Effect of Agricultural Practices on Nitrate Leaching and Nitrogen Fertilizer Recovery in a Semi-arid Region

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Introduction

- In the Judith River Watershed (JRW) of Central Montana (northern Great Plains), groundwater nitrate contamination has become a major concern for agricultural producers and watershed stakeholders.
- High nitrate levels have been recorded in the JRW since the 1960s (MBMG 2013). Nitrate-N concentrations in the only long term monitoring well in JRW are above 10 mg L^{-1} and doubled from 1994 to 2010 (Schmidt and Mulder 2010).
- Small grain fields may be a major contributor to the contamination, because they are largely located on gravelly soils over shallow aquifers.

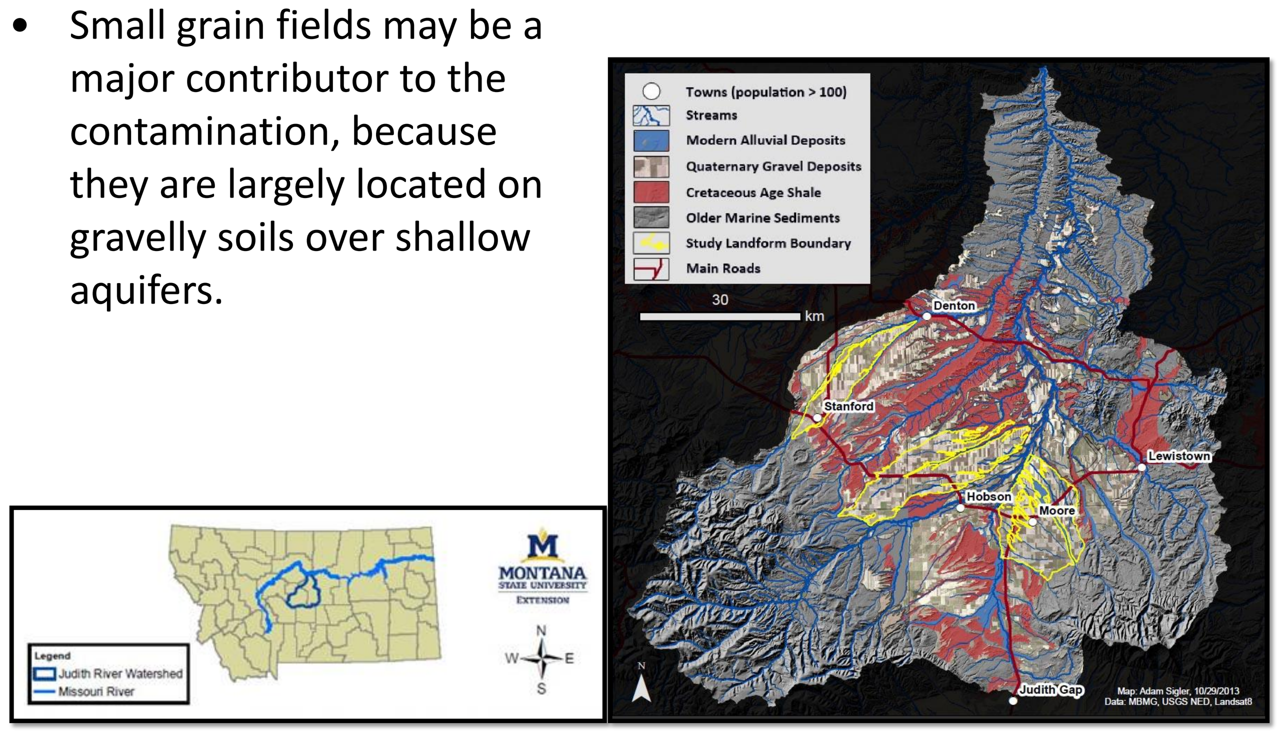

Figure 1. Map on left (Sigler 2012) shows location of JRW in Montana and map on right shows study landforms in the JRW.

Research Objective

- Evaluate the effectiveness of proposed alternative management practices (AMPS) on yield, protein, leaching and available nitrogen recovery (ANR).

