CHAPTER 1

Balances of nutrient inputs and exports (grain) in Alberta, Manitoba, and Saskatchewan

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ABSTRACT

Ratios of nutrient removal/replacement were calculated for Manitoba, Saskatchewan, and Alberta for the period 1965 to 1989 by dividing total crop removal of nutrients by total fertilizer nutrient sales. The nutrient removal/replacement ratios suggested that significant depletions of soil reserves of N, P, and K have taken place over the past 25 years. The average negative balance of N, P_2O_5, and K_2O on the prairies were estimated as: 640 000, 125 000, and 490 000 tonnes per year (24, 5 and 18 kg ha^{-1} yr^{-1}), respectively. Even with a substantial increase in the use of fertilizer recorded during the past five years, compared to the 25 year average, the nutrient deficit continues to be unacceptably high for N (485 000 tonnes) and modest for P_2O_5 (86 000 tonnes), but for K_2O, which is rarely applied, has increased significantly to 570 000 tonnes (18, 3 and 21 kg ha^{-1} yr^{-1}). Overall, our estimates suggest that Manitoba is very close to N and P balance, Alberta is almost as close as Manitoba in balance of N and P, while Saskatchewan has experienced a very high N and P deficit for the past 25 years, and continues to do so.

Estimates of the % contribution of fertilizer N and P to grain production, expressed in wheat equivalents (based on data for the past five years) ranges from 15% to as high as 37%, depending on fertilizer use efficiency. In terms of total production, this is equivalent to 8.2 to as high as 18.8 M tonnes annually.

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INTRODUCTION

An important pillar of sustainable agriculture is a need to balance inputs and "exports" of the major plant nutrients. In the data reported in this chapter for the period 1965 to 1990, certain key assumptions were made:

(1) All grains are removed from the field and all straw is incorporated after harvest; forage crop production is fully removed.

(2) Loss or exports of the major fertilizer nutrients due to leaching, soil erosion, or volatilization, while undoubtedly large in some instances, can be regarded as relatively small as compared to that removed in the grain, and therefore will, as a first approximation, be ignored. Notwithstanding this statement, the reader is referred to Chapters 2, 4, 5, and 12 for further discussion on nutrient loss mechanisms.

(3) Fertilizer nutrient inputs are closely reflected in fertilizer sales.

(4) The recycling of nutrients by incorporating animal manure, while significant and important on specific farms, has not been included as reliable statistics are not available, and the amounts are very small.

CALCULATIONS

The percent summerfallow area in each province was calculated by dividing the total summerfallow area (hectares) by the amount of arable land in each province. The arable land area was calculated by totalling the areas used for annual crop production plus that in fallow (Statistics Canada, 1974, 1981, 1989).

The crop removal estimates (N, P_2O_5, K_2O, or S) were based on data (Table 1) compiled by the Western Canada Fertilizer Association (WCFA) in 1978. Shortly after the nutrient removal data included in this chapter was calculated, WCFA released updated estimates (WCFA, 1992). However, these estimates do not differ appreciably from the earlier estimates, and accordingly, the calculations were not repeated.

Table 1. Plant nutrients used by the grain portion of various crops assuming average yields of each crop.
(Converted from data compiled by the Western Canada Fertilizer Association, 1978)

Crop	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Sulfur (S)
		-- kg nutrient / tonne grain) --		
Wheat	25	10.0	6.7	1.7
Barley	21	7.6	7.0	1.7
Oats	18	7.7	5.2	2.2
Rye†	21	8.4	6.3	1.9
Buckwheat	21	10.0	7.0	3.5
Corn	14	7.2	4.5	1.3
Canola	38	18.0	9.2	6.9
Flax	35	15.0	13.0	2.7
Mustard‡	37	17.0	11.0	5.0
Mixed Grains¥¥	19	8.0	5.8	2.2
Sunflowers	25	8.8	6.9	1.5
Peas	37	9.6	12.0	2.4
Fababeans	45	11.0	39.0	2.0
Lentils¥	41	10.0	26.0	2.2
Sugarbeets	2	0.9	3.3	0.3
Tame Hay¥¥	21	5.7	26.0	2.1
Potatoes¥¥	3	1.5	5.0	0.3

† Taken as the average of wheat, barley, and oats
‡ Taken as the average of canola and flax
¥ Taken as the average of peas and fababeans
¥¥ Goettel (1987)

The ratio of removal of each nutrient to its replacement was calculated as the total nutrient removal by the crop divided by the total nutrient addition (based on fertilizer sales). For example, in 1989 in Alberta, the total crop removal of N was 577 500 tonnes, and the total amount of fertilizer N sold was 346 500 tonnes, thus the ratio of N export to N input was 1.67 (a value of >1 denotes a net loss of nutrients from the system).

Fertilizer export / import ratios were not calculated for S because S fertilizer sales in Western Canada were not reported prior to 1987.

SUMMERFALLOW AREA

Nutrient removal across the three prairie provinces is affected by all factors which directly influence total production. These factors include the fallow area (Table 2). Percent fallow remained relatively constant until the late 1970s. Thereafter, it declined rather dramatically, reaching a low of approximately 23% for the prairies in 1989. As long as the soil has a reasonable reserve of organic N, mineralization of N will be maximized under the more optimum microbial environment which occurs under intensively tilled fallow. Consequently, less fertilizer N would be required for optimum economic yields. However, with rather significant decreases in fallow over the past 15 years, the amount of N nutrients applied as fertilizer has increased. The resulting increase in moisture use efficiency, together with increased seeded area (not shown) has lead to significantly greater grain production and export of total nutrients with the grain.

In all three prairie provinces, there was generally a gradual decrease in the proportion of cultivated land being summerfallowed during the period 1965 to about 1983; but in the last seven years, the proportions have been fairly constant (Table 2). The aberration in 1970 was due to the Government imposed Lower Inventory for Tomorrow (LIFT) Program.

Thus, since 1965 we have seen the proportion of arable land in summerfallow drop from 30% to 19% in Alberta, 25% to 10% in Manitoba, 40% to 31% in Saskatchewan, for

Table 2. Percentage of arable land in summerfallow† in the prairie provinces (1965-1989).

