



CLIMATE CHANGE ADAPTATION PROGRAM

Conservation Tillage

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Climate Action Initiative
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BC Farm Practices & Climate Change Adaptation

Conservation Tillage



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Farm Practices & Climate Change Adaptation Series

This series of six reports evaluates selected farm practices for their potential to reduce risk or increase resilience in a changing climate.

The practices selected are well known in contemporary and conservation-based agriculture. While they are not new practices, better understanding of their potential relationship to climate change may expand or alter the roles these practices play in various farming systems.

Climate change will not only shift average temperatures across the province, it will alter precipitation and hydrology patterns and increase the frequency and intensity of extreme weather events. The projected changes and anticipated impacts for agricultural systems are considered in the practice evaluations. More details regarding climate change and impacts for various production systems in five BC regions may be found in the *BC Agriculture Risk & Opportunity Assessment* at: www.bcagclimateaction.ca/adapt/risk-opportunity

Farming systems are dynamic, complex, and specific to the local environments in which they operate. This makes the analysis of farm practices on a provincial level particularly challenging. The approach taken for this series, is to explore the application of practices regionally and across a range of cropping systems and farm-scales. While the ratings are subjective and may not reflect suitability for a particular farm, the ratings and associated discussion help to identify both the

potential, and the limitations, of selected practices on a broader scale. In some cases, the numerical ratings are expressed as a range, to reflect variation in conditions across regions and cropping systems.

The practice evaluations are informed by background research and input from agriculture producers around the province about their current use of practices. Each document includes: a practice introduction, key findings, an evaluation of suitability to help to address climate change risks, and technical practice background related to adaptation. The documents conclude with practice application examples from various regions of the province. More detailed information about the overall project may be found at: www.bcagclimateaction.ca/adapt/farm-practices

Like farming systems, practice applications are location specific and change over time. Continued adaptation and holistic integrated practice implementation will be required as climate conditions change. The effectiveness of most practices for mitigating climate and weather related risks will vary over a range of conditions. Ultimately, if practice adoption can reduce vulnerability and risk overall, it has some effectiveness in supporting adaptation.

This document is not intended to serve as a stand-alone technical guide. Rather, it is hoped that this evaluation supports dialogue—among producers, agricultural organizations and key government agencies—about how these and other practices may apply in a changing climate, and how to address information or resource gaps to support further adoption and adaptation.

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Introduction

CONSERVATION TILLAGE REFERS TO A BROAD RANGE OF CROPPING SYSTEMS that leave harvested crop residues on the soil surface to minimize wind and water erosion. These practices also reduce nutrient loss, and improve soil health and moisture holding capabilities. Mainly because of these soil and moisture conserving benefits, conservation tillage is advocated around the world as a practice to mitigate crop production risks associated with climate change. In BC, conservation tillage practices are used, to some degree, in all regions and for a variety of crops. However, it is in grain and oilseed production in the Peace River region that conservation tillage is most prevalent. The Peace River region has a relatively long history with conservation tillage, providing an example of successful practice adoption and adaptation (see Historical Development of Conservation Tillage in BC, page 16).

Related Practices

- Residue management
- Nutrient management
- Pest management
- Vertical tillage
- Soil conservation
- Water conservation

WHAT DOES CONSERVATION TILLAGE INVOLVE?

Conservation tillage is an integrated cropping system in which low disturbance tillage, seeding and harvest equipment, crop rotation and weed control are all managed together to match soil and weather conditions. Conservation tillage is broadly defined as any tillage practice that leaves most of the previous crop's residues on the soil surface, and includes zero-till (no-till), and minimum-till systems.¹ Conventional tillage, on the other hand, incorporates most of the crop residue into the soil.

Tillage is usually associated with the preparation of soil for planting crops and, over time, various tillage methods have been developed.² The primary objective of tillage is to create a suitable seedbed and the physical conditions (soil micro-sites) that will support seedling growth. When tillage is minimized, seedbed conditions remain critically important for seeding success. Consequently, the relative pre-seeding and post-seeding soil disturbance caused by seeding equipment is an important consideration in conservation tillage systems (see the Conservation Tillage Continuum on page 10). A secondary objective of tillage in conventional tillage systems is the control of weeds, to allow establishment of the seeded crop. Therefore, weed management using a combination of crop rotation and herbicide, is of considerable importance in conservation tillage systems.

CURRENT ADOPTION IN BC

The classification of tillage-methods is challenging because they are highly variable and are continually adjusted to obtain the desired effect in any given cropping system. In the 2011 Census of Agriculture, conservation tillage practices were well distributed among BC regions (Figure 1). Of the farms that had land prepared for seeding, between 43% and 50% used conservation tillage practices (either zero-till or minimum-till) on some of those lands.

The area of land under conservation tillage practices is an indicator of the potential conservation impact of the practice, but unfortunately does not provide important details about application (Figure 2). The Peace River region has the most land under conservation tillage followed by the Thompson-Okanagan. The conservation tillage systems used in the Peace River region and the Bulkley-Nechako region are identifiable based on the types of crops grown. However, it is less clear how conservation tillage practices are being applied in other regions of the province.

The percentage of seeded area under conservation tillage in the Bulkley-Nechako has almost doubled since the last census (2006), and now sits at nearly 64% (2011). This is likely due to adoption by grain producers in that area. In the same time period, the percentage of area under conservation tillage decreased in the Thompson-Okanagan (45% to 43%), and was steady in the Lower Mainland (around 29%). It is uncertain to which cropping systems conservation tillage practices are being applied in these regions.

Despite positive results with long-term zero-till research trials with forage corn at the Pacific Agri-Food Research Centre in Agassiz, BC, field trials have been disappointing, with little or no adoption by farmer cooperators.³ The reason for reduced crop yields on the zero-till cooperator farms is not fully understood, but may be related to drainage issues, and lower soil surface temperatures at seeding. It is possible that much of the conservation tillage adoption in the province—with the exception of grain and oilseed production—may involve various tillage and seeding methods, including broadcast seeding, but where most crop residue is retained on the soil surface (e.g., with some annual vegetable crops, forage, and cover crops).