Methods

Field Characterization:

- Fields A (near Stanford), B and C (near Moore) are located on three major landforms in the watershed (Figure 1).
- Pre-treatment soil parameters were generally not different (P<0.05) across treatment boundaries (Table 1), allowing observation of treatment effects.
- Annual precipitation is 36-cm (10-yr average). Highest precipitation amounts are in the spring, and 2013 was much wetter than 2012 (Figure 2).
- Fields were chosen that have shallow gravel contacts in soil, only one soil series or complex, and were fallow in the first year of the study (2012).

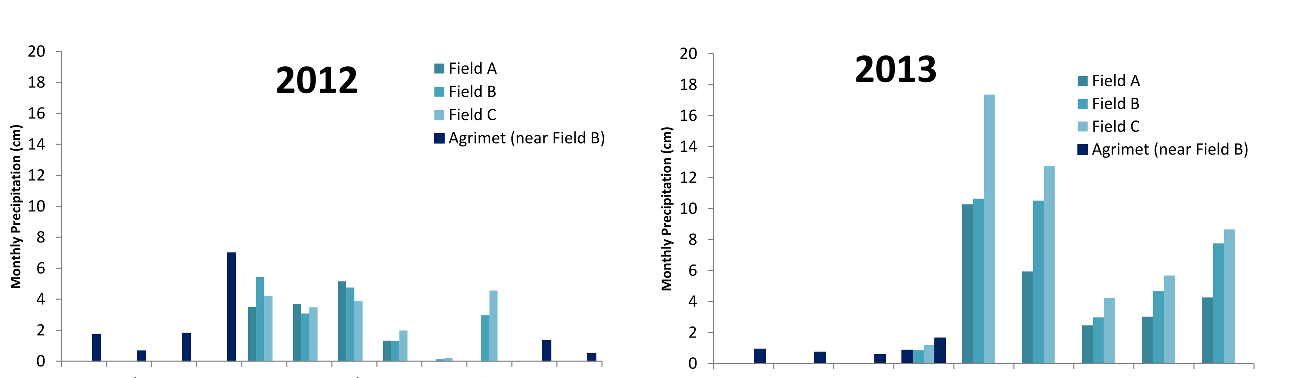

Figure 2. Cumulative monthly precipitation for 2012 & 2013 at or near treatment fields. Wet spring in 2013 is observed on all fields.

Methods

Experimental Design:

- Three AMPs were selected with help from two local research advisory groups, and tested on three local producers' fields by the producer using field scale equipment.
- AMPs: Controlled release urea (CRU; ESN®, Agrium), split application (early spring & late spring), or N-fixing crop (peas).
- Grower standard practice (GSP): fallow-winter wheat-barley, spring broadcast urea
- Comparisons: grain yield, quality, fertilizer N recovery and leaching across eight boundaries (Figure 3); focusing here on initial results for six 2013 winter wheat boundaries.

Table 1: Selected pre-treatment soil parameter comparisons.

Soil Parameters	A1E	A2W		A3E	A4W		A4E[15]	A5W[15]		B1E[15]	B2W[15]		C1E	C2W		C2E	C3W	
Nitrate-N (kg N ha^{-1} fines)	49.9	53.5	NS	28.5	34.1	NS	13.1	12.8	NS	16.0	15.7	NS	36.2	48.1	NS	47.0	54.8	NS
TN (g kg^{-1}fines)	1.48	1.40	NS	1.33	1.30	NS	1.38	1.49	NS	1.93	1.87	NS	1.56	1.61	NS	1.61	1.64	NS
SOC (g kg^{-1}fines)	17.6	17.2	NS	16.7	17.3	NS	21.3	22.1	NS	25.2	24.9	NS	20.6	21.9	*	21.2	22.7	NS
Clay (g kg^{-1}fines)	326	320	NS	328	324	NS	332	338	NS	328	330	NS	324	330	NS	310	306	NS
Coarse Fraction (g kg^{-1} soils)	131	81	NS	131	131	NS	107	109	NS	139	78	*	61	42	NS	37	34	NS
Depth to Rock (cm)	56.5	53.2	NS	49.3	47.0	NS	49.2	46.1	NS	29.1	38.1	NS	45.4	55.9	NS	56.9	46.5	NS

NS - boundaries where specific soil parameters (top 15 cm unless stated) were not significantly different between sides. (*) describes boundaries where a specific soil parameter was significantly different (P < 0.05). Nitrate-N is the total nitrate above depth to rock. (15) describes a boundary where only the top 15 cm was used for the nitrate-N (kg ha-1). Data from the other boundaries are from cores that came in contact with rock or gravel. Methods: TN by combustion, SOC by Walkley-Black, clay by 2 hour hydrometer, and nitrate-N extracted with 1 M KCl/analyzed using cadmium flow injection. All paired t-test were run in R.

