Influence of Selected Land Application Strategies on the Fate and Transport of Antimicrobials and Antimicrobial Resistance Genes

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Project Team

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- United States Department of Agriculture
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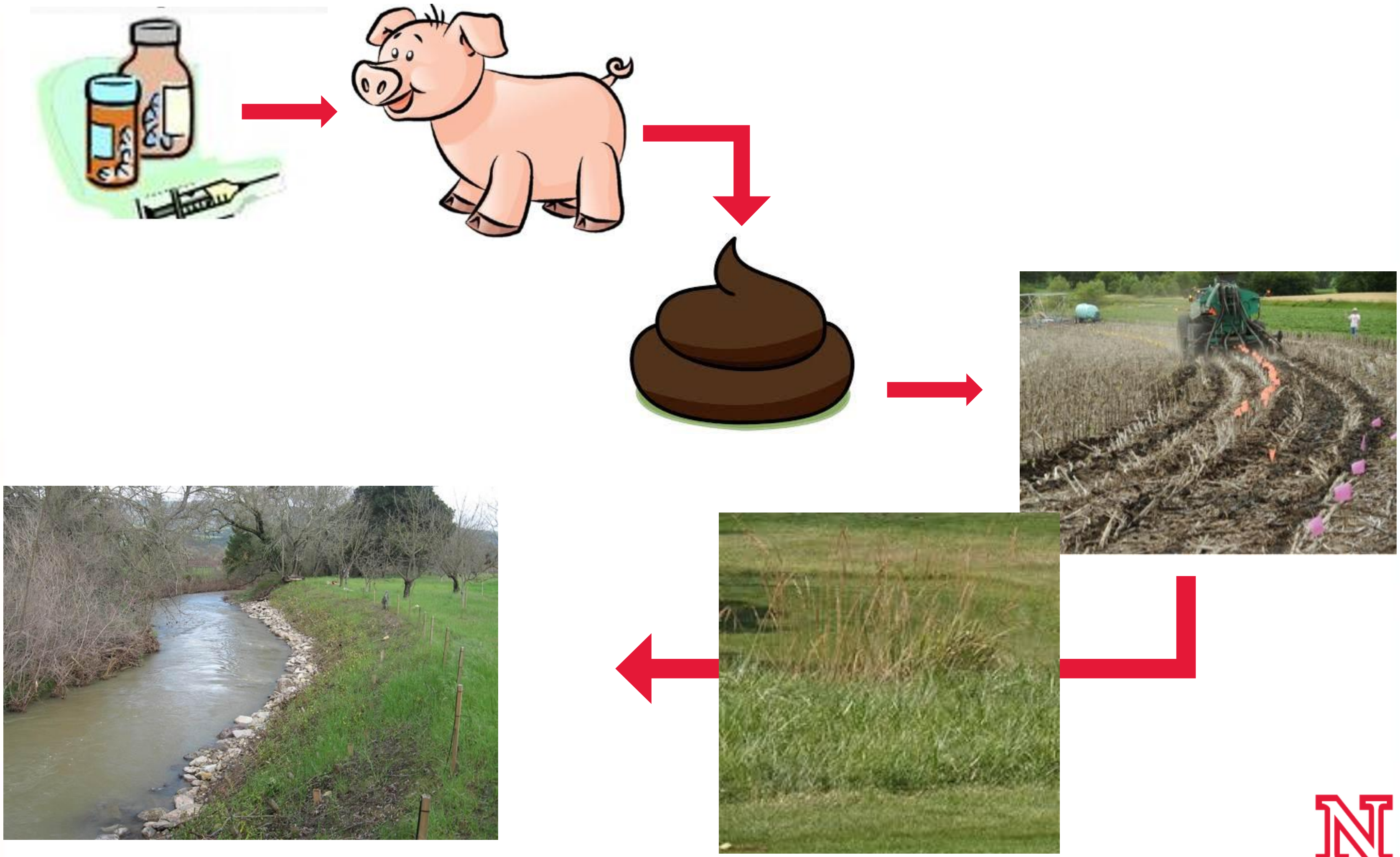
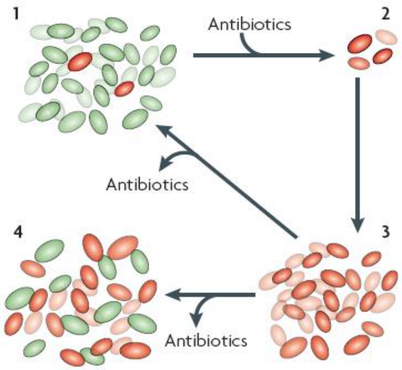
Background



Antimicrobials and Antimicrobial Resistance

- ❑ Antimicrobials in livestock production
  - – Therapeutic level: disease treatment
  - – Sub-therapeutic level: prophylaxes and growth promotion
  - – A substantial amount not absorbed and released with wastes
- ❑ Antimicrobial resistance
  - – Emerging in hospitals
  - – Emerging in the livestock gut and the environment
  - – Commensal and pathogenic bacteria
  - – Antimicrobial resistance infections: $20 billion in excess health care costs and 8 million additional hospital days



