Landscapes Transformed:

The History of Conservation Tillage and Direct Seeding

edited by C. Wayne Lindwall
and Bernie Sonntag

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Foreword

Murray Fulton[*]

Thoughts on Conservation Tillage and Why Summerfallow Was So Difficult to Replace as a Practice.

The story of conservation tillage highlights the manner in which major transformational changes occur in an industry. As a transformational technology, conservation tillage did more than just change the tillage and seeding system used by Prairie farmers. It also had a major impact on the crops grown and processed on the Great Plains, spawned a new machinery industry, fundamentally altered the labour arrangements on and off the farm and allowed Western Canada to remain an important international agricultural exporter.

Understanding how a transformational change like this came about requires an understanding of a wide range of forces and factors. Economic pressures were clearly important, since new technology will not be adopted if it is not profitable to do so. But economic factors alone cannot explain the shift in mindset that was required to get farmers and the industry in general to accept conservation tillage as a legitimate approach.

The shift from conventional to zero-tillage [1] is a striking example of how adaptation and change occurs. The purpose of this book, and the diverse perspectives that it contains, is to document the process by which this change occurred. While part of the focus is on the technological changes that were required for the implementation of zero-till, the book also addresses the changes in thinking and in organization that had to occur before the technological changes could be both envisioned and adopted.

A cornerstone of the Knowledge Impact in Society (KIS) project is the idea that the way the world is perceived is often critical to the decisions that people make. The KIS project also recognizes that effective knowledge mobilization requires

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[1]In this Foreword, the term “zero tillage” is used synonymously with conservation tillage and no-till.

two-way communication. More than simply sharing academic research, the KIS project sees value in providing forums for discussing the issues facing agriculture and rural communities. This book, with authors from university, industry and government, represents a form of the knowledge sharing that is critical to the success of agriculture in the years to come.

In the Beginning

As is the case with all transformative technologies, zero-tillage had its beginnings with new information, in this case new information about the causes of soil and water erosion and how they could be addressed. Everyone, however, did not immediately accept this new information. Farmers, for instance, could either incorporate the new knowledge into their belief system and make a production change (i.e., stop summerfallowing) or they could discount the information and keep on with their current practices. For a considerable length of time, this second strategy dominated; indeed it took many decades for the farming community to shift away from the belief that summerfallow was the only way to farm to a belief that minimum/zero tillage was more advantageous. Here are some thoughts on why it took so long for the change in beliefs to occur and what happened that allowed them to change.

As far back as the early 1900s, soil scientists understood that soil fertility would decline over time as a result of tillage.[2] For the most part farmers did not share this understanding; for them, the soil was a rich resource that they could not contemplate ever depleting or degrading. As well, for the first 20-30 years of settlement on the Prairies, any depletion of the resource was so small that it went unseen.

Moreover, the pressures to survive economically were the primary concern. Most farmers were barely getting by – in part a result of a land policy that created incentives to farm small economically unsustainable parcels of land which attracted people with little or no knowledge of farming – so with economic survival at stake, long-term sustainability of the soil took second place.

And, very importantly, there was little in terms of options. The machinery was very crude and had been developed for a different set of conditions. As well, everyone – farmers, government personnel, scientists – was focused on moisture, something that should not be unexpected given that farming was being done in an area that barely received more rainfall than a desert (in some cases the area was technically a desert). This focus is part of the reason why summerfallow was so hard to dislodge – it seemed common sense that summerfallow would allow moisture to be built up, thus allowing a crop to be grown the following year. Indeed, the idea of a dust mulch that would help retain water was promoted for some time as a moisture management technique.

[2] See, for instance, Janzen, H.H. 2001. Soil science on the Canadian prairies – Peering into the future from a century ago. *Canadian Journal of Soil Science.* 81: 489-503.

Thus, as a consequence of a number of forces (economic, technological, social, psychological), summerfallow obtained dominance both as a farming practice and as a belief system about how moisture management should take place. Economically and technologically, there were few options available. As a result, it made little sense for people to think about other possibilities. Socially, to deviate from the established norm created significant personal costs. These costs were still evident in the 1970s and 1980s – witness the resistance that Professor Don Rennie faced when he challenged summerfallow's desirability, as well as the refusal of Saskatchewan Agriculture to initially support the Saskatchewan Soil Conservation Association. The idea of moisture conservation seemed to be unassailable.

There are two psychology terms that can help explain what was going on cognitively among farmers who summerfallowed – anchoring and the confirmation bias. Anchoring is the tendency to put too much emphasis on an initial position and not enough on subsequent information. Confirmation bias is when information acquired to test assumptions is chosen to support initial beliefs.

Over time summerfallow became the dominant belief system, which in turn meant that it was difficult to think of other ways to farm. Anytime new methods were presented they would be interpreted in the light of the status quo. Prairie farmers were "anchored" to the belief that summerfallow was a must for successful crop production and any attempt by others to suggest otherwise was overlooked or discounted, while information that supported summerfallow was heralded.

Seeds of Change

Although widespread zero-till adoption did not take hold until the late 1980s and the early 1990s, the seeds for change were sown in the 1930s. During the 1930s – the so-called Dirty 30s – an awareness was created that the soil resource was vulnerable. While this awareness may not have had much immediate effect, it did mean that the system was, in effect, primed to consider some other possibilities. The creation of PFRA (Prairie Farm Rehabilitation Administration) (and other initiatives in the area of resource management) created a group of people that were thinking about the issues of resource sustainability and environmental degradation. This group and their successors were available to be drawn upon in the 1970s. As well, the farmers and scientists active in the 1960s and 1970s lived through the 1930s and this experience no doubt affected their perspectives.

In retrospect, the 1970s can be seen as the tipping point – the time at which a number of forces came together to create a change. The reasons were varied – what is interesting is that they all emerged at roughly the same time. Economically, the grain market boom that began in 1973 provided farmers with the economic means to adopt new technologies and consider new ways of doing things. As well, the better economic conditions meant that farmers were not focused solely on survival – they could begin to think about long-term sustainability. For some, long-term sustainability was now an issue as they began to see the effects of organic matter depletion on water retention abilities and yields.

Prior to the market boom, the LIFT (Lower Inventories for Tomorrow) program was introduced in 1970. Seeded wheat acreage dropped by half as farmers were given incentives to take land out of production to help reduce grain stocks. After two years of cultivation without cropping, farmers noticed salinity problems, which may have triggered some to begin considering alternatives to summerfallow.

The 1970s were also a period when other parts of the agricultural system were being challenged. The lack of protein grading, for instance, was being raised, as was more generally the role of the Canadian Wheat Board (CWB) in grain marketing. While summerfallow fit well with the CWB's efforts to stabilize the world wheat price in the 1960s through very tight quota requirements, it did not fit well with a marketing environment in which there was a demand for increased grain production.

Farmers were demanding changes to the grain handling system – witness the formation of Weyburn Inland Terminal and the policy debate on grain transportation (the Hall Report). New groups were being organized – the Palliser Grain Growers and the Saskatchewan Soil Conservation Association, among others.

New crops were also coming on line, most importantly canola. The emergence of canola changed the crop rotation needs, which led to a further need to reconsider summerfallow; at a minimum, canola changed the economics of this long-established practice. The development of pulse crops further created a need for more complex rotations and provided nitrogen-producing crops that could support more intensive cultivation.

There also emerged a group of farmers and scientists that were prepared to, and indeed did, reconceptualize the role of summerfallow in the farming system. As early as the 1960s, farmers began to experiment with new tillage practices. A few scientists were in a position to examine these new practices and to rethink the problem facing Prairie agriculture. What emerged was a focus on organic matter (and the role that it played in water and nutrient availability), rather than a focus on moisture management.

On the technological front, Roundup was introduced (it was first marketed to farmers in 1973). The introduction of this herbicide was very important in being able to control weeds in rotation systems that did not involve summerfallow. Farmers and short-line machinery manufacturers were also coming up with new equipment that allowed for direct seeding into crop residue.

By the 1980s and the early 1990s all these forces had built upon and interacted with each other so that they created a new "status quo."

Looking back what is intriguing is that no one event or development was singularly responsible for the development and spread of zero-till. Instead, what was required was a set of forces that came together more or less at the same time. These forces were not just economic, although the economics were important; these forces involved new technologies, new ways of understanding and viewing the problem facing farmers, and a willingness to see outside the accepted paradigm. And these forces were assisted by the work of a great number of people – some of them farmers acting as entrepreneurs, some of them farmers working collectively to form new organizations that could push for change, some of them scientists who did the methodical research that substantiated claims made about higher yields and better economics, and some of them bureaucrats who supported funding for what was initially a fringe idea.

Lessons Learned

What can be learned from the conservation tillage story? First, a clear message is that the accepted wisdom can often be wrong and indeed quite wrong. Second, major innovations cannot be planned – they occur as a result of a constellation of factors and events that interact in powerful and complicated ways. Third, some of the conditions that are required for change may be set in motion decades before the change actually occurs – witness the formation of PFRA in 1935 and the role that it played some 30-40 years later. Fourth, governments, university researchers, agri-business companies and farmers all play critical roles in driving change.

These lessons are important as a new round of innovation is contemplated in the agri-food sector. It is now fairly well accepted that innovation has declined during the last decade or so, and that greater attention has to be paid to this activity. Part of the identified reason for this fall off is a lack of funding. However, simply restoring funding may not solve the problem, and even if it does, the impact may not be felt for 20 or 30 years.

To be effective, funding has to be in place over the long term and it has to encourage a wide variety of activities – everything from basic research to applied research to the creation of organizations within and outside government that have the mandate and the long-term financial ability to think about new and emerging issues. Also needed is an environment in which farmers can at fairly low cost create new collective organizations to deal with issues that they face. And universities need to place themselves in a position where they are able to both respond to new issues and to redefine old issues and mindsets.

The need to be in a position to rethink the way in which agricultural production is carried out is critical. Zero-tillage, like summerfallow before it, is now locked in, both technologically and cognitively; simply put, at some point in the future zero-till will be as hard to dislodge as summerfallow was to dislodge in the 1970s and 1980s.

The experience with conservation tillage provides some evidence of the immense challenge that will be required to generate further transformational changes when they are required. As the chapters in this book discuss, what is required are ways of offsetting the large fixed costs required to set up new technologies and new organizations, of altering many parts of the system at the same time so that they fit with the required changes, and of changing the expectations of the many players in the system about how the technology will develop. Key to all of these strategies is a change in the mindset that people have about how the world works.

Chapter 1

History of Early Western Canadian Agriculture – Setting the Stage for Conservation

***Fred Fulton*[*] *and Bernie Sonntag*[†]**

The 20th century problems in soil and crop management on the Canadian Great Plains can be traced to political and business decisions leading up to and following shortly after Confederation. The solutions to the problems have their origins in the actions of many visionary farmers, engineers and scientists; various public institutions and farmers' own organizations.

The British North America Act (BNA), an action taken by the British Parliament in 1867, was the legislative basis for the formation of Canada. It encompassed a vast area north of the United States, including four initial eastern provinces (Nova Scotia, New Brunswick. Quebec and Ontario), a small former British outpost (Vancouver) and a vast inland territory called the Northwest Territories (NWT) that was sparsely populated by aboriginal peoples and was part of the land area managed by the Hudson Bay Company for the preceding 250 years as the base for its fur trade business. The Hudson Bay Company had no interest in settlement or agriculture.

An important early legislative action by the Canadian government that had a major impact on subsequent land management practices was the Dominion Land Act. "…One hundred and sixty acres of land was offered by the Dominion Land Act of 1872, to each settler who paid a filing fee of $10.00 and who resided on the land for three years. The settler, during that time, was required to build a domicile

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and to break at least fifteen acres of his land…" This Act was modeled on earlier similar legislation in the United States and was the impetus for settlement of the American West (*The Homestead Act*, 1862). Subsequent assessment of that legislation attributes considerable environmental harm to that legislation – "it resulted in a preponderance of small farms whose poor practices led to erosion".

Other early legislative action by the Canadian government respecting agriculture was the Department of Agriculture Act in 1886 followed in the same year by the Experimental Farm Stations Act. These were the legislative platforms for subsequent actions to establish a network of Experimental Farms across the country. The initial mandate of these Stations was mainly agricultural technology extension – testing and dissemination of agricultural technology from elsewhere for its suitability for Canadian conditions. Research programs to develop "made in Canada" technologies were a later development step for the Experimental Farms and universities.

Agriculture was an important economic activity in eastern Canada long before the legislation mentioned above. It was focused on provisioning military garrisons, timber trade, fur trade and ocean fisheries. A small amount of grain was exported to England as early as 1802. Many of the farmers came from the United States at the time of the American Revolution, settling in southern Quebec and Ontario. The agricultural practices used were largely adopted from Europe where soil and climatic conditions were similar. Intensive culture based on annual plowing was a key feature of land management.

Consolidating the Nation

The BNA launched a new, large sparsely populated nation. Political leaders of the day considered it vital to link the nation from sea to sea via construction of a transcontinental railway. The Americans had already built railways across their western plains and settlers began occupying this area in response to their Homestead Act (1862). There was serious concern in Canada that the Canadian west might be absorbed into the United States as an outgrowth of settlement of the American west. A southern route for the CPR across the western plains was a deliberate response to this perceived or, perhaps, real threat.

The CPR received large tracts of land along the railway as partial compensation for constructing the railway. The CPR needed traffic to generate revenue, thus it needed settlers to buy the land and output to transport to ports for export. The clear intent of the southern route was to occupy the landscape near the US border despite the fact that it traversed a large land area not well suited to cultivated agriculture (The Palliser Triangle). A different route might have been selected had the government of the day accepted the Palliser and Hind recommendation rather than the more optimistic Macoun report on suitability of the area for cultivation.

The Canadian Pacific Railway reached Calgary in 1882. Thus, a transportation link had been established to transport settlers to the Canadian west and to ultimately transport their products to the UK – the beginning of the Wheat Economy.

Getting Ready for Settlers

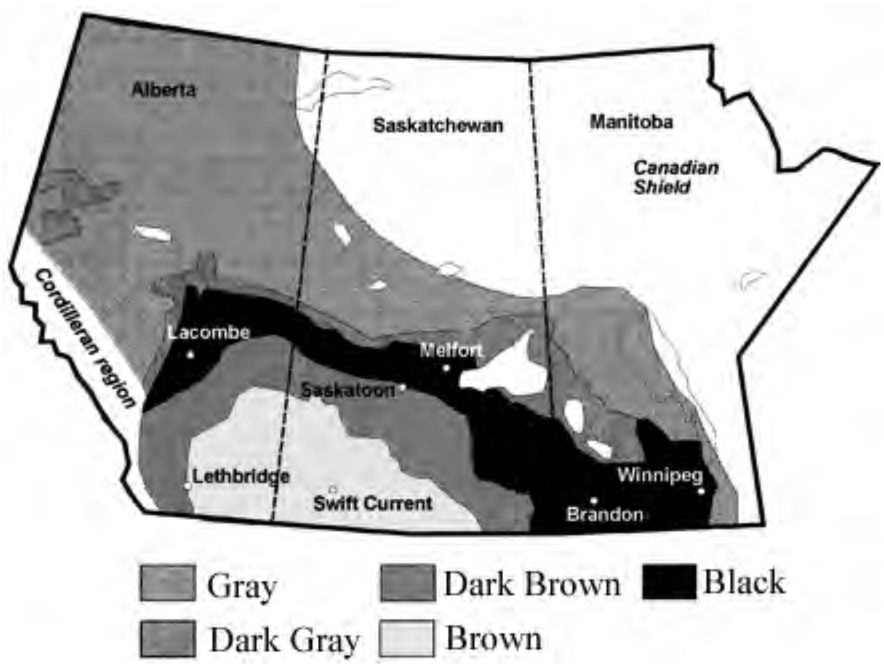
The national government commissioned surveys to assess the suitability of the Great Plains for settlement and cultivation agriculture. Two surveys were conducted in different years and came to different conclusions; an early indicator of the climatic variability of the region. The expedition of Palliser and Hind in 1857, a dry year, drew the conclusion that a large tract of land in what was then known as the Districts of Alberta and Assiniboia was unsuitable for anything but ranching. This area became known as the Palliser triangle – the light grey area in Figure 1.1. Another expedition sponsored by the Federal Government in 1879 and 1880 led by John Macoun occurred at a time when there was good rainfall and lush growth. He reported a rich resource ready to be settled and developed. The optimistic Macoun report was good news to the government and became the basis for a subsequent advertising campaign to attract settlers to the area. The Macoun assessment fit well with the decision to build the CPR along the southern route; a decision that resulted in massive land management problems a generation later and much suffering for the immigrant families who settled there with different expectations.

In the late 1800s and early 1900s many very large ranches were established in SW Saskatchewan with cattle from the US. A severe winter in 1906/07 killed a great many cattle and most of the large American ranchers returned to the US. At about the same time a wave of settlers looking for homesteads settled the same area and the land was broken up for crop production. Much of this area was later to become the centre of the "Dust Bowl" where soil drifting was most severe.

Following completion of the CPR in the 1880s a policy decision was made by the Government of Canada regarding its intent to occupy the Great Plains of western Canada. The main inhabitants at the time were nomadic native hunters. A series of treaties had been negotiated with the Saulteax, Assiniboine, Cree, Blood, Blackfoot, Stoney and Sarsi tribes. These treaties facilitated the wave of European settlement that followed.

The entire area depicted in Figure 1.1 had been surveyed some years earlier using a system similar to one used in the United States. The land was divided into 36-square mile blocks called townships (see Figure 1.2). Each square mile (section) was subdivided into four 160-acre quarter sections – the basic land unit for individual farms (homesteads). Prior to the arrival of settlers a considerable amount of land was allocated to the CPR as partial compensation for constructing the railway. The "CPR" sections were concentrated along the CPR main line (Winnipeg–Regina–Calgary). Some sections were allocated to the Hudson's Bay Co. as compensation for relinquishing its rights to the area draining into Hudson

Figure 1.1. Soil Zones of Western Canada



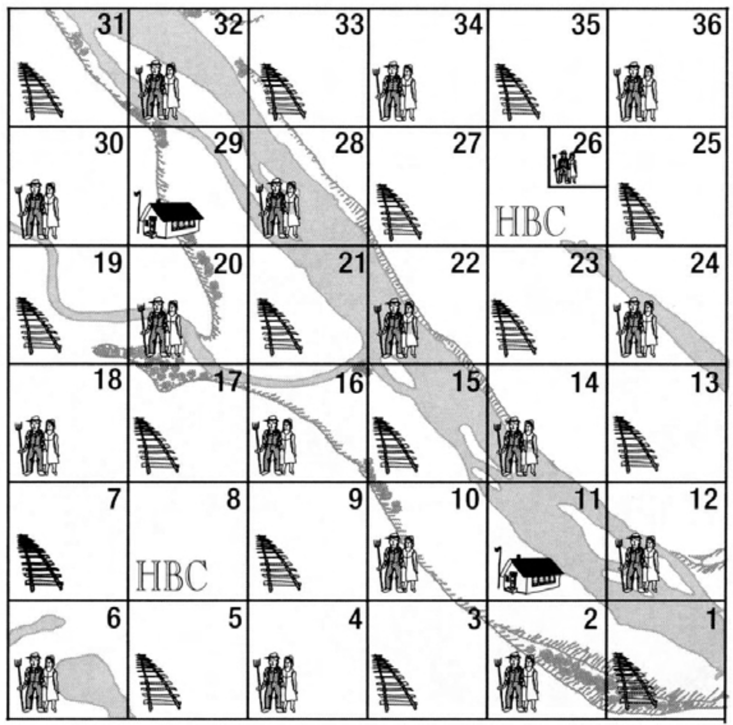
Source: Zentner et al.[1]

Bay – rights granted in the early 1600s by the British government and associated with the fur trade. The Hudson Bay "quarters" were sold to settlers. Two sections in each township were allocated as school lands to facilitate construction and financing of schools. Road allowances were incorporated into the survey to provide public road access to every quarter section. The land survey paid no heed to the suitability of the soils for cultivation, natural contours of the landscape or location and accessibility of water; the sources of some later soil management problems.

Settlement of the West

The government accepted the optimistic Macoun conclusion regarding suitability of the Great Plains for farming and proceeded with a plan to invite immigrants from Europe. The main incentive was 160 acres of "free" land at a specific location. The freedoms for citizens stated in the Canadian constitution were also instrumental in their emigration from Europe – freedoms that many did not have in their home

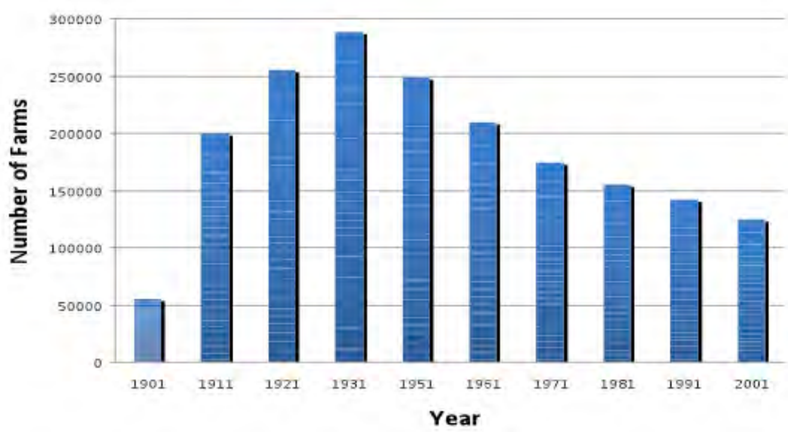
Figure 1.2. A Township Map Near the CPR Main Line Depicting Land Allocation Prior to Settlement



Source: Unknown.

countries. A massive promotional campaign (containing considerable exaggeration) attracted over two million settlers in a 20 year period (1895-1914). Many of the immigrants were the victims of ethnic, religious and economic depravation in their home countries. Most were poor, many were not farmers, most were poorly educated, a high proportion came from non-English speaking countries and all were unfamiliar with climatic conditions for agriculture in western Canada. Immigration from Europe and some from the United States continued at a much lower rate for another 20 years after the initial wave. The number of farms on the Great Plains reached about 290,000 by 1930 and began to decline thereafter; a trend that is still continuing (see Figure 1.3).

Figure 1.3. Number of Prairie Farms, 1901-2001



Source: Census of Agriculture, various years.

Agricultural Technology Extension

The first extension service available to settlers was the Experimental Farms – e.g., Indian Head and Brandon (1888), Lethbridge and Lacombe (1906), Rosthern (1909), Scott (1911), Swift Current (1921) and others later.[2] The initial services were very basic – serving the needs of "subsistence" farmers – food and draft animals, vegetables, cereals, forage, and shelterbelts. Agricultural colleges were established at the provincial universities during the early settlement period and augmented the extension efforts of the Experimental Farms. Adaptation of introduced technologies – breeds, varieties, production methods – was the main service. There was no time to develop new technology pertinent to the region since settlers were arriving at the same time that Experimental Farms were being established. Extension services were delivered in various ways – newspapers, technical newsletters and brochures, town hall meetings, personal contact, direct correspondence with individual farmers, field days at the Experimental Farms, demonstration sites, etc. Experimental farms produced trees for shelterbelts on farms, distributed hatching eggs for establishment of farm flocks, distributed vegetable seeds for home gardens, kept stallions and bulls for breeding services and other services to a pioneer industry.

Provincial governments were established in Manitoba in 1870 and in Saskatchewan and Alberta in 1905. Agricultural extension services were established in all three provinces, however, in Saskatchewan that service was managed for some years by the College of Agriculture, much like extension services at the land grant colleges in the US. Many of the early graduates of the Agricultural Colleges worked in agricultural extension. Thus, well-trained extension workers became an important component of publicly-funded support services to agriculture. A network of extension workers was established across the agricultural landscape to serve farming communities – crop and animal production technology, problem-solving, marketing advice, etc. This service played a pivotal role in the evolution from "subsistence" farms in the early settlement period to commercially competitive farms selling into international product markets.

Farming Practices

Early settlers practiced continuous cropping as was the general practice in their homelands. Stubble from the preceding crop was often burned in the spring before seeding. The land was fertile, thus crops grew well when there was enough rain.

In 1885, the Riel Rebellion was in progress at Batoche and a large armed force was sent to deal with the uprising. Horses were obtained from farmers in the Fort Qu'Appelle area. Much of the land didn't get seeded and lay fallow for a year. The next year was very dry. Crops on the previous year's crop land yielded only 2 or 3 bushels per acre while crops on the fallow land produced about 25 bushels per acre. This confirmed the practice that had been used in the US Midwest for a couple of decades and had been introduced by the settlers from the Midwest US. Angus Mackay, a participant in this event and soon to become superintendent of the Experimental Farm at Indian Head, became a strong proponent of this idea.

Summerfallow was to become the key to farming the dry western prairies. The practice of summerfallow, which made farming practical in the dry prairies, was the same practice that would later be the cause of severe wind and water erosion and depletion of organic matter. Coupled with the practice of summerfallow was harvesting with the binder and thresher that removed most of the plant residue from the field, piled it in large straw stacks that were later burned.

Settlers from the US mid-west introduced considerable machinery technology into Canada that became widely used across the Prairie region – moldboard plow, seed drill, disc harrow and other types of harrows.

Dust Mulch

Stories have been told of the American innovator who reasoned that moisture was lost from the soil by capillary action, which could be greatly reduced if the surface of the soil was in the form of dust mulch.[3] "Dustmulch" Campbell was brought to Alberta to lecture on the value of this technique. The practice claimed some success, but wind erosion soon became a serious problem. Interestingly this practice, in a modified form, was practiced every spring until very recently – it was called pre-seeding tillage.

Weed Control

In the early years weeds were not a big problem, but soon became one. Tillage was the only method available to control weeds, thus summerfallow was the main way to bring about this control. This meant working the soil several times during the summerfallow year. The generally accepted routine was to plow the field as soon as possible after the crop land was seeded and then worked, as needed, with the disc harrow and harrows. In later years many farmers used a duckfoot cultivator to do some of these tillage passes.

Equipment Complement of Early Settlers

Plow – This universal machine came in various sizes. It is the implement that “opened up the west”. The plow was used annually on most farms until the late 1930s.

Disc Harrows – This is another universal machine that was the basic follow up machine to the plow and the machine of choice to prepare the fields for seeding.

Harrows – This implement was used widely to break up the soil surface as well as level uneven fields.

Seed Drill – The seed drill was designed as single disc, double disc or hoe.

Power Source

Oxen and horses– These were the principal sources of power in the early years of settlement.

Large steam tractors– Widely used to break up the prairie sod, pulling several furrow plows and then used to power the threshing machines. The smaller tracts of land were broken with the plow and oxen or horses.

Innovations

Noble Blade – Frustration with the frequent dust storms in the Lethbridge area of southern Alberta, led to the invention of the Noble Blade. C.S. Noble, a farmer, and W.H. Fairfield, Superintendent of the Lethbridge Experimental Farm, were each awarded the Member of the British Empire in 1934 for this invention. The heavy subsurface blade cut off the weeds without burying the trash cover on the soil surface. It was the first significant invention to prevent the extreme soil drifting experienced in southern Alberta and south western Saskatchewan. Many of these machines were sold in several countries over the next few decades. They were however, not as successful in the more moist areas of the west because there was not sufficient soil disturbance to get good weed control.

One Way Disc Plow – This implement was invented by Charles Angell Sr., Plains, Kansas, in the 1920s and became a well-accepted replacement for the moldboard plow. It only partially buried the plant residue and had much lighter draft than the plow. Its use spread to the Canadian plains during the late 1930s and 1940s and was soon widely adopted.

One Way Disc Harrow – This innovation was developed in Saskatchewan in the 1940s, combining some of the features of the one way disc plow and the disc harrow. With the addition of a seeding mechanism, it soon became the tillage machine of choice for summerfallow and for seeding for many years. These machines did retain some of the plant residue on the soil surface while providing good weed control.

Deep Tillage or Heavy Duty Cultivator – The Graham-Hoeme Chisel Plow was developed by Fred Hoeme, an Oklahoma farmer, in the mid 1930s to combat the terrible soil drifting problems of the US plains by ripping up the soil, bringing lumps to the surface and making deep ridges. This was the forerunner of the deep tillage cultivators that were introduced in the late 1940s and became widely used in Western Canada over the next few decades. These cultivators did much to reduce the major wind erosion problems of the 1930s. The development and addition of air seeding technology to these cultivators was a later step toward where we are today.

Summerfallowing with various types of machines

It is important to make some distinction between the summerfallow made with the plow and that made with the newer machines. The Noble Blade left a surface well protected against wind erosion. The one-way disc harrow left a less protected surface with the level of protection depending on the frequency of operations and operating speed. The faster they were operated the more trash was buried and the greater the soil was pulverized. The soil condition after the deep tillage cultivator depended on a number of factors. The type of shovels being used made a great difference. Low profile shovels gave very little soil disturbance and buried very little trash but gave poorer weed kill. Conversely, higher profile shovels, particularly if operated at higher speeds, buried much more trash and left the field with more prominent ridges. To combat the ridging and often to get a better weed kill, harrows were attached which resulted in more soil pulverization.

The newer methods of summerfallowing, while reducing the potential for wind erosion, did not control water erosion, particularly in rolling land. Filling in water runs after the spring runoff or a heavy rain was a standard procedure.

Government Action

Government actions and policies that were designed to settle the west and reap the rewards were responsible for setting the stage for later problems with soil degradation. Governments did little to remedy the situation until the devastating dust storms of the 1930s, when soil drifting became a national disaster. The first concrete action came in 1935 with the creation of the Prairie Farm Rehabilitation Administration (PFRA), which was set up to arrest soil drifting and promote water conservation in the drought stricken short grass areas. Illustration Stations managed by Experimental Farms staff were funded through the PFRA budget. At one point there were over 240 of these Illustration Stations spread across the prairies. These were located on private farms and served as a readily accessible source of information and technology demonstrations. PFRA staff also cooperated directly with Experimental Farm staff in experimental work directed at new technology for soil erosion control. Some of the most severely eroded areas were seeded to grass and transformed into Community Pastures managed by PFRA. Strip farming was promoted as a means of controlling the drifting problem.

Gray noted that "it was only with the questioning of the scientific basis of summerfallowing …that the first scientific steps could be taken toward the solution of the problem of wind erosion.[4] It was not only the absence of fundamental information which handicapped our Experimental Farm researchers. They had to clear away a lot of unscientific debris before they could even get started." Gray further noted that "the abandonment of the dust mulch theory was symptomatic of the whole process that began with Swift Current – the process of unlearning and forgetting most of the practices which the farmers had been taught to follow over the generations".

Another significant Government action came five decades later in 1984 when Senator Herb Sparrow from Saskatchewan led a major Senate committee study of the issue of Soil Conservation and produced the report "Soils at Risk". This report led to the formation in 1987 of the Soil Conservation Council of Canada, with Senator Sparrow as the first president. The Saskatchewan Soil Conservation Association was formed that same year and similar associations in Alberta and Manitoba followed soon thereafter.

Soil Scientists

Janzen provides an excellent review of the work of soil scientists in Western Canada in the period from the 1880s to the 1920s.[5] Their soil testing confirmed the richness of the centuries old prairie soils. They tracked the reduction of organic matter and available nitrogen following cultivation. They sent out warning signals that a fallow-wheat cropping system was not sustainable. Various crop rotation experiments were conducted with the inclusion of legumes and grasses. While these rotations met some of the objectives of maintaining soil quality, they by and large failed in the practical reality of a very rapidly expanding farm population, and an urgent demand for wheat for the export market. Zero-till and direct seeding were among the practices tried, but in the absence of appropriate equipment and any incentive to pursue these practices, they were not adopted. After several attempts to warn of the dangers of these farming practices, with few tangible results, they became fairly silent. The energy required to change a well-established status-quo was too great. Even in the 1970s, stalwarts like Dr. Don Rennie, University of Saskatchewan, met resistance from farmers when suggesting that cultivated summerfallow was at the root of their land management problems.

The People – The Farmers

Who were these people? It is hard to imagine putting together a more diverse collection of people. The promise of a new life, with virtually free land, captured the imagination of throngs of people. Some came from the US mid west and brought some dry land farming experience. Those who came from eastern Canada, the British Isles and Europe were unprepared for the conditions they would encounter. The Europeans also had a language barrier. This collection of people was thrust into circumstances for which there was no manual of instruction. Nobody had done it before. For the first few years after they settled, survival was the most immediate need. Farming methods would be developed from a combination of what they knew from other places, what they saw work or not work for their neighbour, what information they could obtain from the Experimental Farms, what various salesmen would tell them, what they were equipped to do with the limited resources they had, and their own ingenuity. The history of settlement of the west is an impressive story of tenacity and durability. During the past few years many of these farms have been honoured for being in the same family for 100 years – a remarkable achievement.

Politicians and bureaucrats played major roles in determining who was welcome as a settler. As Berton describes, the ideal immigrant in 1896 "was a white Anglo-Celt with farming experience, preferably English or Scottish".[4] Despite massive promotional efforts, few came – they were well off in their homeland. The rationale for bringing in peasants from northern and eastern Europe was that their expectations, based on their homeland experience, would be conservative. Three years later, Sifton, Minister of the Interior, turned his attention to the American Mid-west. The accompanying campaign attracted over 200,000 Americans to Canada by 1912 despite a vigorous anti-Canadian campaign in some states – most took up homesteads in Saskatchewan and Alberta. The American settlers subsequently made important contributions to agricultural development since many had prior farming experience in similar environments and brought with them considerable technology that proved useful in Canada during the settlement years. American Blacks, however, were not welcome and their migration to Canada was actively discouraged – thousands applied, but only about 1500 were admitted.

Voluntary, self-help associations played a pivotal role in the initial survival and ultimate success of many Great Plains farmers. Many communities were settled as fairly distinct ethnic/religious communities (Ukrainian/Orthodox, German/Lutheran, etc.). The pastor was often the best educated person in the community and played a leadership role in community development (community hall, schools, road construction, etc.) These voluntary community associations became the building blocks for more formal broader farmer associations, credit unions, co-op stores, commodity-specific organizations and the like that contributed immeasurably to the transition from subsistence in the settlement years to the commercial, internationally competitive and environmentally responsible rural economy of today.

Summary

A number of factors, some based on politics and bureaucracy and others rooted in ignorance or wild expectations, resulted in an agricultural sector in the Canadian prairies that was not initially sustainable in social, economic or environmental terms.

1. A political decision to route the CPR across the heart of the Palliser Triangle and subsequently encourage immigration and settlement of a vast area deemed unsuitable for cultivation by the government's own consultants.
2. The implementation of a land survey method and land allocation process that paid no attention to extreme variations in the land's capability for sustaining the livelihoods of immigrant settlers.
3. Invitations to settlers from many countries who had little or no farming experience, farming experience in vastly different soil-climatic regions, little formal education and spoke different languages.
4. Exaggerated claims in countries of origin of prospective migrants about the prospects for economic prosperity on the Canadian plains.
5. A rudimentary set of experimental farms to test, develop and disseminate technologies suitable for implementation across the prairie landscape.
6. No functional technology extension system to adequately service farmer needs in the early settlement years.
7. Limited access to essential equipment and draft animals for establishment and operation of farming operations.
8. An initial focus on production of wheat for export to the UK in the absence of adequate transportation, storage and marketing services to ensure equitable returns to producers.

Despite these hardships, some due to the natural conditions of the prairie landscape and others due to political and administrative shortcomings, progress towards a more sustainable prairie agricultural economy occurred through actions of many players:

1. Massive expansion of the railway network and roads to facilitate immigration and settlement of the entire prairie region and servicing of it to enable acquisition of needed inputs and transport products to markets. These infrastructure improvements were complemented by product grading systems, marketing rules and other institutional innovations to ensure equitable returns to prairie farmers.
2. Establishment of services to settlers for education of their children, access to health care and the like.
3. Federal government investment in a much expanded network of experimental farms. The establishment of agricultural colleges at provincial universities complemented the work at experimental farms.
4. The creation of PFRA in 1935 brought new resources to supplement the efforts of the experimental farms through a) a widely distributed set of Illustration Stations throughout the prairie region and b) enhanced on site research capability at several experimental farms
5. PFRA reclaimed large areas of severely eroded lands and converted them into community pastures – many private initiatives duplicated this approach to more sustainable land use. PFRA was also instrumental in alleviating water supply problems on individual farms (dugouts for runoff capture for household use and livestock) and development of irrigation projects.
6. Establishment of agricultural extension capacity at university colleges of agriculture and in provincial departments of agriculture to service information needs of farmers.
7. Early self-help community groups initially focused on own-community needs gradually became the building blocks for a vast array of organizations aimed at efficient access to various needs – farm inputs, market information, technology development, financial services, etc.
8. Diversification of agricultural production systems in response to market opportunities and to reflect comparative advantage of unique Canadian resource endowments and farmer skill sets.

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Chapter 2

Policy and Program Response to Land Management Issues

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Overview

The major policies and programs that influenced soil conservation activity on the Canadian Prairies and eventually led to the universal adoption of conservation tillage and direct seeding are identified and discussed in this chapter. Generally the policy focus was on the broader issue of soil conservation. The programs contained the elements which more directly focused on conservation tillage and direct seeding. Both will be discussed within the timeframe of the last eight decades.

From an economic policy perspective, it was not a case of domestic policy dictating minimum till or direct seeding, but rather policy that impacted the bottom line on farm operations and indirectly causing change in on-farm production systems. In contrast, domestic environmental policy was more direct and thus more identifiable. Environmental policy clearly targeted soil conservation, signifying government attention and funding that was typically correlated with significant drought events. Economic policies drove practice change, while awareness was created by environmental policy with significant climatic events as the catalysts. The policy chronology continuously expanded where the programming efforts occurred on the ground. Program design was certainly important, but implementation factors such as government resource levels, existence of partnerships, credibility

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and persistence of extension staff or other programs were critical to the overall success of technology adoption.

Birth of PFRA

The origins of the soil conservation debate in Western Canada can be traced back to 1857 when Captain John Palliser was requested to report upon the geology of the region and the nature of its soil, its capacity for agriculture, the quantity and quality of its timber and any indications of coal or other minerals. Most notably, in terms of soils and agriculture, he defined the Palliser Triangle as a desert. Palliser's observations were quite different to those of John Macoun, who in 1882 concluded in his book "Manitoba and the Great North West", that the area was favourable for agriculture but noted a scarcity of water. Seemingly these different assessments were, inadvertently, the first indicators of drought cycles on the Canadian prairies.

Within the context of the more positive Macoun assessment, the government of John A. MacDonald pursued a settlement policy in the late 1800s which set in motion an annual cropping agriculture (a wheat monoculture) based on European agronomy. In reality, this became the underpinning of soil conservation efforts for the next century. Annual cropping agriculture rapidly transformed the landscape. In 1934, after eight years of falling grain prices, unrelenting drought, severe wind erosion, and the resulting wide scale abandonment of farms, the Bennett Government set up a committee to study the situation and make recommendations. This led to a critical policy step when Royal Assent was given to the *Prairie Farm Rehabilitation Act* on April 17, 1935. The Act covered a 4 to 5 year period and had an initial appropriation of approximately five million dollars. By 1937, the need for a permanent organization had become apparent and the PFRA legislation was extended.

The summer of 1937 saw the most severe drought in the history of the west and resulted in the policy decision that the most erosion-prone lands could only be stabilized and protected with permanent cover. Beginning in 1938, large tracts of eroded or abandoned land were directly seeded with crested wheatgrass to convert these erodible lands to livestock production under what has become known as the Community Pasture Program (CPP).

By 1939, even though it was believed that the menace of soil drifting was largely under control, PFRA's financial appropriations were increased, and the five-year limitation in the Act was removed. In the early years, PFRA was little more than an extension of the Experimental Farm system. In fact, the two worked hand in hand. L.B. Thomson was named Superintendent of the Swift Current Experimental Farm in 1935 and in 1948 he assumed the role of PFRA's second Director General, a position he held until his death in 1956. L.B. Thomson could ignite enthusiasm in farm audiences and instil them with hope and confidence that their livelihood could be saved. He believed in taking the fruits of modern science to the farms and showing the farmers how to use them; an approach the PFRA perfected.

Policy, programs and other drivers

Coupled with policy decisions to establish institutions to deal with soil conservation were other market factors which in turn guided producers to new production systems that incorporated minimum tillage and direct seeding. The energy crisis of the 1970s was a motivation to use less energy and it led to concerns over declining natural resources such as soil degradation. Farmers began to look seriously at ways of reducing fuel use and adopting conservation measures. In 1974, Monsanto introduced the broad spectrum herbicide Roundup (glyphosate) that controlled a wide range of weeds. Farmers were able to substitute herbicides for one or two tillage passes, thus reducing both wind and water erosion while also reducing fuel costs. The price of Roundup started to decline in the 1990s as the patent expiry date approached in 2000. This was one of the factors that led to the increased adoption of direct seeding. The role that glyphosate and other herbicides have played in the adoption of soil conservation practices is best described as one of facilitation, rather than specifically leading or following the trend of soil conservation. However, Monsanto did actively promote the agronomic and economic benefits of zero and minimum tillage systems and the role that Roundup played in those systems in the late 1990s.

In the late 1970s and early 1980s farms were specializing as well as increasing in size. The larger fields and intensive tillage was contributing to increased soil degradation. The larger farms pursued ways of reducing the amount of labor required for conventional tillage systems and some started looking at one pass or direct seeding systems. However, many of the early attempts were unsuccessful due to inadequate seeding equipment, methods for handling crop residues, and fertilizer placement. Many of the early adopters of this period became leaders in modifying seeding equipment and promoting the adoption of direct seeding in the 1990s.

There are some tenuous and indirect links between the Canadian Wheat Board's (CWB) marketing decisions and the adoption of soil conservation practices in western Canada as well. Some suggest that if the CWB had increased efforts in marketing winter wheat it is likely there would be more acres grown with its superior conservation benefits. Some would also argue that the CWB's delivery quota system and the way summerfallow acreage was handled throughout the time period in question retarded the adoption of continuous cropping. Another discussion revolved around pulse crops and the CWB's influence on allocation of system capacity. In conclusion, however, CWB policy was mostly reactive and it is hard to establish conclusively that CWB policies were as influential as many suggest.

The realization that change was necessary, agronomically as well as economically, resulted in continued institutional developments. With the recurring droughts of 1977, 1980 and 1981, PFRA began to revitalize its historic soil conservation role with the establishment of a long term, holistic planning and policy approach for soil and water conservation under the leadership of Dr. Harry Hill. After a period within the Department of Regional Economic Expansion, in 1982 PFRA returned to the Department of Agriculture and in 1983 published the ground breaking report entitled, "Land Degradation and Soil Conservation Issues on the Canadian Prairies". Wind and water erosion, salinity and declining organic matter were identified as the major soil degradation issues. The report concluded that the farming practices of bare fallow and intensive tillage on the prairies led to inefficient use of soil moisture and increased soil erosion, organic matter decline and increased salinity. PFRA recommended that the most effective methods of conserving soil moisture for crop use was through snow management, trash cover, minimum or zero tillage systems and reduction in summerfallow.

In 1984 the Honourable H.O. Sparrow chaired the Senate Standing Committee on Agriculture, Fisheries and Forestry which examined the issue of soil degradation. The recommendations in the report, "Soil at Risk - Canada's Eroding Future" brought the issues of soil degradation and conservation before the general public. The report made 20 recommendations, including; "That a comprehensive federal soil and water conservation policy for Canada be developed and adopted immediately." The report also identified the need to provide technical assistance and financial incentives to farmers, through federal-provincial agreements, to defray the costs of conservation practices. The Sparrow report in conjunction with soil science research, the PFRA report, and other reports (Science Council of Canada) resulted in soil conservation funding under the Economic Regional Development Agreements (ERDA) with the provinces.