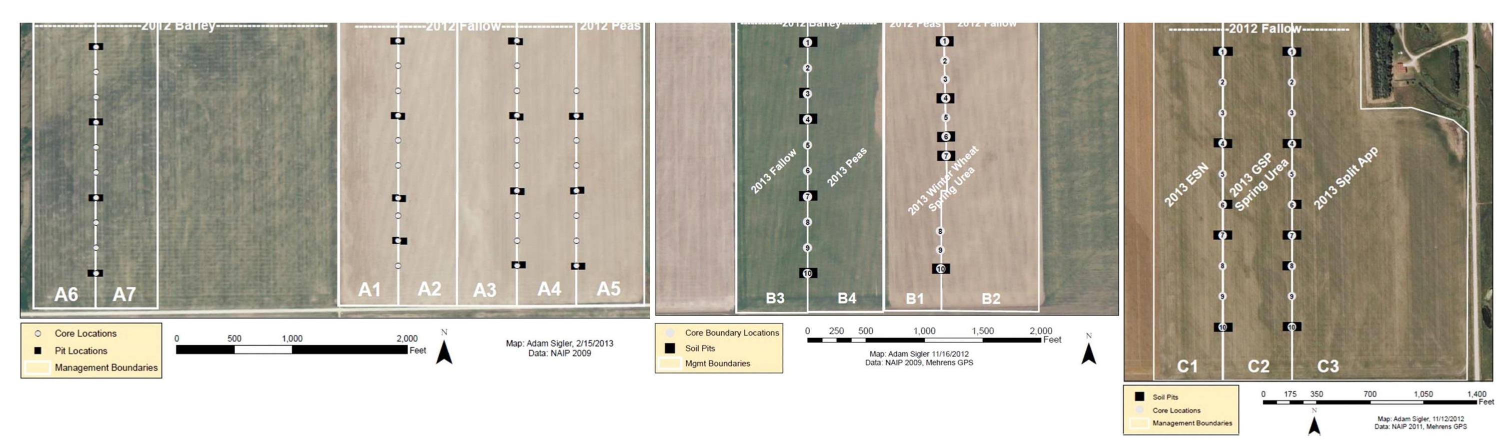

Figure 3. Aerial images of treatment fields showing location of soil core/grain and soil pit sample sites. Note that these fields are on the order of 20 to 30 km apart.

Biomass/Soil Sampling and Analysis:

- **Soil:** Core sampled August 2012 by hydraulic probe 7.5-m east and west of each boundary; ten per side in 15-cm increments. Four to five locations per side sampled manually from excavated 1x2 m pits (Figure 3).
- Soil sample extracts (1 M KCl) analyzed for nitrate using Lachat Flow Injection Analysis.
- Root zone nitrate calculated using two linear regression relationships between total nitrate, 0-15 and 0-30 cm nitrate in pits.
- **Biomass:** Sampled late July 2013, 10 winter wheat samples (0.51 m^2), near core sites.
- Total-N was analyzed using automatic combustion analyzer

Figure 4. B1-B2 winter wheat field, 2013 (B2 is on the left of middle furrow and B1 is on the right).

Calculations and Data Analysis:

- Grain protein was calculated by multiplying total-N (g kg^{-1}) by 5.7 (Tkachuk 1969)
- ANR = 100*(aboveground biomass N/(fertilizer N + soil N)).
- Paired t-tests were run in R.

ACKNOWLEDGMENTS
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Results and Discussion

Yield: AMP vs. GSP (Figure 5)

- Grain yield difference was only observed on Field B (higher after fallow than after pea), likely due to higher moisture and/or soil nitrate.