Antimicrobial pressure

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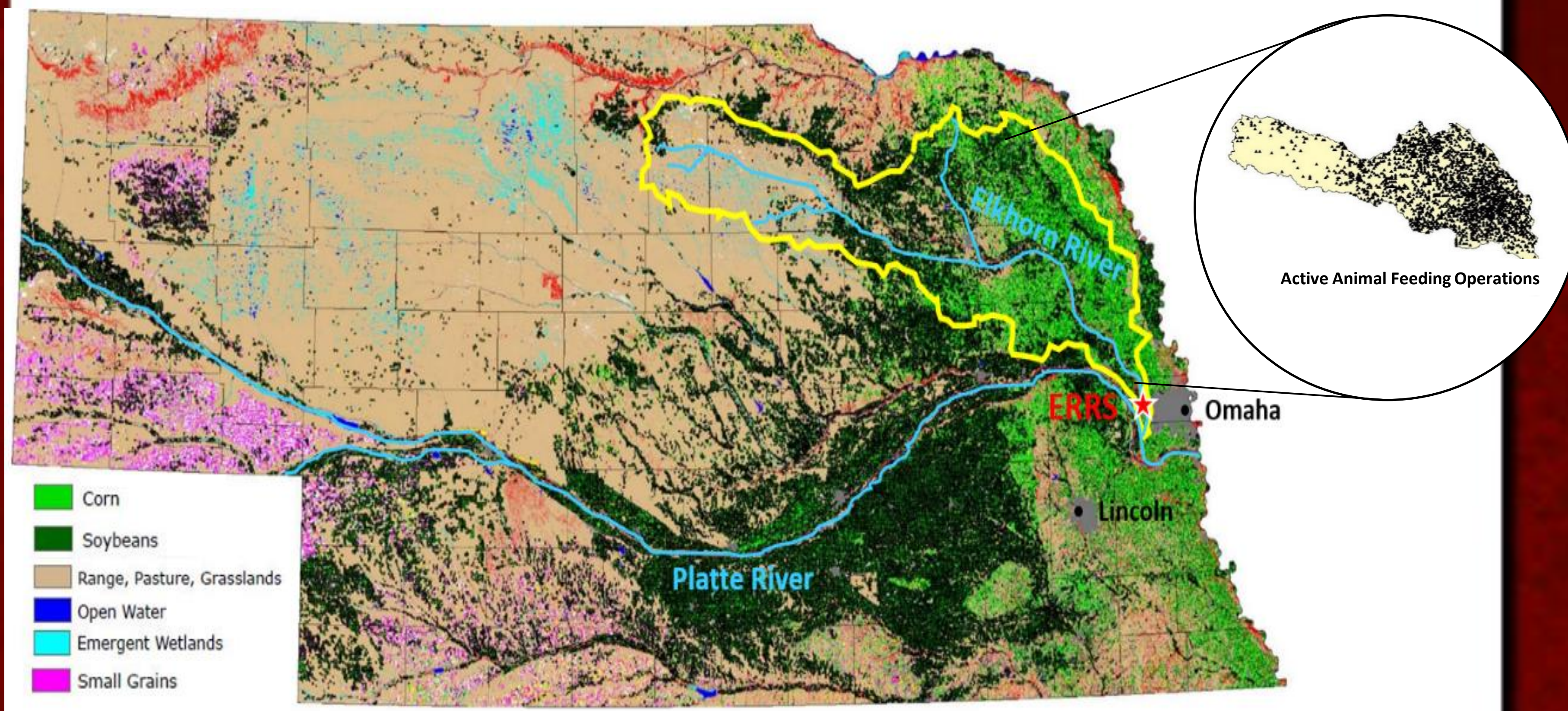
Relative abundance of resistant bacteria

Animal production and crop production in Nebraska



Motivation

- Runoff from fields where manure is land applied can contain antimicrobials and antimicrobial resistance genes (ARG)
- Limited studies investigating the influence of land application strategy and mitigation strategies such as grass buffer strips on antimicrobial and ARG transport
- Limited studies have investigated the fate of both antimicrobial and ARG concurrently

Research Objectives

(1) Evaluate the fate of antimicrobial and ARG after land application of swine manure as a function of land application method

(1) Evaluate removal of antimicrobial and ARG in runoff by a narrow grass hedge

AB and ARGs in runoff – study design

- Manure was collected from US Meat Animal Research Center (USDA) from various animal production barns using different antimicrobials: chlortetracycline, tylosin and bacitracin