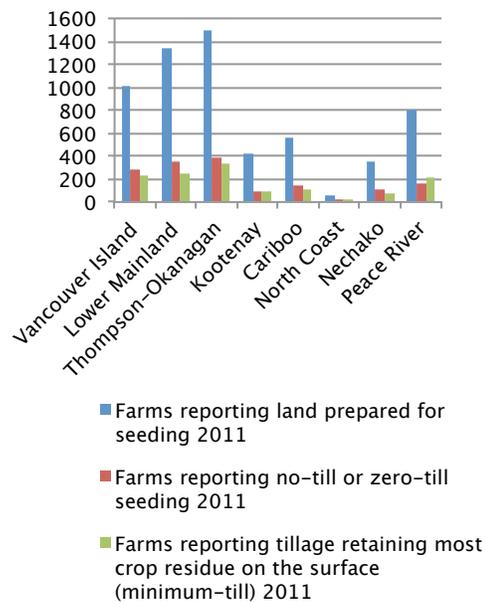


FIGURE 1 Number of farms reporting land prepared for seeding and farms reporting minimum-till or zero-till (no-till) practices in 2011

Source: Statistics Canada, 2011 Census of Agriculture, Farm and Farm Operator Data, catalogue no. 95-640-XWE.

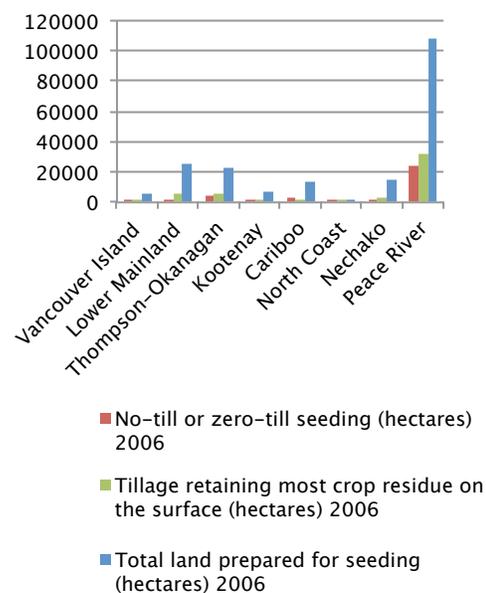


FIGURE 2 Total land prepared for seeding (hectares), and land seeded with minimal or zero-till (no-till) practices in 2006

Note: 2011 data suppressed for the Peace River Region. Source: Statistics Canada, 2011 Census of Agriculture, Farm and Farm Operator Data, catalogue no. 95-640-XWE.

Key Findings

- Conservation tillage is a proven practice for supporting maintenance of soil moisture and mitigating soil erosion from wind and water (anticipated to become a more frequent challenge with climate change).
- Conservation tillage practices are variable, and dependent on farm scale, cropping system, soil type, field conditions and the technology in use (zero-till vs. minimum-till); this makes broad based provincial assessments of effectiveness challenging.
- The effectiveness of conservation tillage in moderating the impacts of climate change is likely to:
 - Be greatest in annual cropping systems involving grain, oilseed, pulse and annual forage crops; and
 - Increase over time in some of these production areas if average growing season moisture deficits increase.
- Though snowfall is predicted to decrease, residue and stubble left in the field with conservation tillage practices will help to trap and hold precipitation that does fall as snow.
- Climate change may increase the frequency of wet spring conditions, which may lead to delayed seeding and reduced yield of some crops under conservation tillage systems.
- Economics and moisture conservation benefits have also driven adoption, and these factors are clearly identified by producers.
- In cropping systems where conservation tillage applications are well-developed (grains, oilseeds, pulses):
 - Continued adaptation and refinement of practices could improve their effectiveness in a changing climate;
 - Continued refinement of associated practices (residue management, nutrient management and pest management) is integral to supporting adaptive use of conservation tillage;
 - Further adaptation may be needed to address the issue of herbicide resistant weeds; technological innovation may have reached a critical threshold; and
 - Current effectiveness of practices depends substantially on new technology and equipment investments that are not economic for many smaller-scale farms. For these farms, technological or equipment limitations may also impact results (see page 12).
- Demonstration and applied research are an important part of the conservation tillage story in BC, and this work needs to continue to facilitate further adoption and adaptation.
- Further adoption in BC will likely require a full “suite” of conservation tillage approaches, matched to the range of BC cropping systems.

AREAS FOR FURTHER ADAPTATION RESEARCH & SUPPORT

- Collection of more specific information on current conservation tillage applications in forage-based livestock operations (and other cropping systems), to help to evaluate effectiveness on a broader scale.
- Research to more clearly identify benefits and effects of minimum tillage systems (as opposed to zero-till) in a variety of cropping systems, including perennial forage establishment.
- Demonstration and applied research of secondary tillage equipment to support continued adaptation in developed conservation tillage systems.
- Identification of linkages between technology-based conservation tillage practices, and cultural practices that might be applied at smaller scales (e.g., mulching, composting, green manure and cover crops, and pest management).
- Conservation tillage research, demonstration and extension, for a variety of cropping systems and farm scales.
- Pest control monitoring and research in areas where there is high adoption of conservation tillage to stay ahead of potential herbicide tolerance and pest outbreaks.
- Integrated pest management and crop rotation extension programs.
- Crop variety testing and new crop research trials in the context of conservation tillage practices.



FIGURE 3 Conventional tillage for rhubarb planting following irrigation on the Sumas Prairie in the Lower Mainland

Evaluation: Adaptation & Conservation Tillage

MULTI-CRITERIA EVALUATION

Agricultural research is typically undertaken to establish the efficacy of a product or practice under specific conditions. Similarly, cost-benefit analysis is valuable for assessing whether an investment is economically efficient (whether it pays to invest in a particular practice or asset). An evaluation of adaptation options for climate change needs to consider more than just effectiveness and economic efficiency to be useful for both farmers and those interested in supporting climate change adaptation. Multi-criteria evaluation provides a framework for this evaluation—enabling a set of decision-making criteria to be examined simultaneously.

