

Long-Term Cropping Studies on the Canadian Prairies: An Introduction

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Summary

Historically, crop rotations were some of the first integrated agricultural field research studies established in Canada, a reflection of the interests in determining the most optimum and economic crop sequences. Over the years, agricultural research evolved immensely with crop rotations now representing only one of many facets of current agronomic research. However, interest in crop rotation, cropping system or cropping sequence studies is still very high amongst the research and farming community. The last crop rotation bulletin published for the Canadian prairies was in 1990. This issue of *Prairie Soils and Crops* provides an overview of the more recent findings pertaining to the on-going long-term crop rotation studies on the Canadian prairies; easy access to various historical crop rotation and related documents pertaining to the Canadian prairies for students, agronomists, producers, the research community and anyone else interested in long-term crop rotation studies; an up-to-date and searchable bibliography of scientific publications pertaining to long-term studies (>20 years in length) on the Canadian prairies; and an awareness of the existence of long-term studies in Western Canada. Hopefully, this will serve as a stimulus to more discussions on what new questions might be answered in these studies and what new studies might be required for the next generation of scientists.

Introduction

The settling of the Canadian Prairies occurred over a period of about three hundred years and early settlements were associated mainly with the fur trade. Settlements revolving around agricultural activities are more recent. When compared to other parts of the world such as Asia and Europe, agriculture on the prairies is still very recent—less than 130 years old. The production and export of wheat from the late 1880s to the 1950s provided the foundation for infrastructure development to support an expanding Canadian prairie economy. The increase in land seeded to grain, mainly spring wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and oat (*Avena sativa*) was rapid¹⁵, rising from 0.1 million (M) ha seeded in 1880 to 1.1 M in 1910, 11.6 M in 1920, and 30.1 M ha in 2001 where it more or less remains today.

The development of Prairie agriculture was not based on principles of best land use as a function of climate, soils and geography, but according to the government policies of the day¹³. However, the suitability of prairie soils for growing cereals was already recognized in 1889 from measurements of soil organic nitrogen at various locations across the Prairies⁷. Unknown factors were the extent of soil heterogeneity in terms of texture, organic matter, topography and parent material, and the extent of climatic variability. The large scale conversion of native prairie, combined with the cultural practices available at the time, resulted in severe land degradation and important losses in soil productivity—effects still noticeable today^{1,7}.

The early establishment of Experimental Farms after 1886 provided unique benefits. As stated by Janzen⁷, “When the ploughs began to invert the prairie sod, scientists were already there to record the effects. And from the onset, preserving the soils was a priority.” Over the next 20 years, extensive and detailed measurements of soil organic matter led Shutt⁷ to report on its rapid decline and raise concerns about the ‘permanence’, now referred to as ‘sustainability’ of agriculture on the Prairies. Uncultivated prairie soils contained from 0.2 to 0.7% nitrogen and by the 1940s, 15 to 40% of it had been lost⁹. This trend continued so that, by the 1980s, most soils had lost 40% or more of their initial organic nitrogen content.

From the very beginning, Prairie farmers were interested in new and innovative farming systems with respect to crop rotations, increased crop diversity, soil fertility management, more effective weed control methods and also ways to

arrest wind and water erosion. These interests were a major factor behind the establishment of long-term crop rotation Studies⁷. These interests are reflected in long-term crop rotation study bulletins published since the early 1900's^{4,10,5,14,11,2} and the hundreds of scientific papers written over the last 100 years on this topic. Dr Con Campbell, scientist emeritus with Agriculture and Agri-Food Canada, prepared a bibliography of scientific papers from the current long-term studies (>20 years in length) that is referenced in this volume.