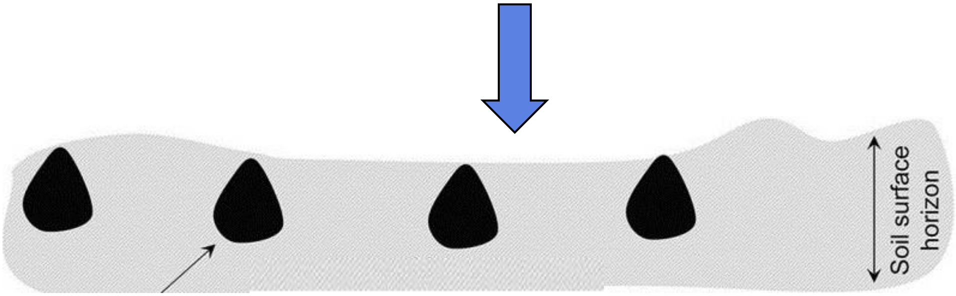
Manure slurry	Antimicrobial (mg/kg ww)	Antimicrobial (mg/kg dw)	ARG (copy/mL)	
CTC-manure	CTC		*tet*(Q)	*tet*(X)
	3.3 ± 1.6	404 ± 138	$(2.5\pm 1.3)\times10^4$	$(1.3\pm0.7)\times10^3$
TYL-manure	TYL		*erm*(B)	*erm*(F)
	0.29 ± 0.12	32.5±7.2	$(1.6\pm 1.1)\times10^4$	$(1.4\pm0.5)\times10^2$
BAC-manure	BAC		*bcrA*, *bcrB*, *bcrC*	*bceA*, *bceR*
	0.78 ± 0.75	320±31.5	ND[#]	ND

Land Application Methods

Broadcast

Incorporation

Injection



Manure slurry

Antimicrobial loading through land application of manure is estimated at the kg/hectare level (Winckler & Grafe, 2001)

Experimental Methods

Manure slurry collected at the USDA Meat Animal Research Center (MARC)

Field testing site at the UNL Roger's Memorial Farm

Experimental design allowed for statistical analysis of the data

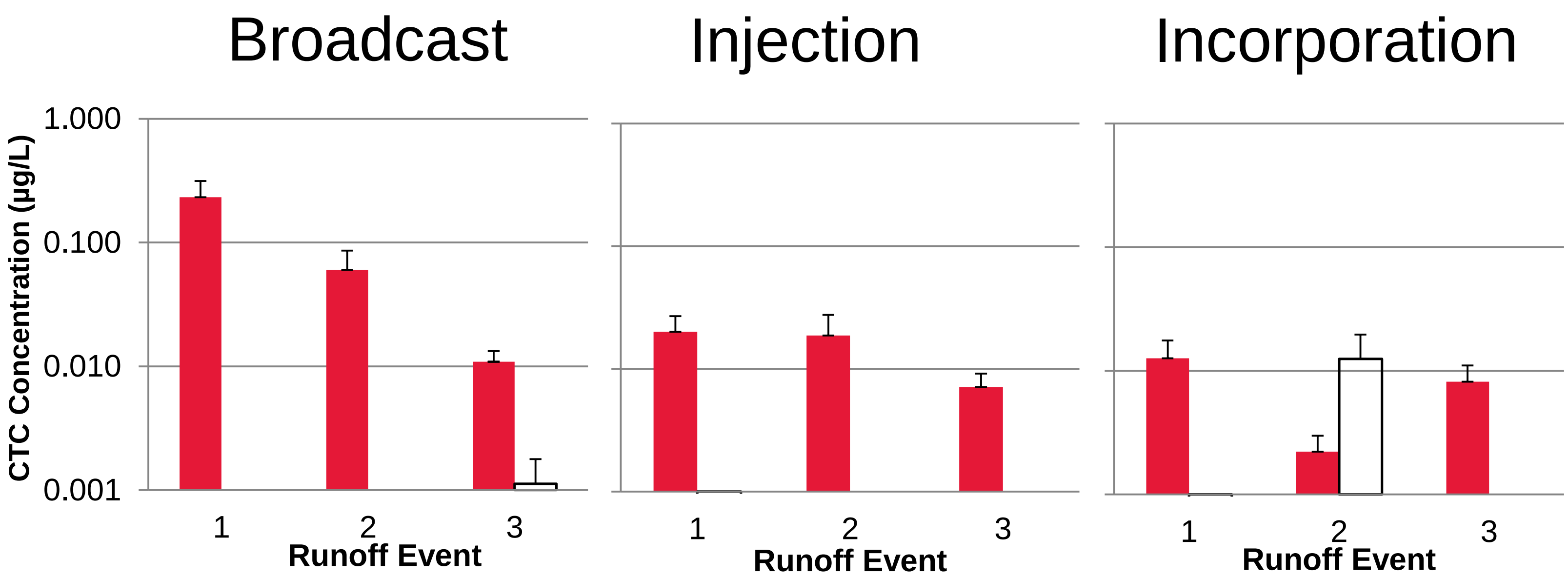
Broadcast BAC	Broadcast CTC	Broadcast CONTROL	Broadcast TYL				
Incorporation CONTROL	Incorporation CTC	Incorporation TYL	Incorporation BAC	Injection TYL	Injection BAC	Injection CONTROL	Injection CTC
Injection CTC	Injection BAC	Injection TYL	Injection CONTROL	Incorporation TYL	Incorporation CTC	Incorporation CONTROL	Incorporation BAC
Broadcast BAC	Broadcast CTC	Broadcast CONTROL	Broadcast TYL	Incorporation BAC	Incorporation TYL	Incorporation CTC	Incorporation CONTROL
Broadcast TYL	Broadcast BAC	Broadcast CONTROL	Broadcast CTC	Injection TYL	Injection CONTROL	Injection BAC	Injection CTC

