INFLUENCE OF GRAIN GROWING ON THE NITROGEN AND ORGANIC MATTER CONTENT OF THE WESTERN PRAIRIE SOILS OF CANADA

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THE INFLUENCE OF GRAIN GROWING ON THE NITROGEN AND ORGANIC MATTER CONTENT OF THE WESTERN PRAIRIE SOILS OF CANADA*

BY

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Canada's western prairies, lying within the confines of the provinces of Manitoba, Saskatchewan and Alberta, are generally recognized as comprising one of the largest and most important agricultural areas on the American continent. The immense acreage of their arable lands, the great depth and high fertility of their soils and the unexcelled quality of their wheat, have made them widely and favourably known throughout the civilized world. As yet but sparsely settled, they will for many years offer a large and attractive field for agricultural occupation and development.

Though as a grain-growing region the beginning of settlement does not date further back than the early eighties, so marked has been the development, more especially within the past twenty-five years, that last year, 1923, the three provinces produced over 450,000,000 bushels of wheat, nearly 392,000,000 bushels of oats, about 60,000,000 bushels of barley, nearly 21,000,000 bushels of rye and 7,000,000 bushels of flaxseed. When it is stated that of the estimated 167,000,000 acres[1] of arable and productive land within their limits less than 40,000,000 acres as yet are under field crops, it will be unnecessary to emphasize further the wonderful heritage, the almost invaluable asset, that Canada possesses in her northwestern prairies.

PHYSICAL GEOGRAPHY OF THE GREAT PLAINS REGION

Very briefly, these prairies comprise all the lower portion of the Great Plains Region north of the 49th parallel within the confines of the three provinces already named, a huge wedge-shaped area with a base on the international boundary line some 800 miles long. Northward this area narrows to about 400 miles at the 56th parallel and continuing to contract may be said to terminate about the 65th parallel. It consists in reality of three great plains or prairies. The first and lowest, with an average elevation of 800 feet above sea level and commencing at a point about 50 miles east of Winnipeg, is the bed of the former glacial "Lake Agassiz" now known as the Red River Valley. This prairie extends to the escarpment comprising the Pembina Mountains and is an extremely rich area. The second or middle prairie with an average elevation of 1,600 feet, extending from the aforementioned escarpment to a second and practically parallel rise known as the Missouri Coteau, is an area less regular in its topography than the first prairie and not so uniformly rich as to its soils. The third steppe, with an average elevation of 3,000 feet, continuing from the Missouri Coteau to the foot hills of the Rocky Mountains is still more diversified as to its topography than the second steppe and more varied as to the character of the soils.

* Read before the Agricultural Section of the British Association for the Advancement of Science, Toronto, August 6, 1924.

[1] Canada: Natural Resources and Commerce, Department of the Interior, Ottawa, 1923, p. 41.

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PLANT FOOD CONTENT OF PRAIRIE SOILS

In 1909 a collection was made of virgin soils representative of typical prairie areas in the three provinces. From the results of the analyses of the samples the table of maxima, minima and averages has been prepared.

TABLE I.—PRAIRIE SOILS

Collected to a depth of 8 inches. Results calculated to the water-free basis.

Province	Organic Matter (Loss on Ignition) Per cent		Nitrogen Per cent		Phosphoric Acid (P_2O_5) per cent		Potash (K_2O) Per cent		Lime (CaO) Per cent		Available Constituents					
											Phosphoric Acid (P_2O_5) Per cent		Potash (K_2O) Per cent		Lime (CaO) Per cent	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Manitoba	26·29	11·27	1·01	·35	·29	·12	1·03	·19	3·54	1·02	·054	·007	·076	·007	1·121	·462
Average of 7 samples	15·85		·53		·19		·69		1·73		·030		·048		·713	
Saskatchewan	14·23	5·54	·57	·13	·39	·06	·87	·16	2·89	·50	·044	·005	·059	·011	1·261	·264
Average of 9 samples	11·92		·42		·22		·46		1·19		·022		·037		·632	
Alberta	17·63	4·46	·67	·19	·24	·12	·67	·25	1·28	·37	·050	·004	·045	·015	·959	·385
Average of 10 samples	11·94		·44		·17		·46		·88		·022		·030		·578	

These data give proof of the richness of the virgin prairie in all the essential constituents necessary for crop growth; they record amounts far in excess of those present in ordinary fertile soils and furnish evidence of vast resources, placing these prairie lands with the richest of known soils. It is thus seen that chemical analysis supports the practical field experience of the past twenty-five years which has so well borne witness to the high fertility of these western plains.

It is to be noted that the percentages of the mineral constituents—phosphoric acid, potash and lime—as obtained by extraction by dilute hydrochloric acid (in the 3rd, 4th and 5th columns of the table) are well above the average—and in this connection special attention may be directed to the more than usually large carbonate of lime content, a feature undoubtedly intimately related with high fertility, and one furnishing favourable conditions for ready nitrification. It is further worthy of note that the percentages of these mineral constituents, as obtained by the Dyer method (solvent: 1 per cent citric acid solution) and generally understood as indicating " available " stores, are far above those found in ordinary productive loams.

