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Effects of precision farming, N rate and temporal trends on wheat yield and productivity

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Study Issue

- Land management, cropping systems, and nutrient management significantly affect nutrient use efficiency and profitability.
- Over use of fertilizer cause significant environmental and economic impacts.
- With the significant attention to precision agriculture in recent time, more research is needed to assess the effectiveness of this technology

Importance of precision agriculture

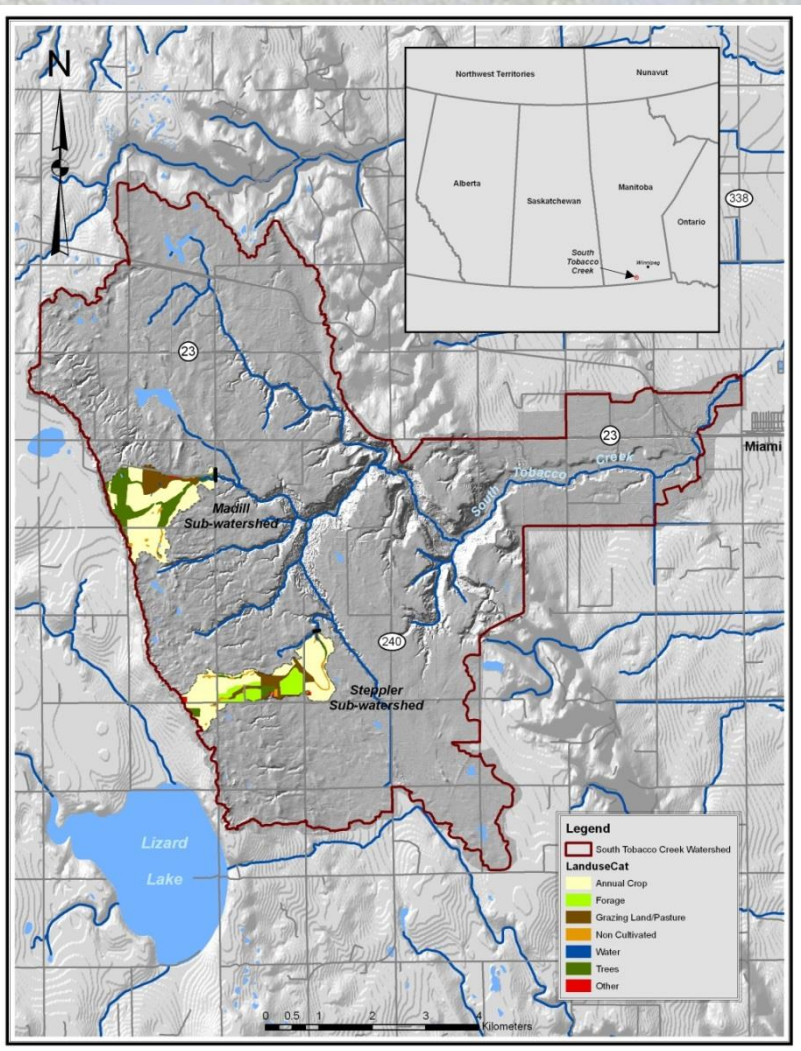
- **Research Question:** Can variable rate N management be used to improve efficiency of fertilizer use and farm economy?

Objective

- Evaluate the economic and environmental viability of precision agriculture to improve N use efficiency and profitability at the farm and watershed scale.

Study Area

- South Tobacco Creek (STC) Watershed
- 150 km^2 SW of Winnipeg, Manitoba, Canada

