

CHAPTER 8

Trends in available soil N, P, K, and S

D.A. Rennie¹

ABSTRACT

Large depletions of soil reserves of N, P and K have been shown to take place in western Canada soils with the highest in the province of Saskatchewan. This chapter includes an examination of available soil test information with a view to ascertaining whether trends for N, P, K and S reflect the impact of negative nutrient balances as well as the extensive soil degradation that has taken place.

Statements on three soil testing laboratories that supplied much of the soil test data, namely, the Agricultural Soils and Animal Nutrition Laboratory, Edmonton; Norwest Labs, Edmonton; and the Saskatchewan Soil Testing Laboratory, Saskatoon, provide an insight into the philosophy and general operation of these three relatively large prairie laboratories.

Nutrient trend lines, the majority of which cover at least 25 years, are graphically displayed in some thirty figures. These in summary show:

1. A clear and relatively defined upward trend in levels of available soil N in Manitoba, a slight trend towards the increasing levels of soil N in Alberta, and flat trends in Saskatchewan. These differences in N trends coincide with general farming practices in the three provinces, i.e. summerfallow almost non-existent in Manitoba accompanied by the highest per acre application of fertilizer N; summerfallowing accounting for approximately 30-35% for the cultivated acreage in Saskatchewan, and the lowest rate of fertilizer N usage in the prairies; and Alberta falling between these extremes.
2. Clearly defined downward trends in available soil P in Saskatchewan bottomed out in the early 1980s and have increased since that time. Phosphorus trends in Alberta are somewhat similar, but on a micro scale. Soil P levels in Manitoba declined initially as for Saskatchewan but in the past 10 years have remained remarkably constant. It is speculatively suggested that the amount of P recycled from lower depths plus the amount of P mineralized from degrading soil organic matter and residual fertilizer P has equalled (Manitoba) and exceeded (Saskatchewan and Alberta) crop removal during the past 10-15 years, thus resulting in increased P fertility.
3. Soil K levels are essentially unchanged; in some cases slight downward trends were obtained and in others levels remained constant. It would not be expected that crop use of available K or K lost through wind and water erosion would be sufficient to significantly change the available soil K across the prairies.
4. Records of available soil S are too limited from the Saskatchewan and Alberta Soil Testing Laboratories to establish any trends. It is of interest to note that over the past 10 years in Manitoba the percentage of fields requiring the addition of fertilizer S have increased from 10 to 18% suggesting a significant decline in available soil S.

¹ Dean Emeritus, College of Agriculture, Univ. of Saskatchewan, Saskatoon, SK, S7N 0W0.

The chapter concludes with a note of concern that with the decline in public funding in support of soil testing, it is highly unlikely that the data reported in this chapter will be available in the future. The cost of establishing ongoing data storage and retrieval facilities poses too high an additional cost on these laboratories which, with only one exception, no longer receive any public funding.

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INTRODUCTION

Soil testing is perhaps the most important technological tool which assists each farmer to maximize fertilizer use efficiency (Chapter 3). While it is estimated that in any one year no more than 20% of the farmers submit soil samples to one of the several soil testing laboratories in the prairie region, the resulting data sets are more than adequate to monitor changes in the soil fertility status over long periods of time. In preparation for this chapter, the directors of the larger soil testing laboratories, Mr. Jean Crepin (Norwest Labs, Edmonton), Mr. Daniel Heaney (Alberta Soils and Animal Nutrition Laboratory, Edmonton), Dr. Rigas Karamanos (The Saskatchewan Soil Testing Laboratory, Saskatoon), and Mr. Ken McGill (The Manitoba Soil Testing Laboratory, Winnipeg) were invited and agreed to provide summaries of N, P, K and S plant nutrient trends based on soil samples analyzed by their respective laboratories over the past several decades. They were also requested to provide brief statements on the general philosophy supporting soil and plant testing as an agent in improving fertilizer use efficiency and farmer profits. Descriptions of the scope and extent of program offerings, together with comments supporting the current extraction procedures used by each laboratory were prepared by Mr. Len Kryzanowski, the Alberta Soils and Animal Nutrition Laboratory, Dr. John Ashworth, Norwest Laboratory, and Dr. Rigas Karamanos, the Saskatchewan Soil Testing Laboratory. Regretfully, Mr. Ken McGill was transferred to other responsibilities in the Manitoba Department of Agriculture and so no report on his laboratory is included in this chapter. However, Mr. McGill did forward nutrient trends for that province.

In contrast to other chapters, imperial units have been used in this one because these are the units preferred by most producers and they are the primary clients of soil testing laboratories.

THE SASKATCHEWAN SOIL TESTING LABORATORY²

Preview

The Saskatchewan Soil Testing Laboratory introduced a new system for fertilizer nitrogen recommendations in the fall of 1991. The system, referred to as F.A.R.M. (Fertility Analysis and Recommendation Manager) has two phases in its present form. Phase I, which contains the whole database and regulates the whole analytical process is used by the laboratory itself. Phase II, which allows manipulation of target yield, actual precipitation, soil N (in lb/Ac) applied, targeted protein level and available soil moisture (specified directly or as depth of moist soil/texture combination), is available on disk for the soil testing user. The new system of recommendations is based on the development of target yields based on crop production functions that take into account soil moisture as of May 1 and rainfall probabilities for May, June and July. The philosophy on which development of the new system was based and the main parameters utilized in arriving at nitrogen recommendations are discussed along with changes in reporting procedures and methodology for "available" P, K and B.

The greater impact of the new system is not in the way by which fertilizer nutrient recommendations are derived but rather in the change in *philosophy* of providing fertilizer recommendations whereby *the management decision making process has been taken out of the hands of the soil testing laboratory and has been placed into the hands of the user*. As such, the "economic" analysis of the fertilizer N recommendations has been eliminated and the "optimum" rates to arrive at potential target yields and protein levels (where applicable) are now provided.

² R.E. Karamanos, Director, Saskatchewan Soil Testing Laboratory, University of Saskatchewan, Saskatoon, SK, S7N 0W0.

Soil Testing - A Process

Soil testing must be viewed as a process rather than simply an analysis. A process that reaches beyond the good implementation of the four steps in soil testing, i.e. soil sampling, analysis and extraction, calibration and interpretation, and fertilizer recommendations. A process, which inherently contains margins of error and generalizations but also a process, for which both historical evolution of soil test levels and service are integral parts. As long as Soil Testing is looked upon as a once-in-a-while exercise or simply as a means of obtaining a document with a "number" that must be followed to the letter, or as long as soil testing laboratories foster the impression that one laboratory's "number" is better than another laboratory's, the soil testing process is not served justice.

The Saskatchewan Soil Testing Laboratory, which services as many as 1000 to 1200 customers per day during peak season cannot, humanly or otherwise, provide a personalized service to each individual for whom it prints a report. Neither can the laboratory know the individual's management style and field history. A soil testing laboratory can only provide general guidelines, which describe "average" situations and these definitely have to be scrutinized by the producers and adjusted for field conditions and style of management.

The Fertility Analysis and Recommendation Manager (F.A.R.M.) System

Why the changes?

Two types of changes were introduced through Phase I of F.A.R.M., namely, procedural and those regarding the system of recommendations for major crops. The need to change procedures arose because the volume of samples handled by SSTL has increased substantially in the last few years but, more importantly, because the user requires communication of the results as soon and as efficiently as possible.

The need to change the system of recommendations was identified for sometime, since the database was becoming outdated and in some cases irrelevant. Further, soil testing as a process has undergone a tremendous change, as it should have, in recent years.

What is different about F.A.R.M.?

F.A.R.M. utilizes crop water production functions rather than nutrient response functions. It is well established that the potential yield of any given crop under any given set of climatic conditions is determined by solar energy. According to calculations performed by E. de Jong and E.H. Halstead (Saskatchewan Institute of Pedology, 1987), the potential yield for hard red spring wheat in Saskatchewan is approximately 73 bu ac⁻¹. The same scientists also demonstrated that the main modifier to this potential yield, as far as factors beyond our control are concerned, is water use. On this premise, the evolution of the new system of recommendations under F.A.R.M. appears almost natural. However, beyond the scientific basis for this development, F.A.R.M. presents the opportunity for refining predictions and recommendations both by the producer and the soil testing laboratory. It will also allow the farm dealer or agent to improve services offered to the customer. The opportunity also exists for treating different management styles and goals as separate entities, rather than different points on the same nutrient response function. Since a nutrient response function is merely an "average" of many situations (experimental points, farms, etc.), it provides the opportunity for treating those situations which are either below or above the "average" differently for any given nutrient level.

How does the new system of recommendations work?

Since the early 1970s, the Saskatchewan Soil Testing Laboratory has made N fertilizer recommendations based on three moisture scenarios. We have variously described "wet", "normal" and "dry" moisture conditions and significantly altered N recommendations on that basis. While qualitative descriptions of the three moisture regimes were given, there has been no quantitative information about moisture status. As well, the three moisture

regimes were used to generate expected yield increases from N but the actual yield goal was not given.

The new system of recommendations is based on the development of target yields based on crop production functions that take into account soil moisture as of May 1 and rainfall probabilities for May, June and July. The following sections focus on the main features of the System in its current form.

Soil climatic zones: Seven soil climatic zones (SCZ) have been identified, namely, Dry Brown, Brown, Dark Brown, Moist Dark Brown, Black, Moist Black and Grey. An extended version of this system for Alberta recognizes an additional two SCZ, namely, Wet Black and Dry Grey. Only four SCZ are recognized in Manitoba (Moist Dark Brown, Black, Moist Black and Grey).

Development of yield equations: Yield equations have been developed for wheat (hard red spring, durum, soft white, semi-dwarf and CPS varieties), barley (malt and feed), oats, corn, flax, buckwheat and canola on the basis of water use efficiency data from long-term experiments. The yield models are simple linear-plateau type, since this type of model has been shown to provide more realistic fertilizer recommendations (Cerrato and Blackmer, 1990). The linear portion of the models is reproduced from Henry (1990, 1991a) for the three major crops (Tables 1 and 2).

Probability of precipitation: Long-term (1958-88 for Saskatchewan and 1951-1980 for Manitoba and Alberta) climatic data formed the basis for the rainfall probability data presented in Table 3. These data also form the basis for yield predictions for 25, 50 and 75% probability of obtaining a certain yield in each soil climatic zone.

Fertilizer N recommendations: Determination of N fertilizer recommendations is based on crop nutrient removal. The values for total N uptake shown in Table 4 were derived for the total N uptake in both grain and straw. They were obtained by examining numerous experiments where N response was evident. At the peak of the yield curve, the grain protein, straw N and grain-straw ratio were determined.

Table 1. Moisture use-yield equations for barley and wheat.

Soil Zone	Barley	Yield for 10" WU	Wheat	Yield for 10" WU
		(bu ac ⁻¹)		(bu ac ⁻¹)
Dry Brown	$Y = (WU - 2.5) \times 5.3$	40	$Y = (WU - 2.5) \times 3.5$	26
Brown	$Y = (WU - 2.25) \times 5.7$	44	$Y = (WU - 2.25) \times 3.75$	29
Dark Brown	$Y = (WU - 2.0) \times 6.2$	48	$Y = (WU - 2.0) \times 4.0$	32
Moist D. Brown	$Y = (WU - 1.8) \times 6.2$	51	$Y = (WU - 1.8) \times 4.12$	34
Black	$Y = (WU - 1.75) \times 6.4$	53	$Y = (WU - 1.75) \times 4.25$	35
Moist Black	$Y = (WU - 1.5) \times 6.7$	57	$Y = (WU - 1.5) \times 4.5$	38
Grey	$Y = (WU - 1.25) \times 7.2$	63	$Y = (WU - 1.25) \times 4.75$	42

Table 2. Moisture use-yield equations for canola.

Soil Zone	Yield equation	Yield for 10" WU
		(bu ac ⁻¹)
Dry Brown	$Y = (WU - 2.5) \times 2.0$	15
Brown	$Y = (WU - 2.25) \times 2.5$	20
Dark Brown	$Y = (WU - 2.0) \times 3.0$	24
Moist D. Brown	$Y = (WU - 1.8) \times 3.0$	25
Black	$Y = (WU - 1.75) \times 3.3$	27
Moist Black	$Y = (WU - 1.5) \times 3.6$	31
Grey	$Y = (WU - 1.25) \times 4.0$	35

Table 3. Precipitation probabilities during the growing season (May, June and July) in inches of rainfall.

Soil climatic zone	Alberta			Saskatchewan			Manitoba		
	75	50	25	75	50	25	75	50	25
	----- % -----			----- % -----			----- % -----		
Dry Brown	4.1	5.3	6.4	4.3	5.6	7.0	--	--	--
Brown	4.4	5.7	6.9	4.5	6.0	7.5	--	--	--
Dark Brown	4.9	6.4	7.7	4.9	6.4	8.1	--	--	--
Moist Dark Brown	5.2	6.8	8.2	4.9	6.5	8.2	5.7	7.6	9.1
Black 5.8	7.5	9.0	5.3	6.8	8.5	6.1	8.0	9.6	
Moist Black	6.5	8.0	9.5	5.8	7.0	8.6	6.6	8.2	9.8
Wet Black	7.0	8.7	10.2	--	--	--	--	--	--
Grey 7.8	9.5	11.0	5.8	7.4	8.8	6.8	8.5	10.0	
Dry Grey	5.4	6.9	8.6	--	--	--	--	--	--

The N model requires input of soil organic N levels and typical straw yield values for the purposes of calculating the mineralization and immobilization components. The N mineralization values are adjusted through a function for the level of precipitation (Table 6). Typical straw yields are based on a 20 bu ac⁻¹ wheat producing 2000 lb ac⁻¹ straw and a linear function between grain and straw yield. The assumptions for calculation of the mineralization and immobilization components of the model are listed in Table 5.

The F.A.R.M. system does address the differences between stubble and summerfallow fields, which was *not* the case in the old system as recommendations for both crop practices were estimated from the same response curve.

Crop production functions for the remaining crops are not yet in place and until such functions are developed N recommendations are still offered using the traditional DRY, NORMAL and WET conditions.

Benchmark N recommendations

Benchmark recommendations have been developed on the basis of "typical" spring (May 1) soil available moisture for each soil climatic zone. A software package (F.A.R.M. Phase II) allows the user to adjust target yields and N fertilizer recommendations using the actual soil available moisture data. Typical soil available moisture are provided in Table 7.

What does typical soil moisture mean? The strength of the new system for calculating N recommendations is the potential to adjust these recommendations for changes in environmental conditions. Our estimate of the long-term average level of available moisture in the soil for a soil climatic zone is indicated on the soil test report just below the fertilizer recommendations. If the moisture level in a field is higher at seeding time than this estimate, the producer should adjust his target yield and N recommendation upwards to reflect the above average levels of water potentially available to the crop. On the other hand, if the moisture level in the field at seeding time is lower than indicated on the soil test report, then the N recommendation should be reduced to reflect the reduced yield

Table 4. Aboveground N uptake by crops.

Crop		Aboveground
		lbs N bu ⁻¹ of grain
Wheat	- HRS	1.8
	- Durum	1.8
	- CPS	1.5
	- Soft white	1.5
Canola		2.5
Flax		2.3
Barley		1.2
Oats		1.0

Table 5. Typical straw yields and soil organic N values.

SCZ	Typical straw yields*	Soil organic N
----- (lb ac ⁻¹) -----		
Dry Brown	2000	2000
Brown	2500	2500
Dark Brown	3000	3000
Moist Dark Brown	3200	3500
Black	3500	5000
Wet Black (Alberta)	3500	10000
Moist Black	3500	6000
Grey	3500	2000

* To calculate N immobilization from straw use 1% of the weight of straw. This is based on the fact that straw is 0.5% N and the N requirement for no immobilization is 1.5%.

Table 6. Nitrogen mineralization values used (% of total N in 0-6" depth mineralized during the growing season).

Rainfall probability	N mineralization (% of total N)		
	75	50	25
----- % -----			
Browns & D. Brown	1.05	1.25	1.45
Moist Dark Brown	1.03	1.23	1.43
Black	1.00	1.10	1.25
Moist Black	0.95	1.05	1.20
Grey	0.95	1.15	1.35

Table 7. Typical soil moisture values.

SCZ	Available soil moisture	
	Summerfallow	Stubble
	----- inches -----	
Dry Brown	3.0	1.0
Brown	4.0	1.5
Dark Brown	4.0	2.0
Moist Dark Brown	4.5	2.5
Black	5.0	3.0
Moist Black	5.5	3.5
Grey	6.0	4.0

Table 8. Available moisture (inches).

Depth of moist soil	Sand	Loamy sand	Sandy loam	Loam	Clay loam	Clay
(feet)	----- available moisture (inches) -----					
0.5	0.38	0.50	0.63	0.75	0.88	1.00
1.0	0.75	1.00	1.25	1.50	1.75	2.00
1.5	1.13	1.50	1.88	2.25	2.63	3.00
2.0	1.50	2.00	2.50	3.00	3.50	4.00
2.5	1.88	2.50	3.13	3.75	4.38	5.00
3.0	2.25	3.00	3.75	4.50	5.25	6.00
3.5	2.63	3.50	4.38	5.25	6.13	7.00
4.0	3.00	4.00	5.00	6.00	7.00	8.00

outlook. Using the soil texture rating on the soil test report and the depth of moist soil in the field, the actual soil moisture level in a soil is indicated by referring to Table 8.

