Characterization of Spatial and Temporal Nutrient Leaching Patterns in a Central Kentucky Pasture Undergoing Forage Renovation

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INTRODUCTION

- Tall fescue (*Festuca arundinacea* Schreb.) is an important cool season perennial forage for animal production in Kentucky. Unfortunately, tall fescue suffers from endophyte infection (*Neotyphodium coenophialum*) that produces toxic alkaloids in leaf tissue and causes animal health disorders when ingested.
- Prior research showed that soil under tall fescue with high endophyte infection had 13   8% higher soil organic C and N concentrations and particulate organic N to a depth of 30 cm than fescue with low endophyte infection; perhaps because of reduced soil microbial activity on plant residues containing endophyte byproducts.
- In central Kentucky, potential effects of forage transition to overcome problems related to animal growth and productivity are exacerbated by the underlying karst topography. Numerous sinkholes that develop in this landscape provide rapid conduits for surface contaminants into shallow groundwater resources.
- Transition to forages more palatable to grazing animals may alter soil organic matter dynamics and consequently affect soil aggregation, soil structure, and soil hydraulic characteristics that control water flow and solute transport and may cause unintended detrimental effects with respect to groundwater quality.
- The experiment shown here is a part of a larger study that focuses on the potential effects of pasture renovation on transport processes in the vadose zone of sinkholes and potential contamination of shallow groundwater.

OBJECTIVES

Determine if transition from endophyte infected to endophyte free forage influences nutrient fluxes and nutrient leaching potential under field scale conditions and investigate the spatial and temporal variability of nutrient leaching under different forages and their spatial association with hydrological and physiochemical parameters that control transport processes.

STUDY SITE AND NUTRIENT LEACHING EXPERIMENT

The experiment was conducted at the University of Kentucky Animal Research Center in Woodford Co., Kentucky. The soil at this site is a Maury silt loam (Typic hapludalf) with 6-12% slopes. An existing sinkhole in permanent pasture was treated with glyphosate herbicide (Roundup™) to remove the existing vegetation in Fall 2008, and again in Spring 2009. Two tall fescue cultivars were direct seeded into the killed sod in April 2009. Three (3 X 160 m^2) strips were established to represent the original and the two new forage varieties as follows:

1) The original undisturbed native pasture (OG) (a mixture of Kentucky bluegrass [*Poa pratensis*] and tall fescue).
2) KY 31 – Endophyte-infected and alkaloid-producing tall fescue (KY31).
3) KYFa9301/A584 – Endophyte-infected, non alkaloid-producing tall fescue (NE)

Tension Lysimeters and Zero Tension Ion Exchange Resin Lysimeters (IERL)

IERL were used to capture the leached nutrients under forage treatments. IERLs were constructed by placing 2 layers of anion and cation exchange resins between two 3 cm layers of sand in a 10 cm diameter, 10 cm long, PVC coupling. Eighty one IERLs, 27 in each strip, were installed at 50 cm depth, in transects with a 5m lag distance between lysimeters (Fig.1). IERLs were installed on 7/1/09 and replaced with a new set of lysimeters 5 months later. The second set was replaced on 4/8/10. Resin bags were extracted with 5% NaCl solution.

Tension lysimeters were used to assess changes in soil solution chemistry. A factorial within RCBD design was implemented for tension lysimeter distribution. Tension lysimeters were installed on 5/1/10 in batches of 6 lysimeters at 50 cm depth. Each grass strip had three tension lysimeter batches representing the south, middle, and north (S, M, N) parts of each grass strip. Soil solution samples were collected 2 to 3 days after rain events and frozen until analysis. The results shown here represent six rainfall events between 5/27/10 and 8/6/10.