But the outstanding characteristic of these soils is their high nitrogen and humus content. If we assume that on an average the prairie soil has a nitrogen content of 0.5 per cent to a depth of 8 inches, calculated on a water-free basis, (a very reasonable figure, for the larger number of the soils collected to this depth show an amount between 0.5 and 1.0 per cent) then an acre of soil, to the same depth, will contain 10,000 pounds of this element.[2] Since ordinary fertile soils to a like depth contain from 3,000 to 4,000 pounds, the vast reserve of this valuable constituent in the prairie soils will be apparent.

The excellent physical condition is also a matter worthy of comment and in this connecton it should be remembered that the nitrogen-holding organic matter is well broken down and intimately associated with the mineral constituents of a homogeneous soil, with conditions at once favourable to a satisfactory tilth, a high moisture conservation and rapid nitrification. All our field experience and laboratory work points to the conclusion that it is the high nitrogen and organic content, more than any other feature, to which the wonderful fertility of these soils is due and which places them among the most productive known to agriculture.

[2] The weight of 1 acre of soil to a depth of 8 inches is taken as 2,000,000 pounds.

GRAIN GROWING THE PREDOMINATING FEATURE OF WESTERN AGRICULTURE

Until a few years ago the farming of the western prairies—as apart from ranching proper—may be said to have been nothing more or less than grain growing. Though, recently, mixed farming, including dairying and stock raising, has been introduced and is more or less well established in certain districts, (more particularly perhaps in Manitoba and northern Alberta, but by no means absent from Saskatchewan), grain growing, and more especially wheat growing, is still the predominating phase of typical prairie agriculture. Further, a consideration of conditions, climatic and economic, points to this vast area remaining probably for all time with grain as its chief product. It is now the second largest wheat exporting area in the world, and as yet it is but partly developed. The agricultural future of the prairies as a wheat producing country would thus appear to be largely settled.

Looking to the up-keep of soil fertility, grain growing as practised to-day on the prairies must be regarded as irrational; the teachings of agricultural science would pronounce it as wasteful, for it means destruction of organic matter and the carrying off of plant food with no attempt at any return. As generally conducted, the practice of grain growing on the prairies keeps the land two years in grain—the second crop being grown on stubble—and the third season in summer fallow. This third year of fallow, during which the land is worked as required throughout the growing season, has a two-fold object; the destruction of weeds and the conservation of moisture. Unfortunately, it results in the destruction of organic matter, in the dissipation of nitrogen and physically, in the breaking up of the soil's fibre, permitting the soil on drying to become powdery and to blow or drift under the prevailing strong winds of the prairies. The loss of valuable surface soil from this cause, drifting, has in some sections become so serious that in them this effect of fallowing far overshadows the loss of nitrogen and humus.

THE EFFECT OF GRAIN GROWING ON THE FERTILITY OF WESTERN PRAIRIE SOILS

Nearly twenty years ago an attempt was made to measure the effect of the practice of grain growing upon the virgin prairie soil, in so far as the effect might be traced or measured by chemical analysis. Collections of soil—virgin (uncropped, unmanured) and cultivated—were made at two points: Portage la Prairie, Manitoba, a district lying some fifty miles directly west of Winnipeg and one noted for its high quality wheat, and Indian Head, Saskatchewan, three hundred and fifteen miles due west of Winnipeg—a district also producing wheat of the highest grade.

The Portage la Prairie series might be described as a black, friable loam containing a considerable proportion of sand. The virgin soil showed more root fibre than the cropped soil and was somewhat darker in colour. No detailed record could be obtained respecting the cropped area as to cultivation and yields further than the assurance that it had been under cultivation continuously for twenty-five years, during which time the wheat crops had been interspersed with fallowing. Probably there had been nine seasons of fallow and sixteen of grain.

The soils from Indian Head were taken from the Experimental Farm at that point. They are black, heavy clay loams. The cropped soil had been under cultivation for twenty-two years, without manure and our records showed six crops of wheat, four of barley, and three of oats, with nine seasons in fallow.

The samples examined were of a composite nature, from collections to a depth of 8 inches. Every precaution was taken to make them thoroughly representative and there is every reason to believe that at the outset, both at Portage la Prairie and Indian Head, the soil over the whole area examined (including virgin and cropped) was of an extremely uniform nature.

TABLE II.—PRAIRIE SOILS: VIRGIN AND CROPPED

Locality	Character	History	Organic and Volatile Matter	Nitrogen
			p.c.	p.c.
Portage la Prairie, Man.	Black: friable loam, sandy.	Virgin; uncropped, unmanured..	19·43	0·651
" "	" "	Cultivated; grain growing for 25 years, fallowed but not manured.	14·79	0·506
Indian Head, Sask.......	Black: heavy clay loam	Virgin; uncropped, unmanured..	12·83	0·371
" "	" "	Cultivated; grain growing for 22 years, fallowed but not manured.	10·70	0·254

Both these cultivated soils, notwithstanding their cropping for nearly a quarter of a century, are still very rich; possibly to-day they would yield as fine a crop as at the outset. Yet compared with the virgin prairie, the significant fact is brought out that there has been a serious reduction in both organic matter and nitrogen, following the practice of exclusive grain growing.