Evaluated in a randomized block design on fields that had never received manure application

Rainfall Simulation Experiments

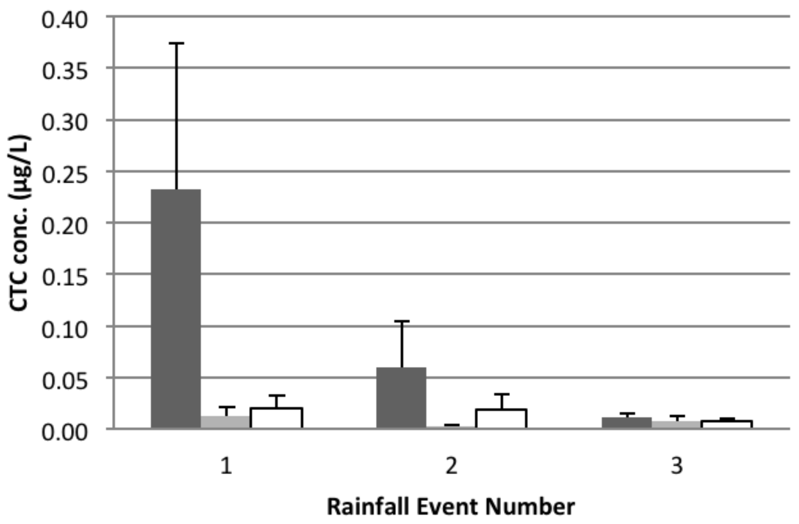
- Simulated rainfall intensity 70 mm/hr
  - 3 sequential events (#1, 2, and 3)
- All runoff collected and a composite sample taken
  - Stored at -20^{o}C until analysis
- Soil cores collected before and after rainfall simulation

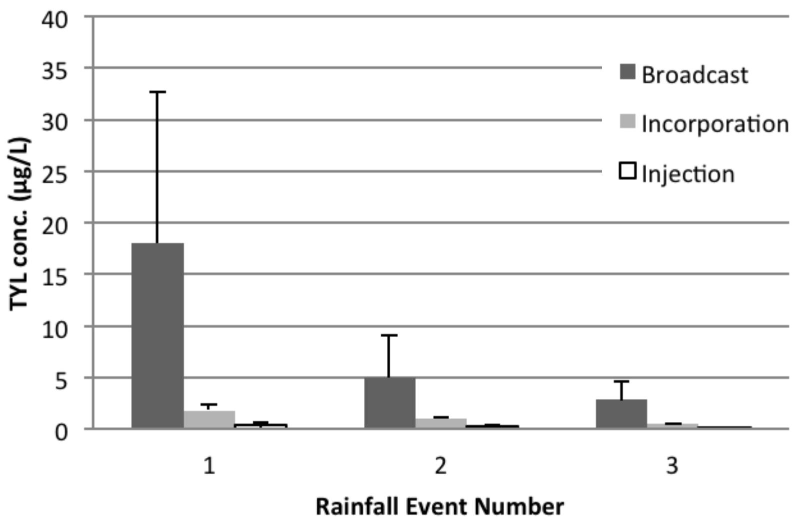
CTC in Runoff



Run	Mass Loading (average ± std.error, µg/m²)		
	Broadcast	Injection	Incorporation
1	4.54±1.65	0.30±0.14	0.23±0.11
2	1.11±0.50	0.27±0.14	0.06±0.02
3	0.15±0.03	0.09±0.03	0.14±0.04
Sum	5.80	0.66	0.43
Fraction in Run 1	0.78	0.45	0.55

