Developing Precision Farming Management Strategies

D. Pennock, F. Walley, and M. Solohub,
Dept. of Soil Science, University of Saskatchewan
B. McConkey, SPARC, Agriculture and Agri-Food Canada
A. Johnston, Melfort Research Station, Agriculture and Agri-Food Canada
T. Hogg, SIDC, Outlook
G. Hnatowich, Saskatchewan Wheat Pool, Saskatoon

Introduction

Precision farming involves matching the management techniques used in different areas of a field to the agronomic goals of the producers. The potential of this type of site-specific management has been evident for many years. However it was only when the appropriate technology became widely available to allow producers to practise site-specific management that a demand arose for agronomic support for its use.

The agronomic support required for successful adoption of precision farming takes many forms: information on variable fertility conditions across typical Saskatchewan landscapes; evaluations of the technology used in precision farming; reliable, low-cost maps of fields; and economic evaluations of the potential benefits to Saskatchewan producers. As well, the rapid adoption of these techniques requires that the information gathered is quickly made available to producers to assist in their successful implementation of precision farming.

Our purpose in this paper is to present a research approach we are currently applying to deliver some of the basic agronomic information required for the successful adoption of precision farming. The approach builds upon a research design developed for a precision farming project located near Hepburn, Saskatchewan which was funded by the Agricultural Development Fund of the Province of Saskatchewan. Funding under the Agri-Food Innovation Fund (AFIF) allowed us to extend this project to four sites

The overall objective of the AFIF project is to increase the profitability of Saskatchewan producers and the sustainability of their farms by developing and extending precision farming technologies that work for Saskatchewan conditions. The specific objectives are:

1. To develop the agronomic information required for successful adoption of precision farming. The information required includes data on variations in fertility and related productivity (e.g. moisture, temperature) conditions in typical agricultural landscapes and field-scale maps of these productivity conditions.
2. To evaluate the suitability of precision farming equipment currently being purchased by Saskatchewan producers.
3. To determine the economics of precision farming systems in Saskatchewan.
4. To develop and deliver the extension materials required for Saskatchewan producers to make an informed decision about the suitability of precision farming for their specific operation.

Our Current Understanding of Soil Variability

Soil scientists have spent many years studying the pattern of soil properties in fields and the processes responsible for these patterns. The AFIF and ADF fimded research focuses on the types of soil variation which occur in the most typical of Saskatchewan landscapes – a gently rolling surface. Formed on glacial till deposits, these are landscapes which have a series of knolls and sloughs in a given field; the knolls typically have a grayish colour, and the surface of the soil has scattered stones on it.

Different soils in a field occur because of the action of soil-forming processes through time. In Saskatchewan soil formation in most of our landscapes began about 14,000 to 10,000 years ago, after the last of the ice sheets retreated to the north. Most of the soil forming processes which have influenced the landscapes since that time are controlled by the amount of water present at any point in the landscape. The pattern of water movement in a landscape is in turn controlled by slope and soil properties, and the pattern of water movement is well understood (Figure 1).