There are no " yield " data in the case of the cultivated Portage la Prairie soils and therefore we cannot arrive at the proportionate amounts of nitrogen removed in the grain and that dissipated through cultural operations—including fallowing. The results, however, show that during this period of twenty-five years almost 25 per cent of this valuable soil constituent has disappeared, and that there has been practically an equal loss in organic matter.

For the Indian Head series we have a complete record of crops and yields from the cultivated area, making it possible to calculate, at least approximately, the proportion of this loss of nitrogen due to removal by crops and that to cultural operations. The data are as follows:—

DEPLETION OF NITROGEN, 1884–1905

VIRGIN AND CULTIVATED SOILS, INDIAN HEAD, SASK.

	Nitrogen per acre to a depth of 8 inches
	Lb.
Virgin soil..	7,420
Cultivated soil, 22 years (1884–1905)........................	5,080
Difference or loss, due to removal in crops and to cultural operations............	2,340
Removed by grain crops..	700
Difference or amount dissipated by fallowing and other cultural operations......	1,640
	2,340

These results make very clear the serious loss in nitrogen consequent upon our system of grain growing and particularly emphasize the dissipation of this element through summer fallowing. In a period of twenty-two years the soil, apparently, has lost 30 per cent of its original nitrogen, of which approximately 10 per cent was due to removal by the grain crops and 20 per cent to loss by fallowing and other cultural operations.

It is not at all probable that these losses would continue at the above rate, for the richer the soil the more rapid its deterioration. There is undoubtedly a slowing down in this process of depletion, towards a point of constancy or equilibrium. This conclusion receives support from the analysis of a further series of soils, virgin and cultivated, collected at Indian Head in 1922, the data of which are given in the following table.

DEPLETION OF NITROGEN, 1884–1922

Virgin and Cultivated Soils, Indian Head, Sask.

	Nitrogen per acre to a depth of 8 inches Lb.
Virgin soil	8,580
Cultivated soil, 38 years (1884–1922)	5,180
Difference or loss, due to removal in crops and to cultural operations	3,400
Removed by grain crops	1,465
Difference or amount dissipated by fallowing and other cultural operations	1,935
	3,400

Thus in a period of 38 years the loss of nitrogen from the virgin soil has been approximately 40 per cent, of which roughly 17 per cent was removed by crops and 23 per cent by cultivation and the practice of fallowing. These results show that while the loss from fallowing during the first twenty-two years of cultivation was 20 per cent, the loss from similar causes during a further period of eighteen years was only an additional 3 per cent. In all these calculations we have assumed that the nitrogen content of the virgin prairie soil had not appreciably changed during the period of investigation, which though of course not strictly true may be considered as being sufficiently close to the truth for our present purpose.

THE MAINTENANCE OF SOIL FERTILITY BY CROP ROTATIONS

To obtain further and more precise data in this matter and to ascertain the influence of certain rotations including the introduction of grasses and clovers, on the soil's plant food content, a series of plots was set out in 1910 on virgin areas on the Experimental Farms and Stations at the following points on the prairies: Brandon, Man.; Indian Head, Scott and Rosthern, Sask.; Lethbridge and Lacombe, Alta. The soils on these plots were sampled 0 to 6 inches and 6 to 12 inches and placed under various cultural schemes described in discussing results at the several points. A second set of samples was taken in 1921-22, after an interval of eleven years. The data for the analysis of the two sets at Brandon, Scott and Lethbridge are available and will be discussed Station by Station.

Brandon, Manitoba

The soil is a black clay loam, containing from 50 to 60 per cent of clay, 30 to 40 per cent of silt, 3 to 5 per cent of fine and very fine sand and very small amounts under 1 per cent of medium and coarse sand.

Seven plots were set out, the details of the rotations being as follows:—

Plot	Rotation
1. 6 years	Grain, Grain, Grain, Hay (grasses and clover), Hay, Hoed crop (manured).
2. 6 "	Grain, Grain (manured), Fallow, Grain, Hay (grasses and clover), Hay.
3. 6 "	Flax, Grain, Fallow, Grain, Hay (grasses and clover), Hay (manured).
4. 5 "	Grain, Grain, Hoed crop (manured), Grain, Hay (grasses and clover).
5. 10 "	Grain, Grain, Hoed crop (manured), Grain, Grain, Alfalfa, Alfalfa, Alfalfa, Alfalfa, Alfalfa.
6. 4 "	Grain, Grain (manured), Grain, Fallow.
7. 4 "	Grain, Grain, Grain, Fallow.

The data respecting the nitrogen and organic content of these soils in 1910 and 1921, together with the losses and gains in nitrogen due to cropping and soil treatment, may be summarized as in Table III.