Changes in reporting nutrient recommendations

The soil testing process contains errors that need to be recognized to make the whole process logical. The F.A.R.M. system generates a fertilizer recommendation that is rounded off to the nearest 2.5 or 5 lb increment and then the error is added and subtracted to provide the range. For example, a 53 lb N ac⁻¹ recommendation will be rounded off to 55 and will appear on the Report as 50-60; a 52 lb N ac⁻¹ recommendation, however, will be rounded off to 50 and appear as 45-55. Quality Assurance procedures have shown that 80% of the error is due to variability in the soil sample and 20% due to analytical procedures.

Special cases for reporting recommendation ranges

It is important to understand that certain ranges are provided as *Guidelines* and *not* to reflect experimental error.

Phosphorus: On soils with a high P test level, a 0-10 lb P₂O₅ ac⁻¹ recommendation will appear independent of the soil test level because benefits from the "pop-up" effect may still be realized in these soils in cool, wet springs.

Potassium: On soils with a high K test level, a 0-15 lb K₂O ac⁻¹ recommendation will appear independent of the soil test level. Benefits from seed-placement of this amount have been attributed to: (a) chloride portion of potash fertilizers, and (b) reduced diffusion of K to plant roots in cool springs. In some instances chances of achieving malt barley or averting lodging have been enhanced.

Sulphur: On Black, Moist Black and Grey soils with a high S test level, a 0-10 lb S ac⁻¹ recommendation for canola will appear independent of the soil test level. Occasionally a N:S interaction which cannot be detected by a soil test may result in reduced canola yields.

These special recommendations do not imply that application of these nutrients is necessary. They are provided for the benefit of the user and should be followed only if the user desires to experiment with the concepts described above. They will not necessarily result in positive yield responses in all soils and conditions.

Economic considerations

A space is provided at the back of the Soil Test Report for the user to calculate the *Contribution Margin*, which is the excess of total revenue minus variable costs that directly relates to the farm business operation. This can be expressed either on a per bushel or per ac basis. Table 9 is printed at the back of each Soil Test Report to allow assessment of the contribution margin with various targets and nitrogen fertilizer rates.

Changes in methodology

P and K extraction: After two years of internal development and cross-checking, a modification of the Kelowna extract presented by Qian et al. (1991) was adopted by SSTL in the spring of 1992. The original method was first used in British Columbia in 1984 to simultaneously extract P, K, Ca, Mg, Na, S and NO_3 from acid and calcareous soils (van Lierop, 1988). The extracting solution consists of 0.25N HOAc and 0.015N NH_4F with a measured pH value of 3.2. The modification consists of 0.25N HOAc, 0.015N NH_4F plus 0.25N NH_4OAc with a measured pH of 4.9. Levels extracted by this method were highly correlated with those extracted by bicarbonate in over 1200 fields and correlations were excellent for all texture and soil pH ranges. Levels extracted by the Kelowna modification are similar to those extracted by bicarbonate.

F.A.R.M. PHASE II: F.A.R.M. Phase II is a software package, which accepts the following: (i) soil texture, (ii) electrical conductivity, (iii) spring soil moisture, (iv) soil climatic zone, (v) crop type, (vi) target yield, (vii) targeted protein level, and (viii) N test level in lb ac^{-1} for each analyzed depth or depths.

The program allows manipulation of target yield, actual precipitation, soil N (in lb ac^{-1}) applied, targeted protein level and available soil moisture (specified directly or as

Table 9. Calculation of the Contribution Margin.

	Target:	1	4
PART 1. CALCULATION OF VALUE OF PRODUCTION				
101	Yield in bu/acre		_____	_____
102	Price \$/bushel		_____	_____
103	Value of production/acre (multiply line 101 X line 102)		_____	_____
PART 2. CALCULATION OF VARIABLE COSTS				
201	Seed (\$/acre)		_____	_____
202	Fertilizer - Nitrogen		_____	_____
	- Others	_____	_____	_____
203	Herbicides		_____	_____
204	Machinery		_____	_____
205	Insurance		_____	_____
206	Marketing		_____	_____
207	Interest/Opportunity		_____	_____
208	Total Variable Costs (add lines 201 through to 207)		_____	_____
PART 3. CALCULATION OF CONTRIBUTION MARGIN				
301	Value of production/acre (from line 103)		_____	_____
302	Variable cost (from line 208)		_____	_____
303	Contribution Margin/acre (Subtract line 302 from line 301)		_____	_____
304	Contribution Margin per Bushel (Divide line 303 by line 101)		_____	_____
305	Price to cover variable costs per bushels (Subtract line 304 from line 102)		_____	_____

Table 10. Acetic/fluoride test results and cereal response to phosphate fertilizer.

<u>P level</u>	<u>Acetic/fluoride test result (ppm)</u>	<u>Probability of response to P* (% of sites in stated P range)</u>
Deficient	< 9	100
Low	9 - 14	47
Marginal	14 - 26	24
Optimum	> 26	6

* Response is defined as crop yield more than 15% above yield of no P check plots

Table 11. P concentrations (mg kg⁻¹) in soil samples (0-15 cm) taken by corer or slot cutter.

Sample #	1	2	3	4	5	6	7	8	9	10	11	12	<u>Mean</u>	<u>%CV</u>
Corer	11	8	10	34	7	6	28	8	13	8	8	9	13	72
Slot cutter	16	11	18	16	15	14	13	14	16	14	16	22	15	24

depth of moist soil/texture combination). The user can specify up to four of the above parameters and the program will calculate the fifth one. Typical values will be substituted for parameters which have not been specified in order to calculate the amount of fertilizer required. If the precipitation is not specified, the program will use typical values for the 25%, 50% and 75% precipitation probabilities in order to calculate the required fertilizer. If adjustment of other nutrients (P and S) is necessary due the targets selected, the program will provide comments for fertilizer rate adjustment.

NORWEST LABS ³

Improved Test for Available P and K

Available P and K in soil has been measured at Norwest Labs since April 1988 by the "acetic/fluoride" (A/F) method.

In the A/F extractant, ammonium fluoride in a relatively concentrated solution of weakly-dissociated acetic acid is used, rather than a dilute solution of a strong acid such as HCl (Bray extractants) or sulphuric acid (Miller and Axley). Thus, the A/F extract is buffered at pH \approx 4.5 even in the presence of soils with free lime. The extracting solution also contains ammonium acetate.

For comparison purposes, several hundred soils submitted for routine testing were extracted using the Olsen, Miller and Axley and A/F procedures (Ashworth and Mrazek, 1989). For acid and neutral soils, available P results obtained by the A/F method were better correlated with Miller and Axley values, whereas for soils with free lime, A/F-P correlated well with Olsen-P but the Miller and Axley method gave low, erratic results.

Extractable K results were well correlated (1:1) with values routinely obtained using ammonium acetate solution.

³ J. Ashworth, Norwest Labs, 9938 67th Ave., Edmonton, AB, T6E 0P5.

Predictive Capability of the A/F Method

Two sets of soils were used to calibrate the A/F extractant; one set of 92 soils from sites of the well known Alberta-wide "RAYP" barley trials (1970-1974) and another set of 59 soils from more recent barley and wheat trials (1984-1988) testing different rates of phosphate fertilizer at various farm sites in Alberta and Saskatchewan. The A/F extractant successfully categorized responsive and unresponsive sites (Ashworth and Mrazek, 1989).

Results for the more recent set of soils are given in Table 10; the chance of obtaining a visible crop yield response to added P (defined for this purpose as a greater than 15% yield increase over no P addition) falls off sharply as the A/F soil test result increases. Similar results were obtained for the soils from the RAYP trials. This similarity indicates that, whether or not the available P status of farm soils changed in the (roughly) 15 years between the two sets of trials, the predictive capability of the A/F test did not.

As a result of its successful performance in tests of various extractants (Qian et al., 1991) the A/F method has recently also been adopted by the Saskatchewan Soil Testing Laboratory and therefore is now used for available P and K at major labs in all prairie provinces.

Soil P Tests and Phosphate Fertilization Rates

Although the A/F test is reliable in predicting the percentage chance of a crop responding to phosphate fertilizer, the correlation between soil test P and the optimum phosphate fertilizer rate actually observed in trials (though better than with other tests) is not very high. Cooke (1971) noted that many factors which affect the availability of P to a crop (soil tilth, moisture, temperature, etc.) vary from year to year. Therefore, in contrast to the agronomics of nitrogen fertilization, it is not feasible to calculate an "economic" rate of phosphate fertilizer on the basis of a soil test. Twenty years later, Henry (1991) repeated this warning. An approach compatible with the concept of sustainable agriculture is to fertilize so as to maintain optimum P (and K) soil test values (allowing for annual crop

removal of P and K), then to apply an economic rate of nitrogen fertilizer. The N rate should be based on both the available soil test N and on local management and available moisture conditions.

Slot Sampling Versus Core Sampling of Soils

The usual method of estimating available nutrients in cropped fields involves taking samples from up to perhaps 25 well-separated points using a corer or auger, then analyzing a specimen of the composite material thus obtained. The residues of most banded fertilizer (especially of P) remain close to the line of application, particularly under conservation tillage. Therefore, point sampling techniques can fail to provide a representative composite sample.

Analytical results for 12 samples of soil from narrow slots 15 cm deep cut across two or three stubble rows (Table 11) showed much less variability in P than results for 12 cores taken to 15 cm from plots with residues of seed-placed phosphate (Ashworth, 1990). The lower % coefficient of variation (CV) in the case of the slot sample results suggests that far fewer subsamples would be required to provide a representative composite sample. To ensure a mean result falling within $\pm 2 \text{ mg P kg}^{-1}$ of the true population mean (95% probability) would require a composite made up of only 12 slot samples in the above case; in contrast, 90 cored subsamples would be required. Ashworth (1990) used a modified chain-saw to take the slot samples; because of chain tooth wear problems, a chain saw may not be a practical tool, but other designs are possible.

THE AGRICULTURAL SOILS AND ANIMAL NUTRITION LABORATORY, ALBERTA AGRICULTURE ⁴

Soil testing in Alberta was first started in the 1940s by Mr. A.S. Ward at the Department of Soil Science, University of Alberta. The soil samples were tested using spot plate methods which gave only qualitative results. These tests were only useful in identifying salts and high nutrient levels.

In 1956, through the joint efforts of Alberta producers, the University and the Alberta Department of Agriculture, a combined agricultural soil and feed testing service was established and named the Alberta Soil and Feed Testing Laboratory (ASFTL). In 1967, the laboratory was transferred to the Soil Branch, Alberta Agriculture and was located at the University of Alberta and shared joint facilities with the faculty of Agriculture until 1968. Late in 1968, the laboratory was moved to the new O.S. Longman building joining several other government laboratories serving the agricultural industry. The functions of the laboratory today included (a) providing an analysis and recommendation service for soils, plants and animal feeds to the general public on a fee basis, (b) providing diagnostic and investigational services for the Department of Agriculture with regard to special soil, plant and animal feed problems, (c) conducting applied research to delineate major problems and where possible, to initiate studies to solve them, and (d) to compile and summarize analytical data for scientific and diagnostic use.

Initially, the ASFTL was the only soil and feed analysis laboratory operating in Alberta. However, since the mid 1970s, various private laboratories have been able to provide similar analytical capabilities to producers. Since then the volume of producer samples submitted to the ASFTL has decreased to the point that the laboratory now handles less than 10% of all Alberta producer samples. In 1986, the name of the laboratory was

⁴ L. Kryzanowski, Agricultural Soils and Animal Nutrition Laboratory, Edmonton, AB, T6H 4P2.

changed to the Agricultural Soils and Animal Nutrition Laboratory (ASANL) to reflect its change in mandate.

The ASANL has four major objectives:

- (1) To identify and develop diagnostic and routine laboratory methodologies in soil, plant and animal feed analyses.
- (2) To transfer results of research and development to producers, directly and through private sector laboratories, agri-business and department extension so as to ensure the farming public has access to the latest technology and recommendations.
- (3) To provide basic diagnostic and analytical services to private and public research and extension institutions.
- (4) To participate as an active partner with agencies conducting multi-disciplinary applied research.

The services of the laboratory includes:

- (a) Analyses and recommendation services to Alberta farmers and other producers for economic maximization of crop and animal production.
- (b) Diagnostic services to Alberta Agriculture staff to enable efficient extension and advisory functions to farmers, greenhouse operators and other producers with special soil, crop and animal problems.
- (c) Research analysis services to public and private agency researchers for projects directed toward the improvement of crop and animal production.
- (d) Reference laboratory services to private sector laboratories for the purposes of cross referencing methodologies, confirming analyses on unusual samples and quality assurance.

SOIL NUTRIENT TRENDS - ALBERTA (1962-1991) [†]

The ASANL database for producer submitted soil samples covers a 30-year period from 1962 through to 1991. The volume of soil samples analyzed by the laboratory has varied during this period, with the recent years showing a steady decline as discussed earlier. Soil nutrient trends over time are presented as five year running averages and separated into irrigated stubble, non-irrigated stubble and non-irrigated fallow. For the purpose of comparing major agroecological zones over time, data summaries were prepared for four soil groups: Brown and Dark Brown soils, Thin Black and Black soils, and Dark Grey and Grey Luvisols.

The nutrient data for N, P, K and S were plotted initially as annual fluctuations. The annual fluctuation trends are not included but it is important to note that the yearly changes for each nutrient often range in excess of 100% of the average values. Such variations would be expected for soluble nutrients such as nitrate-N, but not for P and K. While reasons for these widely differing annual levels of plant nutrients requires further research, it is suggested that the more important are extent of crop removal during the preceding summer season, the random inclusion of samples taken from banded fertilizer applications, and non representative sampling of major soil regions. It should be noted that similar widely fluctuating nutrient levels were also typical of both the Saskatchewan and Manitoba data.

Nitrogen

The quantity of nitrate-N in soil has been consistently used as an index of N availability. However, unlike Manitoba and Saskatchewan, early research in Alberta indicated that the 0-6 inch depth was nearly as effective as the two feet sampling for assessing N availability and for making fertilizer N recommendations. However, the laboratory and Alberta Agriculture still recommends and encourages soil sampling to two feet to determine available N levels.

[†] See previous footnote 4.

Available soil N as defined in the Alberta system has shown a small but consistent increase over the past 25 years (Figs. 1, 2 and 3). The similarity between irrigated and non-irrigated stubble (Figs. 2 and 3) is remarkable considering the vastly different ecosystems that these two farm systems represent. It is interesting to note that zonal differences are almost non-existent for the non-irrigated stubble, whereas the traditional differences between the more humid and leached northern soils and the southern Brown and Dark Brown Chernozemic soils is reflected in the fallow (Fig. 3). Comparing fallow and stubble soil N levels (Fig. 3 versus Fig. 2) indicates that fallow levels were approximately 2 to 2.5 times as great as stubble.

Phosphorus

The ammonium floride-sulphuric acid (Miller and Axley, 1956, modified Bray P.2) extractable P in the 0-6 inch depth has been used as the index of available soil P since the beginning of soil testing in 1962.

As found for $\text{NO}_3\text{-N}$, available P has moved slowly in irrigated stubble land. The five year running averages (Figs. 5 and 6) indicate that initially the Grey Luvisolic and Peace River soils had the highest annual soil test P levels, the Thin Black and Black soils intermediate levels and the lowest levels were in the Brown and Dark Brown soils. For all soil zones, there was an initial decline in soil test P. After this decline, the soil test P levels for the Brown and Dark Brown, and the Thin Black and Black soils leveled off and was followed by a general increase. In contrast, the Grey Luvisolic and Peace River soils continued to decline until the average P levels of these soils were lower than the Brown and Dark Brown, and Thin Black and Black soils. The irrigated Brown and Dark Brown stubble soils indicate a relatively constant to slight increase in available soil P level over time (Fig. 4). The observed zonal differences may be due to soil pH and free CaCO_3 which can influence the effectiveness of the acidic extraction.

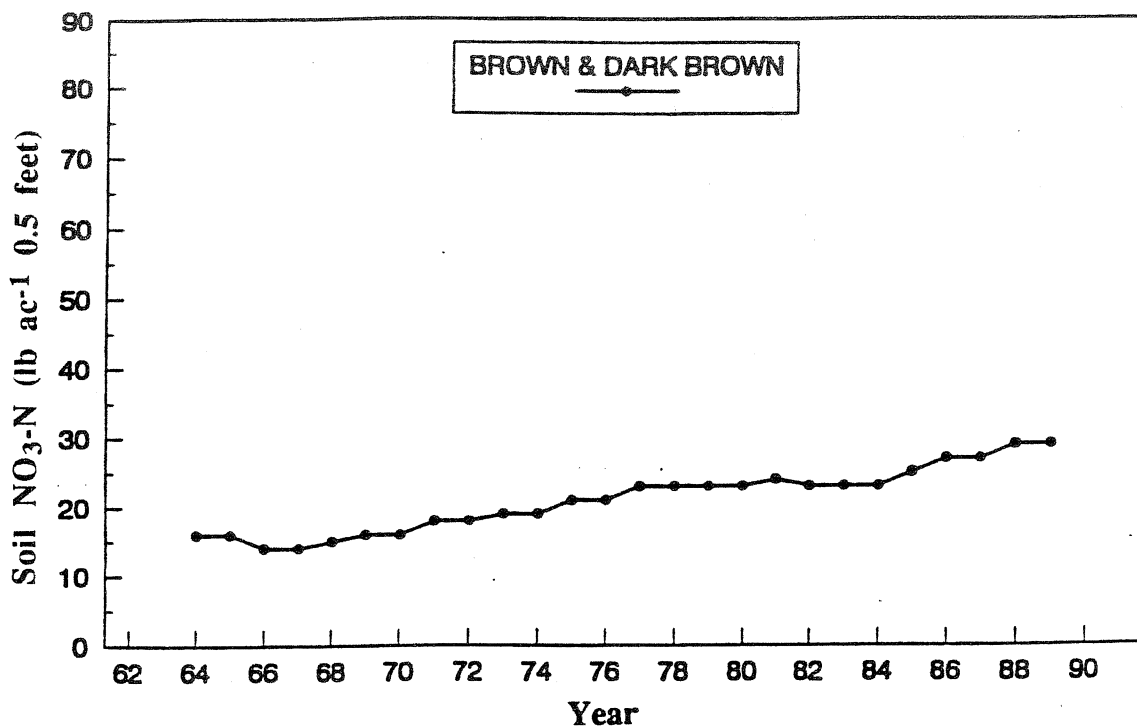


Figure 1. Five year running averages of soil N for irrigated stubble - Alberta.