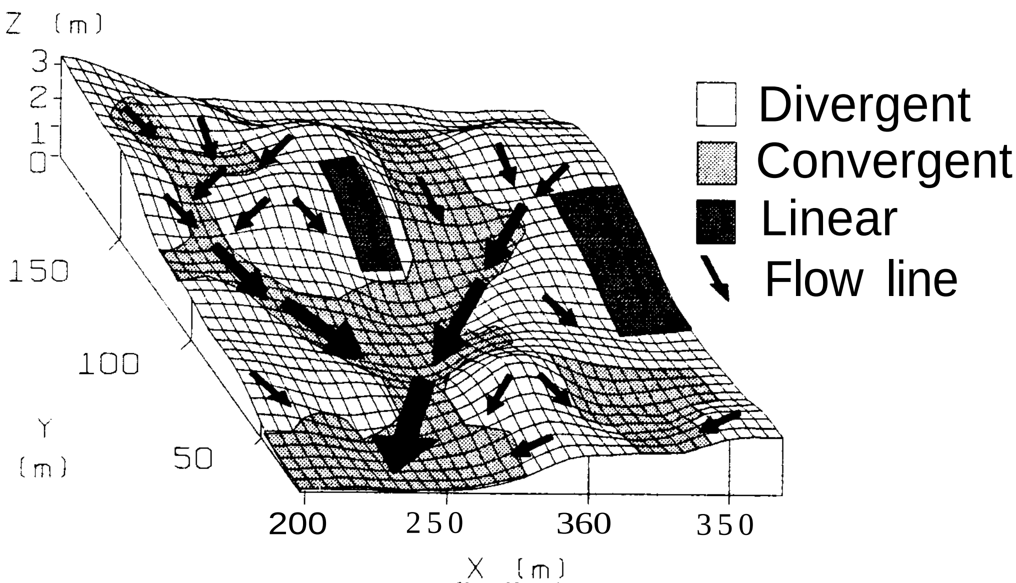


Figure 1: Pattern of water redistribution in a typical glacial till landscape

Because the soil-forming processes are so closely linked to water movement, a clear pattern of soils occurs in many Saskatchewan landscapes (Figure 2). Water is shed from knolls or upper slope positions and drier conditions occur. These dry conditions limit the amount of organic production that occurs in both natural conditions and in agricultural fields. Erosion of soil by wind, water, and tillage since the breaking of the land has removed topsoil from the knolls, and in many cases has mixed the grayish lime layer in with the remaining topsoil resulting in a thin Apk horizon. Soils on the upper slope positions are typically classified as either Regosolic soils or thin variants of the Chemozemic Order.