TABLE III.—NITROGEN AND ORGANIC MATTER,
BRANDON, MANITOBA, 1910–21

—	Plot 1		Plot 2		Plot 3		Plot 4	
	Per cent	Pounds per acre	per cent	Pounds per acre	per cent	Pounds per acre	per cent	Pounds per acre
Nitrogen 1910, 0″–6″	0·460	6,900	0·384	5,760	0·375	5,625	0·333	4,995
" 1921, 0″–6″	0·398	5,970	0·393	5,895	0·382	5,730	0·334	5,010
" 1910, 6″–12″	0·250	3,750	0·230	3,450	0·183	2,745	0·179	2,685
" 1921, 6″–12″	0·317	4,755	0·247	3,705	0·306	4,590	0·299	4,485
Organic matter, 1910, 0″–6″	10·98	....	10·09	....	9·85	....	8·91	....
" 1921, 0″–6″	10·03	....	10·46	....	10·01	....	8·77	....
" 1910, 6″–12″	7·53	....	7·27	....	6·74	....	6·70	....
" 1921. 6″–12″	8·93	....	7·56	....	8·60	....	7·88	....
Nitrogen, 1910, 0″–12″	....	10,650	....	9,210	....	8,370	....	7,680
" 1921, 0″–12″	....	10,725	....	9,600	....	10,320	....	9,495
" loss or gain 0″–12″	....	+75	....	+390	....	+1,950	....	+1,815
" removed by crops	....	370	....	330	....	304	....	360
" added by manure	....	100	....	100	....	100	....	200

—	Plot 5		Plot 6		Plot 7	
	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre
Nitrogen, 1910, 0″– 6″	0·414	6,210	0·359	5,385	0·348	5,220
" 1921, 0″– 6″	0·391	5,865	0·330	4,950	0·329	4,935
" 1910, 6″–12″	0·206	3,090	0·202	3,030	0·217	3,255
" 1921, 6″–12″	0·263	3,945	0·314	4,710	0·227	3,405
Organic matter, 1910, 0″–6″	11·26	....	9·66	....	10·03	....
" 1921, 0″–6″	10·42	....	9·26	....	9·39	....
" 1910, 6″–12″	6·47	....	6·89	....	7·13	....
" 1921, 6″–12″	7·72	....	8·55	....	7·75	....
Nitrogen, 1910, 0″–12″	....	9,300	....	8,415	....	8,475
" 1921, 0″–12″	....	9,810	....	9,660	....	8,340
" loss or gain 0″–12″	....	+510	....	+1,245	....	−135
" removed by crops	....	613	....	356	....	330
" added by manure	....	100	....	300	....	....

Plot 1.—During the period of experiment this plot has borne six crops of grain (of which four were wheat) two of hay (grasses and clovers), one of Indian corn (manured) and two of grain cut green for hay.

There was a loss of nitrogen in the first 6 inches of soil, amounting to, approximately, 930 pounds per acre. In the second 6 inches there has been a gain of 1,005 pounds. We might, therefore, conclude that under this scheme of rotation, which includes the growing of legumes (two years) and one dressing of manure, the nitrogen content to a depth of 12 inches will be maintained.

Plot 2.—Cropping: six of grain (five of which were wheat), two crops of hay (grasses and clovers), one of grain cut green for hay, one dressing of manure and two fallows.

There has been a slight increase in the nitrogen content of both layers, the data indicating that the losses from cropping and fallowing have been more than fully met by this rotation.

Plot 3.—Cropping: four of grain (of which two were wheat), two of flax, two of hay (grasses and clovers), one of grain cut green for hay, one dressing of manure and two fallows.

As regards the first 6 inches of soil, the nitrogen content remained practically constant; there was, however, a very considerable increase in the 6 inch-12 inch zone. Under this rotation therefore, it would seem that the supply of nitrogen to a readily available depth might well be maintained.

Plot 4.—Cropping: seven crops of grain (of which five were wheat), one of hay (grasses and clovers), two of Indian corn, one of grain cut green for hay and two dressings of manure—no fallow.

In all essential particulars the results are similar to those from Rotation 3. The amount of nitrogen in the surface 6 inches remained constant, markedly increasing in the 6 inch-12 inch zone. The gain in nitrogen to a depth of 12 inches is practically the same for both rotations.

Plot 5.—Cropping: four crops of grain (two of which were wheat), one of Indian corn, five of alfalfa, one dressing of manure and one fallow.

The results from this rotation are somewhat remarkable. The first 6 inches of soil lost nitrogen at the rate of 345 pounds per acre, while the second 6 inches gained 855 pounds, leaving a net gain for the 12 inches of soil of 510 pounds. This gain was effected notwithstanding that, compared with the other rotations of the series, twice the amount of nitrogen, approximately, was removed in crops. The explanation probably lies in the assimilation and storage of atmospheric nitrogen by the alfalfa, which occupied the land for five successive seasons.

Plot 6.—Cropping: nine crops of grain (of which seven were wheat), three applications of manure and two fallows.

This cropping and treatment resulted in a slight decrease (435 pounds per acre) in nitrogen in the surface 6 inches, with a considerable increase (1,680 pounds per acre), in the second 6 inches. With but two fallows in the eleven-year period, this scheme of cropping, notwithstanding the addition of 300 pounds of nitrogen in manure, reduced the nitrogen content of the surface soil.