PFRA Soil Conservationists implemented the ERDA funding through local conservation groups to enable farmers to try new practices on a single field. Despite relatively low adoption up to that point conservation tillage quickly became the most popular practice, particularly conservation fallow. The price of Roundup was too high for wide scale adoption over the entire farm, but the ERDA funds gave farmers the opportunity to gain experience and knowledge with this practice by using it on one or two fields each year. At the same time obstacles which constrained low disturbance direct seeding were addressed, such as the inability of seeding equipment to clear crop residue and accurately place seed and fertilizer. While the first machines tried by farmers under ERDA were heavy with high draft requirements, these demonstrations helped lay the foundation for developing improved no-till seeding technology.

During the four field seasons under ERDA (1985 to 1988) the number of groups and producers receiving incentives steadily increased and built momentum for the next round of programming. The soil conservation accords and agreements in 1989 resulted in the National Soil Conservation Program (NSCP) that funded practices similar to those under ERDA, but the delivery model changed slightly. Resources were provided for delivery groups to hire a technician to deliver the program at the local level. PFRA Soil Conservationists were responsible for managing the funds for a number of groups within larger regions in each province. As with ERDA, conservation tillage was the most popular practice under NSCP. Conservation fallow was still dominant, but beginning in 1990 the number of low disturbance seeding projects increased as new air seeders and air drills became available.

PFRA allocated a portion of these funding programs to support provincial and national producer groups. These included the Soil Conservation Council of Canada (SCCC), Saskatchewan Soil Conservation Association (SSCA), Manitoba-North Dakota Zero Tillage Farmers Association (ManDak), Alberta Conservation Tillage Society (ACTS), Reduced Tillage Linkages (RTL), the Eastern Canada Soil and Water Conservation Centre (ECSWCC), and others. In the Prairies the groups conducted awareness, extension, and demonstration projects for conservation tillage through workshops and field days; some with attendance of over 1000 in the mid 1990s.

Agri-environmental programs driving adoption

As the conservation tillage revolution gained momentum, there was increasing awareness of broader environmental issues linked to agriculture, such as water quality, greenhouse gases (GHG), and biodiversity. Recognition of broader agri-environmental issues was reflected in subsequent programming; Green Plan, National Soil and Water Conservation Program (NSWCP), Agri-Food Innovation Fund (AFIF) in Saskatchewan, Canadian Adaptation and Rural Development (CARD) fund, and the Greenhouse Gas Mitigation Program (GHGMP). In general, the programs that followed Green Plan did not provide money for direct producer incentives, but did support conservation tillage through specific applied research projects, watershed based initiatives, or support to provincial or national producer groups.

Under the Agriculture Policy Framework (2004 to 2008), the concept of Environmental Farm Planning (EFP) resulted in a new approach. Integral with EFP was the establishment of the National Farm Stewardship Program (NFSP) whereby producers could receive cost-share funding to implement Beneficial Management Practices (BMPs) such as conservation tillage through equipment modifications or enhancements.

In addition to program funding, PFRA also conducted a number of studies to better understand issues associated with conservation tillage adoption. For example, through a multi-year Saskatchewan wide survey in the mid 1990s, PFRA was able to provide evidence for the accuracy and credibility of the tillage data in the Agriculture Census, which is used in many situations for policy and program analysis and development, such as the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) and the National Soil Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS) developed by scientists from the Research Branch of AAFC. In 2005, PFRA conducted an extensive series of meetings with no-till producers to identify constraints and potential opportunities for further conservation tillage adoption across Canada. One of the key findings is that no-till may not be adaptable to some specialized cropping systems or regions and that even successful no-till producers require flexibility for periodic, discretionary tillage. One example is the need to use tillage to repair wheel ruts resulting from poor trafficability under wet soil conditions.

Benefits of adoption

The widespread adoption of conservation tillage is indisputable. This adoption is the result of various policy/program initiatives, technological developments, and economic/social forces influencing this trend simultaneously. Conservation tillage is closely linked with a number of other beneficial crop and soil management practices such as diverse crop rotations, reduced fallow, and more effective weed, nutrient, moisture and crop residue management. A number of specific economic benefits for producers associated with conservation tillage include reduced labor, reduced energy consumption, improved crop yields, improved soil productivity, and higher fertilizer efficiency. Environmental benefits associated with conservation tillage include reduced soil erosion, reduced GHG emissions through increased soil organic matter, and in some cases increased biodiversity and improved water quality.

Overall adoption trends of conservation tillage and some other closely associated practices demonstrate:

- The rate of no-till seeding has increased dramatically from < 15% in all eco-zones in 1991, to 61% in the brown and dark brown soil zones of the prairies, about 45% for black soils, 40% for gray soils, and 26% in the mixed wood plains (southern Ontario /Quebec) as of 2006.
- Similarly, the use of chemical fallow has increased from <5% to 13, 24, 41, and 52% in the gray, black, dark brown, and brown soil zones, respectively, over the same time period.
- The practice of reduced till, which is a transition between conventional tillage and no-till, has remained fairly constant around 30% since 1991.
- The amount of land in fallow has been declining since 1971, but the largest decline in the brown and dark brown soil zones occurred after 1991 when no-till seeding began to increase.

- The increased adoption of conservation tillage on the prairies has been accompanied by increased crop diversification with oilseeds and pulses. While increased crop diversification began before conservation tillage, diversification after 1991 has been more pronounced with pulses on brown and dark brown soils, and oilseeds on dark brown soils.

In summary, there was about a six year lag between when conservation tillage programming began to directly impact producers (1985) and when adoption began increasing dramatically (1991). By this time there was more 25 years of scientific research from several prairie Research Centres and universities documenting the soils, agronomic and economic benefits of conservation tillage systems.

Environmental research focus

Much has been accomplished already but there is much more to do. Initial research on conservation tillage focused on soil and water conservation benefits but in the past fifteen years the emphasis has focused on greenhouse gas (GHG) reductions and capture through soil carbon sequestration. AAFC, including PFRA, has been involved in a number of initiatives related to development of carbon credits for offset markets from conservation tillage. However, considerable challenges still remain in the development of a nationally recognized carbon credit and trading system for conservation tillage and other beneficial agricultural practices.

Environmental Goods and Services (EG&S) has received considerable attention as a potential future policy and programming instrument, and conservation tillage has been included with a number of other BMPs as possible candidates for inclusion. There are considerable similarities in the policy debate between EG&S and carbon credits, with both having some common challenges.

The Watershed Evaluation of Beneficial Management Practices (WEBs) project was designed to help isolate the environmental and economic benefits of conservation practices like reduced tillage, which decreases soil erosion losses and aids in specific improvements to water quality. WEBs also seeks to better understand the private/public costs of implementing conservation practices and the environmental tradeoffs (e.g. increased soluble phosphorus runoff from zero tilled fields) that might occur. WEBs is geared to better understand the landscape factors that drive BMP performance overall, such that future BMPs can be more prescriptive, as new conservation challenges emerge.

Despite the rapid and high adoption rate of conservation tillage, a recent study by PFRA identified a number of constraints that may prevent adoption in some regions and specific cropping systems. Researchers, program technicians and policy makers need to watch for opportunities to address these ongoing constraints and at the same time recognize producer needs for flexibility and adaptation as they manage conservation tillage systems in an ever changing environment.

Closing Comments

Are yesterday's institutions up for the challenge? After 73 years of working with Canadian producers, PFRA began the process of evolving into a new Branch of AAFC in January 2008. The PFRA & Environment Branch is an amalgamation of PFRA, the National Land and Water Information Service (NLWIS), the Agri-Environmental Policy Bureau, and the land resource specialists from Research Branch. This reorganization has transformed the original prairie focused PFRA into a national Branch within AAFC. How this will change the culture of PFRA and provide for future contributions to soil conservation efforts within the agriculture sector in the decades ahead can best be described as a work in progress.

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Chapter 3

Foundations for Growth - The Role of Researchers and AAFC Research Stations

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Overview

Researchers and the Agriculture and Agri-Food Canada (AAFC) Research Stations have played an essential role in developing and spreading low-disturbance direct seeding technology (LDDS) on the Canadian prairies. One key role was to conduct the initial trials of new conservation tillage and direct seeding technologies before they were economically viable practices. The researchers also worked directly with the innovative farmers in early conservation tillage developments and provided encouragement, advice, supporting measurements, and, sometimes, material assistance to these farmers. The researchers stepped outside of research and played a valuable role in extension of LDDS principles and practices to early technology adopters within the farming community. Researchers also played a pivotal role in geographical spread of promising technologies throughout the prairies by leapfrogging technologies across the network of Research Stations and on the land of cooperating farmers. The researchers and Research Centres were very successful in refining technologies because they were uniquely able to effectively compare a wide range of variants and make measurements to determine the underlying principles and identify superior practices. Also, the researchers were able to involve a range of scientific disciplines into LDDS issues so that a systems-approach to agro-

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nomic management within LDDS was developed. The researchers also provided hard data on the benefits of direct seeding that undoubtedly strengthened the conviction of farmers, governments and industry that direct seeding was a necessary transformation. Perhaps all the above roles may be viewed as planned results of establishing and maintaining a network of skilled agricultural researchers across the prairies. One role that was certainly not planned, but which was both important and fortuitous, was that many of researchers were dedicated advocates and visionaries of direct seeding who worked selflessly to improve, promote and extend adoption of LDDS.

The Research Establishment

The Canadian government passed the *Experimental Farm Stations Act* in 1886. This Act was in part the result of agriculture sector lobbying and favourable response to what we would now call a stakeholder focus group. This Act established five Stations including two on the Canadian prairies – Indian Head and Brandon (the others at Ottawa, ON, Nepean, NS, and Agassiz, BC). These were joined by other experimental stations on the prairies – Lethbridge in 1906, Lacombe in 1907, Fort Vermillion in 1907, Rosthern in 1909 (closed in 1940), and, in 1911, Scott, Melfort, and Saskatoon. These were joined by Experimental Stations at Morden and Beaverlodge in 1915, and Swift Current in 1920. The Winnipeg Research Station was added in 1925 to focus on cereal rust. To address wind erosion and weed control issues, the last Experiment Station was opened at Regina in 1931. From the 1920s into the late 1950s, the Experiment Stations also managed substations and illustration stations to both test and extend field technologies beyond the Stations' sites. These did not have staff or permanent facilities but were joint efforts between the main Experiment Stations and cooperating farmers.

The Manitoba Agricultural College was established in Winnipeg in 1906 and became part of the University of Manitoba in 1924. The Agriculture program at University of Saskatchewan was started in 1912 while that at the University of Alberta started in 1915.

Thus, between universities and the now AAFC Research Centres and Farms, there was a well distributed network of researchers and facilities dedicated to improving farming practices.

Setting the stage – trash cover farming during the 1930s and 1940s

Major soil drifting was observed in the 1917 to 1920 period over much of the prairies[1] including on the experimental stations themselves (OHH). A.E. Palmer of Lethbridge Station worked as early as 1920 with farmers in the Monarch area to control soil drifting. This included strip cropping and use of the "Noble blade" (wide blade cultivator) initially developed by innovative farmer C.S. Noble with helpful suggestions from researchers at Lethbridge and Swift Current Stations.[2] Close cooperation between innovative farmers and researchers at the Research Stations has been and continues to be an important reason for the successful development of better conservation tillage systems. In fact, the collaboration was fundamental for wind erosion research since erosion could not be well studied in small plots.[2]

The need to retain crop residues on the soil surface to control soil drifting was obvious during the dust bowl years of the 1930s. Palmer was instrumental in developing and promoting minimum tillage methods that left sufficient residue at the surface. Interestingly, the original term for this practice of stubble mulch farming was not accepted by prairie farmers because it suggested a degree of neatness that was not the reality. At a field day a farmer suggested the term trash cover to Palmer who adopted it enthusiastically and henceforth was often called “trash cover Palmer”.[2] This need for appropriate terminology that does not bother the farmer adopters foretold later debates over the terms no-tillage and zero tillage versus the less prescriptive direct seeding.

Much to the displeasure of AAFC in Ottawa, Palmer moved beyond his research duties into active technology transfer to farmers. He was instrumental in developing a manual aimed at farmers on soil drifting control. He was also a strident advocate for trash cover farming to AAFC managers – another role that was not well received in Ottawa. However because of the magnitude of the soil drifting crisis at the time, he was able to keep his position. In many ways, Palmer became the archetype for future researchers in direct seeding in terms of conviction, work ethic, the fostering of collaborative research that involved several researchers and innovative farmers, combined with an important component of extension activities to the farming community.

Other researchers at the time also played important roles in furthering trash cover farming including W.S. Chepil, S. Barnes, J. Taggart and L.B. Thomson of Swift Current Station.[2] Taggart and Thomson were particularly instrumental in gaining broader government support.

One important development of the period was the one-way discer seeder. Many variants of this machine concept were developed by farmers during the 1930s and 1940s. R.A. Johnson, a Saskatchewan farmer, is credited with coming up with the most effective design in the early 1940s and this design was soon produced by many machinery companies including Cockshutt.[2] The discer seeder gave the prairie farmer and researcher a practical direct seeding capability, albeit with complete disturbance of the soil surface and much burying of residue.

Another role for researchers was to provide the scientific rationale for the need to change farming systems. By the early 20th Century, researchers were already aware that prairie soils were being degraded in terms of organic matter and that contemporary farming practices were not sustainable from a soil perspective.[3] The scientific basis of how tillage increased soil erosion was also developed.[4,5,6]

No-tillage – the initial trials from the 1950s to 1975

In 1943, *The Plowman's Folly* by Edward H. Fowler was published. It makes a persuasive argument for abolition of the plow and stated "no one has ever advanced a scientific reason for plowing". Several researchers on the prairies took up this challenge to develop no-tillage.

With the development of herbicides after World War II, there was immediate interest in using them to replace tillage for weed control. Early experiments into chemical seedbed preparation were done in the 1950s in Europe and the USA. By the 1960s there were a number of farmers, mostly in the eastern US, using no-tillage and the first commercial no-till drill was introduced by Allis-Chalmers in 1967.

Given the prevalence of fallow on the prairies and its undeniable role is causing excessive soil erosion, it is not surprising that the major effort for eliminating tillage in the prairies was directed at summerfallow. In 1956 a suite of experiments on various combinations of tillage and herbicides for summerfallow, including summerfallow without any tillage (chemical fallow), were conducted at Indian Head, Lacombe, Regina, and Swift Current. This early research was summarized by C.H. Anderson in a 1964 annual report to AAFC. The conclusion was that the herbicides available at the time provided inadequate control of weeds in some years so, although tillage could be reduced, tillage could not be totally eliminated on summerfallow The first herbicide for broad-spectrum weed control, paraquat, was registered in 1962 and brought much new research interest on chemical fallow. With paraquat, satisfactory control of weeds for summerfallow became practical[7,8] although combinations of tillage and herbicides were most profitable.[9]

Use of the discer seeder had shown that high disturbance direct seeding produced as good as or better crop yields than methods using fall and/or spring tillage.[10,11] Research into low-disturbance direct seeding (LDDS) was underway in the 1960s. Anderson reported that direct seeding with hoe- and double-disk press drills provided yields equal to those with pre-seeding tillage at Swift Current.[12] Other researchers who were doing low-disturbance direct seeding at this time included Wayne Lindwall at Lethbridge and Ken Bowren at Melfort. University researchers included Elmer Stobbe at the University of Manitoba and Brian Fowler at the University of Saskatchewan. Dr. Fowler's interest was to improve production of winter cereals by leaving standing stubble after seeding to trap winter snow. LDDS became essential to expanding winter wheat production outside of southern Alberta.

These early investigation of no-till were more feasible for Research Stations than for farmers. In Anderson's description of one major no-tillage experiment:

"Economics was not considered: we wished only to ascertain whether cultivation had any beneficial effect other than for weed control".

Laying the foundation for growth – 1976 to 1990

From 1976 onward, LDDS evolved from an experiment into a successful farming system for the Canadian prairies. Although in 1976 there were few farmers using direct seeding consistently, the number grew dramatically over the period.

Importantly, glyphosate was registered for general broad spectrum weed control in 1976, It provided better weed control than paraquat, particularly for broadleaf weeds. Glyphosate could also be tank mixed with 2,4-D or dicamba that further improved broadleaf weed control. Although initially expensive, glyphosate was and remains an important weed-control tool for LDDS.

Seed drills for LDDS available from the US were too expensive and not entirely appropriate for the large, relatively low yielding farms of the Canadian prairies. Seed drills adapted from existing machines designed for tilled conditions were not fully satisfactory for LDDS conditions. Although limitations in seeding machines for LDDS were seen as a critical problem for widespread adoption of LDDS, the public researcher community played a less critical role with machinery development than for other components of LDDS. A major reason was that there were relatively few engineers employed as researchers and those engineers, such as Sylvio Tessier (AAFC Swift Current) and Wayne Lindwall (AAFC Lethbridge), were more involved in agronomic aspects of LDDS than machine design itself. An exception was Ben Dyck (AAFC Swift Current) who did considerable work on direct seeding machinery[13,14], but also devoted much of his efforts to agronomic investigations.[15,16,17,18,19]

One reason why researchers did not play as large a role in machine development as in other areas was that many farmers had the skill, facilities, and eagerness to undertake their own machinery modification and design. Air delivery of seed and fertilizer became widely available with the Prasco air seeder in the mid 1970s. When mated with a cultivator, the combination became a relatively low-cost seeding machine capable of high-disturbance direct seeding. These open frame cultivator-based seeders were both rugged and relatively easy to modify. Some farmer-designed seeding machines loosely based on the air seeder-cultivators became the start of significant manufacturers including ConservaPak (John Deere) and Seed Hawk/Seed Master. Several enterprising machinery manufacturing companies saw an opportunity for building equipment suitable for LDDS. Simple gravity box press hoe drills that were capable of LDDS were available from Edwards and Noble/Versatile by the mid 1980s. Other companies like Flexi-coil, Morris, and Bourgault were busy developing large seed drills from their existing cultivator businesses. By the early 1990s, there were a number of reliable seeding machines developed specifically for prairie conditions, thus machinery adequacy ceased to be a critical issue for adoption of LDDS.

The major and essential roles of the researchers during this period were technology transfer and the refinement of the LDDS. Significant LDDS trials were initiated at Lethbridge by Lindwall, Scott by Stewart Brandt, Swift Current by Dyck and Tessier, and Indian Head by Guy Lafond. In many cases more trials were conducted off-station than on-station.[20,21,22] Conducting trials on the land of cooperating farmers allowed a wider range of soil and weather conditions to be included in the research as well as providing more local examples of LDDS to show producers. The researchers also worked closely with innovative farmers using LDDS to both support the farmers and to learn from them.

Researchers involved in LDDS spent much time speaking to farmers at small local meetings as well as larger government and/or industry sponsored workshops and conferences. The entire concept of LDDS was not universally accepted in the scientific community, thus the researchers involved needed strong conviction, perseverance and local management support to pursue LDDS research. These motivated researchers spoke passionately about LDDS rather than simply communicating research data. They were often advocates of LDDS rather than unbiased scientists and observers. Dean Don Rennie of the University of Saskatchewan's College of Agriculture was a particularly passionate and effective speaker about the lasting damage to the land caused by summerfallow and the need to adopt new conservation farming systems.

Three major farmer organizations involved in LDDS: the Manitoba-North Dakota Zero-Till Farmers Association, the Alberta Conservation Tillage Society, and Saskatchewan Soil Conservation Association all started during this period. A perusal of the programs of any of their annual conferences shows that researchers from AAFC Research Centres were a large proportion of the speakers. No doubt their passion and interest aligned well with those of these farmer organizations and that explains why the researchers were frequently repeat speakers. Researchers were also directly involved in technology transfer at Research Station field days where LDDS was always shown and discussed.

Several dry years during the 1980s helped to reinforce why LDDS was necessary to both achieve better conservation of water and soils. It was an exciting time for researchers as the LDDS technology transformed from an experiment to a farming system.

An important factor in the success of LDDS researchers was their determination to make the system practical and ready for adoption. They saw no sense in the scientific paper being either the goal or the endpoint of the research effort. The widespread adoption of a better farming system, in terms of economic and environmental performance, was the researchers ultimate goal.

Filling in the system – 1991 to present

By the mid to late 1980s, the question had changed from whether to adopt LDDS to how to best manage LDDS as a system. Therefore, starting at this time and continuing to this day, the researchers played a key role in improving the LDDS system. Their multifaceted studies to evaluate the how and why are more effectively investigated in controlled experiments than inferred from anecdotal field evidence. Importantly, the researchers were able to work collaboratively at many Research Centres so that they could test hypotheses relatively quickly and across a wider range of environments. Consequently, the researchers were able to make important advancements in nutrient management[23,24,25,26,27], weed dynamics and control[28,29,30,31,32,33,34], crop diversification and sequencing[35,36], seeding management[37,38], and disease management.[39,40] The farmers were hungry for this information, thus researchers were frequently asked to make presentations that summarized important messages to improve LDDS management. It is testimony to their proactive research that no insurmountable problem has developed within LDDS.

Initially, LDDS systems were based on cereal-intensive rotations that were well suited to minimum tillage systems. In fact, with tillage, the cereal intensive systems were the most sustainable because the crop residue served to reduce the erosion risk and they were tolerant of the sometimes dry upper seedbed produced with tillage. However, with LDDS, successive cereal crops could produce too much residue. Further, weed control of some grassy weeds was difficult in monoculture cereal rotations under LDDS. The mixing of broadleaf and cereal crops worked better for both residue and weed control under LDDS. This also allowed the capture of rotation benefits of mixing crop types. At the same time, the environment for for broadleaf seeds and seedlings was often better with LDDS than with a tilled surface. LDDS worked better with diverse rotations and diverse rotations worked better with LDDS. Consequently the crop diversification that has occurred over the past 20 years is largely a product of LDDS.

The water conservation benefits of LDDS have been a major factor in reducing the need for summerfallow.[41,42] The steady drop in summerfallow has paralleled the increase in conservation tillage and this drop is also largely a product of LDDS.

One key feature of research in support of LDDS has been the fluidity and extent of collaboration among AAFC researchers. The successes are the result of teams of integrated researchers from many disciplines working in several locations over extended periods. The major developments did not come out of individual scientist's "laboratory". This approach was highly successful and is likely still a better approach than the apparent trend toward a more academic model of research that appears to be emerging in AAFC.

Several researchers, such as Guy Lafond, adopted LDDS within their entire research programs well before it was the predominant tillage practice in their areas. Making LDDS the normal Research Station practice helped to further convince farmers that LDDS was the way of the future and ensured that all information generated within their research programs was relevant to LDDS systems.

Other researchers were able to evaluate how LDDS was impacting the soil and the broader environment.[43,44,45,46,47,48,49,50] This information has become part of the data base to inform government policy development in areas such as greenhouse gas mitigation.

Conclusions

The Canadian prairies were fortunate to have a good network of research centres with researchers of tremendous ability and dedication and supportive local managers. These researchers played many critical roles in the development, adoption, and improvement of LDDS: conducting initial trials to show it was possible, conducting the research that laid the foundation for practical LDDS, transferring technology from and to farmers, spreading LDDS geographically, developing the scientific basis for successful systems approaches to LDDS, providing the hard scientific evidence of the benefits of LDDS, and advocating LDDS. Without doubt the prairie direct seeding research community and the AAFC Research Centres have played an essential role in the success of direct seeding in transforming the prairie landscape.

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Chapter 4

Breakthroughs in Engineering and Equipment Development

Wayne Lindwall[*]

Overview

Conventional tillage is no longer conventional on the Canadian prairies. In fact, more than 70 percent of Canada's cropland is under some form of conservation tillage with direct seeding (no-till) the most popular or predominant production system on the prairies.[1] Engineering breakthroughs in crop residue management, chemical weed control and seed and fertilizer placement played key roles in this transformation of prairie landscapes. Innovative farmers and producer groups recognized the need to develop more sustainable land management practices and encouraged researchers, engineers and manufacturers to develop more effective equipment. Canadian manufacturers were the leaders in this development and today there are more than a dozen companies including several multinationals that manufacture specialized harvesting, spraying and seeding equipment for growing domestic and international markets for direct seeding technology.

Introduction and Early History

Various types of reduced or conservation tillage have been practiced on the southern prairies of Canada for nearly 70 years. Alerted to the dangers of wind erosion during the "Dirty Thirties", farmers practiced strip farming and plowless tillage with one-way discers and cultivators that buried only 40-50 percent of the crop

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residue. Although these practices reduced erosion substantially, it was not until the development of the wide-blade cultivator in 1936 that the potential benefits of "trash-cover farming" were recognized. Trash cover farming with the wide-blade "Noble" cultivator did more to stabilize and improve dryland farming than any other previous innovation. The ravages from wind erosion and resulting soil degradation could finally be minimized or halted.

The trend toward larger farms and wider equipment in the 1950s and 1960s made strip farming (30-60m wide) inconvenient or impractical. As a consequence, the fields became larger and wider. Most farmers returned to more intensive tillage equipment (cultivators and discs) because weed control with the wide-blade cultivator was not particularly good under wet soil conditions or outside the Brown soil zone. Also, the additional crop residue left on the surface by the blade cultivator made seeding difficult because of trash clearance and plugging problems. Furthermore, with the advent of soil incorporated herbicides and increasing popularity of inorganic fertilizers, more intensive tillage operations seemed necessary. This more intensive tillage coupled with the drier conditions and lower yields in the sixties left the prairie soils susceptible to wind and water erosion. These factors plus the general lack of awareness by a new generation of farmers resulted in severe soil erosion problems in the late 1960s and early 1970s.

Early Focus on Chemical Summerfallow

In the sixties, herbicides like paraquat and atrazine made it possible to study the effects of reducing or even eliminating tillage. Although it was known that repeated applications of these herbicides on summerfallow were not economical, early research on the prairies demonstrated that little, if any, tillage was necessary to maintain yields.[2,3] Hence, most of the early research with minimum or zero tillage was targeted toward chemical summerfallow in an effort to increase crop residue conservation and provide greater erosion protection. Seeding equipment of the day was adequate because crop residues were not excessive under chemical fallow and there was little need or emphasis on fertilizer placement. Research with chemical fallow clearly demonstrated increased erosion protection, greater moisture conservation and equivalent or higher yields compared to conventionally cultivated fallows. [4]

The greatest potential application for zero tillage and chemical fallow seemed to be in the Brown soil zone where the risk of soil erosion was greatest and the benefits of increased moisture conservation could result in higher yields. But the high cost of repeated applications of herbicides and the risks associated with residual-type herbicides were too high in relation to the potential benefits of chemical summerfallow. Economic evaluation of various minimum tillage practices indicated that a significant yield advantage was necessary to offset herbicide costs and it was difficult to demonstrate the economic value of soil conservation.[5] But as a consequence of this early work and experience many producers began questioning the value of fall tillage and repeated summerfallow tillage and began substituting herbicides for tillage for winter-annual weed control or pre-seeding weed control. It became clear that zero tillage could reduce the need for summerfallow and that research and development efforts should be targeted to more intensive re-cropping systems and crop rotations that included little or no fallow.

Early Successes with Winter Wheat and No-till Re-cropping

By the late 1970s, there was already considerable interest and some adoption of zero tillage systems for re-cropping in Manitoba[6] and in the more moist areas of the Dark Brown soil zone in Saskatchewan and Alberta. Much of the interest in Saskatchewan was as a consequence of the renewed interest in winter wheat production between 1977 and 1984 and the importance of direct seeding into standing stubble to improve winter survival of the crop.[7] Winter wheat yields on untilled stubble were often equal to spring wheat yields on fallow because of the crop's improved water use efficiency and compatibility with the no-till microclimate. The most effective seed drills of the day were high clearance semi-deep furrow hoe drills like the Noble DK5 or similar machines from Edwards. Early research identified relative benefits and limitations of conventional equipment.[8,9] A few innovative farmers had success with modifying International Harvester or John Deere hoe drills with disc coulters or low disturbance hoe openers. The need for more effective straw choppers and chaff spreaders was addressed by some excellent engineering innovations from engineers at the University of Saskatchewan and rapid adoption by the industry.

There were many concerns about the impact of zero tillage on weed incidence, diseases, insect pests, soil fertility, soil physical properties, soil micro-organisms, and a growing concern about the residual effect of repeated or long-term herbicide use. Fortunately, most of these potential concerns did not materialize but they did slow the adoption of the technology until research or experience demonstrated that these issues were manageable. Producers were concerned about the lack of suitable seeding equipment and the high cost of herbicides for pre-seeding weed control. By the late seventies there was already good awareness about the potential benefits of zero tillage for soil and water conservation but adoption was limited because of the apparent lack of no-till seeding equipment (at a reasonable cost) and the high cost of suitable non-residual herbicides. Specialized triple-disc drills (Melroe/Bettinson) from the U.K. and no-till drills from other countries met with limited success on the Prairies because of problems with seed placement or ineffective packing.

In an effort to minimize soil disturbance to conserve moisture and avoid stimulating weed germination, early engineering efforts focused on narrow offset double-disc seeders and narrow hoe openers. This work by Ben Dyck at AAFC Swift Current stimulated the development of commercial no-till drills by Versatile-Noble, Haybuster and other manufacturers. In addition, specialized plot seeders developed by Ben Dyck and other engineers at Swift Current made it possible to evaluate the relative merits of different row spacing and fertilizer placement under controlled conditions. This advanced knowledge and understanding in this important domain.

Key Role of Producer Groups and the Sparrow Report

By the early 1980s there was considerable information available and thanks to efforts by groups like the Alberta Conservation Tillage Society, the Manitoba-North Dakota Zero Tillage Farmers Association and the Saskatchewan Soil Conservation Association, governments began to provide more support for the growing conservation movement. This culminated with Senator Sparrow's *Soil at Risk* report in 1984 and the formation of the Soil Conservation Council of Canada, all of which were important milestones that helped stimulate conservation programming and R&D efforts.

Equipment developments were slow because there was limited incentive (because of the existing small market) for major American or Canadian manufacturers to develop specialized seeding equipment for zero tillage. But, given the concerns and potential opportunities associated with fertilizer placement, additional research helped establish the relative benefits of fertilizer banding and timing of fertilizer application for various crops. The availability of liquid fertilizers stimulated interest in novel techniques like high pressure and point injection with spoke wheel applicators.[10,11]

Several important engineering and development contracts involving industry (Versatile-Noble) and engineers from AAFC Research Centres, Prairie Agriculture Machinery Institute (PAMI) and Universities helped establish many of the important design criteria required for effective soil penetration, crop residue clearance and packing.[12,13] For hoe type drills it was clear that for effective trash clearance the minimum vertical and horizontal dimension was 50 cm (20 inches) between openers under most Prairie conditions. When crop residue levels exceeded 5000 $kgha^{-1}$ (typically a rare situation) it was sometimes necessary to remove a portion of the loose straw or chaff to achieve effective seed placement with any seeding equipment. It should be noted that 1200-1500 $kgha^{-1}$ of crop residue cover will eliminate the risk of wind and water erosion and 3000-4000 $kgha^{-1}$ provides near optimum soil moisture conservation. For disc machines it was determined that narrow angled (8 degree) offset double-discs were equal to or more effective than the more costly triple-disc designs provided vertical loads were sufficient for soil penetration and in-row packing.

The other primary constraint at this time was the cost of the most suitable herbicides [Sweep (paraquat) and RoundUp (glyphosate)]. Although the price of these herbicides was becoming more attractive, costs were still high relative to mechanical weed control. Given the anticipated expiry of the glyphosate patent and potential competition, Monsanto reduced the price and developed formulations for no-till systems. Important developments in shielded (wind-proof) sprayers, improved markers and nozzle technology helped reduce the risk of failure with chemical weed control.

The severe drought in the early eighties helped emphasize the importance and need for more effective land management practices and clearly demonstrated the benefits of no-till. The Prairies experienced some of the worst soil erosion and dust storms since the thirties, including millions of acres in the Black soil zone. One of the biggest surprises, in terms of adaptability of zero tillage or direct seeding was the successful adoption of it in wetter areas of the Dark Brown soil and in the Black Soil Zone and Parkland regions of the Prairies. Part of the reason for this success was that re-cropping or extended crop rotations with significant fertilizer inputs were already quite common. Also, most of the direct seeding practiced today involves more soil disturbance than originally advocated to qualify as zero tillage (less than 20 percent soil disturbance). Some soil disturbance can be quite beneficial to increase soil temperature and improve germination and early growth and minimize concerns about nitrogen immobilization or de-nitrification. It is difficult to argue with success and one of the main reasons farmers have successfully adopted direct seeding is because of developments in the Canadian air-seeder industry.

Air-Seeder Revolution

There has been a revolution in equipment development for conservation tillage and direct seeding in the last 10 years. Air-seeders now dominate the market and there are a countless number of furrow opener and fertilizer placement options available to producers. Low disturbance (knife-type) openers are available that minimize stubble knockdown, but most producers are using medium or high disturbance openers that are effective in providing some control of weeds as well as providing effective seed and fertilizer placement in one pass. The greatest improvement in air-seeders over the last several years has been in their ability to provide more uniform depth control and effective packing over the seed row. Most air-seeders can now provide as uniform and effective seed placement as the best high clear hoe drills or no-till disc drills; but the air-seeders generally have greater trash clearance capabilities than most hoe or specialized disc drills. There continues to be some healthy debate about row spacing and the trade-offs between trash clearance, weed competition and water use efficiency. The bottom line for producers is still economics and that will usually dictate their selection for the most suitable seeding machine for their situation.

The best seeding system or row spacing often depends on soil type, crop residue levels and moisture conditions. Large quantities of crop residues coupled with moist soil conditions at seeding time enabled producers in the Parkland region to have great success with direct seeding by taking advantage of the residue clearance benefits of a narrow 7cm (<3") seed spread on a 30cm (12") row spacing. Compelling testimonials from leading producers and related research by Lafond[14] and others have demonstrated that there are no significant yield differences among row spacings up to 30cm (12") wide.

Concluding Comments

In spite of the significant benefits of conservation tillage and no-till that were well documented more than 30 years ago, development of appropriate seeding equipment was slow because the large, main-line equipment manufacturers had a vested interest in conventional tillage equipment and saw limited market potential for no-till systems. Innovative producers and a few short line equipment manufacturers working with government and university researchers were the early pioneers in equipment development. Although there were some early and important success stories in the 1970s and 1980s with high clearance hoe drills and a few more specialized no-till disc drills, widespread adoption of direct seeding was made possible in the 1990s with the development of air-seeders that could provide effective seed and fertilizer placement under a wide range of soil and crop residue situations.

The principles of soil and water conservation are universal. The successful adoption of conservation tillage systems in North America and particularly in western Canada has taken more than 35 years. During this period there has been a 75 percent reduction in summerfallow on the Prairies. Today more than 70 percent of Canadian farmland is under some form of conservation tillage, including 46 percent adoption of the direct seeding (no-till) culture. Successful technology transfer of conservation tillage (particularly direct seeding) required significant commitments by both the private and public sector but, were it not for the leadership and dedication of conservation producer groups, the state of our land resources and environment would be much different. There have been many technological innovations in harvesting and crop residue management, seeding equipment, weed control and fertilizer placement that have contributed to the successful adoption of conservation tillage and transformation of Prairie landscapes. This technology has been successfully transferred to many developing countries, particularly those countries with similar challenges related to soil and water conservation and adaptation to climate change. The future looks exciting with continued innovations in remote sensing, GIS and associated engineering applications for precision farming and automated controls to reduce energy inputs.

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Chapter 5

Manitoba-North Dakota Zero Tillage Farmers Association

Bob Bradley*

The stimulus for the initiation of ManDak Zero Tillage Farmers Association in the late 1970s was the recognition by a handful of innovative farmers, extension works and a few researchers that the status quo or traditional farming practices were not sustainable. The prevailing crop production systems being practiced on the Prairies of Canada and the great central plains of the United States were observed as being a major contributor to soil degradation, including wind and water erosion. This raised a serious concern among farmers, researchers, agricultural extension workers and the general public.

Summerfallow was a mainstay in many crop rotations and while continuous cropping was being encouraged and adopted, there were usually several tillage operations between the harvest of one crop and the planting of the next. It appeared obvious that excessive or unnecessary tillage needed to be challenged. During the mid-seventies, the concept of zero tillage (more often referred to as no-till in North Dakota) began to be discussed at meetings organized by provincial, state, federal and university extension and research workers. There was little well documented information available and limited experience regarding zero tillage/no-till. But one of the best learning opportunities was thought to be "farmers talking to farmers".

In the summer of 1978, interested individuals from Manitoba and North Dakota decided to organize a Zero Tillage Workshop at which farmers, researchers, extension workers, equipment manufacturers and others could share ideas, experiences and concerns relating to zero tillage. The first "workshop" was held in Brandon,

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Manitoba on January 10-11, 1979. The success of this first event (attendance by invitation only) resulted in a second open workshop held February 15-16, 1980. At this second workshop there was considerable interest in establishing a farmers zero till association.

In the meantime, field demonstrations and research were being conducted and monitored by university and extension personnel. A few farmers had already adopted the zero till system on all or a portion of their cropped land. It is interesting to note that at this time there were very few seeding implements available for purchase which could successfully plant a crop directly into the residue of the previous crop with minimal soil disturbance. Consequently, farmers took it upon themselves to modify their own equipment to do the job. What a challenge!

In March 1981, a third workshop was held. Each year, the attendance was growing and although there was still much skepticism, more and more farmers were beginning to believe that zero tillage could be a practical alternative. There was now sufficient positive feedback and a call for action in support of establishing a formal association. An ad hoc committee was established to draft a constitution in preparation for a fourth workshop in Minot, North Dakota on January 21-22, 1982. It was at this event that the Association was officially organized, a name chosen, the constitution and by-laws adopted and a Board of Directors elected. From that time forward to the present, the organization has continued to flourish and play a major role in supporting applied research and greater adoption of the zero tillage cropping system. In the interest of brevity, the name of the organization has sometimes been shortened to “ManDak”.

As the Manitoba-North Dakota Zero Tillage Farmers Association matured over time, some formal reference statements were adopted: The purpose of the Association is to “facilitate the exchange of ideas, encourage zero tillage research and disseminate zero tillage information”. A mission statement was also developed as follows: The Association (ManDak) pledges “to preserve our agricultural soil resource for future generations by promoting a system of crop production which drastically reduces soil erosion and builds up organic matter”.

The Association is governed by an elected board of twelve farmers representing agricultural areas of Manitoba and North Dakota plus eight appointed advisors from government, industry, university or conservation organizations. An executive secretary responsible to the board was hired to manage an office and coordinate a wide range of duties. ManDak welcomes membership and communication from not only North Dakota and Manitoba, but also from surrounding states and provinces and abroad.

Sources of funding included (but does not necessarily represent all funding) various levels of government, industry and resource related organizations. Additional revenue was generated from membership and workshop attendance fees, as well as from workshop exhibitor and sponsorship fees.

Membership in the Manitoba-North Dakota Zero Tillage Farmers Association increased over the first five years to 524 in 1987, with moderate fluctuation in origin (Manitoba vs North Dakota). Membership numbers have declined somewhat in later years as zero till becomes more readily adopted and information was available from other sources.

The Zero Tillage Association used several methods of sharing information, including the annual workshops, farmer extension meetings, tours, field days, radio and television, farm papers/magazines and the internet. Other special communication projects were: Manitoba-North Dakota zero till brochure, a film entitled "A Practical Alternative", and Newsletters distributed quarterly. Two Information Manuals have been produced entitled "Zero Tillage Production Manual" and "Zero Tillage – Advancing the Art" and a third manual is currently being worked on.

There are several important links which facilitate communication and discussion relating to the zero tillage crop production system. Examples of those linkages (which change over time) include:

- Western Australia No-Till Farmers Association
- South Australia No-Till Farmers Association
- Mallee Sustainable Farming Inc.
- Conservation Technology Information Centre
- Dakota Lakes Research Farm
- Saskatchewan Soil Conservation Association
- Conservation Farming Inc.
- South Dakota No-Till Association
- No-Till on the Plains
- North Dakota Natural Resource Conservation Service
- Ducks Unlimited
- No-Till Farmer
- Manitoba Zero Tillage Research Association
- SW North Dakota Soil Health Demonstration
- Agriculture and Agri-Food Canada
- Manitoba Co-operator
- Farm and Ranch Guide
- Manitoba Agriculture Food and Rural Initiatives
- North Dakota State University Extension Service
- ARS Northern Great Plains Research Lab
- Crop Rotation Intensity and Diversity Spreadsheet
- Northern Plains Sustainable Agriculture Society
- North Dakota Farmers Union Carbon Credits
- Web Soil Survey
- The Land Institute
- National Sustainable Agriculture Information Service

- Dakota Farmer
- North Dakota Natural Resource Conservation Service
- Soil Health
- Pacific North West STEEP

There were some early challenges and barriers to overcome in promoting the understanding and adoption of no-till farming. Certainly, there was the challenge of overcoming tradition and some of the intensive tillage systems which had been practiced since the early pioneers first plowed the land in the region. Many were skeptical of a system which did not include tilling the soil. Further barriers which slowed adoption included management of crop residue (other than burning), economic and broad spectrum weed control and the fact that effective seeding machines were not yet available commercially. The most successful early no-till pioneers built or modified their own specialized seeding equipment.

Annual workshops, which alternated between North Dakota and Manitoba have continued to the present time. Other activities and milestones included summer tours, newsletters, special "show and tell" sessions, published proceedings from each workshop, an educational film, two production manuals, encouragement and lobbying for research needs, and sharing of information among similar groups, here and abroad. A formal exhibit (information and promotion booth) was created and used at numerous trade fairs and agriculture/conservation conferences in Manitoba and North Dakota.

By special request, the Association held its Ninth Annual Workshop in Regina, Saskatchewan in 1987. This was a kick-off for the formation of the Saskatchewan Soil Conservation Association (SSCA). In the early 1990s, farm groups in Australia were organizing no-till associations and called on the Manitoba-North Dakota folks "blokes" for a pattern or suggested blueprint to help direct their formation.

Over its 30 years of existence, ManDak has maintained in a broad sense, its purpose and mission statement as described earlier. However, there are now several other sources where farmers can access information, such as the internet, farm service centres, implement manufactures, conservation organizations and the many farmers who have successfully adopted no-till practices.

Financing of the Association's activities has more recently been supported by partnership agreements with conservation organizations and other agricultural industry entities who subscribe to the principles of the zero till cropping system. Given the widespread acceptance and adoption of conservation tillage technology, all conservation groups should strive to carefully monitor "the big picture" and focus their efforts on activities and information which best complement other resources in this domain. A wealth of information is available on the web but farmers can learn a great deal from visiting with and listening to other farmers at local and regional producer meetings and field days. .

Organizations and individuals can wrestle forever with the name of the practice or the definition of the cropping system. But, does it matter whether it is called Zero Till, No-Till, Direct Seeding, Conservation Tillage, Reduced Tillage or whatever? The important thing is the result. The question must be asked: “Is the land managed successfully using a cropping system which eliminates or significantly reduces the amount of tillage and consequently reaps the many benefits from such management?”

There has been a well documented trend toward direct seeding or no-till systems. The term “conventional tillage” has been used in contrast to “zero tillage” to refer to a system which involved several tillage passes each year. It was the most widely accepted cropping system. Today, according to Statistics Canada and the most recent Census of Agriculture, zero tillage (or by whatever name) is now “conventional” and has become the most widely accepted cropping system on the Prairies.

