CONTROLLED TRAFFIC FARMING Alberta

2014-2017

CTFA Project Final Report

ACIDF

ALBERTA CANOLA PRODUCERS COMMISSION

ARECA AGRICULTURAL RESEARCH AND EXTENSION COUNCIL OF ALBERTA

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Executive Summary

Controlled traffic farming (CTF) is a crop production system in which the crop zone (cropped area) and traffic lanes are distinctly and permanently separated. In practice, all wheel tracks are confined to specific traffic lanes which in turn require that all implements have a particular span or multiple of this width.

Controlled Traffic Farming Alberta was formed to explore the agronomic and economic benefits that might accrue to implementing CTF over a wide range of soils and climatic zones in Alberta, Canada. The University of Alberta partnered in the project with the cooperator sites providing data that was the basis of a Master's thesis[1].

Replicated, field-scale plots were established in the 2014 growing season on six cooperator farms and increased by two farms in 2015. Data collected over three growing seasons included water infiltration, plant and weed counts, soil biology, and yields. The soils at the sites ranged from sandy loams to heavy clays. A wide variety of soils, terrain and climate was achieved in the site selection. The treatments were controlled traffic farming (CTF) and random traffic (RT).

The growing seasons under study were characterized by dry springs and relatively low soil moisture at seeding. Rainfall in 2014 and 2015 was below normal for most sites with 2015 being very dry. 2016 was very wet and harvest was disrupted by rain and snow.

The plots were established in fields in which direct seeding had been implemented for many years. The controlled traffic treatments were implemented through systems that were developed and employed by the individual producers. Random traffic (RT) treatments were imposed on plots by the cooperating farmer driving over the plots close to seeding time with equipment to achieve at least 50% trafficked area including the established tramline. The controlled traffic and random traffic plots were in the exact same locations each year so that they had up to three years of observations.

Weed counts for 2014 through 2016 do not reveal any population shift which was consistent with expectations for the short time frame of the project. There were however, a few instances where significant differences were observed in the weed populations between the two treatments. However the scarcity of significant differences supports the conclusion that there are no weed population shifts occurring.

Most fields exhibited no significant differences for crop emergence between CTF and RT with the exception of the Lacombe site in 2014, where canola emergence was significantly better in the random traffic plots. No trends in crop emergence were observed.

In 2016, soils were collected from each site and analyzed by Agriculture and Agri-Food Canada for soil biological activity. Microbial biomass C, carbon, nitrogen, phosphorus and sulphur cycling were measured and no significant differences were found between treatments with the exception of C and N cycling at Rolling Hills where RT had significantly higher C and N cycling.

Infiltration rate under CTF management was significantly greater than under RT management. Looking at all site years, the average infiltration rate under CTF was 40.9 ml sec^{-1} as compared to the average

[1] Soil Dynamics Driven by Controlled Traffic Farming in the Canadian Prairies, Kris Guenette, 2017

infiltration rate of 22.0 ml sec^{-1} under RT. There was a great deal of variability within plots when measuring infiltration. Infiltration rates tended to be faster in the controlled traffic plots starting in the first year. Visual observation noted that surface soil tilth improved in the clay soils starting in year one in the CTF.

Cooperators were able to maintain yields as they implemented CTF. Overall, looking at all site-years, the yield under CTF management was significantly greater than yield under RT management, albeit the difference was small. Relative yield (expressed as a percentage of average yield of both the CTF and RT plots) was 101.1 % for CTF as compared to 98.9 % for RT (a difference of 2.2%).

The springs were quite dry each year at seeding at most sites when random traffic was imposed on the plots, so less compaction occurred than if soils were at field capacity. Given Alberta's climate and soil types it is uncertain as to how long soils may take to repair the effect of years of random traffic and high axle loads, especially in the subsoil horizons. There is evidence that soils take a long time to recover from compaction.

While the yield advantage to CTF was small, other advantages of the system are also proving to be valuable. The timeliness and efficiency of operations was a significant benefit. The ability to do accurate, reliable, on-farm research was valuable. The precision of a CTF system opened up a whole new world of agronomic and economic opportunities such as in-crop nitrogen application, on-row fungicides and precision seed location.

The research project has led to observations of system benefits that indicate that CTF can contribute to a number of critical factors that will improve the cropping system and make an individual farm business more sustainable.

Controlled traffic farming and on-farm research with controlled traffic and random farming systems – 2014F015R: April 1, 2014 - March 31, 2017

Introduction

"Controlled traffic farming (CTF) is a crop production system in which the crop zone (cropped area) and traffic lanes are distinctly and permanently separated. In practice it means that all implements have a particular span or multiple of it and all wheel tracks are confined to specific traffic lanes".[2]

CTFA 2014-2017 was a joint project with the University of Alberta, Department of Renewable Resources and was funded primarily by the Alberta Crop Industry Development Fund (ACIDF) and the Alberta Canola Producers Commission. Further contributions and help were provided by our partners: Beyond Agronomy, Demeter Solutions, AgViser Crop Management, Paradigm Precision and our managing partner the Agricultural Research and Extension Council of Alberta. The cooperating farmers made significant investments and undertook additional risk to implement CTF on their farms.

Controlled traffic farming was introduced to Alberta by Australian farmer Robert Ruwoldt at a Reduced Tillage LINKAGES event. An exploratory project was initiated in 2010 by cooperating farmer Craig Shaw. That developed into a 3-year project where cooperators implemented CTF. The 2014-17 project added more cooperators and implemented a replicated plot on-farm research design.

Figure 1. CTFA Partners

[2] No Tillage seeding in Conservation Agriculture. 2nd Edition. Eds C.J. Baker and K.E. Saxton. FAO and CAB International, 2007.

Project Description

Controlled Traffic Farming Alberta (CTFA) is a farmer led, on-farm research project designed to enable farmers to make informed choices about the adoption of controlled traffic farming; improve farmers' ability to do on-farm research; and extend the findings to farmers. The agronomic and economic viability of CTF in Alberta was assessed. There were eight cooperating farmers who had field-scale replicated plots using their own equipment.

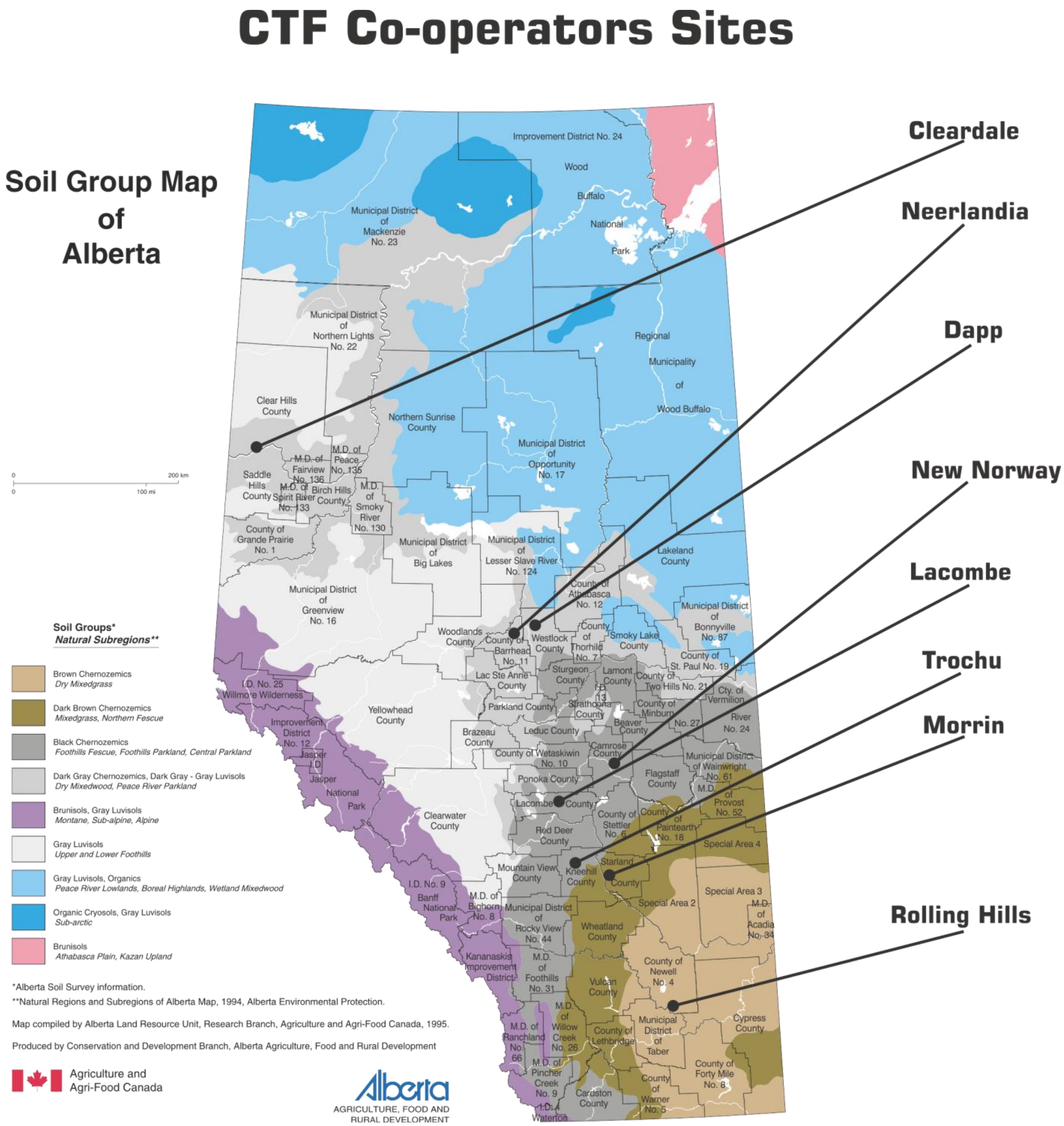

Figure 2. Location and soil groups for CTFA cooperators

Protocol

The on-farm trials and CTF evaluation were designed to function within a controlled traffic farming system. The methodology was as follows:

- The CTF tramline system was implemented on the entire field or area selected, with farmers using their own field-scale equipment.
- A treatment of random traffic was imposed on the CTF field at three to five randomly selected locations.
- Random traffic passes with a tractor and implement or sprayer were made yearly near seeding time so wheel tracks covered 50-65% of the soil surface within each plot. Wheel traffic in a CTF system typically covers 12-20% of the soil surface. The treatment width matched the combine header or swather widths or multiples of them.
- All treatments were swathed or straight cut. The swather and/or combine ran on the tramlines. Yield data was recorded by combine yield monitors, and where possible, grain carts with weigh scales were used for data collection, and calibration of yield monitors.
- If a practice such as an in-season application of nitrogen were to be investigated, the application would occur in strips based on the tramlines and match the combine header or swather widths or multiples of them with three to five replications.