The objectives of Volume #5 of Prairie Soils and Crops are:

- (1) To provide easy access to various historical crop rotation research and related documents pertaining to the Canadian prairies and to inform students and the research community who are interested in long-term soil and crop management studies.
- (2) To provide a summary of major findings obtained to date from various on-going long-term cropping studies in Western Canada. A listing of these studies is provided in Table 1.
- (3) To provide an up-to-date bibliography of scientific publications pertaining to long-term studies on the Canadian prairies (>20 years in length).
- (4) To create awareness of the existence of long-term studies in Western Canada and to stimulate discussion on what new questions might be answered with these and potential future studies.

Historical Perspectives of Crop Rotations Studies in the Canadian Prairies.

Interest in crop rotations or the influence of crops on following crops is not new. In fact, it goes back thousands of years. In 30 BC, Vigil recognized the value of certain crop sequences recommending a fallow-cereal-pulse rotation. One of the earliest observations in agriculture concerns the use continuous cropping which led to a slow decline in production over time and the need to include fallow or the inclusion of legume green manure crops to restore soil productivity. The advent of inorganic fertilizers provided a solution to this dilemma and their impact on not only grain yield but also soil quality is well documented in a number of studies described in this Volume.

One of the earliest documented crop rotation studies in the world were those experiments established at the Agriculture Experiment Station in Rothamstead, England in 1852³. The original four-year rotation involving swedes (*Brassica napus napobrassica*), barley, clover or fallow and wheat is still on-going.

In Canada, the first recorded crop rotation experiment was established in 1888 and consisted of growing oat, barley, wheat, mangels (fodder beet), turnips and corn continuously in rotation on the same soil¹². The experiment was terminated in 1910 and replaced with other studies across Canada. The famous Rotations A (Continuous Wheat), B (Fallow – Wheat) and C (Fallow – Wheat – Wheat) are still being grown at the Lethbridge Research Center in Alberta and at the Scott Research Farm (Rotation C only) in Saskatchewan. These studies are now over 100 years old. The focus for many of these early studies involved looking at the influence of various crops on following crops using various species and referring back to Rotations A, B or C as their check or benchmark.

E.S. Hopkins with the help of S. Barnes published a crop rotation bulletin in 1928 summarizing the findings from various long-term studies established in 1911⁴. The objective was to evaluate the value of different crop rotations and their economic and agronomic suitability across the various Experimental Farms in Western Canada. The largest impediments to continuous cropping were weed management and the ability of the soil to supply nutrients. The introduction of herbicides and inorganic fertilizers represent important solutions to this dilemma.

In 1941, P.O. Ripley published a review article summarizing the findings from many of the crop rotations studies established after 1910, which is provided in this Volume¹⁰. The review focused for the most part on long-term studies conducted in Eastern Canada. There was a lengthy discussion on the underlying reasons for the beneficial effects of annual and perennial legume crops on following crops. Many of these questions have been answered with numerous studies conducted in Western Canada over the last 30 years. He also referred to a few long-term studies as they apply

to the Canadian prairies and a few of the highlights are provided: (1) Given the dry conditions of the Canadian prairies, crop production was favored when the preceding crop or practice was a low water user i.e. summerfallow (which is obvious) and corn were the best preceding treatments; (2) carbon dioxide production was always higher from incubated soils collected after alfalfa or red clover which reflects the rapid decomposition of the residues due to their high nitrogen contents; and (3) applications of farmyard manure increased crop yields, soil organic matter, soil nitrates and phosphates and carbon dioxide emissions. He also discussed at length the benefits of various annual and grain legumes on succeeding grain crops and the possible reasons for these benefits. Many of these reasons have since been elucidated.