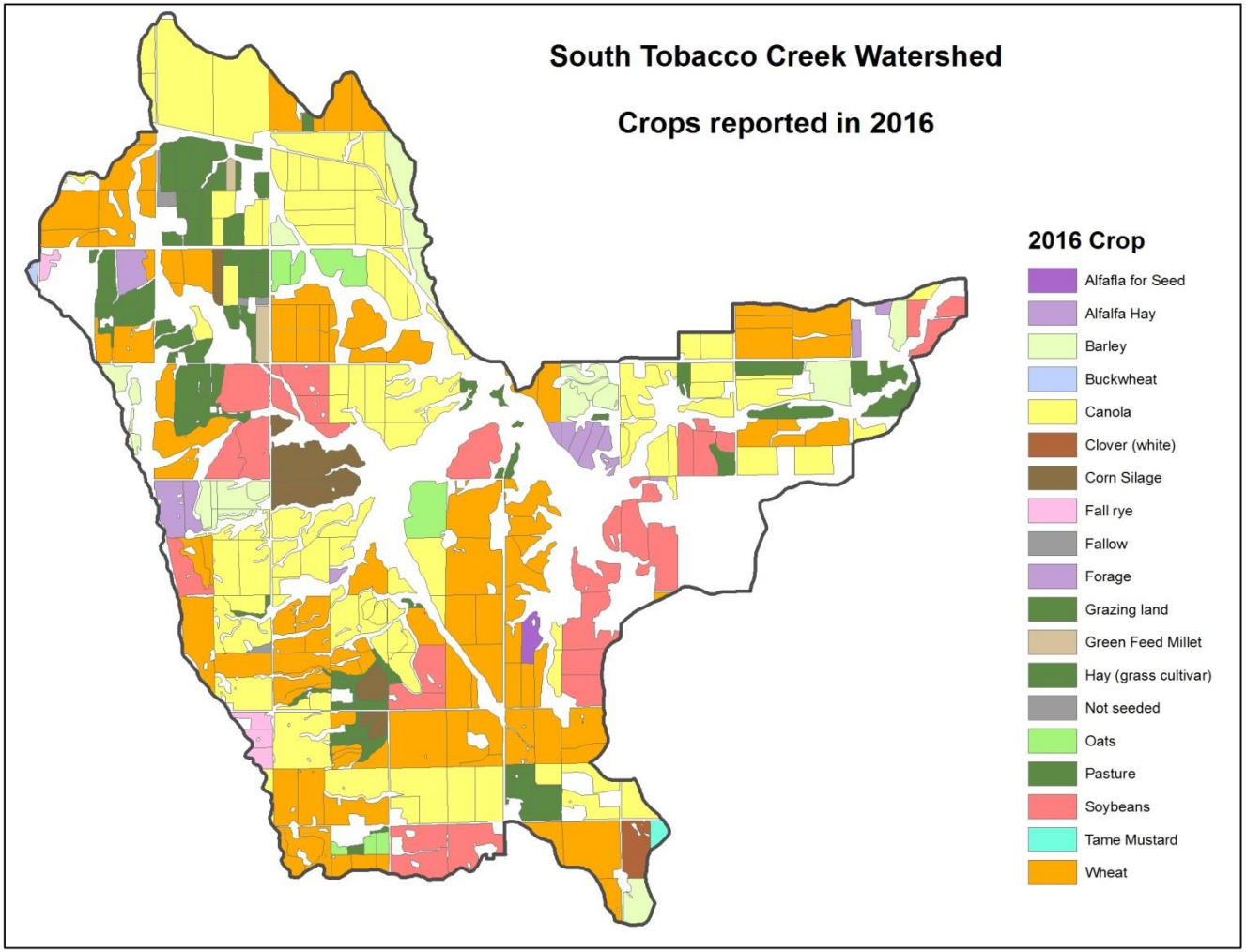


Study Area – Crop Management

Spatial distribution of crops in 2016