Site Descriptions

Table 1. Climate data for the CTF sites. Agroclimatic Atlas of Alberta 1971-2000 (AFRD)

Location	Frost Free Days	Days Above 5^0C	Degree Days $+5^0C$	Growing Season Precipitation (mm)	Total Precipitation (mm)
Dapp	105-115	175-180	1200-1350	300-325	500-550
Lacombe	105-115	175-180	1200-1350	300-325	500-550
Trochu	105-115	180-185	1350-1500	250-275	400-450
Morrin	115-125	180-185	1500-1650	225-250	350-400
Rolling Hills*	>125	>185	1650-1800	<200	<350
Neerlandia	105-115	175-180	1200-1350	300-325	500-550
Cleardale	105-115	175-180	1600-1800	250-275	450-500
New Norway	115-125	180-185	1350-1500	275-300	450-500

* Rolling Hills - Irrigated site

Soils Information[3]

Dapp - The sandy loam to sandy clay loam soils at the Dapp site are Dark Gray Luvisols on fine textured (C, SiC) water-laid sediments. The soil polygon is 60% Heldar; 20% Westerose and 20% miscellaneous Gleysol. The polygon includes poorly drained soils and soils that are coarser textured than the dominant or co-dominant soils. The land is an undulating, low relief landform with a limiting slope of 2%.

Lacombe - The sandy loam soils at the Lacombe site are Eluviated Black Chernozems on medium textured (L, CL) till (Cygnet) as well as Orthic Black Chernozems on medium textured (L, SiCL, CL) materials over medium (L, CL) or fine (C) textured till (Lonepine). The series is 50% Cygnet and 50%

[3] http://www4.agric.gov.ab.ca/agrasidviewer/

Lonepine. The polygon may include soils that are not strongly contrasting from the dominant or codominant soils. The land is an undulating, high relief landform with a limiting slope of 4%.

A Tweedsmuir soil series dominates the northern and western hilly portion of the field. Tweedsmuir is an Orthic Black Chernozem on moderately coarse textured (SL) sediments deposited by wind or water. These occupy an undulating, high relief landform with a limiting slope of 4%.

Trochu - The clay soils at the Trochu site are Orthic Black Chernozems on very fine textured (HC) water-laid sediments (Three Hills). The polygon includes poorly drained and Solonetzic soils. The series is Three Hills 60%; miscellaneous Solonetz 20%; miscellaneous Gleysol 20%. The land is an undulating, high relief landform with a limiting slope of 4%.

Morrin - The clay to heavy clay soils at the Morrin site are Orthic Humic Vertisols on very fine textured (HC) water-laid sediments (DMH). The series is Heldar 60%; Westerose 20%; and miscellaneous Gleysol 20%. The polygon may include soils that are not strongly contrasting from the dominant or codominant soils. The land is an undulating, high relief landform with a limiting slope of 4%.

Rolling Hills - The fine sand to fine sandy loam irrigated soils at Rolling Hills are Orthic Brown Chernozems on medium textured (L, SiL) sediments deposited by wind and water. The series is Chin 60%, Tilley 20%, Wardlow 10% and Karlsbad 10%. For irrigation it is classified as Class 2, well drained and low in salts, with some Class 5 traits, characterized by imperfectly to poorly drained soils with some strongly saline and sodic profiles. The corners of the center pivot irrigation are dryland.

Neerlandia – The loam to silty loam soils at the Neerlandia site are Orthic Dark Gray Chernozems on medium textured sediments deposited by wind and water. The series is Rimbey 80% and miscellaneous Gleysol 20%. The polygon includes poorly drained soils. The land is undulating, low relief landform with a limiting slope of 2%.

Cleardale – The clay soils at the Cleardale site are Gleyed Solonetzic Dark Grey Chernozems on very fine (HC) water-laid sediments (FAL) and Gleyed Solonetzic Gray Luvisol on very fine textured (HC) water-laid sediments (NMA). The series is Falher (FAL) 40%, Nampa (NAM) 40% and Goose 20%. The polygon includes poorly drained soils. The land is undulating, low relief landform with a limiting slope of 2%.

New Norway – The loam to silty loam soils at the New Norway site are Eluviated Black Chernozems on medium textured sediments deposited by wind and water. The series is Ponoka 80% and Peace Hills 20%. The land is undulating, high relief landform with a limiting slope of 4%.

The equivalent soil names in the Canada to US systems are: Luvisol = Boralf; Black Chernozem = Udic Boroll; Orthic Humic Vertisol = Humicryerts and Brown Chernozem = Aridic Boroll.
http://www.pedosphere.ca/resources/CSSC3rd/table8getALL.cfm
https://www.agronomy.org/publications/aj/articles/103/3/709?show-t-f=tables&wrapper=no.

Bulk Density and Pore Space

Alberta Agriculture and Forestry took core samples from four sites in the fall of 2011 and two in 2015.

Figure 3. AARD soil core from New Norway site

Table 2. Average bulk densities (Mg/m^3 and pore space (%)

Average Bulk Densities & Pore Space – Fall 2011 & 2015					
		Check		CTF	
	Depth (inches)	Db	Pore %	Db	Pore %
Dapp	0-6	1.36	48.51	1.27	52.07
	6-12	1.53	42.14	1.45	45.39
	12-24	1.50	43.35	1.48	44.16
	24-36	1.51	42.83	1.55	41.55
Lacombe	0-6	1.33	49.80	1.12	57.89
	6-12	1.39	47.48	1.11	58.05
	12-24	1.38	47.80	1.20	54.71
	24-36	1.75	33.88	1.48	44.30
Trochu	0-6	1.12	57.66	1.08	59.24
	6-12	1.30	50.80	1.34	49.27
	12-24	1.28	51.78	1.34	49.42
	24-36	1.29	51.22	1.56	41.16
Morrin	0-6			0.84	68.20
	6-12			0.95	64.21
	12-24			1.05	60.43
	24-36			1.20	54.63
Neerlandia	0-6			1.12	57.74
	6-12			1.48	44.15
	12-24			1.57	40.75
	24-36			1.71	35.47
New Norway	0-6			1.22	53.96
	6-12			1.30	50.94
	12-24			1.47	44.53
	24-36			1.44	45.66

The soil samples were used to determine bulk density, porosity, particle size, texture, pore space and water holding capacity. As bulk density increases soil strength increases. The average pore space and bulk densities for the sites are shown in Table 2.

See Figure 4 for a visual example of the impact of a castor wheel on soil structure.

Figure 4. Morrin site: Soil structure under castor wheel left side and no traffic right side (photo Steve Larocque)

Weather

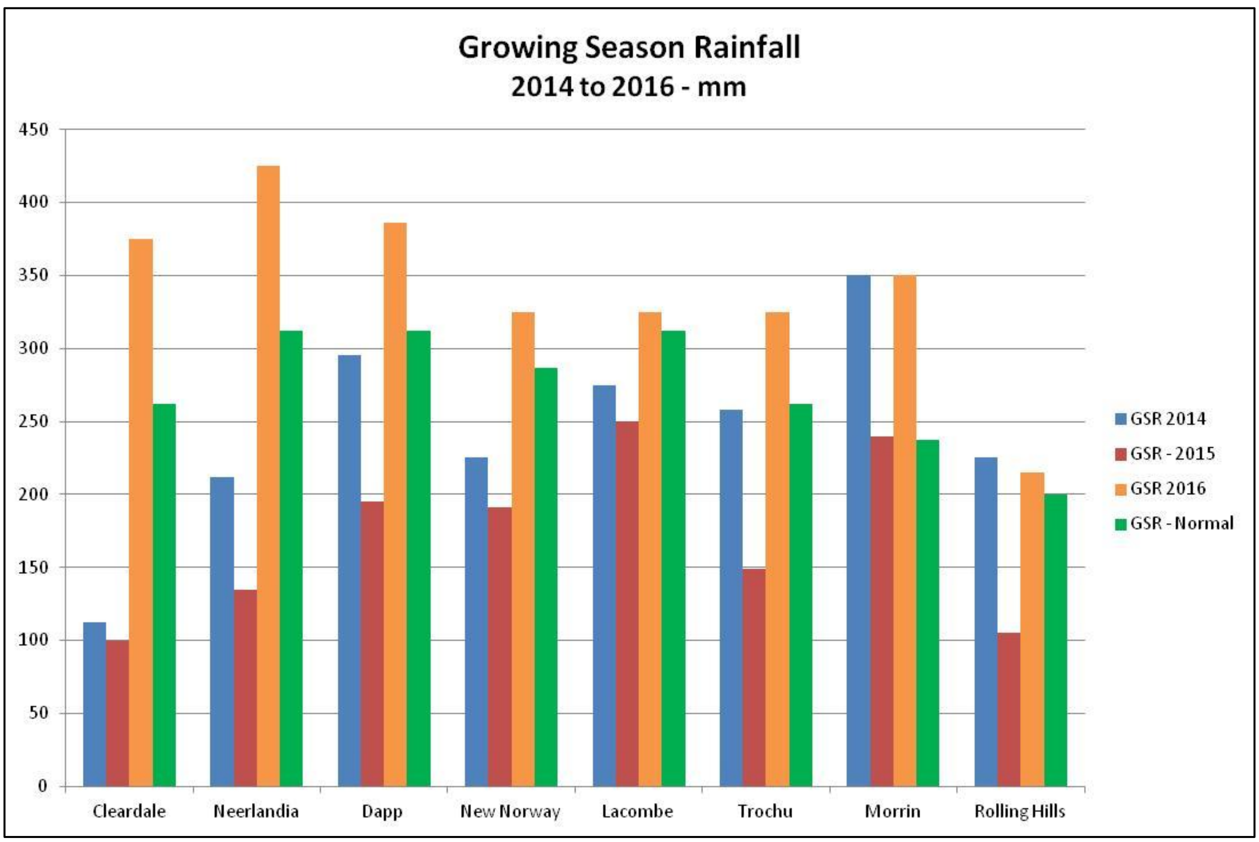

Figure 5. Growing Season Rainfall vs Normals (May-August)
Rolling Hills irrigated site; AARD weather station data
Normals 1970-2000

Rainfall for 2014 and 2015 was for the most part below normal. All three years had relatively dry springs, especially 2016. Excessive rainfall from mid May on in 2016 was detrimental to crops. A very wet fall in 2016, including snow, resulted in no data being collected at the New Norway and Neerlandia sites. Most sites experienced significant rutting which was confined to the tramlines and headlands.

Weed Communities and Crop Emergence

The Lacombe Research and Development Centre, Agriculture and Agri-Food Canada, monitored crop emergence and weed populations in the CTF and random traffic treatments at all sites. Weed populations were counted each spring, prior to or just after in-crop spraying, with a view to determining if there were any shifts in populations between the CTF and random traffic. Crop emergence counts were taken at the same time.