In 1944, Hopkins and Leahy published a crop rotation bulletin for the Canadian prairies focusing on the different rotation studies established after 1910⁵. The publication highlighted not only the results from the various rotations but also other studies related to the effects of commercial fertilizers, farm manure and green manure on crop production. The authors recognized the diversity of soils and climatic conditions on the prairies and their impact on the observations, always cautioning farmers to rely on those studies that were closest to their soil zone and climatic conditions. The authors also commented that the business of farming is an on-going activity and every effort should be made to not only maintain the productive capacity of the soil but to also try to enhance it. This provides evidence that the notion of sustainability has always been in the mind of the research and farming community. One interesting observation was the beneficial effects of mixed-farming rotations over straight grain rotations in the black and gray wooded soils; these benefits were not observed in the Brown and Dark-Brown soil zone. For example mixed-farming rotations provided effective means of weed control like wild oat in the black soil zone but not in the drier areas of the prairies. The value of using sulfur fertilizer on leguminous hay crops was recognized for the grey wooded soils. The response to ammonium phosphate was reported as being inconsistent, especially in the Brown and Dark Brown soil zone. Interestingly, they reported that the response of crops to commercial fertilizers was better than with animal manures, when a response was observed. However at Beaverlodge, AB (a grey wooded soil) they found that the response was better with animal manure than commercial fertilizers. With regards to the benefits of green manure plough down crops, their results did not support this practice, especially in the drier areas of the prairies. More recent studies at Swift Current have shown that with refinements to the management of green manure crops, benefits can be obtained even in the Brown soil zone. Although fallow – crop and fallow – crop – crop rotations were very successful in the Brown and Dark-Brown soil zone, serious concerns were nonetheless raised about the effects of wind and water erosion and their associative degrading effects with summerfallow practices. The concerns raised were greatest for the black soil zone. They also emphasized the benefits of mixed-farming rotations. For the Grey wooded soils, they also reiterated that summerfallowing was not necessary and that the low inherent fertility of these soils remained the main problem. They did recognize that the long hours of daylight combined with the generally cool conditions were well suited for forage grass and forage legume seed production.

In 1963, L.B. Siemens of the Department of Plant Science at the University of Manitoba published another review article on crop rotations focussing on research results from North America up to 1959¹⁴. He states: “Although the recorded history of crop rotation studies goes back just over a century, and although volume upon volume of data and findings are recorded in the literature, few conclusions of a fundamental nature have as yet been drawn. Because of the dynamics of this broad and general field of study, and because of the interaction of living creatures – from bacteria to man – there may be but a limited number of authoritative conclusions that can be recorded with finality and that can be depended upon to apply in all instances.” In his discussion he stressed the importance of measuring soil and climatic conditions, the use of proper experimental designs and the overriding economic effects in order to more correctly understand the effects of crop rotations. In many cases, economics alone dictated the choice of a particular rotation. It is safe to say that some of the more recent scientific publications have indeed produced some authoritative conclusions.

Another crop rotation bulletin was published in 1969 by P. O. Ripley. The author provided an excellent historical overview and summaries from various well-known and published long-term crop rotations studies from different countries. Within the context of the Canadian Prairies, he continued to emphasize the merits of summer fallowing every second or third year for wheat production in the semi-arid areas of the Canadian prairies and the difficulty in

producing grass and legume crops. For the black soil zone, summer fallowing was not considered to be necessary.

The last crop rotation bulletin was published in 1990 by Campbell and others². They reported not only on the agronomy but also on the economic and energy impact of the various crop rotations which provided a new dimension to our understanding of crop rotations. They also touched upon the concept of soil building and how crop rotations can be used for soil building as well. Their findings again emphasized the merits of summerfallow practices in the Brown and Dark Brown soil zone with the optimum economic frequency determined to be 1 year in three. However, with the advent of more crop diversification combined with no-till production systems, summerfallow area has decreased by 67% for the period 1996 to 2006 on the prairies with most of the decrease observed in Saskatchewan⁸. As reported in previous bulletins, perennial forage crops in rotation were best suited for the Black and Gray soil zones and not recommended in the Brown and Dark Brown soil zone because of their large water depleting effects. They concluded that the influence of a crop on a subsequent crop was largely a function of how much water and fertility was left behind and their beneficial impact in reducing plant diseases. With the extensive use of summerfallow and its associated degrading effects, the benefits of commercial fertilizers were becoming more obvious. They documented the benefits of nitrogen fertilizers through increased water use efficiency from better root growth, improved water conservation from better snow trapping and greater presence of crop residues on the soil surface when using conservation tillage practices, and overall improvements in soil organic matter quantity and quality. They concluded that agronomic practices impact soil quality and that soil productivity can be maintained indefinitely by adopting economically viable, conservation-oriented management practices. They postulated that previous trends of gradual losses in soil productivity can actually be reversed with changes in agronomic practices; this is now observed with the majority of current farming practices on the prairies.