A satisfactory explanation for the increase in nitrogen in the lower zone is not apparent; the sampling may have been at fault, but the evidence at present is against accepting this as the cause.

Plot 7.—Cropping: nine crops of grain (of which six were of wheat) and two fallows.

This scheme, with a fallow every fourth year, represents more nearly than any other of the series the usual practice in grain-growing districts, which calls for a fallow every third year. The land was not put in sod and no manure was applied. Under this practice, the nitrogen content of the surface 6 inches of soil was slightly reduced as in the case of plot 6, the cropping of which was similar to that of plot 7: plot 6, however, received two dressings of manure. A very slight increase of nitrogen apparently occurs in the lower 6 inches, but this is not sufficient to balance the loss referred to, with the result that there has been an appreciable, though not large, reduction in nitrogen in the soil to a depth of 12 inches.

Relation of Nitrogen to Organic Matter.—The organic content as determined by "loss on ignition" follows fairly closely the nitrogen, so that the ratio, nitrogen to organic matter, is more or less constant.

Humus was determined in the surface soils, employing the usually-accepted method. The ratio, nitrogen to humus, is not so consistent as the aforementioned ratio but the data confirm in a general way our previous findings viz., that with the destruction of organic matter there is a concomitant dissipation of nitrogen, and vice versa, with the accumulation of organic matter there is a corresponding increase in the nitrogen content. The data are given in Table IV.

TABLE IV.—NITROGEN, ORGANIC MATTER, HUMUS,

SURFACE SOILS, BRANDON, MANITOBA, 1910-1921

Plot	Year	Nitrogen	Organic Matter	Humus	Ratio Nitrogen to Organic Matter	Ratio Nitrogen to Humus	Ratio Humus to Organic Matter
		p. c.	p. c.	p. c.			
1	1910	·460	10·98	2·24	1 : 24	1 : 4·8	1 : 4·9
	1921	·398	10·03	2·04	1 : 25	1 : 5·1	1 : 4·9
2	1910	·384	10·09	2·31	1 : 26	1 : 6·0	1 : 4·4
	1921	·393	10·46	2·65	1 : 27	1 : 6·7	1 : 3·9
3	1910	·375	9·85	2·13	1 : 26	1 : 5·6	1 : 4·6
	1921	·382	10·01	2·86	1 : 26	1 : 7·4	1 : 3·5
4	1910	·333	8·91	2·52	1 : 27	1 : 7·5	1 : 3·5
	1921	·334	8·77	2·16	1 : 26	1 : 6·4	1 : 4·1
5	1910	·414	11·26	2·79	1 : 27	1 : 6·7	1 : 4·0
	1921	·391	10·42	2·36	1 : 27	1 : 6·0	1 : 4·4
6	1910	·359	9·66	2·46	1 : 27	1 : 6·8	1 : 3·9
	1921	·330	9·26	2·05	1 : 28	1 : 6·2	1 : 4·5
7	1910	·348	10·03	2·59	1 : 29	1 : 7·4	1 : 3·9
	1921	·329	9·39	2·16	1 : 29	1 : 6·5	1 : 4·4

Summing up the results from the Experimental Farm at Brandon, we may conclude that during the eleven-year period the nitrogen content of the soil, as measured to a depth of 12 inches, has been maintained and in certain instances materially increased in those rotations which included the growing of grasses and legumes with light dressings of manure.

On the other hand, the results of the plot (No. 7), which for nine years was in grain and was fallowed twice, confirm our previous work in respect to the effect of pure and simple grain growing, in showing a serious reduction in the nitrogen content of the soil. This is to be interpreted as a distinct loss in fertility, for nitrogen is undoubtedly the limiting factor in crop production in so far as plant food is concerned.

SCOTT, NORTHWESTERN SASKATCHEWAN

The soil is a black silty clay loam, containing about 20 per cent of clay and 40 per cent of silt, the remainder being chiefly very fine sand.

Conditions in connection with the working of this Station resulted in the abandonment of the original plots and the setting out of a new series in 1916. This series consisted of four plots, and the soil samples were collected to one depth, 8 inches. The second collection of samples was made in 1922. The rotations adopted are as follows:—

Plot	Rotation.
1.	Wheat continuously; no Fallows.
2. 6 years	Peas (manured), Wheat, Fallow, Wheat, Wheat, Fallow.
3. 6 "	Wheat, Wheat, Oats, Hay (grasses and clovers), Hay, Fallow.
4. 6 "	Wheat, Wheat, Fallow, Peas (manured), Barley, Hay (grasses and clovers).

In table V the data for the nitrogen and organic matter content are given, together with the losses and gains in nitrogen due to cropping and soil treatment.