Multi-criteria evaluation (MCE) can be highly structured, or, as it is applied here, more subjective and exploratory. To have value, the evaluation has to have the decision makers it aims to serve in mind. Often when MCE is employed, considerable time is spent gathering input on decision-making criteria and the needs of users. Given the limited scope of this project, it was not possible to gather user-specific input, and instead the criteria were developed by looking at other studies in the field of adaptation to climate change.⁴ However, producers did provide input on the relative importance of the selected decision making criteria in a ranking exercise (27 of 29 participants). Perhaps not surprisingly, economic efficiency and effectiveness were the top ranked criteria followed by adoptability, adaptability,

flexibility and independent benefits. Institutional compatibility was ranked last by the majority of farmers.

Often MCE is used to select the most desirable option from various alternatives. Ratings for each criterion are determined, and then added together to provide a total score for each alternative. The relative importance, or weight, given to a single criterion can affect the overall suitability rating for a practice. However, for this evaluation, it is the scores for individual criteria that provide insight into how a practice might be suitable for adapting to climate change, and what might need to change to make it even more suitable. The purpose of the evaluation is not to aggregate ratings and compare practices, but rather to improve understanding of how the individual practices relate to adaptation to climate change.

The evaluation takes a broad view (coarse-scale) across areas and farming systems in the regions (and production systems) where the practice might be applied or considered. The ratings were determined under the assumption that there is some basis for the application of a practice within certain farm types. For example, management-intensive grazing does not have application on a farm without livestock, and therefore it would be ineffective as an adaptive practice for that farm when compared to other alternatives.⁵ If carried out at a fine-scale (individual farm level), the suitability rating of any practice could

be quite different because the specific circumstances of the farm would be considered for each criterion. Likewise, ratings could vary depending on the purpose (e.g., policy formulation vs. farmer adoption), and the perspective of the individual(s) carrying out the evaluation. Even though, a broad view is taken in the evaluation, the criteria in this series are considered from an on-farm perspective.

The evaluation below assesses a farm practice through the following set of decision-making criteria: *Effectiveness, Economic Efficiency, Flexibility, Adaptability, Institutional Compatibility, Adoptability* and *Independent Benefits*. Each of the criteria are defined and a numerical rating (in some cases a range) has been assigned across a scale from 1–5 to reflect its potential value in adapting to climate change. The discussion that accompanies the rating captures some of the issues contemplated in determining the rating, as well as some of the variation and complexity of practice application across the province and farm systems.

EFFECTIVENESS

Whether the adaptation option reduces the risk or vulnerability, and/or enhances opportunity to respond to the effects of climate change.

RATING: 3–4
neutral to moderately effective

On balance, the adoption of conservation tillage on BC farms is likely to be a neutral to moderately effective option to reduce the risk or vulnerability associated with climate change on farms where only conventional tillage is currently practiced. Effectiveness will vary, but will likely be greatest in annual cropping systems involving grain, oilseed, pulse and forage crops. Continued adaptation and refinement should improve current effectiveness of existing conservation tillage practices. Effectiveness of conservation tillage could increase over time in some areas if average annual moisture deficits increase. The effectiveness of zero-till for forage corn in the Fraser Valley may improve if drainage is maintained and there is an increase in total average heat units. There may be greater effectiveness for forage corn in areas of the Thompson-Okanagan

where drainage is not an issue and spring soil temperatures are warmer.

The amount of soil disturbance and crop residue left on the surface is variable within the practice types (i.e., zero-till, minimum-till or conventional till), and assessment by these criteria is subjective. Actual effectiveness of conservation tillage practices will vary with the type of cropping system, soil type and farm location (see Background Information, page 10). Zero-till, or no-till, seeding may remain impractical in some of those systems, and problems have been noted with zero-till working for establishment of forages in very dry compacted conditions. However, some form of minimum-till practice should be possible in all cropping systems, although continued adaptation and technological development will be required.

Though total precipitation is predicted to increase across BC, summer precipitation and precipitation falling as snow are expected to decrease. With corresponding increases in temperature, growing season moisture deficits are expected to increase. Zero and minimum-till have produced superior yields to conventional tillage in annual cropping systems, especially during dry years.⁶ Moisture conservation is achieved through increased organic matter and improved soil structure in surface layers, improved infiltration and reduced evaporation from the surface.⁷ Though snowfall is predicted to decrease, residue and stubble left in fields will help trap and hold precipitation that does fall as snow. Grain yields can be improved, and are directly related to the level of moisture conservation, regardless of the crop.⁸

The frequency of extreme weather events is also expected to increase. Crop residues left on the soil surface, and land left in stubble will help to mitigate soil erosion from wind and water. Conservation tillage will also be effective for reducing water use for crops under irrigation, and this could be increasingly important as irrigation water demand increases.

ECONOMIC EFFICIENCY

The economic benefits relative to the economic costs that are assumed in implementing the adaptation option.

RATING: 3–4

neutral to moderately efficient

The economics of conservation tillage have been documented by a number of long-term research studies of annual grain and oilseed cropping systems on the prairies (including in the Peace River region). Crop rotations are an important factor in these long term studies, and can impact both income and expenses. Most analyses show that conservation tillage practices provide increased returns over conventional tillage practices in the long-term.⁹ The cost-benefit of conservation tillage can be affected by the crops grown, changes in crop prices, and input costs.

Under current conditions, cost-savings in labour and fuel are the main contributors to efficiency in grain-oilseed-pulse production areas. These savings are sometimes offset by increased costs for herbicides and other inputs. An economic analysis of lettuce production in California showed that net financial returns were higher with minimum-tillage and organic matter inputs despite lower yields—the result of cost savings from less tillage.¹⁰ Establishment success for forages can be variable with direct seeding (no-till methods), and there is a cost associated with seeding failure. These costs need to be balanced against benefits of increased tillage for seedbed preparation, and can often be mitigated with a clear identification of seeding objectives and proper assessment of field conditions.

FLEXIBILITY

The ability of an option to function under a wide range of climate change conditions. An option that reduces income loss under specific conditions, and has no effect under other conditions, would be considered inflexible.

RATING: 4

moderately flexible

Conservation tillage can be considered moderately flexible. It helps to mitigate the effects of low moisture conditions by reducing evaporation at the soil surface, and reduces soil erosion. Improved soil

conditions support healthier plants that are better able to handle environmental stressors. However, seeding may be delayed under very wet spring conditions, because surface drying is slowed. Cooler damp spring conditions may also affect yields in some years, even if fields are workable, if the soil temperatures remain low.

