Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Tillage Trade-offs in a Prairie Watershed

Effects on environmental and economic performance

Conservation tillage—including zero tillage and minimum tillage—aims to maximize the amount of crop residue remaining on the soil surface and is a beneficial management practice (BMP) widely promoted for its role in reducing soil erosion and the export of soil-bound nutrients into surface water. It can also play an important role in soil carbon sequestration. BMPs are farming practices designed to minimize potential negative impact on the environment. Yet most BMPs, conservation tillage included, have both environmental and economic trade-offs—side effects resulting when actions are taken to address a primary problem.

For example, although conservation tillage significantly reduces soil erosion, a biophysical (environmental) study in the 7,500-ha (18,500-acre) South Tobacco Creek (STC) Watershed in south-central Manitoba (1993-2007) (Figure 1) has shown that conservation tillage can increase dissolved phosphorus (P) export in a cold-climate region, where spring snowmelt is a major portion of annual runoff. A separate economics study in the same watershed (1998-2006) also found that the economic performance of conservation tillage is generally positive for cereals but is negative for canola. In recent years, both studies have been conducted as part of the **Watershed Evaluation of BMPs (WEBs)** program—an Agriculture and Agri-Food Canada (AAFC) national initiative.

Water quality decline caused by excess nutrients in surface water bodies is a growing problem in many agricultural regions across Canada. In Manitoba, there is increasing concern, for example, regarding the health of Lake Winnipeg. The STC Watershed is situated on the edge of the Manitoba Escarpment and is part of the Lake Winnipeg Basin.

What is WEBs?
A long-term research program initiated by Agriculture and Agri-Food Canada in 2004, WEBs evaluates the economic and environmental performance of BMPs at a small watershed scale. To gain a regional perspective, this information is being scaled up to larger watershed areas using hydrologic models.

WEBs findings are helping researchers and agri-environmental policy and programming experts to understand how BMPs perform and interact with land and water. This knowledge will also help producers determine which BMPs are best for their operations and regions.

WEBs studies are conducted at nine watershed sites across Canada. These outdoor living laboratories bring together a wide range of experts from various government, academic, watershed and producer groups. Many valuable findings have emerged and research continues at all sites.

Figure 1. Conservation tillage study site in south-central Manitoba

Canada

What's in a name?
Tillage practices can be divided into three main categories which reflect a decreasing number of tillage passes and associated increase in remaining plant residue:

- **conventional tillage** - at least one tillage pass in the spring and one in the fall
- **minimum tillage** - often only one tillage pass in the spring or fall
- **zero tillage** - no tillage

The term **conservation tillage** can be applied to practices ranging from minimum tillage to zero tillage—as is the case in the STC economic analysis. In the STC biophysical (twin watershed) study, conservation tillage refers to a field treatment that approached zero tillage. It received no heavy duty tillage in the fall, yet soil disturbance sometimes occurred prior to spring seeding when ammonia fertilizer was injected in a separate field operation, or when harrowing was used to break up the straw cover.

Figure 2. Conventionally-tilled field on the left, conservation-tilled field on the right

How was conservation tillage studied in Manitoba?

To study the water quality impacts of conservation tillage, the STC study used a pair of small (5 ha, 12 acre) adjacent agricultural watersheds (Figure 2) to compare the effects of conservation tillage and conventional tillage under a cereal/canola rotation.

To provide a basis for comparing the two watersheds, both were monitored under conventional tillage for the first four years. One watershed was converted to conservation tillage in 1997 and allowed to stabilize (equilibrate) for seven years. Data on snowmelt and rainfall runoff and sediment and nutrient transport were then compared for the two tillage systems. This analysis is based on a comparison of pre-conversion data with four years of post-stabilization data.

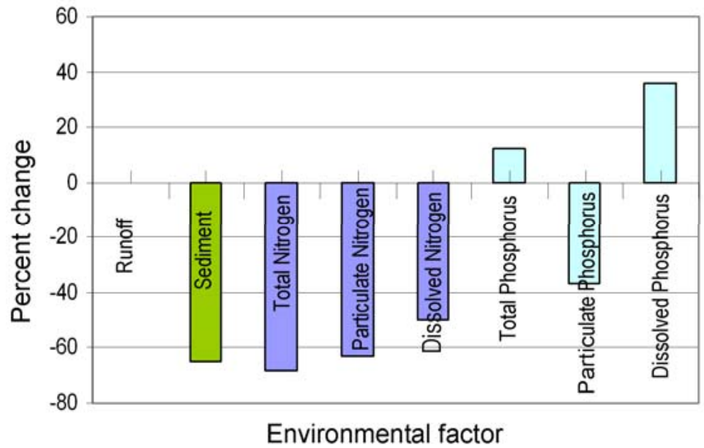

Figure 3. Percent change in sediment and nutrient export after conversion to conservation tillage

What effect did conservation tillage have on water quality[1]?