Year	Summerfallow			
	Alberta	Manitoba	Saskatchewan	Prairies
	%			
1965	30.3	25.2	40.2	35.0
1966	28.0	23.9	37.5	32.6
1967	28.0	23.8	39.1	33.5
1968	28.9	24.1	38.6	33.6
1969	30.5	28.3	42.1	36.6
1970	36.7	34.8	55.4	46.7
1971	29.2	22.8	38.2	33.2
1972	31.4	24.8	47.2	36.6
1973	28.4	21.1	39.5	33.4
1974	30.5	23.5	41.2	35.4
1975	28.2	21.7	41.1	34.3
1976	26.5	19.8	40.8	33.3
1977	28.4	19.4	40.4	33.6
1978	25.1	16.7	38.3	31.0
1979	25.6	17.5	38.4	31.4
1980	24.1	18.5	40.5	32.1
1981	21.6	12.4	36.7	28.5
1982	20.5	12.0	36.1	27.8
1983	19.7	11.1	35.2	26.9
1984	19.2	8.1	32.6	24.8
1985	19.1	8.1	31.6	24.3
1986	19.4	10.2	30.1	23.9
1987	19.5	10.6	31.5	24.8
1988	19.6	9.4	33.0	25.4
1989	18.1	9.6	30.9	23.5

Calculated from data obtained from: Manitoba Agriculture (1989), Saskatchewan Agriculture and Food (1989) and Statistics Canada (1974, 1981, 1989).

† [(total summerfallow area / total cultivated area) x 100]

an average of 35 to 24% on the prairies as a whole. The more rapid decline in Alberta and Manitoba compared to Saskatchewan is due to the more favorable water regimes.

NUTRIENT ADDITION / REMOVAL

The majority of N, P, K, and S removal in the prairie provinces is via cereal grains (wheat, barley, oats, and rye). The 25 year (1965-1989) average cereal grain production as a percentage of total production was 61% for Alberta, 58% for Manitoba, 81% for Saskatchewan, or 67% for the prairie provinces as a whole (Statistics Canada, 1989). These cereal crops also have a high requirement for N, P, K, and S (Table 1).

The average total N, P_2O_5, and K_2O removed in the grain and tame hay, and the amount of fertilizers added for Alberta, Manitoba, Saskatchewan, and the prairies, are presented in Tables 3 to 6. For comparison of recent trends, similar calculations for the five-year period ending in 1989 are also shown in these tables. These data suggest a very significant draw-down in soil reserves of N, P, and K has taken place over the past 25 years. Accordingly, for the prairies (Table 6), the negative balance expressed on a yearly average for N, P_2O_5, and K_2O has been 638 700, 123 400, and 488 200 tonnes, respectively. Even with the substantial increase in use of fertilizers during the past five years, compared to the average for the past 25 years, the nutrient deficit continues to be unacceptably high for N (485 400), and very modest for P_2O_5 (86 400); however, as expected for nutrients such as K_2O that are rarely applied, the draw down has actually increased in recent years to 568 500 tonnes.

In later chapters we will present further information on other losses (leaching, denitrification, and volatilization) of N and avenues for input (free N fixation and symbiotic N fixation). Nitrogen fixation produces only minute quantities of N for plant growth in comparison to the loss mechanisms, but the major loss of N is through the sale of produce. The negative P balance is relatively small and arguments could be made to suggest that P is in relatively good balance especially in Manitoba. Accordingly, from a plant nutrient

Table 3. Average annual N, P_2O_5, and K_2O removed as grain and hay and addition via fertilizers—Alberta.

Note: assume nutirent removal by grain only, i.e., straw is returned to soil

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	---------- tonnes yr^{-1} ----------		
1965 -1989:			
Crop removal			
Average	424,300	152,300	239,600
Std. dev.	82,400	29,800	50,800
Fertilizer addition			
Average	198,100	113,300	12,900
Std. dev.	108,000	39,000	12,300
1984 -1989:			
Crop removal			
Average	536,500	192,700	311,400
Std. dev.	81,700	27,800	61,000
Fertilizer addition			
Average	322,800	151,000	28,800
Std. dev.	26,800	14,600	2,400

Crops = Wheat (spring, winter, durum), Oats, Barley, Rye, Flax, Canola, Mixed Grains, Mustard, Sunflowers, Lentils, Peas, Canary Seed, and Tame Hay

1965 - 1979 data from Statistics Canada Fertilizer Trade Catalogue (46-207 Annual) Pub. Minister of Industry, Trade, and Commerce. Information Canada, Ottawa. Western Canadian Fertilizer Association

Crop data = Spearin and O'Connor (1991)

Table 4. Average annual N, P_2O_5, and K_2O removed as grain and hay and addition via fertilizers—Manitoba[1]

Note: assume nutirent removal by grain only, i.e., straw is returned to soil

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	---------- tonnes yr^{-1} ----------		
1965 -1989:			
Crop removal			
Average	189,800	70,800	98,600
Std. dev.	48,400	18,800	21,700
Fertilizer addition			
Average	124,000	70,800	9,900
Std. dev.	77,900	28,500	9,200
1984 -1989:			
Crop removal			
Average	243,000	91,700	121,900
Std. dev.	52,500	20,100	24,100
Fertilizer addition			
Average	232,800	103,700	21,600
Std. dev.	11,000	5,400	2,100

[1] See footnote for Table 3

Table 5. Average annual N, P_2O_5, and K_2O removed as grain and hay and addition via fertilizers—Saskatchewan[1]

Note: assume nutirent removal by grain only, i.e., straw is returned to soil

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	---------- tonnes yr^{-1} ----------		
1965 -1989:			
Crop removal			
Average	476,314	185,407	179,496
Std. dev.	97,246	38,526	36,073
Fertilizer addition			
Average	124,642	106,810	4,030
Std. dev.	107,217	50,627	4,811
1984 -1989:			
Crop removal			
Average	542,788	214,397	200,897
Std. dev.	135,396	52,876	47,219
Fertilizer addition			
Average	261,424	148,459	11,863
Std. dev.	14,499	10,107	4,662

[1] See footnote for Table 3

Table 6. Average annual N, P_2O_5, and K_2O removed as grain and hay and addition via fertilizers—three prairie provinces[1]

Note: assume nutirent removal by grain only, i.e., straw is returned to soil

	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
	---------- tonnes yr^{-1} ----------		
1965 -1989:			
Crop removal			
Average	1,085,700	415,200	515,900
Std. dev.	202,200	82,500	91,500
Fertilizer addition			
Average	447,000	291,800	27,700
Std. dev.	287,900	116,000	26,900
1984 -1989:			
Crop removal			
Average	1,320,900	507,000	632,300
Std. dev.	196,100	74,500	86,800
Fertilizer addition			
Average	835,500	420,600	63,800
Std. dev.	39,500	32,700	5,900

[1] See footnote for Table 3

perspective, contemporary agriculture, even during the past five years, is unsustainable from the standpoint of N balance. Although K is in a very strong deficit situation, soil reserves of K are more than sufficient to counteract this situation, except on soils with relatively small K reserves. Fortunately, these soils have been clearly identified on the prairies, and fertilizer K is being added.