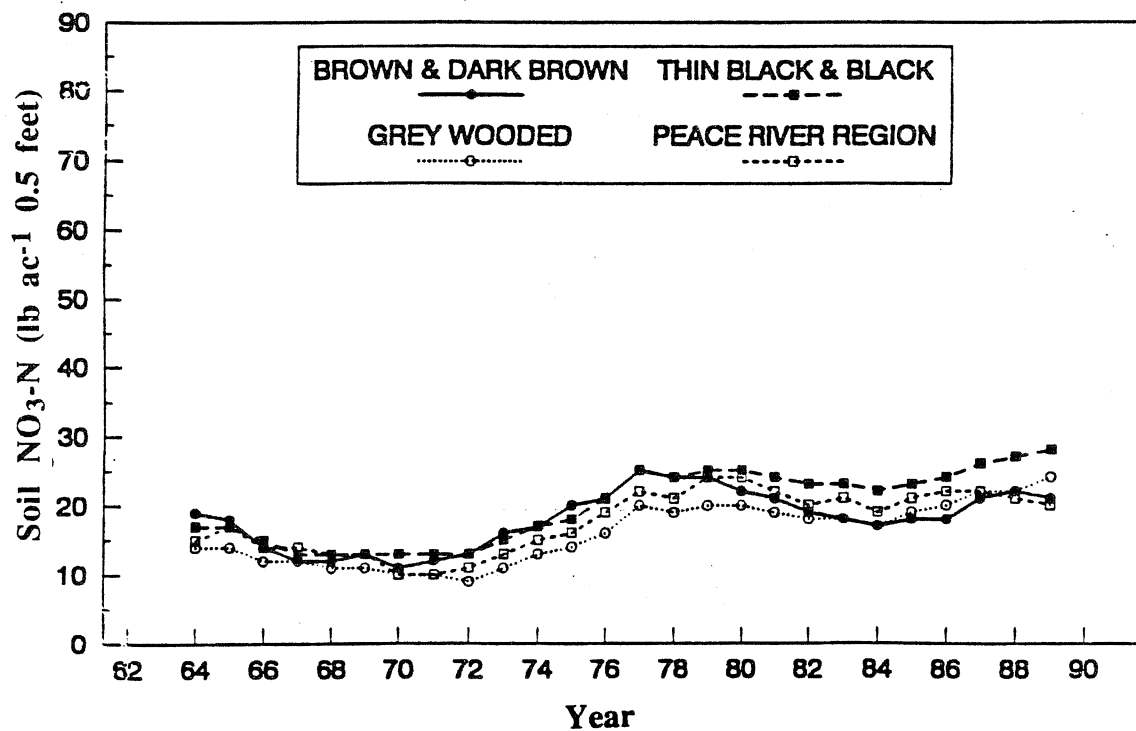


Figure 2. Five year running averages of soil N for non-irrigated stubble - Alberta.

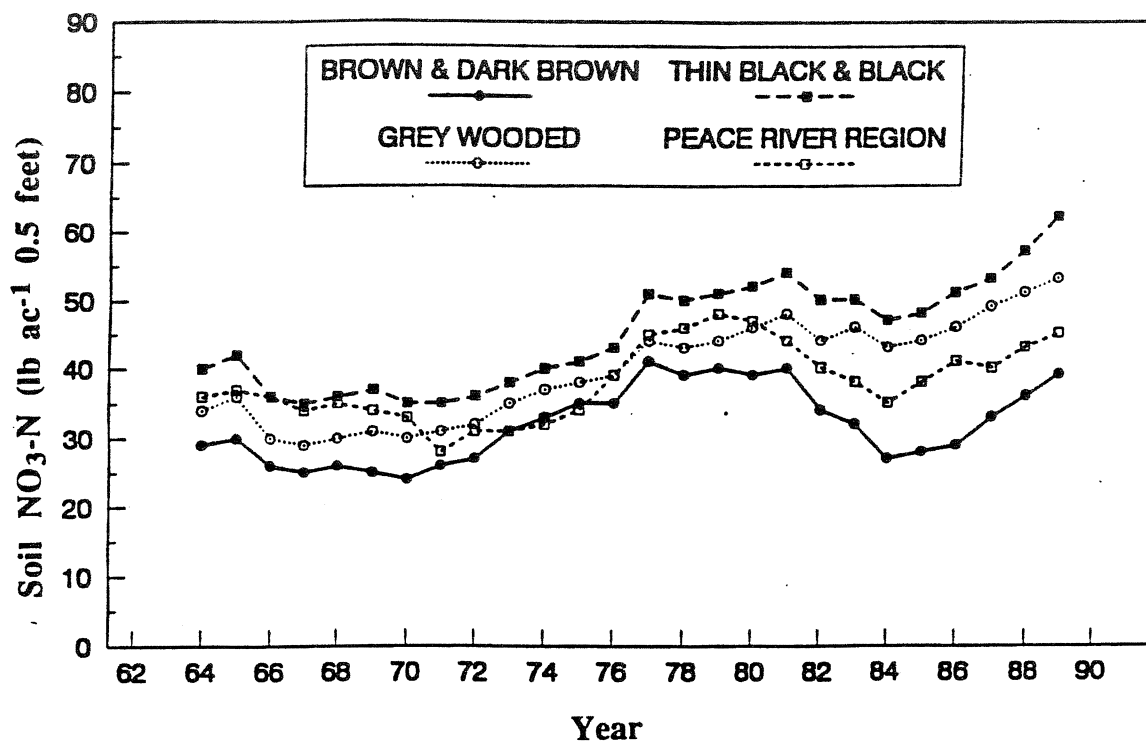


Figure 3. Five year running averages of soil N for non-irrigated fallow - Alberta.

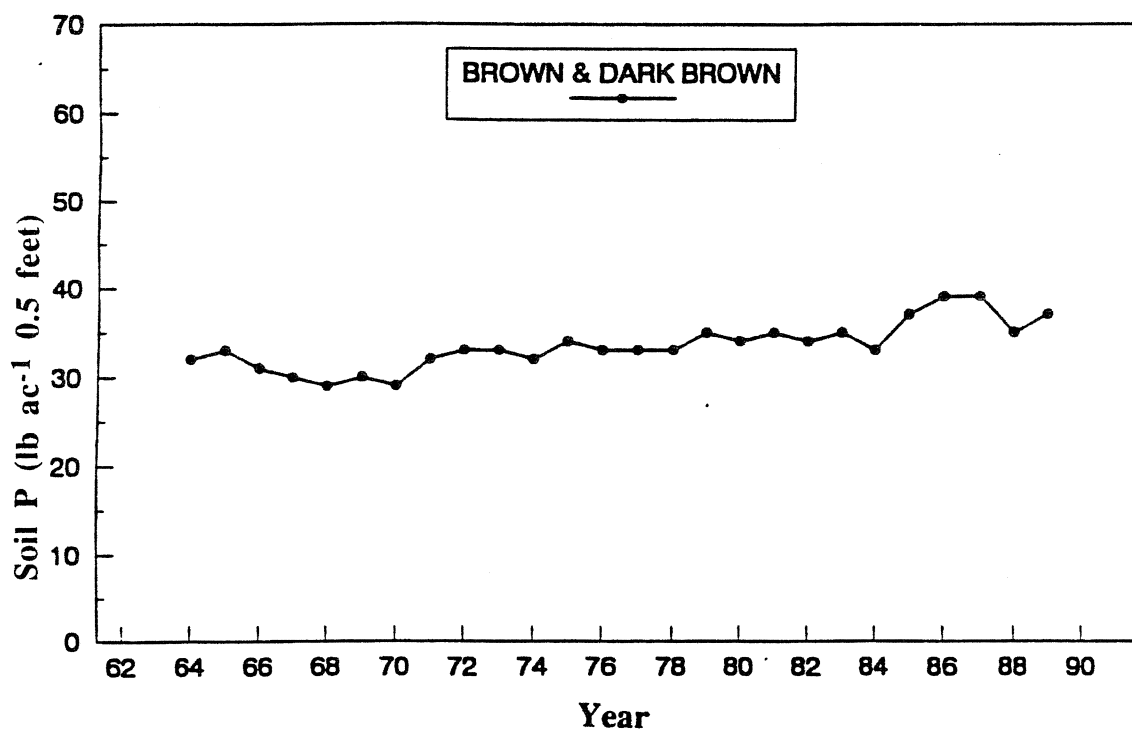


Figure 4. Five year running averages of soil P for irrigated stubble - Alberta.

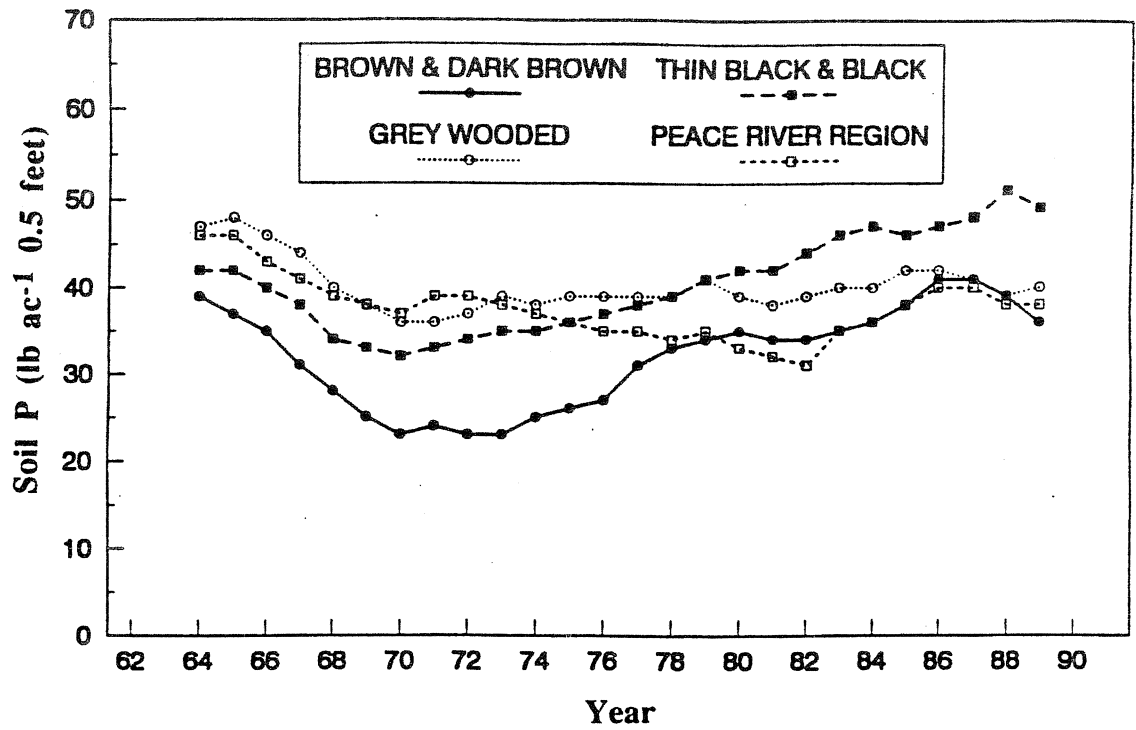


Figure 5. Five year running averages of soil P for non-irrigated fallow - Alberta.

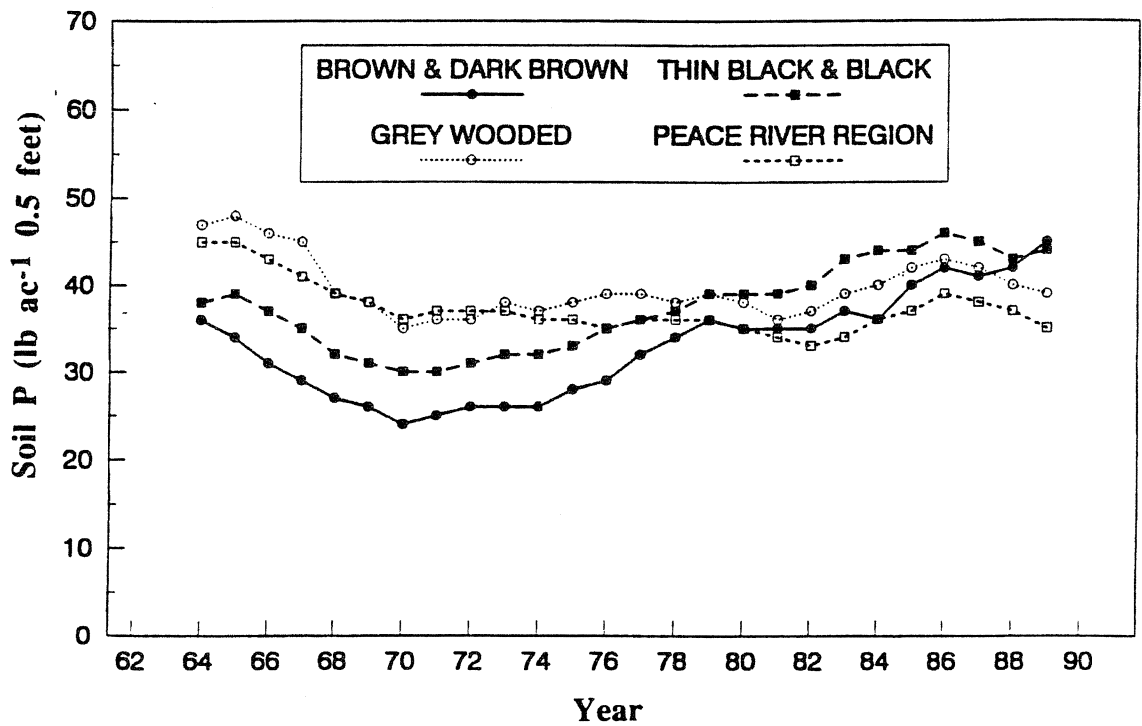


Figure 6. Five year running averages of soil P for non-irrigated stubble - Alberta.

In terms of total agricultural area (Table 12), only about 7% of the land would be considered as having available P level adequate for crop production. Approximately 93% would have some degree of deficiency, with 41% classed as very deficient.

Potassium

The available soil K in the 0-6 inch depth is measured using ammonium acetate extraction. This procedure has been used since 1965.

Trends in available K in the Brown and Dark Brown zones were similar for irrigated stubble, dryland stubble and fallow land (Figs. 7, 8 and 9). Generally there was a slight increase in the 1960s, followed by "no change" trends in all zones. A distinct zonal effect on the soil test K level is evident (Figs. 8 and 9). For both fallow and stubble fields, the highest soil test levels are for the Brown and Dark Brown soils, while the Thin Black and Black, and Peace River soils have intermediate, and the Luvisolic soils the lowest levels.

Studies in Alberta have indicated that the division between deficient and sufficient soil test K classes ranges from 125 to 150 ppm (150 to 300 lb ac⁻¹). Based on this range, some degree of K deficiency could be expected for a maximum of 6.8 million acres (21%) of the agricultural land in the province (Table 13). However, the majority of this acreage (5.2 million acres) would probably be only marginally deficient such that crop response to K fertilization would be dependent on other growth conditions. Approximately 1.6 million acres (2%) would be considered severely deficient where the soil K level is the primary limitation for crop growth.

Sulphur

Available soil sulphate-S was measured using a weak calcium chloride extraction starting in 1969 for most of the province and 1971 for Brown and Dark Brown soils. Although the ASANL makes S fertilizer recommendations based on surface (0-6 inch) soil samples, the laboratory and Alberta Agriculture encourages sampling to two feet to assess the available S level of a soil. The data summary presented is only for the 0-6 inch soil layer.

Table 12. Acreage estimates of various levels of soil P in the 0-6" depth - Alberta[†].

Soil test category	Soil test level (lb ac ⁻¹)	Area estimate (acres)	Percent of provincial area
Deficient	Below 21	12,572,000	41
Marginal-deficient	21-40	10,209,000	33
Marginal-adequate	41-70	5,808,000	19
Adequate	Above 70	2,280,000	7

[†] Kryzanowski and Lavery, 1985Table 13. Acreage estimates of various levels of soil K in the 0-6" depth - Alberta[†].

