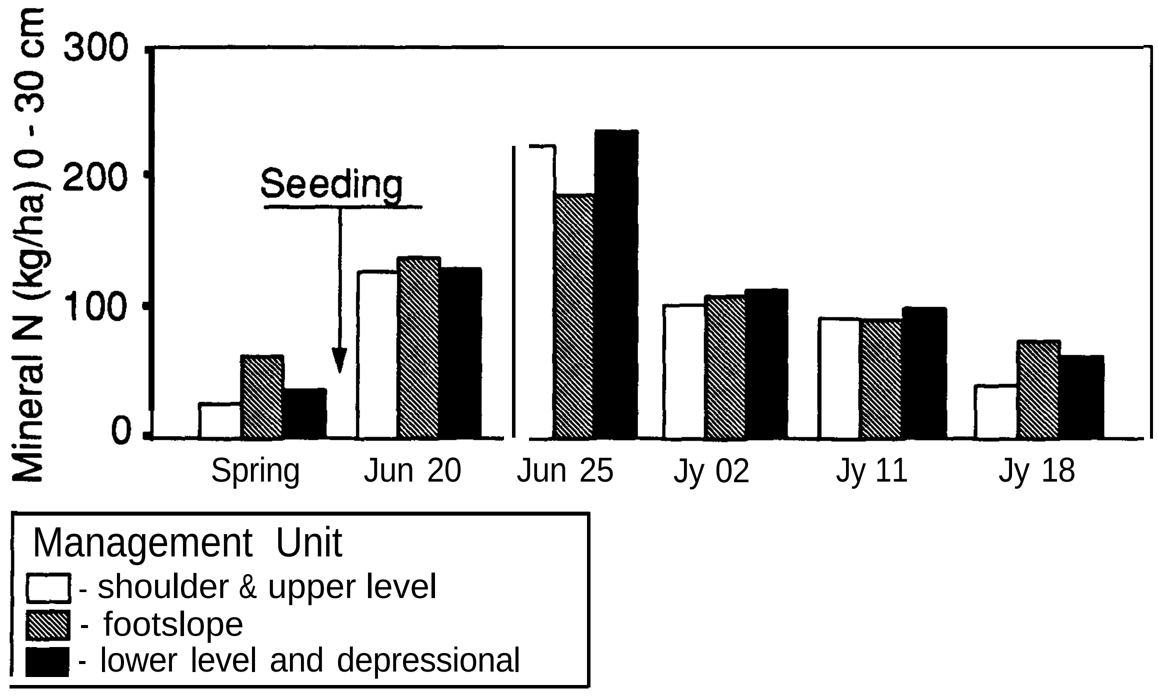

Figure 6: Spatial and Temporal Variations in Soil Mineral Nitrogen

4.0 Crop Yields across Management Units

Yield samples were obtained at the same 90 sampling points that were established for nutrient and moisture sampling (figure 2). One meter square yield samples were obtained from each of the sampling points, each sample was taken to be representative of the grid cell from which it was obtained. Preliminary results indicate that grain yields did not vary with fertilizer treatment; this is particularly evident in the lower level and depressional positions. This lack of fertilizer response in the lower level and depressional positions may be due to a large N supply power in these areas; this possibility should be investigated in an attempt to gain a better understanding of the N dynamics across management units. It should be noted, however, that grain yields appeared to be approximately 10 bushels/acre greater in the lower level depressional positions.

5.0 Economic Analysis of Variable Rate Fertilization

The ultimate success of Variable Rate Fertilization is dependent upon the economic advantage of implementing this technology into a farm based management plan. The four main factors that control the profitability of this approach are; 1) the value of the commodity, 2) the savings in fertilizer costs, 3) the change in crop yield, and 4) the cost associated with implementing Variable Rate Fertilization. Obviously if commodity prices are extremely low and increases in yield, or reductions in input costs are marginal, it is unlikely that Variable Rate Fertilization will be implemented.

At Birch Hills, based on grain yields and input costs for the different fertilizer rate / management unit combinations, the value of the crop minus the cost of fertilizer was calculated. The net profits obtained for the different fertilizer rate/management unit combinations were compared to the net profits obtained when the field was fertilized at a conventional rate of 60 kg N/ha. In 1995, at Birch Hills, net returns over constant rate fertilization were not maximized for either the "wet" year or "dry" year scenarios. Maximum net returns were realized, however, for the fertilizer rate / management unit combination where shoulders were fertilized at a rate of 60 kg N/ha and lower level and depressional positions were fertilized at 30 kg N/ha. Based on $5.00/bu wheat and $0.30/lb. N the most profitable fertilizer rate/management unit combination yielded an increase in profit of $3.26/acre over conventional rate fertilization. If, for example, fertilizer N costs increased to $0.50/lb. an increase in profit, over conventional rate fertilization, of $4.77/acre would be attainable.