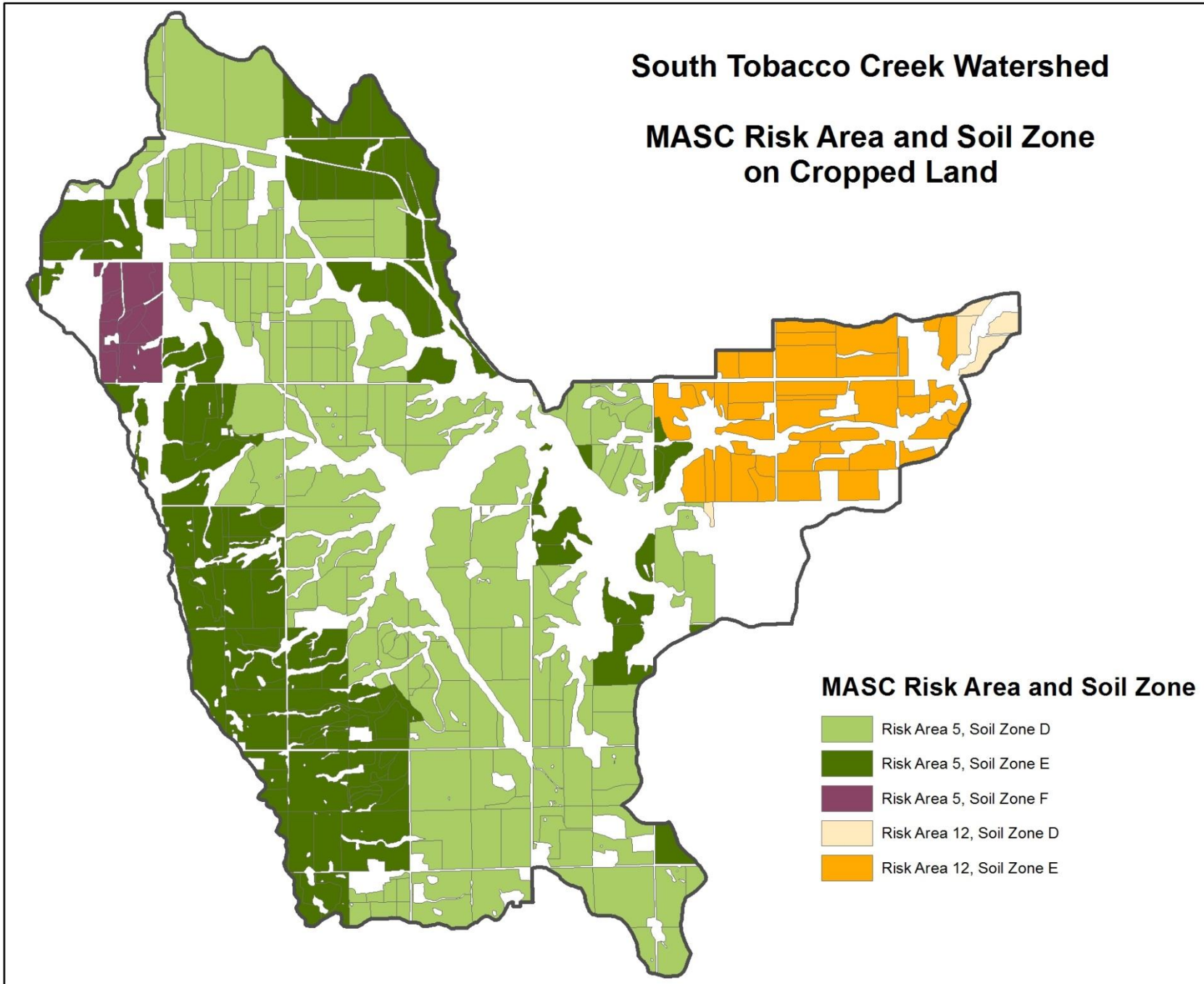
Wheat and canola are common crops in STC