Protein: AMP vs. GSP (Figure 6)

- Increased wheat after fallow protein likely due to higher fallow soil nitrate concentration.
- Higher protein with seed placed CRU on Field A but not C, possibly due to more late N from CRU or shallow groundwater.
- Higher protein with split application treatment on Field A but not C (which experienced leaf burn), likely reflecting higher N availability from the split application.

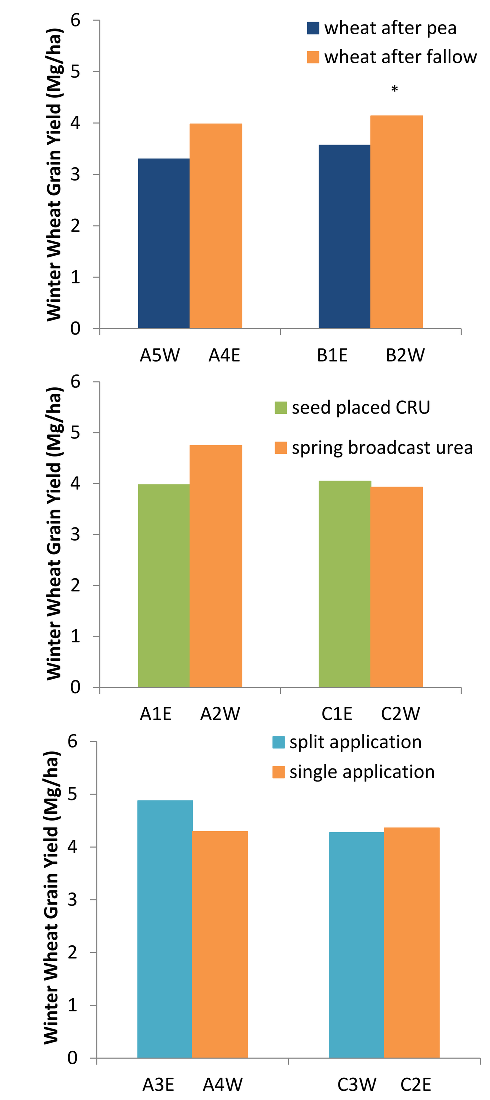

Figure 5. Mean winter wheat yield in three AMPs and GSPs. (*) indicates a significant difference.

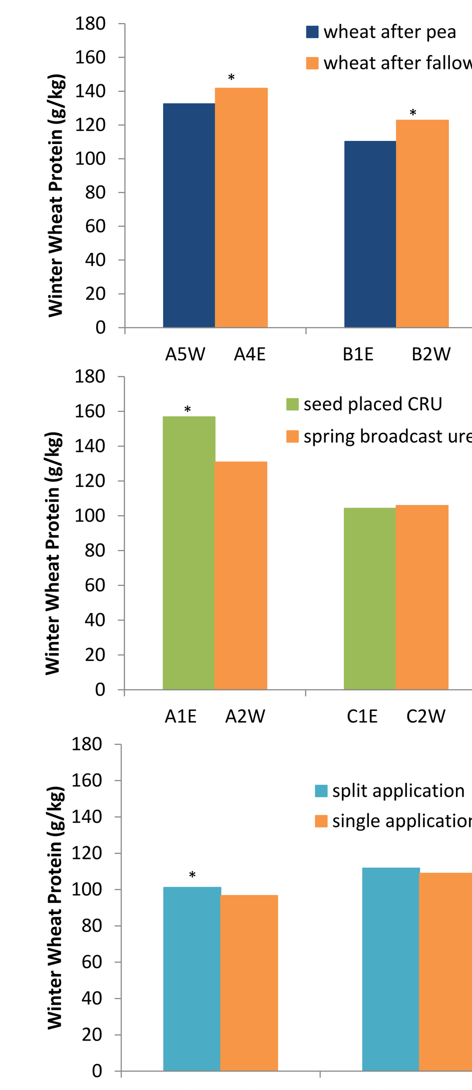

Figure 6. Mean winter wheat protein in three AMPs and GSPs. (*) indicates a significant difference.