The above summary does not attempt to cover the complete history of the Manitoba-North Dakota Zero Tillage Farmers Association, but hopefully outlines some of the key milestones and highlights.

The Association has developed and maintains a fairly comprehensive web site which can be accessed at www.mandakzerotill.org . The proceedings from most of the workshops are available on line, as are the two Zero Till Manuals which were developed. A wealth of related information and useful links are available from this site.

Current and past executive board members of ManDak are gratefully acknowledged for their input in preparing this summary.

Chapter 6

Saskatchewan Soil Conservation Association

Blair McClinton [*] ***and Juanita Polegi*** [†]

The Saskatchewan Soil Conservation Association (SSCA) was formed in the late 1980s as a cooperative effort between progressive farmers and interested individuals working within Saskatchewan Agriculture, PFRA and the University of Saskatchewan.

Organizational Years (1986-1989)

In the early 1980s, many producers were experimenting with no-till (zero till, direct seeding) systems across the Prairies with varying degrees of success. Both the Manitoba-North Dakota Zero Tillage Farmers Association (ManDak) and the Alberta Conservation Tillage Society (ACTS) formed as a way for farmers to share their experiences. Since there was no Saskatchewan organization, several innovative Saskatchewan farmers interested in no-till began attending the ManDak conference. A few of these farmers began to ask the question, "Why don't we have a Saskatchewan-based farm group?"

Dr. Don Flaten, a provincial soils specialist with Saskatchewan Ministry of Agriculture at the time, played a key role in establishing the SSCA. Even though he had little support from the Ministry, Don developed a proposal to the Saskatchewan Agriculture Development Fund (ADF) for a study to gauge producer interest in a provincial soil conservation group. Approval and funding for the project enabled Jim Halford to be hired as coordinator. With guidance and support from ManDak,

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[†] Saskatchewan Soil Conservation Association, 1990-2008.

ACTS and PFRA; Jim set out on a cross-province tour to discuss the idea with interested producers in Weyburn, Moose Jaw, Swift Current, North Battleford, Melfort, Yorkton and Rosetown.

Manitoba-North Dakota Zero Tillage Workshop, Regina, January 22-23, 1987

In the fall of 1985, ManDak was approached to hold their 1987 Workshop in Regina, Saskatchewan. The workshops normally alternated between Brandon, Manitoba and either Minot or Bismarck, North Dakota. Jim McCutcheon – one of the earliest zero-till pioneers in Manitoba – strongly supported this idea. Given that about 50 percent of the attendees at recent ManDak Workshops were Saskatchewan farmers the offer to go to Regina in January 1987 was accepted.

The Saskatchewan Workshop Planning Committee for the 1987 workshop consisted of:

- Farmers – Jim Halford (Chairman) and Dale Heenan
- Saskatchewan Agriculture – Don Flaten, Larry Koturbash, Ken Pedersen and Charlie Carlson
- University of Saskatchewan – Glen Hass and Bruce Hobin
- PFRA – Fred Kraft and Gary Carlson

The 9th ManDak Workshop held January 22-23 in Regina had an overwhelming attendance of 1200 and proved to be a huge financial success to ManDak – with some funds also retained in Saskatchewan. It was also the momentum that helped launch the SSCA.

Birth of SSCA

It was at this 1987 ManDak Workshop in Regina where the Saskatchewan farmers present strongly endorsed establishment of an organization of what later became the SSCA!

It was then that Glen Hass, Professor of Extension at the University of Saskatchewan, was approached to become involved.

As the first executive manager, Glen did the key legwork to have SSCA incorporated under the *Saskatchewan Non-profit Corporations Act*. This included the development of the governance structure, mission and bylaws (see governance structure detailed below). Glen also had SSCA registered as a charity by the Canada Revenue Agency which allowed SSCA to receive tax-deductible, charitable donations. Glen said, “At its inception, SSCA was modeled after ManDak, where the volunteer board members were responsible for most of the Association’s activities.

The regional board structure was developed to follow Saskatchewan Agriculture's extension regions to make it easier for regional directors to work with provincial extension staff." Glen also put together the first SSCA newsletter in April 1988.

SSCA Governance

Membership Structure

- Full Members – Individual, farmer members who hold voting rights
- Association Members – Individual, non-farmer members with limited voting rights
- Supporting Members – Corporate members with limited voting rights

Board Structure

1987-1992 (9 members)

- President-elect – Elected by entire membership for 3-year term
- President
- Past President
- 6 Regional Directors (SW, SE, WC, EC, NW, NE) – Elected by members in the specific regions for a maximum of two 2-year terms

1992-1997 (11 members)

- Same as above, with the addition of:
- 2 Industry Directors-at-large (non-farmers) – Elected by entire membership for a maximum of two 3-year terms

1997-Present (11 members)

- 6 Regional Directors (SW, SE, WC, EC, NW, NE) – Elected by members in the specific regions for a maximum of two 3-year terms
- 3 Producer Directors-at-large (farmers) – Elected by entire membership for a maximum of two 3-year terms
- 2 Industry Directors-at-large (non-farmers) – Elected by entire membership for a maximum of two 3-year terms
- The Board of Directors elects the executive consisting of the President and two Vice-Presidents.

Mission and Vision Statements

1987-1995 To promote soil conservation practices that reduce soil degradation and maintain economic viability.

1995-2001 To promote conservation farming systems that improve the land for future generations.

2001-2009 To promote conservation farming systems that improve the land and environment for future generations.

2009-Present To promote conservation agriculture systems that improve the land and environment for future generations.

Vision

To be the recognized driver and facilitator of change that leads to conservation agriculture being practiced on prairie agricultural land.

Projects and Funding

Canada-Saskatchewan Agreement on Soil Conservation (1989-1994)

Over the the next couple of years, there was an opportunity for input into the Canada-Saskatchewan Agreements on Soil and Water Conservation. When the federal government indicated it was supportive of a provincial group involved in the soil conservation program, Glen said, "things really began to gel for the SSCA". With funding from the Agriculture Development Fund (ADF), the SSCA could begin to hire staff and initiate extension activities.

The support from the Saskatchewan ADF was $3 million from 1989 to 2004. Provincial specialists and regional conservationists were hired for a 3-year period from 1990-1993. The original staffing complement consisted of an Executive Manager, Office Manager, four Specialists (Shelterbelts, Weeds, Economics, Range and Forages) plus six Regional Soil Conservationists.

In 1991, the staff complement was adjusted to include a communications specialist and an education specialist with the weed specialist being eliminated.

The first staff member hired by the SSCA was John Kiss who became the Executive Manager in late 1989. John recalled that there were a number of factors that influenced the success of both the SSCA and the soil conservation effort. "The time was right!" he said. "At the time the SSCA received its contract from ADF, there were serious concerns in the communities about the environment. Grain prices were low. The price of Roundup dropped. Equipment manufacturers began focusing on new markets and new machines at that time. The producers were willing to change and try something different."

Pat Flaten, one of the first employees of SSCA, recalls being interested in the organization almost from the beginning. "I attended the ManDak Conference in Regina in 1987, the first annual SSCA meeting in Saskatoon in 1988 and the second annual meeting in Swift Current in 1989," said Pat. "Soil conservation was up and coming," she explained, "and an exciting bunch of forward thinking people were involved in the effort." Pat also liked the philosophy of the Board. "Many of the people on the Board had lots of integrity and the desire to 'do the right thing'."

One of those who wanted to do the right thing was Brett Meinert, the first SSCA president. Brett remembers how he first became involved in the SSCA. "I was one of the lucky ones selected by my ADD (Agriculture Development and Diversification) Board to attend a meeting about soil conservation organized by Jim Halford in Swift Current," he said. "When I attended the meeting in Regina, I was excited to see the interest in soil conservation in Saskatchewan!" When it was decided at that meeting to form a provincial soil conservation group, Brett said the group had the potential to be a lobbying organization, educational organization and a support group all rolled into one.

Brett recalls the first few SSCA Board meetings were very "stimulating". Brett said, "While the meetings themselves were interesting, it was the evening sessions that were most valuable. In the evenings we (the Directors) talked about anything and everything. It was an excellent group to work with". Brett also paid tribute to Glen Hass. "Glen is a tremendous individual. He helped the Association's organizational pains and growth." It was during these growth pains that the opportunity for a non partisan group to lead the soil conservation effort in the Save Our Soils Program presented itself. "It took the Board a lot of discussion to decide how much we (the SSCA) wanted to be involved in this," Brett said. "But we decided to jump in with both feet and I was very proud of the folks we hired and it appears that trend has continued."

SSCA's objectives in this program were to coordinate extension and awareness activities for the *Soils Agreement* at both the regional and provincial levels. The main priority was to support the Save Our Soils (SOS) Program being delivered by the Agriculture Development and Diversification (ADD) Boards. The regional staff were the heart and soul of SSCA's programming; where the "rubber hit the road". The Regional Conservationists worked closely with the ADD Board Technicians to develop, implement and administer the SOS program at the local level. The regional staff led regional planning and extension efforts developed by the Regional Conservation Teams that included Saskatchewan Agriculture, PFRA, Ducks Unlimited Canada and Saskatchewan Environment staff. Provincial staff worked to coordinate provincial level activities that supported the local efforts by the ADD Boards and SSCA regional staff.

Most of SSCA's success can be attributed to the teamwork of SSCA staff members at both the provincial and regional levels. By working together, SSCA was able to coordinate extension and communication messages at both the local and provincial levels. This coordinated effort helped to build local farm interest in direct seeding as the "thing to do".

Some of SSCA's key achievements in this period included:

- Prairie Steward Newsletter,
- SSCA Annual Direct Seeding Conference,
- Soil Conservation "How-To" Videos 1 and 2,
- Direct Seeding Field Day,
- Project SOILS education program,
- SSCA/PAMI Direct Seeding Manual.

While the key achievement of the *Soils Agreement* programs like *Save Our Soils* was starting the movement to direct seeding, the program itself focused on a wide variety of soil conservation practices. Direct Seeding was just one of a couple dozen practices being promoted. Even within SSCA, direct seeding was not the initial focus. Direct seeding was considered uneconomical and impractical in 1990 by most farmers and agrologists. However, a few innovators, helped by lower Roundup prices and better seeding equipment began to push for more information on direct seeding.

While there was interest in doing direct seeding demos through the SOS Program, the program restrictions would not allow ADD Boards to purchase equipment. However, once suitable air-seeders became available, local dealers and equipment manufacturers developed lease programs for ADD Boards. SSCA regional staff encouraged the ADD boards to take advantage of these opportunities and develop direct seeding demonstration programs.

One year into the program, it became very apparent to SSCA staff that interest in direct seeding was building. In early 1991, SSCA staff began planning the first Direct Seeding Conference to be held in Prince Albert in 1992 and also initiated the production of a "How-to" video on direct seeding.

Direct Seeding Conference

Many have suggested that SSCA's 1992 *Direct Seeding Conference* in Prince Albert as its "coming out" party. This was the first time SSCA dedicated its annual conference to a single approach to soil conservation. The planning committee mostly consisted of SSCA staff (Garry Meier, John Kiss and Blair McClinton) and Saskatchewan Agriculture extension staff (Barry Swanson, Roy Button and Eric Johnson). After being criticized by its Board (and other farmers) over its 1991 "policy-centred" conference, SSCA made it a goal to design a conference program that would interest farmers.

According to Blair McClinton, "We were tossing around a few conference themes, when Roy Button said that we should focus on direct seeding if we wanted to interest farmers. Upon reflection, it should have been an obvious choice. However, it was both risky and controversial at the time. Our grass roots instincts were telling us that this was the right thing to do, but policymakers in Regina were very skeptical of this decision at the time. I do credit John Kiss for trusting our instincts and defending the committee's decision."

The success of the event even took the committee by surprise. They planned the event for between 250 and 300 people. Agricultural events larger than this were unheard of at that time. Two weeks before the conference 300 registrations had been received. McClinton remembers the excitement the Board and staff felt as the registration numbers grew. More than 400 people had pre-registered by the meeting date. The only unknown was how many people would try to walk-in.

The event itself was held during a cold spell with daytime highs of -30 C. Even with the bitterly cold temperatures, more than 600 farmers attended. The *Direct Seeding Conference* seemed like a ray of sunshine that broke through all the "doom and gloom" messages in the agriculture industry at the time.

SSCA decided to continue focusing the conference on direct seeding for the following year in Moose Jaw, where 800 farmers filled the building to capacity. The *Direct Seeding Conference* continued by that name until 2006. In the peak years of 1994-2000, the conference's annual attendance averaged 1200 people.

Direct Seeding Manual

While the direct seeding conference was an example of good planning, the Direct Seeding Manual was developed almost by accident. What started out as a series of individual projects with two different organizations evolved into something whose value was far greater than the sum of its parts. In 1992, SSCA was developing guides on crop rotations and weed management and when it was learned that PAMI was working on a residue management and seeding equipment guide it was suggested that the managers from the two organizations get together to discuss the development of a single manual. As a consequence the Direct Seeding Manual was born.

SSCA developed a one-day course based on the Direct Seeding Manual; the fee to attend the course was $25. During the three month period in the spring of 1993, some 3000 farmers attended one of the courses and took home the Direct Seeding Manual. Over the next few years, a couple of revisions were made including a major rewrite in 2000. To date more than 7000 manuals (representing 12% of Saskatchewan farms) have been sold.

Canada-Saskatchewan Agricultural Green Plan/TransAlta Utilities/Monsanto Canada (1994-1997)

The *Save Our Soils* program and SSCA's support programs ended in March 1993 as a consequence of changing policy priorities of Saskatchewan Agriculture and PFRA. However, the SSCA Board was able to offer contract extensions to Blair McClinton and Garth Patterson to help organize the 1994 Direct Seeding Conference being planned for Lloydminster. In the spring of 1993, TransAlta Utilities contacted SSCA about developing a program to promote direct seeding systems as a way to sequester soil carbon and help offset some of their emissions. Canada had just signed on to the "Rio and Kyoto Accords" in 1992 and TransAlta, as Canada's largest privately held utility, was concerned about how they would be affected by proposed climate change regulations.

SSCA also began discussing program funding with Monsanto Canada given that Roundup sales were growing rapidly in Saskatchewan compared to other provinces. They identified SSCA as a key driver behind direct seeding in Saskatchewan and wanted to help ensure SSCA's programs continued.

SSCA submitted a proposal to develop a direct seeding extension effort that would be cost shared (50:50) through the new Green Plan program and Monsanto and TransAlta. This was a somewhat controversial decision for the SSCA Board as it was the first time SSCA would focus solely on direct seeding. And there were concerns that SSCA's independence, real or perceived, would be lost due to the large corporate funding component.

The Green Plan management committee approved two-thirds of the funding requested by SSCA with the provision that certain components of the proposal be removed. This reduced level of support put the entire project in jeopardy since the private funding levels were tied to matching public support. Nonetheless, the Board decided to proceed with the project. Head Office was then moved to the Indian Head Research Farm with the support of Agriculture and Agri-Food Canada (AAFC) and management at the Semiarid Prairie Agriculture Research Centre at Swift Current. Soon after, John Kiss resigned and Doug McKell was hired as the new Executive Manager and former NW Soil Conservationist, Blair McClinton as the Assistant Manager.

SSCA received $1.6 million in contract funding from all sources between 1994 and 1997 and with the revenues from the increasingly successful Direct Seeding Conference helped build SSCA's financial coffers.

While SSCA continued to deliver successful programming to promote direct seeding, this particular project saw the SSCA enter the climate change policy arena. One of SSCA's obligations to TransAlta Utilities was to advocate soil carbon sinks to be accepted as a recognized carbon offset. SSCA began working with other provincial and federal soil conservation groups in Canada and the Soil Conservation

Council of Canada to promote this idea. SSCA's work in this domain helped create interest to not only impact policy development but also support research to more fully document carbon sequestration potential on agricultural land across Canada.

Direct Seeding Field Days

SSCA held its first *Direct Seeding Field Day* in June 1993 near Moose Jaw in conjunction with the *Western Canada Farm Progress Show* in Regina. This successful extension effort continued until 1999. In 1996, SSCA held a second "north" field day near Wilkie to accommodate farmers in the northern grain belt. From 1997 to 1999, the north field day was held in cooperation with the Seager Wheeler Farm at Rosthern. From 2000 to 2006, SSCA continued to assist the Seager Wheeler Farm with their *Seeding Trends Field Day*.

Saskatchewan Conservation Learning Centre (1993-1997)

In 1993, Agriculture and Agri-Food Canada (AAFC) approached the SSCA to set up a demonstration farm in the parkland area of Saskatchewan under the Parkland Agricultural Research Initiative (PARI). From 1993 to 1997, AAFC provided funding to SSCA to establish and manage the demonstration farm and hire a farm manager. A site, provided by Ducks Unlimited Canada, was located south of Prince Albert. The name of the new farm was the Conservation Learning Centre (CLC). Its purpose was to focus on promoting and demonstrating soil and water conservation practices. The CLC also developed an education program to work with schools in the region. Pat Flaten, former SSCA SW Soil Conservationist, was hired as the farm manager. Even though it was administered by the SSCA, the CLC operated under the guidance of a local steering committee.

By 1997, the SSCA Board wanted the CLC to strike out on its own as an independent organization. The CLC was incorporated as the Saskatchewan Conservation Learning Centre, Inc. in 1998. To help through the transition, the SSCA provided the CLC with a $30,000 per year grant for three years. The CLC continues to operate south of Prince Albert and has maintained a close relationship with the SSCA.

Project SOILS

Project SOILS is an activity-based education resource for K-12 teachers in Saskatchewan. It was modelled on the highly successful Project WILD wildlife education initiative that is coordinated by the Canadian Wildlife Service and provincial Environment Ministries. Project SOILS was originally developed in 1993 under the guidance of SSCA Education Specialist, Yvette Crane. SSCA received additional funding under the Agricultural Green Plan to revise the Project SOILS manual and offer workshops to train teachers on how to use the materials. The manual was translated into French with the help of the translation service in the Saskatchewan

Intergovernmental Affairs Ministry. Lizabeth Nichols, an Education Specialist with Saskatchewan Environment and the Saskatchewan Watershed Authority, helped to champion the use of Project SOILS materials to Saskatchewan teachers as part of her work promoting wildlife and water conservation education.

Canada-Saskatchewan Agri-Food Innovation Fund (AFIF) (1997-2000)

Over the three-year period 1997-2000, SSCA received around $1 million through four Agri-Food Innovation Fund (AFIF) projects. In addition to the AFIF funding, Monsanto Canada provided SSCA with $450,000 over this same three-year period.

The programming continued to focus primarily on direct seeding systems. However, with direct seeding becoming more common, SSCA staff began developing new methods to reach new adopters. One of these methods was called "Kitchen Table Meetings". With this delivery model, SSCA staff would identify a key local innovative farmer or "Innovator". This innovator identified a few local neighbours who did not direct seed and invited them to an informal meeting at the innovator's home. The SSCA staff person would attend and facilitate these informal meetings. The staff person would use materials in presentation binders to help address the discussion. Another variation of this delivery model was "half-ton tours". In this case, local farmers would show up at a specific location and then proceed to have a local crop tour facilitated by an SSCA staff person. The advantage of this type of approach was that it allowed SSCA to get into direct contact with farmers who normally did not attend meetings or tours.

In the late 1990s, equipment manufacturers began marketing precision agriculture equipment like yield monitors and GPS systems. SSCA, along with Saskatchewan Agriculture staff, began to work with local farmers who were interested in precision farming techniques. SSCA also helped the Indian Head Agricultural Research Foundation (IHARF) establish a Precision Agriculture research site near Indian Head.

SSCA began establishing a series of demonstrations showing the "Do's and Don'ts of Direct Seeding". In these demonstrations, SSCA staff set up plots where they deliberately made common seeding mistakes like seeding too deep or too fast or too much seed-placed fertilizer. These demonstrations were effective in helping remind farmers about the direct seeding principles. In 1999, SSCA ordered two plot drills that were funded through the AFIF infrastructure program. SSCA was able to continue using these drills until its staff programs ended in 2006.

GIS Internet Mapserver

In 1998, SSCA began a joint project with the PFRA GIS Unit to establish an internet mapserver at the GIS Unit. SSCA received funding for this through the AFIF Infrastructure program. The purpose of the program was to provide public access to PFRA's GIS mapping data. This project helped lay the groundwork for the establishment of AAFC's National Land and Water Information Service (NLWIS).

2000-2003 Projects

When the AFIF program came to an end in early 2000, there was no obvious source for continued government support. SSCA's management team developed several proposals to the CARDS (Canadian Adaptation and Rural Development in Saskatchewan) program and to ADF with little or no success. The new funding programs did not have a provision for supporting project staff. In late 1999, SSCA announced that it would be terminating its programs without continued government support. In early 2000, Saskatchewan Agriculture informed the Board that it would provide SSCA with $200,000 per year for the next three years. Even though this was not sufficient to cover the costs, the Board decided to keep the staff on as part-time employees to help maintain some programming. The Saskatchewan Agriculture funding was reduced to $150,000 over three years in 2003. This, however, meant changes for SSCA's staffing. Doug McKell, Executive Manager, Claire Neill, Office Manager and Ken Sapsford, WC Soil Conservationist all resigned. Blair McClinton was appointed the new Executive Manager. The five remaining regional staff worked on a two-thirds time basis.

This was a short-term situation. By fall, Ducks Unlimited Canada contracted SSCA to lead extension efforts to support their new winter wheat program. This was enough to bring everyone up to full-time again. In early 2001, Monsanto Canada agreed to provide program funding which allowed SSCA to refill the West Central Region and Assistant Manager positions.

Programming in this period remained focused on direct seeding. However, staff efforts were focused more specifically on field demonstrations, the SSCA website, the annual conference and the *Prairie Steward* Newsletter. Monsanto was interested in working with the staff to develop targeted programs in areas with low adoption levels.

SSCA has had an internet presence since 1994. The website includes newsletter articles and conference papers. In 2000, with a greater focus on the website, SSCA staff developed basic technical information highlighting the basics of direct seeding management.

SSCA developed the Crop Advisors Workshop to provide training to agrologists and crop advisors working in industry. This train-the-trainers concept ensured that the people advising farmers had the background to provide accurate information on direct seeding and other soil management issues.

Greenhouse Gas Mitigation Program (GHGMP) (2003-2006)

The GHGMP was the last major program effort delivered by the SSCA. This federally funded program was coordinated nationally by AAFC and the Soil Conservation Council of Canada (SCCC). This program provided SSCA with around $340,000 per year for three years to promote practices that either sequestered soil carbon or reduced nitrous oxide emissions. The main focus of SSCA's efforts was nutrient management in direct seeding systems. This integrated approach to GHG management was intended to build on the successes achieved with direct seeding. In addition to field demonstrations, presentations and one-on-one visits, SSCA staff developed 22 fact sheets highlighting a number of practices that helped address GHG emissions. When the GHGMP ended in 2006, SSCA was forced to layoff its regional field staff.

Other Miscellaneous Projects

SSCA has delivered a variety of smaller projects over the years. Some of these include: on-farm fuel use in direct seeding, direct seeding forages, forage rejuvenation with fertilizer and the *Prairie Soils and Crops eJournal*.

Current Projects

SSCA has received project funding for a few small projects since 2006. The *Prairie Soils and Crops eJournal* is partially supported by ACAAF (Advancing Canadian Agriculture and Agri-Food) funding. This journal is intended to provide some revenue for SSCA in the future.

SSCA is currently testing the Holos On-farm GHG software with farmers in Saskatchewan as part of a national SCCC project.

Climate Change Policy and Research

SSCA has been at the forefront of climate change policy in the agriculture industry. SSCA's involvement began with project funding from TransAlta Utilities in 1994. By 1997, SSCA began to look into policy implications of carbon trading for agriculture. One of the first efforts was to promote the concept to policymakers and to put agricultural soil carbon credits on the table for discussion. Since the carbon sink potential of agricultural soils was left out of the Kyoto Protocol, SSCA helped lead a coordinated lobby effort along with other Canadian soil conservation groups to promote the importance of agricultural soil sinks to municipal, provincial and federal government officials.

The Board led by John Bennett from Biggar, SK, were concerned that farmers were not going to be fairly compensated for their carbon credits and that companies wanted to sign up farmers to buy their credits before they understood its true value. Another concern John identified was the problem of transferring permanence risk from the emitters to farmers who would then be responsible for maintaining the soil sink. SSCA was one of the first groups to suggest using temporary credits or credit leasing as a way to address permanence risk. SSCA prepared several consultation documents on offset system structure for the agriculture sector including papers addressing permanence and baseline issues. As one of the few agricultural organizations working on climate change issues, SSCA has given many presentations on these policy questions to governments and agricultural groups across Canada and the USA.

SSCA was the only farm organization in Canada to have a representative (John Bennett) on the national Sinks Issue Table in the late 1990s. This "Table" was one of several issue tables established to identify how to best meet Canada's obligation under the Kyoto Protocol. Even though this table was dominated by forestry interests, John was able to have agriculture sinks prominently featured in the "Options Report" that came out of this committee.

To deal with the lack of knowledge in the farm community about carbon trading, SSCA directors began giving presentations to farmers in the late 1990s explaining carbon trading and how it could affect them. In 2005, SSCA became involved in the first agricultural soil pilot trade through Environment Canada's Pilot Emission Removals, Reductions and Learnings (PERRL) program. This program operated for three years and helped provide the foundation for the national tillage reduction offset protocol that is currently being used by the Alberta government.

Prairie Soil Carbon Balance Project (PSCB)

The PSCB is an AAFC research project (managed by Dr. Brian McConkey, Swift Current) that was established in 1997 to track soil carbon changes over time at a series of benchmark sites located throughout Saskatchewan. This project was initially jointly funded by the Greenhouse Emission Management Consortium (GEMCo) and AAFC's Matching Investment Initiative. SSCA was a partner in the project and was responsible for identifying cooperators, and collecting site history data. The PSCB sites were sampled in 1997, 1999 and 2006. They will be sampled again in the fall of 2010.

The Future for SSCA

With the changing priorities of the federal and provincial governments and associated lack of program funding, the SSCA is in a transition period. In 2010, SSCA will be making further staff reductions and from an operational point of view will come full circle to its beginnings where its activities are led by its volunteer directors.

However, the SSCA still sees a need for work to protect our land resources and the environment. At least 30% of Saskatchewan's farmland is still not adequately protected from soil degradation even though Saskatchewan is a leader in the development and adoption of conservation agriculture systems. There is an opportunity for Saskatchewan to build on this great success story to position itself as a global centre of excellence for conservation agriculture systems. SSCA is committed to seeing this happen.

Acknowledgements

The authors would like to thank the following individuals for their contributions to this document: Brett Meinert, Jim Halford, Glen Hass, John Kiss, Don Flaten, Pat Flaten, Ken Panchuk.

Table 6.1. SSCA Presidents, 1987-2009

Term	Name and Location
1987-1988	Brett Meinert, Shaunavon, SK
1988-1989	Brett Meinert, Shaunavon, SK
1989-1990	Brett Meinert, Shaunavon, SK
1990-1991	Ken Alport, Kyle, SK
1991-1992	Gary Schweitzer, Eston, SK
1992-1993	David Bueckert, Tugaske, SK
1993-1994	Gerry Willerth, Indian Head, SK
1994-1995	Dean Smith, Swift Current, SK
1995-1996	Marv Fenrich, Wilkie, SK
1996-1997	Lorne Crosson, Limerick, SK
1997-1998	Clint Steinley, Empress, AB
1998-1999	Bernie Niedzwiedz, Wynyard, SK
1999-2000	Greg Kane, Nokomis, SK
2000-2001	Don Kelsey, Choiceland, SK
2001-2002	John Bennett, Biggar, SK
2002-2003	Don Horsman, Fort Qu'Appelle, SK
2003-2004	John Clair, Radisson, SK
2004-2005	Darryl Reynolds, Nokomis, SK
2005-2006	Darryl Reynolds, Nokomis, SK
2006-2007	Edgar Hammermeister, Alameda, SK
2007-2008	Edgar Hammermeister, Alameda, SK
2008-2009	Laura Reiter, Radisson, SK
2009-2010	Doyle Wiebe, Langham, SK

Table 6.2. SSCA Staff

Staff Position	Name	Period
Executive Manager	Glen Hass	1987-1989
	John Kiss	1989-1994
	Doug McKell	1994-2000
	Blair McClinton	2000-Present
Assistant Manager	Blair McClinton	1994-2000
	Juanita Polegi	2002-2008
Office Manager	Carolyn Fife	1990-1994
	Claire Neill	1994-2000
	Marilyn Martens	2000-Present
Regional Conservation Agrologists	Pat Flaten (SW)	1990-1993
	Bob Linnell (SE)	1990-2002
	Garth Patterson (WC)	1990-1995
	Juanita Polegi (EC)	1990-2002;2004-06
	Blair McClinton (NW)	1990-1994
	Garry Meier (NE)	1990-1993
	Eric Oliver (SW)	1994-2006
	Garry Mayerle (NE)	1994-2006
	Ken Sapsford (WC & NW)	1994-2000
	David Shortt (NW)	1995-1996
	Tim Nerbas (NW)	1996-2006
	Rich Szwydky (WC)	2001-2006
	David Larsen (SE)	2002-2004
	Travis Goebel (EC)	2002-2004
Weed Specialist	Steve Paquette	1990-1991
Shelterbelt Specialist	Chris Ruschkowski	1990 (8 mos)
	Howard Fox	1991-1992
	Chris Zabek	1992-1994
Range and Forage Specialist	Nancy Fraser	1990-1993
Economics Specialist	James Lokken	1990-1994
Communications Specialist	Guy Chartier	1991-1992
	Ray Kettenbach	1992-1993
	Lorne McClinton	1994 (4 mos)
Education Specialist	Yvette Crane	1991-1993
Conservation Learning Centre Manager	Pat Flaten	1993-1998

Chapter 7

Alberta Conservation Tillage Society, Alberta Reduced Tillage Initiative & Alberta Reduced Tillage LINKAGES

Peter Gamache *

Background

The Alberta Conservation Tillage Society (ACTS) was founded in April 1978 by Gordon Hilton of Strathmore, Alberta after a tour of Wayne Lindwall's no-till research plots at the Lethbridge Research Centre. Gordon had asked his local District Agriculturist (Len Robinson) to organize a visit to Dick Middleton's farm at Champion and the Lethbridge Research Centre for a group of about 15 interested farmers. Gordon's enthusiasm and commitment to the principles of soil and water conservation were infectious so it was not surprising that several farmers signed up when he proposed the formation of the "Canadian Western Farmers No-till Association" (a name that was soon changed to the Alberta No-Till Farmers Association and later to the Alberta Conservation Tillage Society). Within a couple of months the Association had appointed an interim Board of Directors with Gordon as the Chairman. ACTS was born held their first annual meeting on March 23, 1979 with the initial objective of farmers sharing their experiences with no-till and encouraging more applied research and development. More than 80 enthusiastic producers attended this first meeting. With good support from the private sector and Alberta Agriculture, ACTS grew and thrived. For the next 25 years ACTS played a leadership role in technology transfer in support of the conservation tillage movement.

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* Alberta Reduced Tillage LINKAGES, Team Leader (1995-2009). Peter gratefully acknowledges the input from Gordon and Spencer Hilton, Murray Green, and Bryan Hearn.

In 1993-94, the Alberta Conservation Tillage Society, Conservation 2000 (the Alberta Wheat Pool's conservation clubs) and Alberta Agriculture presented seventeen direct seeding courses reaching more than 700 hundred producers across Alberta. They also coordinated four direct seeding demonstrations days in May and June that gave over 2,500 producers the opportunity to observe direct seeding drills. Given the interests of other corporate sponsors and the need for more local grass roots extension efforts, the Alberta Reduced Tillage Initiative (ARTI) was established in 1994. In 2000, ARTI became known as Reduced Tillage LINKAGES (RTL).

Key drivers for start-up

ACTS was started because a small group of innovative farmers lead by Gordon Hilton of Strathmore recognized the need for an Alberta based farmer organization to collect and share information and experience with conservation tillage systems. A similar farmer group, the Manitoba North Dakota Zero-Till Farmers Association (ManDak) established in 1978 was already quite successful. The other key driver, particularly in southern Alberta, was the growing concern with severe wind erosion caused by excessive cultivation and unprotected fields of summerfallow. Severe drought and soil erosion in the early 1980s lead to a nationwide government task force and ultimately Senator Herb Sparrow's *Soil at Risk* Report (1984). This report along with several major soil erosion events across the Prairies spurred government action and development of federal-provincial soil conservation programs. Given the mission and vision of ACTS, they were a logical vehicle to help deliver these vital programs. ACTS popular motto was "Soil is #1, Don't Blow It". It was already well established that standing stubble and direct seeding were the best ways of preventing soil erosion and conserving soil moisture.

Early champions in group's development

In addition to Gordon Hilton, several other innovative farmers and champions of soil conservation played key roles in the development and early growth of ACTS. People like Dick Middleton, Wayne Wilderman, Henry Graw, Jack Swainson, Murray Sankey, Dan Stryker, Richard Walters and Bryan Hearn were just a few of the early producer champions. Inspired by his father's leadership and commitment, Spencer Hilton was elected president of ACTS (1997) and remained active in the organization for many years. But the Hiltons and other Past Presidents of ACTS are quick to acknowledge the early contributions and support from several government officials as well. Larry Welsh, Murray Green and John Hermans from Alberta Agriculture and Wayne Lindwall from Agriculture Canada were valued advisors and supporters. Corporate sponsorship from companies like Monsanto, Westco Fertilizers and Ducks Unlimited Canada made it possible to hire a full-time Executive Manager (Russ Evans) to manage the administrative affairs for the

Board of Directors and help organize successful annual meetings with nationally and internationally recognized speakers.

With respect to the development of ARTI and RTL the key players were the Alberta Conservation Tillage Society, Conservation 2000 (Alberta Wheat Pool), Ducks Unlimited, Monsanto and Alberta Agriculture, Food and Rural Development. They recognized the need to accelerate the adoption of reduced tillage as a means of preventing soil erosion. A partnership of industry, producer groups and government was seen as the best way to accomplish this. The Alberta Reduced Tillage Initiative was formed in July of 1994. The Alberta Conservation Tillage Society became the managing partner of ARTI.

Sources of funding

Funding for ACTS initially came from producer membership, government and industry contributions. During the 1980s and early 1990s much of the funding came from Federal/Provincial conservation programming including the Green Plan. Over the years, corporate sponsorship for meetings broadened to include several chemical and machinery companies as well as commodity groups. In later years the funding was pooled to accomplish ARTI's objectives. Alberta Agriculture dedicated a considerable amount of its regional conservation coordinators' time to ARTI activities. Project funding obtained from the Canada Adaptation and Rural Development Fund in 1997 enabled ARTI to hire its own agronomists. Funding up to 2009 was a combination of partner contributions and project funding.

Membership statistics

ARTI/RTL was never a membership based organization. However the managing partner, ACTS maintained a large province-wide producer membership. RTL has a Farmer to Farmer Network of about 940 producers. This network includes a database of farmers and their seeding and cropping systems.

Group's Mission and objectives

Although the ACTS Mission Statement has changed slightly over the past 30 years, the Society "promotes the advancement of sustainable soil management and continued improvement in agricultural cropping methods".

The early mission of ARTI was:

> To accelerate a reduction in the amount and intensity of tillage Alberta farmers use for annual crop production.
>
> To develop a comprehensive network of partners who believe in the philosophy of reduced tillage as a means toward industry sustainabil-

ity and who will benefit through a commitment of resources to that philosophy.

The Mission statements of ARTI/RTL were amended slightly every three years with the renewal of the program. The ARTI Phase II (1997-2000) Mission was "to reduce the amount and intensity of tillage in Alberta", while the RTL 2000-2003, 2003-2006 and 2006-2009 Missions were "to increase the adoption of sustainable cropping systems by Alberta farmers". The "objectives" of ARTI/RTL also changed over the years (see below).

ARTI 1994-1997

- Increase the direct seeded area of annual crop production in Alberta by 1.5 million acres per year for 1995, 1996 and 1997, and to reduce the annual summerfallow area in Alberta by at least 300,000 acres per year

ARTI 1997-2000

- Increase the area of direct seeded fall and spring annual crops.
- Increase reduced tillage practices in summerfallow.
- Increase reduced tillage practices in the removal and establishment of forages.

RTL 2000-2003

- Develop networks of reduced tillers and information sources.
- Increase access to and add value to sustainable cropping information.
- Assist farmers in assessing the impact of new technologies on their production.
- Increase understanding of greenhouse gas issues.
- Increase area of reduced tillage in annual and forage cropping.
- Increase area of fall seeded crops to enhance biodiversity.

RTL 2003-2006

- Increase sustainable production systems based on reduced tillage systems.
- Reduce tillage in fall and spring annual cropped area.
- Increase fall seeded crops to enhance biodiversity.
- Reduce tillage in the removal and establishment of forages.
- Reduce the amount of tillage in summerfallow.
- Integrate nutrient management/livestock manure in reduced tillage systems.
- Reduce greenhouse gas emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O) and increase carbon sequestration.

- Strengthen economic profitability of farmers.
- Assist farmers in implementing the BMPs for sustainable cropping systems.

RTL 2006-2009

- Increase the adoption of sustainable production systems based on reduced tillage.
- Document and promote the benefits of improving soil quality through reduced tillage systems.
- Reduce tillage in fall-seeded and spring-seeded annual crop fields.
- Diversify crop rotations with the inclusion of fall-seeded crops, pulse crops and perennial forages.
- Reduce tillage in the removal and establishment of forages.
- Reduce tillage in summerfallow.
- Integrate soil nutrient and livestock manure management in reduced tillage systems.
- Increase awareness of the positive effects of reduced tillage systems on climate change adaptation, greenhouse gas emissions of carbon dioxide (CO2) and nitrous oxide (N2O) and carbon sequestration.
- Increase adoption of beneficial management practices (BMPs).
- Increase integration of crop and livestock BMPs.
- Improve nutrient management practices.
- Measure greenhouse gas emissions from representative cropping systems.
- Reduce cropping risk.
- Improve soil quality through reduced tillage systems.
- Increase adoption of residue and cropping practices that capture and make more effective use of available moisture.
- Increase adoption of diverse and dynamic rotations.
- Reduce wind and water erosion.
- Increase awareness of the positive effects of reduced tillage systems on surface water quality.
- Increase awareness of the importance of reduced tillage to surface water quality.
- Increase adoption of soil, nutrient and livestock manure BMPs to protect surface water quality.

Governance structure

The ACTS governance structure has been similar to other provincial conservation groups with an elected President, Vice-President, Treasurer and regional Board of Directors with several ex-officio Directors and Advisors. The Executive Secretary/Manager received direction from the Board.

However, ARTI/RTL was a non-binding partnership that adheres to a Memorandum of Understanding (MOU). The MOUs covered a period of three years and were renewed and slightly revised over the years. Partners signed the MOU confirming their contributions and expectations of the partnership. The MOU described the vision, mission priorities, basic functions and general operations of the initiative. The partnership structure and limitations were clearly defined as well as the initiative's commitment to the partners.

The partners agreed to the following: that sustainable production systems provide an integrated approach to addressing priority environmental and economic issues for agriculture; reduced tillage and direct seeding are basic practices that conserve and enhance Alberta's natural resources and the quality of the environment for future generations; cropping systems, such as direct seeding, have a wide range of environmental and economic benefits that will enhance our soil, water and air quality and biodiversity.

Overall responsibility for the program was provided by a Steering Committee. The Steering Committee was chaired by an ACTS II Board member and consisted of representatives of partner organizations. ACTS II was the managing partner of both ARTI and RTL.

The program portion of ARTI/RTL was managed by a Team Leader, hired by and responsible to the Steering Committee. The Team Leader was responsible for staffing, program planning, budgets and program implementation.

The Steering Committee ultimately was responsible for the successful implementation of the program plan. Accepting this responsibility, the committee or its appointees provided clear and timely direction to the Team Leader to ensure successful implementation of the program plan.

Methods of sharing information

When ACTS first began in 1978 there was limited information available to producers about conservation tillage or no-till and the web was in the formative stages at that time. One of the primary objectives of ACTS initially was to provide a forum for farmers to access information and foster greater farmer to farmer communication. For many years the annual meetings/workshops and newsletters were the primary methods of information sharing but later ACTS had their own website with an extensive electronic library and valuable links to the worldwide web.

ARTI/RTL created and shared information in a wide variety of ways. Its philosophy was to have agronomists working with farmers and industry. The agronomists developed programs to deliver information to farmers. The primary means of information delivery were: workshops, field demonstrations, field trials, field tours, farm visits, newsletters, publications (primarily factsheets), articles in farm publications, website and radio/TV.

A major early emphasis was a joint effort with Alberta Agriculture to produce the *Direct Seeding Factsheet* series. Thirty-three factsheets were produced and widely distributed. Many are still on the RTL and Alberta Agriculture web sites.

From 1994 to mid-2009 the agronomists participated in and conducted 923 workshops with attendance of 58,380. Two hundred and twenty-seven demonstrations were seen by nearly 5,275 people. Four hundred and eighty-three tours were attended by 19,277 people.

Linkages to other groups

ARTI/RTL, from its beginning, worked with many organizations. Most projects were planned and carried out in cooperation with grassroots organizations and ARTI/RTL partners. ARTI/RTL worked with local municipal agricultural service boards, producer groups, applied research associations, forage associations and government funded conservation programs.

ARTI/RTL also worked with many agribusinesses. Workshops and demonstrations were often joint projects with local agribusinesses. As well ARTI did a series of demonstrations with FlexiCoil and ConservaPak air-seeders.

There has been a strong connection with the Soil Conservation Council of Canada (SSCC) over the last 10 years. RTL also worked with and shared information with the Saskatchewan Soil Conservation Association (SSCA). More recently RTL became a member of the Conservation Agricultural Systems Alliance, a North American no-till group (www.conservationinformation.org).

Early challenges or barriers

The barriers to adoption of direct seeding have been identified through surveys over the life of the program. Surprisingly they have not varied much over the years. The top barriers as reported by farmers have been:

- Capital cost of the best seeding equipment
- Cost of inputs (particularly suitable non-residual herbicides)
- Soil and climatic factors
- Equipment performance
- Crop residue management
- Fertilizer management

During the early years of the program, farmers were sceptical of direct seeding and the barriers stated may have reflected their reluctance to try something seen as new, risky and costly.

Key developments that lead to more widespread adoption of direct seeding were the declining price of Roundup, significant improvements in machinery (seeders and sprayers) and better soil moisture conservation in drought years. As well, farmers began to understand the direct seeding system and made great strides agronomically. Farmers were always the best extension agents and willingly shared their knowledge and experience.

Program funding was not a serious problem until 2006 when it became clear that RTL might not be able to function until the end of its 2006-09 mandate due to changing government priorities.

Key milestones and accomplishments

Gordon Hilton, the founder of ACTS, was the first inductee into the Soil Conservation Council of Canada's Hall of Fame in 1990 for his leadership in the soil conservation movement.

It was also about this time that ACTS was able to hire a full-time Executive Secretary (Russ Evans) and this greatly reduced the administrative burden on the Executive and Board of Directors. The Society now had more capacity to influence conservation programming and foster linkages with government and industry. Growing corporate sponsorship was gratefully acknowledged.

