

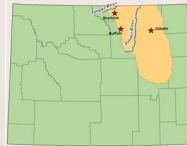
Managed irrigation with coalbed natural gas produced water: Changes in soil chemistry and morphology through time

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Introduction

- Coalbed natural gas (CBNG) production continues to increase in the Powder River Basin (PRB) of Wyoming
- The PRB has ~713 billion m³ of recoverable CBNG¹
- CBNG production will extract ~ 700,000 ha-m of ground water²
- CBNG produced water is unaltered groundwater rich in:
 - Soluble salts
 - Sodium
 - Bicarbonate
- Several water management strategies are necessary – one strategy available is managed irrigation
- Managed irrigation is the application of soil science, water chemistry, agricultural engineering, and agronomic principles to utilize CBNG-produced water in a beneficial manner to produce forage for livestock and wildlife while protecting soil physical and chemical properties



Managed Irrigation Objectives

- Beneficially utilize CBNG produced water
- Maintain soil salinity at levels suitable for crop growth
- Prevent excessive sodium accumulation in the soil profile
- Produce a forage crop

Field Study Objective

- Evaluate the long-term effects of managed irrigation with CBNG produced water on soil physical and chemical properties

Materials and Methods

- 6 CBNG managed irrigation sites in the PRB
- 2 sites near the Tongue River (TR Pivots)
- 4 sites near the Powder River (PR Pivots)
- 2-6 years of CBNG irrigation has occurred at each site
- Long-term average CBNG produced water quality is as follows:

CBNG Produced Water										
		Anions				Cations				
		pH	EC	SAR	HCO ₃ ⁻	CO ₃ ²⁻	SO ₄ ²⁻	Ca	Mg	Na
Location	s. u.	(dS m ⁻¹)		(mg L ⁻¹)						
PR Pivots		8.2	3.7	30	2800	120	14	27	33	940
TR Pivots		8.3	2.2	43	1300	690	133	9.3	4.0	570

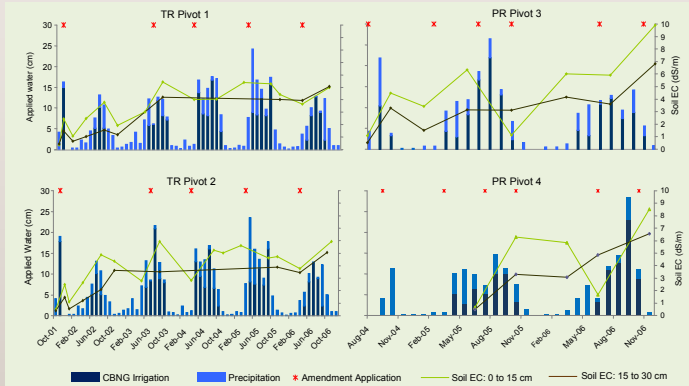
- Soil baseline conditions documented prior to irrigation
- Soil samples collected 2-3 times annually
- Infiltration data collected periodically with a tension infiltrometer (Soil Measurement Systems, Tucson, AZ)
- All data is from non-replicated, field-scale managed irrigation sites
- All chemical analyses performed by certified commercial laboratories



Results and Discussion

Soil chemical conditions 0 to 30 centimeters:

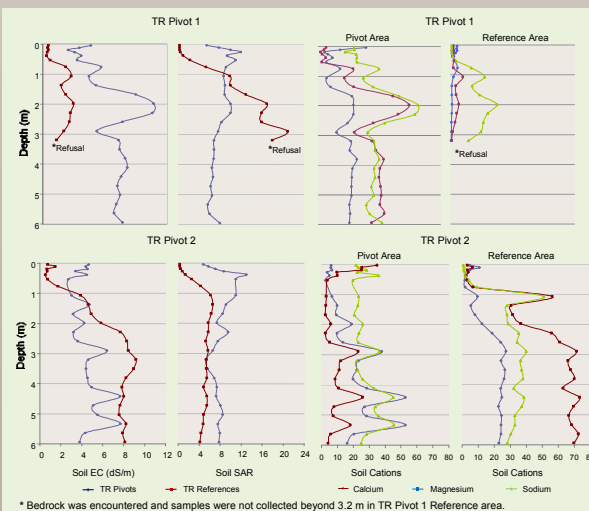
- 6 years of CBNG managed irrigation at the TR Pivots, cropped to alfalfa
- 2 and 3 years of CBNG managed irrigation at the PR Pivot 3 and PR Pivot 4, cropped to range grasses