Research on clay-loam soils within the STC Watershed has shown no statistically-significant difference in the amount of annual runoff between the conservation-tilled and conventionally-tilled fields (Figure 3). This might be due to the fact that the majority of runoff in this watershed occurs during snowmelt when the ground is still frozen and impermeable. However, on an annual basis, conservation tillage was highly effective in reducing annual sediment and total nitrogen (N) export as compared to conventional tillage.

Sediment and total N export were reduced on average by 65% (23 kg/ha, 21 lb/acre) and 69% (2.3 kg/ha, 2.1 lbs/acre) per year respectively. However, total P export was 12% greater under conservation tillage. This is because while the export of particulate P (the small proportion of P lost that was attached to soil sediment) decreased by 37% under conservation tillage, the portion of dissolved P (the large proportion of P that was water soluble) increased by 36%, resulting in a net increase of 0.06 kg/ha (0.05 lb/acre) in exported total P. The average P loading for conservation tillage was therefore 0.17 kg/ha (0.15 lb/acre).

[1]Tiessen, K. H. D., J. A. Elliott, J. Yarotski, D.A. Lobb, D. Flaten, N.E. Glozier. 2010. **Conventional and Conservation Tillage: Influence on Seasonal Runoff, Sediment, and Nutrient Losses in the Canadian Prairies.** Journal of Environmental Quality 39: 964-980.

Even though these nutrient losses may be minor from an agricultural production standpoint, they are ecologically significant since as little as 1 to 2 kg of P/ha/yr (0.9 to 1.8 lb of P/acre/year) is associated with the accelerated eutrophication of lakes. The STC Watershed is one of many that may contribute P to Lake Winnipeg.

These findings suggest that the increase in total P is due to an increase in dissolved P released from crop residues during freeze-thaw events, and/or from soil P that accumulates in surface soils because it has not been mixed during tillage. Results demonstrate that although conservation tillage can effectively reduce sediment and sediment-bound nutrient export from agricultural fields, it can increase the export of dissolved P occurring during snowmelt runoff. In these situations, it may be appropriate to implement additional management practices (such as intermittent tillage) to reduce the accumulation of P at or near the soil surface. These findings could apply to much of the cold, semi-arid landscape of the Canadian Prairies (Figure 4) and may be relevant wherever snowmelt runoff dominates and dissolved P is the major form of P in runoff.

Figure 4. Conservation tillage may not reduce the export of dissolved P in snowmelt runoff.

Don Flaten, a University of Manitoba soil scientist working on the STC WEBs project, emphasizes that conservation tillage has many environmental and agronomic benefits; however, it is not a cure-all in terms of reducing P export from agricultural watersheds in the Lake Winnipeg Basin. “If you take a look at overall environmental health,” he said, “you are better off with conservation tillage than conventional tillage, but we’ve got to be objective and not depend on conservation tillage to solve our P export problems in Lake Winnipeg.”

Jim Yarotski, the AAFC hydrologist leading the STC WEBs project, points out that the research team and participating producer have modified the study to try to reduce dissolved P losses. The conservation tillage field has been converted to intermittent tillage, whereby limited fall tillage will be used to reduce the amount of dissolved P build-up at the soil surface, hopefully without compromising the BMP’s erosion control effectiveness.

Conservation tillage economics in the STC Watershed[2]

Conventional tillage, not conservation tillage, is the dominant tillage practice in the STC Watershed (for reasons cited below). The economic response to conservation tillage is generally positive for cereals (wheat, barley and oats combined) but is negative for canola (Table 1). This economic analysis is based on nine years (1998-2006) of monitoring the tillage and cropping operations for all 357 fields on some 40 farming operations with at least a portion of their land located within the watershed. Cultivated fields range from 200 ha (500 acres) to only a few hectares, with the average being 18 ha (45 acres).