Over the years, ACTS prepared several position papers and made presentations to federal and provincial policy makers on a variety of issues including herbicide pricing, pesticide registration review and recognition of soil carbon sinks. In 1987, ACTS conducted a survey of producers related to pesticide use and adoption of conservation practices. Information from this survey was used to support their position in presentations made at hearings regarding changes required for pesticide registrations.

The Alberta Reduced Tillage Initiative received the Premier's Award of Excellence (Silver) in 2001. Reduced Tillage LINKAGES received the Growing Alberta Leadership Award for Environmental Stewardship in 2004, the Certified Crop Advisors' Certificate of Recognition for Continuing Education in 2005 and The Emerald Award - Not-for-Profit in 2006. The Premier's Award, the GALA Award and the Emerald Award were significant media covered events.

ARTI/RTL has produced eleven years of proceedings from highly successful Direct Seeding Advantage conferences. Prior to this ACTS had proceedings papers from its annual conferences in hard copy or on-line from 1979 to 1999. A more detailed history and report on the impact of direct seeding can be downloaded from the website: www.reducedtillage.ca .

One of the most significant media events for RTL has been the ongoing series of direct seeding stories in major farm magazines in Western Canada. RTL with the help of two writers has run 10-20 stories per year in magazines such as *Top Crop Manager*, *Country Guide*, *Cattlemen*, and *Grainews*. The potential audience each year was more than 300,000 readers (producers and agri-business).

The most significant milestone has been the widespread adoption of direct seeding or no-till by Alberta farmers. In 1996 about 10.3% of the annually seeded area was no-till (Statistics Canada). No-till grew to 47.8% in 2006 and was projected to be more than 56% in 2009.

The RTL Assessment Surveys of 1999, 2003 and 2005 have reported that RTL has had a significant influence on farm practices. Seventy-three percent of the Farmer to Farmer Network members surveyed in 2005 reported that RTL had influenced their farming practices. About 47.6% of the randomly selected group reported that RTL had influenced their farming practices.

Change in focus over time

The focus of ACTS and ARTI/RTL did change somewhat over the years, in part to be able to access government programs with changing or broadening priorities. Its role as an extension group has not. Direct seeding and no-till systems have always remained the foundation of the partnership. As the understanding of direct seeding systems and the agronomic, environmental and economic benefits increased the group broadened its focus. The initiative was never solely about tillage or no tillage since early on the power of thinking in terms of cropping and sustainable systems was recognized.

A significant change in focus occurred when the Soil Conservation Council of Canada (SCCC) received funding to deliver the Greenhouse Gas Mitigation Program. The heart of the program was direct seeding, but the message broadened to include the sequestration of carbon and reduction in greenhouse gas resulting from direct seeding. More recently, program funding has continued in support of greenhouse gas reductions and validation of sources and sinks as well as energy conservation and efficiency. This has resulted in a deviation from the extension of direct seeding information but RTL's primary focus still remains to increase the adoption of sustainable direct seeding systems.

The drivers for change were primarily a switch from pooled funding to project funding. Project funders have certain goals and RTL adapted theirs to fit the funding. The environmental movement probably was significant in this.

Partners and sponsors have changed over the years. ARTI/RTL has had twenty-four different partners. Six partners have stayed the course over the fifteen years. The partnership mix for any of the five three-year periods ranged from ten to seventeen. Financial support grew from the early years to a peak in 2003 to 2006. The percentage of support received from partners has decreased since 2000 while project funding has increased.

Closing Comments

Reduced Tillage LINKAGES closed operations as of August 31, 2009. The primary reason for termination was the lack of funding from partners and the inability to maintain focus on conservation agriculture systems when accessing project funding. ACT II continues to exist as a farmer member organization (see www.areca.ab.ca/acts for further information) but it is unclear at this point how their role will change with the changing priorities of government and termination of RTL.

It is unlikely that farmers will be able to continue delivering RTL programming on a voluntary basis. Time and financial constraints will make it difficult to continue no-till/conservation agriculture extension with the RTL model. Employing agronomists whose sole job is extension is expensive. Without a commitment from government and/or industry it will be difficult to continue this level of support. It may be appropriate to explore new ways to deliver information and establish new partnerships, perhaps interprovincial in nature.

Chapter 8

The Early Adopters of Zero Tillage

Multiple Authors*

Even in early discussions about the content for this history book there was consensus that we would include stories from the early champions (adopters) of zero-till. Interviews with farmers in Manitoba, Saskatchewan and Alberta were conducted in early 2010 by Wayne Lindwall and Kathy Larson. This chapter features seven short bios on early adopters. If there is one thing we learned from this experience it is that interviews could comprise an entire book of their own. At nearly every interview we were told of another farmer or researcher that we should speak with.

One of the misnomers is that we interviewed "early adopters", as one interviewee pointed out, according to the technology adoption lifecycle he was actually an "innovator". The technology adoption lifecycle was first introduced by Rogers (1962), the area under a bell-shaped curve is divided into innovator, early adopter, early majority, late majority and finally, laggard to depict the progression of technology adoption (see Figure 8.1). The farmers interviewed for the book can be classified as innovators – they took risks in adopting zero-till and were one of the first, if not the first, in their area to adopt. There was a lack of experience, lack of equipment, and highly priced inputs (glyphosate) associated with this new technology. Despite all these drawbacks the benefits for their operation and the environment outweighed the costs.

The innovators featured in this chapter are the pioneers of zero-till who faced skepticism from neighbours and family. These are their stories.

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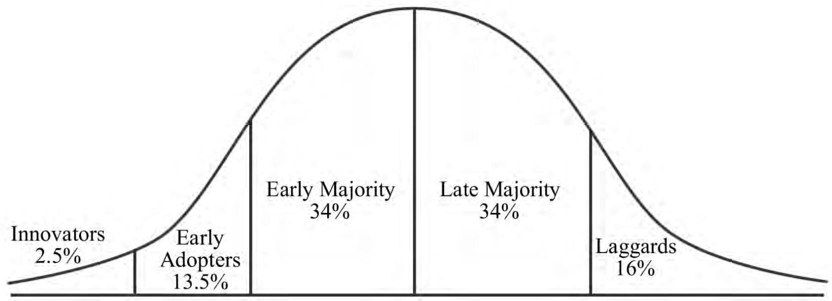
*This chapter is based on seven personal interviews conducted with early adopters of zero tillage in Manitoba, Saskatchewan and Alberta. The interviews were written into short bios by Wayne Lindwall and Kathy Larson.

Figure 8.1. Technology Adoption LifeCycle



Source: Based on Rogers (1962)

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Jim McCutcheon

Homewood, Manitoba

Southwest of Winnipeg, near Carman, Manitoba – Homewood to be precise – is where the "Father of Zero Till" made his mark. Jim McCutcheon graduated from the University of Manitoba's Agriculture Diploma program in 1955 and began farming shortly thereafter. Jim recalls soil science lectures from University where he learned increasing nitrogen rates would increase his yields. Jim says "I'd been increasing my nitrogen rates and my crops responded alright, but so did the weeds, and wild oats in particular." Not being fond of long hours on his tractor cultivating and watching the front wheel turn, Jim was open to improved ways to do things.

Early motivation

It was the late 1960s or early 1970s when Jim first met University of Manitoba weed scientist, Dr. Elmer Stobbe. Jim says if he can be called the "Father of No-Till" then Stobbe is definitely the "Grandfather of No-Till". Dr. Stobbe was traveling around with a representative from Chipman Chemical and they came to Jim's farm to see if he would be interested in having some zero till field trials on his farm. McCutcheon remembers thinking to himself at the time, "Oh, this would never work." But the interesting thing for Jim was, not long after he heard Dr. Stobbe speak at a weeds meeting in Carman and Stobbe came out with a statement that wild outs were peculiar to cultivated soil. That really caught Jim's attention because he was having a "heck of a time with wild oats" so he thought "this deserves a look" as zero tillage might be the answer to his weed problems and could save him time and money through reduced hours on his tractor.

In 1974, McCutcheon tried zero-till on one-third of his farm. Jim was the first in his area to pursue no-till, and for a long time after he continued to be the only zero-till farmer in the area. Even today McCutcheon says there are few farmers practicing zero-till in and around Carman. His reasoning for this lack of adoption is the Red River Valley's soil and climatic conditions. Jim says zero-till is a "hard sell, simply because quite a bit of the time you are concerned about excess moisture, zero till saves moisture, so you can't save it and get rid of it at the same time."

Even as one of the only zero-tillers in his area Jim does not have any recollections of neighbours discounting his change in farming practice. To him the opinions of neighbours had "no influence whatsoever". Reason being, "if it wasn't zero till, someone in the area would be trying something new. It is just one of those areas where there are a lot of innovative farmers…somebody trying sweet corn to sell on the fresh market or they'd be trying corn for grain for the distillery at Gimli. We call it the Pembina Triangle – Carman, Winkler, Morden, Altona area – just a lot of innovation." However, not all Manitoba was accepting of innovative practices.

McCutcheon remembers stories about another Manitoba farmer who tried zero-till on one field and “neighbours gave him so much hassle that he went out there and ripped it up”.

Issues and on-farm solutions

After three years (in 1977) McCutcheon converted his entire farm to zero-till, but it was not without issues. In the mid-1970s, Jim was restricted to paraquat for weed control, as RoundUp was not yet available, and it was pretty expensive. Right from the beginning Jim had four concerns that he knew he had to solve for zero-till to be successful on his operation:

1. Germination - it was decent for cereals, but not so good with oilseeds
2. Cost of chemical weed control - RoundUp was not yet available
3. Straw and chaff spreading
4. Best use of fertilizer

Like many early adopters of zero-till, Jim used his creativity and his machine shop to make on-farm adjustments to machinery. McCutcheon remembers an International press drill being used on nearby research plots by Dr. Stobbe and his grad student (Dave Donaghy); they had modified it with cutting coulters mounted in front of the disc openers. To Jim it “looked like a good idea” so he copied the idea and it “worked pretty good for the first few years”. Researchers from the University of Manitoba even measured Jim’s prototype and drafted up plans for other farmers to follow. After ten years of zero-tilling Jim discovered his soil properties had changed; “the surface of the soil got quite soft” so that the “cutting coulters didn’t cut through that softness. It was like trying to slice fresh bread with a dull knife, you were just pushing it [straw] down instead of cutting it and consequently you were pushing the straw and chaff into the bottom of the groove where you are trying to put the seed so you didnÕt get good seed to soil contact”. McCutcheon sold the press drill and purchased a hoe drill and “of course did some modifications to that as well”.

One of Jim’s inventions was quite successful. After Jim moved away from the disc drill he purchased an International hoe drill with “eagle beaks”. When applying fertilizer in the fall McCutcheon discovered the tips were not doing their job; the fertilizer was sitting on top of the ground. Jim decided to copy an opener concept – inverted “T” – he had heard was being used in New Zealand to seed straight into pasture. Unfortunately these openers were also unsuccessful, so Jim used a cutting torch to modify the points into “miniature bulldozer blades”. “It worked so well that a friend of [Jim’s] saw it and asked where he could buy them. [McCutcheon] told him he wasn’t in the business of doing it.” His friend took one of Jim’s openers to a small manufacturing business – Atom Jet – located in Brandon, Manitoba. Atom Jet made a batch for the friend, and when they were sitting on the floor ready for pick up another farmer came in, saw them and he asked for a set. Pretty soon Jim's idea blossomed into a very significant part of Atom Jet's business, transforming the company from a basic machine shop into an ag product company, by accident.

No-till supporters and nay-sayers

When asked what companies and organizations had the greatest impact in accelerating the adoption of zero till Jim answers Haybuster and Manitoba-North Dakota Zero Tillage Farmers Association. At one of the first meetings Jim ever spoke at in North Dakota there was a representative from Haybuster. As Jim saw it, Haybuster invested large sums of money in the research and development of drills because they saw the potential, while mainline companies were slower to get involved. McCutcheon also gives credit to Jim Halford for his efforts and money invested in developing useful equipment for zero tillage.

Jim says he noticed a lack of initiative on part of the Federal Department of Agriculture's Research Branch. McCutcheon does recognize there were individuals in the Research Branch that were doing research early on; Wayne Lindwall was one of those individuals, Guy Lafond and Ashly O'Sullivan two others. To Jim the lack of initiative stemmed from the Director General level; Jim felt there was an unwillingness to reallocate funds for zero-till research. While Jim recognizes he has not spent time within the walls of the research branch, this was the impression he got, that there was no encouragement from the top down. However, Jim was on a minimum tillage research committee for a while and recalls one individual on the committee saying "We're not ready for this to happen, we should use our influence to slow it down."

Major drivers of adoption

McCutcheon identified a few important developments and milestones that stimulated the broader adoption of zero tillage. "The development of improved seeding equipment was a very big factor and the eventual lowering of the price of glyphosate was right up there in being a big stimulant. The price of glyphosate was a big sore in our side for quite a while, that's a story in itself." Additionally, Jim reiterated his germination problems that were resolved with improved equipment and openers.

Jim feels the years it took to reach major conversion to zero-till were not too surprising considering the major change that occurred. McCutcheon recalls post-graduate research by a student named Barry Forbes at the University of Manitoba. Forbes' father, Jack, had been in extension and was a strong supporter of zero-till. Forbes' research looked at how long it would take for zero-till to be adopted. Jim was involved in the research and he remembers Barry telling him "it took 15 years in the corn belt for people to convert from straight corn seed to hybrid corn seed. And all they had to do was put a different type of corn in their planter and it took

15 years to complete the adoption of that practice." Considering the magnitude of change involved with zero-till, Jim feels the adoption of zero-till "went pretty darn fast considering zero-till is an entirely new paradigm."

Going forward, Jim suggests raising the price of oil to drive further adoption of zero-till. He feels we have been through the cycle of being very concerned about the impact being made on topsoil. Jim feels that concern has been resolved. His proof was the lack of black soil he saw when he flew his plane from Carman to Airdrie in September 2007. In times past he would see people out in their fields making them black. Now once he left the Red River Valley he never saw any black soil till he got around Lethbridge. It was quite amazing as McCutcheon recalls, "From the beginning I thought zero till makes a lot of sense for that hardcore Palliser Triangle, but it didn't happen there that quick, not as quick as I thought it would. It came into northern Saskatchewan as fast as southern Saskatchewan because the guys could see how they could save some money. It happened for different reasons."

Jim retired from farming in 1999. He turns 75 this year and still has an impeccable memory about his early days in zero-till, perhaps it is because he has been asked numerous times to share his story. One need only to type his name into an internet search engine to learn McCutcheon was the first President for the Manitoba-North Dakota Zero Tillage Farmers Association and in 2002 he was inducted into the Manitoba Agriculture Hall of Fame – two major accomplishments not mentioned by Jim during his interview for this chapter. He is quick to give praise to all the other researchers, farmers, and extension personnel that he has connected with over the years. McCutcheon is a true innovator and ambassador for the zero-till movement on the Prairies.

Bob McNabb

Minnedosa, Manitoba

Bob McNabb of Minnedosa, Manitoba did not originally set out to be a farmer; he had different plans. After high school he attended the University of Manitoba in Winnipeg and completed a four-year Bachelor of Science in animal science with a plan to go into veterinary medicine. However, at the end of his undergrad degree he lost interest in vet school and turned his sights to the sky. Bob had a commercial pilot's license and worked in the aviation industry for eight years. When a job opportunity was offered in Edmonton , Bob opted to return to the family farm rather than live in a big city with his young family.

He returned to Manitoba to farm land his father had been renting out for several years. Bob recalls having nothing when he first started farming. The only money he and his wife had was spent on fertilizer. However, the choices Bob has made over the last 32 years have allowed him to remain in farming and quite successfully. Today, Bob can proudly say they own all their land.

Early motivation

For Bob "trying to kill weeds with a blunt instrument and watching the front wheel of your tractor go around didn't sit right". Therefore, he was open to different ways to farm his land and manage weeds. It was 1977 when he first recalls hearing about zero tillage.

During the 1978-1980 period, prior to the formation of the Manitoba-North Dakota Zero Tillage Farmers Association (ManDak), Bob attended informal gatherings in Brandon. These gatherings were the precursor to ManDak. The level of enthusiasm among all who attended was a strong motivation for Bob. "Even though we didn't know the answers (to zero tillage cropping issues), we continually experimented until we found what we thought were the best solutions." Being surrounded by like-minded individuals was very stimulating and encouraging to McNabb. He credits ManDak for helping him get through the early years of zero-till adoption.

Fellow zero-tillers Jim McCutcheon and Gordon McPhee were also a source of inspiration for Bob. In fact, there was a key group of individuals that Bob credits: Elmer Stobbe, Dave Donaghey, Owen Beaver, Bob Bradley, Joe Breker, Garth Butcher, Robert Stevenson, Carl Fanning and Lyle Samson to name a few. These individuals were all strong proponents of zero-till and some suffered criticism from their peers for supporting zero-till. Bob thanks all of these individuals for their efforts; for him they were part of making zero-till possible. The collaboration between Manitoba and North Dakota was a "nice synergy" which moved zero-till forward in Bob's opinion.

Major issues, barriers and solutions

Like many early zero-till innovators, Bob identified the high price of glyphosate as a drawback to zero-till adoption. And like many farmers, he worked hard to find a way to use the product in the least-cost and most-effective manner. For McNabb that was "1/4 L per acre mixed with 2-4,D or Banvil". He knew this was "off-label" and considered illegal, but he had to make things work and doing things "outside the envelope" was his way to learn.

A greater drawback for McNabb was the mental struggle that he faced in his third year of zero-till. Bob didn't switch all of his acres to zero-till at once. He started with one quarter, then sowed half of his section with no tillage in the following year and by the third year he had converted his entire section of land to no-till. . The reason for the gradual shift was that Bob did not own a suitable seed drill, he rented a British-built Melroe-Bettinson triple-disc drill from the local dealership in his first year of zero-till. He was "so impressed (with the results) it was like baiting a hook and the next winter (he) bought that very drill." McNabb used that drill for the next 13 years (until 1982), then he purchased a hoe-press drill which he still uses today.

The first two years in zero-till were quite successful. In the third year he was faced with a wet, late spring. McNabb still remembers the mental struggle of waiting around while conventional farming neighbours were out on their fields. He was in "a high state of anxiety" when one day his father came over to chat. His dad asked Bob if he had made money or lost money zero-tilling over the last couple of years. Bob replied that he had not lost money. His dad simply said, "Then get on with it". For Bob this was his "TSN Turning Point"; his father's affirmation pushed him "off the fence" and made him commit to zero-till farming.

Key milestones and overcoming prevailing thinking

In the early days it took persistence to get acceptance from the farming community and eventual widespread adoption. One story Bob shared was ManDak's efforts to find sponsorship for their zero-till manual. The first manual used a photo taken on McNabb's farm for the cover. It was a photo of two John Deere combines harvesting a field of zero-till barley. When it came time to publish a second manual ManDak approached John Deere to see if they would like to be a sponsor given that their machinery was featured on the first manual's cover. ManDak's request was turned down. The same photo was used for the second manual, but an inset photo was added to cover up brand name equipment from the cover (see figure 8.2).

McNabb views the big mainstream manufacturers' initial distaste with zero-till as "understandable". "Zero-till was not viewed as being good for the long-term (economic) health of (mainline manufacturers) at that time." This perspective was fairly common; zero-till threatened the lucrative equipment market for conventional

Figure 8.2. ManDak's Zero-Till Manuals

Source: Bob McNabb

tillage. The hesitation by mainline companies, however, provided an opportunity for small manufacturers to come up with designs and develop fairly significant businesses (i.e., Flexi-Coil, ConservaPak, Bourgault, SeedHawk).

Bob also vividly remembers a speech his wife gave to some other farm wives. The speech was on their experiences and views of zero-till. In her speech Elaine shared stories about comments she had received regarding the farmÕs zero-till fields. A neighbour from whom the McNabb's rented land had asked Elaine if Bob had lost his mind. Even the McNabb's own children were concerned. One morning as Elaine drove the kids down the lane to meet the school bus one of the four McNabb children asked "Mom, do you think dad screwed up again?" Bob laughs whole-heartedly when he retells these stories.

Overall, the criticism and skeptics did not bother him. He had "an intense desire to make (zero-till) work…" with "…a great backup of friends and peers trying to do the same." The McNabb's phone bill in those days was testament to the fact that a strong network of zero-tillers was emerging and eager to share their experiences while encouraging one another to keep up with zero-till.

McNabb cannot say enough about ManDak's role in advancing zero-till. "If you were on the executive or board (of ManDak) it was a wonderful time to share and understand what was going on in different parts of two countries." He is pleased with ManDak's focus, even as the smallest of the three main Prairie soil conservation associations. ManDak still remains strong today. In fact, the association is in the middle of writing its third zero-till production manual.

McNabb credits ManDak's decision to host its annual convention in Regina in 1987 as the move that got Saskatchewan on board; "that to me was the turning point for the Prairies." Bob recalls that it was not a unanimous board decision to host the convention in Regina, but the "turn out" was phenomenal. He still remembers a moving speech given by Jim McCutcheon at the convention. The speech was on herbicide pricing and Bob considered the speech "very motivational" for all in attendance.

The future of zero-till

Bob made reference to a book he is now reading for a third time – *Topsoil and Civilization* by Carter & Dale (1995) – as a key driver for continued conservation efforts in agriculture. As McNabb interprets the message in the book, "farmers and society need to continually find ways to be sustainable in order to avoid following the path of every civilization before ours". All past civilizations have only survived for about 1500 years and every decline can be traced back to a loss of topsoil and productivity (self-sufficiency).

Conservation tillage and zero-till are definitely a step in the right direction, but the system's heavy reliance on fertilizer and herbicide inputs concerns McNabb. He points out that monoculture cropping, evident in the US' corn-soybean rotation, as a troubling concern.

McNabb has tried his hand at a potentially more sustainable approach called "pesticide-free production". He was part of a group of farmers interested in having four to five year rotations that included a "pesticide-free" year of production. They were convinced some consumers were looking for a product (rolled oats, flour, flax) like this; "knowing it was certified as being grown without the use of pesticide." This is not organic farming, but could be described as an organic-conventional (zero-till) hybrid. Unfortunately the group disbanded after three or four years; it seems finding a buyer willing to pay a premium for the "specialty" crop was not possible.

Bob is confident, however, that the day will come when pesticide-free production does have a place in the market. Consumers are increasingly more aware of where their food comes from. There is also a growing population of individuals that have strong, negative reactions to certain chemicals, scents and food ingredients. These individuals are sourcing very specific food items that meet specific production criteria (i.e. free of hormones, lactose, gluten, pesticides). Perhaps McNabb was simply ahead of his time, much like he was with zero-till, and pesticide-free production will become a common practice.

In terms of further conservation tillage and zero-till adoption Bob hopes he has another opportunity to be involved in international projects that bring conservation agriculture to subsistence farming. McNabb has twelve years experience volunteering in Zimbabwe.

Nationally, he believes economics and the demonstrated lower costs of production will continue to drive further zero-till adoption. Technological advances like the use of GPS to seed between rows of stubble and variable rate fertility are just a couple of examples of how zero-till will continue to make producers more efficient.

McNabb is proud to be a farmer because of farmers' ability to innovate and make things work. Zero-till is a classic example of farmers thinking, building, creating and achieving. Bob is confident that agriculture is on the road to sustainability as long as we work with nature rather than always trying to change it.

John & Shirley Bennett

Biggar, Saskatchewan

Near Biggar, Saskatchewan John Bennett and his wife Shirley have been practicing no-till for the last 30 years (see figure 8.3). Being the first farmer in his area to practice no-till, John said he made the choice to move away from conventional tillage after spring rains caused major washouts on his clay-based, hilly soil. Bennett recalls asking neighbours what he should do about the erosion, their response was "[j]ust run a rod weeder across the washouts a few times, they'll fill in and you can farm through them". For Bennett, this would not do, so he set out to find a way to improve moisture retention. His solution was to leave his stubble standing rather than cultivating it under so that it could catch and trap snow.

Figure 8.3. Photo of Bennett farm.

Source: Photo provided by John Bennett.

The transition from conventional to no-till farming was easy for Bennett because he was open to new things and unlike his neighbours he "didn't have a farm background" so he "hadn't bought into the [conventional] system". Without the "baggage of a long history in conventional tillage" Bennett said he had a sense of objectivity and was able to review things and consider major change. Bennett had grown up in Alberta where his father was a school principal. In fact, both John and his wife were schoolteachers for five years before they started their dream of being farmers. John feels that because farming was his second occupation he was willing to change and could be objective about the inherent problems with conventional tillage. John found that objectivity with one other group – retired farmers – "they were finished their farming careers so they had no need to be bought into it any longer so it allowed them a bit of objectivity" and willingness to review and consider alternate options.

John became a member of the Manitoba-North Dakota Zero Tillage Farmers Association (ManDak). After attending some of the association's meetings he decided no-till was worth a try. John joined ManDak because the Saskatchewan Soil Conservation Association (SSCA) had yet to be formed. Even after SSCA's formation in 1981 John maintained his allegiance with ManDak. However, in recent years he has been both a director and president (2001-2002) with SSCA.

Bennett converted all of his acreage to no-till in the first year he tried it. He used a 16-foot Haybuster 8000 drill to seed his six-quarters of land. John recalls the troubles in the early days of conservation tillage where farmers struggled with equipment and often resorted to modifying and building their own prototypes. Bennett said he "was absolutely fortunate that [his] first drill worked."

Innovator versus early adopter

John says he is not an early adopter, he is an innovator. He is correct. In the adoption life cycle, innovators are the first to adopt a new technology. Innovators take the risks and they mistakes and they deal with the losses from those mistakes. Innovators are ideologists experimenting not for profit but because they like an idea. As an innovator, John was the first in his area to pursue no-till. He remembers the variety of responses he received from his new farming practice. His own brother-in-law predicted he would be broke in a matter of years.

One memorable moment that has stuck with Bennett was the day he walked into the local John Deere dealership – Biggar's "coffee row" – to purchase a bearing. When John entered the front door the whole place went silent. "I knew the reason it went silent, because they were talking about me!", John recalls jovially, "And it was probably because I was (considered) a loony."

Despite being ostracized, Bennett stuck to his plan of no-till farming and within three years three of his neighbours also started no-till farming. In John's view these farmers were the early adopters, the "second string", "the ones that really spurred widespread adoption". These early adopters were viewed as "good operators" by everyone in the Biggar area and "in essence once they made the switch into no-till the world changed. It's easier to discount a 'fringe loony', but when your 'avant garde' makes a move, everybody looks. That was a quantum leap."

John has done some thinking on why neighbours wanted him to fail and in retrospect it is very easy to understand. As John saw it, if he succeeded with no-till "they would have to acknowledge what they were doing wasn't right." They would have to acknowledge that conventional tillage – a system they had been perfecting and finessing for generations was wrong. Farmers "should feel reluctant after they have spent a tremendous amount of energy finessing a system and then are expected to abandon it for a system where very little is transferrable and a great deal is unknown. It is a frightening thing."

No-till knowledge mobilization

When asked about knowledge sources on how to no-till John says it was mostly farmers sharing with each other. There were tours organized by the local agriculture extension representative that would bus around a few dozen farmers to look at fields where no-till was practiced and the no-till farmer would share his experiences. John and his neighbours took these tours one step further, they organized the "No Tillers No-Till Tour". "[T]he rules were show us what worked the absolute best and show us your worst wreck." Through frank and honest sharing of their experiences John and his no-till peers built a growing pool of information and improved results.

Farmers were the first to share knowledge on no-till practices, but John is well aware of the importance of the ag research stations who carried out field trials to examine the science behind no-till. Bennett gives credit to researchers Guy Lafond and Doug Doerksen who explored no-till even when they were told their careers were at risk. Bennett understood that the science to back-up farmers' claims would take some time as field trial replications over several years are part of the process for achieving scientific rigor. In the meantime, farmers continued to share with each other and according to John "farmers have the most faith in other farmers" especially when it comes to unchartered territory such as no-till.

Farm meetings were a major way to spread the word about no-till. During the 1980s when high interest rates were threatening the livelihoods of farmers they were looking for a way to be more efficient and more economical. At one meeting, John shared a major benefit (or by-product in his conservationist mind) of his no-till system – "I put 200 hours a year on my tractor." In fact, John still farms with the three tractors he started with. The farmers at that meeting were doing the math in their heads and "they knew they put 600-800 hours per year on their tractors. All of a sudden that was completely tangible to them. Soil structure, moisture infiltration, snow catch – those were not tangible." The buy-in for no-till was growing.

At one of SSCA's first few annual conventions the thirst for knowledge by the farming community began to really show. John recalls radio announcements warning that if you did not have a ticket for the convention you would be turned away, there would be no walk-in registrants because the meeting room was at full capacity. At one of these sold out conventions John told the story of how he silenced coffee row in his hometown and the crowd broke into laughter. For John this signalled "the tipping point where [no-till] was on its way."

When asked what the key drivers for widespread adoption of no-till were, Bennett identified three things: declining glyphosate prices, turn key seeding technology, and a pool of information. John still has negative memories about the exorbitant price Monsanto used to charge for RoundUp. Chemical burnoff was critical to the success of no-till, so until the price came down he learned about blending down from his ManDak friends; "0.3 L of RoundUp and ammonium sulphate to make it work".

Came for economics, stayed for conservation

John Bennett is not your typical farmer, he considers himself a "rabid conservationist". Even with the high price of glyphosate and imperfect seeding equipment John stayed committed to no-till because of the improved productivity and reduced soil erosion on his land.

Most of John's neighbours bought into the system for its economics, increased efficiencies and increased productivity. John estimates that even with "75% of the right pieces in place [for no-till]…you were about on par with the conventional guys." This meant that with every year of experience and each improvement in equipment, no-till would gain on the conventional system. In John's words no-till's "increase in productivity and effectiveness actually made [him] a competitive farmer on a smaller land base". Even though John's neighbours took up no-till for the economics, "they became conservationists. And some of these guys are now tough on their neighbours who do not practice no-till."

The advent of the pulse industry is another benefit from no-till. John hails no-till as the driving force for his start into growing pulses. Crop rotations were key to the success of no-till; "the guys that failed early on in no-till were trying to continuous crop wheat and disease killed them." John remembers thinking how he could seed into stubble and he could combine, but he felt his crop rotation was not good enough. Growing peas was his solution and like many others have said, John feels "the pulse industry is an off-shoot of no-till." John explained how one only has to look at the change in wheat, canola, flax and pea acreage from 1969 to now to see the diversity that the no-till system created. Wheat acreage is down 47% since 1960 while canola acreage has increase fourteen-fold and pea acreage has gone from 3,000 to nearly 3 million acres in Saskatchewan (Statistics Canada).

Closing comments

No-till has been successful for John and Shirley Bennett. When asked for some advice for technology transfer efforts in developing nations, John stressed the need for research scientists to support the early adopters. "[I]t is absolutely imperative that if you are going to change a system, that the first guys succeed. If they don't it sets you back a long, long way." Bennett recognizes the potential to really increase the adoption rates abroad because of the technology and knowledge available after 30 years experience here in Canada. When Bennett was starting out in Saskatchewan it was much different, the knowledge came from farmers not from researchers. Bennett still stresses the need for farmer bonding and trust and sees this role being played by farmer co-operatives. Through proper support no-till can even flourish in places of subsistence agriculture like Africa.

A driving force for further adoption of no-till in Canada and globally will be the conservation benefits, which John truly believes are going to be increasingly important in coming years. As it turns out, this Saskatchewan farmer was ahead of his time, taking the steps to change the way he farmed his land 30 years ago in order to protect and conserve the soil.

Lucien & Hervé Lepage

Montmartre, Saskatchewan

Lucien Lepage farms with his brother Hervé near Montmartre, Saskatchewan which is situated 80 kilometres southeast of Regina. This year marks their 31^{st} year in no-till production. Like many other early adopters, the Lepage brothers experimented with no-till on one section before converting all of their land to no-till. The impetus for their foray into no-till was wind erosion. Their first section of land sown under no-till was light, sandy soil described by Lucien as "very erodible" (see figure 8.4). Early results with no-till were impressive. Despite issues with seeding equipment and herbicides, continuous cropping was achieving "the same yields as summerfallow". With yields matching summerfallow the Lepages felt confident that no-till had merit and they had proof that land did not need "rest" if properly managed.

Figure 8.4. Water erosion in Lepage field.

Source: Photo provided by Lucien Lepage.

Equipment and other obstacles

The switch to no-till was not without its problems. The Lepages had to make due with the equipment that was available. They “bought a set of Haybuster no-till drills in 1979” because “there was nothing on the market other than the Haybuster drills with a disc-type opener.” They did experience problems with disc openers – “they were high maintenance machines with poor seed placement because of hair pinning”. Ten years later they made a switch to Jim Halford’s ConservaPak air-seeder.

Lucien explained that he and his brother “were one of the first to buy [Jim Halford’s] seeder with a hoe-type opener.” Lucien feels very fortunate to have farmed where he did – in close proximity to Jim Halford and the researchers at the Indian Head Research Station. And he gives a lot of credit to Jim Halford and Guy Lafond for the start of the Saskatchewan Soil Conservation Association which further assisted to the widespread adoption of no-till.

In addition to opener issues, Lucien identified (the price of) RoundUp as one of his biggest barriers. He recalls paying $32/litre for the herbicide. The recommended application rates were 1-1.5l/ac or up to $32/ac for weed control; “this was a major drawback to the adoption of no-till in western Canada”. Lucien is not alone in this feeling – nearly all the early adopters interviewed for this book mentioned the exorbitant price of RoundUp being a major drawback. More than once Lucien made the point that Monsanto did not know the product they had – the efficacy and potential of RoundUp. The Lepages – like many other farmers – used “off-label” rates to make no-till economically viable. They needed the weed control but risked applying the herbicide at lower than recommended rates in order to remain profitable. Lucien also talked about investing in a sprayer with covered booms and high-pressure, low-volume nozzles to apply the herbicide at rate of 0.33l RoundUp to two gallons water. The lower rates were effective and as Lucien recalls “[i]t didn’t take very long after that for Monsanto to (register) the use of lower rates.”

Neighbourly influence

When asked if neighbours were supportive or questioning Lucien said he could write a book about his experiences. “Right off the bat, [neighbours] were raising eyebrows. I could tell you all sorts of stories….” Reflecting back now, Lucien realizes the reactions of neighbours are typical human nature when something is “new”; people would say “What are you doing?”, “You can’t grow a crop like that”, or “You’re going to lose the farm.”

As an early owner of a ConservaPak seeder, Lucien also became an employee (of Jim Halford and ConservaPak) which provided him several opportunities to speak about no-till and ConservaPak across western Canada. Through his speaking engagements he observed that the older generation seemed more reluctant to consider no-till. “Zero-till changed agriculture, it did a 360-degree change…you take an older generation, their mentality is wheat-barley rotations on summerfallow.” Under no-till, doing away with summerfallow and seeding canola, flax and peas was not acceptable (to the older generation), it was too drastic a change for some to grasp.

Challenging beliefs

Lucien worked for ConservaPak for ten years, delivering countless presentations on change and the merits of no-till production. He remembers one meeting in particular, 30 minutes into his presentation someone in the front row stopped him and asked, “Are you trying to tell me that everything my dad taught me about farming is no good?” This is a strong example of the challenges to one’s beliefs that no-till created. It is a major disruption to one’s beliefs if all they have ever known is conventional agriculture and summerfallowing. Lucien replied to the individual that conventional agriculture did work, but times and equipment were changing and by making adjustments you could make better use of your land and help in the prevention of soil erosion, which had a huge impact on the environment. In all his presentations Lucien tried to pitch his talks as introductions to something different for people to consider.

Summerfallow was always a point of contention during his presentations.. The belief that land needs “a rest” was well-established and very few were willing to contest such a well-founded belief. How does one delicately broach a subject that very few are willing to negotiate on? Lucien’s approach was to ask people to consider their pasture and the lawn surrounding their home – “Pasture grows year after year…you don’t rip up your lawn every second year, yet it always grows.” By sharing simple facts, Lucien worked to help open the minds of Prairie farmers to the idea of modifying their existing beliefs and consider change.

Lucien admitted zero-till challenged his own beliefs. When the Lepages first started no-till farming Lucien said “it drove [him] nuts because you can’t see anything [sprouted plants] until July.” Lucien recalls going out in his fields on his hands and knees scouring for seedlings. The visual affirmation that your seeding efforts paid off is camoflauged by the standing stubble, which can be unsettling when across the road your neighbours’ cultivated fields seem filled with new plant seedlings.

Spreading adoption

Lucien estimates it took five years before other farmers in the area began no-tilling. He referred to the technology adoption lifecycle – innovators, early adopters, majority and laggards – when describing the adoption process. Similar to comments made by John Bennett, Lucien said “[i]t depends who in what area picks it [zero-till] up. If it's a guy in the community that is considered to be a good farmer it will pick up faster compared to somebody that you are unsure if he knows what he is doing."

The Lepages are innovators in the technology adoption lifecycle; the local zero-till "guinea pigs" that others watched before making the switch themselves. In the fall , family and friends would ask the Lepage brothers what their crop yielded. "If you tell them it did 30 bushels per acre they would look at you like you were lying." Others asked to drive through the Lepages fields and afterward would complain about the roughness. Lucien joked that people made a mistake, "when [they] asked to drive through my field, what [they] should have done is tapped on my bins. They were full and that's what counts. It's what you produce and at what cost."

The economic benefits from no-till have been substantial. Lucien estimates their switch to no-till likely reduced fuel consumption on their operation by 40 to 50 percent. He still has the same tractor from when he started zero-till – a 1980 Versatile – that gets used 250 hours per year. Another benefit has been their expansion into canola and pulses which has diversified the Lepages earning potential and cash flow; "I derive most of my income from non-board grains…wheat and barley are 'filler' crops for rotations."

The tipping point

Lucien's source of no-till information was from ConservaPak (Jim Halford) and the Indian Head Research Farm (Guy Lafond and crew). The Lepages were also very fortunate to have the Indian Head Ag Rep office of Saskatchewan Agriculture & Food (namely Larry Koturbash, Doug McKell and Ed Tanner). Lucien was also pleased with the resource people associated with the Save Our Soils (SOS) program.

When asked to identify the most important milestones that drove widespread adoption, Lucien said it was the development of equipment by multiple manufacturers. In Lucien's opinion, most of the companies' equipment developments were a result of ConservaPak's leadership.

The future

Lucien still comes across summerfallow fields during his travels while cleaning farmers' seed each spring (with his seed-cleaning business). If he was to wager a guess on the owner of those fields he would say they are older farmers who "have it in their mind that they cannot no-till because they don't get enough rain. It's a mental thing." Despite years proof that no-till works, Lucien feels there are some who are still not ready to modify their established belief that summerfallow is paramount to annual cropping.

When asked about the need for government policies or programs to drive further adoption, Lepage suggested fair compensation for environmental benefits derived from no-till such as carbon sequestration. In the past, Lucien has sold (carbon) credits to an aggregator, but he does not feel the compensation was adequate to entice him to participate again. "A better policy could be fair compensation for what farmers are doing environmentally. How much is farmers' adoption of no-till worth (to society)?"

Lucien and Hervé Lepage saw past skepticism from neighbours, imperfect equipment and an exorbitantly priced herbicide (as necessary) in order to save their soil. They even had to overcome their own beliefs and trust their instincts that no-till would not only work but would outperform conventional tillage. The Lepages are proof that access to information and support are invaluable in driving change. Their close proximity to resources at Indian Head – Jim Halford and the Research Station – were key in their early success with no-till.

Gerry Willerth

Indian Head, Saskatchewan

Gerry Willerth did not have aspirations to be a farmer – he wanted to be an engineer. However, a couple of years into his engineering degree he changed his mind and six years later he found himself farming near Indian Head, Saskatchewan. It may seem peculiar that two of the early adopters featured in this book are from the same area – Mr. Willerth and Mr. Lepage – but it shouldn't, early adopters from around the same area suggests that the zero-till movement had "hotbeds" across the Prairies and adoption radiated outward from these "beds". Indian Head could easily be considered one of the "hotbeds" for zero-till activity; it is home to an AAFC Research Station and the founder of ConservaPak (Jim Halford).

Gerry's farmland was "really heavy clay, which is fine like flour when it is dry." Willerth remembers tremendous dust storms in the years before he started no-tilling. One day in particular he had been discing a field and after a couple of rounds he turned his tractor and noticed the wind had blown away his tracks so he could not see where he had just worked the field. He quickly realized he was losing soil – and lots of it.

First comes conservation tillage

A blowdirt ridge between his and his neighbour's farm is what inspired Gerry to find ways to save his soil. The ridge was so high that three fences had been built – one on top of the other – as blown topsoil accumulated over the years. He knew there were three fences because over a 20-year span Gerry worked that ridge down and distributed the soil on his fields. Then with the help of the PFRA (Rudy Esau), Gerry planted shelterbelts on his land and stopped his wind erosion completely. This was the start of Willerth's conservation agriculture approach to farming.

Gerry explained that it wasn't until the 1970s that he began to hear about ways to eliminate summerfallow. He says his wife used to joke about "recreational tillage" being Gerry's way to have some alone time from family commitments where he could just relax and get away from it all. Managing summerfallow became more than a recreational activity; Willerth recalls some years working the land nine times to control weeds. It was costly and time consuming, not to mention the moisture depletion and potential soil degradation caused by all the cultivation. Gerry looked into chem-fallow, but it was just not affordable; "I remember the first jug of RoundUp I bought, I paid $60 for this little tiny jug and I used it around the yard…there was just no way you could put it on the field, it was just way too expensive."

As Monsanto lowered its price Gerry used RoundUp on conservation tillage summerfallow for a number of years. It was not until the early 1980s that he made the switch to no-till. He did not make a full switch away from conventional tillage. Using the subdivided fields created by his shelterbelts, Gerry tried one 80-acre field the first year and then expanded to another field the following year and so on. "I started small and then worked my way…I didn't have the equipment to do it so I could only afford to do it on a little land base, not the whole farm." In fact, Gerry and some of his neighbours leased equipment from Haybuster to seed in those early years, "but it was the wrong type of machine (for their conditions). It was a disc-type machine and it just didn't work."

While the price of RoundUp was still quite high, it was still cheaper for Gerry to spray his fields twice versus making nine cultivator passes. Besides the high chemical price, his main problem was the inferior equipment. He mentioned the shortfalls of the seeding and sprayer equipment and the general lack of experience and expertise on how to spray weeds that were sometimes as tall as the sprayer.

ConservaPak connection

Gerry and Jim Halford were classmates in school growing up and they both started farming about the same time. Willerth knew Halford was working on developing a machine to help solve the water erosion problems plaguing Jim's rolling, loam soil situation on the edge of the Qu'Appelle valley. Gerry "used to go down and see what he [Halford] was doing. It was a little bit primitive because we didn't have zero-till machines". With the abundance of trash left on the fields after harvest disc machines (like Haybuster's) were not working, Halford was developing "a cultivator-type machine with a shank. He needed some other place to try it since it would work ok on his land, but when he brought it to my farm it didn't work well ,and wasn't the proper design". The heavy clay (at Willerths') plugged the packer wheels forcing Jim to go back to the drawing board. Modified prototypes continued to be tested on Gerry's land by his childhood friend. After Halford perfected the machine, Willerth purchased a seeder and continued to used it successfully until he retired from farming.

Peer pressure

Gerry admitted there was peer pressure as an early adopter of no-till; "You didn't want to be sticking out like a sore thumb." Unfortunately for Willerth, his farm "was right on the main road, whatever I did, all my neighbours saw." However, having Jim Halford as a close personal friend had to certainly help Gerry deal with any questioning glances and remarks he received from passersby.