TABLE V.—NITROGEN AND ORGANIC MATTER

SCOTT, SASK., 1916–1922

	Plot 1		Plot 2		Plot 3		Plot 4	
	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre
Nitrogen, 1916—0″–8″	0·286	4,290	0·280	4,200	0·235	3,425	0·211	3,165
" 1922—0″–8″	0·260	3,900	0·318	4,770	0·289	4,335	0·232	3,480
Organic matter, 1916—0″–8″	7·22	....	6·90	....	6·33	....	5·77	....
" " 1922—0″–8″	6·59	....	8·04	....	7·19	....	5·86	....
Nitrogen loss or gain—0″–8″	....	−390	....	+570	....	+910	....	+315
" removed by crops	....	201	....	194	....	202	....	211
" added by manure	....	....	....	150	....	....	....	150

Since the experimental period of this series is but six years, a minute discussion of the detailed data may not be justified; it may better suffice for the present purpose to discover the trend of the changes that may have taken place in respect to nitrogen and organic matter under the several rotations.

Plot 1 provides the most significant data. Wheat was sown consecutively, the land being ploughed and a seed bed prepared each spring. No manure was applied. To epitomize: The soil to a depth of 8 inches had lost per acre 390 pounds. During the six-year period approximately 200 pounds of nitrogen per acre had been removed in the wheat crop. Thus in the course of six seasons a loss of 190 pounds of nitrogen resulted from cultural operations. It is to be noted that these plots were laid out on land which had been under cultivation for some years and therefore the case is not strictly comparable to that of virgin prairie soil as at Portage la Prairie and Indian Head.

Plots 2, 3 and 4 all showed an increase in nitrogen, the range being from 315 to 910 pounds per acre. The removal of nitrogen was approximately 200 pounds in each case. *Plot 2,* with a gain of 570 pounds, received 150 pounds in manure and had grown a crop of legumes (peas). It had been fallowed twice.

Plot 3, with a gain of 910 pounds, had been two seasons in hay, (grasses and clovers), and had been fallowed once. *Plot 4,* with a gain of 315 pounds, had received 150 pounds in manure and had grown one crop of legumes (peas), and one crop of hay (grasses and clovers). It had been fallowed once.

The data for organic matter follow those of nitrogen, *plot 1* showing a decrease, *plots 2, 3 and 4* an increase.

The results at Scott furnish evidence in line with that from the Brandon data, which show that a loss of nitrogen and organic matter ensues from exclusive grain growing but that the amount of these constituents has been maintained or increased by a rotation in which one or more hay crops (grasses and legumes), with or without manure, are included.

LETHBRIDGE, SOUTHERN ALBERTA

The soil, a sandy calcareous loam, at the time of setting out the plots (1910) was in alfalfa and had been cultivated for some years under irrigation. It was very uniform throughout the area, containing approximately 20 per cent of clay, about 22 per cent of silt, the remainder, 58 per cent, being chiefly fine and very fine sand.

Ten plots were laid out and the soil on each sampled to the depths of 0 to 6 and 6 to 12 inches.

The ten-year rotation adopted was the same throughout the series; it comprised six successive crops of alfalfa, one hoed crop and three grain crops. The cropping of the first year (1911) was so arranged that each year of the rotation was represented in the series. The period of investigation included eleven crops, 1910-1921, inclusive.

The nitrogen and organic matter data are presented in table VI.

TABLE VI.—NITROGEN AND ORGANIC MATTER—IRRIGATED ROTATIONS

LETHBRIDGE, ALTA. 1910-1922.

	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre
Nitrogen, 1910—0″-6″......	0·166	2,490	0·162	2,430	0·177	2,655	0·194	2,910	0·215	3,225
" 1922—0″-6″......	0·230	3,450	0·198	2,970	0·212	3,180	0·207	3,105	0·196	2,940
" 1910—6″-12″.....	0·148	2,220	0·117	1,755	0·088	1,320	0·094	1,410	0·118	1,770
" 1922—6″-12″.....	0·155	2,325	0·179	2,685	0·174	2,610	0·190	2,850	0·146	2,190
Organic matter, —										
" 1910—0″-6″......	4·31	....	4·47	....	4·55	....	4·78	....	4·74	....
" 1922—0″-6″......	5·51	....	4·86	....	5·15	....	4·95	....	4·70	....
" 1910—6″-12″.....	4·03	....	3·29	....	2·88	....	3·19	....	3·48	....
" 1922—6″-12″.....	3·79	....	4·58	....	4·33	....	4·79	....	3·60	....
Nitrogen, 1910—0″-12″.....	......	4,710	......	4,185	......	3,975	......	4,320	......	4,995
" 1922—0″-12″.....	......	5,775	......	5,655	......	5,790	......	5,955	......	5,130
" loss or gain 0″-12″	......	+1,065	......	+1,470	......	+1,815	......	+1,635	......	+135
" removed by crops	......	1,945	......	1,848	......	1,264	......	1,400	......	1,193
" added by manure	......	....	......	....	......	....	......	....	......	....