The weeds and crop were counted in five quadrats (each 0.5 m^2) in a zig zag pattern going down the CTF and adjacent RT treatment. The counts were repeated three times (3 reps) to equal 30 quadrats per field.

Weed counts for 2014 through 2016 did not reveal any population shifts, as expected in the short time frame. Table 3 shows the few instances where there were significant differences in weed populations between treatments. However, the scarcity of significant differences supports the conclusion that there are no weed population shifts occurring.

Most fields exhibited no significant differences for crop emergence between CTF and RT with the exception of the Lacombe site in 2014 where canola emergence was significantly better in the random traffic plots.

Table 3. Summary of Significant Weed Count Differences (p=0.05)

Summary of Significant Differences (p=0.05)			
Species	Site-Crop	CTF	RT
	2014 Crop Year		
Stinkweed	Morrin - Canola		✓
	2015 Crop Year		
Hempnettle	New Norway - Peas	✓	
	2016 Crop Year		
Cleavers	New Norway - Wheat	✓	
Volunteer Wheat	Rolling Hills - Corn	✓	
Shepherd's Purse	Neerlandia - Canola		✓
✓ **Indicate significantly more weeds**			

Soil Microbial Activity

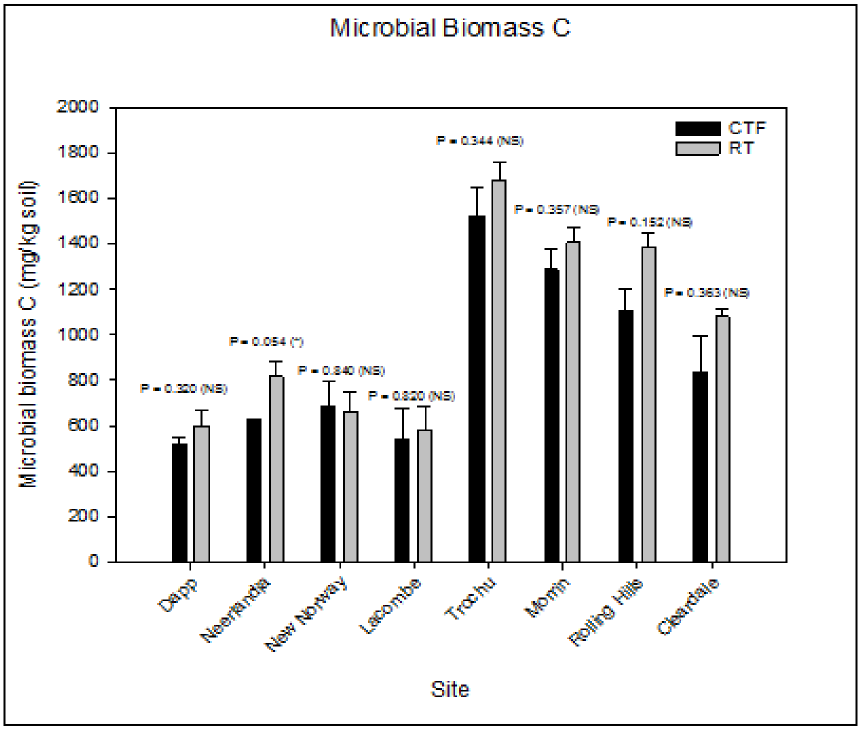

Figure 6. Microbial Biomass C

In 2016 soils were collected from each site and analyzed by Agriculture and Agri-Food Canada for soil biological activity. Microbial biomass C (Figure 6), carbon, nitrogen, phosphorus and sulphur cycling were measured and no significant differences were found between treatments with the exception of C and N cycling at Rolling Hills where RT had significantly higher C and N cycling.

Data Analysis[4]

Analysis of variance of water infiltration rate (ml sec^{-1}) assuming a lognormal distribution was conducted using the GLIMMIX procedure in SAS 9.3 (Littell et al 2006). Site-year combinations (22 site–years), traffic and traffic by site-year interaction were considered fixed effects while sample nested within traffic, sample nested within traffic by site-year and replicate nested within site-year were considered random effects.

In order to compare yields from a variety of different crops across the eighteen site-year combinations, a relative yield was calculated (expressed as a percentage of the mean yield of each site-year). Analysis of variance of relative yield (%) was conducted using the same procedure in SAS 9.3 assuming a normal distribution (Littell et al 2006). Traffic was the only factor considered fixed. Replicate within site-year and site-year combinations were considered random effects. The yield data from Rolling Hills 2014 was excluded from the statistical analysis as two different varieties of corn with different yield potentials were sown on the different reps.

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[4] Little, R. C., Milliken, G. A., Stroup, W. W., Wolfinger, R. D. and Schabenberger, O. 2006. SAS® for Mixed Models, Second Edition. Cary, NC: SAS Institute Inc.

Water Infiltration

Water infiltration is affected by soil bulk density, pore space, and continuity of pores among other factors. Water infiltration is a measure of the time it takes to infiltrate water into the soil.

Aluminum rings with an eight inch (20.32 cm) diameter were inserted into the soil to ensure a good seal between the soil and ring. The equivalent of one inch (2.54 cm) of water was poured into the ring and the time for the water to infiltrate was measured. Two sets of five rings were placed horizontally across the plots, avoiding the main tramlines, in order to capture any random traffic effect on infiltration.

Infiltration rates were significantly greater under CTF management as compared to RT management (p=0.0042). Overall, infiltration rate under CTF management was 40.9 ml/sec in comparison to infiltration rate under RT management of 22.0 ml/sec.

Over the eight sites, infiltration rates were greater at the sites with higher clay content soils. This is likely due to more pore space in clay soils as compared to sandy or silty soils and also likely due to continuity of large pores spaces such as cracks in the clay soils. There was a significant effect of site-year on infiltration rates ($p < 0.0001$) reflecting the different soil textures at the different sites. Figure 7 illustrates this relation between soil texture and infiltration rate. It is also interesting to note that the infiltration rate improved in many cases after only one year of removing traffic.

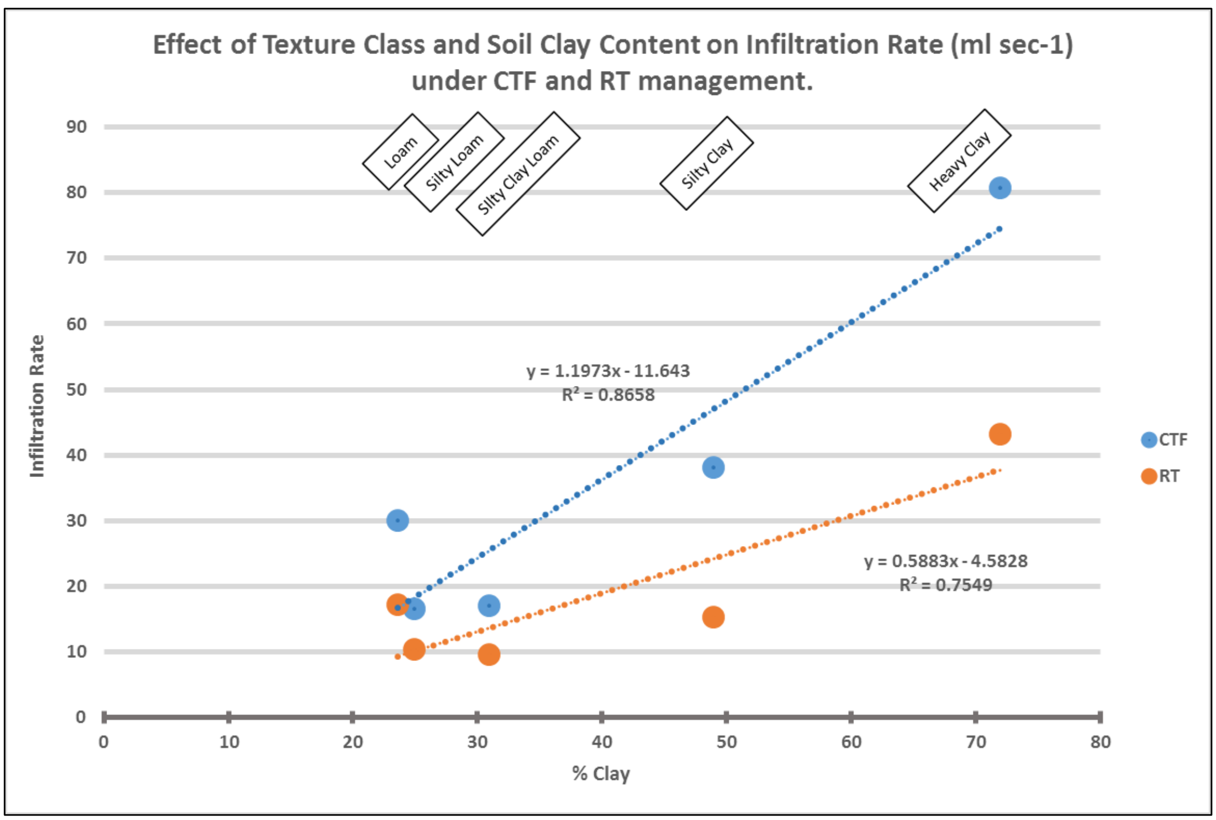


Figure 7. Effect of Texture Class and Clay Content on Infiltration Rate (ml/sec)

Figure 8 shows the infiltration rates for the sites over the three years of the project. This allows for a simple visual comparison of the infiltration rate over the three years. Infiltration rates in seconds to infiltrate one inch of water are shown in Appendix 1.