ADAPTABILITY

Whether a practice can be built upon to suit future conditions and allows further adaptation.

RATING: 4–5

moderately adaptable to very adaptable

The continued adaptation of conservation tillage practices over the last several decades suggests a moderate to high adaptability. The long-term preservation of soil resources is the key to adaptability for future conditions. The USDA's National Resources Inventory data suggests there was a 43% decrease in soil erosion from water and wind on U.S. cropland between 1982 and 2003, and much of this decline is attributed to conservation tillage practices.¹¹ Future adaptation may have to address the issue of herbicide resistant weeds, and technological innovation in this area may have already reached a critical threshold.

INSTITUTIONAL COMPATIBILITY

Compatibility of the adaptation option with existing institutional and legal structures.

RATING: 3

neutral

Current institutional structures are highly supportive of conservation tillage as a practice. However, there are some aspects of specific cropping systems that are not supported universally by society. These include the heavy reliance on herbicides for weed control, and the use of herbicide resistant genetically modified crops.

ADOPTABILITY

The ease with which farms can implement the practice under existing management practices, values and resource conditions.

RATING: 3
neutral

There has been wide adoption of conservation tillage practices in grain growing regions of the Canadian prairies since the 1970s. In the period of transition from 1991 to 2001, it was found that farm size, proximity to a research station, type of soil and weather conditions are important variables explaining a farmer's decision to adopt conservation tillage.¹² Rates of adoption were higher in the provinces of Saskatchewan and Manitoba. The generally more moist conditions found in the Peace River region were thought to be a possible explanation for lower rates of adoption of conservation tillage in Alberta during that period. Similar factors are likely to explain patterns of adoption in BC.

Adoption will continue to be limited by farm size, as economies of scale are needed for specialized equipment purchase. Also, adoption will likely be limited in BC as a whole until a full suite of conservation tillage approaches, matched to a full range of BC cropping systems, is developed. Particular emphasis should be placed on minimum-tillage practices, and the effects those practices may have for moisture conservation. Appropriate,

broad-based zero-till technologies will likely be more challenging to develop given the wide range of conditions and crops grown in BC. At the same time, BC research, demonstration and extension are an important part of the conservation tillage story in BC, and this work needs to continue to facilitate further adoption and adaptation.

INDEPENDENT BENEFITS

The potential for a practice to produce benefits independent of climate change. For example, a practice that reduces income loss regardless of climate change effects, would be rated high.

RATING: 5
high independent benefits

The potential for conservation tillage to produce benefits independent of climate change is high. An entire range of conservation benefits, including reduced soil erosion and downstream sedimentation can be realized. These benefits accrue regardless of climate change effects, and have been shown to increase income under existing conditions. More details regarding benefits/payoffs and costs/trade-offs of conservation tillage are provided in the next section (page 12).

TABLE 1 Conservation tillage evaluation summary

Evaluation Criteria	Rating	Meaning
Effectiveness	3-4	Neutral to moderately effective
Economic Efficiency	3-4	Neutral to moderately efficient
Flexibility	4	Moderately flexible
Adaptability	4-5	Moderately adaptable to very adaptable
Institutional Compatibility	3	Neutral
Adoptability	3	Neutral
Independent Benefits	5	High independent benefits

Conservation Tillage Background Information

CONSERVATION TILLAGE AS AN INTEGRATED CROPPING SYSTEM

In practice, there can be different levels of disturbance associated within each type of tillage system, depending on the type of seeding equipment used, the kind of crop seeded and field conditions. When forages or sod-forming grass crops are introduced in a rotation, a combination of tillage equipment may be used in the successful establishment of a new crop. Some crops produce more residues, and depending on the previous

growing season conditions, minimum tillage or disturbance may be required to allow seeding equipment to work properly. Figure 4 shows how different tillage methods fit together on a continuum based on the amount of soil disturbance and the amount of crop residue left on the soil surface. Systems that use zero-till drills with vertical disc-type openers typically produce the least disturbance, and leave the most crop residue on the soil surface (see Figure 5).

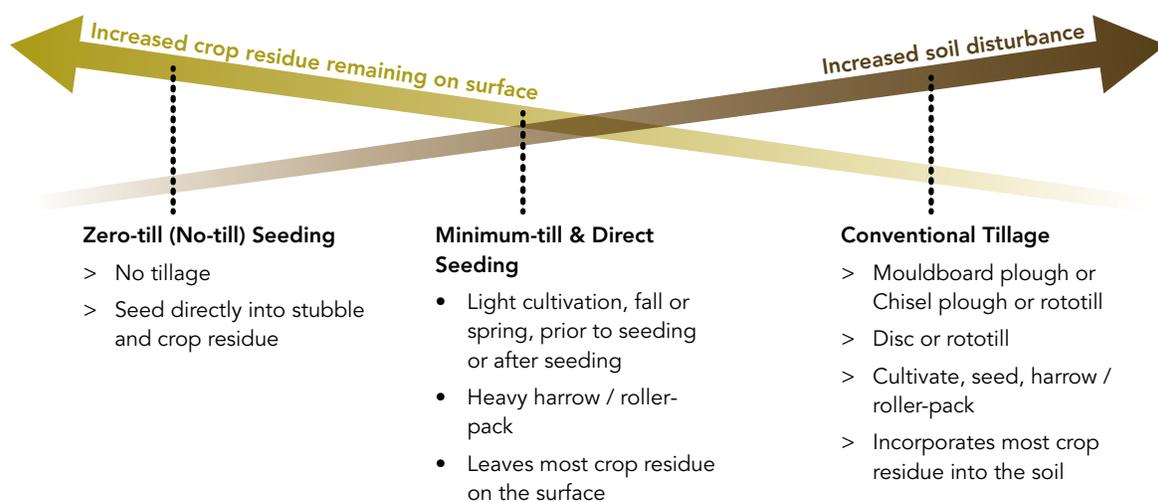


FIGURE 4 Crop tillage continuum, showing the relationship between zero-till, minimum-till and conventional tillage systems, and the associated levels of soil disturbance and crop residue left on the soil surface

Annual Crops

Conservation tillage is appropriate for most field crops, forages and some vegetable crops, but is not directly applicable to root crops like potatoes. Zero-till and minimum-till cropping systems are highly developed and specialized in the Peace River region where annual grains, oilseeds and pulses are grown. Adoption of these systems is linked to a combination of technological developments, including seeding equipment, herbicides, new plant varieties, and crop rotations. Economics and the current scale of grain farming operations are important drivers, as is the benefit of soil moisture conservation. The lack of effectiveness of zero-till technology for use in forage corn has been a limitation to adoption in the Fraser Valley (see Current Adoption in BC, page 3).