Soil test category	Soil test level (lb ac ⁻¹)	Area estimate (acres)	Percent of provincial area
Deficient	Below 151	525,000	2
Marginal-deficient	151-200	1,021,000	3
Marginal-adequate	201-300	5,209,000	16
Adequate	Above 300	25,661,000	79

[†] Kryzanowski and Lavery, 1985

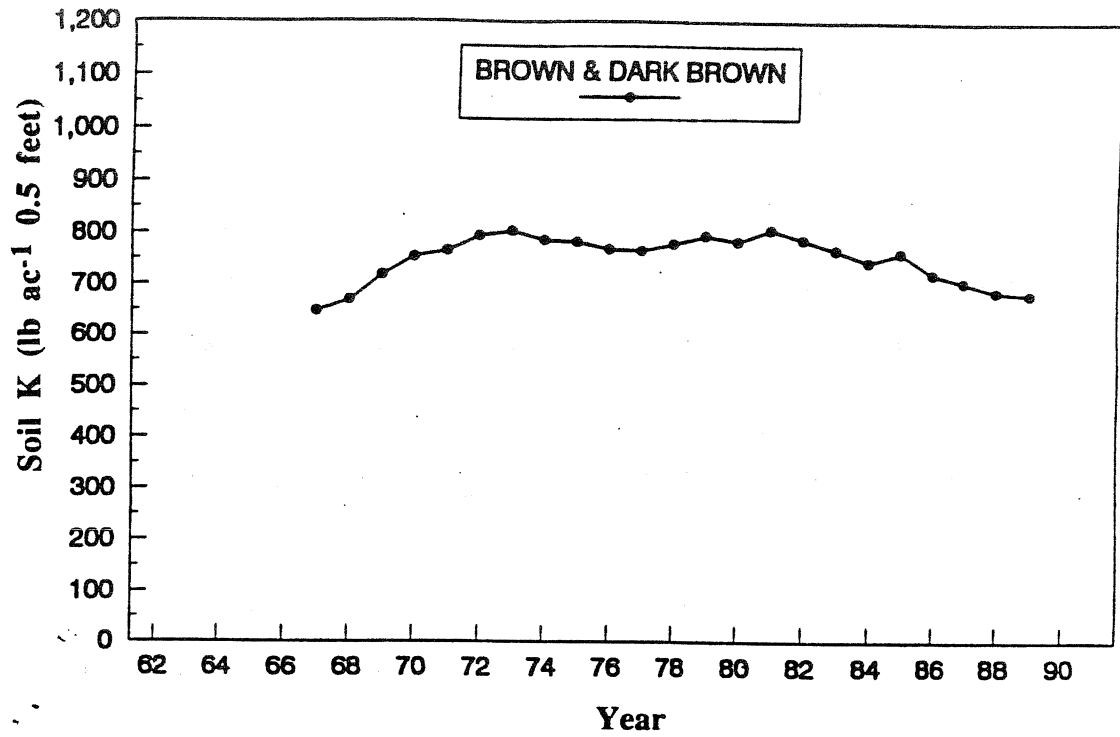


Figure 7. Five year running averages of soil K for irrigated stubble - Alberta.

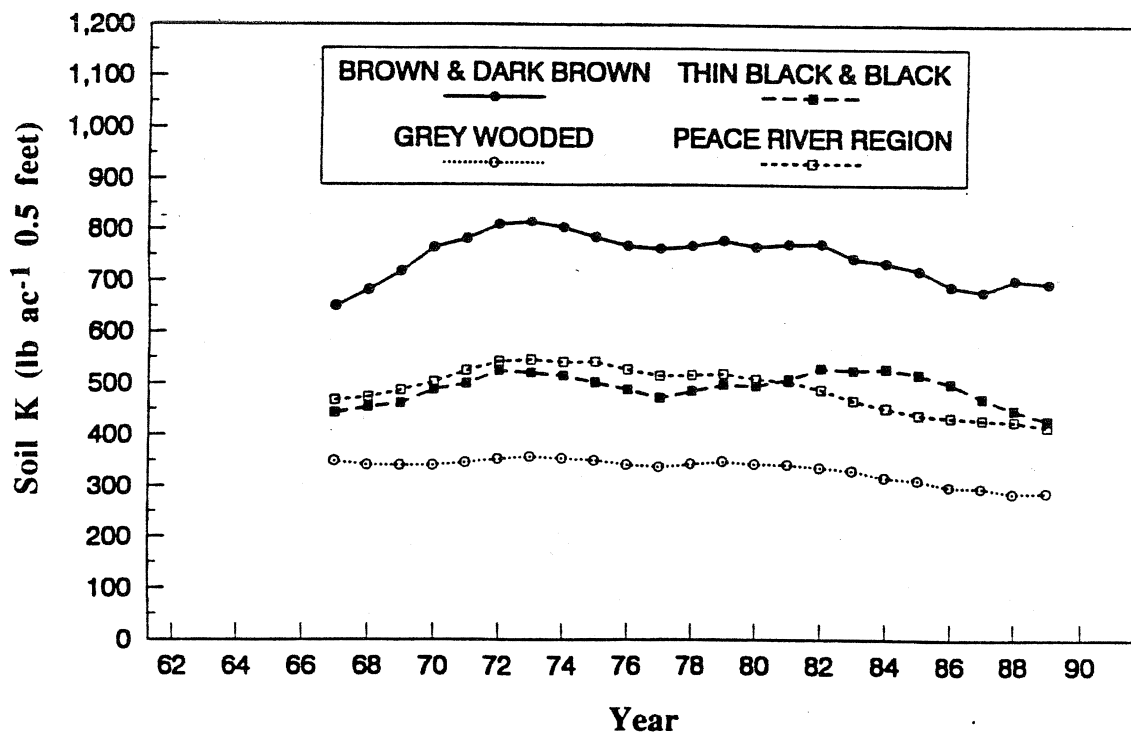


Figure 8. Five year running averages of soil K for non-irrigated stubble - Alberta.

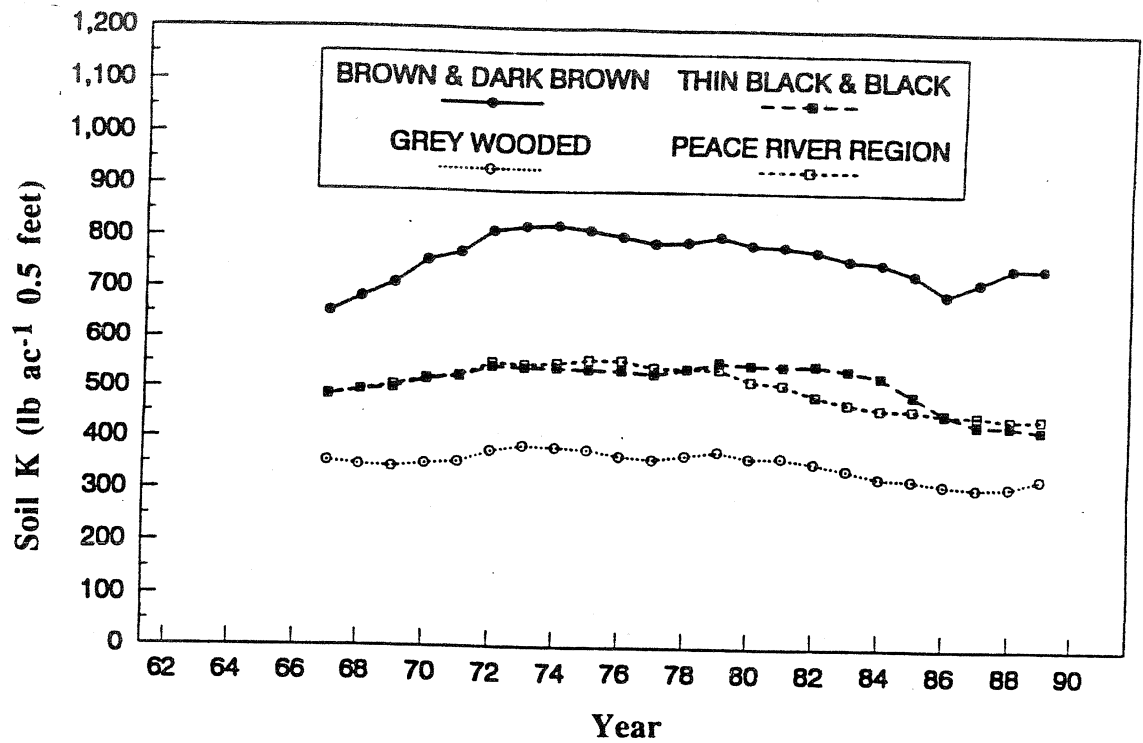


Figure 9. Five year running averages of soil K for non-irrigated fallow - Alberta.

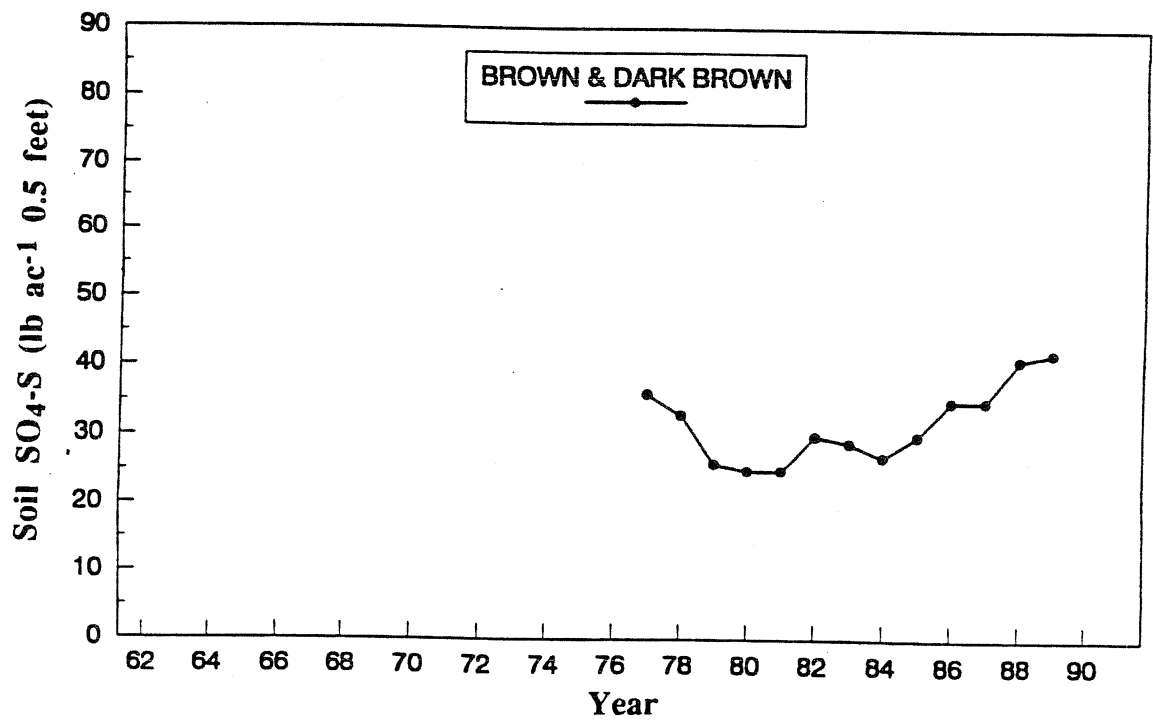


Figure 10. Five year running averages of soil S for irrigated stubble - Alberta.

The available S in the irrigated stubble soils (Fig. 10) has shown a clearly defined upward trend during the past 10 years. This trend is not evident in the non-irrigated stubble soils (Fig. 11) or fallow (Fig. 12). There appears to be little doubt that the upward trend in available soil S in the irrigated stubble soils reflects addition of S from irrigation water.

While the trend line for the available soil S in Grey Wooded soils was consistently lower than the other zones (Figs. 11 and 12), the differences were not large. In general, there is no discernible difference between the available S level between any of the Chernozemic soils.

SOIL NUTRIENT TRENDS - SASKATCHEWAN ⁵

The Saskatchewan Soil Testing Laboratory commenced operations in September of 1966. Routine farm field testing for fertilizer recommendation purposes involved analysis of standard 0-6, 6-12 and 12-24 inch depths for N, P, K and S. Those standard depths of analysis for farm fields remained in place continuously until 1989. The extraction procedures were uniform throughout that period of time as well, with one exception. In 1966 and 1967 K was measured as exchangeable K extracted with ammonium acetate. From 1968 onwards, the sodium bicarbonate extractable K has been used as the measure of available K. The sodium bicarbonate extraction removes about two-thirds of the amount extracted by ammonium acetate, except in clay soils. For clay and heavy clay soils the sodium bicarbonate extraction can remove as much or more K than the ammonium acetate extractant.

Because the methods have remained fundamentally the same, standard depths were used and soil test summaries were generated each year, it is possible to use the long term records from the Saskatchewan Soil Testing Lab as a measure of available N, P and K nutrient changes in Saskatchewan soils over time.

⁵ J.L. Henry, Department of Soil Science, University of Saskatchewan, Saskatoon, SK, S7N 0W0.

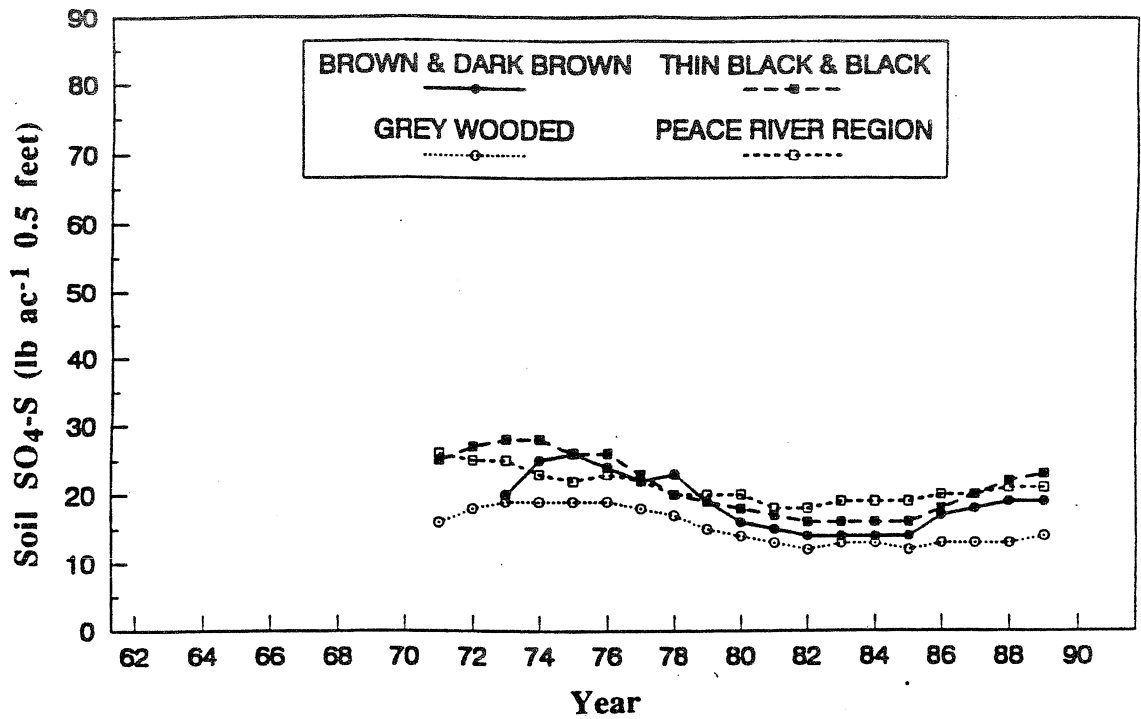


Figure 11. Five year running averages of soil S for non-irrigated stubble - Alberta.

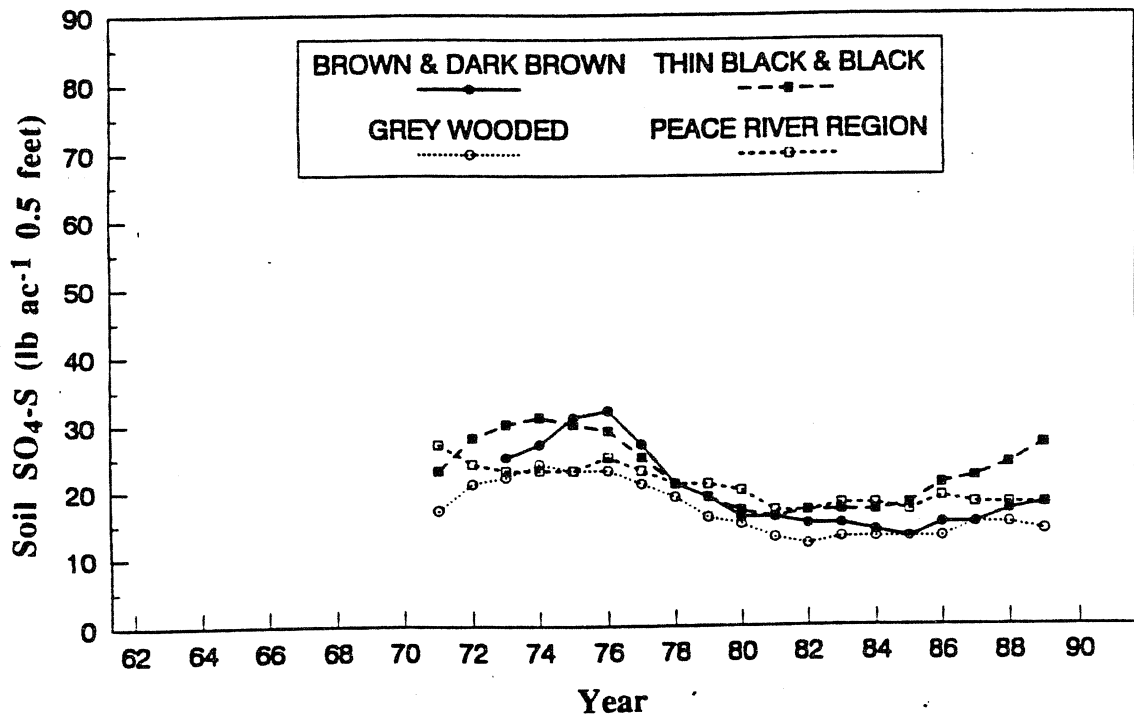


Figure 12. Five year running averages of soil S for non-irrigated fallow - Alberta.