Comparison of antimicrobials in runoff

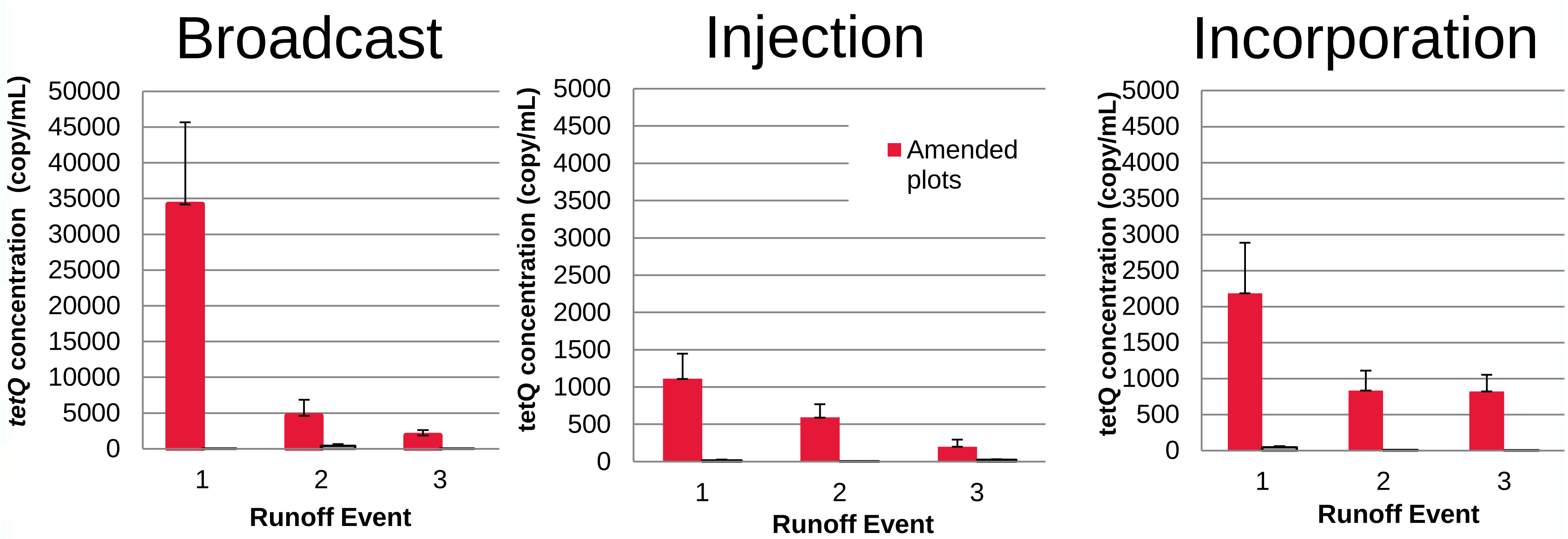




Tylosin mass transport in runoff

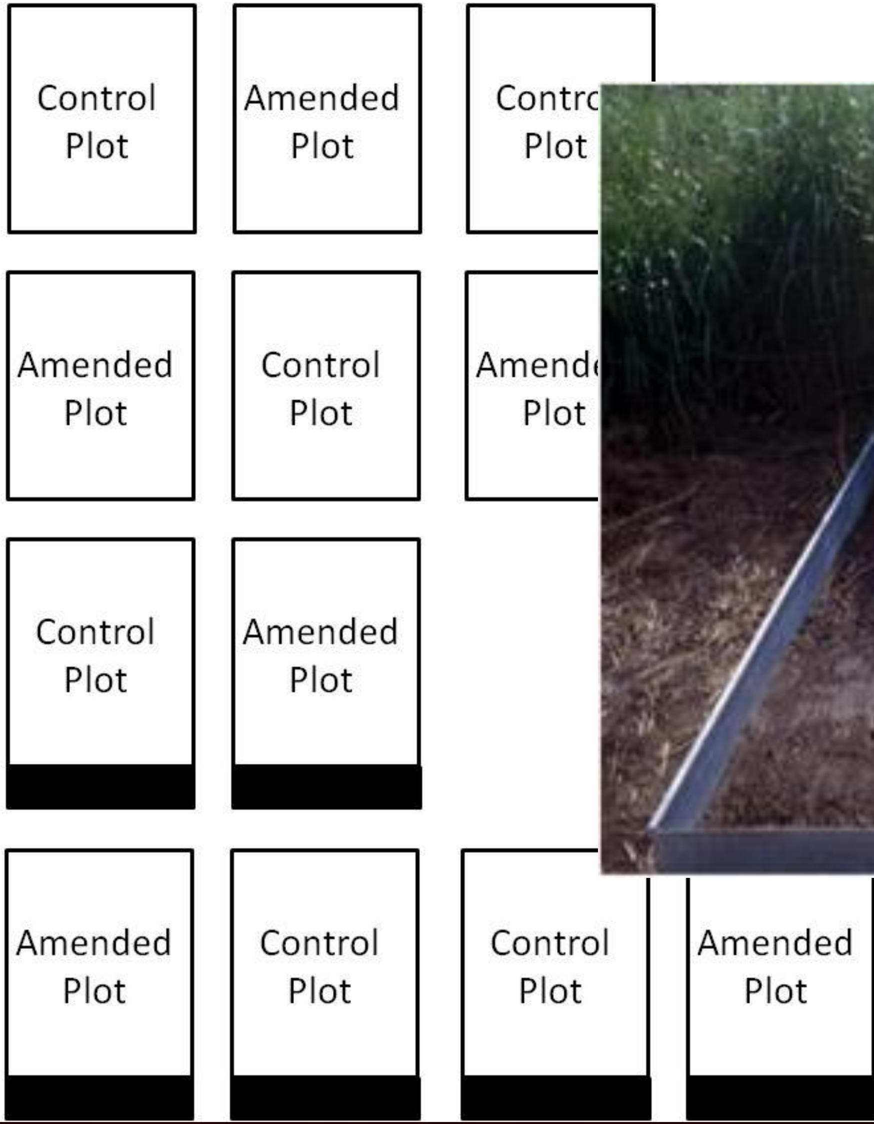
Run	Mass Loading (average ± std.error, µg/m^2)		
	Broadcast	Injection	Incorporation
1	280.41±213.66	5.23±2.28	33.56±22.45
2	89.02±70.28	4.59±1.84	11.55±1.64
3	56.37±34.12	1.73±1.25	4.50±0.56
Sum	425.90	11.55	49.61
Fraction in Run 1	0.66	0.45	0.68