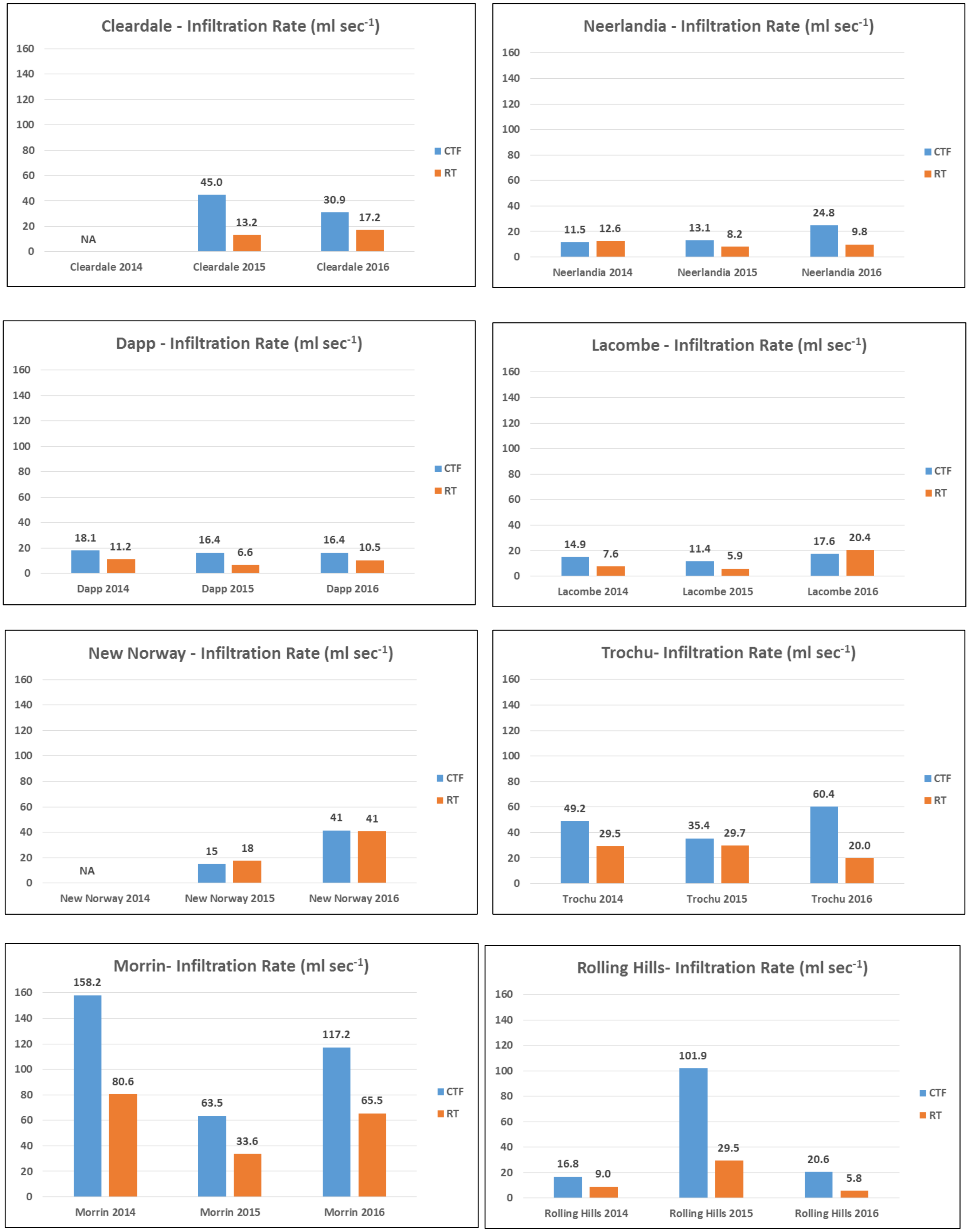


Figure 8. Infiltration Rate ml/sec

Yield

The plots were replicated field-scale plots. Plots were in the exact same location for each of the three years. Replications ranged from three to five. The data was collected from combine yield monitors and in the case of Dapp, New Norway, Lacombe and Trochu grain carts with scales were also used to record yields. Yields were collected from random traffic swaths and from the CTF swaths immediately adjacent to the random traffic swaths.

Figure 9 shows a typical layout of the plots. The black lines are the replicated treatments where random traffic was imposed after seeding. Cooperators drove on the plots with tractors and an implement or grain cart. The implements were not engaged with the soil. Total tracked area of the plots was over 50%, simulating the approximate area covered in a random traffic no-till system.

The percent area a farmer drives on in their field can be calculated using a desktop app called Wheeltrak. It is available at http://controlledtrafficfarming.org/index.php/links.

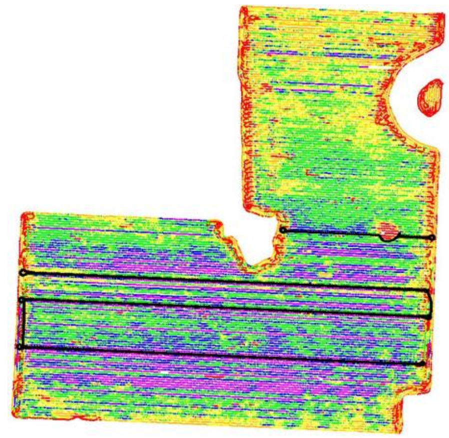


Figure 9. Typical plot layout

Cooperators were able to maintain yields as they implemented CTF. Overall, looking at all site-years, the yield under CTF management was significantly greater than yield under RT management, albeit the difference was small. Relative yield (expressed as a percentage of average yield of both the CTF and RT plots) was 101.1 % for CTF as compared to 98.9 % for RT ($p=0.016$).

Looking at individual site-years (Table 4), the Trochu site had significantly better yields for controlled traffic in 2015 and 2016. The Cleardale canola in 2016 had significantly greater yield under CTF as compared to RT. The yield data from Rolling Hills 2014 was excluded from the statistical analysis as two different varieties of corn with different yield potentials were sown on the different reps.

Figure 10 shows the relative yields expressed as percentages. Appendix 2 shows graphs of actual yields in bushels and tonnes per acre.

It was fairly dry every spring at most sites when random traffic was imposed on the plots so less compaction had occurred than if soils were at field capacity. Given Alberta's climate and soil types it is uncertain as to how long it may take to repair the effect of years of random traffic and high axle loads, especially in the subsoil horizons. The cooperators have experienced fairly good growing seasons with adequate to excessive moisture in some cases, with 2015 being by far the driest.

Improvements in soil quality indicators such as bulk density, macropores and infiltration rates in CTF bode well for the future (Figures 8 and 12). Dr. Jeff Tullberg (personal communication 2016), of the Australian Controlled Traffic Farming Association (www.actfa.net), notes that: "We have spent 50 years optimising the system for degraded soil, so perhaps it is unsurprising that other factors intrude when we improve soil condition. In our traditional side-by-side agronomic comparisons everything happens at the same time on all treatments. That is okay if we are looking for a positive response to the absence of compaction, but not when the optimum timing of operations is often different".

There is evidence that soils take a long time to recover from compaction. A summary of 20 soil compaction experiments in North America and Europe indicates that “compaction due to axle loads of 10-12 tons reduced yields approximately 15 percent in the first year, decreasing to 3-5 percent 10 years after compaction”[5].

Table 4: Yield in bushels/ac and tonnes/ha (Individual Site-year Yields)

	2014 Yield (bu/ac)		
	CTF	RT	p value
Cleardale			
Neerlandia CPS	104.4	100.6	0.26
Dapp Canola	54.3	53.6	0.59
New Norway			
Lacombe Canola	54.1	52.2	0.17
Trochu Canola	62.1	60.9	0.10
Morrin Canola	55.9	57.5	0.46
Rolling Hills Corn	82.8	85.7	0.14

2014 Yield (tonnes/ha)		
	CTF	RT
Cleardale		
Neerlandia CPS	7.02	6.77
Dapp Canola	3.04	3.00
New Norway		
Lacombe Canola	3.03	2.93
Trochu Canola	3.48	3.41
Morrin Canola	3.13	3.22
Rolling Hills Corn	5.20	5.38

	2015 Yield (bu/ac)		
	CTF	RT	p value
Cleardale CPS	65.9	66.3	NA
Neerlandia Peas	45.7	40.6	0.22
Dapp CPS	72.1	70.4	0.43
New Norway Peas	85.6	86.3	0.78
Lacombe Wheat	67.5	67.8	0.80
Trochu Barley	70.3	69.1	0.05
Morrin Fababeans	51	49	NA
Rolling Hills Peas	81.1	81.3	0.92

2015 Yield (tonnes/ha)		
	CTF	RT
Cleardale CPS	4.43	4.46
Neerlandia Peas	3.07	2.73
Dapp CPS	4.85	4.73
New Norway Peas	5.76	5.80
Lacombe Wheat	4.54	4.56
Trochu Barley	3.78	3.72
Morrin Fababeans	3.43	3.30
Rolling Hills Peas	5.45	5.47

	2016 Yield (bu/ac)		
	CTF	RT	p value
Cleardale Canola	57.0	53.5	0.05
Cleardale CPS	93.1	91.4	0.43
Neerlandia Canola	not harvested		
Dapp Canola	54.5	53.7	0.59
New Norway GPW	not harvested		
Lacombe Barley	84.5	87.1	0.28
Trochu Canola	63.5	60.6	0.004
Morrin Barley	99.8	89.7	0.13
Rolling Hills Corn	154.1	161.1	0.06

2016 Yield (tonnes/ha)		
	CTF	RT
Cleardale Canola	3.19	3.00
Cleardale CPS	6.26	6.15
Neerlandia Canola		
Dapp Canola	3.06	3.01
New Norway GPW		
Lacombe Barley	4.55	4.68
Trochu Canola	3.56	3.40
Morrin Barley	5.37	4.83
Rolling Hills Corn	9.67	10.11

[5] Avoiding Soil Compaction, http://extension.psu.edu/plants/crops/soil-management/soil-compaction