Nitrogen

For N, the quantity of nitrate-N in total to a depth of two feet has been used as an index of N availability (Chapter 3). For the purpose of comparing major soil climatic zones over time, annual mean values were prepared for three soil groups. The Brown and Dark Brown soil zones were treated as a group as were the Thin Black, Thick Black and Gray Black. The Gray soils were treated as a separate group. Assembly of the data in the above grouping for fallow land shows the superior N status of Black soils, the inferior status of Gray soils with Brown and Dark Brown soils occupying an intermediate position (Fig. 13). While large annual fluctuations are clearly evident in the data, there is no long term trend apparent. A declining trend line was present from 1976 to 1986 but this was reversed with the drought conditions in the late 1980s.

The comparable N data for stubble land (Fig. 14) shows the clearly inferior N supplying power of Gray soils, but the Brown and Black soil groups were not markedly different. The average stubble N of the Black group was affected by low levels of Gray Black soils. Again, there was no long term trend. The annual fluctuations on stubble were less than those observed for fallow fields.

The overall comparison of fallow and stubble (Fig. 15) shows soil available N levels to be approximately 40 lbs per acre for stubble fields and approximately 80 lbs per acre for fallow fields. Year to year fluctuations were greater for fallow than stubble and the two curves run more or less parallel with no long term trends evident.

Phosphorus

The sodium bicarbonate extractable P in the 0-6 inch layer has been used as the index of available soil P since the beginning of soil testing in 1966.

For fallow fields the highest P levels were recorded for Gray soils, intermediate levels for Black soils and the lowest levels for Brown soils (Fig. 16). The available P level

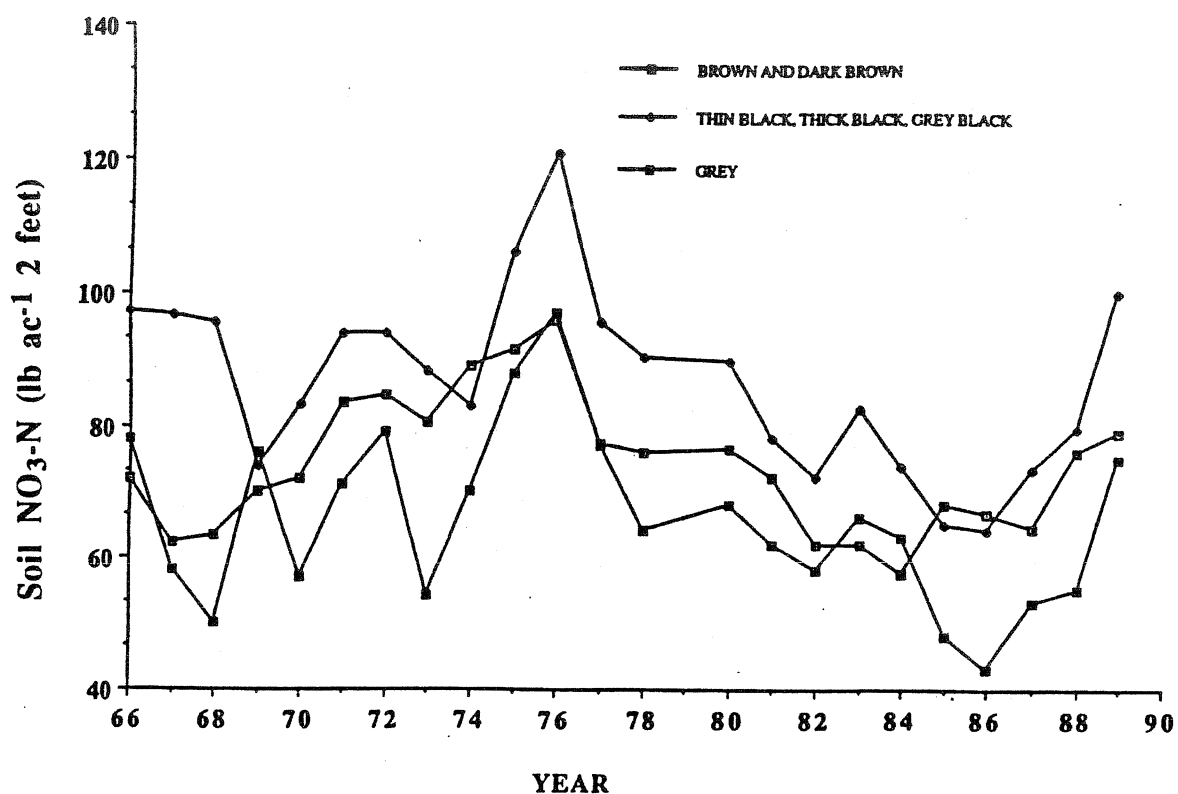


Figure 13. Soil N on fallow - Saskatchewan.

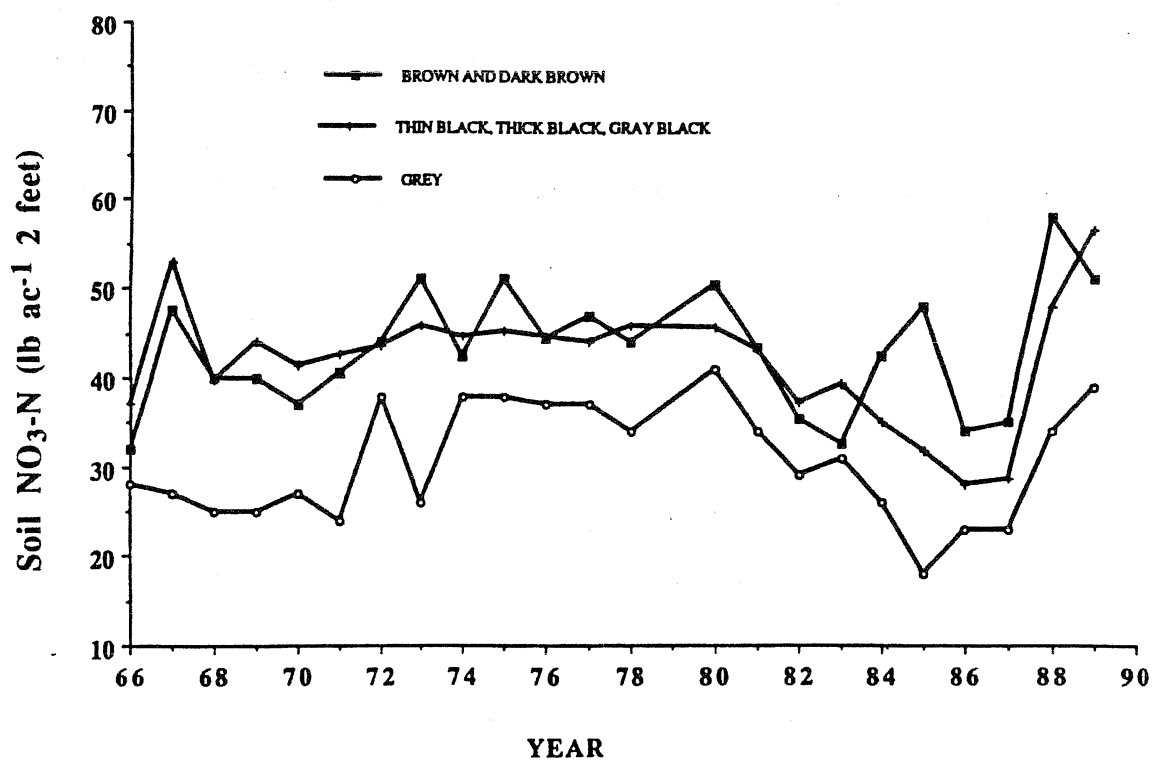


Figure 14. Soil N on stubble - Saskatchewan.

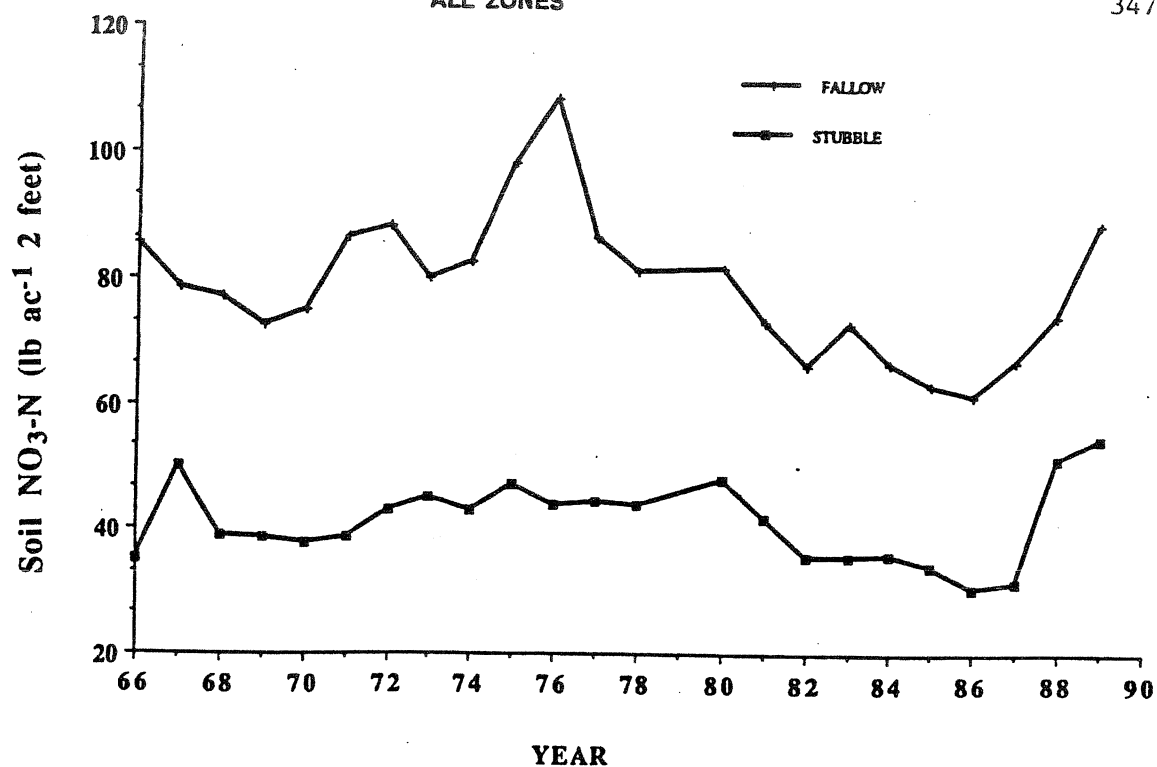


Figure 15. Soil N - Saskatchewan.

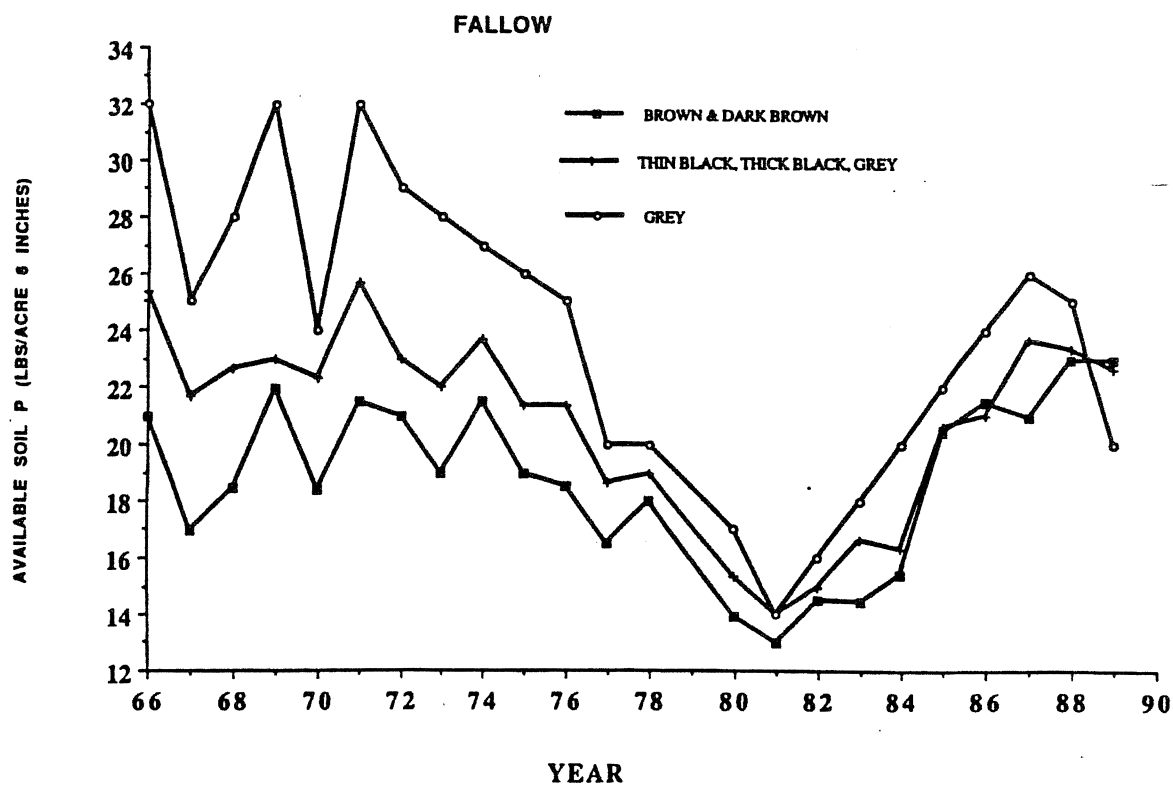


Figure 16. Soil P on fallow - Saskatchewan.

for Gray soils is probably related to the lower pH value in those soils. Figures 16 (fallow), 17 (stubble) and 18 (all zones) provide a consistent, but as yet unexplainable, pattern of change in soil test levels over time. From about 1972 through 1981 a sharp decline in P levels was recorded. After the low levels of 1981, a sharp rise in P levels has been recorded since that time. Because the pattern is the same across all soil zones, it does not appear that changing distribution of samples provides any insight into the apparent cyclical P pattern. Changes in soil test users from those using P fertilizers consistently to new clients who had not previously used P fertilizer could result in a decline in measured level but there is no basis on which to establish such a relationship. It is significant to note that soil-P trends in Alberta (Figs. 5 and 6) follow a similar pattern on a microscale, notwithstanding the differences in extraction procedure.

Potassium

Before examining the K soil test data, it must be recalled that in 1966 and 1967 the K soil test utilized was the ammonium acetate extraction technique. From 1968 onward the K was measured by a sodium bicarbonate extraction, which removes about two-thirds as much K as ammonium acetate. Therefore, the sharp decline from 1967 to 1968 is due to a change in extraction procedures rather than any change in actual levels in the field.

The K status of fallow fields by soil zone group shows the clearly higher levels for Brown soils, the intermediate level for Black soils, and the lower level for Gray soils (Fig. 19). From about 1974 through 1989, there does appear to be a gradual and small decline in available K levels.

The available K levels for stubble fields (Fig. 20) show essentially the same trends as for fallow fields with the soil zone groups being in almost exactly the same positions (Fig. 20).