About 35 farms and 350 fields



Methodology

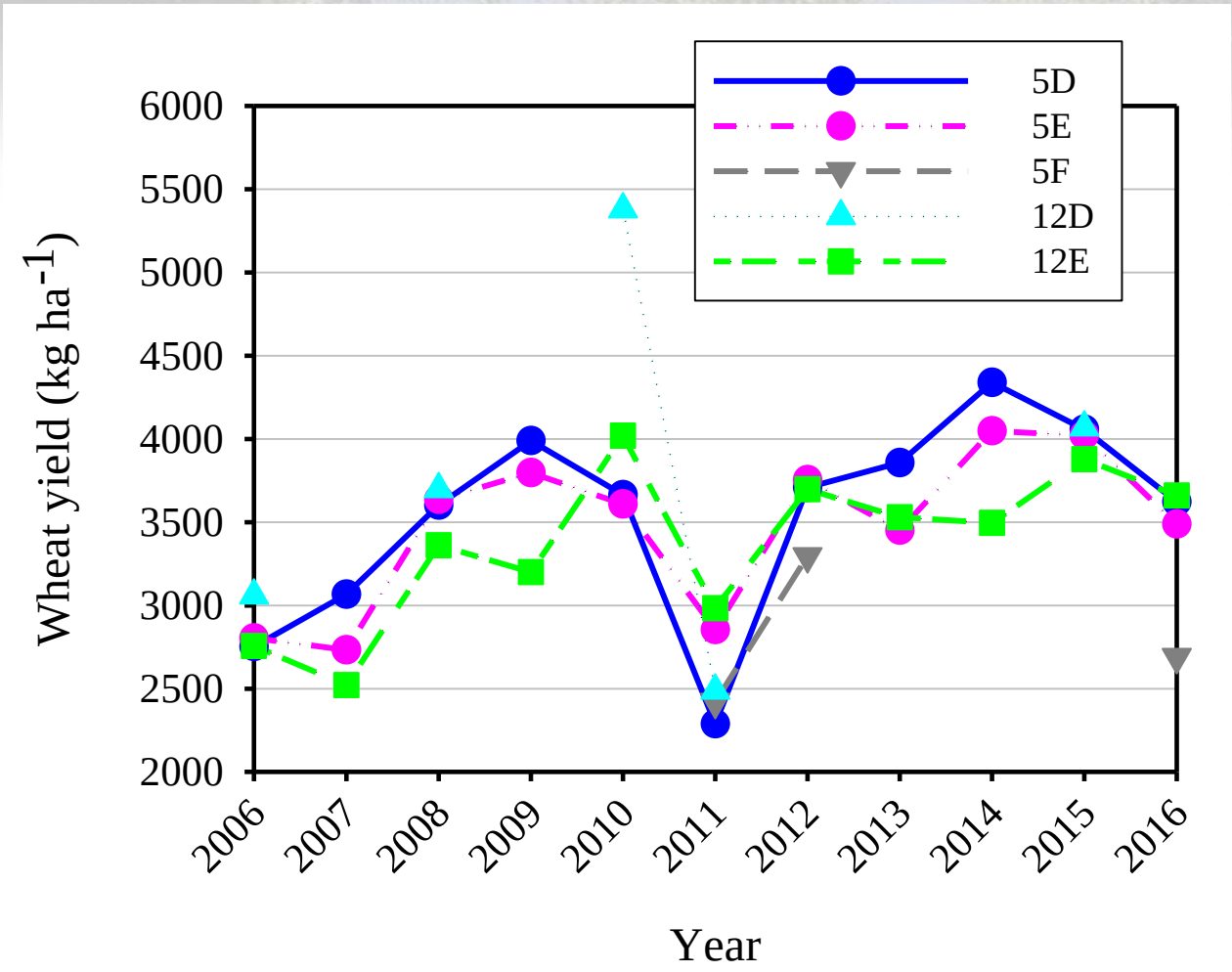
- Agronomic, yield and soil data were compiled by field for the STC from 2006-2016.
- These data and **productivity Index (MASC)** based on a 10-year moving average were used to delineate management zones in the watershed.
- GIS and Limdep (NLOGIT 4.0) Econometric Software was used to analyze the data because Limdep is more suited for the STC panel data analysis.


South Tobacco Creek Watershed
MASC Risk Area and Soil Zone
on Cropped Land
MASC Risk Area and Soil Zone
Risk Area 5, Soil Zone D
Risk Area 5, Soil Zone E
Risk Area 5, Soil Zone F
Risk Area 12, Soil Zone D
Risk Area 12, Soil Zone E

