PRECISION FARMING IN SASKATCHEWAN: TO PURSUE OR NOT TO PURSUE, THAT IS THE QUESTION.

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Introduction

Soil properties are characterized by an inherent variability that is either static or dynamic in nature. For example, properties such as soil texture or soil organic matter content are relatively stable and detectable changes in these properties only occur over an extended period of time (Pennock et *al.,* 1994). In contrast, soil properties including moisture and available nitrogen content share a dynamic status and typically vary both temporally and spatially.

Topography plays a critical role in modifying both the microclimate and the hydrological conditions within a landscape. Within a field, these modifications can in turn influence or control the type and intensity of many soil processes (Pennock et *al.* 1994). In an undulating or hummocky terrain, the redistribution of soil organic matter and plant nutrients is controlled largely by the influence of surface features on the redistribution of water (Pennock et *al., 1987).* Water moves from upper levels and knolls to lower levels and depressions, carrying with it important soil constituents including soil nutrients and soil organic matter. As a consequence, higher areas within a field eventually are depleted in soil nutrients and organic matter whereas depressional areas undergo a concomitant increase in these soil constituents. Although nutrient redistribution is influenced by topography, the intensity and the controls on the redistribution are dependent on fundamental hydrological and pedological processes.

Soil properties characterized by a dynamic status can exert a major influence on crop production and, therefore, are of more practical significance than soil properties with a more static status. For example, it is well established that available soil nitrogen, a critical component of successful crop production, can vary greatly both within a field and from year to year. In light of the importance of many dynamic soil variables on crop production, avenues are now being sought to predict the status of dynamic soil properties and subsequently, to manage the field (i.e., fertilizer inputs), accordingly to their distribution (Robert et *al.,* 1993). This approach to fertilizer management is known as ‘precision farming’ or ‘variable rate technology’. Ultimately, one of the goals of variable rate technology is to achieve increased nutrient use efficiency whereby crop yields are sustained and nutrient inputs are reduced.

Agronomic research at the landscape-scale.

Depending on the direction of water movement, fields can divided into basic spatial units or landform complexes called shoulders, footslopes, and upper and lower levels (Pennock *et al.,* 1987). The shoulder and upper level landform complexes are areas which shed water, sediments and nutrients, whereas footslopes and lower level landform complexes are areas of accumulation. Because topography exerts a principle control on the basic hydrological conditions within a landscape, areas within a field sharing similar topographical features also share similar hydrology. Therefore, dynamic soil processes and properties that are controlled directly or indirectly by water similarly are expected to reflect the basic site topography. For example, sampling of an undulating field in the Birch Hills area in the spring of 1994 revealed the presence of a clear spatial pattern of both soil moisture and available soil N (Fig 1.). Footslope and lower level areas were characterized by relatively high soil moisture and available soil N content whereas shoulder and upper level areas had significantly less soil moisture and available soil N.

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Figure 1. The landscape-scale pattern of landform complexes, soil water content, and soil mineral N.

Applying hydrological principals to a more practical realm, topographical features within a field can be identified and classified into different landform complexes. Because similar landform complexes are expected to share similar soil properties, landform complexes can be considered management units, and fertilized or managed accordingly. For example, the amount of N fertilizer required to achieve a particular yield is dependent on many factors including existing levels of available soil nutrients in the spring (including soil N), the rate of net N mineralization during the growing season (i.e., the potentially available N), and soil moisture availability. Availability of soil nutrients can be determined in the spring using a limited number of soil samples taken from the various management units. Each management unit (i.e., level, shoulders and footslopes) should be sampled separately but the samples taken from a particular unit can be composited. Although many of the factors that affect plant growth can be predicted to some degree, the large unknown parameter remains the amount and the distribution of available soil moisture during the growing season. Clearly, crop response to available N remains dependent on adequate moisture availability.

Landscape-scale versus small-plot scale research.

Due to the restrictive nature of 'classical' experimental designs which utilize relatively small plots as experimental units, much of the agronomic research conducted over the years has not been able to address the effect of differences in soil properties (including soil moisture, nutrient mineralization, and nutrient availability), occurring across an undulating field, on crop production. In order to determine the fertilizer requirements of a crop seeded on an undulating field, there is a need to conduct research at the landscape-scale level rather than at the small-plot level. Furthermore, parameters that are controlled by hydrology and have an effect on nutrient availability and subsequent crop growth, also will have to be assessed and integrated into models predicting fertilizer requirements. Therefore, agronomic research related to variable rate technology must be based on a landscape-scale or a systems approach rather than limiting investigations to single parameters at the small-plot scale.

Conducting agronomic research at the system or landscape-scale might also necessitate a different approach to the collection and analysis of data. Classical agronomic research typically strives to exclude variability by using homogenous, level plots and experimental designs such as the randomized complete block design. Parametric statistics are most frequently used to analyze the resulting data. In contrast, landscape-scale research strives to encompass variability. Thus, locations with a uniform distribution of soil characteristics are not a requirement. Indeed, locations characterized by a high degree of variability in soil characteristics are particularly well-suited for landscape-scale research. Because many soil variables often are not normally distributed, non-parametric statistics play an important role in analyzing data collected at the landscape-scale.