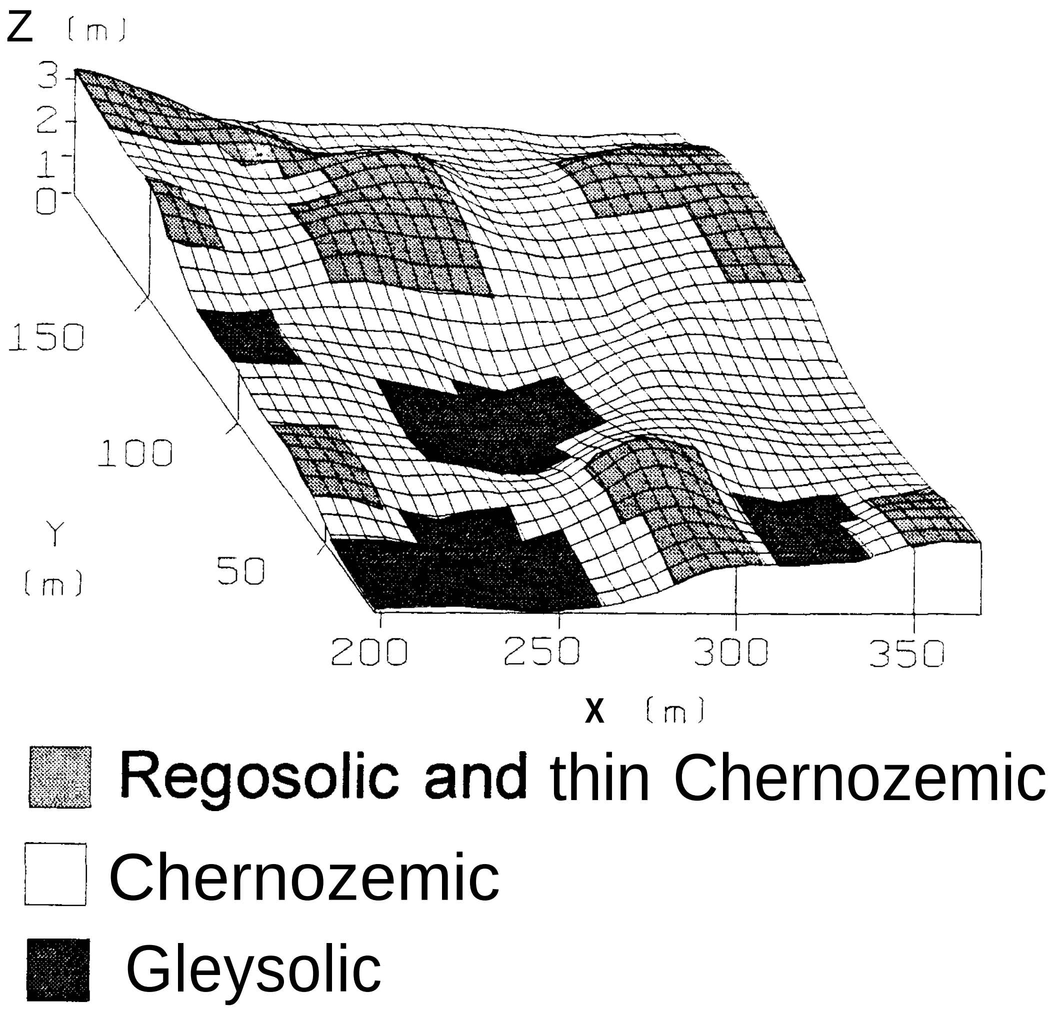


Figure 2: Distribution of major soil groups in typical Saskatchewan glacial till landscapes.

Soils in the midslope position typically show a consistent change in their properties as we move downslope. These soils are generally classified into the Chemozemic Order and have lime-free A horizons that increase in thickness as we move from adjacent to the knolls to the edge of the lower slope positions. In some cases tillage has mixed some of the Bm horizon underneath the topsoil into the plough layer, and these soils can have a reddish-brown surface in the field.

The lower slope soils show the greatest variations between fields and even within fields for it is in these positions that the interaction between the soil and the groundwater becomes a factor. For most fields in the agricultural portion of the province the groundwater table is far below the surface. The lower slope positions receive the snowmelt water and runoff water from upper slope positions, and this runoff water ponds in the lower slope position for some period of time. The water displaces oxygen from the pore space of the soil, and a set of soil processes typical of oxygen-depleted conditions occurs. For example, in oxygen-poor conditions, nitrate undergoes a series of chemical changes and can be converted back to nitrogen gas and is lost to the atmosphere. As the ponded water percolates through the soil it carries with it dissolved ions and other larger particles such as clay. These processes associated with water-saturated conditions give rise to the Gleysolic soils.

In other fields (or even within the same field) the groundwater table is closer to the surface, and water moves from the groundwater table to the surface. This means that the ponded water from runoff cannot drain as rapidly from these areas. As well, when the groundwater reaches the soil surface and is evaporated, solutes dissolved in the groundwater are deposited in the topsoil. If the groundwater is high in dissolved salts, then the evaporation of the groundwater over time causes the build-up of salinity in these lower slope soils. Hence in a given field the lower slope soils may have a deep, well-developed soil such a thick Chernozemic or Gleysolic soils in the lower position while another lower slope position a 100 meters away may have plant-limiting levels of Salinity.

Relationship of Soil Variability to Soil Fertility Variability

The soil differences discussed above translate into differences in both the nutrients and moisture available in a given year and these two properties are two of the main determinants of crop yield. The relationship to moisture is clear – soil conditions are driest on the knolls, increase through the midslope areas and are wettest in the lower slope positions. This pattern will be the same in all years; however the actual difference between the three positions will depend on the amount of precipitation received in a given year.

The differences in moisture between the three positions are, for the most part, unmanageable. Certainly a good residue cover acts to even out moisture variations between different parts of the field by trapping snow in winter and by allowing the soil to absorb more moisture during rain storms. Generally, however, it is the fertility variations that we are trying to manage by using precision farming technology.