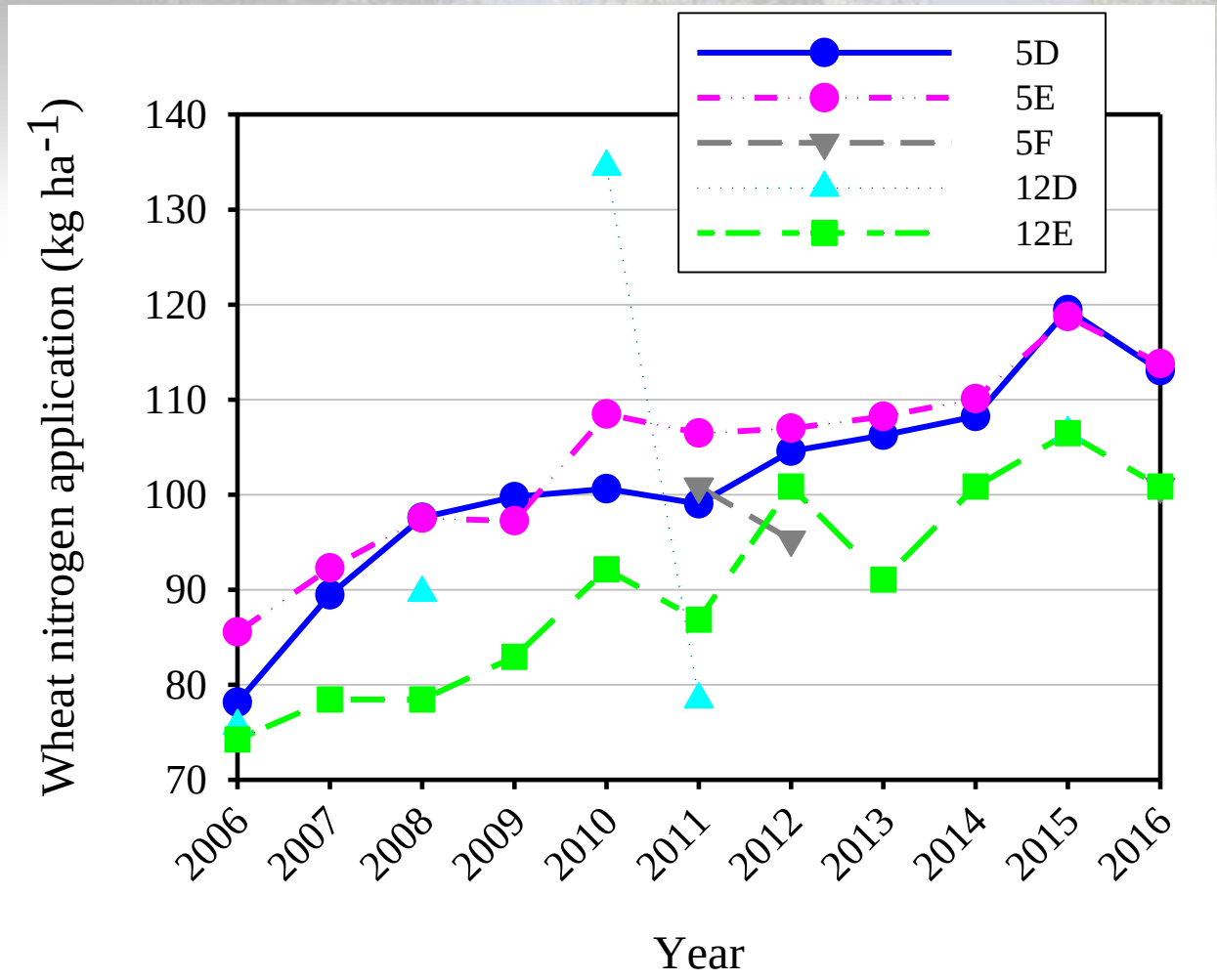
Methodology

- A yield function and net revenue were estimated taking into account zones, temporal trends, and individual management practices.
- Zone (spatial), time (temporal), and other conservation management effects (X_i):
- $Yield = a+bN+cN^2+\beta_i X_i+\lambda*Zone + \theta*Time$
- Quadratic and linear was tested to find the fit

Average yield per zone for wheat



Average N per zone for wheat



Effects of input variables, zones, and years on wheat yield

			Estimated fixed effects			Estimated fixed effects		
Variables	**Coefficient**	**t-ratio**	**Zone**	**Coefficient**	**t-ratio**	**Period**	**Coefficient**	**t-ratio**
N	22.73	3.85	5D	36.05	2.08	2006	-415.64	-5.94
N2	-0.04	-1.77	5E	-56.75	-2.28	2007	-519.25	-5.73
P	2.98	1.54	5F	-607.40	-2.97	2008	154.04	2.57
K	0.72	0.45	12D	215.08	0.97	2009	393.39	5.67
S	0.50	0.20	12E	52.54	0.87	2010	110.07	2.23
Res Cov	328.18	2.09				2011	-995.29	-16.17
Constant	1486.52	4.21				2012	126.94	2.45
						2013	76.02	1.06
						2014	512.02	10.34
						2015	280.57	4.34
						2016	-148.68	-2.86