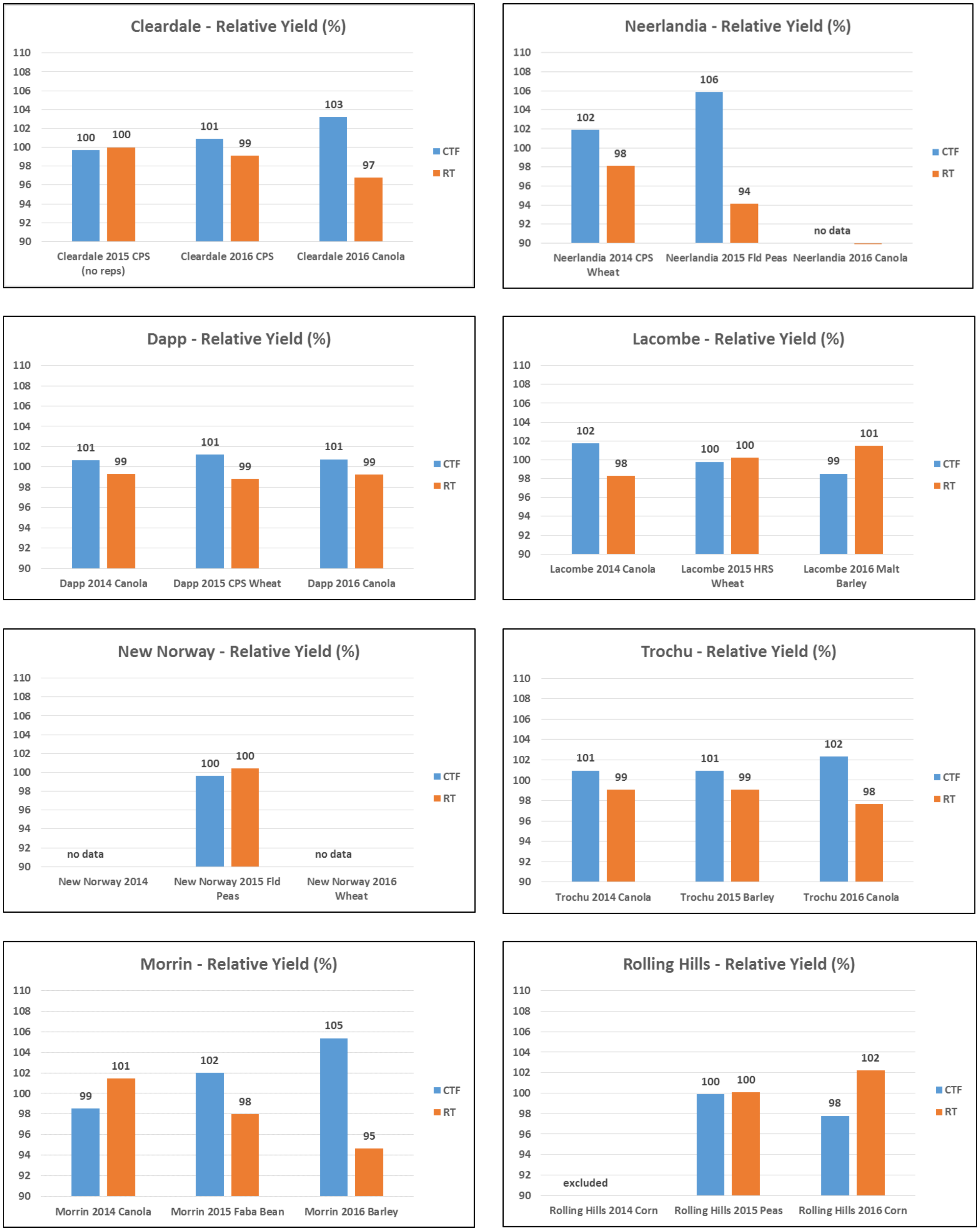


Figure 10. Relative Yield (%)

Economic Analysis

The complete economic analysis is available as a separate report at:
http://controlledtrafficfarming.org/index.php/ctf-plot-reports/plot-reports

The key economic question for farm managers considering controlled traffic farming (CTF) is whether incorporating CTF into an existing cropping system will make the farm better off. In addressing this question, decision makers can apply different frames or perspectives to guide their thinking and how they assess the benefits of CTF. The analyses looked at the economic performance of CTF through three different lenses. These are:

- Whether there are yield differences due to CTF compared with random traffic (RT) that generate Net Economic Benefits.
- Investment Analyses using Internal Rate of Return (IRR) to determine whether the returns on the capital invested to implement CTF are acceptable.
- Whether there are systems benefits that are important to the cropping system and the farm business.

The gross margin (Table 5) was mostly positive but variable in favor of CTF with the exception of the Rolling Hills site which had negative gross margins in all years.

Table 5. Net CTF Effect on Gross Margin

Net CTF Effect on Gross Margin Versus RT						
Location	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Cleardale						$15.50 (CPS)
Dapp	$3.70 (Canola)	$79.33 (CPS)	$54.08 (Peas)	-$7.56 (Canola)	-$5.25 (CPS)	$8.80 (Canola)
Neerlandia				$20.27 (CPS)	$31.80 (Peas)	No Data
Camrose					$-4.56 (Peas)	No Data
Lacombe	-$10.00 (HRSW)	$25.57 (Barley)	$42.50 (W. Wht)	$17.84 (Canola)	-$2.17 (HRSW)	-$9.36 (Barley)
Trochu	$32.80 (Canola)	$44.04 (Barley)	$9.50 (Peas)	$15.76 (Canola)	$11.99 (Barley)	$31.50 (Canola)
Morrin				-$16.47 (Canola)	n/a	$55.05 (Barley)
Rolling Hills		-$40.53 (W. Wht)	-$16.04 (Conf. SF)	-$10.33 (Corn)	-$7.39 (Yellow Peas)	-$35.00 (Corn)

Incorporating CTF into a cropping system requires an initial investment of capital with the expectation of receiving a stream of net cash inflows over the life of the investment. Internal Rate of Return (IRR) is the discount rate at which the Present Value of the cash inflows equals the Present Value of the initial investment. IRR provides a useful measure of the returns earned by the capital investment that can be compared with other investment opportunities.

Table 6 presents the key elements in determining the IRR for each farm over the three year investment life. The capital investment ($/acre) reflects the cost of implementing the CTF component in the cropping system, net cash flows are the impact of yield differences on gross margins, and salvage value is the estimated value of the initial capital investment at the end of the investment life.

The wide range in the IRR measures reflects the different approaches to acquiring or modifying equipment to conform to CTF as well as the effect of economies of scale where the initial costs can be spread over more acres. Where modifications have a higher labour component, there may be limited salvage value. Certain assets such as Real Time Kinematics (RTK) systems retain their market value quite well with the salvage value being strong.

Table 6. Internal Rate of Return on Investment in CTF (Statistical Sample Data and Producer Field Data)

	April 1, 2014	Net Cash Inflows ($/Acre)			April 1, 2017	
Location	Capital Investment ($/Acre)	2014	2015	2016	Salvage Value ($/Acre)	IRR (%)
Cleardale	n/a					
Dapp	$2.13	-$7.56	$57.58	$0.66	$1.06	274.16%
Neerlandia	$6.99	$20.27	$31.80	$0.00	$4.58	305.96%
Camrose	$17.89		$7.94	$0.00	$14.44	14.74%
Lacombe	$17.69	$17.84	-$2.17	-$9.36	$10.24	-6.59%
Trochu	$4.44	$15.76	$11.99	$31.50	$1.23	350.79%
Morrin	$23.67	$23.25	$17.00	$21.72	$2.66	73.71%
Rolling Hills	$11.97	-$10.34	$6.47	-$35.45	$10.63	-48%

System benefits are not easily quantified in terms of increased revenues or reduced operating costs. Their value is in how they contribute to achieving other objectives of importance to the cropping system and the individual farm business. An indexed system evaluated the systems benefits in five categories:

- Improved soil quality
- Continuous improvement of the cropping system
- Continuous learning
- Timeliness
- Resiliency

These were all ranked higher than the random traffic systems the cooperators had been in.

Overall Economic Assessment

There is no definitive answer to the question of whether incorporating CTF into the existing cropping system can consistently achieve higher yields and net economic benefits. However the research project has led to observations in which CTF can contribute to a number of critical factors that will improve the cropping system and make an individual farm business better off.

Accordingly, the issue of whether CTF will make the farm better off can be framed through the lens of whether CTF might provide these critical factors. The following groups of questions can guide individuals in determining whether their unique circumstances might enable CTF to make the cropping system and farm business better off.

Are there key economic factors that could enable CTF to make a farm better off including the following?

- Would CTF enable the cropping system to overcome a production constraint such as compaction?
- Would CTF enable the farm to achieve precision while operating at large scale?
- Would CTF provide improved soil structure and soil porosity that benefits the cropping system over time?
- Would implementing CTF have acceptable upfront costs both in dollars and management time?

Are there key sustainability factors that could enable CTF to make a farm better off including the following?

- Would implementing CTF provide greater ability to recover from extreme weather events including drought and excessive rainfall?

- Would implementing CTF be supported by being part of a network of producers willing to share experiences and provide guidance?

Are there key strategic factors that could enable CTF to make a farm better off including the following?

- Would implementing CTF provide greater agility and ability to adapt to changing conditions through a platform for on-farm research?
- Would implementing CTF align with the vision for new technologies in crop production including autonomous machines?
- Would implementing CTF enable the farm to adapt and take advantage of changing market opportunities such as meeting standards for nutrient density?

Are there key organizational factors that could enable implementing CTF to make a farm better off including the following?

- Would implementing CTF be supported by the various individuals involved in the cropping system operations?

The overall economic benefits of implementing CTF will be unique to each individual farm business. Accordingly these questions will assist individuals in assessing whether the farm business will improve.

Cooperator Profiles

Profiles of each of the cooperators are available as separate reports at:
http://controlledtrafficfarming.org/index.php/ctf-plot-reports/plot-reports
The profiles titled ONTRACK feature descriptions of each cooperator's system and farm, how each cooperator implemented CTF, and future system modifications being considered.

Cooperator Observations and Questions

The cooperators have learned a lot about CTF over the last six years, and the following is a summary of their observations and questions. Most of the cooperators have over five years of experience with controlled traffic and have implemented CTF on most of their cropped acres.

- Tramline renovation will be needed soon mostly in sprayer tracks.
- If drainage is an issue on your farm it may pay to do that before implementing CTF.
- It has been a long process to get all equipment on the same tracks.
- It is fairly easy to switch a four wheel drive such as a JD 9000 series from duals to singles with a 30 inch tread width. It is very important to have the tires and tractor weighted up properly.
- Traction problems in some hills have improved as tramlines set up.
- Wet conditions are leading to rutting, traction problems and residue issues.
- Rutting on tramlines in wet areas and headlands is no worse than a random traffic system and may be less in some cases.
- Normal farm operations or weather issues such as hail, manure application and other events may result in the use of custom operators. They are not likely set up for CTF so you may be forced to deviate from your system. What is the cost and how often will this occur?
- What about subsoiling headlands? Does that speed up the process of rejuvenation?
- Subsoiling does improve structure, not soil quality overall, but subsequent traffic causes soil to revert back quickly.
- How can we use soil biology and cover crops to renovate soils?
- Newer swather track widths are around 134 inches and wider, which is beyond feasible tired tractor axle widths. The same goes for newer SP sprayers.
- Interrow seeding is not always successful due to skewing, especially on slopes.
- Interrow seeding works best if you seed in the same direction as the year before.
- Guidance on side hills is still iffy; sprayers tend to climb up.
- Accuracy of yield monitors is a concern (need to tie to grain cart weights).
- There will likely be better benefits from CTF in some climatic conditions – which are they?
- Australians have noted that wetter years provided more opportunity.
- What about drought?
- Residue management is critical.
- Harrowing in the direction of tramlines is not always effective for residue management.
- Residue management to 40 feet is fairly good with newer residue managers on combines.
- Growth regulators and higher cutting will likely help with residue management.
- The precision of a CTF system opens up a whole new world of agronomic and economic opportunities such as in-crop nitrogen application, on-row fungicides and so on.
- CTF is a good way to engineer fields for efficiencies and future technologies such as robotics and unmanned vehicles.

Extension Activities

The CTFA project is primarily about applied research and extending the information gleaned to farmers. The website www.controlledtrafficfarming.org is a primary source of information about the project. Twitter, @CTFAlberta, was also used to convey concise information and links.