	Plot 6		Plot 7		Plot 8		Plot 9		Plot 10	
	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre	Per cent	Pounds per acre
Nitrogen 1910—0″-6″......	0·174	2,610	0·161	2,415	0·164	2,460	0·181	2,715	0·181	2,715
" 1922—0″-6″......	0·231	3,465	0·217	3,255	0·211	3,165	0·234	3,510	0·222	3,330
" 1910—6″-12″.....	0·135	2,025	0·092	1,380	0·146	2,190	0·144	2,160	0·153	2,295
" 1922—6″-12″.....	0·161	2,415	0·185	2,775	0·176	2,640	0·194	2,910	0·165	2,475
Organic matter—										
1910—0″-6″............	4·51	....	4·53	....	4·57	....	4·54	....	5·18	....
1922—0″-6″............	5·28	....	5·02	....	4·27	....	4·63	....	4·40	....
1910—6″-12″...........	3·86	....	3·32	....	4·20	....	3·53	....	3·73	....
1922—6″-12″...........	3·97	....	4·01	....	3·77	....	3·92	....	3·51	....
Nitrogen 1910—0″-12″......	......	4,635	......	3,795	......	4,650	......	4,875	......	5,010
" 1922—0″-12″......	......	5,880	......	6,030	......	5,805	......	6,420	......	5,805
" loss or gain 0″-12″	......	+1,245	......	+2,235	......	+1,155	......	+1,545	......	+795
" removed by crops	......	1,541	......	2,628	......	1,608	......	1,552	......	1,826
" added by manure	......	....	......	....	......	....	......	....	......	....

It has been noted that throughout the series the rotation was the same—a ten-year course, including six successive seasons of alfalfa.

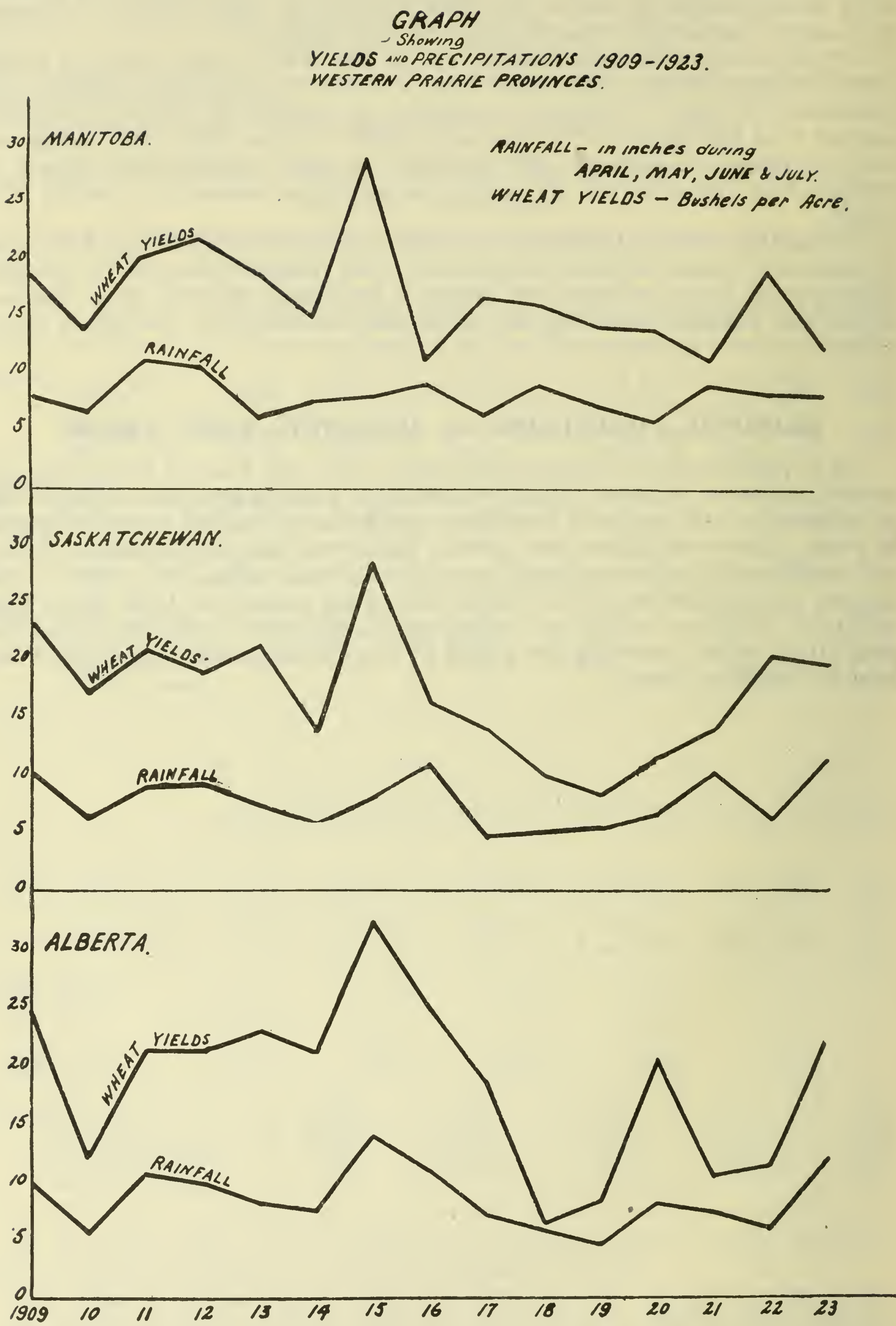
The data are of particular interest in furnishing an example of the value of the legume alfalfa in the nitrogen enrichment of soils. Notwithstanding the large yields of alfalfa hay and cereals harvested during the eleven-year period of the experiment, there was a marked increase in the nitrogen content of the soil of every plot. The amounts of nitrogen removed by crops ranged from 1,193 to 2,628 pounds. The residual gain at the close of the period to a depth of 12 inches, ranged, in nine of the plots, from 795 to 2,235 pounds of nitrogen per acre, or, per annum, from roughly 70 to 200 pounds.