The annual trends in N, P, and K crop removal and fertilizer input on the prairies for the past 25 years are presented in Figures 1-12. The area between the removal and input curves represents the cumulative nutrient deficit. These figures dramatically show the very large N deficit that has characterized crop production in Saskatchewan as compared to Alberta and Manitoba, particularly in the early years when very little fertilizer N was used in Saskatchewan.

The provincial N, P, and K nutrient removal / replacement ratios for Alberta, Manitoba, and Saskatchewan are given for the past 25 years in Tables 7-10. Average ratios for the three prairie provinces and the prairies are summarized in Table 10. A ratio of 1 designates a perfect balance and is regarded as desirable for sustainability. These data (and Figs. 1-8) suggest that Manitoba is very close to "full sustainability" in terms of N and P balance. Alberta is rapidly approaching N and P balance; Saskatchewan, although moving in the right direction, continues to experience an unacceptably high N and P deficit.

CONTRIBUTION OF FERTILIZER NUTRIENTS TO CROP PRODUCTION

The additional production resulting per kilogram of fertilizer N and P applied depends on the efficiency of nutrient uptake. A large number of factors affect fertilizer use efficiency (FUE). Included among these are level of available soil nutrients, available soil moisture, source, timing, and placement of fertilizer, soil nutrient interactions, weed population, biological immobilization, and leaching. For further background information, the reader is referred to Chapter 4.

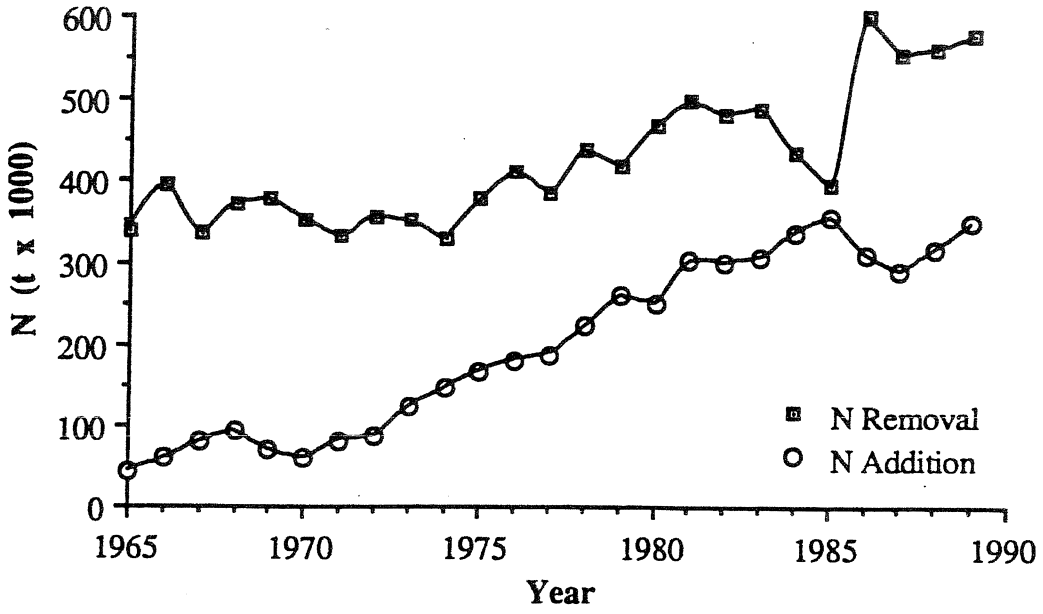

Figure 1. Crop removal and fertilizer replacement of N in Alberta from 1965 to 1989.
Note: Assume that N is removed by seed only and straw is returned to soil. Data from Statistics Canada (1974, 1981, 1989), Spearin and O'Connor (1991) and Western Canada Fertilizer Association (1991).

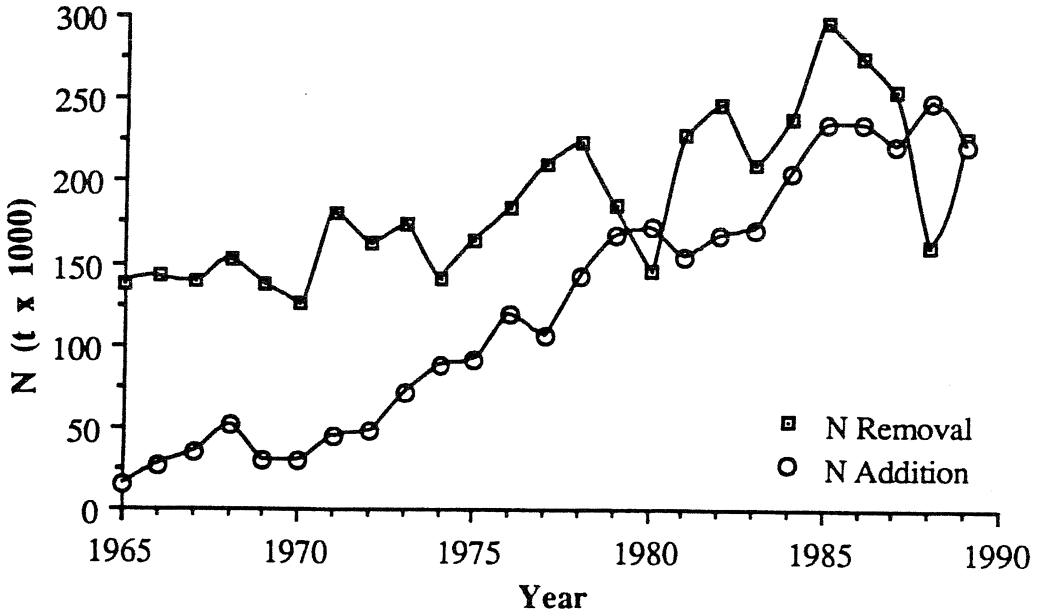

Figure 2. Crop removal and fertilizer replacement of N in Manitoba from 1965 to 1989. (See footnote for Figure 1)