A comparison of the available K across all zones for stubble and fallow fields (Fig. 21) shows stubble fields to be slightly higher than fallow fields, although the differences

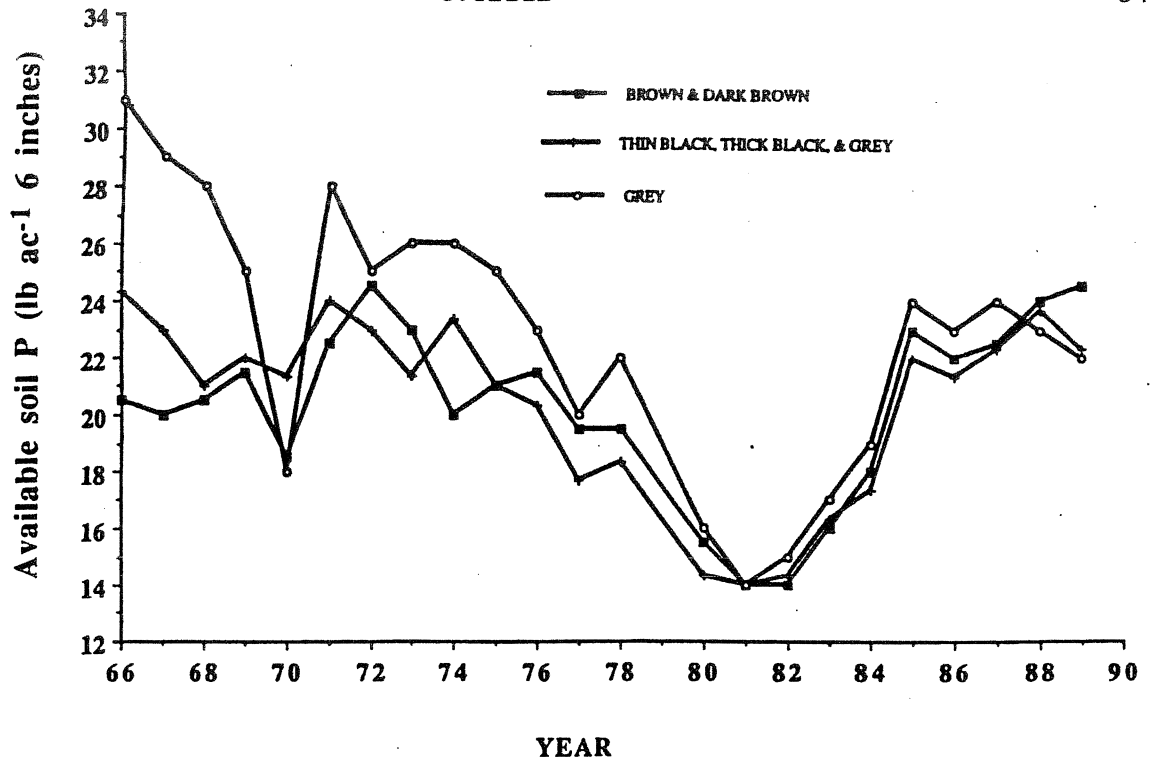


Figure 17. Soil P on stubble - Saskatchewan.

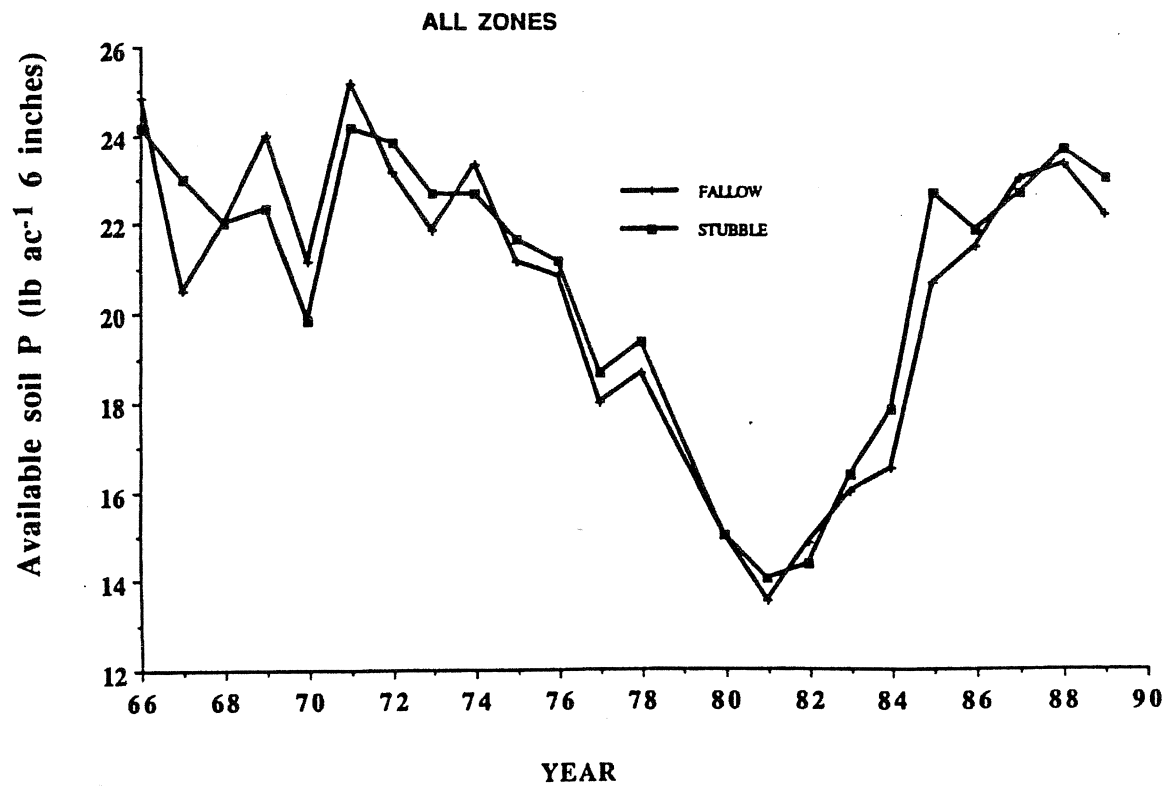


Figure 18. Soil P - Saskatchewan.

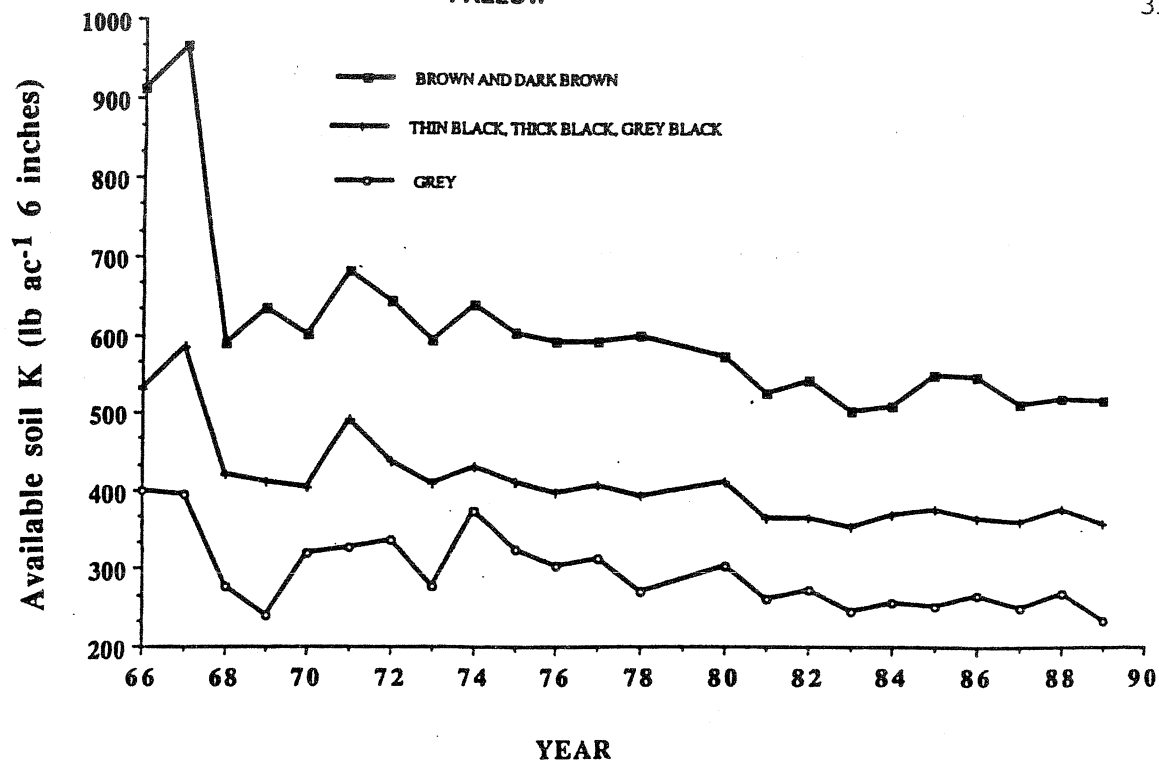


Figure 19. Soil K on fallow - Saskatchewan.

STUBBLE

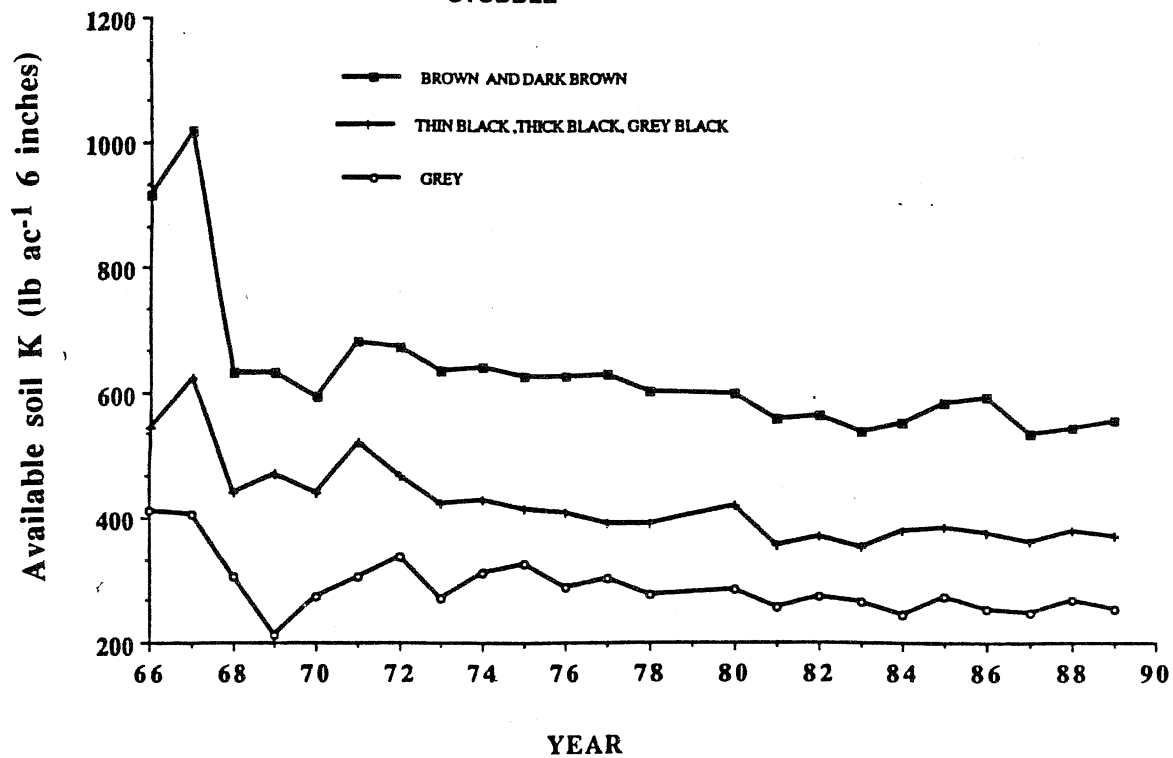


Figure 20. Soil K on stubble - Saskatchewan.

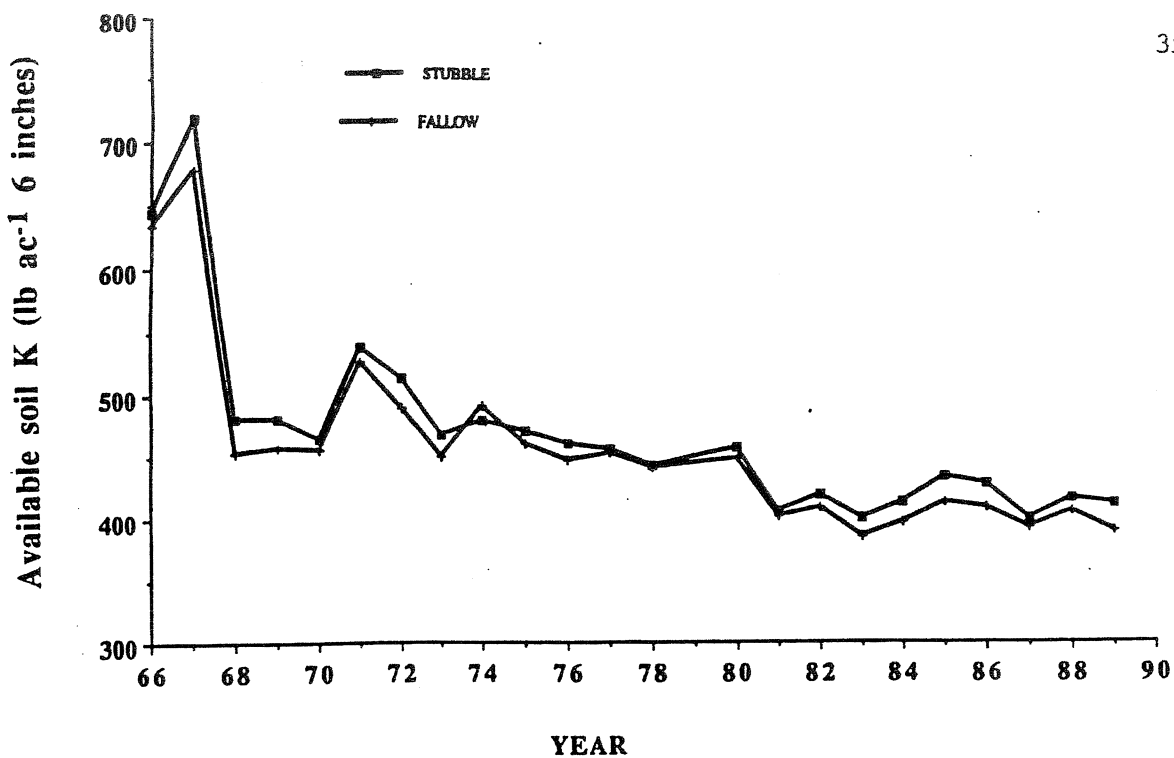


Figure 21. Soil K - Saskatchewan.

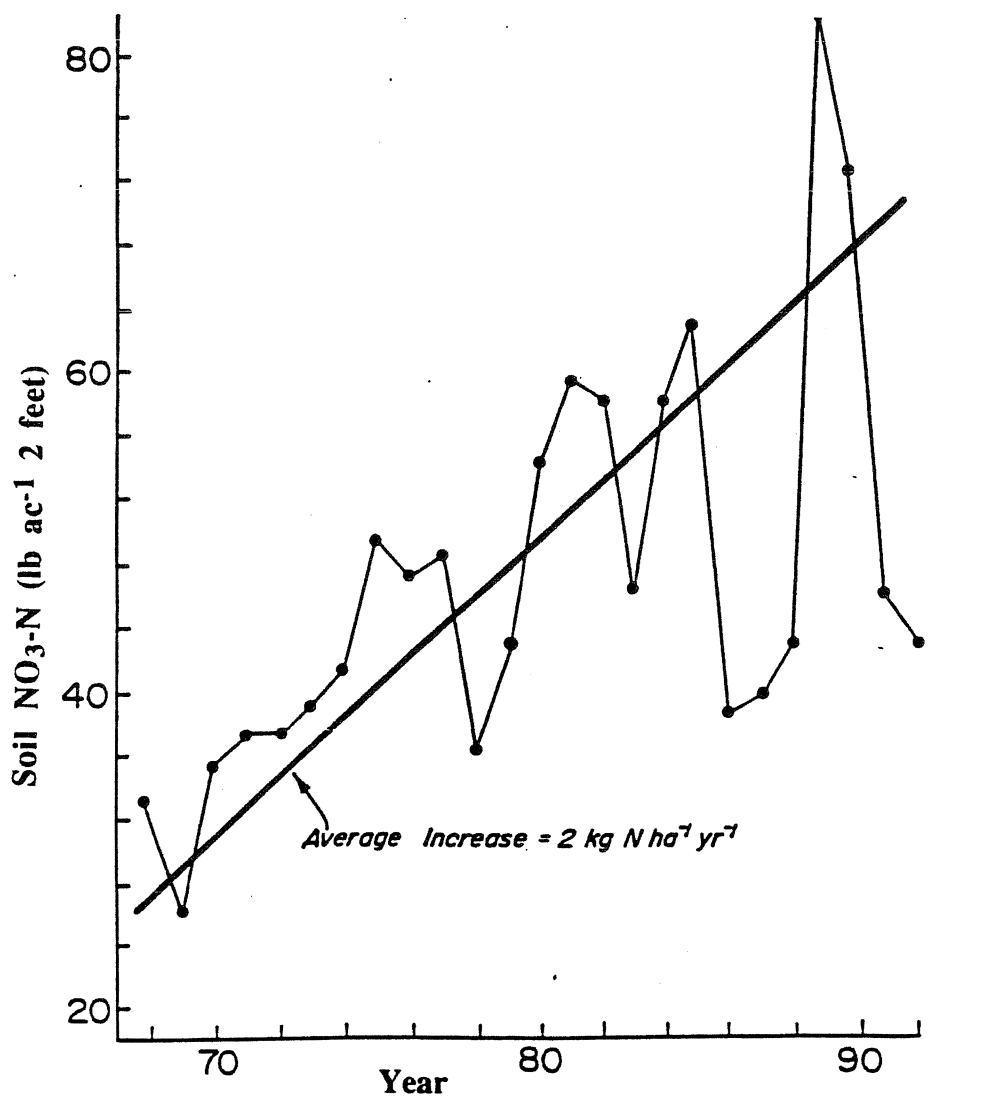


Figure 22. Soil N on stubble (2 foot depth) - Manitoba.

are small and in some years reversals of the trend are noted. The slightly higher value on stubble fields would be expected because the majority of K in cereal grain crops is present in the straw and this K is easily leached from the straw to form part of the available soil K pool in the surface soil. The general decline in available soil K since the early 1970s is now clearly evident.