Table 1. Extent of tillage practices and their estimated net returns to canola/cereal cropping systems within the STC Watershed (1998-2006)

Crop	Area under canola and cereals production				
	Conservation tillage		Conventional tillage		Total
	% of area* (ha)	Net income/ha	% of area* (ha)	Net income/ha	% of area* (ha)
Canola	7.3 (261)	$88	30.1 (1,074)	$106	37.4 (1,335)
Cereals	19.7 (703)	$35	42.9 (1,532)	$10	62.6 (2,235)
Total	27.0 (964)		73.0 (2,606)		100 (3,570)

* % area represents the portion of the total area (3,570 ha) under canola and cereals production.

[2] Agriculture and Agri-Food Canada. 2010. **Watershed Evaluation of Beneficial Management Practices (WEBs) Technical Summary #2 – Economics Component Four-Year Review (2004/5 - 2007/8).** Agriculture and Agri-Food Canada. Ottawa. Ont.

Of the total area farmed within the STC Watershed, 4,200 ha (10,400 acres) are in annual crops, with cereals and canola comprising 85% of this area. Of this cereal/canola portion (3,570 ha, 8,822 acres), conservation tillage occurs on 27% (11% is zero tillage, data not shown) and conventional tillage occurs on the remaining 73% of the land.

Table 1 displays the average net income estimated for canola and cereals for conservation and conventional tillage. For **canola**, the greatest net income of $106/ha ($43/acre) is generated by conventional tillage—perhaps reflecting the yield response of such a small-seed crop to more uniform seedbed conditions. Accordingly, most canola in this watershed is cropped under conventional tillage. About one fifth of the canola is under conservation tillage, where a decrease in tillage frequency results in a decrease in the net income for canola to $88/ha ($36/acre). This decrease may also be due in part to limited experience on the part of some producers when applying zero tillage. However, the sample size for zero tillage in the STC Watershed is too small to draw conclusions about impacts on canola production.

Comparatively, the income for **cereals** is highest under conservation tillage at $35/ha ($14/acre). However, with conservation tillage, the income for specific tillage practices can vary considerably (data not shown), being as high as $47/ha ($19/acre) for minimum tillage (likely a reflection of lower fuel and depreciation costs) to as low as $15/ha ($6/acre) for zero tillage due to its increased equipment costs and possible yield loss. Yet even then, the income from zero tillage ($15/ha) is higher than for conventional tillage at $10/ha ($4/acre).

These net income figures reinforce why most producers in the STC Watershed prefer conventional tillage for canola, and why some might prefer conservation tillage (minimum or zero) for cereals. Yet most cereals are still being cropped under conventional tillage. This may be because producers who want to include canola in their ongoing rotations could find it risky to invest in conservation tillage equipment. Producers are likely to focus on the tillage method that is the most profitable, with canola generally being a higher-income crop than cereals.

If conservation tillage under canola or increased conservation tillage under cereals is to be promoted in this watershed, incentives will likely be required to encourage its further adoption. This merits further study from social sciences and agronomic standpoints.

Modelling in the STC Watershed

Hydrologic modelling is being conducted to extrapolate edge-of-field information to the 7,500-ha (18,500-acre) STC Watershed level. These data, obtained from experiments on a number of BMPs, are also being used to evaluate the water quality impacts of various tillage options at the watershed scale.

The STC Watershed is one of two WEBs project sites conducting integrated hydrologic-economic modelling pilot studies[3]. The integrated modelling approach combines information from hydrologic, on-farm economics, and farm behaviour models. By generating various BMP scenarios—combinations of BMPs and adoption incentives—and determining their environmental and economic impacts, the integrated model can ultimately be used for long-term watershed research and planning.

AAFC leads the national WEBs program and provides funding under its Growing Forward *initiative. Ducks Unlimited Canada has been a key contributing partner. Other partners at the South Tobacco Creek project include: Deerwood Soil and Water Management Association; Environment Canada; Fisheries and Oceans Canada; Manitoba Agriculture, Food and Rural Initiatives; Manitoba Water Stewardship; University of Manitoba; University of Guelph; and University of Alberta.*

For more information on WEBs please visit www.agr.gc.ca/webs or contact WEBs at webs@agr.gc.ca.

[3] Yang, W., A. Rousseau and P.C. Boxall. 2007. **An integrated economic-hydrologic modeling framework for the watershed evaluation of beneficial management practices**, Journal of Soil and Water Conservation, 62(6): 423-432.

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