The Controlled Traffic Farming Alberta Newsletter , a web-based publication, was published three to four times each year. The newsletter has over 130 subscribers and informs interested farmers, researchers and agronomists of the project and new information on CTF. Archived copies are available at: http://controlledtrafficfarming.org/index.php/newsletter

Field days were held at most cooperator sites (Figure 11). The cooperators and project leader also presented at various extension events, conferences and grower associations in Western Canada and other locations in North America.

A final conference was held in March of 2017 to inform interested growers and agronomists of the project results. Conference presentations are available at: http://controlledtrafficfarming.org/index.php/links

Extension style articles were produced at project end to provide summary information on:

- Soil quality
- Infiltration, Yield and Microbial Activity
- Economics of CTF
- On-Farm Research
- Tramline Renovation

They are available at: http://controlledtrafficfarming.org/index.php/ctf-plot-reports/plot-reports.

Eight cooperator profiles called ONTRACK feature descriptions of the CTF systems and farms, how each cooperator implemented CTF and future system modifications. They are available at: http://controlledtrafficfarming.org/index.php/ctf-plot-reports/plot-reports.


Figure 11. Field extension events

On-Farm Research

Enabling farmers to do on-farm research efficiently, collect data and analyze the results with the view of making better decisions was an aspect of the project. Some observations were:

- Controlled traffic farming is an excellent system within which to do on-farm research.
- Randomized plot designs fit well in CTF.
- Keep experiments simple, multiple comparisons within the same plots are difficult to analyze.
- Replication is essential for good decision making.
- Partnership with a number of farms in carrying out the same experiment greatly improves the ability to identify treatment effects. In this project, having the ability to analyze a number of sites over a number of years greatly improved the ability of statistics to identify treatment effects.
- Watch out for anomalies at harvest. If the crop is leaning in such a way that it affects harvest it may affect plot yields and bias the results. If so adjust combine travel to equal out biases.
- Experiments are repeatable, same plots, same locations over a period of years, due to the accuracy of RTK/GPS.
- CTF eliminates many random variables such as traffic, overlaps and underlaps, insuring more accurate and reliable data.
- Developing a prescription map for plots is very valuable and saves time, while reducing errors.
- Prescriptions for harvesting tied to trials are very helpful and results turn around faster.
- Grain carts with scales are very valuable for accurate data collection. Poor harvest weather can play havoc with yield monitors.
- A combination of combine yield maps and grain cart weights is the best way to gather data.
- Setting the GPS grid on all implement widths to match the harvester width (ie 120 foot sprayer set on 30 foot widths to match a 30 foot seeder and harvester), helps with research and identifying where you have a treatment.
- Make sure you get data out of the implement as soon as possible. Streaming data to your agronomist or the Cloud should help prevent data loss, misplaced cards and mangled files.
- Analyzing data is still time consuming but progress is being made.
- Tools for data analysis from groups such as the Indian Head Agricultural Research Foundation http://iharf.ca/on-farm-tool/ or STEEP http://pnwsteep.wsu.edu/agstatsweb/ are very helpful.

Soils Research on the CTFA plots - University of Alberta

Kris Guenette, U of A grad student, utilized the cooperator plots for his Masters thesis. A detailed report is available at:
http://controlledtrafficfarming.org/index.php/ctf-plot-reports/plot-reports

The goals of the study were to:

- Evaluate changes in soil quality between conventional and controlled traffic systems at a regional scale across Alberta, Canada,
- Quantify the differences in soil quality parameters between tramlines and un-trafficked areas of CTF and
- Determine if greenhouse simulated CTF soil conditions can influence faba bean (*Vicia faba* L.) productivity.

The alteration of soil quality parameters that resulted from a comparison between conventional (random) traffic to controlled traffic systems had positive effects within the un-trafficked areas throughout most regional areas in Alberta (Figure 12). This improvement to soil quality is essential when in a CTF system, 65-80% of the field can be considered as un-trafficked areas.

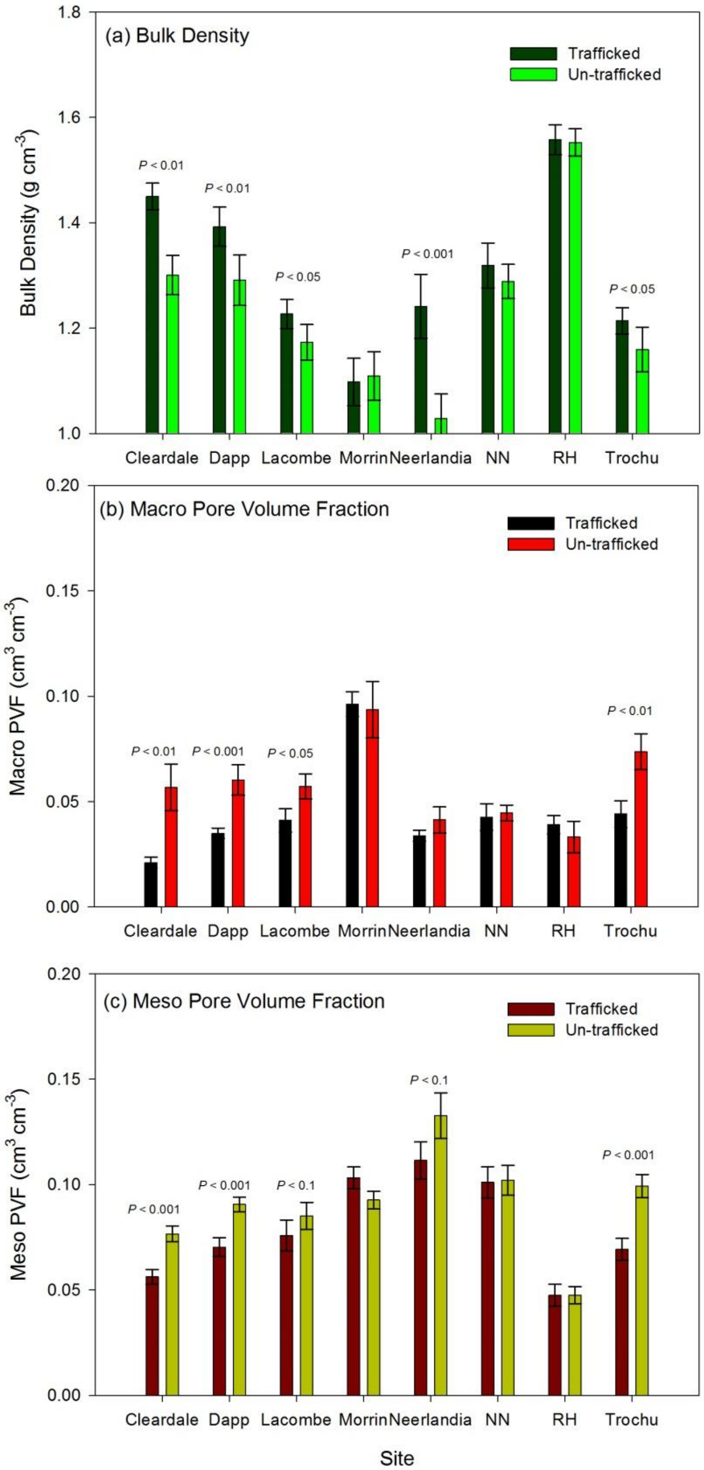


Figure 12. Differences in (a) dry soil bulk density, (b) soil macro pore volume fraction (pore diameter > 60 µm) and (c) meso pore volume fraction (pore diameter from 9-60 µm) between conventional traffic (traffic) and controlled traffic (un-trafficked) systems across eight study sites in Alberta, Canada. P-values displayed above sites that showed statistically significant (α = 0.05) differences between traffic systems.

Contrasting the conventional and controlled traffic systems displayed significant improvements to soil structure in the un-trafficked areas, which was emphasized by increases in water transmission pore volume, soil S-Index and unsaturated hydraulic conductivity.

Additional equipment traffic experienced in sprayer tramlines was shown to have negative effects on soil quality parameters, despite lacking any significant differences between tramline types. However, the observed enrichments to soil physical quality was variable across the regional areas of Alberta and was likely due to the varying duration of CTF implementation in each of the study sites, where longer durations of CTF usage displayed more robust soil amelioration. Furthermore, the regional areas that encompassed the soil types of Black Chernozems and Dark Grey Luvisols produced more visible responses to the reduction of traffic.

The incorporation of these soil types with field soil conditions into a controlled setting of a greenhouse displayed that un-trafficked soil conditions (1.2 g cm^{-3}) experienced in CTF systems yielded optimal growing conditions for faba beans. Conversely, soils with a high degree of compaction, such as those witnessed in conventional traffic systems or tramlines (1.4 g cm^{-3}), produced significantly less than optimal conditions for faba bean productivity. Therefore, the positive impacts the use of controlled traffic systems have on soil quality in Alberta should warrant future consideration of CTF as a means to move towards more sustainable practices.

Conclusions

The CTF systems performed well in a range of climatic and soil conditions and are increasing the resilience of the cooperators' cropping systems. The Morrin cooperator has observed better, more even germination and emergence resulting in evenness of maturity in the CTF plots compared to the random traffic plots. This is the result of removing traffic and improving surface soil tilth.

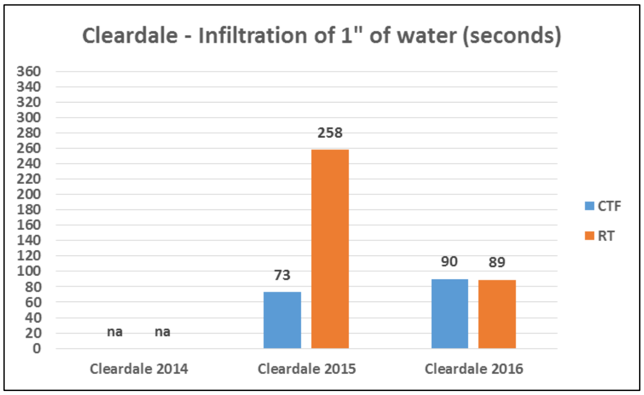
CTF has shown a yield advantage over RT and other advantages of the system are proving to be valuable. The timeliness and efficiency of operations is a significant benefit. The ability to do accurate, reliable on-farm research is valuable. The precision of a CTF system opens up a whole new world of agronomic and economic opportunities such as in-crop nitrogen application, on-row fungicides and precision seed location.

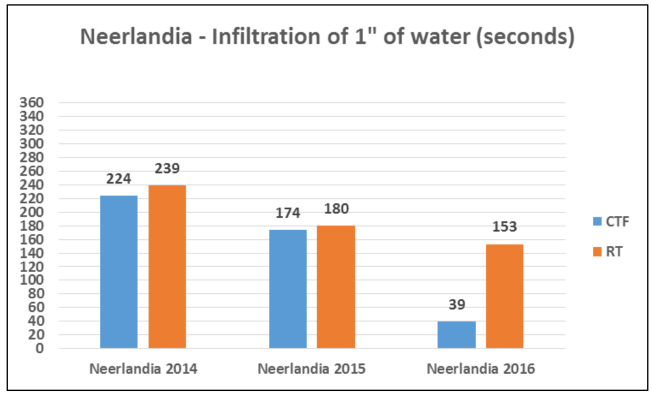
There are challenges to implementing CTF and much to be learned. Careful, long-range planning is essential. Good residue management is a must, just as it is in no-till systems. Tramlines have held up well, however with the wet fall in 2016 some damage was done which will necessitate repairs. The damage is much less than in randomly farmed fields.