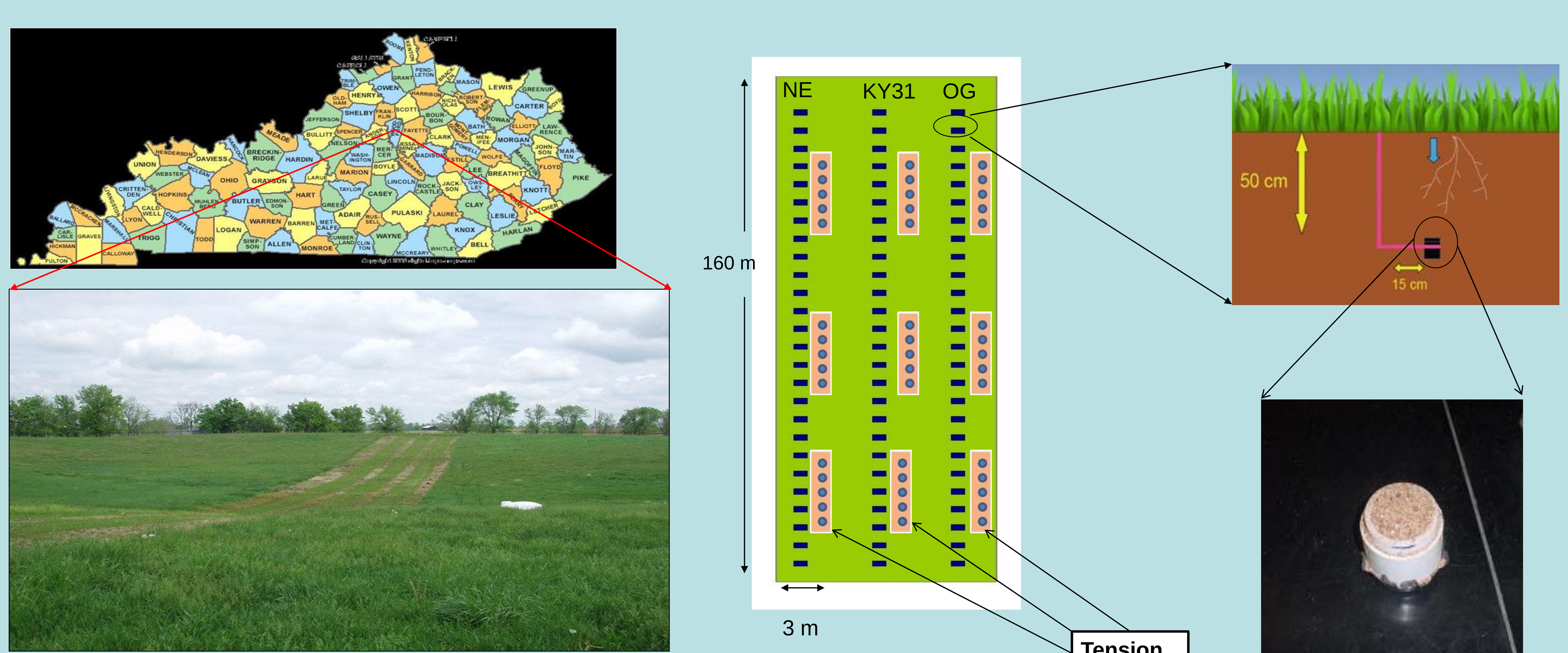

Figure 1. Study site, IERL location map, and design. (Not to scale.)

