

Agriculture et Agroalimentaire Canada

Irrigated Crop Rotations: Soil Quality

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The Vauxhall Irrigated Rotation Study: 2000-11 Background & Objectives

- Expansion in acreages of potatoes, sugar beets, and beans in the late '90s in southern Alberta
- > New growers
- Squeeze on existing land base
- Wind erosion: irrigated land vs. dryland
- How do we ensure that increased production is sustainable?
- Devise crop sequences and tillage management systems for irrigated land that:
 - Optimize crop response
 - Minimize weed and disease problems
 - Reduce soil erosion, enhance soil quality and ensure long-term sustainability





Soil quality: why it's a big deal!



Need long term research to measure soil quality changes





W = wheat; P = potatoes; B = beans; SB = sugar beet; T = timothy, O = oats

Code	Length	Rotation	Management
1CONV	1 Yr	W	Continuous
and the second s	An and a second a second second		wheat
3CONV	3 Yr	P-B-W	Conventional
3CONS	3 Yr	P-B-W	Conservation
4conv 4cobs	4 Yr 4 Yr	SB-B-P-W SB-B-P-W	Conventional Conservation
5 cons	5 Yr	P.W-SB.W-B	Conservation
6 cons	-6 Xr	OR)-T-T-SB-B	-P Conservation

W = wheat; P = potatoes; B = beans; SB = sugar beet; T = timothy, O = oats

The Real Property lies

and the second second

Code	Length	Rotation	Management
1CONV	1 Yr	W	Continuous wheat
3CONV	3 Yr	P-B-W	Conventional
3CONS	3 Yr	P-B-W	Conservation
4CONV	4 Yr	SB-B-P-W	Conventional
4CONS	4 Yr	SB-B-P-W	Conservation
5cons	- 5 Yr -	P-W-SB-W-B	Conservation
B cons	6 Yr	ONT-T-SB-E	-P. Conservation

W = wheat; P = potatoes; B = beans; SB = sugar beet; T = timothy, O = oats

Code	Length	Rotation	Management
1CONV	1 Yr	W	Continuous
and the second second	In an all a second	and the second s	wheat
3CONV	3 Yr	P-B-W	Conventional
3CONS	3 Yr	P-B-W	Conservation
4CONV	4 Yr	SB-B-P-W	Conventional
4CONS	4 Yr	SB-B-P-W	Conservation
5CONS	5 Yr	P-W-SB-W-B	Conservation
No. A COMPANY			

W = wheat; P = potatoes; B = beans; SB = sugar beet; T = timothy, O = oats

Code	Length	Rotation	Management
1CONV	1 Yr	W	Continuous
and the second second	An and a second a second	more harring and he are	wheat
3CONV	3 Yr	P-B-W	Conventional
3CONS	3 Yr	P-B-W	Conservation
4CONV	4 Yr	SB-B-P-W	Conventional
4CONS	4 Yr	SB-B-P-W	Conservation
5CONS	5 Yr	P-W-SB-W-B	Conservation
6CONS	6 Yr	O(t)-T-T-SB-B-P	Conservation

W = wheat; P = potatoes; B = beans; SB = sugar beet; T = timothy, O = oats

26 Rotation Phase Treatments

(W-SB-B-P)cons

15

Each phase of each rotation appears each year

In first year, 2000, each red letter planted and sequences maintained thereafter

Phase	Rotation	Phase	Rotation
1	W	16	P-W-SB-W-B
2	(P-B-W)conv	17	P -W -SB-W-B
3	(P-B-W)conv	18	P-W- <mark>SB</mark> -W-B
4	(P-B-W)conv	19	P-W-SB- <mark>W</mark> -B
5	(P-B-W)cons	20	P-W-SB-W-B
6	(P-B-W)cons	21	O(t)-T-T-SB-B-P
7	(P-B-W)cons	22	O(t) -T -T-SB-B-P
8	(W-SB-B-P)conv	23	O(t)-T-T-SB-B-P
9	(W-SB-B-P)conv	24	O(t)-T-T- <mark>SB</mark> -B-P
10	(W-SB-B-P)conv	25	O(t)-T-T-SB -B -P
<u>11</u>	(W-SB-B-P)conv	26	O(t)-T-T-SB-B-P
12	(W-SB-B-P)cons		
13	(W- <mark>SB</mark> -B-P)cons	26 Phase	es x 4 Replicates = 104 plots
14	(W-SB-B-P)cons	P = potat	toes; B = beans; SB = sugar beet