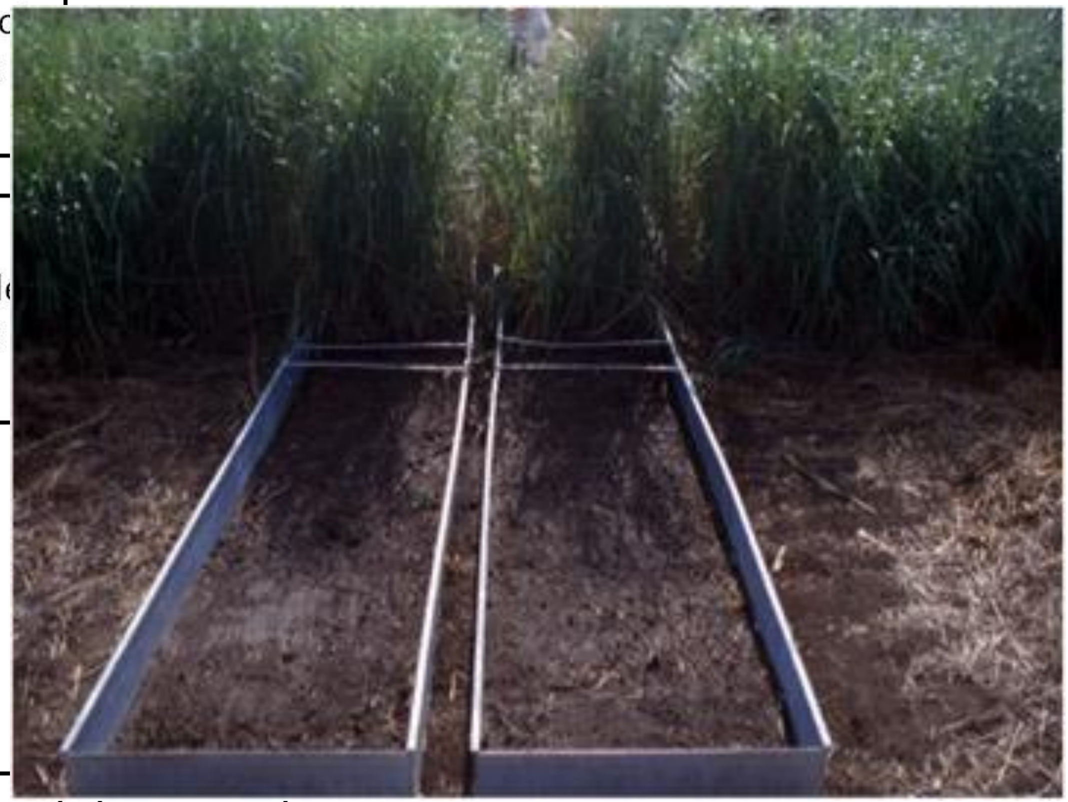
ARGs in Runoff



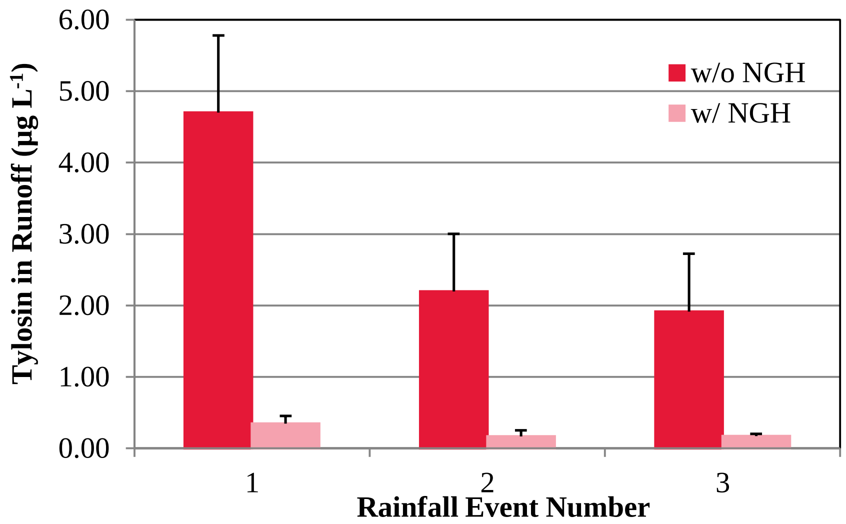
- Highest loads of antimicrobials and ARGs occurred in the runoff during the 1st rain event.
- Broadcast application leads to more antimicrobial and ARGs in runoff than injection and incorporation.