Getting info and getting involved

Gerry fondly recalls the support he received from the Indian Head Research Farm and in particular from Dr. Guy Lafond. Willerth remembers going to meetings with

Jim Halford to gauge the need for a conservation association in Saskatchewan. Gerry was part of the founding members of the Saskatchewan Soil Conservation Association (SSCA) and he eventually went on to become President in 1993-94. He later became President of the Soil Conservation Council of Canada (SCCC) and was inducted into their Conservation Hall of Fame in 2000.

The speed of innovation

Gerry feels no-till adoption could have moved faster, however, key dynamics held progress back. He feels the lack of formal education among many farmers hindered their willingness to consider the new technology. This may not entirely have been an education barrier, but simply human nature at work. Gerry went on to say "[farmers] get entrenched in a system and it is very hard for them to change. You have to prove to them not once or twice, but ten times that it actually does work." This notion of being "entrenched" in a system and a reluctance to change is a problem for most people. Gerry is correct that farmers using conventional tillage had a natural resistance to no-till because they had become entrenched in the current and accepted method of summerfallowing. As noted by most of the early adopters interviewed for this book, conventional tillage and summerfallow were the norm and believed to be necessary practices for growing crops in this region.

This proposed idea of no-till challenged this belief, which caused many farmers to react negatively. Gerry may be correct that the lack of education did play a part in slowing the adoption of no-till, but also at play was human nature's reluctance to embrace a major change.

Gerry also mentioned the fact that the whole system had to change if you started no-tilling – "every piece of machinery I had with the exception of the combine had to change." This was very prohibitive and farmers who tried adding one or two pieces had to add the right pieces first – the seeder. Gerry corrected himself after saying "seeder", "even before that you adapt your combine (with a better straw spreader) so the trash does not become a problem."

The future

Gerry Willerth adopted a conservation agriculture systems approach to farming. First, he planted shelterbelts to reduce wind erosion, and then he used chem-fallow to conserve moisture and reduce fuel consumption. Finally, when seeding technology (suitable for his soil type) had been developed by a childhood friend he made the full conversion to no-till farming.

As for the future of no-till and the potential for further adoption in Canada, Willerth feels there is some research that can be done to promote adoption in areas such as the Red River Valley; "I just don't understand if the technology hasn't been tried or if enough experimenting research has been done in that area."

When it comes to acknowledgement for farmers' efforts thus far, Willerth praises the SSCA and SCCC for promoting agriculture's contribution to soil carbon retention. With the government now on side and "going green" growing in popularity, Willerth is hopeful that farmers will eventually receive recognition and fair compensation for their conservation efforts through mechanisms like carbon credit trading.

Ike & Rod Lanier

Lethbridge, Alberta

Ike Lanier has operated "NeverIdle Farms" eight miles SE of Lethbridge, Alberta since 1955. For the past 30 years Lanier has been practicing various minimum tillage and direct seeding systems with his son Rod. Their land (3300 acres) is primarily classified as a sandy-loam which makes it very workable but also very susceptible to wind erosion. Today their rotations include winter wheat, durum, peas, flax, canola, mustard and safflower grown on both dryland and irrigated land. Their equipment is kept to a minimum and includes only a 32-foot air disc drill, a 4-wheel drive tractor, a sprayer and a combine with a stripper header. Conservation tillage has had a major impact on the crops they grow and the equipment they use. More importantly, they believe that they have developed a more sustainable and profitable crop production system.

Early motivation

Like most farmers in southern Alberta, Ike's father had good success for many years with the traditional cereal-fallow system. But, with drought and wind erosion problems in the early 1960s Ike began questioning the merits of their traditional summerfallow practices. His first experience with direct seeding was when he tried seeding winter wheat (with a conventional hoe drill) directly into stubble from a poor wheat or barley crop. He knew that if he cultivated these fields (with little or no crop residue cover) they would blow. He also thought direct seeding would help ensure a moist seedbed for good germination of his winter wheat. This practice (for winter wheat) was so successful that he tried direct seeding for spring cereal crops. Although he didn't like the high cost of chemical weed control (particularly in the early years), he generally found the benefits of moisture conservation and higher yields (with direct seeding) more than offset the higher costs of herbicides and fertilizer inputs. By the mid-1970s he was convinced that little or no cultivation was necessary. His only use of fallow was chemical fallow before canola in his canola-winter wheat-fallow rotation. Ike was also encouraged by what he was hearing from a few other innovative no-till farmers and the positive results from early experiments at the Lethbridge Research Centre.

Major issues, barriers and solutions

Like many of the early no-till innovators, Ike recalls a few problems with weed control in some years and learned to monitor each field regularly, keeping good records (Rod does this better) and ensure timely application of herbicides (including fall application for perennial weeds). He also learned that crop residue management is critical, beginning with the harvesting operation, so as to minimize seed placement and fertility problems. Although he was able to get by with conventional hoe drills with specialized openers for a few years, he realized he needed to invest in heavier or more specialized no-till drills. Thus in the early 1980s Ike decided to sell all of his tillage equipment ("while he could still get a good price", he said) and invest in suitable no-till seeding equipment and a good field sprayer.

After using 1970 International hoe drills (with a 10-inch row spacing) for a few years he purchased a series of more specialized Haybuster 8000 hoe drills in 1987 that had better trash (crop residue) clearance and more effective seed (paired-row) and fertilizer placement capabilities. These drills worked quite well for several years but required periodic repairs and more specialized furrow openers. Ike said he was fortunate to have a neighbour like Henry Bergen who owned a machine shop (Gen Manufacturing) nearby in Coaldale.[1] Bergen provided Ike with various innovative designs of hard surfaced (carbide) furrow openers that Ike and his son Rod have used for more than 20 years on various seed drills, anhydrous banders and air-seeders. In 1992 they purchased a 28-foot Flexicoil air hoe machine that worked well until they started leaving taller stubble and using the stripper header. In 2002 they purchased a 32-foot John Deere air disc drill that continues work very well and does not plug in the tall 24-inch (60 cm) stubble left by the stripper header.

When asked if he was ever influenced or concerned about the opinions of his neighbours or some of the early critics of no-till, Ike said "no, not at all". "I knew there were some sceptics at the local coffee shops so I just avoided those coffee shops." Ike recalls one story when a neighbour saw him (Ike) on his hands and knees checking out his plant stands. The neighbour proceeded to tell the coffee shop crowd that "no-till had finally brought Ike to his knees!" Ike said, over time the critics have become silent given that none of the early "dire predictions" associated with no-till farming seemed to have materialized. "In fact, direct seeding is pretty much the norm these days."

Key milestones for the conservation movement

Even Ike has been surprised by the widespread and successful adoption of direct seeding and no-till on the Prairies and a 70 percent reduction in summerfallow. But he is not surprised that it took more than a generation (25+ years) to become widely accepted. There was little incentive for the major machinery manufacturers to develop no-till seeding equipment given their investment in traditional ploughs, discs and cultivators. With the relatively small market and limited demand for no-till drills, only a few small or short line manufacturers, like Haybuster, were

[1] Editor's Note - Henry Bergen's inventions have been recognized with awards from the Public Service of Canada, the Alberta Society of Engineering Technologists and the Canadian and American Societies of Agricultural Engineers. He received the Alberta Centennial Medal in 2005, became a Member of the Order of Canada in 2006 and received an Honourary Doctorate from the University of Lethbridge in 2008.

interested in developing suitable equipment. He was concerned when he saw that some Alberta farmers were buying the very heavy and very expensive ($250,000 plus) Yielder Pioneer no-till drills being manufactured in Washington State. The apparent acceptance of these very expensive drills provided an incentive for some prairie manufacturers to begin development of more suitable and cost effective seeding equipment. Haybuster was finally getting some competition from Flexi-Coil, Bourgault, New Noble and Conserva-Pak.

Ike believes the two key milestones that stimulated greater acceptance of direct seeding in the late 1980s were the price drop of Roundup (with the patent coming off glyphosate) and the availability of good quality air-seeders for direct seeding. He also said "there was more good information coming from conservation groups like ACTS and commitment from government agencies after Senator Sparrow's *Soils at Risk* report in 1984." Success stories (with no-till) from well respected farmers throughout the region were being publicized at meetings and in the popular media. Ike gives credit to a number of influential farmers like Dan Stryker, Ron Svanes, Brian Noble, Brian Otto and the Mercers for their early leadership.

Ike does not believe that more government incentives or subsidies would have accelerated the conservation tillage movement. He says "the best thing government can do is stay out of the way" or "remove barriers to innovation". While he is a strong supporter of "public good" research he believes the regulatory review process (for pesticides and other agricultural inputs) is too slow and reduces the competitiveness of the sector.

Impact of conservation tillage and the future

Both Ike and Rod have seen major improvements in soil quality and productivity with the adoption of conservation tillage. In addition to the obvious benefits of soil and water conservation they have seen a dramatic increase in biological activity (earthworms, spiders and other insects) and associated increases in numbers of birds, migratory waterfowl and other wildlife. They credit the tall stubble and moist micro-climate for these important secondary benefits, particularly since they have been using the stripper header in recent years.

The tall 24-inch (60 cm) stubble traps snow, reduces evaporation and always seems to guarantee them a moist seedbed for the diverse range of crops they are now able to grow. They still prefer banding N fertilizer (anhydrous ammonia) in the fall and placing as much fertilizer with the seed as safely possible. Their favourite and most profitable crops include: safflower, peas, lentils, durum, flax, mustard and winter wheat. They have had good success in recent years with direct seeding using a John Deere disc-type air seeder. Ike and Rod believe crop rotations with cereals following pulse or oilseed crops have helped control pest and weed problems.

They both agree that the economic benefits (from labour and fuel savings) associated with direct seeding and straight combining with a stripper header bode well for the future. The ability to farm more land and get high value, high quality crops harvested and to market more quickly is attractive to producers who value the quality and independence of farm life. Rod Lanier is obviously proud that is father has been acknowledged as one of the early innovators and leaders of the conservation movement. Like his father, Rod receives numerous requests to host visiting farmer and extension groups from all over the world. Rod was recently invited by a large farmer association in the Ukraine to share his expertise and experience with conservation tillage. Although Rod learned a great deal from his father, he said he was fortunate to be able to participate in the regional ACTS and Reduced Tillage Linkages seminars and benefit from "farmer to farmer" information sharing and keep up on the latest industry and research developments. Also, like his father, Rod appreciates being close (10 kilometres) to the Agriculture Research Station and access to leading researchers and extension specialists. Rod also makes extensive use of the internet for information.

Both Ike and Rod continue to be optimistic about the future of agriculture. They are confident that being good stewards of the land will continue to be reflected in the quality and diversity of crops they are able to produce for growing global markets. Although Ike and his wife Diana are now happily retired from the day-to-day operation, they know "NeverIdle Farms" will continue to thrive in the good hands of son Rod and his family.

As further testimony to Ike Lanier's role as a pioneer of conservation tillage and impact on agriculture in the region he will receive an Honorary Degree from the University of Lethbridge at their spring convocation in 2010.

Murray Sankey

Veteran, Alberta

Murray Sankey has a 17,000 acre (6800 ha) mixed farm near Veteran, Alberta which is a small rural community about 300 km northeast of Calgary. Since much of the land in the area is most suitable for grazing or improved pasture, many of the farmers or ranchers in the area have livestock. In Murray's case his livestock operation includes 400 beef cows and 200 head of bison on about 13,000 acres of pasture. Although he doesn't consider himself an inventor or pioneer of no-till, like Dick Middleton or Gordon Hilton, he was definitely an "enthusiastic observer", "early adopter" or "risk-taker" in his words. Murray was also an active Director with the Alberta Conservation Tillage Society (ACTS) for many years before being elected President of the Society in the early 1990s.

Early motivation

Murray's early motivation for trying chemical fallow and direct seeding was his view that "there has to be a better way of farming" to reduce the continuous challenge of wind erosion on his farm and in the region. He recalls the little poem often repeated by his father and neighbours "if your land doesn't blow, your crop won't grow". When he took over the farm in the mid-1970s he became active with his county Service Board and was passionate about doing more to promote soil conservation (given the Board's responsibility for enforcing the Alberta Soil Conservation Act).

He first tried direct seeding himself about 35 years ago when he purchased a Haybuster 1206 no-till drill and successfully produced winter wheat in mustard stubble. After hearing about Roundup (glyphosate) herbicide combinations at a field day at the Lacombe Research Station he became excited about trying chemical fallow and no-till for some of his spring crops. He was also motivated by the success stories and "great courage" in his words, of the real no-till pioneers who became outspoken champions of the conservation movement. He gives a lot credit to Gordon and Spencer Hilton of Strathmore, Dan and Paul Stryker of Foremost, Bryan and Mark Perkins of Wainwright and Henry Graw of Manning for their early leadership and enthusiastic support.

Major issues, barriers and solutions

Murray said the biggest issue for most farmers was tradition or their belief that you had to cultivate the soil. But for him, it was cost-effective weed control, particularly with Roundup being so expensive (compared to tillage) at that time (1980). He and other farmers in the area believed they needed summerfallow in their rotation to conserve moisture and control weeds. At the time he could not afford to spray Roundup three or four times a year to control the weeds on summerfallow. But today, because of the decrease in glyphosate costs, Murray continues to have about 25 percent of his cropped land in chemical fallow.

The other major barrier was the lack of effective seeding equipment for direct seeding. He found the Haybuster 1206 disc drill (purchased in 1979) worked fine for a few years and then switched to Versatile-Noble hoe drills with the split-boot opener for seed (paired-row) and fertilizer placement. Murray could not justify the purchase of the expensive ($250,000 plus) Yielder Pioneer drills that a few of the bigger no-till farmers bought in the 1980s. He eventually settled on the New Noble Victory Seed-O-Vator air drill developed by Ray Dyken in Lethbridge. This machine worked well for Murray and several other farmers in the region and he was always pleased with the service and modifications provided by Mr. Dyken. He says machinery inventors and developers like Ray Dyken (Victory Equipment) and Fred Kellough of Kello-Built Industries (Stettler and later Red Deer) probably never received the credit they deserved in working with farmers to develop better equipment.

As for institutional or policy barriers, Murray was always frustrated with crop insurance because of the lower "coverage" associated with re-cropping. In his view, this policy encouraged summerfallow and discouraged direct seeding. He also said it took several years for the federal and provincial governments to support the idea of no-till and direct seeding. Fortunately, Senator Sparrow's task force report *Soils at Risk* in 1984 seemed to change all that.

"Although I may be biased" he said, "ACTS and the associated Reduced Tillage Linkages (RTL) program played a crucial role in increasing awareness and successful technology transfer of conservation tillage in Alberta." These and other groups clearly delivered on their mandate and he is not surprised that governments have chosen to support "new or different" priorities.

Impact of conservation tillage and the future

Murray feels very proud to have been a small part of the successful conservation tillage movement. Even though he didn't harvest a bushel of grain in 2009 (because of the drought in his region) he believes the widespread adoption of no-till on the Prairies has made it possible for him and thousands of other farmers to not only survive but thrive. He is able to grow a diverse range of oilseed and pulse crops like yellow peas that would not be possible in his region with conventional tillage.

His says with the challenges facing the livestock industry in recent years (like BSE) farmers have had to diversify and he believes those using conservation tillage systems have more time and ability to adapt. The word "problem" is not part of Murray's vocabulary, he says "there are always new challenges in life and in farming" and you have to be prepared to "adapt to these challenges."

Murray feels the "new" drivers for conservation tillage systems today are probably fuel and labour (time) savings. A single operator can easily manage 4000 to 5000 acres these days with size and technological advances in equipment. He says, with GPS, automated controls, new sprayer (and nozzle technology) precision farming and more straight cutting at harvest, he expects farm sizes to get larger and more efficient. He also expects more Roundup Ready crops, including cereals, and he is not concerned about the growing consumer demands for organic food or the anti-chemical lobby groups. He would like to see a more streamlined pesticide registration process so farmers can get quicker access to new products without compromising safety. He is concerned, however, about the often unbalanced media coverage of agriculture, particularly when the merits of organic and chemical farming are discussed.

Murray continues to be optimistic about the future for Prairie agriculture with the development of new crops and new technologies to produce them. He would particularly like to see more research and development for slow release fertilizers to reduce the need for fertilizer banding.

Chapter 9

Dispelling Myths and Making Progress with No-Till on the Canadian Prairies

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Introduction

The current understanding is that 99% of food consumed by humans comes from the land.[1] On a global basis, there are 1.351 billion hectares of land available for annual cropping[2] but 45% of arable soils worldwide are affected by one form or another of soil degradation.[3] It has also been estimated that every year, 2-12 million hectares of the world's arable land is rendered unsuitable for agricultural production from excessive soil degradation.[4] Wind and water erosion accounts for 84% of this degradation.[4] Given that Manitoba has 4.2 million hectares of arable land, global annual soil degradation is equivalent to 0.47 to 2.9 times the cultivated area of Manitoba.

For the Canadian prairies, uncultivated native prairie soils contained from 0.2 to 0.7 percent nitrogen and by the 1940s, barely 60 years after the first plough turned over the virgin prairie sod, 15 to 40 percent of it had been lost.[5] This trend continued so that, by the 1980s, most prairie soils had lost more than 40% of their initial organic nitrogen content. Thus good management to protect the soil against

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further degradation is critical to meet the world's future needs for food and fibre[6] and possibly fuel to meet increasing energy needs.

Another form of soil degradation is arable land lost to urbanization. In 2008, the world reached an invisible but important milestone. More that 50% of the world's population now live in urban areas.[7] In Canada, between 1971 and 2001, 1.2 million hectares of agricultural land was consumed for urban uses and 18% of Ontario's best Class 1 farmland is now urban.[8] Loss of land to urbanization also has important effects on watersheds, aquifers and micro-climates around large urban areas.

It is imperative that people do everything possible on a local, national and international level to sustain and enhance the global soil resource and that the knowledge and expertise gained on the Canadian prairies be shared freely with the rest of the world to ensure protection of the global soil resource.

Given that the major causes of soil degradation are wind and water erosion, it has long been known that the most efficient way to reduce or arrest this undesirable phenomenon is to maintain surface residues and standing stubble. In order to attain this desirable state requires the reduction or elimination of tillage, the adoption of continuous cropping practices, elimination of summer fallow practices, proper crop fertility, appropriate pest management practices, appropriate seeding equipment and crop diversity. These key factors have been well investigated and are the foundation for conservation agriculture on the prairies and else where.[9,10,11,12,13,14]

At the recent *Fourth World Congress on Conservation Agriculture* (CA) in New Delhi on February 5, 2009, Shivaji Pandey, Director of FAO's Plant Production and Protection Division, endorsed conservation agriculture as the key step to meeting the long-term global demand for food and feed. CA is defined as a farming system that does away with regular plowing and tillage and promotes permanent soil cover and diversified crop rotations to ensure optimal soil health and productivity.

It is important to realize that the adoption of CA was met with a lot of opposition at the start in part because it meant radical changes in the way that land was managed and a lot of uncertainty. A number of myths infiltrated the movement in its early beginnings, in part due to lack of knowledge and scientific speculation. The remaining discussion will attempt to outline and dispel these myths.

Myths about No-Till Dispelled

Humans are born with two innate fears, the fear of loud noises and the fear of falling. Unfortunately as humans mature, they also develop the fear of the unknown. Not to say that there may not be some justification for it, the fact remains that if we are ignorant of a concept, the human mind tends to gravitate to the worst case scenario. A good example of this was the recent experiments with the famous Hadron Collider, the biggest atomic particle smasher ever built. Concerns were raised that this experiment could potentially result in the creation of a black hole.[15] As it turns out, no such thing happened. The same can be said about no-till in the late 1970s. A large number of concerns were raised about the technology and many reasons were given as to why it would fail. As it turns out, these concerns turned out to be myths and one by one, these myths were dispelled and proven unfounded over time through sound field research, the collective experience and the test of time. An attempt is made to identify these major myths and show how they were dispelled.

Myth: Long-term Health of Prairie Soils

It was a myth to think that one could keep on managing our soils without regard to sustainability and expect them to keep producing like they had in the past. Agricultural managers could not see the devastating effects of wind and water erosion and the degradation from many of the production practices in use.[5,16]

The facts are that in order to sustain the prairie soil resource, a combination of no-till or conservation agriculture with proper nutrient management, continuous cropping and crop diversification is required. The good news is that these practices can actually improve the overall productivity of prairie soils.[17,18] David Montgomery said "History makes it clear that sustaining an industrialized civilization will rely as much on soil conservation and stewardship of the land as on technical innovation".[19]

Myth: Impact of No-Till on Soil Temperature

One of the first concerns expressed by producers with respect to no-till was the potential effects of lower soil temperatures on germination and emergence when residues are left on the soil surface. The sensitivity of germination and emergence to low temperatures, especially the temperatures observed in early spring have been well documented.[20,21] It was hypothesized that crop emergence would be delayed more with no-till relative than conventional tillage. Some of the first documented research on this problem in Western Canada did indeed show that surface soil temperatures were lower under no-till.[22] However they observed that when crop residues were burnt, there was no difference in soil temperature between no-till and conventional tillage but when the surface residues were physically removed from the soil surface, sometimes the soil temperatures were actually higher for no-till than conventional till. This was explained by the higher heat flow in the soil due to the higher soil bulk densities at the soil surface under no-till.

The ability to measure the agronomic treatment effects on crop emergence under field conditions without having to do repeated measurements was made possible by using a method for quantifying plant development in wheat[23] and combining it to research that showed that these plant development measurements were highly correlated to speed of emergence in wheat.[24] Given this method, the effects of tillage systems and crop rotations on crop emergence could then be evaluated under field conditions. Using this methodology, it was shown that no-till system did not delay the emergence of spring wheat because the plant development scores were the same among no-till, minimum-till and conventional-till systems. This was due in part to the shallower depth of seeding observed under no-till and the better surface soil moisture conditions. Of interest also was the fact that spring wheat emergence under no-till was the same regardless of whether it was grown on spring wheat and field pea stubble. In fact there was a slight delay in plant development when spring wheat was grown on conventional-till fallow compared to a full chemical fallow.

The impact of no-till on soil temperature was also studied using measurements of soil temperature and periodic measurements of crop emergence in the Dawson Creek area of British Columbia, a cold semi-arid climate, using different soil textures.[25] In this study they compared no-till (NT) with conventional tillage (CT) plus a modified no-till (MNT) treatment which consisted of pushing the crop residues aside from a 7.5 cm zone above the planting rows. The plots were seeded with a double-disk drill to minimize soil disturbance. The MNT and CT treatments showed higher average weekly soil temperatures than NT. When speed of emergence was measured, MNT was favoured over the NT and CT treatments and in many cases emergence was faster than for NT than CT. In general, barley growth was more retarded with CT than NT or MNT and canola emergence under MNT was favoured over CT under prolonged dry conditions and better than NT under extremely wet conditions.

Given the results from these cited studies and the collective experience during the last 20 years, the hypothesized negative effects of no-till lowering surface soil temperatures and delaying crop emergence has not materialized. The extensive use of the hoe openers, which in essence pushes the crop residues away from area above the seed rows combined with shallow seeding, may have indirectly contributed to avoiding these negative effects. This may also explain why no-till seeders with hoe-openers are by far the dominant seeding technology used on the Canadian Prairies even though numerous types of no-till disc seeders are available to producers.

Myth: Crop Residue Decomposition and Residue Accumulations under No-Till

Another common concern expressed by producers in the early adoption phases of no-till continuous cropping production systems was the potential for residue accumulation at the soil surface. The belief was that tillage was necessary because crop residues at the soil surface would decompose very slowly resulting in a rapid build-up leading to difficulties with seeding and more problems with cool surface soil temperatures.

These concerns were addressed by two studies. The first study showed that residue decomposition was determined almost exclusively by the nutrient content of the crop residues rather than by their biochemical composition.[26] The research showed that when wheat, lentil and canola crop residues had similar nitrogen concentrations, their rate of decomposition were the same.

The second study showed that the initial nitrogen content of the crop residues, the accumulated heat units and their placement (buried vs surface) after a minimum amount of precipitation had been received were the determining factors in explaining the rate of residue decomposition.[27] Like in the first study, it also showed that differences amongst crop species for rate of residue decomposition were a function of their nitrogen concentration rather than their biochemical composition. They also showed that crops residues at the soil surface were decomposing at about 66% the rate of buried residues.

Although the biochemical composition of crop residues is not the major determinant of the rate of decomposition, the physical characteristics of crop residues behave differently depending on the crop species, the design of the seed opener, soil texture and soil moisture content at time of seeding. For example, seeding through heavy canola residues is much different than seeding through heavy wheat residues even though their rate of decomposition and their amounts at the soil surface may be the same. Experience has also shown that when no-till is combined with diversified crop rotations, the concerns about crop residue accumulation at the soil surface have not materialized and the start of seeding has not been compromised. This is because crop species produce different amounts of crop residues, have different residue characteristics and have different amounts of nitrogen concentrations. For example, finely cut pulse crop residues have higher nitrogen contents resulting in faster decomposition than wheat residues which greatly reduce any potential problems with plugging. Producers are also very aware that proper residue management, which starts with harvest and includes adequate chopping and spreading, is essential to avoid the seeding problems.

Myth: Poor Nitrogen Fertilizer Management under No-till – One Pass Seeding and Fertilizing System

Nitrogen fertilizer management involves four components – form, timing, placement and rate. In the initial stages of no-till, nitrogen fertilizer management proved to be a major challenge. The two placement options were seed-placed or surface broadcast and the timing for surface broadcast was either late fall, early spring or after seeding. There were also severe limits as to how much nitrogen could be applied with the seed, depending on the fertilizer form and the amount of seed-bed utilization. It wasn't till the late 1970s and early 1980s that the technology for in-soil banding became possible on a commercial scale and this could be done either in late fall or prior to seeding, allowing ammonium-based fertilizers like urea and anhydrous ammonia to be used effectively.[28] Research conclusively showed that losses from volatilization with urea could be almost eliminated if it was placed in the soil and covered properly.[29,30] The major nitrogen fertilizer forms available to early no-till producers were ammonium nitrate (granular), urea (granular), and urea-ammonium nitrate (liquid). Early no-till producers would add as much nitrogen as was deemed safe with the seed but the balance was surface broadcast with ammonium nitrate as their preferred choice, leaving them at the mercy of rainfall to move the fertilizer into the soil for access by the plants. With the introduction of urea with its higher analysis and lower price than ammonium nitrate, usage of urea increased rapidly. However, problems with nitrogen use efficiency quickly became apparent due to the high potential for volatilization losses with urea when applied on top of residues and soil and the strong interactions with environmental factors like temperature and moisture, especially under no-till. The amount of urea that could be safely placed with the seed was also less than for ammonium nitrate resulting in more surface broadcast applications. One could argue that yields under no-till were initially limited because of the inability to apply all of the nitrogen required by the crop with the seed even though there was more soil water available for crop growth. The use of liquid urea-ammonium nitrate reduced the problems with volatilization losses but did not eliminate them altogether because half the amount of the nitrogen present was still in the urea form. The lack of ability to apply the required amounts of N fertilizer under no-till exacerbated the problem as the applied N was utilized by micro-organisms to breakdown crop residues instead of for crop nutrition.

Given the now recognized benefits and efficiencies of in-soil placement of all nitrogen fertilizer forms, the attention of no-till producers shifted to the potential of applying all the nitrogen fertilizer during the seeding operation either as a side-banded treatment and more recently as a mid-row banded treatment or by spreading the fertilizer with the seed over a large area, as was the case with airseeders in the early days of no-till. Research showed that it was possible to apply urea and anhydrous ammonia as a side-banded treatment in a one-pass seeding and fertilizing no-till system using a ConservaPak side-banding system as the test opener.[31] This study destroyed the myth that it was not possible to safely apply anhydrous ammonia at time of seeding and to apply all of the crops nitrogen fertilizer requirements using either urea or anhydrous ammonia to meet the crops needs in a one-pass seeding and fertilizer no-till system. This concept was also verified with other third-party bolt-on openers capable of side-banding using urea during the seeding operation.[32] Some producers use some of these openers to also apply anhydrous ammonia at time of seeding.

The one-pass seeding and fertilizing no-till system is now regarded as a highly efficient way of managing nitrogen fertilizers for achieving high nitrogen use efficiencies[30,33] and also recognized as a best management practice for minimizing the potential for nitrous oxide emissions.[34]

Myth: No-Till and the Long-Term Impact on Weed Densities and Weed Community Shifts

Another concern expressed with early adopters of no-till was the long-term impact of no-till on weed densities and the potential for major shifts in weed community composition towards more perennial type species and from selection pressure resulting from the continued use of particular herbicides.[35,36] More recently, the no-till producers have expressed concern over the increase in weeds becoming resistant to herbicides. The myth was that weed control under no-till is dependent entirely on herbicides.

To date, the large anticipated shift in weed communities with no-till has not yet materialized although some shifts have occurred. There are a number of documented reasons as to why these large shifts have not occurred. One reason has to do with crop diversification which allows for a broader range of herbicide chemistries with more diverse crop types and growth habits (spring or winter crops) which provides for varied selection pressure.[36] Another reason has to do with the precise placement fertilizers with the one-pass seeding and fertilizing system which increases the competitive ability of crops against weeds.[37] A third reason is the large differences in weed communities on the same plot from year to year due to temporal variability in climatic conditions (A.G. Thomas, *pers. comm.*). The temporal variability of temperature and moisture on the Prairies represents an important source of varied selection pressure to prevent dominance of particular weeds. A fourth reason is the combined impact of planting rates, crop rotations, crops, planting dates and herbicides in lowering weed seed recruitment in the soil seed bank thereby reducing densities in future years.[38] The final reason is the introduction of canola crops resistant to three specific herbicide chemistries.[39] This provided new tools to combat weeds like wild oats (*Avena fatua*) and green foxtail (*Setaria viridis*) that were showing resistance to the ACCase (Group 1) and ALS/AHAS (Group 2) group of herbicides.[40]

In conclusion, the myth that no-till producers would have to resort to tillage to stay on top of their weed problems has not yet materialized. Some producers in Saskatchewan now have 30 years of no-till on some of their fields and they have yet to resort to tillage because of an insurmountable weed problem. In general, lower weed populations were reported by farmers that practice no-till in western Canada, which is indicative of lower weed seed banks.[41] It should be noted that changes in weed communities occur slowly and that environment followed by crop management practices are the dominant factors influencing weed densities and communities, not the presence or absence of tillage. The long-term weed management strategy for no-till producers on the Prairies is to employ a diversity of weed management tools and to ensure that no one tool gets a disproportionate amount of use lest its effectiveness be greatly diminished.[38] With integrated weed management, no-till producers on the Prairies have numerous strategies at their disposal to continually vary selection pressure and thus prevent particular weed species from becoming dominant well into the future. In addition, the effectiveness of current crop production practices for weed management is reflected in the overall reduction of weed densities.[42]

Myth: No-till and the Long-Term Impact on Plant Diseases

Another frequent concern about no-till systems was the potential for increased leaf and root diseases because of the residues left at the soil surface. However the effects of tillage systems on the incidence and severity of plant diseases are small relative to the effects of environment and crop rotation.[43,44] Nonetheless, no-till has shown to reduce the severity of common root rot in cereals.[43] No-till reduces many crop diseases because of its direct and beneficial effects on soil biology.[45] A healthy soil with diverse and balanced populations of soil micro-organisms will provide substantial competition against root pathogens as these often compete for the same organic carbon substrate.

The best strategy to minimize plant diseases in cropping systems on the Canadian Prairies is to adopt no-till practices combined with diverse crop sequences that include cereal, oilseed and pulse crops. The temporal variability of climate on the Prairies also reduces the risks of certain diseases from becoming dominant. Attention also needs to be given to other disease control methods such as providing disease-resistant cultivars, disease-free seed with high vigour, use of seed treatments or foliar fungicides if warranted, balanced soil fertility, control of weeds and volunteer crops to break pathogen cycles, and careful record keeping of disease incidence.[45]

Therefore the myth about increased root and leaf disease pressure with no-till has not materialized and in fact may ameliorate some situations such as the reduction of blackleg disease of canola in no-till soils compared to tilled soils.

Myth: Negative Impact of No-Till on Soil Physical, Chemical and Biological Properties

A frequent concern with no-till was the potential negative impact on soil physical properties. Concerns about increased soil bulk densities resulting in reduced root penetration from wheel traffic and lack of tillage were often mentioned. This would lead to reduced crop yields over time thereby affecting long-term soil biological and chemical properties and overall soil productivity.

Soil Physical Properties

Early studies with no-till showed that after 5 years, changes in bulk density and penetration resistance were not large enough to affect crop production.[46] It was found that no-till increased macroaggregation (>0.25 mm) and mean weight diameter of aggregates, even in coarse textured soils.[47] This implied that the higher level of macroaggregation with no-till could lead to net increases in carbon sequestration in the form of soil organic matter, a concept that has since been verified. It was also shown that with no-till, water retention could be increased with little change in soil bulk density due to a redistribution of pore size classes into more small pores and less large pores.[48] Better water infiltration into no-till soils and better internal structure will lead to better carrying capacity of equipment and less potential for compaction. The increased earthworm activity observed under no-till also contributes to better water infiltration.

Consequently the initial concerns about the long-term negative effects of no-till on soil physical properties did not materialize. In fact, producers have observed that over time, no-till has reduced the draft of seeding implements and the carrying capacity of the soil has increased. The increased carrying capacity of the soil could result in earlier planting.

Soil Chemical Properties

The soil chemical constituents of greatest interest to producers are soil organic carbon and nitrogen. There is great interest in understanding the impact of tillage and cropping systems on soil organic carbon and nitrogen.

In the Brown soil zone, increases in soil organic carbon and nitrogen are closely related to the amount of crop residues returned to the soil and the nitrogen content of the residues. The amount of residues returned is dependent on the use of an appropriate fertility regime.[49,50] Their research also showed the importance of ensuring a positive nitrogen balance. If nitrogen removal is greater than nitrogen input, a gradual decrease in soil organic C and N will occur. This further indicates the need to conserve and manage soil water appropriately in order to sustain crop growth which is necessary to sustain soil organic matter. The combination of no-till, tall stubble and proper fertility will greatly increase the potential to increase soil organic carbon and nitrogen as a result of higher grain yields due to increased water conservation, reductions in water losses from evaporation and increases in water use efficiency.[51,52,53]

In the Dark Brown soil zone, research from long-term studies at Lethbridge showed that if erosion can be controlled, the current practises involving continuous cropping with proper fertility and infrequent summer-fallowing, if required, and the use of chemical fallow rather than tillage fallow, soil organic carbon and nitrogen could be maintained.[54] They also indicated that adopting no-till combined with continuous cropping would likely increase soil organic carbon.

It has been well documented in the Breton plots near Edmonton, a site in the Black soil zone, that the maintenance of soil organic matter is dependent on the continuous growth of crops or the addition of manures or the appropriate use of fertilizers to ensure optimum crop growth. The inclusion of forage crops can also provide added benefits.[55] Other studies in the black soil zone at Indian Head and Melfort indicated that the increase in soil organic carbon was proportional to cropping frequency or the amount of residues returned to the soil, the use of a proper fertility regime or the inclusion of legume-grass forage crops.[56]

More recent studies have confirmed that when no-till is combined with continuous cropping, increases in soil organic carbon are observed.[17,18,57] As mentioned above, the increase in soil organic carbon and nitrogen will be directly related to crop production which in turn will determine the amount of crop residues returned to the soil. Management practices that encourage crop production and residue addition to the soil, taking into account the vagaries of the climate will enhance the soil resource.

The end result of current investigations is that the adoption of no-till combined with proper crop management will not only sustain soil quality but can actually improve the long-term quality and productivity of prairie soils.[18]

Soil Biological Properties

Soil organic matter, as mentioned above, plays a key role in crop production and in describing overall soil health. When examining the microbial aspects of soils, the size of the microbial community is directly proportional to soil organic matter content and soil microbes are the principal mediators of nutrient cycling.[58] Although soil microbial biomass only represents a small proportion of overall soil organic matter, it is more dynamic than total soil organic matter. Because of this, it has been shown that soil microbial biomass is a better indicator of how tillage systems and cropping systems impact soil health and the soil's productive capacity.[59,60] Soil organic carbon and nitrogen, microbial biomass carbon (MBC), light fraction carbon (LFC), light fraction organic nitrogen (LFN) and wet aggregate stability were enhanced with increased cropping frequency, fertilization and also with the inclusion of green manure crops and legume hay crops but LFC, LFN, MBC and potentially mineralizable N were more sensitive to changes in cropping practices than simple measures of total soil organic carbon and nitrogen.[60]

When no-till is included as a factor, Lupwayi et al[61] noted that microbial biomass increased as well as the functional diversity and activity of microbes. They suggested that this would have a positive effect on decomposition processes of crop residues by microbes. In another study, they observed that microbial biomass carbon turnover was higher with no-till than conventional tillage. Nitrogen mineralization has also been reported to be higher with no-till.[62]

The three main factors describing the rate of residue decomposition is temperature, location of residues (on the soil surface vs buried) and the nitrogen content of residues.[27,54] As temperature increases and the nitrogen content of residues increases, the rate of decomposition increases. Residues placed on the soil surface decompose at about two thirds the rate of buried residues. When the effects of no-till on soil microbial activity and diversity are superimposed, some interesting observations are noted. Residues lost nitrogen faster with tillage than no-till but overall crop yield and N uptake tended to be greater with no-till than with tillage.[63] As well, nitrogen mineralization was always greater with no-till even though some initial immobilization of nitrogen was sometimes observed.[64,65,66] The slower rate of decomposition may actually allow for a longer period of nutrient release thereby supplying the crop with nutrients like nitrogen over a longer period of time during the growing season thereby minimizing potential nitrogen losses early in the growing season from adverse climatic conditions.[61]

One can therefore conclude that leaving crop residues on the soil surface will not lead to a reduction in nutrient cycling. In fact there are increased benefits to be had when residues are left at the soil surface as opposed to being incorporated in the soil with tillage.

Major Surprises about Conservation Agriculture over the last 30 years

Although adoption of no-till was initially very slow because of early failures and misconceptions about the need for tillage, no-till is the dominant management practice on the prairies today. The major surprises that facilitated the growth of no-till on the prairies include:

- No-till was more successful in cooler regions than anticipated and on a wider variety of soil types and much less successful on poorly drained clay soils, like the Red River Valley in Manitoba.
- Rapid development of "Canadian" air-seeder technology that could be adapted to different soil and crop residue conditions.
- Gradual and continual decline in the price of the herbicide glyphosate and the development of new herbicides.
- Research continued to find many secondary benefits with no-till and very few problems with anticipated pests or diseases.
- Canada represents an important "sink" for C (CO_2) since 2001 storing 4.4 Mt/y of CO_2 in relation to emissions of >5Mt/y in 1991.

Future of No-Till on the Prairies

Enhanced Water Management

Water and nitrogen are the most limiting factors to crop production on the Canadian prairies.[67] In the past, one of the main argument for no-till was the ability to make more water available for crop growth but in order to make efficient use of the water conserved, proper nitrogen fertility is required. More recently, attention has focused on ways to improve crop water use efficiency by ensuring that more water is being transpired by plants rather than being lost through evaporation at the soil surface and this becomes more critical for the semi-arid areas of the Prairies. Research has shown that seeding crops into tall stubble can improve grain yields through increases in water use efficiency. This has been demonstrated for spring wheat[50], field pea, lentil, and chickpea[52] and for canola[51] in the semi-arid Prairies with reported annual grain yield increases on the order of 10-12%.

Given the proven improvements in water use efficiency with tall stubble and the associated higher grain yields, the strategy going into the future is too develop the necessary technology in order for no-till producers to seed between the rows and capture the full benefits of tall stubble. Technology is required to allow equipment to seed between the rows. A SmartHitch®has been introduced to allow for seeding between the rows (www.seedmaster.ca). This type of innovation needs to be supported by basic agronomic research that studies the effects of wide row spacing beyond 30 cm to make it easier for technology to assist with seeding between stubble rows.

Fine-Tuning Nitrogen Fertilizer Management

Of the four components making up nitrogen fertilizer management (timing, placement, form and rate), arriving at the correct rate is the most challenging aspect to nitrogen management. From an environmental perspective, nitrogen fertilizer is not a benign product due to its potential for leaching into ground water, contamination of surface waters and nitrous oxide emissions.[33]

In recent years, optical sensors have been introduced that allow for greater precision in arriving at a rate of nitrogen that matches the needs of the crops to the field and growing season conditions and capable of addressing temporal and spatial variability at a field level.[68] More recently, crop specific algorithms for these optical sensors have been developed and tested for canola.[69] Algorithms are being developed and tested for spring wheat, winter wheat, durum, oat and malting barley.[70] The results to date are very promising. A strategy is required to bring this technology to the farm gate.

Robotic Applications for Soil and Crop Management

Prairie agriculture production systems are highly dependent on non-renewable sources of energy. Even though fuel use is reduced when adopting no-till production systems, energy is required to produce herbicides which no-till production systems depend on.[71] It has been demonstrated that if reliable estimates of weed densities could be determined spatially in a field, it would be possible to reduce herbicide use on average by 54% with greater reductions depending on the crop and weeds.[72]

These findings have important implications from an energy and environmental loading perspective. The natural solution to these problems is the development of robotic applications. Robotic applications could be extended to soil measurements such as soil moisture content, penetration resistance and crop applications such as plant health with the use of specialized fluorescence sensors.

Inclusion of More Winter Crops into Prairie Production Systems

The inclusion of winter cereals (wheat, rye and triticale) in prairie cropping systems provides many important benefits such as keeping the soil profile virtually free of nitrate thereby eliminating the potential for nitrogen losses through leaching and providing higher nitrogen use efficiencies in certain years.[73,74] Adding crops with winter habits also applies different selection pressure on weeds such as wild oat (*Avena fatua*) and green foxtail (*Setaria viridis*) providing other means of controlling these weeds that have become resistant to Group 1 and Group 2 herbicides. They can also escape certain plant diseases like Fusarium head blight and insect pests like the orange blossom wheat midge due to their growth habits.

The potential of winter cereals in cropping systems needs to be exploited more thoroughly in prairie cropping systems.

Cultivar Development

The development of hybrid canola has been a major advancement in western Canada that allowed producers to manage water-deficits, nutrients, weeds and other crop limiting events more effectively. Future varieties are fundamental to no-till systems in terms of competitiveness, disease resistance, drought tolerance and N use efficiency. Advances in hybrid technologies of cereals and pulses similar to canola will provide innovations in cropping system design and integrated with the previous requirements will continue to increase the sustainability of agricultural management systems. Genetic modification of crop species is another opportunity to enhance no-till systems with traits that ameliorate future cropping problems associated with climate change, particularly in the areas of non-food uses. Integrating new crop development technology with advancements in agronomy and precision farming tools creates a future of possibilities for no-till development to support an increasingly larger industrialized civilization.

Conclusion

Globally, the momentum is towards no-till to ensure the protection of the soil resource. Producers on the Canadian prairies have already made much of that transition and the investment required to do so. As of 2006, the census of agriculture reported that 60% of the cultivated area in Saskatchewan was in no-till followed by 48% in Alberta and 21% in Manitoba and the percentages are growing every year.[75]

Producers are already converting over to the next generation of no-till seeding equipment involving independent seed depth control for each opener allowing for more precise seed placement. The majority of the fertilizer is applied at time of seeding either as a side-banded or mid-row banded placement satisfying a very important component of best management practices.

In addition, Western Canada is home to many manufacturers of no-till seeding equipment, a lot of which is exported all over the world. This has created a strong knowledge industry that further enhances the technology benefiting directly prairie producers and supporting the GDP of Canada through exports.