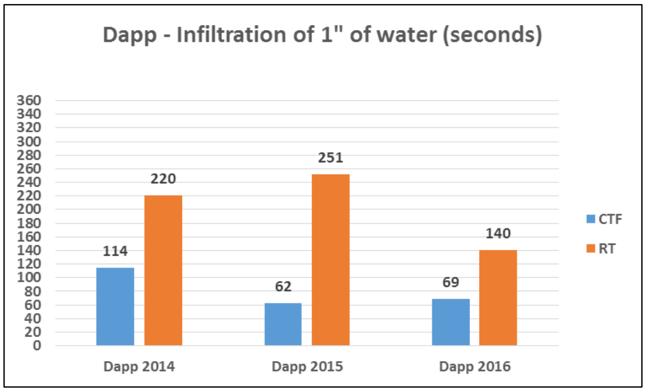
Soil quality properties such as structure, pore space, water holding capacity and infiltration are beginning to improve. This bodes well for the future.

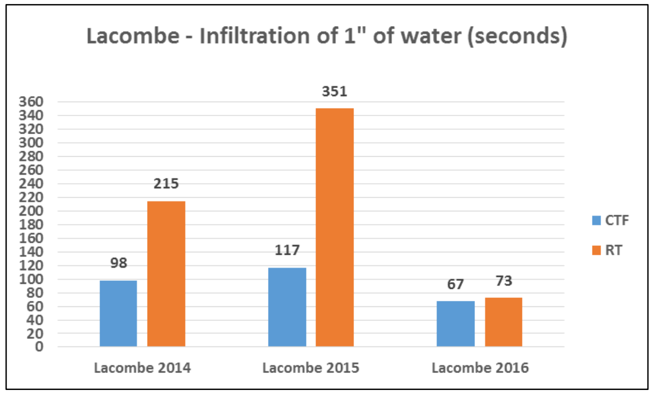
Incorporating CTF into the existing cropping system can consistently achieve higher yields and net economic benefits. The research project has led to observations of system benefits that indicate that CTF can contribute to a number of critical factors that will improve the cropping system and make an individual farm business more sustainable.

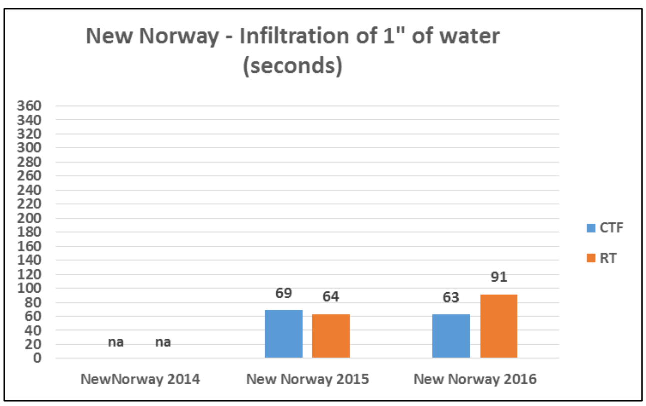
Appendix 1. Actual Infiltration Rates

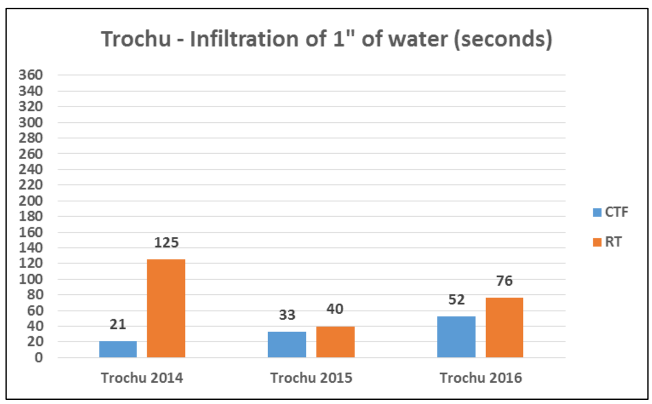


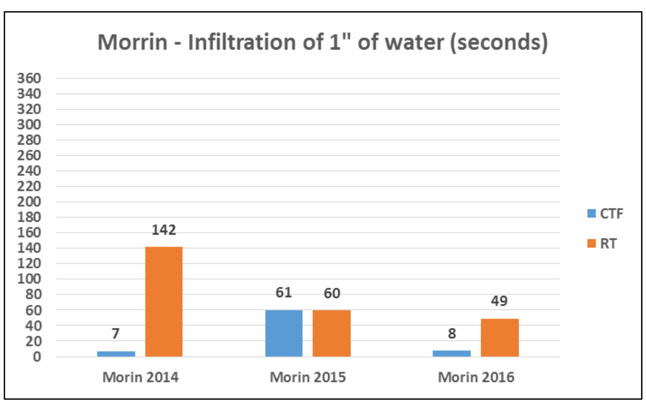


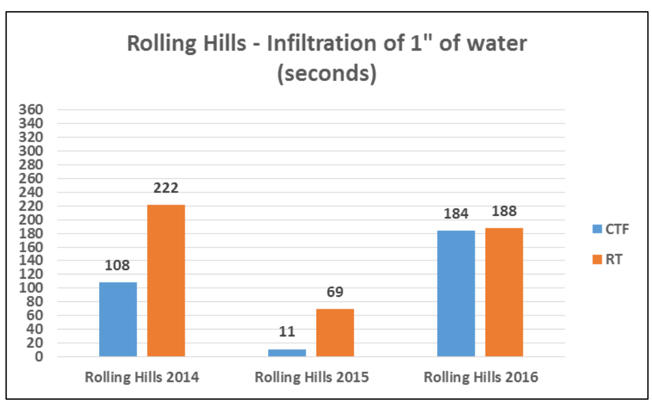






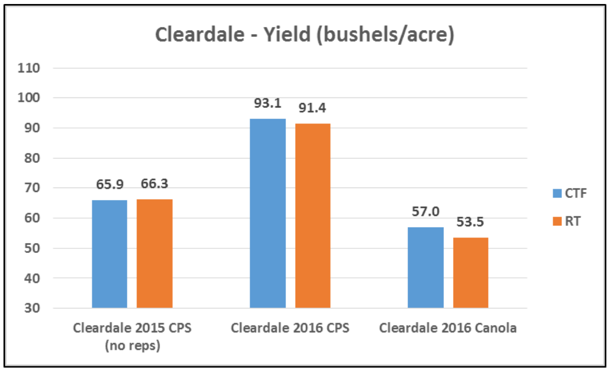


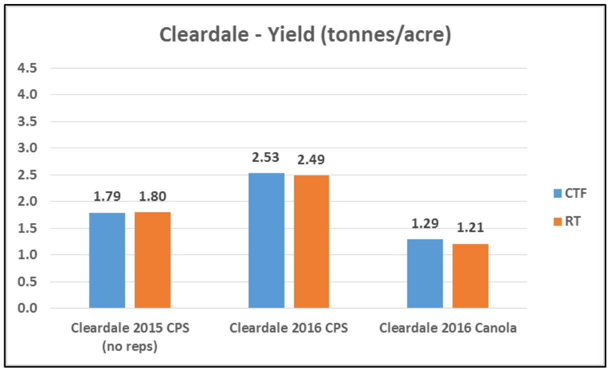


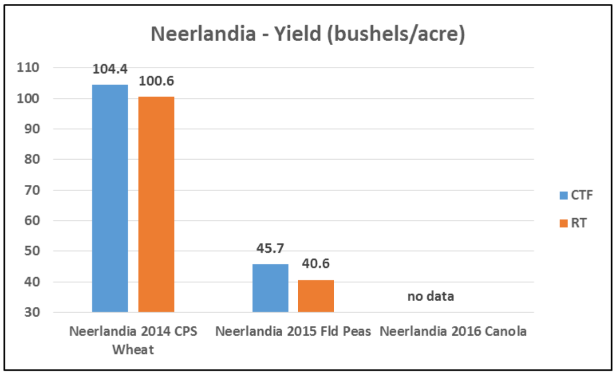


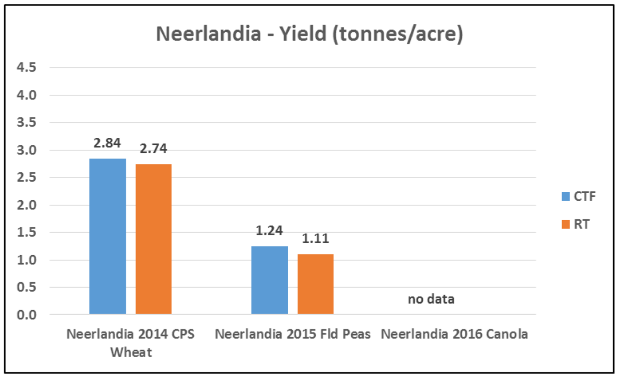
Appendix 2: Actual Yields – bu/ac and tonnes/ac