SOIL NUTRIENT TRENDS - MANITOBA

The nutrient trends supplied by McGill⁶ covered the period 1967 to 1991 inclusive, a 25-year period. As with the data for Saskatchewan, the N data represents the nitrate-N to a depth of two feet whereas the P, K and S data were based on surface soil samples. Extraction procedures for N, P, K and S are the same as for Saskatchewan.

Nitrogen

There is a clear and relatively well defined upward trend in the levels of available soil N (Figs. 22 and 23). The average annual increase is approximately $2 \text{ lb ac}^{-1} \text{ yr}^{-1}$ and the trend appears to be continuing. The trend is perhaps more visible in Fig. 23 where the very large annual differences in levels of available soil N are leveled out by presenting the data as five year running averages. The comparable N data for summerfallow land while showing equally large differences from year to year suggest that during the ten year period ending in the late 1970s, the upward trend disappeared and since that time there has been a gradual decline (Figs. 24 and 25).

Any explanation of the trends in available soil N can at this point in time only be speculative. However, it may not be a coincidence that the upward trend in N fertility levels on the stubble land is closely associated with the upward trend in N fertilizer

⁶ Former Director, Manitoba Soil Testing Laboratory, now Agronomist, Manitoba Dept. of Agriculture, 368 Ellis Bldg., Winnipeg, MB, R3T 2N2.

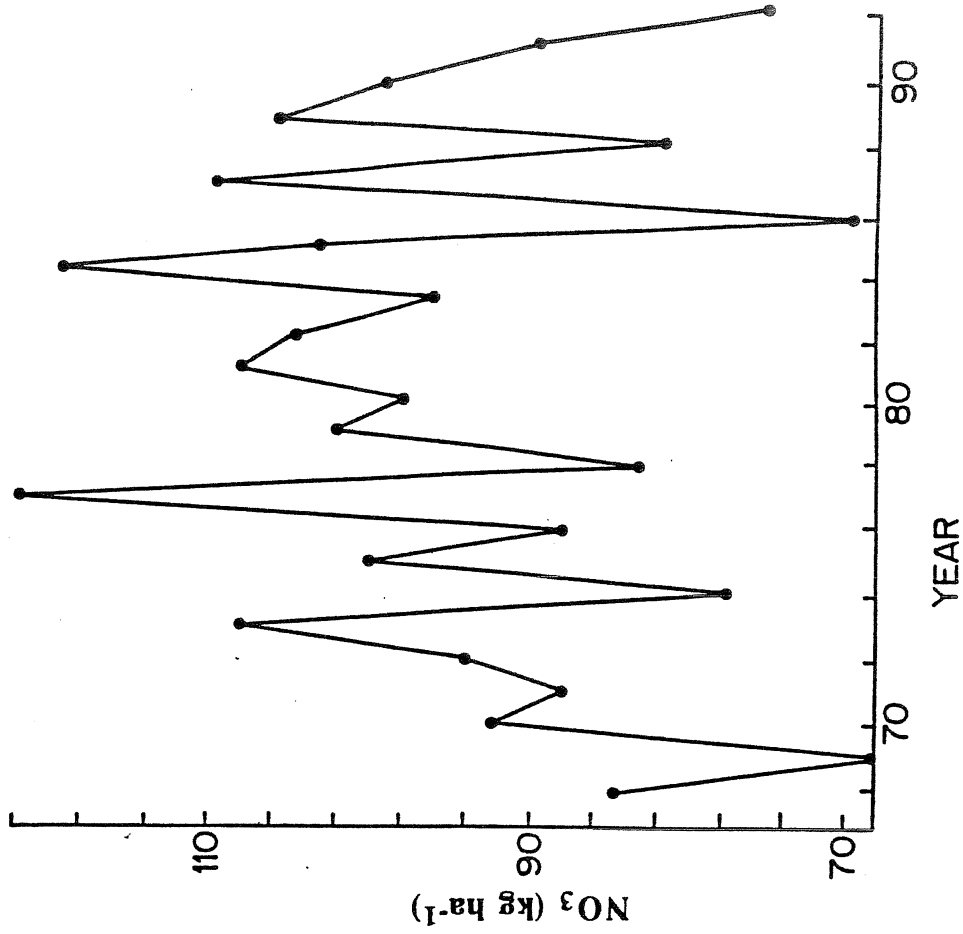


Figure 23. Five year running averages of available soil N, stubble fields - Manitoba.

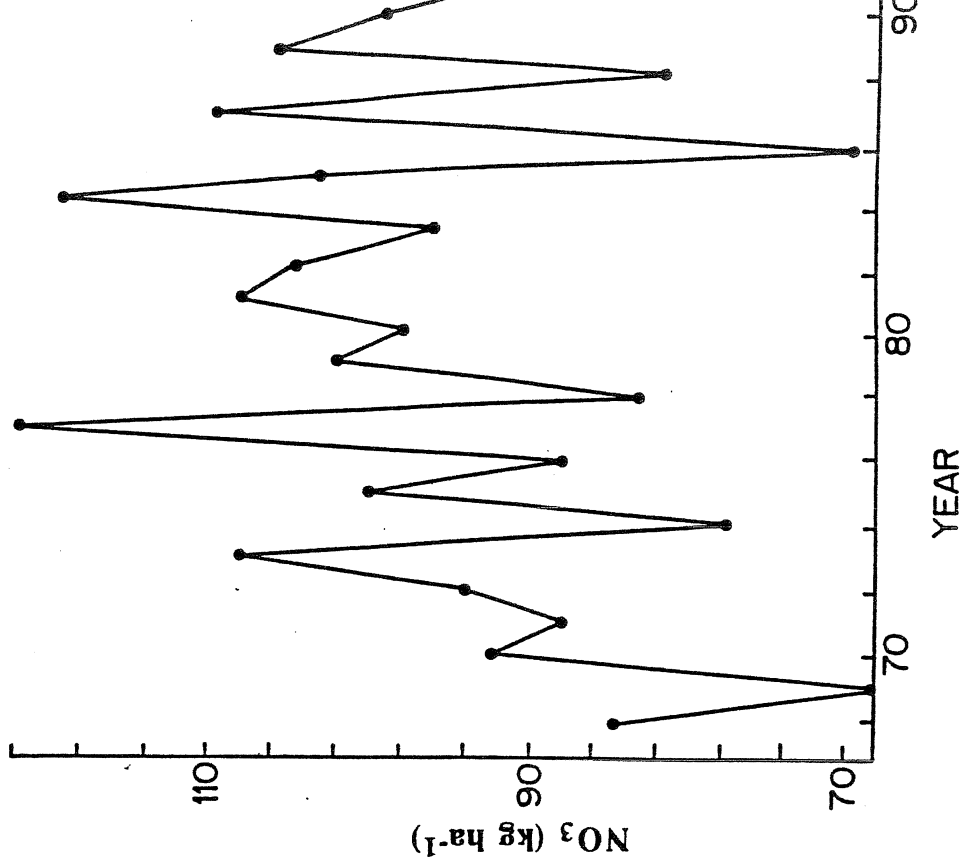


Figure 24. Soil N on fallow (2 foot depth) - Manitoba.

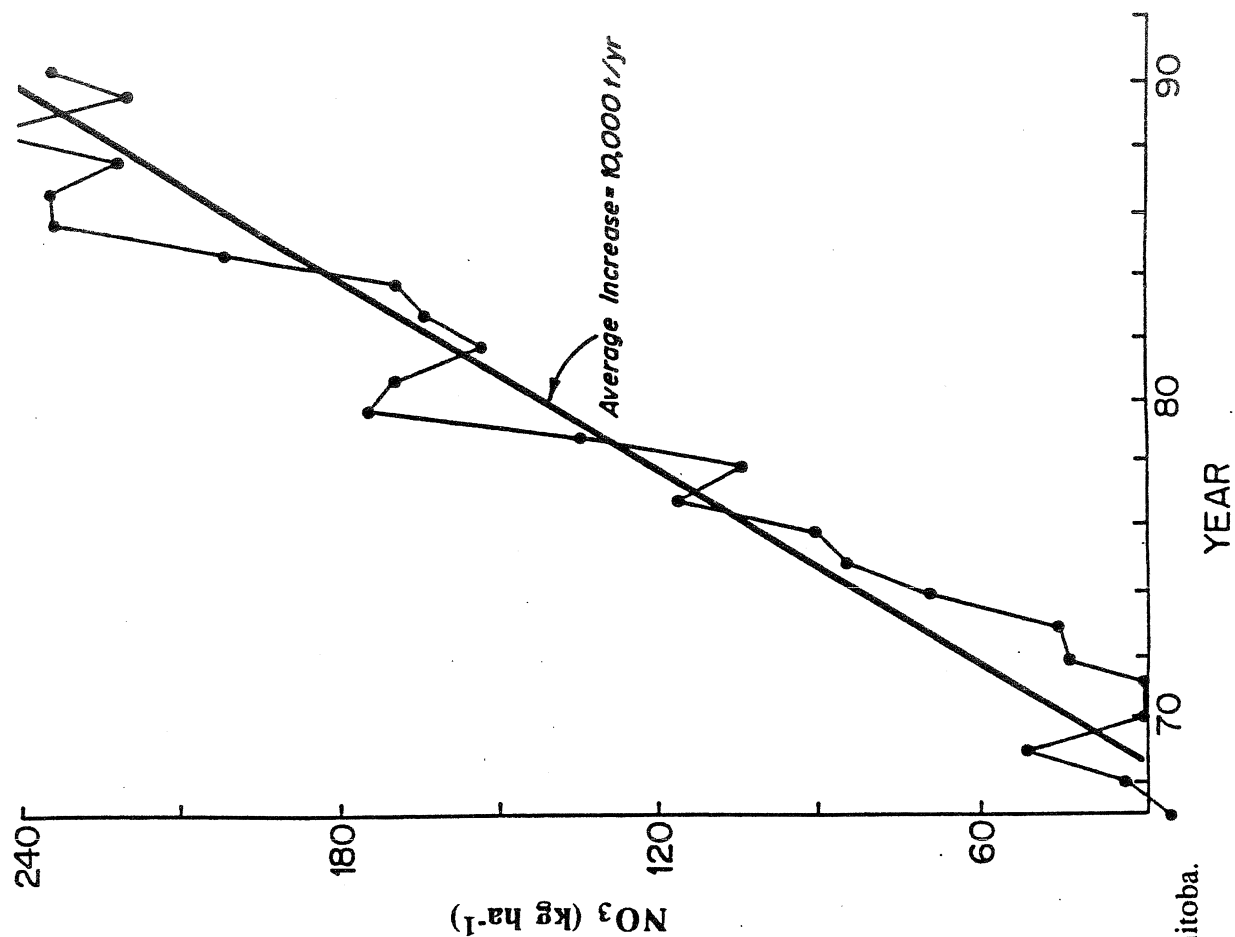


Figure 25. Five year running averages of available soil N, fallow fields - Manitoba.

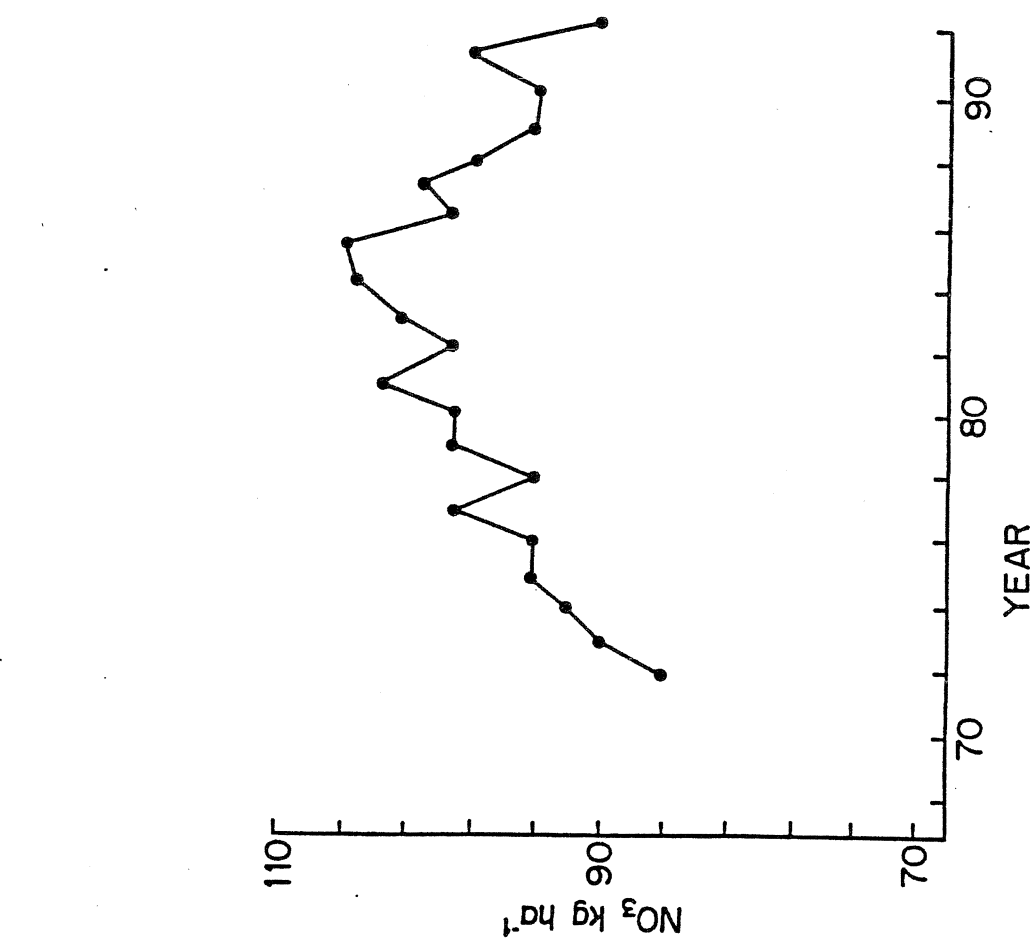


Figure 26. Nitrogen fertilizer consumption - Manitoba.

consumption (Fig. 26). Since a major part of the fertilizer N until recently has been applied by broadcast-incorporation, significant amounts of fertilizer N can assume to have been biologically immobilized; this immobilized N has a relatively short half life, i.e. in the vicinity of 10 or more years (Chapter 9), and conceivably could be partly responsible for the increasing N fertility levels of stubble fields in Manitoba.

It is interesting to note that the difference between N levels of fallow and stubble are of the same magnitude as that for Saskatchewan (Figs. 27 versus 15).

Phosphorus

In general across Manitoba soil P levels were very close to identical on both fallow and stubble land and no significant differences occurred between soil zones (data not shown). The average annual levels of soil P suggest a gradual decline initially took place, levelling off in the early 1980s and have remained relatively constant since that time (Figs. 28 and 29). It is noteworthy that as with Alberta and Saskatchewan P levels vary sharply from year to year, the reasons for which are to date not known. The Manitoba data was similar to that for Saskatchewan only in the early years; available soil P has remained remarkably constant for the past 10 years. The 25-year average level of available soil P was approximately 22 lb P ac⁻¹.

Potassium and Sulphur

The data for both K and S is expressed as a percentage of fields receiving a fertilizer recommendation. Potassium has remained relatively constant; the percent of fields with less than 180 kg ha⁻¹ of available K, expressed on a percentage basis is approximately 6 (Fig. 30). No difference between fallow and stubble fields were obtained (data not shown). In contrast, the frequency of a deficiency in available S, while varying widely from year to year, has increased by approximately 75% over the past 12 years (the length of time S assessments have been carried out). While the mean percentage of fields

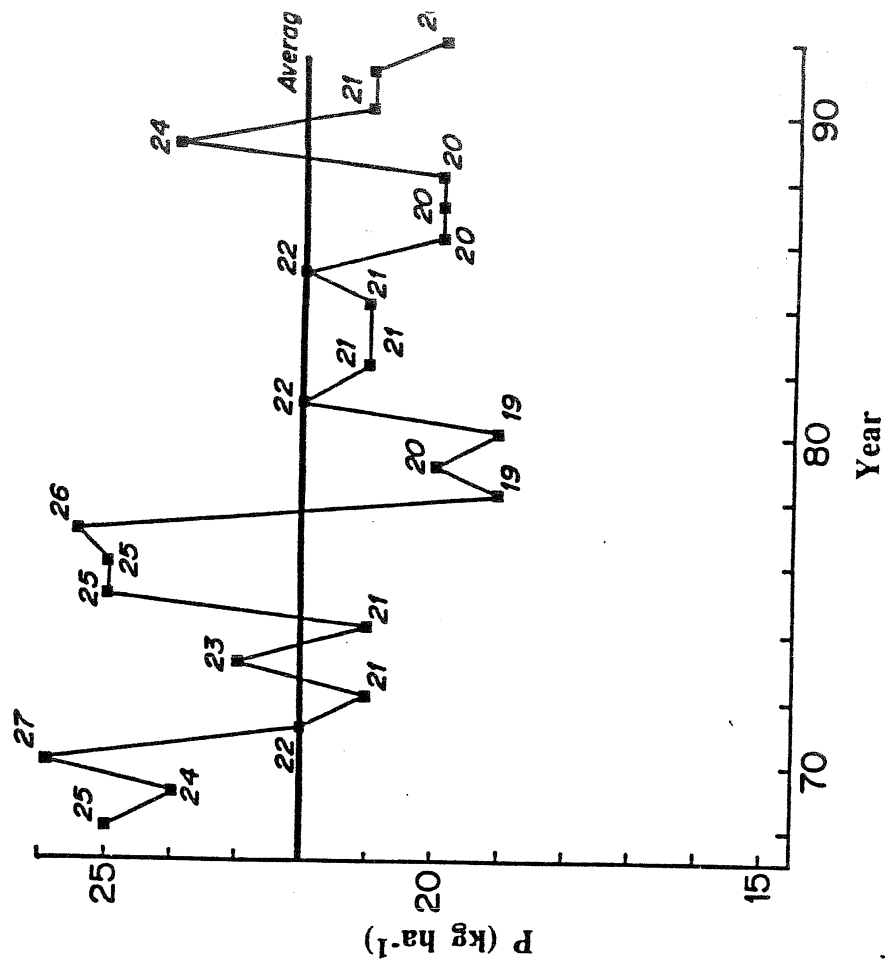


Figure 28. Phosphorus soil test trends over a 25 year period.