Producers on the Canadian prairies have also embraced the concept of supporting research through commodity levies. This has generated a large pool of research funds to further enhance genetic improvement in crops as well as soil and crop management. The end result is prairie producers with highly diversified crop rotations, a level of diversity not seen any where else in the world. It is very common for producers to grow 4 to 7 crops in any one year on their respective farms. This allows for a greater opportunity to deal with weeds, plant diseases and insect problems. It also provides a form of risk management in terms of weather (below-average vs average vs above average conditions) and commodity prices. Commodity markets don't move in unison and crops respond differently to weather conditions.

This level of crop diversity has also created a large number of very efficient marketing and processing chains in Western Canada. This means that producers have many choices in terms of buyers providing for more price discovery and transparency and the ability to sell many of their crops locally. Crop diversity at the farm gate also represents an important risk management component.

Given the overall high level of success of no-till and cropping systems on the Canadian Prairies, the question then becomes, where do we go from here? The obvious one, but not always recognized is to ensure that the public funding commitment to the current efforts is maintained. The most dangerous path to take would be to assume that we have an industry that no longer needs public support. This could only result in a slow deterioration of the industry and the slow erosion of critical research and development capacity over time and the inability to respond quickly to unforeseen problems in the future.

While it is difficult to directly measure the impacts of agricultural research on growth and productivity in the sector, current analyses show that the percent annual growth in Total Factor Productivity (TPF) in the crop sector in western Canada has fallen dramatically since 1990.[76] These troubling results show that between 1940 and 2004 TFP growth has averaged nearly 1.8% per year, while TFP growth has averaged only 0.51% per year between 1990 and 2004. This remarkable slowdown suggests that changes in research policy could be having a profound affect on on-farm productivity growth. Should policy makers be concerned? If there is desire to increase productivity growth rates, greater and more effective research expenditure is required to mitigate this astonishing slowdown in TPF.

The no-till revolution on the Prairies was based on the recognition that we needed to protect our soil resource. The economic benefits were not evident at the time but the arguments to adopt no-till were very compelling, even with limited evidence. It was difficult to see how private industry could benefit from this and yet it was very important for Canada, hence the need to for public good research in instances like these. The biggest on-going challenge for soil and crop management research and development will always remain. How do we recognize the next no-till like revolution? Where will the vision and leadership come from? Who will decide whether a new research path is required with assistance from public funding and how will we choose? Where will the funding come from? Will it have to take 80 years to recognize the problem as was the case for soil degradation and 30 years to develop the solution which culminated in the development and adoption of no-till? How can we structure our public research institutions in such a way as to recognize these over-arching possibilities?

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Chapter 10

Systems Approach to Agronomic Innovation

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Agriculture on the Canadian Prairies was initially based on exploiting the native fertility of our soils. From the late 1800s until about 1920, most of the land suited to annual cropping was tilled and cropped. For most of this era, nutrient supplies far exceeded crop needs and little attention was paid to replacing nutrients removed by the crops grown This was appropriate since it would have been impossible to maintain these levels of fertility without causing serious environmental damage. This mining of nutrients was accelerated by the harvest systems of the day which removed both grain and straw from the land. The result was that nitrogen began to limit crop yield.

Summerfallow was developed as a strategy to mitigate drought, but also addressed declining nitrogen supplying capacity. Summerfallow stored moisture, but also released nitrogen into the soil in forms that crops could readily use. The droughts of the 1930s revealed a darker side to this practice: The dust storm. With less organic matter to hold soil particles together and little protective residue cover, vast areas began to drift. The resulting dust clouds carried soil far beyond the prairies where it originated. Clearly change was needed.

The most fragile and badly damaged land was abandoned and most was revegetated to grasses, and much remains in grass to the present time. The rescue of less fragile fields came from an unexpected source; the swather and combine. This new more efficient harvest system that replaced the binder and threshing machine could leave all the straw in the field. These residues held the key to halting wind

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erosion if only they could be retained on the soil surface. Tillage equipment at the time consisted of plow and disc implements that inverted and mixed surface residues into the tilled layer of soil. Equipment that severed weeds below the surface and left most residues on the surface was developed, evaluated and refined. The resulting wide blades, rod weeders and cultivators proved very effective at killing weeds yet leaving more crop residues on the soil surface, where they reduced wind speeds, and reduced erosion. These implements proved easier to pull, and could be built to till a wider path and their adoption started the era of stubble mulch tillage. Opponents, and there were many, were convinced that "plowless" tillage would create soil structural or fertility problems that would be the demise of stubble mulching.

Improved efficiency (lower cost and more area covered per hour) likely drove rapid adoption of stubble mulch tillage. By the mid 1950s this was the typical practice, and it seemed that declining soil quality was solved. However hints that this practice had limitations soon became apparent. Stubble mulch tillage usually provided adequate protection where land was re-cropped. Summerfallow land however was often vulnerable because repeated tillage and natural decomposition did not always leave enough reside to prevent erosion by the end of the fallow period. This was particularly evident in drought cycles when crop residue production was low. By 1970 there were numerous indicators that soil degradation was not being adequately addressed, and that new innovation was needed. However, what would be needed to address the problem was not apparent to most people.

By 1983, soil degradation caught the attention of government, and the Senate Standing Committee on Agriculture, Fisheries and Forestry was authorized to "examine the subject matter of soil and water conservation throughout Canada". Their report summarized the problem as follows:

> "Canada is facing the most serious agricultural crisis in its history and unless action is taken quickly, this country will lose a major proportion of its agricultural capability."[1]

The report clearly identified intensive tillage and summerfallow as the primary causes of soil degradation in the prairie region. Tillage hastened the decomposition of soil organic matter and buried crop residues that were essential for protecting the soil from wind and water erosion. Summerfallow shared the blame since it did not contribute any fresh organic matter, while facilitating leaching of nutrients from the root zone when moisture exceeded water holding capacity. Leaching ultimately resulted in salts being deposited near the surface at lower elevations and was a major cause of dryland salinity. Other factors identified were lower rates of return of organic carbon to soil with annual crops compared with native grasses and use of large equipment, but clearly tillage and summer-fallow were the major factors.

Thus, if tillage and fallow were causing problems, replacing tillage with herbicides and fallow with "king" wheat would surely correct the problem. By the late 1970s there was ample evidence that herbicides could replace tillage for control of weeds, and there were numerous studies evaluating continuous wheat. There was simply a need to enhance moisture use efficiency slightly to offset the moisture storing benefits of fallow and a solution would be at hand. It appeared that improved moisture storage could be achieved by trapping more snow, and that evaporation losses could be minimized by reducing or eliminating tillage.

However, as this approach was evaluated it became apparent that there were major short-comings that needed to be addressed. Seeding equipment did not always penetrate the soil sufficiently to place seed uniformly at the desired depth; sometimes it plugged with crop residues; sometimes straw was forced into the seed row (a condition called hair-pinning) and interfered with seed placement while hastening drying of the seedbed; and sometimes coverage of soil over the seed-row was inadequate.

Fertilizer placement presented another challenge in minimum tillage systems. Broadcasting without incorporation risked serious losses of fertilizer N while incorporating negated any benefits from reducing or eliminating tillage. Pre-seed banding was efficient but still involved additional soil disturbance, and in-crop top dressing was also quite risky. Only limited amounts of nutrients could be safely seed-placed, so some low disturbance way to apply large quantities of fertilizer during seeding was needed.

While herbicides controlled weeds effectively on summer-fallow, costs were typically much higher than the tillage operations they replaced. Crop residues along with improved moisture levels combined to reduce soil temperatures in the seedbed, a change that was often implicated in poor crop establishment in cooler regions and caused concern where the growing season was already quite short. Without tillage, mineralization of nitrogen during fallow was reduced which could affect fertilizer needs. Continuous wheat itself was a problem because leaf diseases became more serious, and problems with grassy weeds began to emerge. With cereal monoculture, the prospect of herbicide resistant wild oats and other grassy weeds became a reality.

A number of other problems were expected with a change to conservation tillage. Because tillage loosened the soil, soil compaction would surely become much more serious. Many diseases survived on crop residues and tillage was perceived as an effective control measure; surely leaving them on the surface would be disastrous. Pesticides were poisons that were damaging to the environment thus any practice that relied more heavily on them must, by definition, be much more damaging than the practices that they replaced. Crop cultivars were developed in tillage and fallow based systems, therefore they would be less than ideal under this radically changed cropping system. And finally, summer-fallow was seen as a period of "rest" for the land, and continuous cropping would place too much stress on the land, thus such practices were certain to fail according the traditional views of the day.

Clearly the solution was far more complicated than just reducing or eliminating tillage and summer-fallow. Further, the fact that these issues came to light when change in the cropping "system" began suggested that they could not be addressed in isolation, but rather a systems perspective was needed. The systems approach went beyond just dealing with agronomy, but also included equipment and how new information was communicated. What evolved was a group of farmers, equipment manufacturers, extension specialists and research scientists who shared a common belief that only by working together could they identify and resolve the key issues that prevented widespread adoption of conservation tillage. What bound this group together was the knowledge that failure to address soil degradation would ultimately deplete the soil resource to the point where large areas would no longer be suitable for crop production.

Development of straw choppers and chaff spreaders quickly alleviated some of the problems associated with plugging of seeding equipment and some of the concerns about nutrient and possible phytotoxic effects of uneven spreading of crop residues. With uniformly spread residues, equipment manufacturers could design seeding equipment with adequate residue clearance to minimize risk of plugging with straw. Major improvements in seed placement occurred as a result, and with recognition that improved seedbed moisture would allow shallower seeding another limitation was soon overcome. Shallow seed placement meant the seed was placed into warmer soil, effectively overcoming much of the detrimental effect of cooler soils in the absence of tillage. An added benefit was that seedlings were less susceptible to some seedling diseases, and direct seeded crops were often more vigorous because they exhausted less of their energy reserves emerging from the soil than deeper seeded conventionally tilled crops.

Initial attempts to side band fertilizer suffered from inadequate separation of seed and fertilizer or excessive soil disturbance and, sometimes, both. Regardless of the cause, crop establishment was often less than satisfactory. However, designs that actively placed soil over fertilizer or banded it mid-way between rows largely overcame these limitations. An added benefit of such fertilizer placement was that crops had preferential access to the nutrients, improving vigor and competitiveness with weeds.

With better seed placement, it became feasible to grow small seeded oilseed crops like canola and flax in rotation with cereals. Consequently, rotations became more diverse. Major benefits of such changes were reduced losses from pests and, in many cases, higher financial returns. Improved moisture conservation made production of oilseeds possible in regions previously considered too dry. The next major cropping system change occurred with introduction of well adapted lentil, pea and later chickpea cultivars. These pulse crops further reduced losses due to pests and reduced reliance on cereal and oilseeds and diversified market opportunities. Because they used moisture efficiently and were quite drought tolerant, pulses in rotation were instrumental in replacing summer-fallow throughout much of the drier Brown and Dark Brown soil zones. However their greatest benefit was due to their ability to fix nitrogen. It reduced fertilizer nitrogen requirements in both the current and succeeding crop. Because pulses used less soil nitrogen while returning more to the soil, they increased the capacity of the soil to supply nitrogen. This overcame a limitation in conservation tillage systems where minimal soil disturbance slowed cycling or release of nitrogen from crop residues.

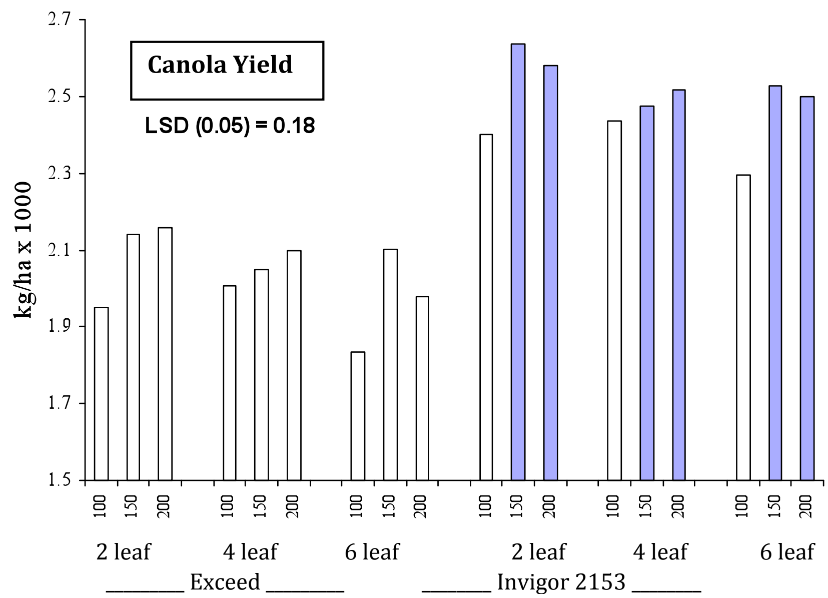
Numerous developments improved the effectiveness and reduced the cost of weed control, both before seeding and in-crop. Improved understanding of how climate, spray and water quality affected herbicides like glyphosate allowed for reduced rates to be used, and largely eliminated the need for repeat applications. At the same time, the manufacturer reduced the price of glyphosate to encourage more rapid adoption of conservation tillage. Diversified rotations initially presented weed control challenges because herbicide treatments for pulse and oilseed crops were generally less effective than for cereals. However, from a systems perspective it soon became apparent that weeds were manageable in such systems and that, over time, reliance on herbicides could be reduced by taking advantage of improved crop competition due to improved crop vigor and better fertilizer placement with conservation tillage.

Dealing with some of the perceived deficiencies of conservation tillage was simpler than some predicted, as in most cases, problems simply did not arise. Soil compaction was not problematic. Disease problems associated with leaving crop residues in the field did not decimate crops, pesticide use generally declined after adoption and cultivars developed for traditional production systems performed well in conservation tillage systems. Most importantly, we learned that soils needed to support vegetation every year to remain productive rather than the traditional notion of needing a periodic "rest" associated with summer-fallow.

What evolved was a new and much improved system of producing crops that enhanced yield and productivity while protecting the soil resource and environment. The system involved uniform spreading of crop residues, effective pre-seeding weed control with herbicides, more uniform and shallower seed placement, fertilizer banded at seeding and diverse rotations of cereal, oilseed and pulse crops in addition to elimination of unnecessary tillage and summer-fallow. Without a systems approach it is unlikely that a suitable solution could have been developed and its adoption would most certainly have been much slower. Rapid adoption also reflects that farmers, extension personnel and industry agronomists played a very active role in promoting the technology and in supporting efforts to develop improvements to the system.

Lessons learned about the systems approach to improving agronomic practices have not been wasted, but are actively being used today in developing improved systems. An example is a recently completed study in Alberta examining the effect of timing of herbicide application combined with seed rate and hybrid vs open pollinated cultivars of canola (figure 10.1). In the study, earlier weed removal, higher seed rates and hybrid cultivars all increased yield, but the combination of all three yield enhancing practices was most beneficial.

Figure 10.1. Canola yield with an open pollinated cultivar (Exceed) and a hybrid (InVigor 2153), weed removal at 2, 4 or 6 leaf stage and seed rates of 100, 150 or 200 seeds per square meter; alone and combined in the same system.



Source: Harker et al., 2003[2]

Another example comes from research on inputs for canola and barley. In this multi- year, multi-location study inputs of improved genetics, higher seed rates, fertilizer and herbicides all increased yield [table 10.1]. When they were combined at near optimal levels, the combined effect was much greater than the sum of individual responses; a benefit that we are calling a stacked benefit.

Table 10.1. Effect of improved genetics, higher seed rates, fertilizer and herbicide on yields of canola and barley averaged over 20 locations in SK and AB.

Factor	Yield increase [bushels per acre]	
	Canola	Barley
Genetics	3	2
Seed rate	2	5
Fertilizer	4	8
Herbicide	13	22
TOTAL	22	36
COMBINED EFFECT	32	42
STACKED BENEFIT	10	6

Source: Adapted from Brandt et al., 2009[3]

Summary

What is clear is that traditional tillage based agriculture is not sustainable and never has been. Tillage and summer-fallow are tools used to mine the soil of nutrients.[4]

Conservation tillage has addressed many of the shortcomings of tillage based agriculture.[5] The lessons of the past surely imply that even this improved system will require innovation to address new shortcomings as they arise. As these are addressed, building on the agronomic systems approach that performed so well in developing conservation tillage should be considered. That approach will likely include biologists, environmentalists and other disciplines who may view the land from very different perspectives. It, too, may rely heavily on systems modeling as a means of understanding and extending knowledge collected to date. Systems models may have their greatest value in understanding the complex interactions of systems.

Innovation in agriculture is likely to be driven by both producers and consumers of food. For most of the past decade food consumption has exceeded production.[6] This shortfall reflects in part a lack of innovation in agriculture because food has been abundant and farmers have been more concerned with cost cutting than with increased output.[7] However, cost cutting often means mining the soil of its productive capacity. Far too often this occurs on the earth's most vulnerable lands. For example, cost cutting practices like summerfallow with minimal use of fertilizer nutrients remain most popular on the more vulnerable Brown and Dark Brown soils of the prairies.[8] On higher organic matter Black soils of the region, summerfallow has been largely eliminated, and fertilizer use is much more extensive.

Conclusion

Conservation tillage presented a unique challenge because the problems and associated solutions were much more complex than what we had dealt with in the past. In the past, innovators like scientists and engineers recognized a need and developed a technology to address the issue. This approach was highly effective in driving the large productivity increases during 1950 to 1980. However the problem of soil degradation proved too complex to be solved with a single change in technology and a different approach was needed. The solution was based on devising a new system of cropping and was developed through cooperative efforts of many different players. The result, conservation tillage, has proven highly effective with much improved sustainability. It established the base for improved systems of the future.

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Chapter 11

Evolution of Effective and Economic Weed Control

Robert E. Blackshaw and K. Neil Harker*

Introduction

One of the primary reasons for tillage throughout history has been weed control. Annual weeds are usually well controlled with tillage but tillage can also stimulate another flush of weeds. Control of most perennial weeds with tillage is only partially effective as multiple passes are required to reduce energy reserves in the rhizome or root systems.

Despite the somewhat mixed success of using tillage to manage weeds, there was widespread concern about increasing weed populations and 'out-of-control' weeds if tillage was eliminated or even reduced. A second major concern revolved around the perceived need to increase herbicide use in conservation tillage systems. Farmers were worried about increased herbicide costs and environmentalists were concerned about greater potential impact on air and water quality.

Potential Tillage Intensity on Weed Populations

Weed populations can readily adapt to new environments because of their diversity. Disturbance is a major habitat trait that favours weed invasion. Froud-Williams states "Arable land is characterized by regular, recurrent, and often highly predictable disturbance. The consequence of this disturbance is that weeds of cultivated land represent the most ephemeral of plant communities, completing their life

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cycles within a relatively short time and producing copious quantities of dormant seed of potentially long life span".[1]

There always seems to be a weed species or biotype that can adapt to and thrive in the agricultural environments we create. Agricultural weeds are thought to have adapted to respond to cues associated with soil disturbance.[2] Cultivated land is often warmer, has greater diurnal temperature fluctuations, higher nitrate concentration, and increased aeration; all of these factors can stimulate weed germination.

Greater surface crop residues with conservation tillage can suppress weed establishment by altering environmental conditions related to germination, physically impeding seedling growth, and through allelopathic interactions.[3] Weed seed dormancy, which allows weeds to persist in the soil for many years, is also reduced when weed seeds are not buried. Vertebrate and invertebrate seed predators have easier access to weed seeds left on the soil surface. In addition, weed seed predators occur in much greater numbers in zero tillage fields. Weed seeds left on the soil surface also experience greater mortality for at least two additional reasons: physiological aging and exhaustion of reserves through respiration and germination at soil positions and times of year that are not suitable for seedling emergence or survival.

Weed Population Shifts with Conservation Tillage

Several long-term studies were conducted in western Canada in the 1980s and 1990s to examine the effect of reduced tillage on soil quality and crop productivity. Fortunately, weed populations were also documented in many of these studies. Eleven field experiments ranging in duration of 4 to 12 years were included in a multi-site weed assessment study.[3]

Of the 71 weed species enumerated, 56% were associated with minimum and/or zero tillage and 27% were associated with conventional tillage. Species ubiquitous across tillage systems represented the remaining 17%. Despite more than one-half of all weeds being associated with minimum-zero tillage, most of these weeds were not new weeds to these agricultural systems but they increased in density and distribution with the adoption of reduced tillage cropping practices.

All perennial species were more strongly associated with minimum-zero tillage than with conventional tillage. Canada thistle, perennial sowthistle and quackgrass were present in all tillage systems but their densities often increased with zero tillage. Others, such as dandelion and foxtail barley exhibited large increases in density with zero tillage. Biennial species were also associated with minimum-zero tillage and rarely occurred with conventional tillage.

Of the 39 annual weed species in these studies, 44% were associated with minimum-zero tillage, 33% with conventional tillage and 23% were ubiquitous across tillage systems. Many of the annual species associated with minimum-zero tillage have wind-disseminated seed capable of germinating on the soil surface; examples being annual sowthistle and prickly lettuce. Species such as stork's-bill and cleavers have taken on a winter annual growth habit with the insulating effect of greater snow cover with zero tillage.

Farmer experience has indicated that when direct-seeding is first adopted, given additional moisture at the soil surface as well as management adjustments to a new system, weed densities may increase for the first few years relative to weeds in tilled systems. However, after 5 to 10 years of zero tillage, overall weed densities are often lower than in tilled systems. In these situations there is potential for less herbicide use, perhaps even less than what was previously used in conventional tillage systems. Indeed, sales data indicate that herbicide use has remained relatively constant with widespread adoption of conservation tillage in western Canada.

Managing Weeds on Conservation Fallow

While fallow is only practiced on 3 million ha annually on the Canadian prairies in 2008, it was a common practice on 10-14 million ha during the 1960s through 1980s. Farmers fallowed land mainly to conserve soil moisture but also to increase soil nitrogen (N) levels and kill weeds. However, fallow maintained by tillage had the negative consequences of reduced soil organic matter, increased soil erosion, deterioration in soil structure, and increased salinity. Thus, developing alternative weed management methods on fallow was a high priority during the early days of conservation tillage.

Studies conducted at Lethbridge and Swift Current developed systems that employed a combination of wide-blade tillage and herbicides to control weeds on fallow.[4] Although not as effective in conserving surface crop residues as sole use of herbicides, the combined herbicide-tillage approach maintained sufficient crop residue to keep the risk of erosion low.[5] Soil water accumulation and crop yields with the combined herbicide-tillage treatments were often superior to tillage only. The economics of chemical weed control became more favourable[6] and thus conservation fallow was rapidly adopted by growers. This was a major positive step in reducing soil erosion on the Canadian prairies.

Managing Weeds in Direct Seeding Systems

Early questions included how to effectively and economically control weeds prior to seeding plus those troublesome weeds (often perennials) that tended to be greater problems with conservation tillage and no-till. Paraquat and glyphosate were widely evaluated for these purposes. Paraquat was cheaper than glyphosate in the 1970s and 1980s but due to its contact mode of action it often provided poor control of grass species (e.g., wild oat and volunteer cereals) at seeding time and only provided topgrowth control of perennial weeds. Glyphosate moves throughout plants and thus was a far more effective herbicide than paraquat. However, it was not until the price of glyphosate was reduced in the late 1980s and early 1990s that it became widely used in direct-seeding systems. Glyphosate is now widely used before seeding to control emerged weeds, preharvest to control perennial weeds, and postharvest to control perennial weeds plus fall emerging winter annual weeds. Recently, herbicides such as florasulam and carfentrazone have been tank-mixed with preseed glyphosate to provide improved control of weeds such as dandelion and narrowleaf hawksbeard.

Specific research was conducted to control troublesome perennial weeds such as foxtail barley[7] and Canada thistle[8] in zero tillage systems. Herbicides were identified to control these species but more importantly integrated multi-year management programs were developed for these weeds.

Adoption of direct-seeding techniques has allowed farmers to grow a greater variety of crops. Snow trapping and reduced evaporative losses with zero tillage have increased soil moisture levels in the Brown and Dark Brown soils of the prairies. This has allowed producers to grow oilseed and pulse crops in these regions where previously only cereals were grown and where fallow was extensively practiced. The net result of this has been a 70% decrease in fallow, 60% increase in canola, and 250% increase in pulse crops on the Canadian prairies.[9] Crop diversification is a cornerstone of all sustainable pest management and crop production systems.[10]

Diverse Cropping Systems

Weeds fortunate enough to grow in simple, repeated cropping systems will continue to have little difficulty adapting and thriving in those systems. Liebman and Staver state "Continuous production of a single crop and short sequences of crops with similar management practices promote the increase of weed species adapted to conditions similar to those used for producing the crops …In contrast,…employing crops with different planting and harvest dates, different growth habits and residue characteristics, weeds can be challenged with a wide range of stresses and mortality risks, and given few consistent opportunities for unchecked growth and reproduction".[11]

Two things govern the successful utilization of crop diversity in weed management systems: the life cycle of the most dominant weed(s) and the life cycle of the rotational crops. Many crop rotations involve substantial crop species diversity but lack crop life cycle diversity. For example, if wild oat is the dominant weed species, crop producers must employ something other than just summer-annual crops in their rotation. Accordingly, in winter wheat, winter-annual downy brome is easily managed when the crop rotation involves a summer-annual crop.[12]

Using crop rotations with varying crop life cycles is not the only way of introducing diversity into a cropping system. Diversity can also be introduced by varying crop seeding date[13], or by varying the date of crop harvest.[14]

Integrated Weed and Crop Management

Other cultural weed management techniques have been extensively researched and are slowly but surely being adopted by farmers.[9] These IWM (integrated weed management) practices include higher crop seeding rates, altered seeding dates, competitive cultivars, strategic fertilization, and growing silage, green manure and cover crops. These weed management practices can be effective on their own but far greater impact is realized when they are combined within a systems approach conducted over several years.

A multi-year study conducted at Lethbridge, Lacombe and Scott found that the combination of early seed date, higher crop seeding rate, and spring-applied subsurface-banded fertilizer resulted in the most competitive cropping system.[9] Weeds were well controlled with this IWM approach and it is notable that the weed seedbank was not greater after four continuous years of using 50% herbicide rates within a competitive cropping system at two of three sites.

Another multi-year study conducted at four locations, where practices were repeated over several years, illustrates well the importance of combining optimal practices in an integrated crop management system.[15] Wild oat seed production at the quarter herbicide rate was reduced by 91, 95, and 97% in 2001, 2003, and 2005, respectively, when tall barley cultivars at double seeding rates were rotated with canola and field pea (high management) compared to short barley cultivars at normal seeding rates continuously planted to barley (low management). Combinations of favorable cultural practices interacted synergistically to reduce wild oat emergence, biomass and seed production, and to increase barley yield. For example, at the quarter herbicide rate, wild oat biomass was reduced two- to three-, six-to seven- or 19-fold when optimal single-, double-, or triple-treatments were combined, respectively. Notably, high management at low herbicide rates often had higher barley yields than low management in higher herbicide rate regimes.

Concluding Remarks

Farmers should not be deterred from adopting conservation tillage practices because of concerns of increased weed control problems but rather be aware of potential changes in weed communities and how they may be managed. Over the last two decades, there is good evidence on the Canadian Prairies to suggest that we have reduced weed density and species numbers via the management practices that have been employed. Effective and economical weed management programs are now available for successful implementation and continuation of conservation tillage cropping systems in western Canada.

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Chapter 12

It All Makes Cents: the Economics of Conservation Tillage

Richard Gray*

Introduction

Economics has been a very important motivator in the development and adoption of conservation tillage (CT) technologies. This chapter takes a retrospective look at how the economics of conservation tillage has changed over time, and how economic incentives were integrally entwined with producer adoption and the development of CT. In describing the economics of CT it focuses on the innovation system and the dynamics of a process that brought so many actors together to successfully launch this revolution in farming.

The analysis of the innovation system for conservation tillage is a key to understanding some of the essential processes and linkages that drove the development and adoption of CT. The systems approach helps to understand the role that producers, engineers, agronomists and organizations played in the process, and in turn, how these groups were influenced and had influence on external markets and policies. The perspective of an innovation system helps to highlight the role that communication, information flows and knowledge stocks played in the innovation process. Finally, greater understanding of this very successful innovation process can provide some additional insights into policies that can better foster future innovation.

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This chapter does not analyze two other important economic aspects of the CT innovation. The economic incentives for on-farm adoption are not examined in detail. While these are a critical aspect of the adoption process, these on-farm economics are self evident given the high rates of adoption, and as such require further study. Second, the economic impacts of the CT revolution are not measured. Given the scale of adoption, the profound impact on farming systems, and the environmental impacts, the economic impacts should be measured and described in a thorough cost/benefit framework. Unfortunately a cost/benefit analysis is well beyond the scope of this chapter, which specifically focuses on the innovation system.

This chapter is organized into three parts. The first part is used to introduce a simple economic framework to examine the farm level viability of the technology. In part two this framework is applied to four periods of development to identify how the viability and the perceptions of viability changed over time. Part three concludes the document with a discussion of the role of internal and external economic forces with some discussion about future viability, and the lessons that can be learned from this amazing transformation.

The Economic Forces For on Farm Adoption

In adopting a cropping system, producers compare the expected net returns from the new cropping system to their existing system. In the case of conservation tillage systems, the changes in expected returns include short run cash income and expenses, perceived machinery costs, perceived changes in labor management costs, as well as the perceived value changes to soil quality, and perhaps some adjustment for perceived changes in risk. According to economic theory, producers adopting CT must have perceived a net benefit from adoption.

Changes in the net benefits of CT did not occur spontaneously. Many forces combined and evolved over a long period to improve the viability and to drive the increased adoption of CT technology. Some of the key drivers included: 1) improved agronomic knowledge, 2) improved machinery technology, 3) changes in soil quality, 4) improved herbicides, 5) better pulse and canola varieties, 6) lower market prices for key crop inputs, 7) less constraining agricultural policies and institutions, and, 8) the accumulation of capital on farms. Each of these drivers changed the perceived benefit for producers making their adoption decisions. A brief chronological description of these forces gives us some insight into the nature of the innovation system.

The earliest drivers for CT were the episodic periods of drought and wind erosion. In particular, the dust bowl of the 1930s and the severe drought of the early sixties showed the value of maintaining crop cover. Without sufficient crop cover, severe wind erosion could take place, often with severe impacts on soil quality and many offsite effects as well. In response to the extensive wind erosion in the 1930s, governments established the PFRA and introduced many measures to reduce soil erosion including, re-establishing permanent forage cover on fragile soils and the active promotion of strip farming. Research also began on tillage implements such as the Noble Blade, heavy duty cultivators, and the rod weeder to better conserve surface crop residue. By the late 1960s there was some move away from one way "Discers" towards hoe drills as seeding and tillage equipment because of their propensity to bury trash which left fields vulnerable to erosion. There was also some push toward direct seeding but the inability to effectively and economically control grassy weeds severely limited the adoption of zero tillage prior to the 1970s.

From 1968 to 1972, there was a severe glut on the world grain markets. The United States had accumulated large government stockpiles, while Canada, also a signatory to the International Wheat Agreement, severely restricted export sales in an effort to maintain wheat prices. As a result there were very restrictive delivery quotas for wheat on the Canadian prairies, with large accumulations of on-farm stocks and very low local grain prices. These on-farm stocks were particularly burdensome in the black soil zone, which produced more crop per improved acre. The result was a strong economic encouragement to summerfallow, which was exacerbated by the "Lower Inventories For Tomorrow" (LIFT) program that paid cash incentives to reduce future grain output. Some "double" summerfallowing and increased wind erosion was the unfortunate consequence of these programs. During these "Dark Ages" there was very little interest in intensifying production or in adopting CT technologies, although hoe drills and cultivators continued to replace discers.

Following the "Great Russian Grain Robbery" in 1973, grain prices were dramatically higher and delivery quotas were no longer binding. The result was a seven fold increase in the price of a marginal bushel of wheat, increasing from about 60 cents per bushel for wheat to over $4.00 bushel. The outlook for agriculture became very bright, with farmers looking for ways to intensify production. Farmers, particularly in the black soil zone, were increasing stubble cropping and were experimenting with larger amounts of nitrogen fertilizer which given the seeding equipment had to be broadcast on the soil surface. Seeding stubble with hoe drills also required a good deal of pre seeding tillage to cope with straw.

In 1975 the *Saskatchewan Guide to Farm Practice* first highlighted the long-term decline in soil organic matter in Saskatchewan soils. Professor Don Rennie, a soil scientist who would become the Dean of Agriculture at the University of Saskatchewan, gained a great deal of public attention for his research. He indicated that the current system was not sustainable and that producers should reduce tillage and summerfallow to conserve soil organic matter. While he was not the first to identify the issue, this was the first time where a large number of producers became aware of the issue. The desire to reduce summerfallow and the economic drive to intensify production forced farmers to rethink their tillage and seeding systems.

By the late 1970s there was growing interest in air seeders, which were essentially cultivators with an air delivery system for seed distribution. This move was predated by important innovations in heavy duty cultivator technology including the size of cultivators and the four wheel drive tractors to pull them, rock trip mechanisms, articulated frames, and high trash (crop residue) clearance, gave producers the ability to seed in heavy trash conditions. These early "air seeders" tended to use wide sweeps with high soil disturbance, followed by harrow packers to firm the seed bed. These early machines also could combine seed and fertilizer in a "single shoot" air delivery system, which limited the amount of nitrogen that could be safely applied at seeding.

By the mid 1980s, there was great deal of interest in air seeders with many firms producing and refining the technology. They became a major feature at the *Western Farm Progress Show* held in Regina each summer. Significant improvements in air seeders included in-row packers that precisely controlled seeding depth, variable packing pressure, separate (side band or mid-row band) fertilizer placement, and narrow knife type openers that minimized soil disturbance. These innovations were developed and adopted by several small Saskatchewan companies, such as Prasco, Flexicoil, Bourgault, Morris, and ConservaPak. Many of these mechanical innovations were tested at the Prairie Agriculture Machinery Institute. ConservaPak worked extensively with Agriculture and Agri-Food Canada (AAFC) and the Indian Head Agricultural Research Foundation, to test mechanical and agronomic concepts. Interestingly, during this whole period of development, ideas and technical improvements where quickly adopted by much of the industry with very little cross licensing of the technology, suggesting that effective intellectual property protection was very limited. The result was an industry that remained competitive despite substantial innovation.

Once air seeder technology was refined it became a major driver in CT. Although these seeders did cause some soil disturbance at seeding, they allowed for higher quality one-pass seeding with optimum nutrient placement, saving producers labor, time and fuel. This technology combined with the other drivers, made the CT economically desirable, not only in Saskatchewan but across the Prairies and internationally. Of particular note was the decrease in the price of Roundup (glyphosate) after 1990. During the late 1980s and 1990s conservation tillage field days were very popular and well attended by producers, allowing them to try new CT systems and to adapt these new CT technologies to their own operation.

The adoption of CT has become widespread in western Canada. This adoption is consistent with positive farm level economics. Zentner et al.[1] concluded that minimum tillage and zero tillage (both forms of CT) provide both short run economic benefits and long term environmental benefits in most soil-climatic regions in Western Canada. They found that the Brown and Dark Brown soil zones may favour conventional tillage at lower grain prices while producers in the Black soil zone and to some extent the Gray soil zone favour zero till (ZT) because of a yield advantage despite similar costs.

The Innovation Process

There are several standard models of innovation in the economics and business literature. The simplest is a linear model of product innovation as shown in Figure 12.1. In this model, a new discovery leads to applied science and the development of new products which are marketed and adopted by the final users. This is very much a "push" model, where new ideas are the source with the adoption/commercialization being the end product.

Figure 12.1. Linear Model of Innovation

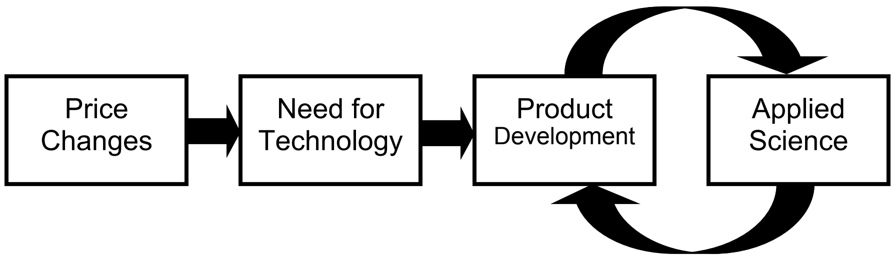
Rogers introduced the concept that adoption was not a passive process but rather a sociological process where early adopters influenced later adopters.[2] The implication was that successful marketing involved reaching the early adopters. In CT the discovery of some ideas, such as side banding of fertilizer eventually led to the development of commercial products, but this does not account for the pent up demand for better tillage technology.

Griliches introduced the concept of induced innovation to the economic literature.[3] As shown in figure 12.2 the idea behind models of induced innovation is that the circumstances for an industry change creating either a severe problem or a real economic opportunity that did not exist previously. This new circumstance changes relative prices, which creates a demand for a new technology. The demand for new technology in turn drives product development and the demand for applied science.

In the case of CT it is clear there were aspects of induced innovation at work. High grain prices combined with knowledge of organic matter depletion sparked an interest in direct seeding technologies. In effect, the demand for new technology pulls the knowledge through to adoption. However this induced innovation model is not rich enough to capture the influence of new knowledge on innovation and adoption.

A somewhat richer innovation model where both push and pull drivers of innovation and two directions of influence are incorporated are known generally as chain models of innovation. Kline and Rosenberg (1986)[4] argue that innovation

Figure 12.2. Induced Innovation

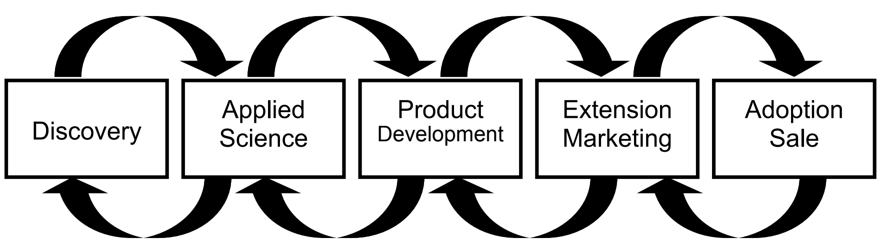


Source: Griliches[3]

is not a single event or product but it more often involves many new products and processes governed by a changed set of relationships. As depicted in figure 12.3 these models recognize that there are many points of interface in innovation, each with two-way flows of information and influence. For instance, marketing affects adoption, yet technologies that are adopted influence product marketing. Applied science affects the types of products that are developed but the products that are developed in turn affect the applied science agenda. These two-way flows of knowledge and influence have been central to the models that recognize that extension activities are really engagement mechanisms where knowledge flows in two directions between science and industries.

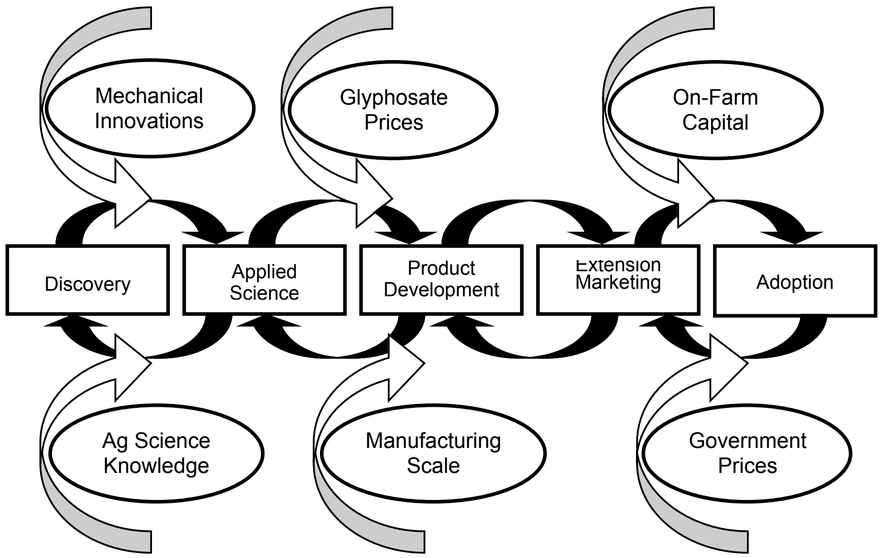
The chain models of innovation fit CT well. Evidence of two-way flows of knowledge with both a push and pull for innovation abounds in the case of CT. Clearly,

Figure 12.3. Chain Models of Innovation



Source: Kline & Rosenberg[4]

Figure 12.4. External Drivers of the CT Innovation Chain



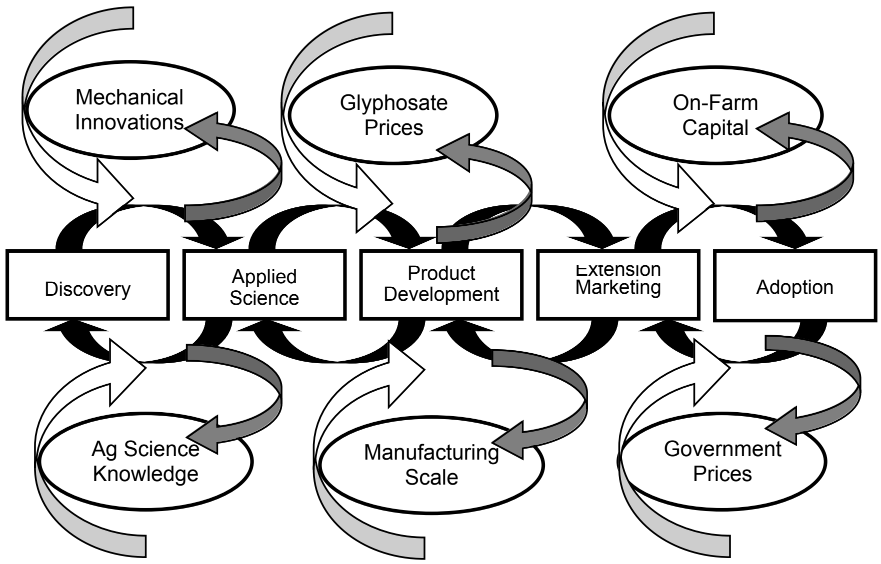
Source: Author's own depiction.

producers and producer organizations were directly involved in the innovation process, both as sources of knowledge drivers of innovations and as customers for innovative products. Similarly, science and scientists played a significant role in creating the conditions for innovation, solving some applied science problems, testing product and process efficacy and communicating the results to large numbers of producers. While this chain model is very rich and captures the two-way flows of information, it does not capture the role of external drivers on CT innovation.

A modern and more complex view of innovation recognizes innovation as a complex process that takes place within a regional, national or global innovation system. As shown is figure 12.4, CT chain innovation can be depicted as being driven by external drivers.

In the model shown in figure 12.4 there are six drivers that accelerated or intensified the innovation process. As drawn, these are external drivers which influenced CT innovation. While the addition of drivers can help explain the development path for CT, this model misses two key aspects of the innovation system. First , some of these drivers are stocks, which accumulate over time. Second, these drivers are not all external to the system. The development, growth and adoption of CT had a

Figure 12.5. Drivers and Positive Feedbacks in the Innovation System



Source: Author's own depiction.

profound effect on many of these drivers. Some of the drivers are therefore part of the CT innovation system, and cannot be viewed as external to the system.