In the rest of the province, different production scales, the potential for fruit and vegetable crops, corn grown for forage, and production under irrigation, have produced different cropping systems and practices. The use of plastics for moisture conservation and weed control, and green cover crops in vegetable production, are examples of alternative adaptive practices. Conservation tillage practices can provide the same benefits under irrigation as they do under dry-land conditions, and can mitigate the pulverizing effects of overhead irrigation. However, the moisture conserving benefits of conservation tillage may be less apparent under irrigated conditions, especially where there are no water restrictions. Strip tilling and relay cropping combine elements of traditional tillage with no-till in row crops and demonstrate how conservation tillage can be adapted to various cropping systems.^{13, 14}

Perennial Forage Crops

Conservation tillage is also appropriate in perennial forage based systems; however, zero-till seeding may be less adoptable for some livestock operations. Successful re-establishment of perennial forages with zero-till seeding requires the elimination of all existing vegetation with herbicide. The necessary seeding and spray equipment could see limited use on a single operation that depends on perennial forages, where re-establishment might occur every



FIGURE 5 Melroe zero-till drill with vertical disc openers, used in early field research trials near Dawson Creek in 1981, leaves nearly all crop residue on the soil surface (conventional tillage can be seen on the right)

5–7 years. Owned or shared equipment is necessary in areas where there are few custom operators. As well, some forage-based livestock operations are moving away from herbicide use as they strive to develop a more “natural” meat product to meet changing consumer preferences.

Work in the Peace River region has demonstrated that the re-establishment of perennial forage stands with zero-till is more successful when a cereal crop is grown for at least one season before the perennial forage stand is re-established. However, minimum tillage can be used for establishment of perennial forages, and works well with various types of broadcast seeding applications when some form of post-seeding disturbance (e.g., harrow-packing) is applied. Creeping Red Fescue, an important forage seed crop in the Peace River region, can be converted back to annual crop production using no-till. However, the effectiveness of this practice is highly variable and most producers use conventional tillage to bring land back into annual production.



FIGURE 6 Early adopter of conservation tillage, seeding with a zero-till drill near Dawson Creek in 1992

SOME BENEFITS & PAYOFFS OF CONSERVATION TILLAGE

The benefits of conservation tillage have been well documented. The primary benefits and payoffs are that it:

- Reduces soil erosion;
- Conserves soil moisture;
- Reduces downstream effects of sedimentation and nutrient loss;
- Increases soil organic matter;
- Improves soil health; and
- Reduces fuel and labour costs.

The positive effects of conservation tillage begin at the soil surface, with crop residues dissipating the energy from rain precipitation, increasing moisture infiltration and reducing runoff. Crop residues also act as a soil cover, reducing evaporation from the soil surface. Over time, crop residues break down and provide an addition to the soil carbon. Soil organic carbon can be increased in the upper layers (0-5 cm, and 5-10 cm) with zero-till, compared to conventional tillage, but total soil carbon and distribution in the profile depends on depth of tillage and cropping history.¹⁵ Increased organic matter improves soil

till, and improves plant nutrient uptake. Minimizing tillage also allows soil fauna and soil structure to develop, to further improve nutrient cycling and moisture holding capabilities. Long-term research trials near Dawson Creek, BC found soil aggregate characteristics led to better overall moisture infiltration in zero-till compared to conventional tillage. This also produces a broader effect of reducing on-farm runoff and nutrient loss.

Fuel and labour costs are lower, because the number of operations are reduced (less tillage), and the replacement operation (herbicide application) can be applied with smaller power units. Air-seed technology has minimized labour requirements for seed and fertilizer loading and allowed planting widths to increase substantially, further reducing labour inputs.

SOME COSTS & TRADE-OFFS OF CONSERVATION TILLAGE

With more than 25 years of experience with conservation tillage in the province, many of the short-term costs and trade-offs associated with conservation tillage are well established. However, some of the longer-term effects related to changes in weed populations, the potential emergence of herbicide tolerant invasive plants, and soil compaction are less certain. Among the trade-offs are:

- Relative cost of equipment needed for successful adoption;
- Some zero-till (low disturbance openers) may be ineffective in some situations (e.g., if tillage has been used for some reason, and soils are left unfirm);
- Heavy reliance on herbicide use to maintain crop yields;
- Unpredictable shifts in weed and other pest populations;
- May initially require more nitrogen fertilizer to maintain crop yields, and affect nutrient management in some systems;
- Grain crop yields can be negatively affected in wet years, in regions where moisture deficits are lower;

- Seeding operations and germination can be delayed, especially in wet springs; and
- Potentially firmer soils (higher sub-surface bulk density), although research near Dawson Creek, BC showed no appreciable difference in bulk density between zero-till and no-till on a sandy loam and silt loam soil.¹⁶

Costs

Costs are highly dependent on the scale and age of equipment (Figure 7). Zero and minimum-tillage equipment has been on the market sufficiently long enough that there is now plenty of used equipment available, and some at reasonable cost. However, the cost of minimum and zero-till seeding equipment is still higher than that of conventional seed drills, and may require more tractor horsepower. Smaller scale equipment is available, but must be appropriately matched to the farm scale and the specific cropping system to be efficient. Successful adoption also requires harvest or other equipment that can chop and evenly distribute crop residues, otherwise additional operations may be required to manage this material (see Figure 8). “Hair-pinning” can be a problem in heavy residue with coulter type openers. The coulter crimps long damp straw into the seed row, and this interferes with seed germination.