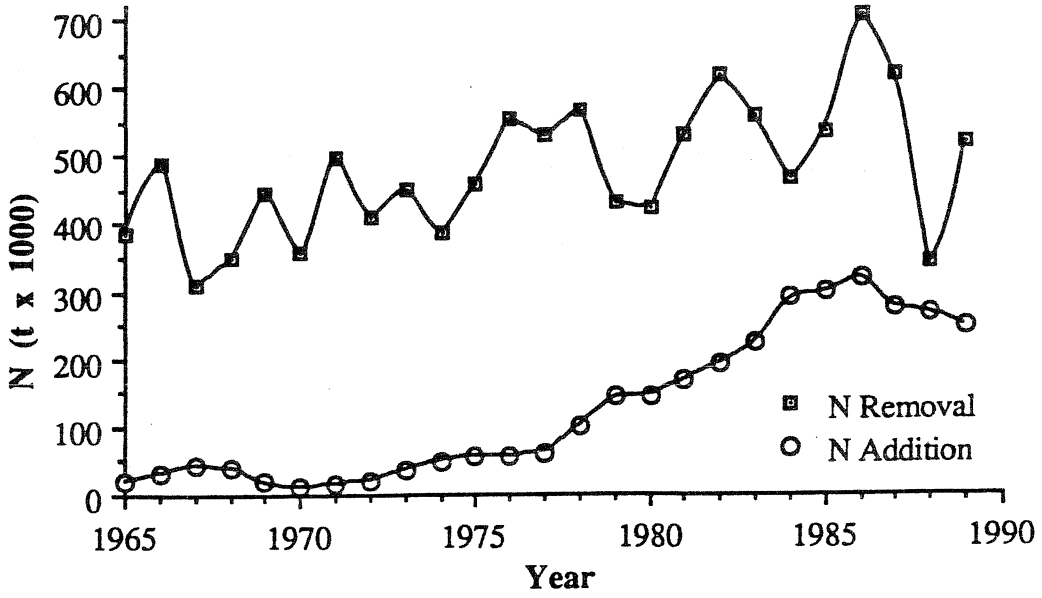

Figure 3. Crop removal and fertilizer replacement of N in Saskatchewan from 1965 to 1989. (See footnote for Figure 1)

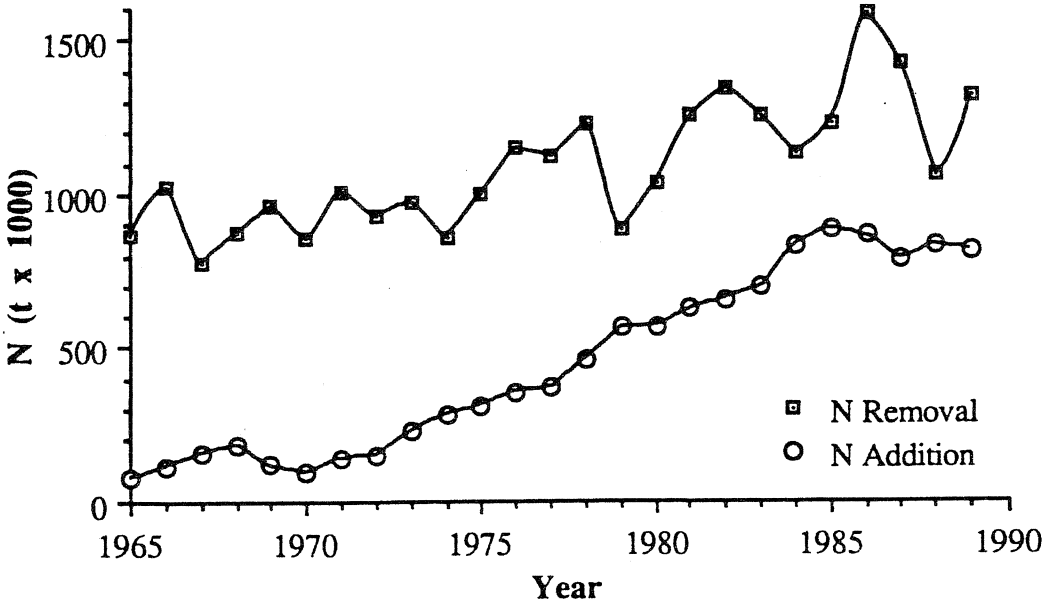

Figure 4. Crop removal and fertilizer replacement of N in the prairies from 1965 to 1989. (See footnote for Figure 1)