The primary focus of many of the current precision farming research projects is on nitrogen fertilization. Nitrogen levels are known to differ in fields and, at least at the broadest scale, these differences are well understood. The largest pool of nitrogen (N) in the soil occurs in the organic matter in the topsoil layer. Nitrogen tied-up in the organic matter is unavailable to plants, and must be converted to a mineral form before it can be taken up and used by growing. Mineralization depends on a number of factors, but a recent summary suggests that between 5 and 15% of the organic N can be mineralized in a given year. Hence, at the simplest level, the amount of organic matter in the soil will control the maximum amount of N available to be mineralized, and the moisture and temperature conditions in a given year will determine the fraction of that maximum available amount that will be mineralized.

This basic understanding of N fertilization can be linked with the soil differences discussed above. Soil organic matter will increase as we move from the knolls through the midslope and will usually be at its highest in the lower slope positions. Hence the maximum amount of organic N available for mineralization will also increase as we move from knolls to depressions. As well, the temperature and moisture conditions for mineralization are usually optimum in the lower slope positions, and we could expect that

the rate of mineralization would be greatest here. Overall, then, we would expect that the ability of the soil to supply N to the growing crop will be strongly related to slope position.

As discussed above, the pattern of soil moisture in a field also shows a clear pattern. Knolls or upper slope positions will have the driest conditions and will often have the lowest ability to deliver N to the crop; midslope positions will have increasing moisture levels and N availability as we move from next to the knolls to next to the lower slope areas; and moisture and N availability may be highest in the lower slope positions. The challenge for researchers and producers alike is to determine how we can use this understanding to achieve optimum use of the soil resource in crop production.

Research Design for Precision Farming Projects

In the fall of 1996 four primary test sites were selected in hummocky or undulating fields within the dominant soil zones of Saskatchewan. Soil sampling and mapping of the sites was carried out in the fall. The sites were located at the Conservation Learning Center near St. Louis, (coordinated by Agriculture and Agri-Food Canada Melfort Research Station, Dr. A. Johnston), Watrous (Saskatchewan Wheat Pool Product Development Farm, Mr. G. Hnatowich), Outlook (Saskatchewan Irrigation Development Centre, Mr. T. Hogg), and Swift Current (Agriculture and Agri-Food Canada Swift Current Research Station, Dr. B. McConkey). The Outlook location is an irrigated site.

At each site, distinct management units were determined using aerial photography combined with image analysis and extensive topographic surveys. The management units are based on soil factors of relevance to crop production (e.g., organic matter levels in different landscape positions) and can be readily extended at low cost to other landscapes in Saskatchewan.

The major emphasis of the 1997 field season was to determine the response of spring wheat to different fertility treatments on typical undulating and hummocky landscapes. Each of **the** four main sites (Swift Current, Watrous, Outlook, and St. Louis) was initially divided into 2 or 3 management units based on slope position and soil distribution, and the each treatment block spanned the full range of management units at the site (Figure 3).

N and P fertiliiation rates were varied according to soil test recommendations. Seeding rates trials were also conducted using the recommended rates of N and P fertilizer. The basic ten treatments used at each site are shown in Table 1.

An RCBD design, consisting of six replicates of the ten treatments, was used. The experiment was designed such that each replicated treatment strip extended over the complete range of management units. Spring wheat (A.C. Barrie) was grown as the test crop at all four research sites. Additional treatments were added at several of the sites to examine questions of local interest (e.g. the yield response form addition of KCl) or to accommodate the research needs of other researchers.