FIGURE 7 A grain tank for minimum-till and no-till direct seeding equipment can cost as much as \$120,000, depending on size and features

Weeds & Crop Rotation

Farmers must also accept reliance on herbicide applications to control weeds to maintain crop yields, and establish new crops, especially for perennial forages. Apparent gains in energy efficiency in production made through on-farm fuel savings may be offset by higher energy associated with nitrogen fertilizer and herbicide applications associated with conservation tillage, depending on the crop rotation.¹⁷ Introduction of pulses can be highly beneficial for improving moisture conservation and energy efficiency. Dry peas, for example, have a lower annual water requirement than canola and wheat, and add fixed nitrogen to the soil. The benefits of conservation tillage methods, in terms of energy efficiency, are more likely to be realized in mixed crop rotations. Crop rotations also allow application of different herbicides, to slow or prevent herbicide tolerance.

Weed surveys have documented shifts in weed populations; however, these have not always been linked to changes in tillage practices. In general, these surveys have shown increases in the relative abundance of perennial weeds (such as Canada thistle and dandelion) compared to annual weeds, but decline in weed populations overall.¹⁸ Continual disturbance associated with tillage tends to favour annual plant reproductive strategies. Therefore, the level of disturbance in conservation tillage can be a factor in weed management.



FIGURE 8 Combine with a high capacity straw chopper with a 12 metre spread, and chaff spreaders below—part of residue management in conservation tillage cropping systems

Nutrient Management

Nutrient management is also a consideration. Increased soil microbe activity under moist and warm conditions, as crop residue breaks down, will decrease plant available soil nitrogen near the surface. De-nitrification occurs when soil microbes strip away oxygen from the nitrate-form of nitrogen, making it unavailable to growing plants. This happens under warm soil temperature and saturated conditions, when there is a supply of decomposing organic matter. There is a greater tendency for de-nitrification in zero-tilled soils than in conventionally tilled soils, especially in the first few years of conversion to no-till.¹⁹ These conditions can largely be managed by deep banding fertilizer. True no-till systems are not all that compatible with manure application, where incorporation with tillage is desirable.

Delayed Seeding & Soil Density

Seeding operations may be delayed because of lower temperatures and less evaporation at the soil surface. Emergence and early growth may be delayed in direct seeded annual crops compared to conventional tillage, although these differences disappear later in the season. In early spring, tilled fields have more heat gain during the day. When fields cool at night, the heat loss may warm crop seedlings making the risk of frost less severe than in zero-till fields.²⁰ Some of the issues related to increased soil density and formation of sub-surface layers, that occur in some soils, are starting to be managed with crop rotation, and specialized minimum-tillage equipment.

HISTORICAL DEVELOPMENT OF CONSERVATION TILLAGE

Real concerns about tillage practices in North America began in the Depression and dust-bowl era. The persistent use of the steel mold-board plough, devised to break and turn over native prairie sod to allow easy planting of annual crops like wheat, was having a destructive effect on fragile prairie soils. Severe drought and wind storms brought consecutive crop failures, blew away topsoil, and left farmers devastated. By the 1940s and 50s the development of effective herbicides for weed control, allowed farmers to manage their fields with less tillage. However,

in dry regions, summer fallowing—the practice of resting a field from cropping, but periodically cultivating it—became a common practice to control weeds, and to improve moisture conditions for the next year’s crop. Summer fallow also left soils vulnerable to erosion.

By the 1960s and 70s, seed drill technologies emerged that allowed seed to be placed directly into the seedbed with minimal disturbance. This created the possibility of using even fewer tillage operations before seeding. Applied research began in earnest to establish the benefits of conservation tillage and minimum and zero-till seeding practices. Technology continued to develop on the equipment side, but also on the weed control and plant breeding side. It was clear in early research that new weed control strategies would be needed to match the different field ecology that came with minimum and no-till cropping, before wider adoption could take place. The development of “Roundup Ready” varieties, tolerant of the broad spectrum and widely used herbicide glyphosate, rapidly increased adoption because the economically important Canola crop could now be successfully worked into minimum and no-till rotations.

Seeding Equipment

The development in seeding technology is one of the main factors allowing wide adoption of conservation tillage systems. The type of seeding equipment, and more specifically the type of opener—how the soil surface is opened to allow seed placement—and the spacing of the openers within the unit, determine how much of the soil surface is disturbed.

Early equipment was built on existing seed drill technology with dedicated disc or hoe-type openers, overhead seed and fertilizer boxes, and some form of packing wheel to firm the seedbed. At the same time, direct and air seeding technology was brought to the market, and this led to an entirely new line of seeding equipment with a variety of opener types. Air seeding technology eliminated overhead seed and fertilizer boxes by consolidating seed and fertilizer in central tanks, with seed and fertilizer distributed to each opener by a series of hoses. This greatly reduced seed filling times, and allowed seeder widths to expand.

Methods of fertilizer application also evolved to fit with no-till seeding technology. Side banded fertilizer placed in the rooting zone, but not directly with the seed, has improved fertilizer efficiency and eliminated the need for separate fertilizer applications in some cases. Figure 9 and Figure 10 show two types of shank openers commonly used in areas where soils have higher clay content, and Figure 11 illustrates how side-banding fertilizer works. Disc-type openers tend to be used where soil textures are loamy or sandy, and where early spring moisture conservation is desirable. However, combination direct seed systems are now available where seed is delivered by a shank opener,



FIGURE 9 Double shank—triple shoot seeding system

The larger narrow leading shank runs deeper and delivers both granular fertilizer (low N, higher P and K), and gaseous ammonium nitrate (N). The second shank is set to the proper seeding depth for the crop, above and slightly to the side of the fertilizer band, and the small packing wheel compresses to get seed-to-soil contact and conserve moisture. The double shanks are on a 30 cm spacing.



FIGURE 10 Single shank—double shoot opener

Fertilizer is delivered in an offset band below the seed row. This unit has mounted tine harrows behind.

and fertilizer is delivered by an off-set disc opener. This arrangement can provide less disturbance, while still creating good seedbed conditions in higher density fine-textured clay soils.