W= wheat; T = timothy, O = oats

Outline of Conservation Practices used over 12 yr

- 1. Composted beef cattle manure as a substitute for inorganic fertilizer
- 2. Cover crops where possible
- 3. Beans: Narrow-row (20 cm) straight cut *vs*. wide-row (60 cm) undercut
- 4. Reduced tillage or direct seeding where possible



Soil quality measurements

- Carbon inputs from compost, crops
- Soil aggregates and organic matter fractions measured on wheat phase at the end of the 12 year study
- Soil samples taken in July 2011 for microbiological analyses on all wheat phases
- Soil samples taken fall 2011 on all plots for soil organic carbon (0-30 cm), nitrate-N (0-120 cm), available P (0-60 cm) on all plots
- Soil carbon change over time:
 - Based on 5 sampling points from 1999 (baseline), 2002, 2005, 2008 and 2011 (Years 0, 3, 6, 9 and 12 of study)





Rotation history: soil samples, fall 2011

Rotation	' 00	' 01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Р	В	W	Ρ	В	W
4-CONV	SB	В	Р	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Р	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W_{T}	W_{T}	SB	В	Ρ	O/T	Т	Т	SB	В	Ρ	0

Rotation history: 1-CONT – Continuous wheat

Rotation	' 00	'01	' 02	' 03	'04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Р	В	W	Р	В	W	Р	В	W
3-CONS	Р	В	W	Ρ	В	W	Ρ	В	W	Р	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Р	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W_{T}	W _T	SB	В	Ρ	O/T	Т	Т	SB	В	Ρ	0

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Р	В	w
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Р	В	w
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Ρ	O/T	т	т	SB	В	Ρ	0

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Р	В	W	Р	В	w
3-CONS	Ρ	В	W	Ρ	В	W	Р	В	W	Р	В	w
4-CONV	SB	В	Ρ	W	SB	В	Р	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	В	Ρ	O/T	т	Т	SB	В	Ρ	0

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Р	В	W	Р	В	W	Р	В	w
3-CONS	Ρ	В	W	Р	В	W	Р	В	W	Р	В	w
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Ρ	O/T	т	т	SB	В	Ρ	0

Rotation	'00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Р	В	W	Р	В	W	Р	В	w
3-CONS	Р	В	W	Р	В	W	Р	В	W	Р	В	w
4-CONV	SB	В	Р	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	В	Ρ	O/T	т	т	SB	В	Ρ	0

Rotation history: 3-CONS — compost @ 28 t/ha

No P fertilizer/N fertilizer cut to 33% on following potato crop

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Р	В	W	Ρ	В	W	Р	В	W
3-CONS	Р	В	W	Р	В	W	Ρ	В	W	Р	В	W
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W_{T}	W_{T}	SB	В	Ρ	O/T	Т	т	SB	В	Ρ	0

Rotation history: 3-CONS — fall rye cover crop

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Р	В	W	Р	В	W
3-CONS	Р	В	W	Р	В	W	Р	В	W	Р	В	w
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W_{T}	W _T	SB	В	Ρ	O/T	т	Т	SB	В	Ρ	0

Rotation history: 3-CONS — narrow row beans

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Р	В	W	Р	В	W
3-CONS	Р	B <u>Narrow</u>	W	Р	B <u>Narrow</u>	W	Р	B <u>Narrow</u>	W	Р	В	w
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Ρ	O/T	Т	Т	SB	В	Ρ	0

Rotation history: 3-CONS — no-till beans and reduced till wheat

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	'09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Р	B	\times	Р	B	\times	Р	B	\times	Р	×	X
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Ρ	O/T	т	т	SB	В	Ρ	0

Rotation	' 00	'01	'02	' 03	'04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	w
4-CONV 4-CONS	SB SB	B B	P P	w w	SB SB	B B	P P	w w	SB SB	B	P P	w w
4-CONV 4-CONS 5-CONS	SB SB P	B B W	P P SB	w w w	SB SB B	B B P	P P W	W W SB	SB SB W	B B	Р Р	w w w

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Р	W	SB	В	Р	W
4-CONV 4-CONS	SB SB	B B	P P	w w	SB SB	B	P P	w w	SB SB	B	P P	w w
4-CONV4-CONS5-CONS	SB SB P	B B W	P P SB	w w w	SB SB B	В В Р	P P W	W W SB	SB SB W	B B	Р Р	w w w