Narrow Grass Hedges – Study Design

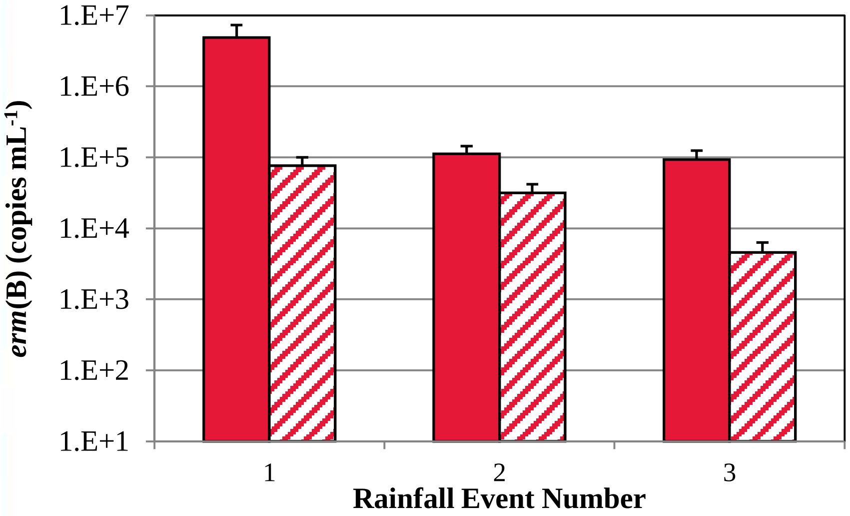


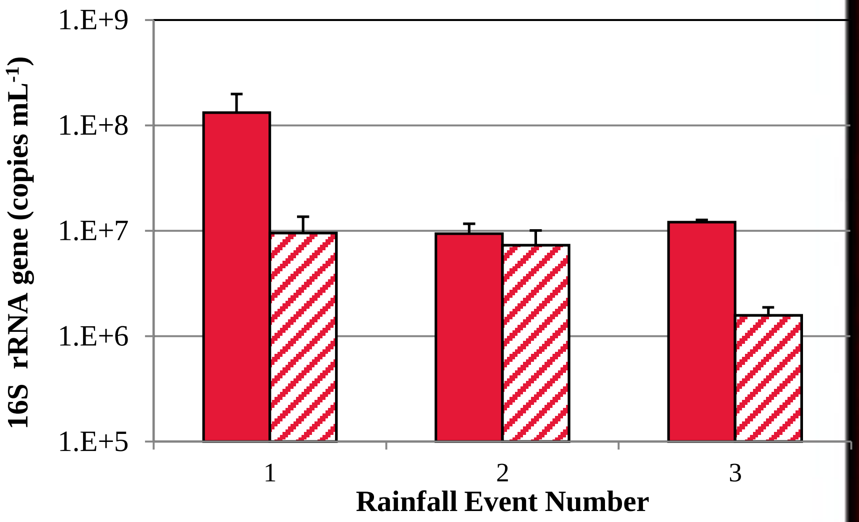


Antibiotic removal by grass hedge



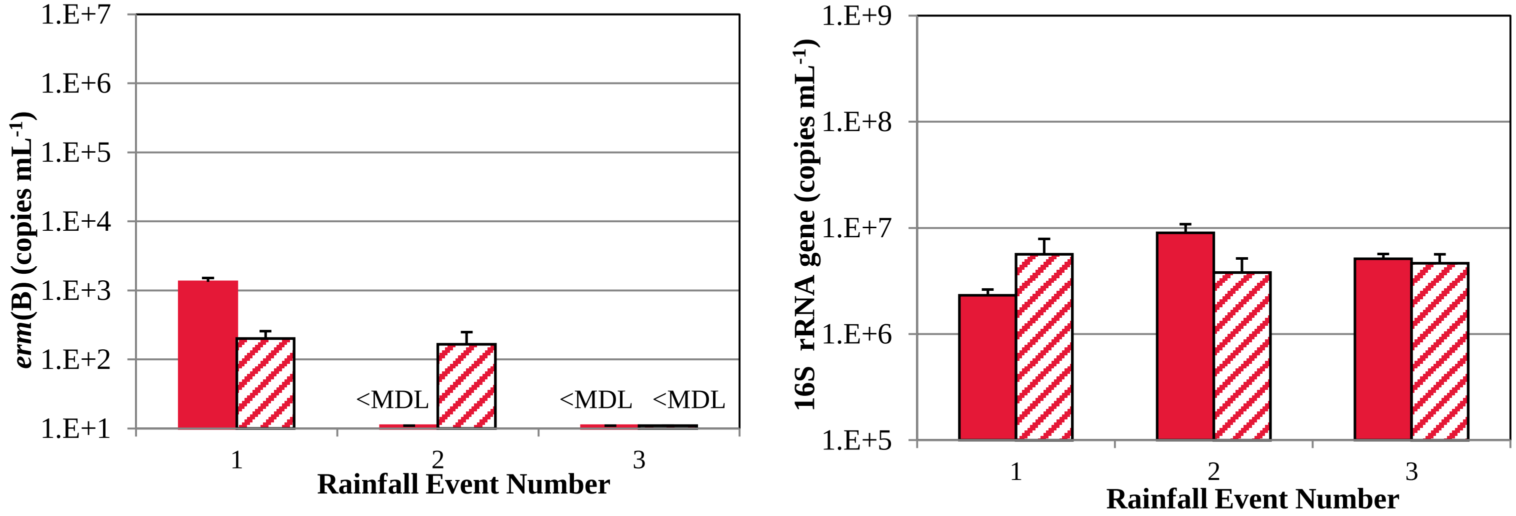
ARG removal by grass hedge





without grass hedge
with grass hedge

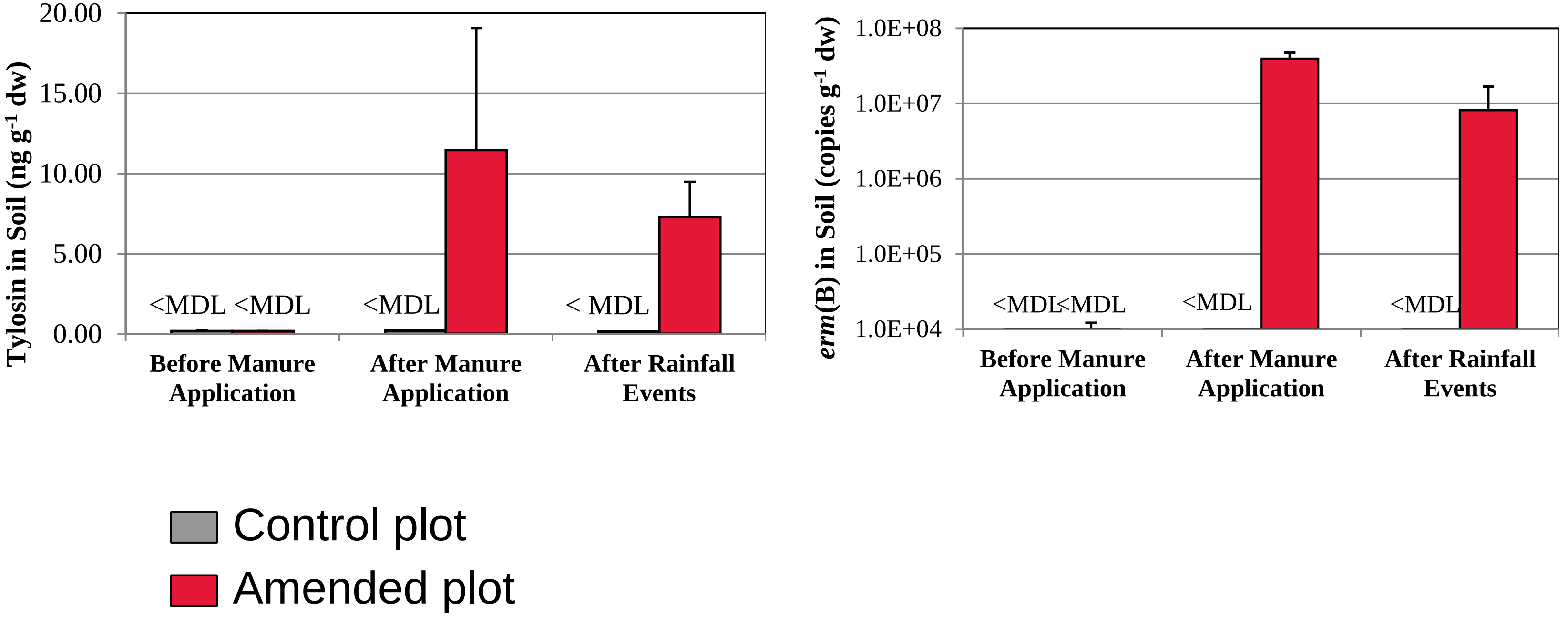
ARG occurrence in check plots



without grass hedge

with grass hedge

AB and ARG occurrence in soils



Conclusions

- Narrow grass hedges reduced tylosin in runoff by over an order of magnitude, likely due to enhanced infiltration or sorption
- *erm(*B) and 16S RNA were also removed by grass hedges
  - Consistent with prior work on removal of suspended sediment and fecal coliforms
- Tylosin and *erm*(B) occurrence in soil can be attributable to manure application

Publications Resulting from this Work

Soni, B.; Bartelt-Hunt, S.L.; Snow, D.D.; Gilley, J.; Marx, D.; Woodbury, B.; Li, X. (2015). Effect of Narrow Grass Hedges on the Transport of Antimicrobial and Antimicrobial Resistance Genes in Runoff Following Land Application of Swine Slurry. Journal of Environmental Quality.