New Developments

New developments in direct seeding technology include independent shank and opener levelling, and GPS variable rate technology that manages application rates to match field yield mapping (from a GPS and monitor equipped combine), and soil test data. Heavier seed and fertilizer tanks needed to supply wider seeders have caused soil compaction issues under some field conditions, leading to the use of large flotation tires or rubber tracks to help eliminate this problem. Some soils, especially heavier fine-textured soils, can be difficult to manage in minimum and zero-tillage systems. However, the workability of these soils can be improved over time with increases in soil organic matter that come with conservation tillage practices. Impermeable sub-surface layers and other conditions can be managed, to some extent, with crop rotation (e.g., there is some interest in the deep-rooted Tillage Radish—see endnote) and equipment innovations.²¹ Vertical tillage equipment using vibrating coulters (Salford), and deep sub-surface tillage (Agrowplow) that has minimal surface disturbance address a variety of soil and crop residue conditions. However this equipment is relatively expensive and new, and has not yet received much independent applied research attention.

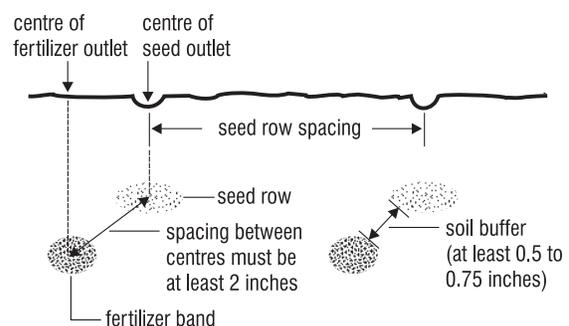


FIGURE 11 Diagram showing the buffer zone between seed and fertilizer in a single shank double shoot side-band system

Source: Alberta Agriculture, Food & Rural Development.

THE DEVELOPMENT OF CONSERVATION TILLAGE IN BC: Zero-till & Minimum-till Seeding in BC's Grain Producing areas



1950s ~ Early rangeland drill used for conservation seeding—an early no-till technology.



1982 ~ A research field day and demonstration near Dawson Creek.



1979–1981 ~ First field research in the Peace Region begins, with the formation of the South Peace Zero-till Association and arrival of a Melroe zero-till disc drill.



1984 ~ Field research continues, here with the Versatile zero-till drill with hoe type openers.

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1984 ~ Early air seeding technology arrives in the Peace Region, matched with standard-type field cultivators this makes seed loading more efficient.



1997 (MODEL YEAR) ~ This Conserva-Pak seeder comes with a triple-shoot opener and an independent packer wheel on each shank.



2012 ~ New 18.2 metre (60 foot) direct-seeder with independent contour adjusting shanks on 30 cm spacing in the Bulkley-Nechako region.



1992 ~ Third year of field adoption by farmer-research cooperator using a JD 750 zero-till drill near Dawson Creek.



2005 (MODEL YEAR) ~ A Flexi-Coil Barton Opener blends double shoot technology with low-disturbance disc openers.

Conservation Tillage Examples

Seeding Canola (*Peace River & Bulkley-Nechako*)

Cropping systems using conservation tillage practices are well established in the grain and oilseed producing areas of the Peace River and Bulkley-Nechako regions. Here producers continue to adapt by changing their conservation tillage practices and, in many cases, turning to more sophisticated equipment. Canola is an important high-value crop in these areas, and re-seeding after establishment failure is risky because a late-seeded crop may not make maturity before the first fall frost. Although longer frost-free periods are predicted for the future, very high seed costs make establishment critical. Canola has a small seed that needs to be placed at a depth of about 0.6 cm – 1.3 cm into a firm moist seedbed with good seed-to-soil contact for germination and establishment. Good depth control of seeding equipment shanks and openers and moisture retention are critical, especially in a dry spring. Producers understand the benefits of correct seed depth, especially after experiencing a seeding failure. This farmer explains a fairly new seeding equipment purchase, a replacement for an older direct seeder that had less depth control.

“It’s New Holland with each individual arm with its own wheel for a gauge. It’s got 60 of them, so it just floats and you can put hydraulic pressure on it to firm it up or whatever. It does a good job. I think we’ve had crops where we normally wouldn’t have had as good. When

you have to work the soil ahead of time, as soon as you put something in the soil it dries out immediately. So then you’ve got to try and go a little deeper to keep it into the moisture. But if you can seed shallow into moisture, [the crop] is going to be up faster and better.

Highlights

- Continued adaptation
- Equipment innovation
- Moisture conservation



A standing canola crop approaching maturity in the Bulkley-Nechako region.



Canola crop in the Peace River region after swathing. Some producers have had success broadcast seeding Canola, followed by light cultivation and a roller-packing. This practice may be less successful under future predicted conditions.

Conservation Tillage in the Bulkley-Nechako Region

Conservation tillage cropping systems are well developed for grains and oilseeds. Though the total acreage in these crops is relatively small in Bulkley-Nechako region, minimum and no-till practices are a good fit for larger farms. There was considerable growth in the number of acres of conservation tillage between 2006 and 2011. The region is at the north end of the interior dry-belt, and some land is under irrigation. Average annual temperatures are projected to rise by an average of 2 degrees by 2020, and though annual precipitation is anticipated to increase, growing seasons are expected to be drier overall with increased evapotranspiration.

So just how effective is conservation tillage under these conditions? An early adopter of conservation tillage near Vanderhoof describes its moisture conserving benefits in this way:



“You know, since we’ve learned how to preserve moisture, we wouldn’t put [irrigation] in again. We wouldn’t spend the money; we would take our chances rather than spend the money. But since it’s there, and obviously in a year like this, it’s pretty nice. It really worked but even so, I don’t know if you’ve seen the crops but they still look pretty good even though we haven’t had the rains [referring to conservation tillage crops without irrigation].”

Forage Establishment *(Vancouver Island & the Cariboo)*

On some farms and ranches, perennial forage is the primary crop and producers look for cost-effective ways to renovate or re-establish forage stands. Conservation tillage practices can come into play in a couple of ways. Zero-till drills are sometimes used to re-establish forage after the existing stand is eliminated with a non-selective herbicide such as glyphosate. Direct seeding is also sometimes used to fill in bare spots in a forage stand. That practice has worked well in Orchardgrass pasture for a Vancouver Island producer in the Comox Valley. The drill is owned by the local Farmers' Institute, and this makes zero-till seeding practical at this small scale.