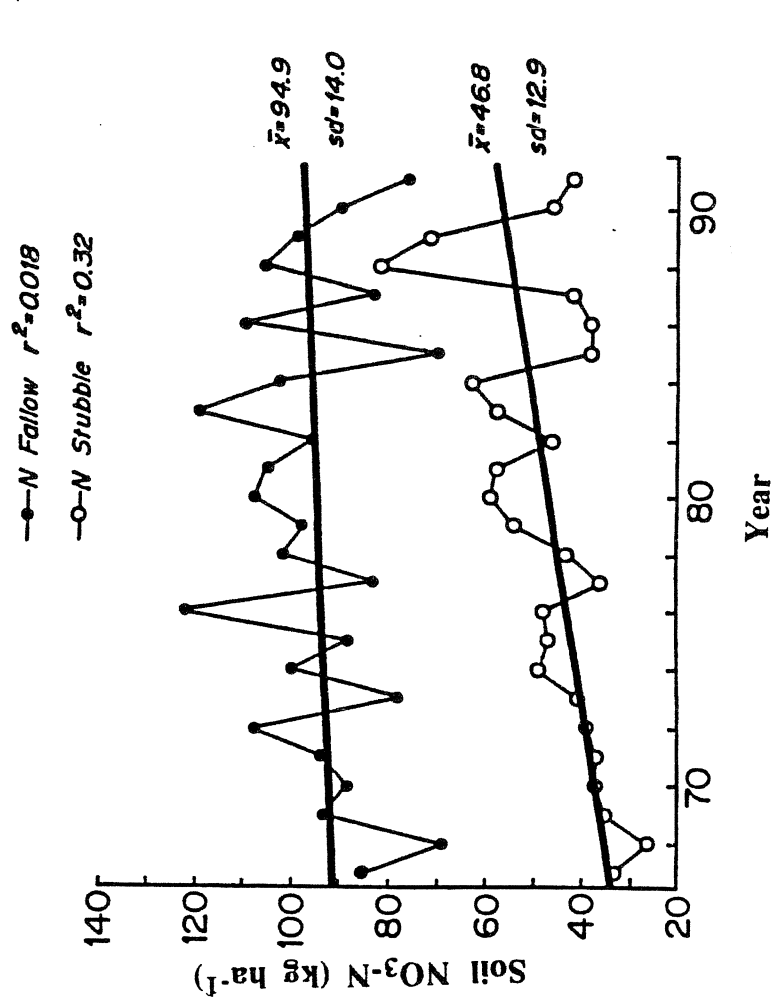


Figure 27. Fallow fields contain approximately twice the amount of available N as stubble fields.

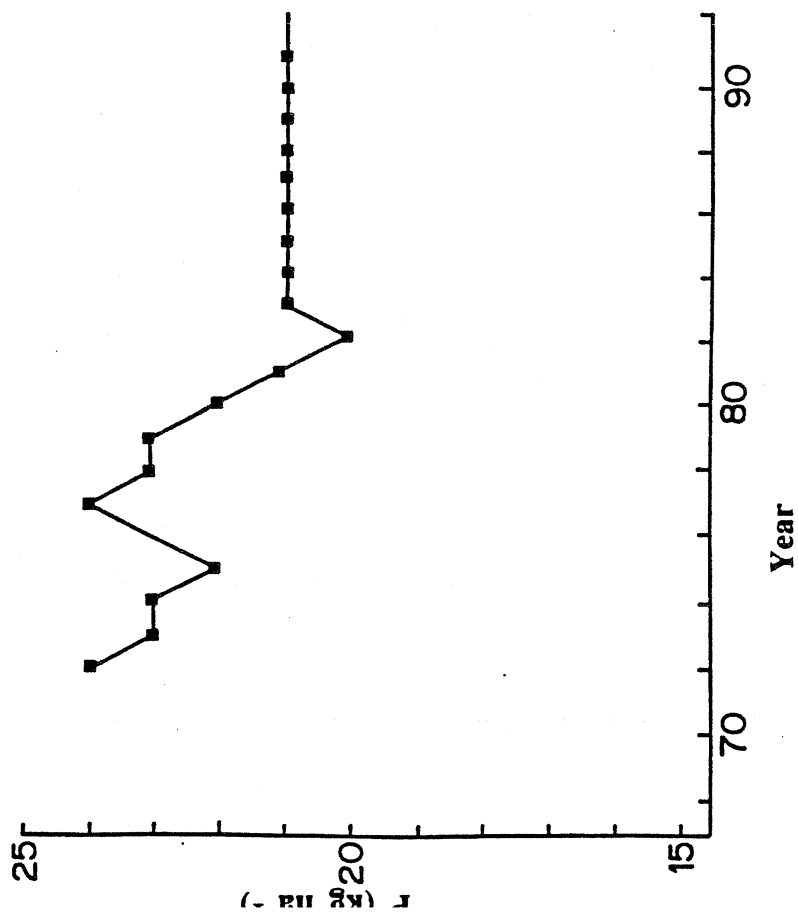


Figure 29. Five year average on soil P levels.

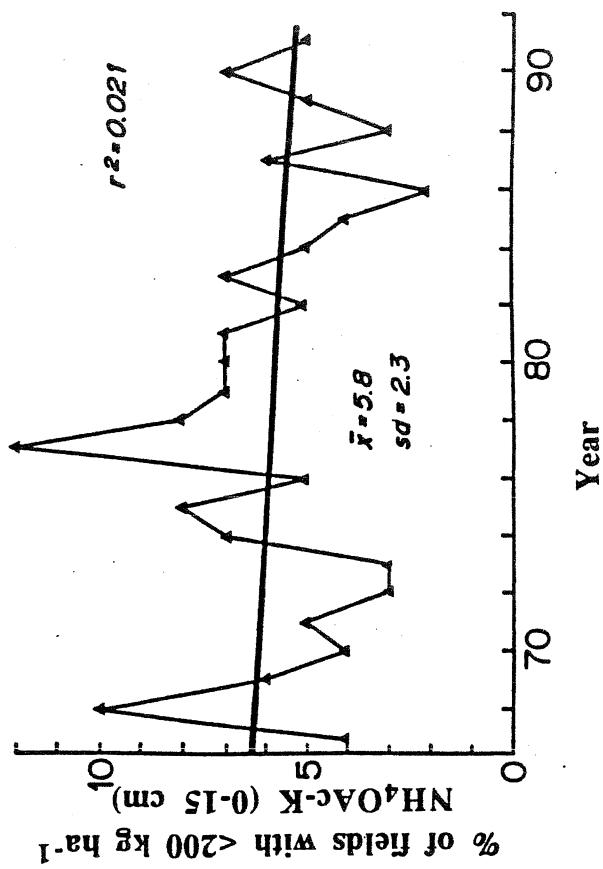


Figure 30. A very low percentage of fields received a recommendation for fertilizer K.

requiring additional S is approximately 14% during the period, it has risen from approximately 11 to 18% - significant upward trend (Fig. 31). Unlike N it is highly unlikely that this upward trend reflects fertilizer S input.

CONCLUSIONS

Perhaps the most significant observation that can be drawn from the long term trends in available plant nutrients in prairie soils is the striking increase in available soil N throughout Manitoba, where continuous cropping has been adopted to a much greater extent than in any other region in Western Canada; this trend provides the first factual evidence of benefits that can be accrued from the use of close to optimum N fertilization practices coupled with annual return of crop residues to the soil. The increase in the N fertility level of these soils is a direct reflection of increased N supplying power. This has undoubtedly reduced the amount of fertilizer N that Manitoba farmers must purchase to achieve maximum economic yields.

The gradual decline of available soil P from the initiation of record keeping in Saskatchewan until the early 1980s followed by a sharp increase can speculatively be attributed to a number of interacting factors. Perhaps the most important of these is the release of organic P as the soil organic matter continues to degrade. The fact that trends in Alberta are similar but on a micro scale support this contention, as in that province the mineralization of organic P would be expected to occur at a much reduced rate due to a much lower incidence of intensely tilled fallow. The P trend in Manitoba followed a similar downward direction in the earlier period, but was followed by a rather extended period of no change. This would suggest that under the cropping and P fertilization practices in Manitoba, available soil P is in equilibrium.

The enhancement of available soil P, particularly during the last decade, may account at least in part for the declining frequency of response to applied fertilizer P (Chapter 2).

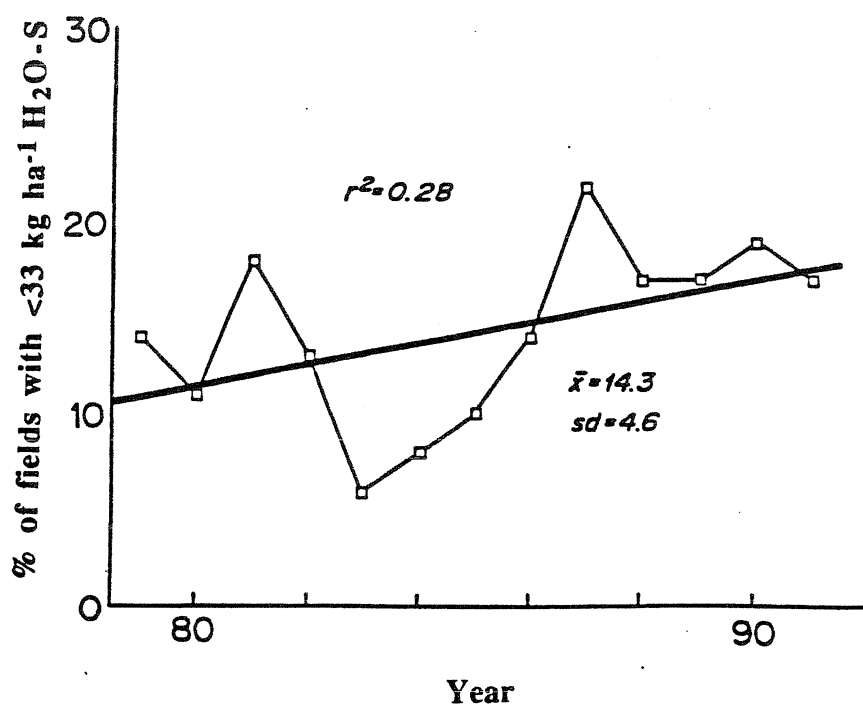


Figure 31. The percentage of fields in Manitoba requiring the addition of fertilizer S.

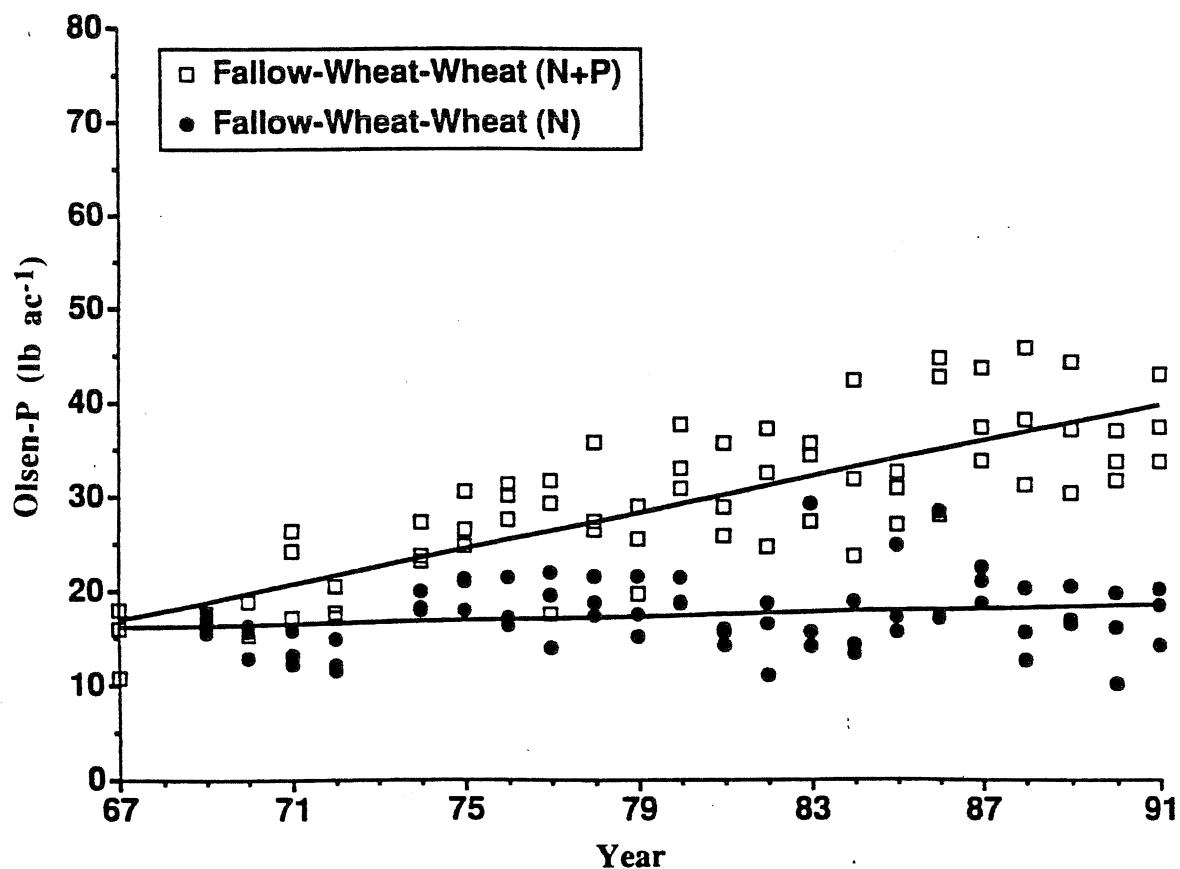


Figure 32. Long term trends in available soil P, Swift Current rotational plots.

The very wide annual variations in available plant nutrients characteristic of the data from all three provinces clearly support the benefits from annual soil testing for fertilizer recommendations. The extreme variations characteristic of available soil N from year to year are understandable as the biological reactions responsible for the mineralization and immobilization of N are a direct result of the widely varying continental climate which prevails across the prairies. This same highly variable climate results in wide variations in yield and consequently determines residual N remaining in the fall. There are no simple explanations for the very wide variations that occur in available P or for that matter K and S.

It is appropriate to conclude this discussion on nutrient trends with reference to 22 year soil P trends obtained from the long time Swift Current rotational experiments (Zentner et al., 1993). A relatively well defined upward trend in soil P occurred on the plots receiving the equivalent of $5.9 \text{ kg P ha}^{-1} \text{ yr}^{-1}$ compared to the 0 P control (Fig. 32). Since there was no drawdown or decline in the control, it would appear that two natural sources of available P, namely, the degradation of soil organic matter and the recycling of P from lower depths were approximately equivalent to crop removal. In contrast both these processes together with the addition of fertilizer P probably resulted in a net positive P balance on the P fertilized treatment. This data in general supports and provides some further explanation for the upward trend in soil P values reflected clearly in the Saskatchewan data (and much less pronounced trend in the Alberta data) over the last 20 years.

With the decline in public funds in support of soil testing, which at the present time is essentially zero in Manitoba and Saskatchewan, it is highly unlikely that the long term records reported in this chapter will be available in the future. Since the cost of establishing ongoing data storage and retrieval facilities imposes too high a cost on the private laboratories currently serving the agricultural industry, consideration should be given to making available funds from public sources to ensure that the extensive soil analyses currently being conducted by the several laboratories in the prairie region can be preserved and made available for future use. Without these data, one of the major mechanisms of

laboratories currently serving the agricultural industry, consideration should be given to making available funds from public sources to ensure that the extensive soil analyses currently being conducted by the several laboratories in the prairie region can be preserved and made available for future use. Without these data, one of the major mechanisms of systemically tracking long-term changes in the inherent fertility of soils over major soil climatic regions is lost, and with it, our ability to properly answer the question of whether crop management is more or less sustainable.

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