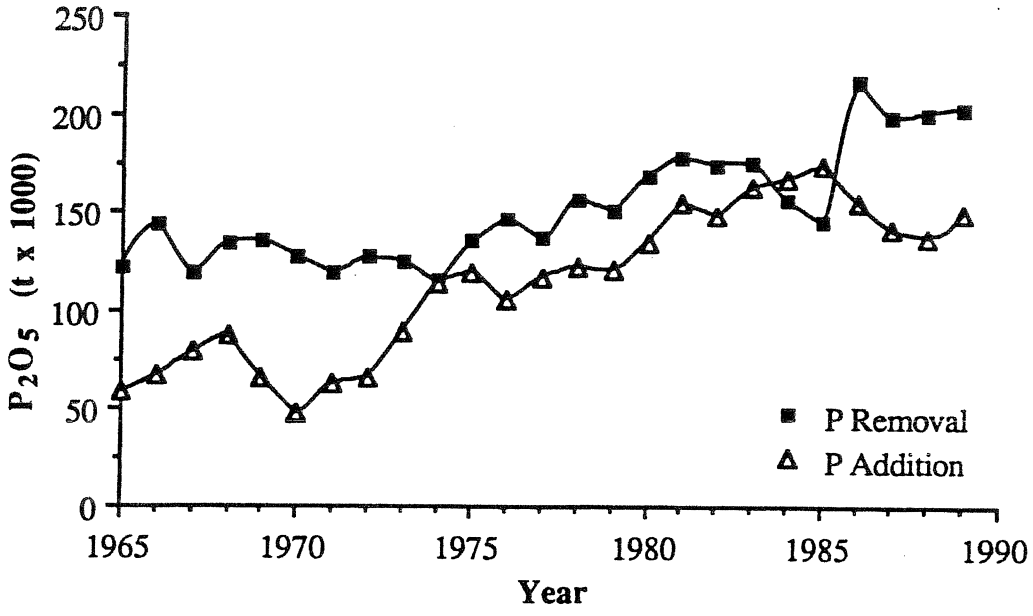

Figure 5. Crop removal and fertilizer replacement of P in Alberta from 1965 to 1989. Note: Assume that P is removed by seed only and straw is returned to soil. Data from Statistics Canada (1974, 1981, 1989) and Spearin, O'Connor (1991) and Western Canada Fertilizer Association (1991).

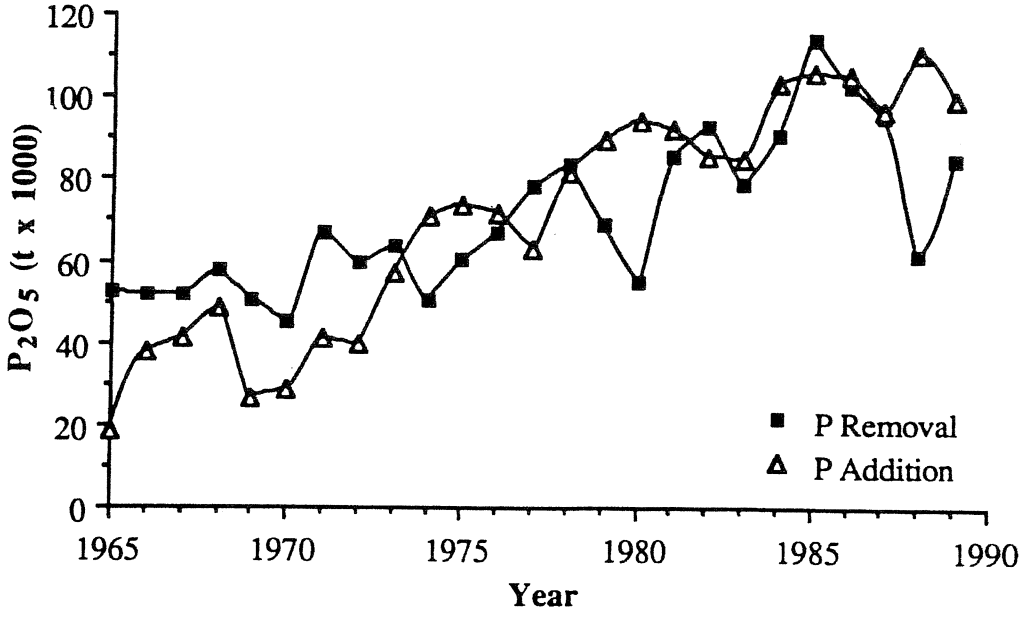

Figure 6. Crop removal and fertilizer replacement of P in Manitoba from 1965 to 1989. (See footnote for Figure 5)

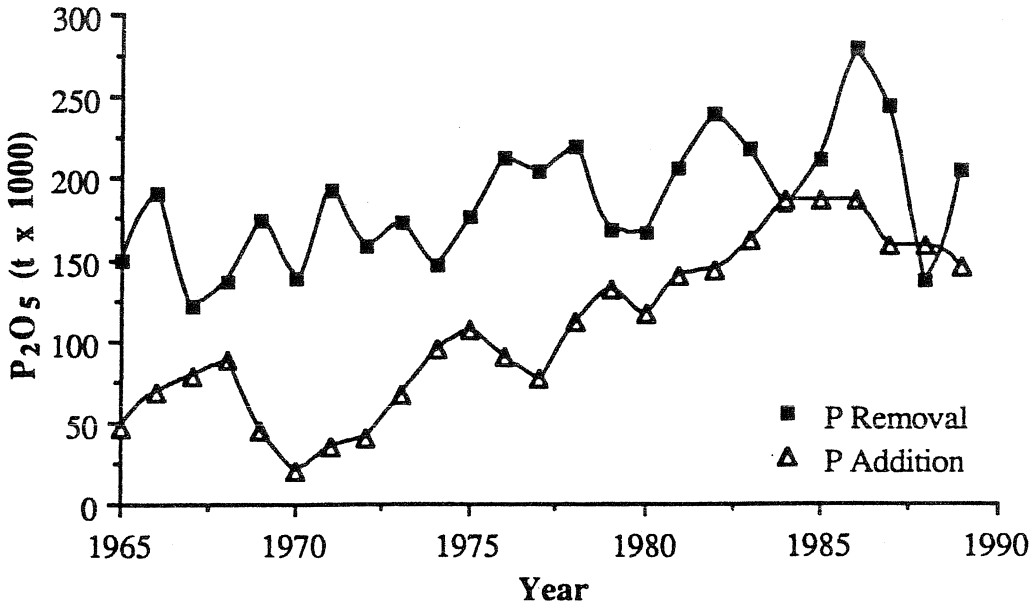

Figure 7. Crop removal and fertilizer replacement of P in Saskatchewan from 1965 to 1989. (See footnote for Figure 5)