“... as the grass depletes we'll no-till some more orchardgrass to make it last longer. We no-till our straight pasture fields occasionally with new grass seed to try and change the mix a bit.

On a ranch in the Cariboo, various approaches are used for forage establishment, depending on the site conditions. This producer explains the challenges of using zero-till to renovate an established, but unproductive forage stand, and how a zero-till drill is sometimes combined with tillage:

“With that kind of a live sward [forage stand], you are not going to get anything. You've gotta kill it out somehow. Either through using roundup and minimum tillage, or just tillage and in with that 750 John Deere drill [zero-till drill]. Advantage is we've got both a grass seed box and a grain box, if we're planting a bit of a cover crop with it. I've had varying success both ways with cover crops.



Forage established for hay under a centre pivot irrigation system in the Cariboo region.

Recently, a mixed grass pasture was established for intensive grazing, but the use of herbicide was avoided by combining minimum tillage and broadcast seeding:

“We got the applicators, the fertilizer guys in town to mix seed and fertilizer and we broadcast and harrowed it, and it actually did a pretty decent job. It had been disced not to real fine seedbed, and then we had them mix the seed with the fertilizer, then they spread it with a floater truck.

Highlights

- Zero-till seeding and minimum tillage for forage renovation and establishment.
- Small scale adoption of zero-till technology
- Continued adaptation to meet conditions and objectives.



Orchard grass pasture seeded with a small-scale Haybuster zero-till drill owned by the local Farmers' Institute on Vancouver Island.

Endnotes

- 1 The USDA defines conservation tillage as any method that retains sufficient crop residue on the surface such that at least 30% of the soil surface is covered after planting. David R. Huggins and John P. Reganold, "No-Till: The Quiet Revolution," *Scientific American* 299, no. 1 (July 2008): 70–77.
- 2 Conventional tillage methods are often classified into primary methods (e.g. moldboard ploughing, chisel ploughing) and secondary methods (e.g., harrowing, packing).
- 3 Bittman, Shabtai, Personal Communication, February 26, 2013.
- 4 See: A.H. Dolan et al., *Adaptation to Climate Change in Agriculture: Evaluation of Options* (University of Guelph, Department of Geography, 2001), [http://www.uoguelph.ca/gecg/images/userimages/Dolan%20et%20al.%20\(2001\).pdf](http://www.uoguelph.ca/gecg/images/userimages/Dolan%20et%20al.%20(2001).pdf)
- 5 Enterprise diversification, may be a suitable adaptive strategy to minimize the effects of climate change, however it is not among the practices evaluated in this series.
- 6 M. A. Arshad, A. J. Franzluebbers, and R. H. Azooz, "Components of surface soil structure under conventional and no-tillage in northwestern Canada," *Soil and Tillage Research* 53, no. 1 (1999): 41–47.
- 7 M.A Liebig, D.L Tanaka, and B.J Wienhold, "Tillage and cropping effects on soil quality indicators in the northern Great Plains," *Soil and Tillage Research* 78, no. 2 (August 2004): 131–141.
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- 9 R.P Zentner et al., "Effects of tillage method and crop rotation on non-renewable energy use efficiency for a thin Black Chernozem in the Canadian Prairies," *Soil and Tillage Research* 77, no. 2 (June 2004): 125–136; A. M. Johnston et al., "Economics of crop diversification and soil tillage opportunities in the Canadian prairies," *Agronomy Journal* 94, no. 2 (2002): 216–230; G. P. Lafond et al., "The effects of tillage systems on the economic performance of spring wheat, winter wheat, flax and field pea production in east-central Saskatchewan," *Canadian Journal of Plant Science* 73, no. 1 (1993): 47–54.
- 10 L.E Jackson et al., "On-farm assessment of organic matter and tillage management on vegetable yield, soil, weeds, pests, and economics in California," *Agriculture, Ecosystems & Environment* 103, no. 3 (August 2004): 443–463.
- 11 David R. Huggins and John P. Reganold, "No-Till: The Quiet Revolution," *Scientific American* 299, no. 1 (July 2008): 70–77.
- 12 Kelly A. Davey and W. Hartley Furtan, "Factors That Affect the Adoption Decision of Conservation Tillage in the Prairie Region of Canada," *Canadian Journal of Agricultural Economics/Revue canadienne d'agroéconomie* 56, no. 3 (2008): 257–275.
- 13 Judy Walters, "Relay Cropping Evaluated," n.d., <http://www.farmwest.com/book/export/html/1038>
- 14 "Relay cropping produces top forage, benefits environment," *Soil Conservation Council of Canada (SCCC)*, n.d., http://www.soilcc.ca/ggmp_region/bc-01.php
- 15 W Deen and P.K Katakai, "Carbon sequestration in a long-term conventional versus conservation tillage experiment," *Soil and Tillage Research* 74, no. 2 (December 2003): 143–150.
- 16 Arshad, Franzluebbers, and Azooz, "Components of surface soil structure under conventional and no-tillage in northwestern Canada."
- 17 Zentner et al., "Effects of tillage method and crop rotation on non-renewable energy use efficiency for a thin Black Chernozem in the Canadian Prairies."
- 18 Julia Y. Leeson et al., *Alberta Weed Survey - Dryland 2010* (Government of Alberta, Agriculture and Agri-Food Canada, 2012), <http://www.agric.gov.ab.ca/flippingbook/weed-survey/files/ab-2010-report-final.pdf>
- 19 Rob Kline, *Fertility Management and Placement in Peace River Conservation Tillage Systems* Order No. 630.000-1, Agdex:530 (BC Ministry of Agriculture & Food, 1991), <http://www.al.gov.bc.ca/resmgmt/publist/600Series/630000-1.pdf>
- 20 Ben Froebel and Allan Howard, *Soil Temperature and Direct Seeding*, 1999, [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex1164/\\$file/590-2.pdf?OpenElement](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1164/$file/590-2.pdf?OpenElement)
- 21 "Cover Crops: Tillage Radish vs. Oilseed Radish," *Real Agriculture*, 2011., <http://www.realagriculture.com/2012/10/cover-crops-tillage-radish-vs-oilseed-radish/>