Implementing variable rate technology.

Once the amount of N fertilizer required to produce a crop for the various management units has been determined, different approaches can be used to vary the rate of fertilizer application across a field. In 1995, the Saskatoon-based company, FlexiCoil, will be testing a prototype of an air-seeder that will enable the producer both to vary the fertilizer rate on-the-go, using a handle installed in the cab, and monitor the subsequent amount of fertilizer applied. The advantage of this technology is that the purchase cost is relatively low and it may well become a standard outfit of all new airseeders. The disadvantage of this technology is that the rate has to be varied by hand and the operator has to be able to visually identify the various management units in the field.

A more advanced system is being developed to vary the rate of fertilizers by means of a computer system, installed within the tractor. Programmed within the computer is a map of the field which indicates the location of various management units and the different levels of fertilizer N to be applied to these units. The airseeder or fertilizer spreader is connected to a global positioning system (GPS) which is used to constantly monitor the position of the tractor within a field. Because the various management units have been mapped previously and are geo-referenced, the position of the tractor in the field relative to specific management units is known at all times. There are various global positioning systems on the market, each with its own accuracy. A global positioning system that can locate the tractor with an accuracy of a few meters costs less than $10,000.00 A global positioning system with an accuracy of less than 5 cm (real time positioning) will likely cost more than $40,000.00.

At harvest, the combine can be equipped with an on-the-go yield monitor. The position of the combine is again determined by the global positioning system and a computer on board the tractor records and stores the yield data every three seconds. A yield map can be generated that allows the farmer to assess whether it was economically effective to vary the rate of fertilizer across the field in a given year.

The future of precision farming.

Varying the rate of fertilizer application, or 'precision farming', can be used for a number of purposes. As previously indicated, precision farming allows the producer to reduce overall fertilizer inputs while maintaining crop yields. In addition, this technology can be used to increase protein content because achieving a balance between residual soil N and the amount of N applied can lead to a more uniform protein content (Fiez et al., 1994a). Another possibleuse of variable rate technology is to promote a more even ripening across a field. Areas within a field that typically are late maturing or produce a crop with a low harvest index receive less fertilizer N, thereby inducing an earlier stress and enhanced ripening.

Other potential uses of the global positioning system as a tool for precision farming includes localized pesticide spraying which can be carried out at night because the computerized system can be used to navigate the tractor through the field. If the weed problem occurs only in certain areas of the field, a map of the weed population is generated, scanned into the computer and when the spraying equipment arrives at the location of the weed problem, the nozzles are turned on. Ultimately, a driver will not be required as the whole process can be fully automated.

Another potential use of the global positioning system is the possibility to change the variety of particular crop when seeded across an non-uniform landscape. At the present time, all crop varieties are selected on well managed, heavily fertilized experimental plots. Although new varieties may well produce the highest yield on a level, fertilized field, these same varieties might not be the best suited for the less productive, more drought prone areas of a field. Therefore, a crop variety that is specifically drought tolerant could be selected whereas a second variety could be selected which yields better under more moist conditions. A seeder equipped with two seed boxes (one for the more moist areas of the field, the other for the more drought prone areas of the field) in combination with a global positioning system could automatically signal when one or the other variety should be seeded. It should be pointed out, however, that the quality of both varieties would have to be similar and both should ripen evenly to allow the producer to harvest both varieties in the same operation.

Cents or nonsense?

At this moment, the key question regarding precision farming is: does sense make cents or just more nonsense? Currently, only a very limited number of studies have been published in which the possible economic benefits of varying the rate of fertilizer across the field have been assessed (Sawyer, 1994). Other potential uses of site specific management are still in the (very) early stages of development.

The variability of winter wheat yield across several landscape positions (management units) was assessed at two sites for two years in the state of Washington (Fiez et al., 1994a). Grain yields across the management units varied by as much as 55 % and the conclusion was drawn that it would be economically justifiable to vary the fertilizer inputs across the field. However, from the same study, but reported elsewhere (Fiez et ***al.,*** 1994b), these authors also came to the conclusion that grain yields did not vary consistently among landscape position between the two years and that the landscape position was "not an adequate criterion for dividing fields into equal productivity units".

An estimated change in the net return as affected by variable rate of N fertilizer application based on four scenarios also was calculated (Fiez ***et al,*** 1994b). When the unit of N requirement among landscape positions was kept constant at 20 kgN/1000 kg of grain (2.7 lbN/bu), the variable rate did not produce an economic benefit. However, by taking into consideration the landscape position, the unit of N required at each landform element to produce 1000 kg of grain, and the residual and mineralized soil N at each position, the net return ranged from US$3.39 to US$14.80/acre.