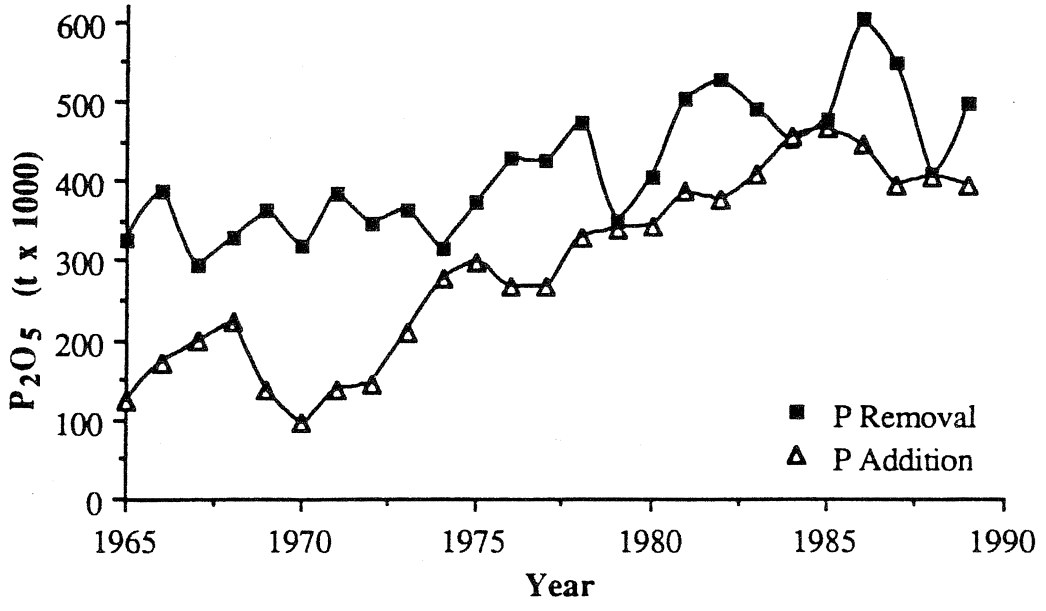

Figure 8. Crop removal and fertilizer replacement of P in the prairies from 1965 to 1989. (See footnote for Figure 5)

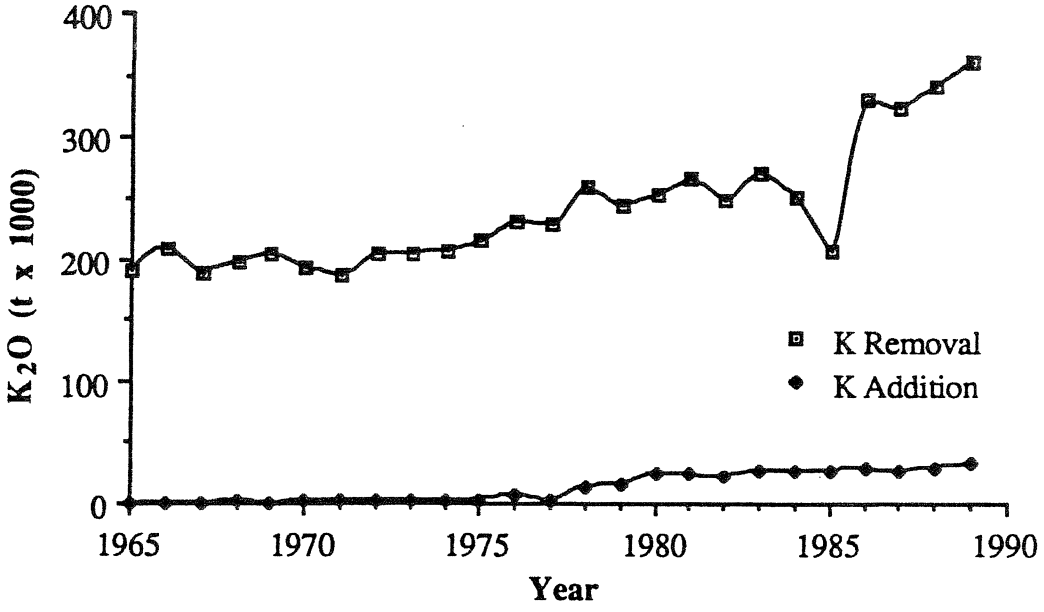

Figure 9. Crop removal and fertilizer replacement of K in Alberta from 1965 to 1989.
Note: Assume that K is removed by seed only and straw is returned to soil. Data from Statistics Canada (1974, 1981, 1989), Spearin and O'Connor (1991) and Western Canada Fertilizer Association (1991).

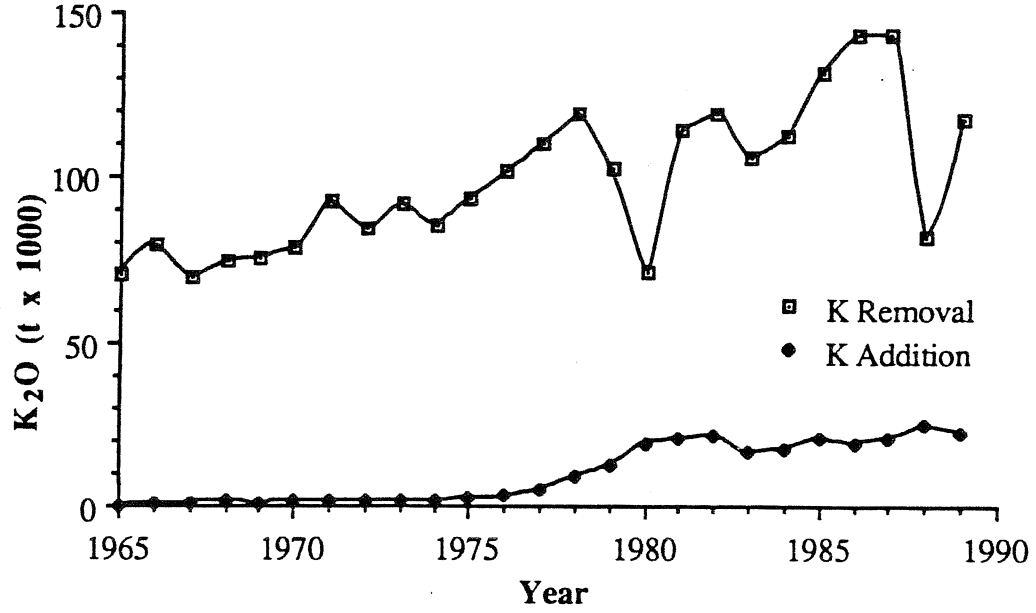

Figure 10. Crop removal and fertilizer replacement of K in Manitoba from 1965 to 1989.
(See footnote for Figure 9)