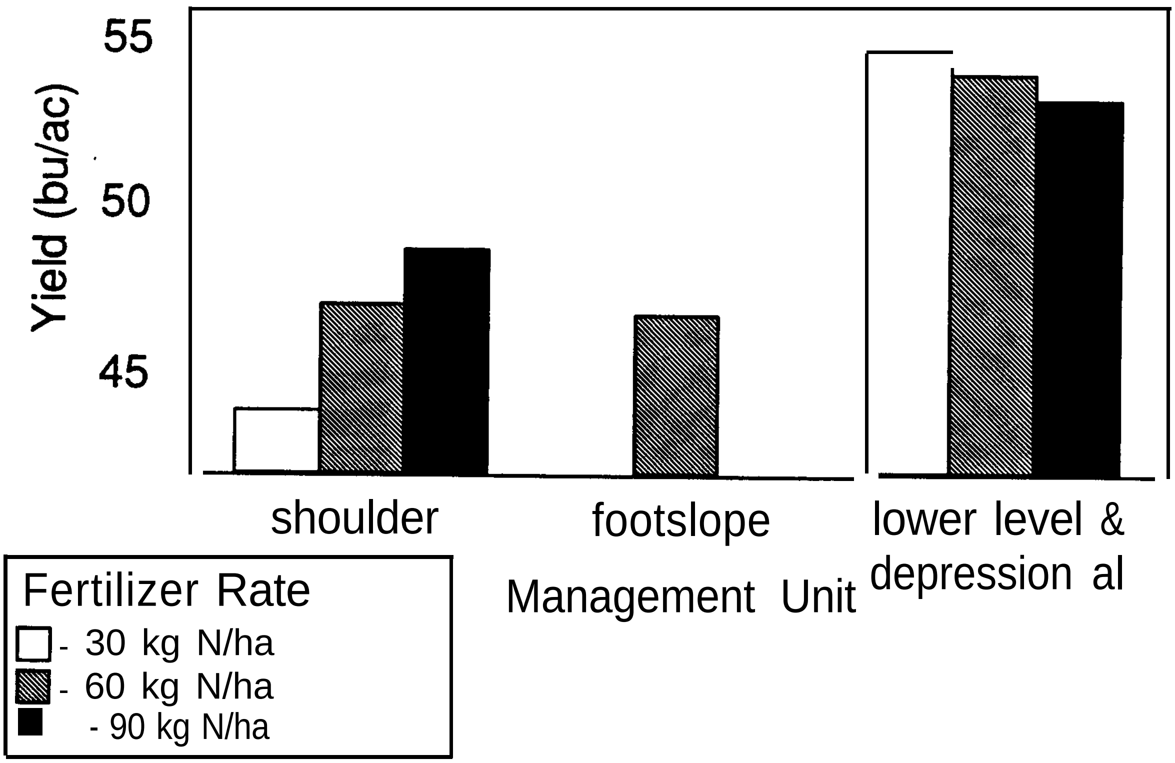

Figure 7: Grain Yield vs. Nitrogen Rate at the Management Unit Level

6.0 Summary

Variability in the soil productivity factors measured at Birch Hills was limited. Soil organic carbon and mineral N did not appear to vary significantly across management units. A strong landscape control was noted, however, for Sodium Bicarbonate extractable Phosphorus and soil moisture. Although the Birch Hills site appeared to be relatively homogeneous, Variable Rate Fertilization yielded an optimum economic return of $3.00 - $5.00/acre.

References

Aandahl, A.R. 1948 The Characterization of Slope Positions and their Influence on the Total Nitrogen Content on a few Virgin Soils in Western Iowa. Soil Science Society of America Proceedings. 13: 446 - 454

Hall, G.F. and Olson, C.G. 1991. Predicting Variability of Soils from Landscape Models. pp. 9 - 24. In Spatial Variabilities of soils and Landforms. SSSA Special Publication no. 28

Hugget, R.J. 1975. Soil Landscape Systems: A Model of Soil Genesis. Geoderma. 13: 1 - 22

Milne, G. 1936. Normal Erosion as a Factor in Normal Soil Development. Nature. 138: 548

Pennock, D.J., Zebarth, B.J. and deJong, E. 1987. Landform Classification and Soil Fertility Studies. Canadian Journal of Soil Science. 40: 146 - 156