Avail N Recovery: AMP vs. GSP (Figure 7)

- ANR was higher in wheat after pea than after fallow only on Field B, suggesting increased leaching after fallow there.

Non-treatment effects on yield, protein, grain N:

- Yield, protein, and grain N were all found to be correlated (P<0.05) with core depth (DTR).

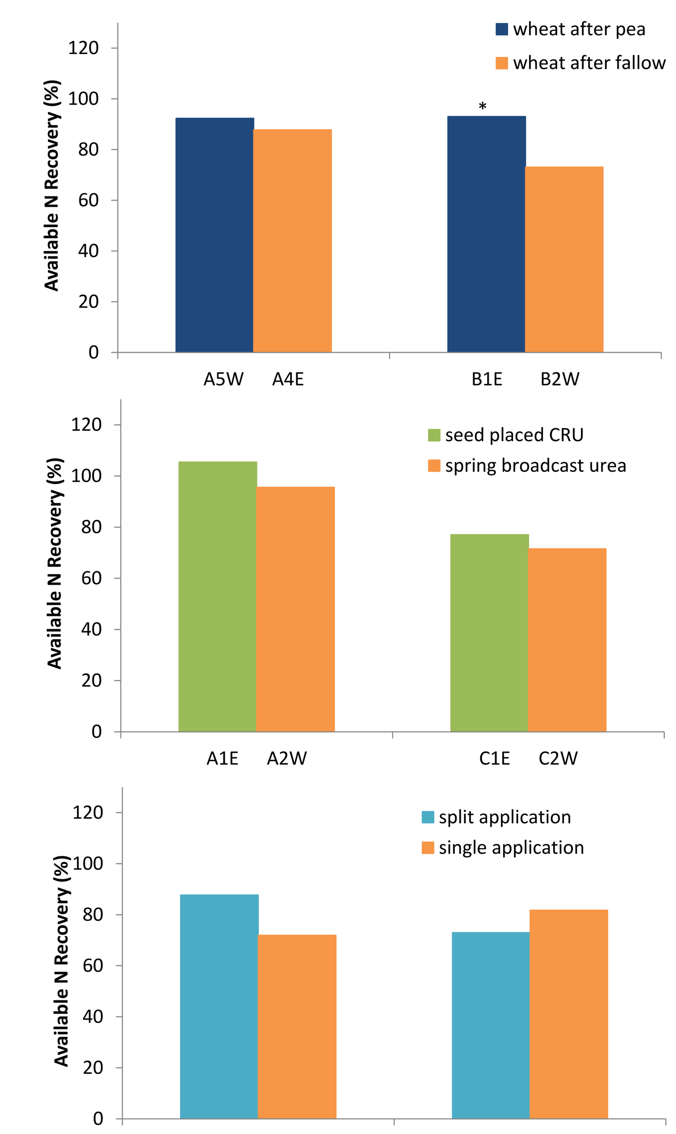

Figure 7. Mean ANR between three AMPs and GSPs. (*) indicates a significant difference.

Conclusions

- Growing pea instead of fallow is likely the most successful practice in reducing nitrate leaching, but following a dry year (2012) there was decreased yield (on one field) and protein (on both) following pea.
- Relatively small differences in yields, protein, and N recoveries suggest that following a dry year (2012), nitrate leaching may be comparable in current practices and alternatives.
- Awaiting data from 2014 to complete this study. Nitrate leaching will be assessed by a mass balance approach and compared with estimates from lysimeter measurements/1-D water model.

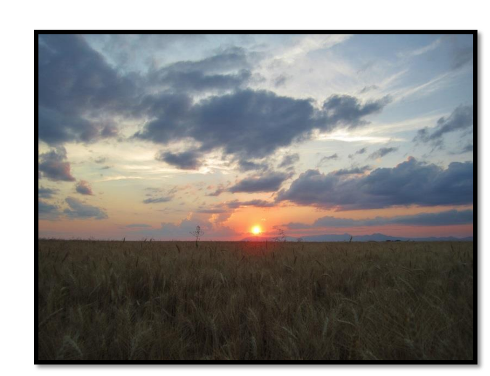

Figure 8. Winter wheat on Field A

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