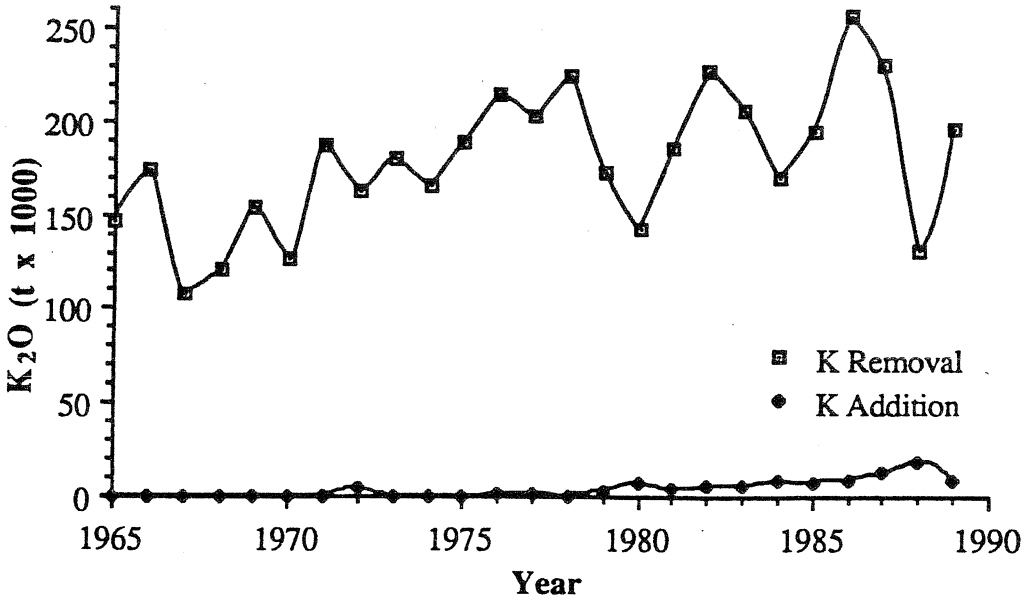

Figure 11. Crop removal and fertilizer replacement of K in Saskatchewan from 1965 to 1989. (See footnote for Figure 9)

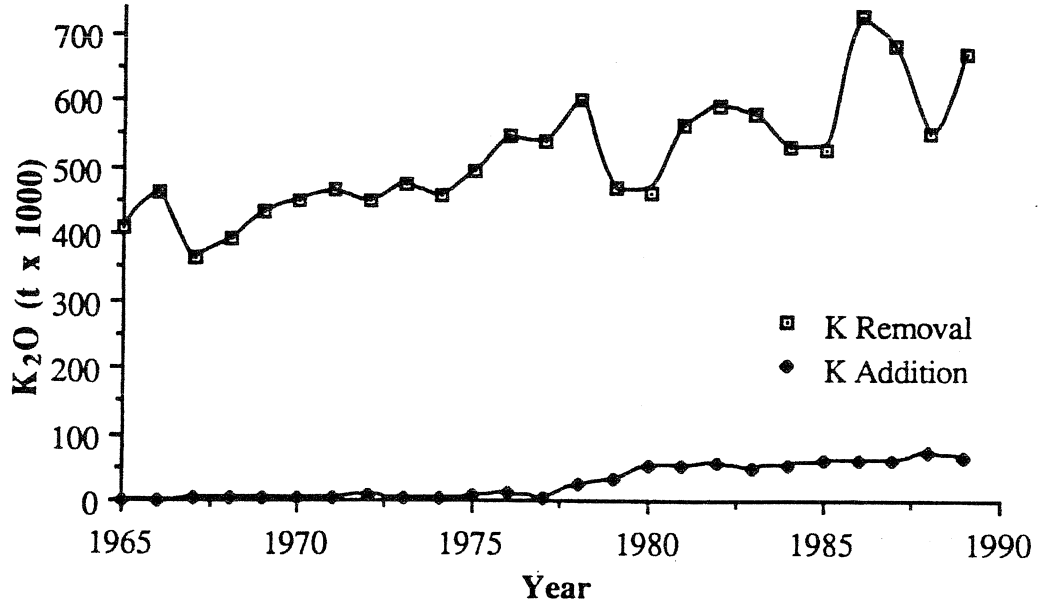

Figure 12. Crop removal and fertilizer replacement of K in the prairies from 1965 to 1989. (See footnote for Figure 9)

Table 7. Nitrogen removal / replacement ratios for Alberta, Manitoba, Saskatchewan, and the prairie provinces (1965-1989).
Note: assume N removal by grain only (i.e., straw is returned to soil)

Year	Alberta	Manitoba	Saskatchewan	Prairies
1965	7.8	9.7	20.6	11.3
1966	6.8	5.3	15.7	8.8
1967	4.3	4.0	7.1	5.0
1968	4.1	2.9	8.6	4.8
1969	5.3	4.6	23.8	8.0
1970	6.0	4.2	35.4	8.7
1971	4.1	4.0	31.6	7.1
1972	4.1	3.4	19.9	6.0
1973	2.9	2.4	12.7	4.3
1974	2.3	1.6	7.8	3.1
1975	2.3	1.8	8.2	3.2
1976	2.3	1.56	9.8	3.2
1977	2.1	2.0	8.8	3.1
1978	2.0	1.6	6.0	2.6
1979	1.6	1.1	3.0	1.6
1980	1.9	0.8	3.0	1.8
1981	1.6	1.5	3.2	2.0
1982	1.6	1.5	3.2	2.0
1983	1.6	1.2	2.5	1.8
1984	1.3	1.2	1.6	1.4
1985	1.1	1.3	1.8	1.4
1986	1.9	1.2	2.2	1.8
1987	1.9	1.1	2.2	1.8
1988	1.8	0.7	1.3	1.3
1989	1.7	1.0	2.1	1.6

Wheat (spring, winter, durum), Oats, Barley, Rye, Flax, Canola, Mixed Grains, Mustard, Sunflowers, Lentils, Peas, Canary Seed, Grain Corn, Buckwheat, Tame Hay, Sugar Beets, and Potatoes

Calculated from data obtained from: Canada Grains Council, Statistics Canada (1974, 1979, 1981, 1989), Agriculture Canada Policy Directorate (1991) and Western Canada Fertilizer Association (1991)

Table 8. Phosphorus removal / replacement ratios for Alberta, Manitoba, Saskatchewan, and the prairie provinces (1965-1989)[1]
Note: assume P removal by grain only (i.e., straw is returned to soil)