Rotation	' 00	'01	'02	' 03	'04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
-												
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONV 4-CONS	SB SB	B	P P	w w	SB SB	B	P P	w w	SB SB	B B	P P	w w
4-CONV4-CONS5-CONS	SB SB P	B B W	P P SB	w w w	SB SB B	В В Р	P P W	W W SB	SB SB W	B B	Р Р	w w w

Rotation history: 4-CONS — compost @ 42 t/ha

No P fertilizer/N fertilizer cut to 33% on following potato crop

Rotation	' 00	'01	'02	' 03	'04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONV 4-CONS	SB SB	B	P P	w w	SB SB	B	P P	w w	SB SB	B	P P	w w
4-CONV4-CONS5-CONS	SB SB P	B B W	P P SB	w w w	SB SB B	В В Р	P P W	W W SB	SB SB W	B B	Р Р	w w w

Rotation history: 4-CONS — fall rye cover crop

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONV 4-CONS	SB SB	B	P P	w w	SB SB	B B	P P	W W	SB SB	B	P P	w w
4-CONV4-CONS5-CONS	SB SB P	B B W	P P SB	w w w	SB SB B	В В Р	P P W	W W SB	SB SB W	B B	Р Р	w w w

Rotation history: 4-CONS — narrow row beans

Rotation	' 00	'01	'02	' 03	'04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
4-CONV 4-CONS	SB SB	B B Narrow	P P	w w	SB SB	B B Narrow	P P	w w	SB SB	B B Narrow	P P	w w
4-CONV4-CONS5-CONS	SB SB P	B B Narrow	P P SB	w w w	SB SB B	B B Narrow P	P P W	W W SB	SB SB W	B B Narrow B	Р Р	w w w

Rotation history: 4-CONS — no-till beans and reduced till wheat

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Р	В	W	Ρ	В	W	Р	В	W
3-CONS	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONV 4-CONS	SB SB	B	P P	× ×	SB SB	B	P P	×	SB SB	B	P P	≥ ≥
4-CONV4-CONS5-CONS	SB SB P	B B B B B B B C C C C C C C C C C C C C	P P SB	*	SB В	B B P	P P W	W SB	SB SB W	B B	Р Р	≥ ≥

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Р	W	SB	В	Р	W
5-CONS	Ρ	W	SB	W	В	Ρ	w	SB	W	В	Р	W
6-CONS	W_{T}	W _T	SB	В	Ρ	O/T	т	Т	SB	В	Р	0

Rotation	' 00	'01	'02	' 03	'04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W_{T}	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Р	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Rotation history: 5-CONS — compost @ 28 or 42 t/ha

No P fertilizer/N fertilizer cut to 33% on following potato crop

Rotation	' 00	'01	' 02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Ρ	W	SB	W	В	Ρ	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Rotation history: 5-CONS — fall rye cover crop

Rotation	'00	'01	'02	' 03	'04	' 05	' 06	'07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Р	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Р	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Р	W	SB	W	В	Р	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Rotation history: 5-CONS — narrow row beans

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Р	W	SB	W	B <u>Narrow</u>	Р	W	SB	W	B <u>Narrow</u>	Ρ	W
6-CONS	W _T	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Rotation history: 5-CONS — no-till beans and reduced-till wheat

Rotation	' 00	'01	' 02	' 03	' 04	' 05	' 06	' 07	' 08	'09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Р	\times	SB	\times	B	Р	\times	SB	X	B	Р	\times
6-CONS	W ₁	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Р	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Р	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Ρ	W	SB	W	В	Р	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	В	Ρ	0/т	Т	т	SB	В	Р	0
Rotation history: 6-CONS: 2 cycles over 12 yr

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	'09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Р	В	W	Ρ	В	W	Р	В	W
4-CONV	SB	В	Ρ	W	SB	В	Р	W	SB	В	Ρ	W
4-CONS	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
5-CONS	Ρ	W	SB	W	В	Р	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	В	Ρ	0/т	Т	Т	SB	В	Ρ	0

Rotation history: 6-CONS — compost @ 42 t/ha

No P fertilizer/N fertilizer cut to 33% on following potato crop

Rotation	' 00	'01	' 02	' 03	' 04	' 05	'0 6	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Р	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Ρ	В	W	Р	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Р	W
4-CONS	SB	В	Р	W	SB	В	Ρ	W	SB	В	Р	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	В	Ρ	0/т	Т	т	SB	В	Р	0

Rotation history: 6-CONS — fall rye cover crop

Rotation	' 00	'01	' 02	' 03	' 04	' 05	' 06	' 07	' 08	'09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Р	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Р	В	W	Р	В	W	Р	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Р	W	SB	В	Ρ	W	SB	В	Ρ	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	W _T	SB	В	Р	0/т	Т	т	SB	В	Р	0