The incorporation of six drivers as part of CT innovation is shown in figure 12.5. As depicted each of these drivers receive positive feedback from the innovation process, which in turn, makes them stronger drivers for CT innovation.

The adoption of CT added to the stock of mechanical innovation through continued research and product development effort that intensified to take advantage of the growing market. As this knowledge stock increased, the quality of these machines improved, thus reducing costs and increasing crop yields. The adoption also led to an expansion of the scale of manufacturing, enabling these companies to take advantage of economies of scale, further augmenting machine quality while reducing manufacturing costs.

The adoption of earlier CT technologies contributed to increases in CT related capital stocks on farms. Not only did farmers accumulate machinery that would complement CT, many adjusted farm size to better fit the technology. Perhaps most importantly, their own stock of human capital and knowledge increased as they learned more about CT. All of these on-farm stocks contributed to and strengthened the adoption of CT.

Government policies were also influenced by the adoption of CT technologies. As cropping intensified, delivery quota rules were changed to reflect production rather than area. As CT technologies became more popular, cropping became more diverse. This created political pressure to modify crop insurance and farm safety net programs to better reflect new crops and cropping systems. As CT became more main stream, government policies, rather than being external, were influenced by CT.

CT innovation also influenced the stock of agronomic knowledge. As producers and CT machinery firms tried new practices, applied scientists examined and worked with these new systems, enhancing their knowledge about what was possible and economically feasible. A good example of an increase in the stock of agronomic knowledge, is how fertilizer recommendations changed over a short period of time. As shown in table 12.1, nitrogen fertilizer recommendations for cereal crops virtually doubled between 1972 and 1984. These increases were no doubt driven by producer desire to crop more intensively. As a result of higher recommendations, more farmers were able to see higher yield and potential benefits from CT.

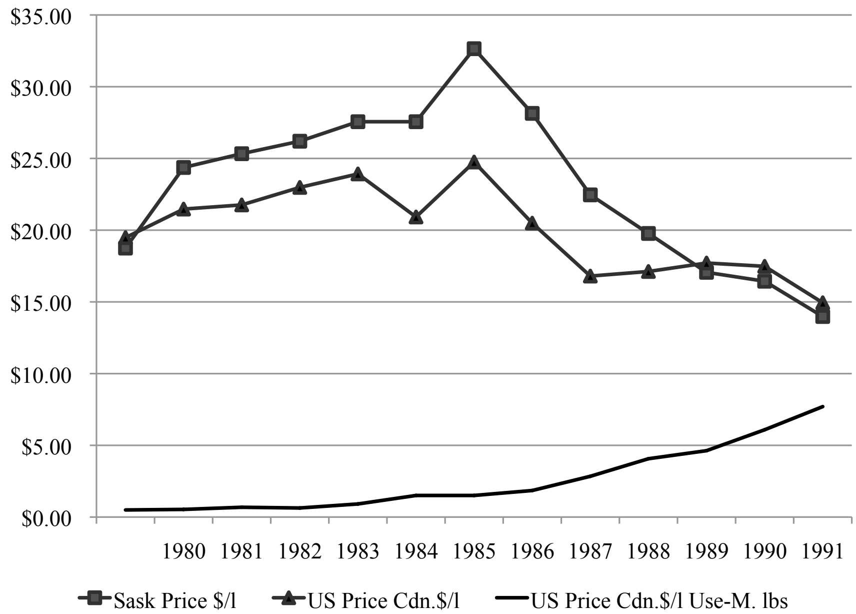
Table 12.1. Guide to farm practice recommended N range for cereals 1972, 1978, 1984.

	Brown Soil Zone	Dark Brown Soil Zone	Black Soil Zone
Year	Recommended Rates (lbs of N per acre)		
1972	0-30	15-40	15-50
1978	10-35	25-50	40-60
1984	10-40	25-65	50-95

Source: Saskatchewan Guide to Farm Practice[5]

Perhaps the most interesting positive feedback from an economic perspective was the relationship between CT adoption and the pricing of RoundUp, Monsanto's patented glyphosate herbicide. As shown in figure 12.6, the Canadian price of RoundUp decreased by 50% between 1986 and 1992. This price decrease occurred at a time when demand was increasing and Monsanto had more than a decade to patent expiry in 2001.

Figure 12.6. RoundUp prices and Canadian use, 1980-1990.



Source: Kowal[6]

A potential explanation for this pricing behavior is shown in table 12.2. Looking at revenue in 1986 versus 1992, revenue more than doubled despite the 50% price drop. The quantity of sales increased more than five-fold when Roundup became priced more competitively with the cost of tillage. A further calculation shows that increases in sales would have contributed positively to Monsanto's profits as long as their production cost was less than $9 per litre. If the adoption of CT was responsible for creating demand conditions that resulted in Monsanto's reduction in RoundUp pricing, this important driver of innovation must be viewed as internal rather than external to the adoption of CT.

Cleary there are a number of drivers for CT innovation that received positive feedback from adoption. These positive feedbacks have implications for the nature of the innovation process and how it can be managed. Before leaving the discussion of drivers, it is important to point out that some drivers such as the price of oil are external to the innovation process and are unaffected by the extent of adoption. Still other drivers become less important over time as negative feedback from adoption

Table 12.2. Saskatchewan and US RoundUp prices and sales quantity, 1980-1992.

Year	Sask Price $/L	US Price CDN$/L	Canadian Use (Millions of lbs)	Canadian Revenue ($ Millions)
1980	18.75	19.48	0.496	9.30
1981	24.37	21.47	0.534	13.01
1982	25.33	21.76	0.683	17.30
1983	26.20	22.98	0.633	16.58
1984	27.56	23.92	0.913	25.16
1985	27.56	20.92	1.506	41.51
1986	32.65	24.75	1.506	49.17
1987	28.14	20.49	1.851	52.09
1988	22.46	16.80	2.843	63.85
1989	19.77	17.12	4.067	80.40
1990	17.06	17.71	4.628	78.95
1991	16.44	17.48	6.085	100.04
1992	13.98	14.94	7.7	107.65

Source: Calculated from Kowal[6]

renders them less important. For example, soil erosion was an important motivator that largely disappeared as CT took hold.

Policy Implications

CT innovation and the adoption process is a rich and wonderfully complex story. The grass roots need to intensify production and conserve soils combined with public sources of knowledge and other economic forces to bring about a transformative change in farming systems.

A closer examination of the forces at work reveals that CT innovation was a complex system with many drivers and many positive feedbacks. These positive feedbacks reveal the need to develop institutions and resources to support early innovators who will in turn help drive subsequent innovation.

In this success story, the interaction with science, which helped identify issues of sustainability, and the ability of producers and small firms to do engineering to address their own mechanical issues, were important factors . With the support of public and producer organizations, these ideas where tested and communicated widely. As the technology developed, the positive feedbacks from commercialization strengthened the innovation forces resulting in widespread adoption and transformation of farming systems. The existence of positive feedbacks makes the path of development extremely hard to predict and manage. In the case of CT it was clearly a success.

There are number of policy implications of this success story.

First, there are some types of valuable research that can take place on the scale of very small firms, indicating a need to support entrepreneurial research. Critical support included interaction and advice from scientists, product testing and concept verification, public trade shows, and support for producer organizations where like-minded individuals can meet and share ideas. In agriculture, research involving agronomic systems, engineering, and perhaps small crop breeding could fall into this category.

Second, CT did not result from a directed research project. It developed over many years, with the public sector undertaking some high risk research over a long period at many locations in order to identify issues, technology needs and potential applications of new technologies. Is the current project and management system for agricultural research in AAFC able to provide the patient capital needed for the next generation of CT-like innovations?

Producer organizations played a critical role in the development and successful adoption of conservation tillage systems. Initially these organizations were small and provided a supportive meeting place for early innovators. As adoption increased, these organizations rapidly grew and played a very significant role in the acceleration of adoption. Despite their past record of success, these soil conservation organizations do not have a stable funding base as they do not fit well in the Canadian system of producer levy collection. Given the long run nature of the problems, and the past successes of industry-driven research, perhaps viable funding models for these organizations need to be explored.

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Chapter 13

Successful Adoption Down Under

Rick S. Llewellyn and Frank H. D'Emden*

Introduction

From a traditional cropping system involving multiple cultivations of typically fragile soil, the shift to no-tillage farming represents one of the most substantial landscape changes in Australian agriculture. In the context of Australia's traditional wheat-sheep based farming systems, the no-till revolution has reduced soil degradation while facilitating major cropping intensification in response to economic drivers such as declining wool prices.

Beginning with study tours of North American conservation farming technology in the 1960s[1], the introduction of no-till technology to Australian cropping has been occurring over decades. Given the current widespread success of no-till technology and cropping systems it is sometimes easy to overlook the fact that adoption of no-till farming systems in Australia is typically both relatively recent and still incomplete. In the majority of regions the most rapid increases in adoption have generally occurred in the past 10 years and a large proportion of growers are still in a period of adaptation. In some major cropping regions, increasing the proportion of growers using no-till and the extent of use of no-till by adopters remains a key natural resource management priority.

The opportunity to learn from past no-till adoption decisions and the need to learn more about opportunities for more extensive and sustainable use of no-till in the future has motivated the research summarized in this paper. The approach taken to explain no-till adoption rates has been one focused on information, learn-

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ing and perceived relative advantage.[2] Giving adequate attention to the range of factors that can determine whether an innovation offers real or perceived relative advantage to farmers compared to the status quo can allow a high proportion of adoption decisions to be explained.[3] In turn, this can reveal new opportunities to target extension and research at factors in the adoption decision that can a) be influenced, and b) be influential in the adoption decision. In addition to previous socio-economic studies of factors influencing the rate of no-till adoption in Australian regions[4], in this paper we also draw on more extensive new data on no-till adoption and trends from across the grain-producing belt of Australia.[5]

A relatively broad definition of no-till seeding has been used throughout. The working definition of no-till is based around seeding with low soil disturbance and no prior cultivation, including crop seeding using either low disturbance points or "zero-till" (with disc machines). The use of disc openers remains relatively low (generally well under 10% of growers), with the exception of the northern cropping region of New South Wales (NSW) and Queensland where both winter and summer crops can be grown. The other major component of conservation cropping systems, full retention of crop residue, has been considered separately and not discussed in any detail here. This is mainly due to the increasing complexities of evaluating crop residue management in mixed (grazed) farming systems and where a range of only partially destructive crop residue management practices may be applied, such as those targeting weed seed kill or removal.

The studies reported on here have had three main aims:

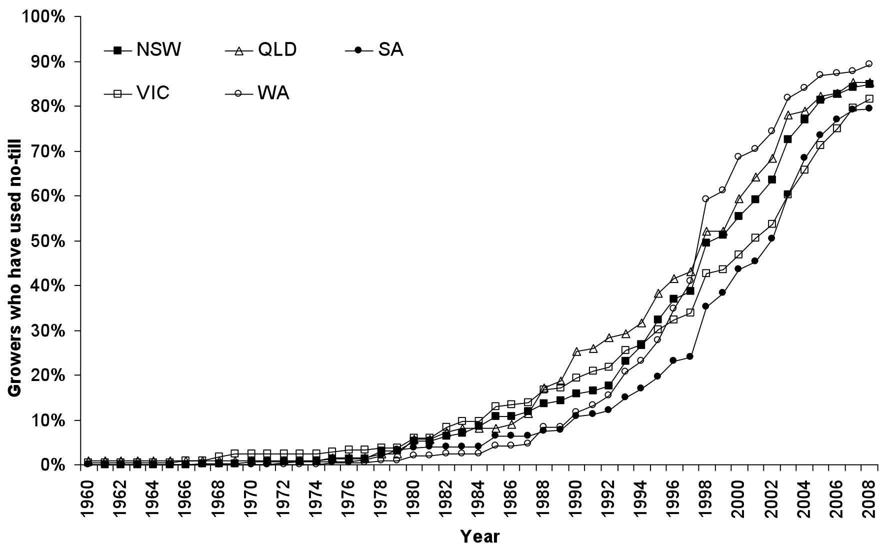
- Use socio-economic data collected from grain growers to identify levels and trends in adoption of no-till and conservation farming practices across cropping regions.
- Identify factors influencing decisions to adopt and extent of use of no-till and conservation farming practices.
- Provide insights for research, development, and extension (R, D & E) and policy to facilitate increased and sustainable use of no-till farming systems.

In this summary paper we start by looking at the current status of no-till adoption in Australia and the path that it has taken to reach the current high levels of adoption. In the second section we look at some of the socio-economic analyses that have helped to identify the major drivers of no-till adoption rates and what we have learnt to further progress this transformation of the cropping landscapes.

The current status of no-till adoption in Australian cropping regions

The diffusion of no-till adoption decisions across Australian grain producing states is shown in figure 13.1. The results show that no-till seeding practices have now been adopted by the majority of grain growers in the regions studied. The proportion of growers using at least some no-till is now peaking at levels nearing 90% in many regions. The results are based on a study of no-till adoption across selected cropping regions of Western Australia, South Australia, Victoria, New South Wales and Southern Queensland involving interviews with 1170 grain growers in 2008.[5] Based on the year of first use, as stated by growers in 2008, the curves display the form of a classical diffusion curve; a long lead time with slow or no adoption followed by a steady increase before a rapid surge in adoption, before slowing as likely peak adoption is approached.

Figure 13.1. Cumulative proportion of Australian crop growers who have used no-till.



Note: NSW - New South Wales; VIC - Victoria; QLD - Queensland; WA - Western Australia, SA - South Australia

Source: Llewellyn et al., 2009[5]

In regions with relatively low adoption five years ago, there have been very rapid increases in adoption, particularly in the period 2003-2006. This result is consistent with the surge in adoption forecast in the 2003 study[6] and also consistent with the influence of low-rainfall years (e.g. the severe drought of 2002) as triggers for subsequent increases in no-till adoption rates. We argue that this can be largely explained through the acute observation/learning experience that very dry seasons provide in terms of the relative benefits of no-till (e.g. benefits of moisture-conservation and seeding timeliness).

Many of the very large relative differences in adoption between states and regions that were clearly evident in 1998 have now closed substantially and are expected to close further over the next 5 years. Although some key regions appear set to peak at a lower level of adoption, in general, it appears that the large differences in adoption 10-years ago were reflecting time lags in the diffusion of no-till more so than major differences in the likely final proportion of growers using no-till. For example, in 2000 the proportion of growers using no-till in Western Australia was 57% higher than in South Australia. In 2008, the difference was only 12%.

It needs to be kept in mind that the curves (figure 13.1) do not account for any dis-adoption. However, it is rare for growers who have adopted no-till to later cease use of no-till. This includes regions where no-till has been an extensive practice over a longer-term (e.g. several Western Australian regions where herbicide resistance issues caused concerns about the sustainability of no-till).[7] Less than 5% of all growers who have ever used some no-till no longer use any no-till. In general, the vast majority of Australian grain growers have made the decision to be using no-till in the near future. Based on grower expectations of future use, the proportion of growers using no-till is expected to exceed 80% in a majority of regions by 2013.

However, extensive practice change across landscape scale requires both the adoption decision and a high extent of use on the land managed by those adopters. Extent of use becomes particularly important in the Australian context where many farmers clearly prefer to retain the flexibility to use some cultivation. The results show that it remains common for no-till adopters to still use some cultivation. The proportion of growers in each state sowing their entire crop using no-till ranges from 43% in southern Queensland to 78% in Western Australia. The average percentage of crop sown using no-till by no-till adopters exceeds 70% in all regions. The remainder of the cropping area is sown using some form of cultivation either pre-seeding, full soil disturbance at seeding or both. In a few key erosion-prone regions, relatively low adoption rates together with relatively low extent of use mean that substantial crop areas are still being cultivated. The remarkable no-till revolution is not yet complete.

Factors explaining no-till adoption

Focusing now on socio-economic data, including perceptions, collected in 2003[4,6], we find that the most common reasons stated for adopting no-till related to soil conservation/erosion prevention, seeding timeliness and moisture conservation. The most common reason stated for non-adoption was machinery costs. However, it is only when more sophisticated analysis is applied that the factors that differentiate adopters and non-adopter can be identified and the factors that are both influential and can be influenced can be determined. The results presented in table 13.1 show the significant factors found to be associated with the adoption of no-till using both logit[8] and duration analysis.[4] Duration (hazard) analysis allows the influence of variables that change over time such as prices, rainfall and farm size to be accounted for. As an example, where cross-sectional analysis and simple comparison of adopters versus non-adopters shows that larger farm size is significantly associated with no-till adoption, including farm size as a time dependent variable using duration analysis showed that the farm size at the time of the adoption decision was not significantly associated with greater likelihood of no-till adoption. Greater farm size expansion post-adoption is commonly observed.

Table 13.1. Factors significantly associated with earlier no-till adoption in southern Australian cropping regions[a]

Years since first awareness of nearby no-till adopter
Higher education
Use of directly paid consultant
Higher participation in extension
Higher perceived effectiveness of pre-emergent herbicide (trifluralin) in a no-till system
Higher perceived soil moisture conserving benefits and improved seeding timeliness of no-till relative to conventional (i.e. full-cut) tillage
Location (region/state)
Fall in price of glyphosate herbicide
Occurrence of a year much drier than average
Higher average annual rainfall (i.e. adoption generally slower in very low rainfall regions)

[a] 82% of adoption decisions in 2003 correctly predicted by logit model (86% adopters;76% non-adopters). Only statistically significant factors listed.

Source: D' Emden et al 2006 & D'Emden et al 2008[4,8]

Information and learning

The results show that no-till adoption and use is clearly an information-intensive process. As well as greater interaction with consultants, researchers and groups of growers, the presence of nearby growers with experience with no-till was shown to be particularly important in explaining adoption. Where growers have had a longer time to observe no-till being practiced in their local district, the likelihood of adoption was higher. The study also found that the likelihood of growers trying no-till for the first time rose after drier than average years including droughts. This suggests that droughts and dry early-season conditions can be a prompt for adoption as some of the benefits of no-till such as moisture conservation and the ability to seed on less rain become most apparent. Consistent with the information processing and learning demands of a complex systems change[9] there was evidence that farmer education was associated with no-till use.

The use of a private cropping consultant was associated with no-till adoption being approximately twice as likely. This has implications in regions where the ready availability of quality farm-specific advisory support is limited. Higher participation in extension, including farmer groups, was also significantly associated with adoption. Unfortunately, the specific role of the major farmer-led no-till farming associations in Australia (e.g. Western Australian No-Till Farming Association (WANTFA) and South Australian No-Till Farmers Association (SANTFA)) could not be statistically accommodated in the study. This was due to the fact that almost every no-till association member was a no-till adopter and the membership trajectories of these groups tracked the diffusion of no-till very closely (membership of the major no-till farmers association peaked at over 1000 members each at the time of the most rapid adoption rates).

In terms of farmer learning opportunities and perceptions, the perceptions that were not significant are of as much interest as those that were. Although soil conservation and erosion prevention was the most common reason for adoption stated by no-till users, perceptions relating to the erosion prevention benefits of no-till did not differentiate adopters and non-adopters. Essentially, non-adopters were well aware of these benefits. The results suggested that continuing to focus extension efforts on demonstrating soil erodibility and its prevention under no-till was likely to be less effective than focusing on learning around pre-emergent weed management options and the opportunities for more timely seeding under no-till cropping systems. Similarly, both adopters and non-adopters were generally well aware of the possible herbicide resistance risks in no-till systems.

No-till, weed management and glyphosate

The real and perceived cost-effectiveness of key herbicides such as glyphosate and trifluralin are shown to be influential in the decision to adopt no-till. For example, the results show that research and extension able to increase the perceived effectiveness of pre-emergence herbicides in no-till systems among non-adopters was likely to be much more influential on adoption decision-making than efforts to demonstrate the erosion-prevention benefits of no-till. Perhaps the finding that best demonstrates the integral role of weed management and herbicides in the adoption of no-till in Australian agriculture is the role of glyphosate price relative to the price of its substitute, diesel. The patent-related fall in the price of glyphosate (from approximately A$18.30/L in 1983 to A$4.50/L in 2003 after the fall) has played a significant role in increasing no-till adoption. The results suggest that if the glyphosate to diesel price ratio had stayed at 1983 levels (*ceteris paribus*) no-till adoption rates may have been halved.

The importance of the herbicide glyphosate in the economics of no-till adoption has long been recognized.[10] Just as glyphosate price falls prior to 2003 led to increased no-till adoption rates in Australia[4], growers in 2008 have indicated that recent glyphosate price rises have led to their increased use of tillage in many regions. Over the entire national study of 1170 grain growers, 21% of no-till users reported increased use of tillage as a result of increased glyphosate prices (72% reporting no change and 7% reporting less tillage), compared to 32% of non-users reporting increased use of tillage as a result of increased glyphosate prices (61% reporting no change and 7% reporting less tillage). In regions where it is more common that 100% of a farm's crop area is sown no-till, the glyphosate price rise has had little or no reported influence on tillage use. Because a majority of growers in most districts still use some tillage, it should be expected that economic and agri-environmental factors will cause seasonal shifts in extent of tillage use. Importantly, very few no-till adopters have indicated a general ongoing shift to greater use of tillage.

Conclusions

The diffusion of no-till across diverse Australian cropping landscapes has been remarkable. The ongoing adoption and lack of disadoption has further confirmed that no-till is highly adaptable and adoptable. Extensive use has so far been sustained across a wide range of agro-ecosystems and the last 5 years have seen many regions with previously lower no-till adoption rapidly increase adoption to levels similar to early-adopting regions.

It needs to be recognized though that there will still be several regions with a combination of a relatively lower no-till adoption levels and lower extent of use. As is clearly evident each summer and autumn, dust storms with public cost are not yet a thing of the past in some Australian cropping regions. Unless current trends and stated expectations change, this will continue to be the case into the next decade.

Reaching very high adoption of no-till and reduced erosion risk in these particular regions will most likely require new and innovative approaches to support greater adoption. It is likely that a new set of influential factors will need to be identified. The enormous level of innovation, motivation, collaborative learning and action that has taken the no-till revolution to its current success gives confidence that this can be achieved.

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Chapter 14

International Development Opportunities – Hot Spots for Future Development

Terry L. Roberts and Adrian M. Johnston*

Introduction

Conservation tillage has been quietly expanding, and evolving, around the globe for the past 3-4 decades. Defined as reduced tillage systems that leave a certain percentage of crop residues on the soil surface after planting, conservation tillage, or any of the many common synonymous descriptors (zero tillage, no-till, direct seeding, reduced tillage, etc.) are being replaced by the more generic term, conservation agriculture. The United Nations' FAO describes conservation agriculture as: *"Involving a process to maximize ground cover by retention of crop residues and to reduce tillage to the absolute minimum while exploiting the use of proper crop rotations and rational application of inputs (fertilizers and pesticides) to achieve a sustainable and profitable production strategy for a defined production system."* The FAO definition integrates residue management with cropping systems and production inputs and appears to best explain its successful adoption in many countries around the world. Conservation agriculture is more inclusive than conservation tillage, with zero tillage as its cornerstone. For our purposes, zero tillage and conservation agriculture will be used interchangeably in this discussion.

There are few countries where conservation agriculture is not practiced successfully by at least some farmers. Conservation agriculture is carried out on farms from 60 °N latitude (e.g. Finland) to the Equator (e.g. Kenya, Uganda) to 40 °S

*Both Roberts and Johnston work for the International Plant Nutrition Institute. This chapter is based off their presentation at *Landscapes Transformed: The Quiet Triumph of Conservation Tillage and Direct Seeding Conference*, March 23-25, 2009, Saskatoon, SK.

(e.g. Argentina, Chile), from sea level to 3000 m elevation (e.g. Bolivia, Colombia), and from extremely dry conditions (200 mm rain; e.g. western Australia) to extremely wet (e.g. 2000 mm in Brazil, 3000 mm in Chile).[1] Conservation agriculture is applied on farms of all sizes, including small landholders (< 0.5 ha) and on soils that vary from 90% sand (e.g. Australia) to 80% clay (e.g Brazil's Oxisols and Alfisols) and in all crops, including root crops. The wide ranging conditions of climates, soils, and geographic conditions where conservation agriculture has been successfully implemented will ensure further interest and development of this technology.

Zero tillage is now estimated to be practiced on over 105 million hectares (M ha) worldwide, mostly in North and South America.[1] South America leads with 47% of the world's zero till acreage followed by 38% in North America, 12% in Australia/New Zealand, and 2% in Asia. South America will continue to be the hot spot for future development, but Asia and Eastern Europe also have great potential.

South America

Brazil is a world leader in successful adoption of conservation agriculture. No-till was introduced to Brazil in the early 1970s, some 10 years after it was started in the U.S. Brazil now has 25.5 M ha under no-till, or 60% of its cropped acreage, compared to 26.6 M ha in the U.S.[1] Brazilian farmers have pioneered the use of cover crops in no-till systems. No-till was relatively easy to apply when it was first introduced in the humid subtropical southern states where two crops a year can be harvested. However, when initiated in the arid cerrado regions where only one crop per year is possible, no-till was only successfully adopted by planting a cover crop (e.g. *Brachiaria ruziziensis*) to provide surface residue during the six month dry season.

Brazil's no-till area will likely increase as the cerrado is one of the few places left in the world where cultivated area can be expanded. Brazil has over 100 M ha of pasture and rangeland in the cerrado region potentially suitable for field crops that has yet to be developed. A survey of leading agricultural scientists in Brazil suggested the following challenges and opportunities for future development of conservation agriculture in this country:

1. Adjustment in production systems. In many areas of Brazil, especially in the cerrado, conventional production systems result in loss or no accumulation of soil organic matter. Additions of crop residues from no-till production systems are necessary to build and maintain organic matter in these soil systems and are critical to soil quality and a more sustainable agriculture.

2. Development of new varieties and higher quality seed. It will be necessary to develop new varieties aiming to increase carbon input into the soil (e.g., plants with more lignin) and to permit seeding at different times of the year to

allow the shortest possible period between harvest and planting. Low quality seed is a major limiting factor to further adoption of no-till. In soybean, lack of seed quality and introduction of diseases like fusarium and anthracnose is a significant concern.

3. Better extension of no-till information for farmers. Many problems with no-till come from inadequate management of the cropping system. Adequate technical assistance for farmers and training of labor on large farms is necessary for further widespread development of conservation agriculture.

4. Grassland rejuvenation and integrated crop/cattle production. Over 50 M ha of degraded grasslands in Brazil could be managed and improved with conservation agriculture, but federal input is necessary. In many areas integrating no-till crop production with cattle production on the same lands is fundamental.

5. Better equipment. No-till in many areas of Brazil is only possible with the use of green manure cover crops, crop rotation, and the maintenance of surface crop residues, which requires specialized equipment. New machinery will be needed to further advance no-till in some areas.

Argentina has been among the most successful countries adopting conservation agriculture. They have 19.7 M ha under zero-tillage, which represents about 70% of Argentina's total cropped area. Initial adoption of the technology was slow due to inexperience, lack of knowledge, seeding equipment, and limited herbicide availability. However, since 1990 area has steadily increased, largely due to the extension efforts of the Argentinean Association of No-till Farmers (AAPRESID) and research by the National Institute of Agricultural Technology (INTA).

Area of conservation tillage in Argentina appears to be leveling off at about 20 M ha. Future increase in no-till area depends on the opening of new agricultural land in the northeastern and northwestern regions of the country. Development of agriculture in these regions is currently under discussion because it would take place at the expense of native forest and savanna ecosystems. Another region of potential increase for no-till is the Southern Pampas, where adoption has been low compared to other areas of the Pampas mainly because of cold soils. The problems of seeding and crop establishment, because of residue accumulation on the soil surface due to slow residue decomposition rates under cool weather, continue to limit adoption.

Adoption of conservation agriculture in other Southern Cone countries has been quite high, so further expansion is not expected. No-tillage is the main soil management system for annual cropping in Paraguay. It has been adopted on an estimated 2.4 M ha, or 90% of their mechanized agriculture. Even small farmers have been adopting the technology with manual no-till on at least a part of their farms. About

70% of the grain production area of the Eastern Plains of Bolivia is under no-till; continuous soybean is the main no-till crop. However, it is believed the trend will continue as alternative crops such as corn, wheat, and sunflower replace soybean area. About 670,000 ha or 82% of the cropland in Uruguay are managed with zero-tillage. Conservation agriculture has not been adopted in Chile as in other Southern Cone countries. The main constraints are the low temperatures and management of the heavy residues produced in the wheat cropping systems.

Asia

Where farm size in North and South America is large, farms are very small, on average, in Asia. In addition to small land holdings, most farmers have no other employment. This means a life of poverty and struggle simply to feed one's family and survive with life's basic essentials. Conservation tillage practices have been studied and promoted in many areas of Asia. Conservation agriculture in China has developed relatively slow due to the small scale of agriculture (average farm size is less than 0.1 ha) and lack of proper equipment. While research and application of conservation agriculture dates back to the 1970s, more work has been done in Northwest China and other arid and/or rainfed cropping systems. There is 158.5 M ha of cropped area in China, of which 19% is in paddy. With an estimated area of 1.33 M ha in no-till,[1] this represents only 1% of non-paddy cropped area.

In South Asia, including the Indo-Gangetic Plains of Bangladesh, India, Nepal, and Pakistan, no-till is estimated to be practiced on about 5 M ha of wheat, double cropped with rice.[1] However, no-till is not applied to the rice phase of the rotation. No-till has been successfully adopted for wheat production because tillage following the rice harvest takes time and for each day planting is delayed beyond the optimum, wheat yields are reduced 1 to 1.5%.

In Asia, the biggest issues with no-till management are farm size, equipment and crop residues:

1. Farms are small in most of Asia, with south Asia having the smallest holdings of 0.5 ha or less on average. These farmers grow 2 to 3 crops/year with often little time between the harvest of one and planting of the next. This rapid turn-around between crops makes handling of crop residues a challenge when working with animal power. This is the reality in most of south Asia. Poverty is also the norm for most south Asian farmers. An example from West Bengal in India showed that farmers in 2007, on 0.5 ha of land, growing two crops of rice and one crop of mustard, made a net income of about US$1.75/day.
2. Equipment options for no-till seeding are a challenge in Asia, requiring everything from one plant at a time to row planting using animal power. While some appropriate equipment exists, its local availability and affordability is another issue. This is the reality for small farmers. A major issue that needs

to be addressed for small scale farmers is how to adapt larger implements to small tractors or animal power.

3. The removal of crop residues in many parts of Asia is a reality which is a major challenge that requires significant attention. Work by CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo) showed clearly that residue retention in the field was critical to the successful implementation of conservation tillage benefits to the farmer.[2] People use residues for heating, livestock feed, and as income in most of these south Asian countries. Many landless poor in south Asia will actually harvest a crop for a farmer if they can have all the residues left in the field for their livestock – and this includes pulling out the stubble from the field. It is potentially a long way down the road for many south Asian countries, but increasing farm size is the main factor which will ultimately lead to fewer residues being used for alternative purposes and more residues being left on the land to build soil quality and support nutrient cycling.

China is well on the way to promoting no-till in the semi-arid and sub-humid regions, particularly where rice is not grown. The concept and equipment have been developed for small holders to use with small tractors. The issue in China remains residue management – their equipment is small and therefore not well suited to passing through heavy crop residues, so in many cases they remove some of the field residues. In other cases they remove all residues, leaving only anchored crop residues. The Chinese government is also promoting the renting of land, so that those who want to leave to work can do so, renting to those who want to stay and farm. This, of course, is the age old rural depopulation scenario which has played itself out in most of the northern hemisphere. Time will tell how far this trend will go, but we are very optimistic about this in that the good farmers stay behind to farm larger tracts of land, and in so doing raise the productivity in these countries. These larger farmers are also well equipped to implement many of the efficiency technologies which improve both yield and profitability.

India, Bangladesh, and Pakistan are very different from China, mainly due to the high unemployment rates keeping large numbers of people in rural areas. They really have nowhere to go for employment; lack of jobs, their lack of education, and lack of money make it difficult to be mobile. As a result, land continues to be subdivided in south Asian families and people struggle to grow enough crop to survive while selling some crops to generate minimal income. The barrier in these systems is the lack of currency – no one has any residual cash, be it for personal items or crop production inputs. All of the available currency is used to buy food and medicines when required. Simple no-till tools have been developed in many of these countries, and in most cases demonstrated to be effective in growing crops without tillage. However, the vast number of farmers, and grossly deficient extension systems, really mean that most farmers have no access to this new information. Surveys conducted in India show clearly that most farmers get their advice from neighbours and input suppliers, with extension agents coming in at a very low level (K. Majumdar, *pers. comm.*). The growth of input suppliers as part of the fertilizer industry, with university educated staff in the dealership, holds great promise in advancing technology directly to farmers. As has happened in North America, it will be industry which will become the principal agent of technology delivery in future agriculture.

Eastern Europe

The Ukraine government estimates that it has 250,000 ha of conservation agriculture, but other estimates range from 30,000 to 1.1 M ha. It is estimated 100,000 ha is in low disturbance no-till, with the balance under a high disturbance direct seeding system.[1] In Russia, resource conservation agriculture comprises various combined technologies including minimum tillage and to a lesser extent, no-tillage (V. Nosov, *pers. comm.*). Resource conservation technology was believed practiced on 35% of the sown acreage in Russia in 2008 and is expected to increase to 50% of sown acres in the next few years. According to various estimates there is about 2 M ha under no-till in Russia, which represents less than 3% of planted area. The region Samara Oblast, located in the drought-prone Volga area, is regarded as the pioneer in the adoption of resource conservation technologies. Conservation agriculture in this region was used on 70% of cereals in 2007. It is worth noting that the production of machinery for minimum tillage operations started in Samara Oblast in 1998.

Constraints to further adoption of conservation agriculture in Russia include inadequate use of fertilizer, low crop yields, and insufficient supporting research:

1. The use of mineral fertilizers and other agrochemical inputs is far from where it should be. Studies have reported conservation tillage decreased grain yield of spring wheat by 12 to 14% if mineral fertilizers and other agrochemicals were not applied.[3] This field experiment was conducted on a typical Chernozemic soil in Samara Oblast (Volga region) where attainable grain yields of spring wheat range from 1.91 to 2.68 t/ha without irrigation. Low use of mineral fertilizers is considered a serious limitation for the successful development of conservation tillage technologies in Russia.

2. Without large scale adoption of modern agricultural technologies, crop yields in Russia are still low (the average grain yield of wheat was 2.02 t/ha during last the 5 years: 2004 to 2008). Hence, low levels of crop residues are left on the soil surface, reducing any potential benefit from conservation tillage practices. These problems often occur in drought affected areas (for instance, in the drought-prone Volga region).

3. No-till and minimum till technologies were not found to be appropriate on heavy textured Chernozem soils in some areas (Western Siberia, South Ural) because of excess soil moisture accumulation in spring. Non-uniform distribution of precipitation throughout the year, for example in Western Siberia, where significant amounts of precipitation occur in winter season, creates a need for autumn tillage on heavy textured soils.[4] Otherwise, the content of soil moisture may be negatively affected. Long-term field experiments conducted at the Siberian Research Institute of Agriculture in Omsk Oblast (Western Siberia) demonstrate that minimum till and no-till practices decrease productive moisture reserves in the 0 to 100 cm soil layer after snow melt by 18 to 25%.[5] Moreover, minimum tillage on slopes causes increased erosion of heavy textured soils.

Large farm size is going to be the dominant form of commercial agriculture in the former Soviet Union. There is not likely to be a resurgence of small farms in this region given the massive changes that have occurred in the society and economy. This is a potentially positive factor in that it will allow the operators of larger land holdings to implement new technologies, including conservation agriculture.

Concluding Comments

In many instances, the greatest barrier to adoption of conservation tillage technology by farmers is their mindset regarding the role of tillage in their farming system.[6] The attitude and buy-in by extension workers can often help overcome some of the challenges with adoption by farmers. As has been the case in the developed world, innovative approaches to scaling up research trials to the farm level, and involving the participation of farmers and extension advisers, is critical to adoption. Once the technology has been demonstrated and adapted to local conditions, the development of economical conservation tillage seeding equipment will allow the effective establishment of crops in fields with residue mulch cover.

Sustainable cropping systems are dependent on high yielding cultivars that will provide adequate crop residues for both conservation goals as well as alternative fodder, fuel, and construction uses. This is of particular importance in regions where crop biomass residue has traditionally sustained livestock feed and home cooking/heating requirements. Innovative approaches to cultivar selection for crop height, methods of partial residue removal, and management of remaining residue mulch cover are required. As always, once the benefits of maintaining residue cover on crop yield are demonstrated, farmer innovation will result in strategies to achieve a balance in residue use between the household and cropping systems.

It is clear from our review of conservation agriculture in many parts of the developing world that adoption and implementation is largely a function of farm size and the demand for crop residues for alternative uses or income. Where large farms are established, or are being developed, conservation tillage crop production is likely an economic and sustainable management system to adopt. Excellent examples of this are South America and the former Eastern Bloc countries. However, where farm size is very small, crop residues are in demand for alternative household and economic value, and poverty and poor education is endemic amongst the rural population, the process of adoption for conservation tillage will be a struggle. The best example of this is south Asia. China likely holds the greatest potential at this time for an increase in conservation tillage adoption, coming in tandem with increasing farm size and mechanization.

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Chapter 15

Charting a Path Forward in China

Brant Kirychuk

Overview

The majority of agricultural land in China is degraded due to a long history of intensive cropping. The implementation of practices to reduce erosion, increase organic matter, and improve the efficiency and productivity of cropping systems is very important to the long term sustainability of agriculture in China. Land degradation is causing many additional issues including: siltation, nutrient and pesticide movement into waterways; dust storms that impact comfort, health, and move pollutants to other areas in China and internationally; reduced output from agricultural land; and increased costs as farmers are putting in high levels of inputs to maintain productivity. A concerted effort to share information on the implementation of practices to reverse this trend is essential. There are successful models for implementing new technologies that have been used in other parts of the world that China could benefit from. The adoption of direct seeding in Canada is an excellent example.

The Challenge

Agriculture in China is very complex, as there is a long history with many cultural influences. There are a number of challenges associated with implementing change on the agricultural landscape.

1. *Information not getting to farmers.*There is a very large extension system in China at national, provincial, county and even village levels. Estimates suggest that there may be as many as 1 million government employees with

at least a portion of their role to conduct agriculture extension. That said, the extension system, with a few exceptions in some counties, is non-functional. The greatest challenge is that there are approximately 700 million rural residents, with a proportion living in remote areas. Further, the local extension stations that deal directly with farmers are woefully under-funded, with no money to conduct extension activities, and in many instances staff receiving less than a full salary. It is common that extension agents have no training in adult education or extension methodology. Further there is a distinct distrust of the extension system by farmers. Part of this may be driven by the fact that often these extension stations sell farm inputs, or provide services for a fee, such as livestock inoculation, to provide some income. This would be an apparent conflict of interest.

2. *Variable landscapes and climate.* China is a very large country with a diversity of agriculture systems, climates, and geology. Climate varies from high moisture, tropical, three-crop agriculture, to arid steppe short season agriculture. A wide variety of landscapes are cultivated in China, from flat open plains and plateaus, to significant slopes, including many that are severely terraced to make them amenable to cultivation and allow capture of moisture. The agriculture systems for the most part are labor and tillage intensive. In some cropping/livestock areas there are challenges regarding retention of organic matter and soil cover as much of the aftermath is used for livestock feed. In moist areas dominated by cropping the opposite often happens with excess aftermath disposed by burning.

3. *Small individual farms and field size.* Farms and individual fields are extremely small. It is quite common for farms to be fractions of a hectare. Thus, the resources available for modernizing agriculture or using advanced direct seeding and harvesting equipment are limited, except where farmers work as a group. Further, equipment sized for these small plots is limited, and lack of roads to many small plots makes equipment access to the fields an issue. The availability of farm labor has been quite variable. For the last decade or more there has been a migration off the farm to work at factories and construction in urban areas. This has resulted in less labor available on the farm and women playing a larger role in agriculture. The migration to urban areas has resulted in some informal amalgamation of land as neighbors made rental, or land usage agreements, and ended up with larger tracts of land. This trend resulted in increased interest in and use of mechanization, as well as the development of farm associations for equipment sharing and purchase of inputs. At the extreme, some land that was abandoned and not cropped due to a lack of labor in the area. More recently, with the down turn in manufacturing in China many people are returning to the farms, thus there

is more labor available, and likely adjustments to farming approach and land use.

4. *Level of education in rural communities.* The level of education in rural areas is lower than urban areas with many of those on the farm having only completed some level of middle school. This makes the development of training programs and useful publications a challenge, so that they are of value to a wide audience with varying education and cultural backgrounds.

The Direction in China

There is political support at the highest levels to both increase rural incomes and improve the health of the environment and sustainability of agriculture. In President Hu Jintao's address to the National Peoples Congress in October 2007 there were four separate references related to improving the agriculture environment and the delivery of agriculture extension to the benefit of farmers. In 2008 there was further emphasis on reducing income disparity between urban and rural areas with the aim of significantly increasing rural wealth.

The new policy emphasis has resulted in increased funding flowing into agricultural programming. There are a number of programs which aim to support development of sustainable agriculture systems. The one most relevant to conservation agriculture is funding to set up demonstration areas for direct seeding and conservation agriculture systems. The purpose of the demonstration sites are to allow local farmers to see and experience the new technology, as well as use them for training purposes.

Research on conservation agriculture equipment and systems is quite widespread. There is very good institutional knowledge and understanding of conservation agriculture. While there is a significant amount of research being conducted, the variety of landscapes and crops has created challenges in developing systems applicable to all the various situations. There is a formal equipment testing and certification system that all equipment has to go through to be proven out as well. While there is good knowledge at the universities and various government research institutions there is a serious gap in getting this information to farmers. This is a key priority to be addressed in a revamped extension system.

There is a real demand for relevant training events, field days and publications. The experience from the China-Canada Sustainable Agriculture Development Project (SADP) was that when good quality, unbiased training or publications were available, there was an overwhelming demand for these products. There is a thirst for good quality information in the farming community, thus a willing audience.

Sharing Canada's Experience

A two phase bilateral project was first established in China in 2000 with funding from the Canadian International Development Agency and counterpart funding from the Chinese government, called the China-Canada Sustainable Agriculture Development Project (SADP). This is a project aiming to provide the technical and extension basis to address the severe degradation of China's rangeland and cultivated lands. The project focused on developing capacity in the rural western regions of China with the objectives of: 1) adaptation of land resource management systems for sustainable agriculture; 2) enhanced sustainable agriculture extension systems, and; 3) improved enabling environment for sustainable land resource management. The project was conducted in the provinces of Inner Mongolia, Sichuan, Xinjiang, Gansu, Hubei and Hunan in north-west China.

The project approach was based on successful models used in Canada regarding the adoption of new agricultural practices and technology. An example often referred to in training programs, and also the model which some of the project design was based on was the spread of direct seeding technology across Canada. The use of multiple approaches, by various sectors, focussed on the farmer, towards a mutual goal of developing and implementing the new technology and improved knowledge. The most important message shared regarding the successful uptake of direct seeding is the dual benefit of environmental health and producer bottom line. The project emphasized developing or sharing these "win-win" practices.

The Approach

SADP used a needs-based, client focussed extension approach. The project developed programs to improve extension skills among specialists, adapted and demonstrated technologies new to north-west China, and implemented model extension programs. The project took a "full farm approach" in most programming. For conservation agriculture that meant developing a program that integrated equipment, crop rotations, soil conservation, nutrient management, pest control and economics. This approach was deemed to be critical in China, as quite often system components were treated separately and integrated systems were not developed or promoted.