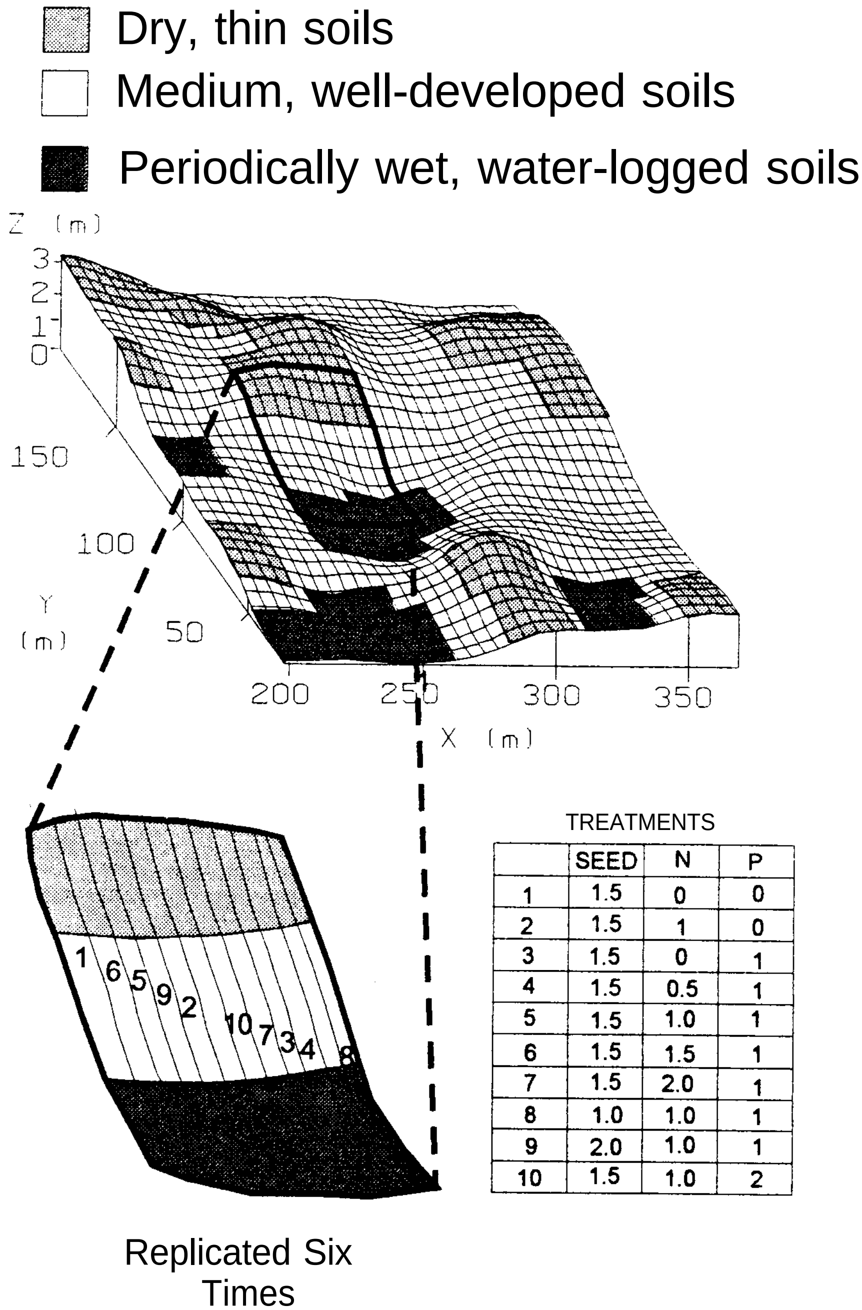
Table 1: Basic treatment structure for the four primary VRF sites

Treatment	Seeding Rate (bu /ac)	N (46-O-O)	P (11-52-O)
1	1.5	0	0
2	1.5	1 X (recommended)	0
3	1.5	0	**1 X**
4	1.5	0.5 x	1 x
5	1.5	**1.0 X**	**1 x**
6	1.5	1.5 x	1 x
7	1.5	2.0 x	1 x
8	1.0	1.0 X	1 X
9	2.0	1.0X	1 x
10	1.5	1.0X	2 x

In the 1997 field season, field operations (i.e., seeding, spraying, and harvest) were carried out by the various research partners. Each site was instrumented with a meteorological station for recording the basic temperature and precipitation regime. A small plot combine was used to harvest seed from representative strips (10 m) from each management unit within each treatment plot. The yields from each treatment were measured and the gram samples will be analyzed for protein, moisture, and thousand kernel weight.