These results in a large measure are in accord with those obtained at the Central Farm, Ottawa, 1902-1912, from a series of experiments instituted to determine, as closely as might be possible, the increase in the soil's nitrogen content from the growth of clovers and alfalfa. It was found that during the ten-year period, keeping the soil constantly in crop (clover), the increase in nitrogen was approximately 50 pounds per acre, per annum, to a depth of 4 inches.

From this work at Lethbridge we think it may be safely assumed that the maintenance of soil fertility is assured for the irrigated districts of southern Alberta in so far as nitrogen and humus is concerned, provided that alfalfa—which is a valuable crop and one particularly suitable for cultivation under irrigation—has a prominent place in the rotation.

SEASONAL CONDITIONS AS AFFECTING CROP YIELDS

It is probably true that impoverishment of the soil has not had as yet any material influence on crop yields throughout the prairies generally. Apart from an outbreak of rust, seasonal conditions constitute the limiting factor in respect to yields. These conditions may include hailstorms and early autumnal frosts, but undoubtedly the outstanding seasonal condition influencing yields is the amount and distribution of the rainfall during the months of April, May, June and July. The data in the accompanying chart clearly show that during the past fifteen years (covering the period of this investigation) this rainfall has been the limiting factor.


GRAPH
Showing
YIELDS AND PRECIPITATIONS 1909-1923.
WESTERN PRAIRIE PROVINCES.
RAINFALL - in inches during APRIL, MAY, JUNE & JULY.
WHEAT YIELDS - Bushels per Acre.
MANITOBA.
WHEAT YIELDS
RAINFALL
SASKATCHEWAN.
WHEAT YIELDS
RAINFALL
ALBERTA.
WHEAT YIELDS
RAINFALL
0 5 10 15 20 25 30
1909 10 11 12 13 14 15 16 17 18 19 20 21 22 23

It will be observed that there is no gradual decline in yields and that the curves for the precipitation and yields for the experimental period in each of the three provinces follow one another fairly closely. Where the curves are not in accord we frequently find that disturbing factors e.g., rust and frost, are responsible. An example of this is the low yield in 1916, especially in Manitoba, due to the prevalence of rust in that year.

CONCLUSIONS

The results of this investigation confirm our conclusion from previous work in this enquiry, that grain growing as at present practised with its necessary summer fallowing, is destructive of the soil's organic matter with a concomitant loss of nitrogen. Certain of the data of this later investigation, as has been pointed out, indicate a slowing down in the rate of this destructive process, and it will probably be found under the climatic conditions existing that following an initial period of cultivation, a point will be reached at which the dissipation though not negligible will be comparatively slight. It is the virgin soil with its exceptional richness in organic matter, rather than the older cultivated soils, which show an excessive rate of deterioration.

Exclusive grain growing must give way to a practice which introduces in a rotation grasses and clovers if the humus and nitrogen content is to be maintained and the " fibre "—the binding element of the soil—preserved. This has been amply proven by the data of the present enquiry. The systematic and periodic putting of the land in sod will serve to maintain the soil's nitrogen and humus, to preserve good tilth and the moisture-holding capacity of the soil and to arrest to a large degree the loss of valuable soil by drifting, an inevitable result following the constant breaking up of the soil's fibre by cultivation and summer fallowing. Drifting or " blowing " is a serious matter in semi-arid districts in which high winds prevail.

Already in many parts of the three prairie provinces mixed farming, including dairying and stock raising, has assumed large proportions and proved successful; the extension of this practice necessarily involves a scheme of soil management which serves to maintain fertility; it will assuredly tend towards the increase rather than the decrease of the grain output of the prairies. This latter statement receives support from the work of the Experimental Farms and Stations of the prairies where it has been shown that forage crops of various kinds can be successfully grown, that these can be profitably used in the feeding of live stock and, further, that under this type of farming, grain yields have increased.

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PUBLICATIONS ON WESTERN SOILS

The following publications of the Department of Agriculture relating to Western Soils are available on application to the Publications Branch, Department of Agriculture, Ottawa:—

Alkali Soils; Their Nature and Reclamation, Bulletin No. 4, S.S. Western Prairie Soils, Their Nature and Composition, Bulletin No. 22, N.S.

OTTAWA: Printed by F. A. ACLAND, Printer to the King's Most Excellent Majesty, 1925.