Year	Alberta	Manitoba	Saskatchewan	Prairies
1965	2.1	2.8	3.2	2.7
1966	2.2	1.4	2.8	2.2
1967	1.5	1.3	1.5	1.5
1968	1.5	1.2	1.6	1.5
1969	2.1	1.9	3.9	2.6
1970	2.8	1.6	6.7	3.3
1971	1.9	1.6	5.6	2.8
1972	2.0	1.5	3.9	2.4
1973	1.4	1.1	2.6	1.7
1974	1.0	0.7	1.6	1.1
1975	1.1	0.8	1.6	1.2
1976	1.4	0.9	2.4	1.6
1977	1.2	1.2	2.7	1.6
1978	1.3	1.0	2.0	1.4
1979	1.3	0.8	1.3	1.0
1980	1.3	0.6	1.4	1.2
1981	1.2	0.9	1.5	1.3
1982	1.2	1.1	1.7	1.4
1983	1.1	0.9	1.4	1.2
1984	0.9	0.9	1.0	1.0
1985	0.8	1.1	1.1	1.0
1986	1.4	1.0	1.5	1.4
1987	1.4	1.0	1.6	1.4
1988	1.5	0.6	0.9	1.0
1989	1.4	0.9	1.4	1.3

[1] See footnote for Table 7

Table 9. Potassium removal/replacement ratios for Alberta, Manitoba, Saskatchewan, and the prairie provinces (1965-1989)[1]
Note: assume K removal by grain only (i.e., straw is returned to soil)

Year	Alberta	Manitoba	Saskatchewan	Prairies
1965	1140	276	818	674
1966	769	116	689	382
1967	253	62	267	161
1968	143	52	192	114
1969	236	64	996	196
1970	149	56	1190	159
1971	117	70	937	150
1972	80	62	35	53
1973	166	54	619	147
1974	97	65	259	112
1975	65	40	324	80
1976	32	35	281	50
1977	18	23	180	117
1978	19	13	351	26
1979	16	8	56	15
1980	10	4	19	9
1981	11	6	48	10
1982	11	6	45	11
1983	10	7	37	12
1984	10	6	21	10
1985	9	6	25	9
1986	7	7	28	12
1987	12	7	19	12
1988	12	3	7	8
1989	11	5	22	10

[1] See footnote for Table 7

Table 10. Average nutrient removal/replacement ratios for Alberta, Manitoba, Saskatchewan, and the prairie provinces for 1965 to 1989 (25 years) and 1984 to 1989 (5 years).

	Alberta	Manitoba	Saskatchewan	Prairies
Nitrogen				
1965 - 1989:	2.14	1.53	3.82	2.43
1984 - 1989:	1.66	1.04	2.08	1.58
Phosphorus				
1965 - 1989:	1.34	1.00	1.74	1.42
1984 - 1989:	1.28	0.88	1.44	1.21
Potassium				
1965 - 1989:	18.60	9.99	44.50	18.60
1984 - 1989:	10.80	5.65	16.90	9.90

Table 11. The relationship between fertilizer use efficency (FUE) and yield increases (wheat equivalents)

	kg grain per kg N or P_2O_5†		
	Theoretical maximum (100%)	Research plot data	Estimated "farm gate"
Nitrogen (N)	28.3	14.2	5.7
Phosphorus (P_2O_5)	81.5	16.3	8.1

† Estimated from the WCFA (1978) nutrient requirement table and Beaton (1980), Campbell et al. (1991), and Rennie (1990)

Table 12. Estimated annual production increase (wheat equivalents) for the prairies due to N and P fertilization, for specified FUE's; 10^6 tonnes (% of total yield due to fertilizers).

	Nitrogen		Phosphorus	
Average	50	20	20	10
	---------- % ----------		---------- % ----------	
1965 - 89	6.3 (15)†	2.5 (6)	4.8 (11)	2.4 (6)
1984 - 89	11.9 (23)	4.8(9)	6.9 (14)	3.4 (6)

† Calculated from the average production data given in Table 6

Approximate estimates of the relationship between FUE and yield increases, expressed in terms of wheat equivalents, are given in Table 11. The figures given for the theoretical maximum of 100% uptake assume a 40 bushel crop of wheat (2690 kg grain) contains in the grain plus straw, 95 kg of N and 33 kg of P_2O_5 (WCFA, 1978). These estimates have been translated into tonnes of increased production for the 25 and 5 year periods ending in 1989, respectively (Table 12). The dramatic impact of FUE is clearly demonstrated; the percent of total yield due to fertilizer N and P for the past 5 years probably approximated 15%, but could have been as high as 37% or approximately 19 million tonnes of additional production with optimum fertilizer management practices.

CONCLUSIONS

From 1965 to 1989, the amount of cultivated land on the Canadian prairies increased from 20 to 27 million hectares. The increase in land base was associated with an increase in total crop production from 38 million tonnes of crop in 1965 to 57 million tonnes in 1989, respectively (Statistics Canada, 1974, 1989). During the same period, the amounts of N, P_2O_5, and K_2O fertilizer applied increased from 76 000 tonnes of nutrients in 1965 to 840 000 tonnes in 1989 (Statistics Canada, 1979; Spearin and O'Connor, 1991). These increases were also partly due to the onset of more extended cropping throughout the late 1970s and early 1980s and a decline in the N supplying power of the soil. Improved fertilizer management (eg. new placement and timing techniques), the introduction of fertilizer blends, and improved soil testing procedures also aided in the increased production as these factors lead to improved FUE. An earlier review by Beaton (1980) provides an excellent information source of some improvements and advances made in the Western Canadian fertilizer industry.

Balancing the N and P removal and replacement is a key to attaining sustainable crop production. Such balances may be achieved through sound agronomic management.

Generally, fertilizer management practices that lead to high FUE simultaneously contribute to maximum economic benefits, while minimizing environmental contamination.

The percent of total yield due to fertilizer N and P has been shown to vary dramatically with changing FUE. Production increases (prairies) from fertilizer N and P expressed as tonnes of wheat equivalent per year, was estimated to be at least 8.2 million tonnes and could range to as high as 18.8 million tonnes, depending on fertilizer management practices. Conversely, improved fertilizer management practices could lead to dramatic reductions in fertilizer use while maintaining current yield levels.

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