Study sites were monitored throughout the growing season by University of Saskatchewan personnel under the supervision of Drs. F. Walley and A. Johnson. Within each management unit, plant emergence (2-3 leaf stage (pre-spraying)), plant development (Haun stage, 5-6 leaf stage (post-spraying)), and days to maturity were determined in representative 1 -m^2 areas in selected treatments. The Haun staging scale is considered the most accurate means of assessing treatment and environment effects on early crop development and involves the determination of seeding depth and staging (by leaf number and size) of the main stem and tillers. In addition, weed populations were determined within representative 1 -m^2 areas in each management unit within selected treatments. At final harvest, final biomass and harvest index were determined.

These treatments and measurements will allow us to examine the influence of variable N (and P) fertilizer and seeding rates on plant establishment and development, weed population, harvest index, gram yield and grain quality. In combination with the soil data, we can begin to develop appropriate yield response models for each management unit.



	SEED	N	P
1	1.5	0	0
2	1.5	1	0
3	1.5	0	1
4	1.5	0.5	1
5	1.5	1.0	1
6	1.5	1.5	1
7	1.5	2.0	1
8	1.0	1.0	1
9	2.0	1.0	1
10	1.5	1.0	2

Figure 3: Schematic diagram of a typical glacial till research site, the layout of one block of replicates at the site, and the basic treatment structure used.

Overview of 1997 Results

The 1997 results show us that there are real differences in the productivity of these different management units at our research sites (Table 2). The Watrous and Swift Current sites are on the type of glacial till landscapes discussed above. The St. Louis site is located on a rolling silty-very fme sand field.

The lower slope units on average yielded about 10 bushels per acre more than the upper slope units under the same fertilization regime (Table 2). The midslope units differed between the sites in their productivity – at Swift Current they produced yields similar to the lower slope units and at Watrous the yields were closer to the upper slope units.

At the irrigated site at Outlook, the degree of soil variation was much lower than at the three sites discussed above. As well, the application of irrigation water removes the moisture limitation that typically limits yields on knolls. The average yields of the three slope positions at Outlook are the same – irrigation and the limited soil variability removes the differences between the slope positions.

Table 2: Average grain yield for the slope positions at the four main AFIF sites in 1997. The crop at all sites was spring wheat. The average is for the five nitrogen treatments used at each site.

Site	Slope Position		
	Upper	Mid	Lower
	Grain Yield (bu/ac)		
Swift Current	***20***	***27***	***29***
Watrous	***28***	***30***	***39***
St. Louis (Conservation Learning Center)	**29**	____	***38***
Outlook (Irrigated)	63	63	61

Summary

Clearly many factors come into play to determine overall crop productivity in a given year. The variability of other nutrients other than N such as phosphorus or sulphur can be critical for certain crops; competition from weeds may be greatest in the lower slope positions; or in a wet year, problems with water-logging or root rot in lower slope positions may lower the yields. Hopefully, through a combination of research trials on non-level fields and of producer trials of different fertility-weed control scenarios a more complete understanding of the management of variable productivity conditions will emerge.

Acknowledgements

The Hepburn research sites are funded by a grant from the Agricultural Development Fund of the Province of Saskatchewan and in-kind funding from the Saskatchewan Wheat Pool. Additional sponsors of the Hepburn project are Flexi-Coil Ltd, Western Co-operative Fertilizers Ltd. (Westco), and the Potash and Phosphate Institute of Canada. The Swift Current, Outlook, Watrous, and St. Louis sites are funded by a grant from the Canada-Saskatchewan Agri-Food Innovation Agreement. In-kind funding for the AFIF project is provided by the Saskatchewan Wheat Pool.