Rotation history: 6-CONS — narrow row beans

Rotation	' 00	'01	' 02	' 03	'04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Ρ	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Р	В	W	Ρ	В	W	Р	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Р	W	SB	В	Ρ	W
4-CONS	SB	В	Р	W	SB	В	Р	W	SB	В	Ρ	W
5-CONS	Р	W	SB	W	В	Р	W	SB	W	В	Р	W
6-CONS	W _T	W _T	SB	B <u>Narrow</u>	Р	0/т	Т	т	SB	B <u>Narrow</u>	Р	0

Rotation history: 6-CONS — no-till beans and reduced till wheat/oats/timothy

Rotation	' 00	'01	' 02	' 03	'04	' 05	'0 6	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Р	В	W	Ρ	В	W
3-CONS	Ρ	В	W	Ρ	В	W	Р	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Р	W	SB	В	Ρ	W
4-CONS	SB	В	Ρ	W	SB	В	Р	W	SB	В	Ρ	W
5-CONS	Р	W	SB	W	В	Ρ	W	SB	W	В	Ρ	W
6-CONS	W _T	WT	SB	Marrow	Р	0/1	Т	т	SB	Marrow	Ρ	0

Results



Soil quality measurements

- Carbon inputs from compost, crops
- Soil aggregates and organic matter fractions measured on wheat phase at the end of the 12 year study
- Soil samples taken in July 2011 for microbiological analyses on all wheat phases
- Soil samples taken fall 2011 on all plots for soil organic matter (0-30 cm), nitrate-N (0-120 cm), available P (0-60 cm) on all plots
- Soil carbon change over time:
 - Based on 5 sampling points from 1999 (baseline), 2002, 2005, 2008 and 2011 (Years 0, 3, 6, 9 and 12 of study)





Soil organic carbon

- The main driver of soil quality
- Soil organic carbon influences many soil characteristics including colour, nutrient holding capacity (cation and anion exchange capacity), nutrient turnover and stability, which in turn influence water relations, aeration and workability

Carbon input from compost, 2000-11





Carbon input from crops, 2000-11



Ertra-

Crop carbon input to soil in each year was calculated from annual yield or biomass using relative carbon allocation coefficients (Bolinder et al., 2007).

Carbon input from crops + compost, 2000-11



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After 12 years...

 In September 2011, wheat phases [except the 2nd one of 5CONS, P-W-SB-W-B], as well as the oat phase from the 6 yr rotation (6CONS) were sampled (0-7.5cm) to explore rotation and management practices effects on soil aggregates and organic matter



Particulate organic matter (> 0.053 mm) [0-7.5 cm depth]

Biologically and chemically active. Part of the labile (easily decomposable) pool of soil organic matter.



Fine organic matter (<0.053 mm) [0-7.5 cm depth]

Larger pool of older organic matter



Total organic C (0-7.5 cm depth)



Percent Particulate Organic C in Total Organic C

Higher values denote additions of 'younger' organic matter



Alkaline phosphatase activity

Nutrirent cycling: Makes organic P plant-available



Percent water stable aggregates (> 1mm diam.)

Aggregate stability associated with resistance to wind and water erosion



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Soil microbiological properties



Rotation history: 5 yr rotation had a 2nd wheat phase: 5-CONS2 (P-W-SB-W-B)

Rotation	' 00	'01	'02	' 03	' 04	' 05	' 06	' 07	' 08	' 09	'10	'11
1-CONT	W	W	W	W	W	W	W	W	W	W	W	W
3-CONV	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
3-CONS	Р	В	W	Ρ	В	W	Ρ	В	W	Ρ	В	W
4-CONV	SB	В	Ρ	W	SB	В	Ρ	W	SB	В	Ρ	W
4-CONS	SB	В	Р	W	SB	В	Р	W	SB	В	Р	W
5-CONS1	Ρ	×	SB	W	B Narrow	Ρ	×	SB	W	Marrow	Ρ	W
5-CONS2	SB	W	B	Р	W	SB	W	B <u>Narrow</u>	Р	W	SB	W
6-CONS	W _T	W _T	SB	В	Р	O/T	Т	Т	SB	В	Р	0

Microbial biomass carbon

A measure of the size of the living component of soil organic matter. The microbial biomass decomposes plant and animal residues and soil organic matter to release CO₂ and plant available nutrients