Conclusions

Perhaps the best way to demonstrate the importance of long-term crop rotation studies to the public at large, as well as to those involved in Canadian prairie agriculture, is to quote Janzen from the Lethbridge Research Center⁶. *“Perhaps the best justification for the establishment and maintenance of long-term sites is that they provide a resource for future scientists posing questions we have not yet anticipated. There was no way of knowing in 1910, for example, that rotation ABC would one day provide information pertinent to the issue of global warming. Indeed, most of the key findings from this site could not have been envisioned at the turn of the century. Future generations of scientists, in addressing the questions that will inevitably arise regarding agricultural sustainability, will cherish the long-term ecological sites they inherit, provided they have been adequately established, documented, and maintained.”*

Table 1. Listing of Long-Term Cropping Studies in Western Canada reported on in Volume 5 of Prairie Soils and Crops.

Province	Long-Term Cropping Studies	Start Date	Institution	Lead Author
Manitoba	Long-term Pesticide Free Production Study – Carman, Manitoba	2000	University of Manitoba	Rob Gulden
	Potato Cropping Study – Carberry, Manitoba	1998	Agriculture and Agri-Food Canada	Ramona Mohr
Saskatchewan	Indian Head Long Term Rotations - Indian Head, Saskatchewan	1958	Agriculture and Agri-Food Canada	Guy Lafond
	Old Rotation Study - Swift Current, Saskatchewan	1966	Agriculture and Agri-Food Canada	Reynald Lemke
	New Rotation Study - Swift Current, Saskatchewan	1987	Agriculture and Agri-Food Canada	Reynald Lemke
	Effect of Tillage and Cropping Frequency on Sustainable Agriculture in the Brown Soil Zone - Swift Current, Saskatchewan	1981	Agriculture and Agri-Food Canada	Con Campbell
	Alternative Cropping Study - Scott	1995	Agriculture and Agri-Food Canada	Reynald Lemke
	Re-establishment of Native Grassland Species onto Annual Crop Land - Swift Current	2001	Agriculture and Agri-Food Canada	Alan Iwaasa
Alberta	The University of Alberta Breton Plots – Breton, Alberta	1929	University of Alberta	Miles Dyck
	Native Grass Plots - Lethbridge	8000 BC	Agriculture and Agri-Food Canada	Ben Ellert
	Rotation ABC - Lethbridge	1911	Agriculture and Agri-Food Canada	Elwin Smith
	Rotation U - Lethbridge	1911	Agriculture and Agri-Food Canada	Ben Ellert
	Long-Term Grazing Study – Stavelly, Alberta	1949	Agriculture and Agri-Food Canada	Walter Wilms
	Rotation 120 - Lethbridge	1951	Agriculture and Agri-Food Canada	Elwin Smith
	Long-Term Erosion-Productivity Relationships: The Lethbridge Soil Scalping Studies	1990	Agriculture and Agri-Food Canada	Frank Larney
	Long-Term Cattle Manure Plots – Lethbridge, Alberta	1973	Agriculture and Agri-Food Canada	Xiyang Hao
	Dryland Crop Residue Study - Lethbridge	1998	Agriculture and Agri-Food Canada	Ben Ellert
	Long-term Field Bioassay of Soil Quality – Lethbridge, Alberta	1990	Agriculture and Agri-Food Canada	Henry Janzen
	C-Quest Study - Lethbridge	1993	Agriculture and Agri-Food Canada	Ben Ellert
	Long-Term No-till Study – Lethbridge, Alberta	1968	Agriculture and Agri-Food Canada	Elwin Smith

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