Joy, S.R.; Li, X.; Snow, D.D.; Gilley, J.E.; Woodbury, B.; Bartelt-Hunt, S.L. (2014). Fate of Antimicrobials and Antimicrobial Resistance Genes in Simulated Swine Manure Storage. Science of the Total Environment, 481: 69-74.

Gilley, J.E.; Bartelt-Hunt, S.L.; Li, X.; Marx, D.B.; Snow, D.D.; Parker, D.B.; Woodbury, B.L. (2013). Runoff nutrient transport as affected by land application method, swine growth stage and runoff rate, Transactions of ASABE, 56: 1295-1303.

Joy, S.R.; Bartelt-Hunt, S.L.; Snow D.D.; Gilley, J.; Woodbury, B; Parker D.; Marx, D.; Li, X. (2013). Fate and transport of antimicrobials and antimicrobial resistance genes in soil and runoff following land application of swine manure slurry. Environmental Science and Technology, 47(21): 12081-12088.

Gilley, J.E.; Bartelt-Hunt, S.L.; Li, X.; Marx, D.B.; Snow, D.D.; Parker, D.B.; Woodbury, B.L. (2013). Narrow Grass Hedge Effects on Nutrient Transport Following Swine Slurry Application, Transactions of ASABE, 56: 1441-1450.

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