A combination of formal needs assessment, partner knowledge of the area, and working directly with clients, was used to develop a program that was focussed on the local needs of farmers. The most successful activities implemented, directly met the needs of the farm clients being targeted and were often more popular than what project resources could accommodate. This was an approach that was quite new to extension personnel who worked in a system, where they implemented programs as they were told by their superiors, with little regard for the situation in the field.

A primary focus of the project was developing extension skills and improving knowledge in the most recent developments in conservation agriculture technology of key partners, predominantly those that are in organizations which have the mandate to work directly with farmers. SADP conducted training both in-Canada and at national and provincial levels in China to develop a cadre of trainers who could deliver this knowledge to their staff and colleagues. Local level training was then carried out in collaboration with project specialists and as skills developed, extension events were then put on by these trained individuals on their own.

In each project province there were one to three counties where needs based, farmer focussed extension models were established. Each province had a Canadian Long Term Technical Advisor, who developed these programs in collaboration with local counterparts, based on the priority needs of the local farmers. This allowed local extension personnel to gain experience in delivering an extension program, and also develop a model on the ground that others could theoretically copy.

Agriculture practices related to conservation agriculture are quite well developed in North America, Australia and Europe, and even at the institutional level in China. There was an opportunity to take some of these key proven techniques and adapt them to a local region through a trial and demonstration program. Some practices that were adapted included seeding equipment, manual seeding techniques, crop rotations, balanced nutrient management, and alternative pest control. Demonstrations were widely used as tools to show technologies not common to an area. This allowed farmers to gain experience with a practice they were not familiar with, by seeing it in the field, getting first hand knowledge on how it was implemented, thus seeing its applicability to the region. These demonstrations were also used as part of the local training and extension program.

Farmer Field Schools (FFS) have been very successful outputs of the project. These were generally half or one day events put on right at the village level on a very specific topic relevant to that community. These FFS were generally delivered by people who came out of the project's "Training of Trainers" program, and would commonly deliver a series of FFS in their local community. Many FFS are now operating independently after initial training and mentoring within the project. Several sessions were held by these experienced FFS delivery agents to train even more people to run FFS. These are a real success story as the FFS model now has a life of its own. Tens of thousands of farmers have been trained throughout China using the FFS model. Many organizations are implementing their own programs to provide training and support for FFS and are being delivered both by local technicians and farmers who are comfortable in a training role and are leaders in their area. The popularity and success of these initiatives is due to their low cost; relevance to local community's needs; objective; and fit into the schedule of the farming community.

SADP conducted training on roles of farmer associations as tools for farmers both in collaborative business arrangements, and also as formal mediums for farmers to work with farmers. The project also collaborated on the set up of new farmer associations that would play a role in a community working together to improve both their agricultural environment and livelihood.

Conclusion

China has some major challenges facing it to reduce agriculture's environmental footprint on the landscape and make it more sustainable in the long term. There are proven agricultural techniques used in other parts of the world that have successfully improved the health of agricultural lands, and the profitability of farms. The expansion and uptake of direct seeding in Canada is an excellent model that could be applied to China. On a small scale, SADP has demonstrated the applicability of this approach. The Chinese government has made improving the environment and rural livelihoods a priority, and they have allocated resources to these areas. Thus the technology, methods, and motivation are in place, and how well these are implemented and accepted will be the key to success.

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Chapter 16

Criteria for Adoption of Conservation Agriculture and Zero Tillage in Developing Countries

Julian Dumanski*

Overview

Land degradation impacts seriously on land productivity, food security, poverty reduction, and environmental services in many developing countries. Conservation agriculture (CA) and zero tillage have considerable potential to mitigate the effects of land degradation, but apart from North and South America and Australia, adoption rates have been very low. In promoting these technologies, the approaches and procedures have to be tailored to the changing conditions in developing countries, and in most cases linked to technologies of Sustainable Land Management, so as to concomitantly improve land quality, improve food security, and reduce rural poverty. This paper discusses the successes achieved with zero tillage in Latin America, and some recent evidence from Sub-Saharan Africa. Recommendations for improved promotion are provided, including technical, institutional, and policy support.

Introduction

The human footprint on global ecosystems is large and growing exponentially. Currently, fully 83% of the world's land area is directly influenced by human

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interventions[1]; 50% of the terrestrial earth's surface has been converted to grazing land and cultivated cropland, and 25% is intensively managed in agriculture, natural and plantation forests, or managed nature preserves.[2] Estimates are that by early in the next century, all land will be under some degree of management.[3]

Land degradation, including erosion, nutrient depletion, and desertification, is recognized as a major global environment and sustainable development challenge[4], particularly for croplands and grazing lands. About two-thirds of global agricultural land has been degraded to some extent during the last 50 years, and about 25% is severely degraded. It is estimated that the cumulative crop productivity losses due to land degradation are about 5% worldwide (about 8.2% for Africa), and the annual loss of agricultural land due to degradation is about 5-12 M ha. This has impacts on the livelihoods, economic well-being, and the nutritional status of almost 1 billion people in developing countries.[2]

Land degradation is especially serious in Africa and South America where there are direct negative impacts on agricultural productivity and rural poverty. It also impacts negatively on ecological services, such as water quality, sedimentation control, biological diversity, and soil sinks for mitigation of greenhouse gases.

The Changing Status of "Developing Countries"

The terms "Developing Countries" or "Emerging Economies" are often used loosely to denote populations with lower per capita incomes than those enjoyed in North America and Europe. Although there are some common characteristics among them, the production systems, economic conditions, and ecosystems of these countries are highly diverse. Also, conditions are changing very rapidly, with the adoption of new marketing structures, new technologies, and new knowledge.

The World Bank characterizes "Developing Countries" into three categories:[5]

Agriculture-based countries (mostly Sub-Saharan Africa). The agricultural sector is the engine for economic growth, poverty reduction, and food security; it generates 32% of GDP, and employs 65% of the labor force. Women make up a major portion of the agricultural workforce.

Transforming countries (examples China, India, North Africa, etc). Major issues are reduction of rural poverty (600 M people) and narrowing the rural-urban income gap. Agriculture contributes about 7% to GDP; a major concern is to avoid falling into subsidy and protection traps that stymie growth and tax poor consumers.

Urbanized countries (mainly Latin America, the Caribbean, Eastern Europe, Central Asia). The broad goal is to link smallholders to modern food markets and provide remunerative jobs in rural areas. However, rural areas are still home to 45% of the poor. Agriculture contributes just 5% of GDP growth, but agribusiness and food services account for as much as 35% of GDP.

The *World Development Report* notes that major driving forces on global food supplies include competing demands for food, feed, and biofuels; the rising price of energy; increasing land and water scarcity; and climate change. Developing country producers are disadvantaged due to the protectionist policies and subsidies in developed countries, the result of which is to limit export opportunities, depress prices, and restrict the evolution of a neutral international market, including biofuels. Also, the report asserts that industrialized countries urgently need to do more to help poor farmers adapt their production systems to climate change.

In summary, developing countries have evolved considerably over the past decades, except for sub-Saharan Africa. Thus the promotion of any new technologies, such as zero tillage, requires that the approach be sufficiently flexible to fit within the range of conditions currently present in these countries. The challenge is to make the technology sufficiently appealing to capture a particular niche in the systems.

Conservation Agriculture and Zero Tillage

The term "zero tillage" and "conservation agriculture" are often used synonymously in the literature, but the concepts behind each are quite different.[1] Conservation Agriculture (CA) is a paradigm involving a combination of principles, procedures and technologies which, when used in combination, promote healthy soil environments and sustainable agricultural production. Zero tillage, on the other hand, is a specific technology for planting with minimal disturbance of the soil surface. It is the most important technology in Conservation Agriculture. "Integrated Zero Tillage" is sometimes equated with Conservation Agriculture in Brazil.

The principles of CA include:[2]

- Maintaining permanent soil cover and promoting minimal mechanical disturbance of soil through zero tillage systems, to ensure sufficient living and/or residual biomass to enhance soil and water conservation and control soil erosion.
- Promoting a healthy, living soil through crop rotations, cover crops, and the use of integrated pest management technologies.
- Promoting the application of fertilizers, pesticides, herbicides, and fungicides in balance with crop requirements.
- Promoting precision placement of crop inputs to reduce input costs, optimize efficiency of operations, and prevent environmental damage.

[1] In this paper, the term "zero tillage" is used synonymously with conservation tillage and no-till.

[2] These principles were developed by an international working group.[6]

- Promoting legume fallows (including herbaceous and tree fallows where suitable), as well as promoting composting and the use of manures and other organic soil amendments.
- Promoting agroforestry for fiber, fruit and medicinal purposes.

Conservation agriculture emphasizes that the soil is a living body, essential to sustain quality of life on the planet. Zero tillage is a “cornerstone” of CA, and it can be practiced in both large and small farming systems.

Adoption of Conservation Agriculture and Zero Tillage

Zero-tillage is now being practiced on more than 95 million ha world wide (see table 16.1).[3] Approximately 47% of the zero-tillage technology is practiced in South America, 39 % is practiced in the United States and Canada[4], 9% in Australia and about 3.9% in the rest of the world, including Europe, Africa and Asia. Adoption rates are faster in South America than in other parts of the world, and these areas are more consistent with permanent soil cover and permanently not tilling the soil. Adoption rates are very low in Europe, Africa and most parts of Asia, despite good and long lasting research.

Table 16.1. Adoption of zero-tillage worldwide, 2004/2005

Country	**Hectares ('000s)**	**Country**	**Hectares ('000s)**
USA	25,304	South Africa	300
Brazil	23,600	Spain	300
Argentina	18,269	Venezuela	300
Canada	12,522	Uruguay	263
Australia	9,000	France	150
Paraguay	1,700	Chile	120
Indo-Gangetic-Plains	1,900	Colombia	102
Bolivia	550	China	100
		Others (Estimate)	1,000
		Total	95,480

Source: Derpsch[7]

[3]This represents about 7% of global cultivated land.
[4]This represents about 22% and 27% of cultivated land in the US and Canada respectively.

Adoption of Zero Tillage in Latin America

On a global basis, zero tillage expanded most rapidly in Latin America, especially, Brazil, Argentina, and Paraguay, starting effectively from the early 1990s. This expansion was from necessity, due to very serious issues of soil erosion, soil compaction, and soil nutrient depletion, with serious concerns on the future sustainability of agriculture in these tropical regions. Traditional engineering techniques had failed, and zero tillage was initiated as a viable alternative. Initially, it was promoted through pioneering efforts by enterprising and far seeing farmers in each country, supported by national research institutions. The common learning experiences which evolved were the basis for formation of an international farmer association for zero tillage, CAAPAS, currently with ten member countries, including Canada and the USA, and two observer countries.[5]

The most important lesson learned from Latin America was the importance of integrating zero tillage with other principles of Conservation Agriculture. In fact, without this, successes would not have been possible. Over time, some common models of sustainable agriculture emerged, called "MOSHPA" in Argentina[8] and "Integrated Zero Till" in Brazil.[96] These approaches include zero tillage but also maintenance of crop rotations, integrated pest and weed management, use of modern varieties and cultivars, careful and selective crop fertilization systems, and many other conservation technologies. These combined approaches have proven to be the main technologies to improve the economic sustainability of both large and small holder agriculture in Latin America. Some estimates for Brazil show that through the integration of crop and cattle enterprises under combined zero till and conservation principles, it may be possible to increase grain, fibre and meat production in Brazil to meet market demand for the next 20 years or more without further deforestation in frontier areas.[10]

The MOSHPA and integrated zero tillage models have also been shown to considerably reduce off-farm externalities, such as reduced soil erosion and silt control, reduced public expenditures for infrastructure maintenance, improved water filtration and aquifer recharge, improved local biodiversity, and improved mitigation of drought. The environmental impacts of these technologies has been increased soil carbon sequestration, reduced emission of non-CO_2 gases, and improved economic and environmental sustainability of agriculture in the tropics and sub-tropics.

Adoption of Zero Tillage in Sub-Saharan Africa

Adoption of zero tillage in African agriculture has not been highly successful, even though soil erosion and soil nutrient depletion has degraded almost 70% of the region's land between 1945 and 1990, and 20% of total agricultural land has

[5]CAAPAS stands for Confederacão de Associações Americanas para uma Agricultura Sustentável in Portuguese or the American Confederation of Associations in Sustainable Agriculture in English.
[6]MOSHPA stands for Modern Sustainable High Productivity Agriculture.

been severely degraded. This extensive degradation is seriously threatening the progress of economic growth and poverty reduction in Africa.

Many approaches to improve on this situation have been tried, with limited success. However, a recent study in Uganda provides some guidance on how to proceed.[11] The most significant finding in the study were that combined investments in land improvement, such as soil and water conservation, agroforestry, and technologies of sustainable land management provided collective impacts beyond those available through financial, infrastructure, or market stimuli alone. On the other hand, investments in financial services, such as access to credit, resulted in improved productivity and higher incomes, but had neither positive nor negative relationships with good land management or mitigation of land degradation. Access to roads, certain other physical assets, and improved land tenure were also positively associated with higher income, but had minimal relationship with good land management.

The study concluded that integrated investments in sustainable land management, including soil conservation, high value crops, and improved market development, can achieve "win-win-win" outcomes, simultaneously increasing productivity, improving household incomes and reducing poverty, and reducing land degradation. Zero tillage can be a component of this integrated set of investments, but needs to be presented as part of a combined approach with a focus on poverty reduction and mitigation of land degradation.

The Top Ten Criteria for Adoption of Zero Tillage

Experience from Latin America and elsewhere has identified a set of criteria for adoption of zero tillage:[7]

1. Improved knowledge about the system, especially weed control
2. Maintaining crop rotations and green manure cover crops
3. Producing high levels of mulch
4. Soil testing to ensure balanced fertilization and soil acidity
5. A level soil surface
6. Avoiding soils with poor drainage
7. Eliminating soil compaction
8. Proper zero till equipment, including seeders, knife rollers, etc.
9. Starting small (10% rule)
10. Continual learning and adaptation

The most important among these is the desire for change on the part of adopters, and the knowledge on how to effect the change. This can be driven by the need to control soil erosion, reduce input and operating costs, or for environmental services. In Brazil, the imperative was to mitigate extensive soil erosion and land degradation; in Africa the driving motivation will be poverty reduction; in other regions it will be linked with improved market opportunities. The growing evidence is that linking zero tillage with the broader objectives of soil and water conservation and the income generating objectives of sustainable land management are the best options.

Conclusions

Zero tillage is currently concentrated in South and North America, with minimal adoption elsewhere, and globally it represents less than 7% of global cultivated land. There is potential for considerable expansion, but this technology has to be presented in combination with Conservation Agriculture and Sustainable Land Management. The benefits of zero tillage, including reduced labour and input costs, have to be promoted in the context of reducing rural poverty, improving rural livelihoods, capturing new market opportunities, and providing environmental benefits. Expansion will occur only if these technologies can fit into the range of farming systems currently evolving in developing countries, and if they find a particular operational niche.

Expansion in the agricultural and transforming economies will require improved institutional and policy support, improved knowledge base, and a new mind set for small farmers. Efforts must be made to create *enabling policy environments*, including removal of obstacles such as perverse legislation, subsidies, and other policies that impact negatively on poor land management, as well as *mainstreaming* of soil conservation and sustainable land management into national and regional policies and programs. Increased emphasis must be placed on *economic instruments and international markets*, and incorporation of non-market values in ecosystem investment, such as payment for ecosystem services, certification schemes, etc. In addition, these initiatives have to be matched with *targeted technological innovations*, which concurrently improve on-farm productivity, reduce rural poverty, and improve the health of the soil and the global environment.

In most cases, expansion of technological innovations, such as conservation agriculture and zero tillage, is based on farmer driven initiatives. The early successes in Latin America were met with high enthusiasm and expectations, and resulted in the formation of farmer associations such as CAAPAS. Greater support for the continued growth of CAAPAS and similar farmer associations, as central players, is needed.

In addition, agreements and partnerships with other major players in soil conservation, such as the nature-based NGOs, are needed to promote rapid adoption.

Under the right conditions, such partnerships can raise a new dynamic in soil conservation, and ensure a more balanced focus on production, economic, and environmental goods and services.

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Chapter 17

Impact of Conservation Tillage on Landscape & Ecological Services: Challenges and Opportunties

Dr. Dan Wicklum and Dr. Brian Gray[*]

Summary

Environment Canada's (EC) mandate to protect and strengthen Canada's environment and economy can be achieved more effectively by working cooperatively with individuals and agencies in agricultural and other sectors. To help achieve overarching environmental and economic goals, EC works with agricultural sector stakeholders to help identify, evaluate and implement agricultural practices, programs and policies to maintain or enhance Canada's air, water and biological resources and economic competitiveness. These environmental and economic goals also are critical components of EC's Science Plan and its results planning structure.[1]

Adoption of conservation farming practices has produced significant improvements to air and water quality in many regions of Canada, but particularly on the Canadian Prairies. Broadly, these practices have also led to air and water quality, biodiversity and carbon storage benefits. However, persistent concerns arise from uncertainties about impacts of reduced tillage operations on wetland hydrology, movement and fate of agrochemicals and populations of some wildlife species. Future work involving environmental and agricultural cooperators could focus on these challenges, and either provide greater certainty about the environmental

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benefits of conservation tillage or identify modified tillage practices that achieve simultaneously greater benefits for producers and the environment.

Introduction

Agricultural landscapes in most regions of Canada have undergone remarkable transformations over the past 20 years. For instance, the area of cropland in summer fallow dropped steadily from more than 9 million ha in the early 1960s to less than 4 million ha by 2006. On the Prairies, notably in Saskatchewan, more than 55% of the arable land is now under no-till management with direct seeding;[2] requiring only a single pass of equipment over a field into the previous year's crop residue.[3] A significant direct benefit of the no-till system for producers and the environment is the substantial reduction in fuel usage, a savings estimated at some 6 liters of diesel ha^{-1} for every pass eliminated.[4] Greenhouse gas mitigation potential from changes in all agricultural operations are considerable , and an estimated mean of 0.17 t $C0_2$eq. $ha^{-1}yr^{-1}$ could result from improved tillage and crop residue management.[5] Most of the Canadian prairie region and other areas of Canada now have low to very low risk of soil erosion due to wind and water.[6] Despite these broad positive developments, there may be significant trade-offs between benefits of reducing tillage operations and costs in terms of agroecosystem sustainability. Here, we review briefly the main environmental challenges and opportunities associated with no-till systems.

Trade-off potentials

Clean Air and Water

Recent work by EC scientist J. Elliott and colleagues from Agriculture and Agri-Food Canada (AAFC) and university suggests that sediments in runoff waters from no-till fields may be reduced by 50-80% compared to that from fields under conventional tillage. However, they also reported high mobilization potential for phosphorous (P) at the soil surface, so P losses may be more significant in reduced tillage systems. Under some circumstances long term no-till could improve soil structure, aggregate stability and hence infiltration[7,8] but this effect is not universal and may depend on soil type and whether the conventional tillage practice includes fall tillage among other considerations.

Unpublished survey data collected in the last 10 years indicate similar frequency of herbicide detection in conventional and zero tillage systems (J. Elliott, *pers. comm.*). Nonetheless, movement and fate of these chemicals must be studied further and mitigated. Because of the increased levels of crop residue and associated changes in the microenvironment favouring pests and diseases, there could be increased use of pesticides in conservation tillage systems.[9] In general, glyphosate (RoundUp) is considered non-toxic to birds and mammals;[10] however, the surfactant POEA (polyethoxylated tallowamine) often used with glyphosate may be toxic to tadpoles of some amphibian species.[11,12]

Natural Wetlands

Continued loss and degradation of natural wetlands remain a concern for EC though this is not necessarily associated with no-till systems. When wetlands are dry, producers are able to work into wetland margins and even basins,[13] increasing the chances that agrochemicals will move from fields to adjacent water sources or other sensitive areas. In some areas of the prairies, the capacity of the landscape to "absorb" water has been substantially reduced, creating serious movement of agrochemicals and even downstream flooding. Retaining natural buffer areas around wetlands can reduce impacts of overland movements and drift of agrochemicals on wetlands[14] and thus protect water sources used by producers and wildlife. This action could also enhance local wildlife habitat conditions. One objective of retaining stubble on fields is to trap snow, creating a potential conflict between producers' desire to enhance soil moisture and wetlands' needs for limited water via snowmelt runoff.[15] This issue requires further evaluation to identify risks (i.e., wetland loss, degradation or salinity) as well as field management challenges and opportunities.

Only recently has interest grown in determining the role of wetlands in storing carbon. Relative to alternate land uses including no-till, the carbon sequestration potential of wetlands had not been fully quantified. Recent EC-supported studies of carbon sequestration and GHG fluxes in prairie wetland systems indicate considerable potential for carbon storage.[16,17] Initial estimates indicate considerable potential for wetlands to sequester carbon, and like agricultural fields, the pool of carbon that can be stored in wetland and riparian sediments reaches an upper threshold perhaps within 10-20 years. Estimates of net GHG fluxes (methane, nitrous oxide and carbon dioxide) and carbon storage are consistent with restored wetlands being net sinks, ranging from 7.3 to 11.8 mega-grams of carbon equivalent ha^{-1} (P. Badiou, *pers. comm.*). Scaling-up studies to estimate prairie-wide impacts of wetland protection and restoration have yet not been fully completed. Given the widespread abundance of wetlands and high overall wetland loss over the past 100 years, there is considerable potential for restoration and carbon sequestration. However, the success of any restoration program will depend critically on numerous socio-economic rather than environmental factors. Still, the potential for restoration should be examined, especially if suitable *incentives* can be directed to producers to restore and protect wetlands.

Wildlife and Biodiversity Conservation

Depending on conditions, lower wetland water levels resulting from local effects of reduced tillage operations could increase wetland salinization, creating poor water quality for livestock use and also lower aquatic biodiversity. In terms of uplands, several studies have shown an increase in the diversity and abundance of arthropods (including beneficial insects) with conservation tillage systems, which also provide food for wildlife.[14,18,19]

With increased crop residue, there is usually an increase in bird species and nest densities compared to conventional tillage (waterfowl[18,20], songbirds, pintail, upland sandpiper[21], songbirds, songbirds[22]). There is often an increase in nest success due to lower risk of farm machinery directly destroying nests, and/or increased cover resulting in decreased predation rates.[18] Martin and Forsyth reported an increase in productivity of songbirds in minimum till versus conventional tillage fields.[22] Whether farm machinery destroys bird nests depends on the timing and number of machine passes during the breeding season; thus, reduced tillage fields could become an ecological trap if increased cover attracts birds whose nests are then destroyed.[23] Indeed, increasing area of reduced tillage operations has been implicated in lower productivity and population declines of northern pintails, *Anas acuta*. Discussions with EC's "Species at Risk" biologists on the prairies raised no specific concerns about no-till production systems. Nonetheless, new studies suggest that winter wheat production systems (particularly no-till) can be highly valuable for priority waterfowl species, like pintail, as well as some shorebirds (e.g., long-billed curlews, *Numenius americanus* [listed as "special concern"]) and marbled godwits, *Limosa fedoa*) in terms of increasing nest densities and improving nest success.[24]

Conclusions

Adoption of no-till production systems has produced numerous environmental benefits. Obviously, no-till cannot begin to approximate the "natural capital" values of wetland and grassland systems (natural capital refers to natural resources and ecosystems that sustain clean air, water and biodiversity[25]). However, conservation tillage, and especially no-till, has considerable potential to enhance biodiversity and sustainability of these systems where this practice is economically viable.

Conservation tillage is only beneficial to wildlife if it replaces more intensive forms of tillage, not if it replaces native grassland, hayland, wetlands or pasture. More favourable conditions for wildlife can be achieved if machine passes during the breeding season are kept to a minimum, pesticide use is not elevated, and pesticides less toxic to wildlife are used. Some animal and plant species are sensitive to pesticides or changes in wetland conditions affected by fertilizer, so the devil is in the details concerning threats posed by no-till farming. Obviously, if chemicals are applied correctly, risks may be substantially reduced.

For most wildlife species, no-till remains "no-match" when compared with natural habitats. Of the various forms of conservation tillage, no-till winter wheat production systems may be the most beneficial, especially to waterfowl and some shorebirds. A quantitative cost/benefit analysis of this and other agricultural production systems with high potential for environmental sustainability would be useful.

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Chapter 18

Role of Conservation Tillage in Meeting Environmental Objectives

Henry Janzen

Farming the land of our grandchildren

Our planet is changing, perhaps at rates not seen before in human history. Globally, there are worries of warming climates, waning water sources, diminishing biodiversity, and depleting pools of cheap clean energy. Beyond these, stands the daunting challenge of feeding the growing billions of us scurrying about on a shrinking earth. These global changes affect us also locally, perhaps especially our farmlands - they will influence the crops we grow, the way we manage the soil, the way we live on the land. And further, meeting the coming global challenges, will depend on wisely nurturing our lands locally.

That raises the question: how do we farm the land of our grandchildren? I choose this sub-title carefully, deliberately. "Farming" denotes a broad perspective; conservation tillage systems, for example, were never solely defined by tillage – they encompassed a wider strategy and attitude. And I say "grandchildren" to evoke the seamless continuity of our influence on the land: the choices we make are influenced by those made long ago, and the way the land looks decades from now depends on what we do today.

Central to the question of "how to farm the land of our grandchildren" is our concept of "land". Sharon Butala, distinguished Saskatchewan author, said: "At the end of the twentieth century and beginning of the twenty-first, I was hardly alone in asking: What is the meaning of land? It is turning out to be the central question of the new millennium".[1] In this essay, I will explore the hypothesis that our meaning of land has shifted and expanded over the decades, and further, that it may need to grow further as we embrace the challenges awaiting our grandchildren.

"Land" as soil

Soon after our prairie lands were first broken, worries arose about rapidly depleting soils. The "great depth and high fertility of the prairie soils come to us as an accumulated legacy...," wrote Shutt in 1910, "one which, looking to the future prosperity of the west, we shall do well to conserve by rational methods of farming."[2] And though it took some decades, and though some challenges remain, we have witnessed remarkable progress in developing such 'rational methods'. Foremost among them, no doubt, was the advent of conservation tillage. Not only does it hold the soil in place, finally taming the blowing winds that ravaged the land, but it holds in the moisture, often making it possible to grow crops consistently without the depletive practice of summer fallow.

"Land" as ecosystem

Preserving and building the soil, the early focus of "land", then, is the crowning achievement of conservation tillage to date. But now we see, ever more clearly, that "land" is more than soil, not just the thin and fragile layer in which we plant our seeds: land includes also the sky above, the waters within, the creatures upon, the trees adjacent, and all their myriad interactions, with each other and their place, in interwoven harmony. Long ago, this intertwined assemblage was called an ecosystem.[3] And this perspective of ecosystem broadens the questions we ask when we ponder the virtues of new farming practices. We still ask: how might this new practice affect the enduring fertility of our soils? But to that question we add: and how does it affect the air, the water, the wildlife, the biota within the soils?

One of the first examples of our new ecosystem perspective is the process of carbon sequestration: the realization that when we build soil carbon, we not only improve the land but also repair the air. The carbon in organic matter, so vital to our soils, comes from the air; so if we increase soil carbon by one tonne, that means there is one less tonne of carbon in the air as CO_2, the principal greenhouse gas linked to global warming. Thus conserving the soil, through practices like conservation tillage and continuous cropping, affects also the air, with all its cascading consequences.

But carbon sequestration and reducing greenhouse gas emissions is only one example of challenges and opportunities in the new ecosystem perspective. For example, as we develop tillage practices further, we may need to look also at the interactions with livestock: How do you apply manures efficiently to a no-till system? How do you best build crop rotations enfolding perennial crops without extensive disturbance? And further, we may need to think more deliberately about other constituents of our ecosystems: the trees on the margins of our fields, the wetlands within them, the birds that nest upon them and the wildlife that seek refuge there. And as water becomes an ever more urgent issue, we may need to look more carefully at how our practices on the land affects the water beneath our fields and the water flowing from them, into the streams and eventually lakes and rivers that connect to them.

All of the myriad species within an ecosystem are connected by flows of energy and nutrients; and further, all ecosystems themselves are connected by these same pathways. That means that what we do on the land reaches far beyond our farm fences. This broadening of view in the ecosystem perspective makes the challenge bigger; but also amplifies the benefits of good farming practices.

"Land" as community

Most of us, now, see land as ecosystem. Though many vexing and enticing questions remain, we have begun to make progress within this expanded perspective. But, I propose, there is still a higher, broader vantage from which to observe and manage the land: the community. By "community", I mean not only the ecosystems but also all the people who live and depend on them. To put it another way: in the past we improved the way we *treated* the land; in the future we will need to know better how to *live* on the land.

We derive many things from the land. Some of them are obvious: the land gives us food, fiber, and fuel. Some are less obvious: the land gives us livelihood, it filters our air, cleanses our water, and decomposes our wastes. And still others are so subtle we cannot even quantify them, except to know that without them we would be deeply impoverished: the trill of a meadow lark at dawn, the smell of newly-mown hay, the freshness of air after a summer storm. In the future we will need to learn how best to till the land, how best to manage the land to preserve and augment all of these wonders, and ourselves among them.

Much of the wisdom on how to live on the land resides in those who walk upon it daily – the farmers and ranchers. For example, much of the creative thought in developing conservation tillage practices came from farmers; without their deep insights and innovative spirit, our systems would not have advanced to where they are today. And future innovations, too, will lean heavily on the wisdom of those rooted in the soil.

But it is not only farmers and ranchers who depend on and influence the land. Our greenhouse gas studies, for example, have shown us that we are all connected, no matter where we reside. The carbon sequestered on a farmers' field benefits also the urban cousin; the demands for food and fuel of the city resident dictate what happens on the farmers' fields. The challenge, then, in coming decades will be, first, to tell more eloquently the stories of our mutual dependence, and then to design farming systems that meet the many demands of all upon the land, while keeping the land productive, vibrant, and flourishing for the generations coming. One way or another, we are all tied to the land.

Closing thoughts

We who care for the land face some vexing challenges. As one writer defined it: “one key challenge for the 21st century is how to produce the food we need, yet ensure the landscape we want”.[4] This prospect is more than a problem – it is an invitation to dream and to explore. We get to face deep, enticing questions: what do we want the lands of our grandchildren to look like? And how do we make them look that way? Those who developed conservation tillage have shown us the power of far-sighted thinking. Though deemed initially to be unrealistic, these practices have now transformed the landscapes in ways few could have imagined. May we be inspired by our predecessors’ boldness, to explore new dreams for the land of our grandchildren.

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Chapter 19

Building on Lessons Learned

Bernie Sonntag and Wayne Lindwall

Conservation tillage (CT) has become the dominant annual crops production technology in North American Great Plains agriculture. CT has also made great inroads in several other important agricultural regions in the world, e.g., Australia, Argentina and Brazil. Its impact has been greatest in areas where landscapes and scale of farming operations are conducive to utilization of large scale machinery. Much of the technology development underlying this phenomenal transformation has its origin in western Canada. Contributions to this outcome have come from many sources – scientists and engineers in public institutions, politicians, farmers, extension workers and private sector innovators. One of the key elements in this success story was good cooperation and communication among the various stakeholders in development and application of the technology, fostered by the leadership of a few champions.

Key Elements and Lessons Learned:

1. **Patient capital** – Perhaps the first significant step into development of CT technology in Canada can be attributed to W.H. Fairfield and A.C. Palmer (affectionately known as "trash-cover" Palmer) at the Lethbridge Experimental Farm while working with a local farmer, C.S. Noble, in the 1930s. They developed the Noble Blade which left crop residue largely untouched on the soil surface. Charles Noble received the Order of the British Empire for his innovative leadership in this domain. The establishment of PFRA in 1935 facilitated expansion of soil conservation work at experimental farms and on Illustration Stations funded through PFRA. Thus began a long period of public investment in soil conservation research and demonstration work.

The initial terms of reference for the Experimental Farms Service precluded their participation in farm equipment development in competition with private companies. However, it did not preclude development of plot machinery to improve efficiency of research plot operations, including those aimed at soil erosion control. Many innovations later incorporated into commercial farm scale machinery had their origins in the research plot equipment shops of engineers (e.g., Ben Dyck and others at Swift Current) and technicians at experimental farms. An important element of the eventual CT revolution was the "patient capital" associated with investments in machinery development for maintenance of "trash cover" on research plots.

Experimental work associated with technology development for soil and crop management in the dry, windy prairie area did not result immediately in high levels of adoption by farmers dedicated to the summerfallow "religion" that was developed and promoted in the early settlement period. Many experiments and demonstrations at sites across the region by Agriculture Canada scientists such as K.E. Bowren at Melfort, and D.T. Anderson and C.W. Lindwall at Lethbridge proved the technical feasibility of CT technology in the late 1960s and early 1970s. But, the economic feasibility was constrained at that time by the high cost of effective herbicides. Research Station Directors exercised considerable patience in continued research budget allocations to this activity in the absence of rapid adoption of the technology by farmers.

Lesson learned: Risk/reward - It was obvious to almost everyone in the prairie region that solving the soil management problem was critical to sustainability of annual crop agriculture. A large and long-term public investment was needed to eventually reap the potential rewards from more sustainable production systems with CT

2. **Supportive Managers** – Perhaps this is part of "patient capital". Superintendents/ Directors at AAFC Research Centres such as Fairfield, Palmer, Anstey, Andrews and Dorrell at Lethbridge and Thomson, Denike, Andrews, Guitard, Pelton and Sonntag at Swift Current came to their centre management positions from a background of western Canadian farm experience, agricultural sciences training, and science careers in the Canadian prairie area. They generally enjoyed a considerable amount of latitude in science program management within general program mandates and allocated budgets. This is not the case today. Budget management and program decisions are now much more centrally controlled and a much lower proportion of the scientist complement has any cultural or academic history associated with western Canadian agriculture. Would the CT technology that evolved over a long period have occurred with the present approach to R&D management?

Lesson learned: Knowledgeable and visionary management was an important component of the resource commitment to support the development of CT systems.

3. **Multi-disciplinary teams** – Engineers, agronomists, plant pathologists, entomologists, plant breeders and other disciplines played key roles in development of CT technology. Fortunately, all of these disciplines were represented in the scientist complement across the Agriculture Canada network and agricultural colleges at universities. There were many examples of multi-disciplinary and multi-institutional working relationships that addressed their common interests – many operated as quite unofficial cooperative efforts with the quiet leadership of supportive middle managers.

   Lesson learned: Multi-disciplinary teams can thrive in addressing multi-dimen- sional problems when management structures and support are flexible enough to foster such relationships. In a knowledge based economy, important assets are enthusiastic, intelligent people who can see the big picture.

4. **Provincial extension services** – The Canadian constitution ascribed responsibility for education to the provinces; extension services to farmers thus became a provincial responsibility. During the settlement period the clientele were generally poor, most had little formal education, many had no prior farming experience and none had any experience with farming in the harsh prairie environment. Thus, extension services were focused initially on facilitating their survival. As immigrant farmers grew in their ability to manage their farms and their offspring became better educated, extension methods adapted to the new circumstances. The provincial extension services became integral components of the technology development and delivery process in the prairie region. However, given the political realities of the day and some reluctance to endorse the CT movement prematurely, the provinces chose to direct resources for conservation programming to enthusiastic producer groups to lead the effort (e.g., ManDak, ACTS, SSCA, etc.).

   Lesson learned: Provincial extension services were integral system components in the development and application of CT technology and fostered the development and support of the leading conservation tillage farmer organizations.

5. **Working relationships with producers and their organizations** – Thousands of informal associations and cooperatives developed at the local community level across the prairie region as self-help groups during the settlement period. These were the building blocks for more formal associations that addressed common production and marketing issues. These associations

became partners with the research community in development and evaluation of new technologies aimed at addressing soil management problems. Economic considerations became important in assessing and evaluating technology options. Farmers had responded earlier to the summerfallow technology option on economic grounds; they now needed to be convinced that new reduced tillage technology was in their own best interests on economic grounds.

Lesson learned: Farmers, as the ultimate clients of the R&D efforts on CT, needed to become partners or, at least, collaborators in the evaluation of the new technologies as replacements for their existing methods. On-farm demos, applied research sites and local field days were critical in the successful technology transfer process.

6. **Interaction between agricultural colleges at universities and Agriculture Canada** – Faculties of agriculture were established at provincial universities soon after the prairie provinces were created. The working relationships in technology development and dissemination among them and with the Experimental Farms were collaborative and cooperative. The R&D capacity at Experimental Farms and the capability of extension services in the region grew rapidly as the graduates joined the professional work force. Many of these good working relationships continue today. Members of agricultural faculties were often invited as members of periodic external review committees to evaluate research programs at individual research centres and/or specific multi-centre programs across research centres. Many AAFC research scientists served as adjunct professors and supervised the research of MSc and PhD students.

   Lesson learned: Cooperation and partnerships among public institutions were and are important contributors to overall performance of the prairie agri-food system. CT is an outstanding example of the benefits and impact of those relationships both domestically and internationally.

7. **Interaction with private industry** – Interaction and cooperation with private sector companies and organizations has been an integral component of the CT revolution. It began early in the CT development process with the Fairfield and Palmer efforts with Noble in development of the Noble Blade and high clearance hoe drills to keep anchored trash cover on the soil surface. Experimental Farm engineers involved in plot machinery development for better protection of research plots from wind erosion often worked with private sector companies. This interaction expanded in later years through evaluations of imported no-till seeders in cooperation with the Prairie Agricultural Machinery Institutes (PAMI) and subsequently to cooperative projects with existing and new short line manufacturers in the prairie

region. One of the important products of this interaction is an internationally competitive CT machinery manufacturing industry in the prairie region.

The interaction with private industry was not limited to engineering and machinery development. The lack of cost effective herbicides was a significant deterrent to rapid adoption of CT. There was also considerable skepticism within the research community, among farmers, in product markets and by environmental groups about residual effects of CT herbicides. These issues were effectively addressed through productive interactions between private and public interests.

Lesson learned: Public-private interaction and cooperation were critical components of the CT revolution and benefitted from the important challenges from environmental groups and concerned consumers.

8. **Political support and government action** – The experimental farms and the faculties of agriculture were, in the first instance, the products of political decisions. The experimental farm service on the prairies expanded over time as the Government of Canada responded to the reality of the size and natural diversity of the region. The creation of PFRA in 1935 was a specific government response to the drought induced ravages of the "Dirty 30s". Its first advisory committee included Experimental Farm superintendents, several farmers, the railway companies, provincial governments and a few others. The resources allocated under the Act were directed specifically at actions to alleviate the impact of droughts – additional resources for the experimental farms, a network of illustration stations across the prairies on private farms, removal of land and its occupants from cultivated agriculture and assistance in development of reliable water supplies on farms and small towns. It was initially a five year temporary measure and later given a permanent mandate to address water supply and land management problems. Its mandate and activities changed several times over the ensuing decades in response to changing soil and water management problems and opportunities. In recent decades PFRA was often the Federal partner for management and delivery of fed-prov programs impacting on agriculture – Economic and Regional Development Agreements (ERDA), Agricultural Rehabilitation and Development Act (ARDA), Agri-Food Innovation Fund (AFIF), Green Plan and others. Many of the projects funded under these programs related to land management problems and the CT technology developed to help solve them.

   Two years of hearings across the country by the Standing Committee on Agriculture lead by Senator Herb Sparrow culminated with the *Soils at Risk* Report in 1984. This report lead to additional resources for projects that supplemented the core budgets of Research Stations, PFRA, provincial departments of agriculture and farmer associations to address land management issues. Ralph Goodale played a major role in development of the Agri-Food

Innovation Fund in Saskatchewan that provided supplemental funding to a range of initiatives, some related to land management. The Farming for the Future program in Alberta supplemented research budgets in that province, including significant resources directed at CT research and demonstrations.

Lesson learned: Individual politicians with interests in agriculture and a series of federal and provincial governments were influential, through base budget and short term program allocations, in providing incremental resources that culminated in advancing CT technology and greater acceptance. While the protection of soil and water resources is a long-term issue requiring long-term investments, supplemental strategic short term programming hastened development and adoption of more sustainable systems.

9. Innovative farmers – No one knows where the CT revolution would be today without the actions taken by innovative farmers over the last several decades – Noble, Bechard, McCutcheon, Halford, Hiltons, Lanier and many others. They modified existing machines and built new ones in their own shops. They modified their land management practices to reduce erosion risks on their own farms. They persisted in their endeavours over many years, often endured the ridicule of their neighbours and absorbed the income losses associated with failed experiments. The land management transformation that is occurring today in many parts of the world can trace its origin to the efforts and imagination of these persistent pioneers.

   Lesson Learned: Many innovative farmers played a crucial role in the development and adoption of CT technology through their active participation and leadership through farm organizations and effective lobbying of government organizations and support of applied research.

10. **Leadership by stakeholders** – "'If it ain't broke, don't fix it' is the slogan of the complacent, the arrogant or the scared" (General Colin Powell). It should not be surprising that there was considerable resistance to the notion that it was not necessary to till the soil other than for planting seeds in a narrow furrow. Man has been plowing the land for thousands of years to grow food and feed for Earth's growing population. But on the Great Plains of North America and in many other parts of the world, plowing and traditional tillage practices were not sustainable after less than 100 years. Severe land degradation from wind and water erosion, loss of organic matter and dryland salinity demonstrated that annual crop production systems "needed fixing". In the early years there were many naysayers and vocal skeptics from within and outside the scientific community regarding the feasibility of CT and especially no-till. But, the many barriers and well meaning pessimists only increased the resolve of early CT champions who recognized the potential impact, secondary benefits and the need to stay on course.

Lesson learned: Challenging conventional wisdom should not be feared when charting new frontiers of our knowledge and understanding. Enthusiastic optimism is a force multiplier and the ripple effects can be transformative.

11. **Role of champions –** The CT revolution was lead by a few respected individuals or "champions" in the various stakeholder groups – scientists, engineers, extension specialists and farmers. These champions fostered communications, provided encouragement and often bore the brunt of the challenges and criticisms from the skeptics and naysayers. These champions led the formation of the farmer associations (SSCA, ManDak, ACTS), the lobbying of public agencies (provincial and national) concerning soil management problems and the management and delivery of programming for technology development and adoption. Similar leadership may be relevant to the next technological revolution (e.g., remote sensing applications, automated controls of equipment, precision input applications, monitoring of environmental management compliance).

    Lesson learned: Perhaps "we ain't seen nothing yet."

About the Book

The University of Saskatchewan's Knowledge Impact in Society Project is pleased to present *Landscapes Transformed: The History of Conservation Tillage and Direct Seeding*. This nineteen-chapter book is the work of 35 individuals who were (and still are, in many cases) involved in the evolution and adoption of conservation tillage and direct seeding.

This book provides insights into the agronomic and economic factors that motivated farmers to shift away from summerfallow and towards conservation tillage practices. The book shares details about the interesting and often controversial history of conservation tillage, and it offers first-hand accounts from some of the Prairies' early adopters ofconservation tillage.

As you read this book you will learn about the farmers, equipment manufacturers, researchers, engineers and producer associations that helped drive the development, adoption and ultimate success of this Prairie-borne technology.

About the Editors

Dr. C. Wayne Lindwall started with Agriculture and Agri-Food Canada in the 1970s and had a successful research career at the Lethbrdige Research Centre in the field of conservation tillage. He retired as Director General from the Agriculture and Agri-Food Research Branch after 35 years of service. Dr. Lindwall now shares his insight and expertise through his consulting firm, Lindwall Agri-Environmental Consulting.

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