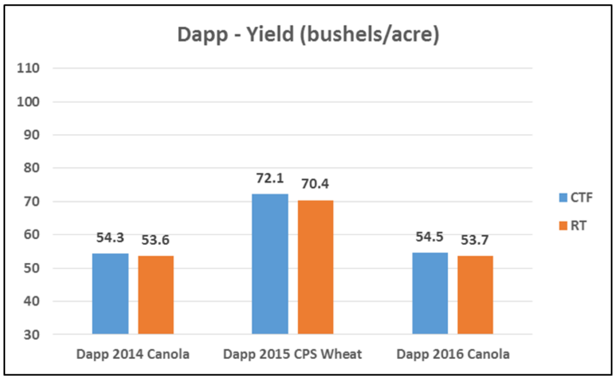
tonne = 2204.6 lbs

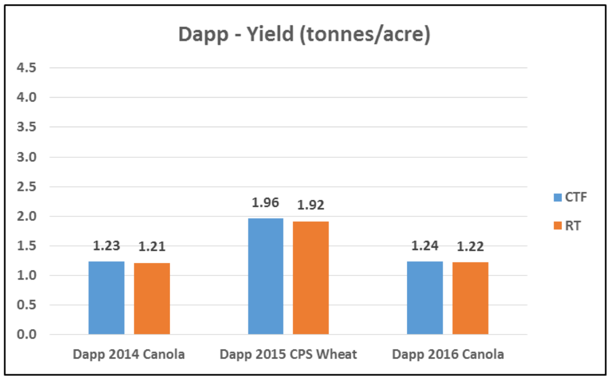


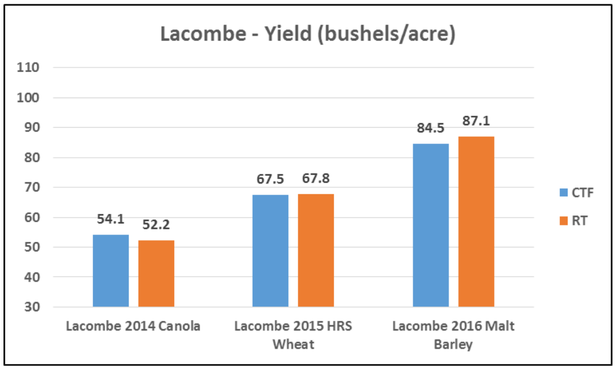


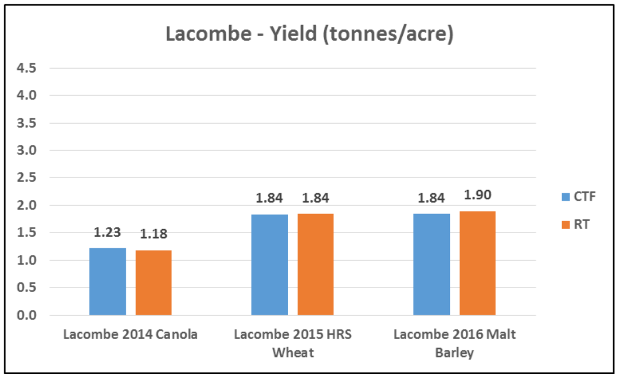


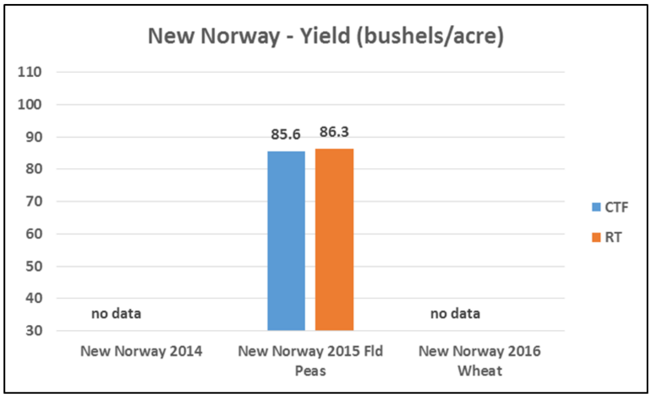




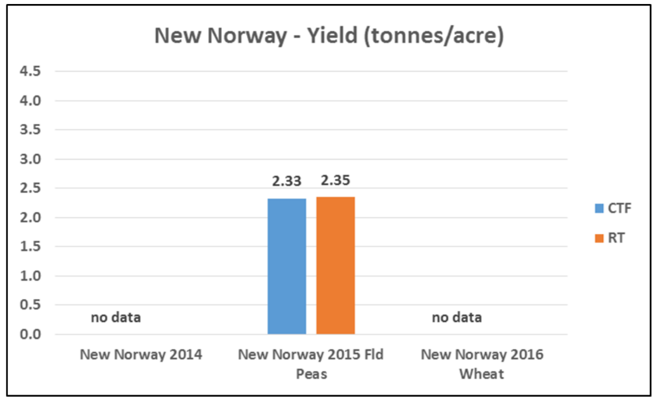




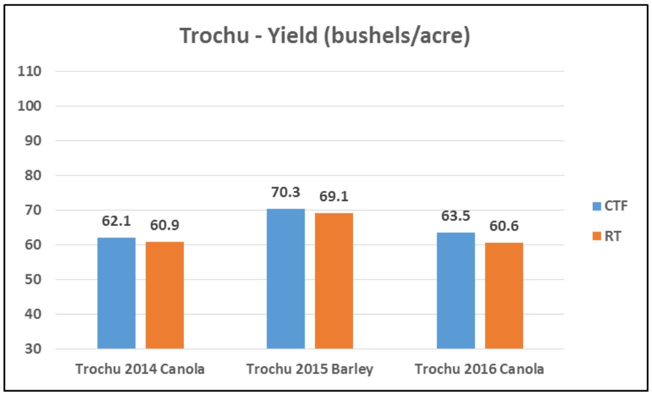




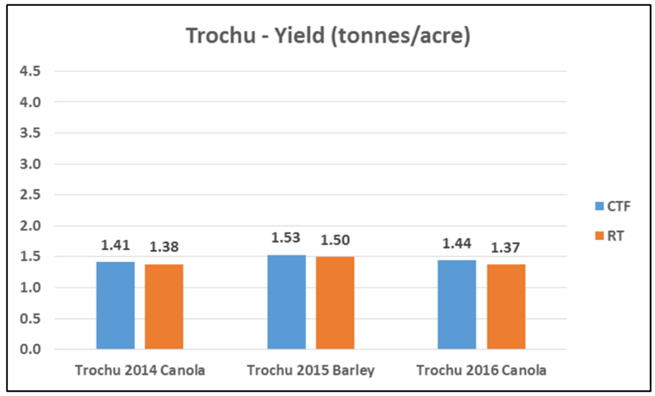
New Norway - Yield (bushels/acre)
110
100
90
80
70
60
50
40
30
85.6
86.3
no data
no data
New Norway 2014
New Norway 2015 Fld Peas
New Norway 2016 Wheat
CTF
RT



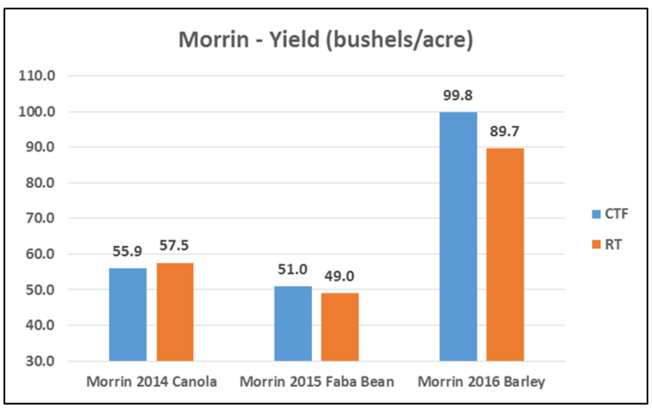
New Norway - Yield (tonnes/acre)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2.33
2.35
no data
no data
New Norway 2014
New Norway 2015 Fld Peas
New Norway 2016 Wheat
CTF
RT



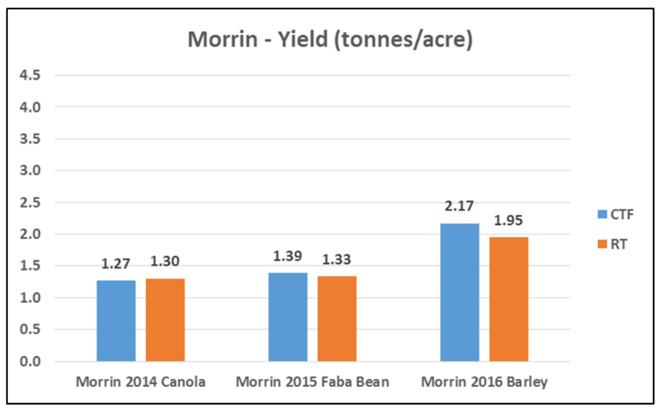
Trochu - Yield (bushels/acre)
110
100
90
80
70
60
50
40
30
62.1
60.9
70.3
69.1
63.5
60.6
Trochu 2014 Canola
Trochu 2015 Barley
Trochu 2016 Canola
CTF
RT



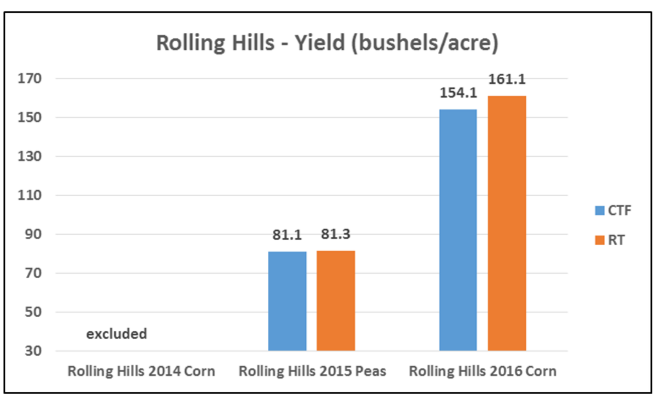
Trochu - Yield (tonnes/acre)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.41
1.38
1.53
1.50
1.44
1.37
Trochu 2014 Canola
Trochu 2015 Barley
Trochu 2016 Canola
CTF
RT



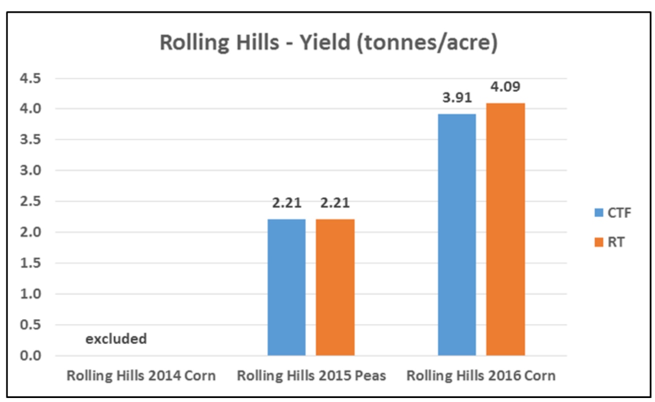
Morrin - Yield (bushels/acre)
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
55.9
57.5
51.0
49.0
99.8
89.7
Morrin 2014 Canola
Morrin 2015 Faba Bean
Morrin 2016 Barley
CTF
RT



Morrin - Yield (tonnes/acre)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1.27
1.30
1.39
1.33
2.17
1.95
Morrin 2014 Canola
Morrin 2015 Faba Bean
Morrin 2016 Barley
CTF
RT



Rolling Hills - Yield (bushels/acre)
170
150
130
110
90
70
50
30
excluded
81.1
81.3
154.1
161.1
Rolling Hills 2014 Corn
Rolling Hills 2015 Peas
Rolling Hills 2016 Corn
CTF
RT



Rolling Hills - Yield (tonnes/acre)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
excluded
2.21
2.21
3.91
4.09
Rolling Hills 2014 Corn
Rolling Hills 2015 Peas
Rolling Hills 2016 Corn
CTF
RT

Appendix 3: Actual Yields – Mg ha^{-1}