Shannon diversity index

A measure of microbial species diversity



β-glucosidase activity

An enzyme that breaks carbon compounds into glucose providing energy for microorganisms. Sensitive to soil management and a soil quality indicator that provides an early indication of changes in organic matter status and turnover



Gram positive bacteria*

Gram positive bacteria are larger in size, have a thicker cell wall, a negative charge on the outer surface, and tend to resist water stress



Gram negative bacteria*

Gram negative bacteria are smaller in size, have a thinner cell wall, and are sensitive to water stress



Total bacteria (Gram positive & negative)*

The decomposers! Convert energy in soil organic matter into forms useful to the rest of the organisms in the soil food web. Perform important services related to water dynamics, nutrient cycling, and disease suppression



Actinomycetes*

A large group of bacteria that grow hyphae like fungi and are similar to fungi in their function. Actinomycetes decompose many substances especially hard to decompose compounds, such as chitin, lignin and keratin



Total fungi*

Fungal hyphae physically bind soil particles together, creating stable aggregates that help increase water infiltration and soil water holding capacity. Mycorrhizal fungi link root cells to soil particles



Fungi:bacteria ratio*

Larger microaggregates have a higher fungi:bacteria ratio as fungi promote aggregate formation



Total phospholipid fatty acid (PLFA) biomass*

Total bacteria + Actinomycetes + Total fungi



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26 Rotation Phase Treatments

(W-SB-B-P)cons

15

Each phase of each rotation appears each year

In first year, 2000, each red letter planted and sequences maintained thereafter

Phase	Rotation	Phase	Rotation
1	W	16	P-W-SB-W-B
2	(P-B-W)conv	17	P -W -SB-W-B
3	(P- B -W)conv	18	P-W- <mark>SB</mark> -W-B
4	(P-B- <mark>W</mark>)conv	19	P-W-SB- <mark>W</mark> -B
5	(P-B-W)cons	20	P-W-SB-W-B
6	(P-B-W)cons	21	O(t)-T-T-SB-B-P
7	(P-B-W)cons	22	O(t) -T -T-SB-B-P
8	(W-SB-B-P)conv	23	O(t)-T-T-SB-B-P
9	(W-SB-B-P)conv	24	O(t)-T-T- <mark>SB</mark> -B-P
10	(W-SB- <mark>B</mark> -P)conv	25	O(t)-T-T-SB -B -P
<u>11</u>	(W-SB-B-P)conv	26	O(t)-T-T-SB-B-P
12	(W-SB-B-P)cons		
13	(W- <mark>SB</mark> -B-P)cons	26 Phase	es x 4 Replicates = 104 plots
14	(W-SB-B-P)cons	P = potat	toes; B = beans; SB = sugar beet

W= wheat; T = timothy, O = oats

Soil organic carbon, 0-30 cm, fall 2011



Soil organic carbon, 0-30 cm, fall 2011


Soil organic carbon, 0-30 cm, fall 2011



Nitrate-N (0-120 cm depth), fall 2011 Effect of Rotation



Available P (0-60 cm depth), fall 2011 Effect of Rotation



Nitrate-N (0-120 cm depth), fall 2011 Effect of crop grown in 2011



Available P (0-60 cm depth), fall 2011 Effect of crop grown in 2011



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Change in soil organic carbon, 2000-11 1CONV: Continous wheat



Change in soil organic carbon, 2000-11 1CONV, 3CONV (P-B-W)



Change in soil organic carbon, 2000-11 1CONV, 3CONV (P-B-W), 3CONS (P-B-W)



Change in soil organic carbon, 2000-11 1CONV, 4CONV (SB-B-P-W)



Change in soil organic carbon, 2000-11 1CONV, 4CONV (SB-B-P-W), 4CONS (SB-B-P-W)



Change in soil organic carbon, 2000-11 1CONV, 5CONS (P-W-SB-W-B)



Change in soil organic carbon, 2000-11 1CONV, 5CONS (P-W-SB-W-B), 6CONS (O(t)-T-T-SB-B-P)



Take home messages

- Irrigated rotations without any kind of "soil building" management run the risk of decreased soil quality especially the 4CONV (SB-B-P-W)
- The vast majority of soil quality indicators responded to soil conservation practices
- Consider replenishing soil organic matter with composted manure if you can
- While all CONS rotations improved soil quality, the 5CONS rotation (P-W-SB-W-B) often had the highest level of soil quality based on numerous indicators
- Need long-term experiments to be able to measure changes
 in soil quality due to soil management practices

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