- ~~Zone (spatial) and time~~ (temporal) effects:

$$\text{Yield} = a + bN + cN^2 + \beta_i X_i + \lambda * \text{Zone} + \theta * \text{Time}$$

- Quadratic and linear was tested to find the fit

Quadratic response of wheat yield to applied N rate in STC

Risk zone	Farm ID	# of land	STC	MASC	N	Simulation model: yield=a+bN+cN^2			
			---------	Kg ha^{-1} ---------		a	b	c	Optimum N
5D	24	15	3049	3578	101	-7573	164	-0.57	144
						(0.148)	(0.146)	(0.323)	
	41	71	3279	3578	107	-257	53	-0.182	145
						(0.846)	(0.065)	(0.224)	
	47	42	3213	3578	89	-3109	111	-0.419	132
						(0.173)	(0.022)	(0.073)	
	101	46	3681	3578	103	-10202	237	-0.984	121
						(0.012)	(0.002)	(0.007)	
	All farms	470	3579	3578	103	-2923	107	-0.415	129
						(0.002)	(<0.001)	(<0.001)	
5E	47	14	3426	3540	84	-9581	278	-1.42	98
						(0.001)	(<0.001)	(<0.001)	
	49	69	3529	3540	102	-2763	102	-0.393	130
						(0.429)	(0.144)	(0.254)	
	62	26	3298	3540	100	-4058	122	-0.461	132
						(0.019)	(<0.001)	(0.001)	
	All farms	318	3540	3540	105	-2254	93	-0.352	132
						(0.007)	(<0.001)	(<0.001)	

Note: P value for each parameter of the model is listed in the parenthesis and optimum N is calculated based on the model.

Effects of input variables, management, and years on wheat yield in Soil Zone 5D

			Estimated fixed effects			Estimated fixed effects		
Variables	**Coefficient**	**t-ratio**	**Farmers**	**Coefficient**	**t-ratio**	**Period**	**Coefficient**	**t-ratio**
N	54.74	3.24	1	-578.33	-4.52	2006	-281.77	-2.66
N2	-0.19	-2.32	2	-66.01	-0.69	2007	-420.91	-3.37
K	5.93	2.19	3	-529.30	-3.43	2008	72.79	1.02
Constant	-66.50	-0.08	4	699.35	9.14	2009	314.40	3.58
			5	-331.12	-6.18	2010	63.10	0.90
			6	-14.93	-0.18	2011	-1190.65	-16.32
			7	-78.85	-1.21	2012	60.40	0.93
			8	4.97	0.08	2013	192.24	1.80
			9	-4.29	-0.06	2014	733.26	11.12
			10	882.33	8.83	2015	284.78	2.93
						2016	-95.20	-1.38

Results

- There were generally no productivity differences between zones when analysis was done over years but when period was assumed as fixed effect there were differences between zones.
- Both spatial (zone) and temporal (time) variability had effects on crop productivity, but temporal trends had the greater effect.
- Also, conservation tillage had positive effects on crop yield and economics.

Economic results

- More productive land showed higher yield and nearly \$40 ha^{-1} more net revenue than less productive land within the STC with the same N rate applied.
- However, the probability of crop loss occurrence due to extreme temporal variability was 36% for the past 11 years for wheat, and average crop loss when it occurred was about 15%.
- Excessive moisture (i.e., 2011) or drought (i.e., 2006) in the past 11 years have caused, on average, about 6% per ha per year yield loss for wheat.
- The average net loss was about \$44 ha^{-1} yr^{-1} for wheat and \$60 ha^{-1} yr^{-1} for a wheat-canola cropping system.
- The effect of temporal trends highlights the importance of other management practices like “tile drainage” in Manitoba.

Acknowledgements

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