- Soil electrical conductivity (EC) is influenced by amendment application, CBNG irrigation, and precipitation
- Surface EC is more variable than subsurface EC
- Soil EC is maintained at a level acceptable for forage crop production

Soil chemical conditions 0 to 6 meters:

- TR Pivot 1 and TR Pivot 2 after 3 years of irrigation with CBNG produced water (n=1)



* Bedrock was encountered and samples were not collected beyond 3.2 m in TR Pivot 1 Reference area.

- EC and sodium adsorption ratio (SAR) are affected in the rooting zone, as predicted, by the application of CBNG produced water and soil amendments - but crop production and soil infiltration are maintained

Soil Infiltration

- Infiltration study conducted at TR Pivot 1, TR Pivot 2, and adjacent (non-irrigated) reference areas following 3 seasons of CBNG irrigation



TR Pivot 1	TR Pivot 1 Reference	TR Pivot 2	TR Pivot 2 Reference
Infiltration rate (cm/hr)			
0.84	2.34	2.41	1.60
4.04	1.91	0.91	2.82
2.46	8.26	1.88	1.19
1.52	6.30	2.36	4.19
3.02	3.25	1.93	5.03
3.61	3.48	2.11	3.02
3.63	0.84	2.41	0.64
3.02	0.51	1.80	2.49
2.46	2.46	2.11	9.14
1.42	0.23	2.11	0.56
2.11	1.42	1.07	6.27
3.15	0.91	1.73	12.19
4.04	1.14	1.02	9.22
1.80	1.07	1.96	5.18
1.27	1.70	2.58	10.41
Minimum	0.84	0.23	0.91
Maximum	4.04	8.26	2.59
Average	2.44	2.39	1.89
Standard Deviation	1.09	2.23	0.52

- Infiltration rates in the pivot areas are more uniform than in the reference area
- TR Pivot 1 is not significantly different from the reference area (n=15, p= 0.05)
- TR Pivot 2 is significantly different from the reference area (n=15, p=0.05)
- Infiltration rates in the pivot areas are considered typical³
- Differences in soil infiltration may be due to both the physical effects of irrigation, tillage, and other agronomic activities³

Soil Profile Physical Characteristics:

- PRB Pivot 1 and PRB Pivot 2 following 6 years of CBNG managed irrigation

PR Pivot 1				PR Pivot 1 Reference			
Horizon	Depth (in)	Texture	Structure	Horizon	Depth (in)	Texture	Structure
Ap	0-3	Loam	2, M, SBK	Ap	0-3	Clay Loam	2, F, PL parting to 2, F, SBK
Bt	3-9	Clay Loam	2, M, SBK	Bt	3-13	Clay Loam	1, M, PR parting to 2, M, SBK
Bk	9-23	Clay Loam	2, M, SBK	Bk	13-25	Sandy Loam	1, C, SBK
Ck	23-33	Clay Loam	MA	C	33-60+	Sandy Clay Loam	MA

PR Pivot 2				PR Pivot 2 Reference			
Horizon	Depth (in)	Texture	Structure	Horizon	Depth (in)	Texture	Structure
Ap	0-5	Loam	2, M, GR	A	0-4	Loam	1, M, GR
Bt	5-13	Clay Loam	2, M, PR, parting to 2, M, SBK	Bt	4-11	Loam	2, M, SBK
Bk	13-27	Clay Loam	2, C, SBK	Bw	11-37	Loam	2, C, SBK
Ck	27-57	Clay Loam	MA	C	37-60	Sandy Loam	MA

- Soil structure remains similar to adjacent non-irrigated areas
- Surface crusting and dispersion are not present in irrigated areas

Summary

- Managed irrigation is a practical and mutually beneficial use of CBNG produced water
- With careful implementation, managed irrigation can maintain soil chemical and physical conditions supportive of plant growth

References

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Acknowledgements

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