Will variable rate technology produce an economic benefit in Western Canada? At present time the answer is inconclusive, principally because information regarding precision farming is limited and agronomic research needs to be conducted to provide a definitive answer. Although the engineers have developed all the required soft- and hardware to carry out variable rate technology, the agronomists have been slow to adapt to this new form of technology. This is due partly to the fact that the needed research itself requires a systems approach, as discussed earlier. Unfortunately, the systems approach to research is a concept that has received a lot of attention but few followers. Another problem is the perceived cost associated with the implementation of variable rate technology. At the present time, the least sophisticated option (manually controlled and no computer) still seems the safest option. Until the basic agronomic research has been carried out so that the fertilizer requirements for a limited number of management units can be accurately predicted, it does not matter whether the fertilizer is delivered by a beaten-up fertilizer spreader or a brand-new computerized fertilizer spreader: in both instances the producer does not know how much fertilizer to apply to the different management units. Once it has been proven that it makes economic sense to apply variable rates of fertilizer on the most diverse units, the field can be divided progressively into more management units, which are distinguishable from each other by progressively more subtle differences.

Ultimately, the use of precision farming at a larger scale will depend largely on two factors:

1. Is there an economic benefit that can be gained from this technology? The number of management practices that are well-suited to the use of precision farming will be of importance as this will reduce the cost of investment per operation.

2. Assuming that there is sufficiently large variability in the soil parameters between production units to significantly affect crop production, are we able to accurately quantify these parameters and respond by changing the management between production units? Variable rate of fertilizer application will be useful only if the variability in the nutrient supplying capacity between the production units (as related to crop production) can be predicted with a degree of certainty. If

the agronomists can not provide reliable data on the nutrient requirements for the various units, the determination of the variable rates of fertilizers becomes merely a probability game. Although the requirement for equipment which allows the producer to vary fertilizer rates on-the-go may already have been met by a manually operated option, the need to accurately predict fertilizer requirements has not been met at the present time. The answer as to whether the second condition can be met, will remain unknown for some years to come.

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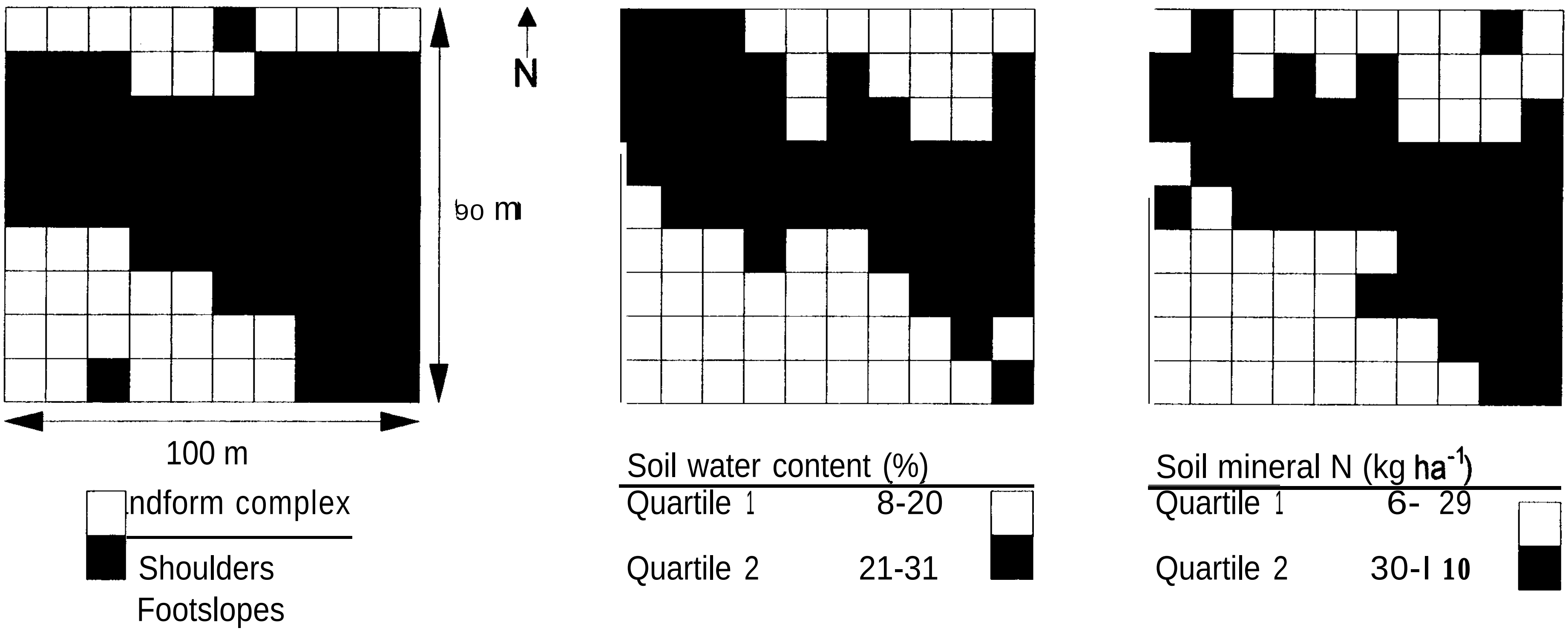

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