NUTRIENT MASS FLUX AND TEMPORAL CHANGE

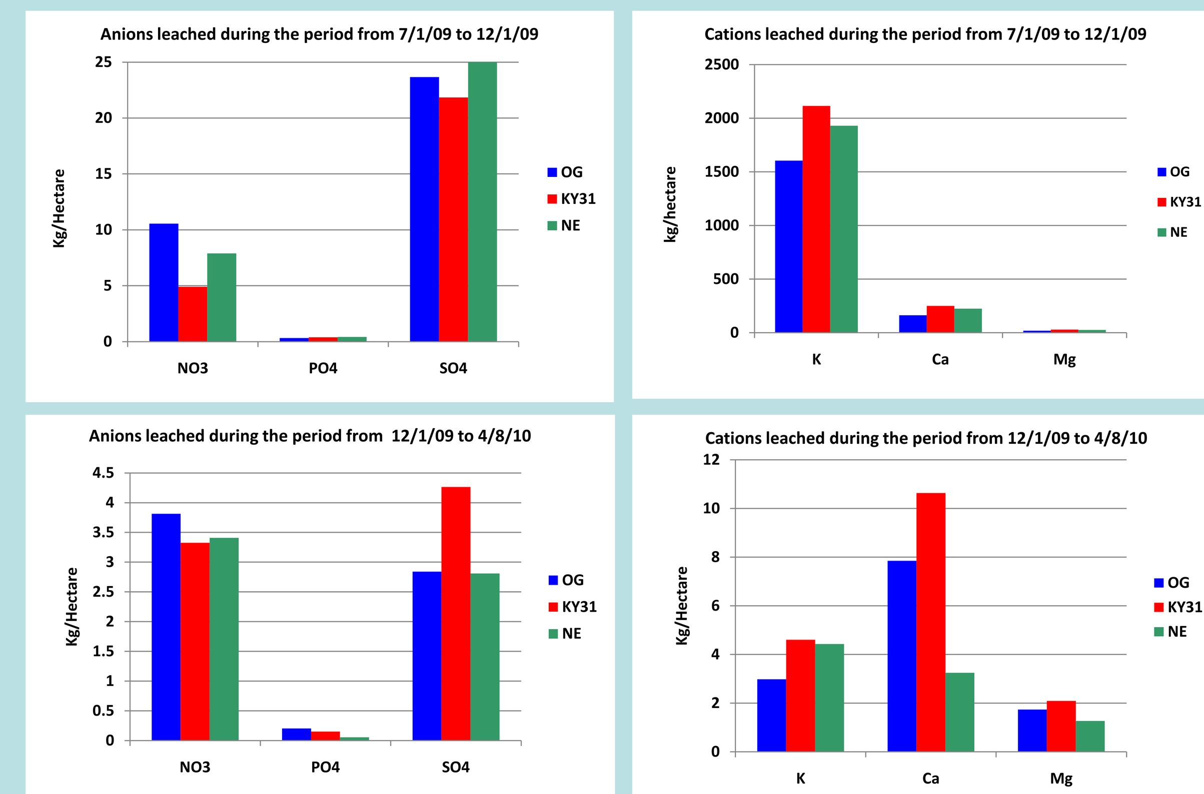

Figure 2. Net mass fluxes of leached nutrients under different grasses and their temporal changes.

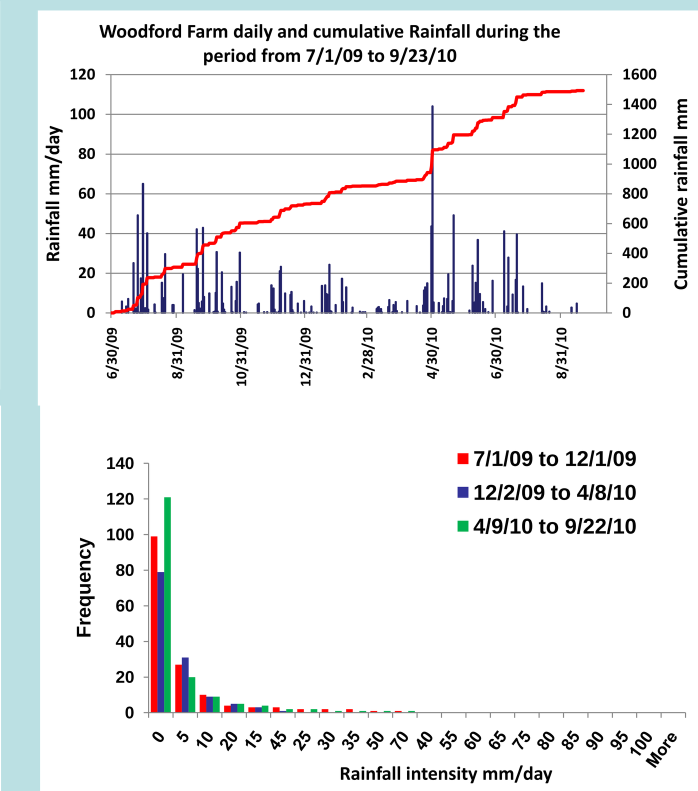

Figure 3. Daily and cumulative rainfall at the study site and their frequency distribution.

- Total rain amount and intensities during the two studied periods had a significant effect on the net nutrient leaching under each grass. A total of 731 mm rain occurred during July-December compared with only 160 mm of rain from December-April (Fig. 3). Rainfall in the study site was dominated by <10 mm/day events.
- Net mass flux of leached nutrients was significantly higher under the three grasses during July-December compared with December-April (Fig. 2). There was a 2 to 3 fold decrease in nitrate and phosphate net mass fluxes, about a 10 fold decrease in sulfate and magnesium net mass fluxes, and approximately a 1000 fold decrease in potassium net mass fluxes.
- The total K flux was very high under all forage treatments during July-December. It reflects the high test level of available K in the experiment site and its previous animal grazing history. The highest net flux of leached K was observed under KY31 followed by NE and OG.
- The total nitrate flux was significantly different under the three forage treatments. Nitrate leaching was highest under the OG treatment during both study periods, followed by NE then KY31. The differences were not significant in December-April.
- Among the different grass treatments, the highest net mass fluxes of leaching cations were observed under KY31. Sulfate leaching under NE was significantly higher than the other grass treatments during July- December while it was significantly different under KY31 during December-April .

SPATIAL CONTINUITY AND TEMPORAL VARIABILITY

Table 1. Semi-variogram model parameters for net nutrient leaching fluxes and their temporal changes.

Forage	Period	Nutrient	Model	Range (m)	Nugget	Sill	Nugget/Sill (%)
OG	7-1-09 to 12-1-09	NO_3^- N	Spherical	39	0.65	0.8	81
		$PO4^{-3}$- P	Spherical	20	0.0002	0.0012	17
		SO_4^{-2}- S	Spherical	20	1.35	2.15	63
		K^+	Nugget effect				
	12-2-09 to 4-8-10	NO_3^- N	Spherical	65	0.06	0.14	43
		$PO4^{-3}$- P	Spherical	30	0.00001	0.00045	2
		SO_4^{-2}- S	Spherical	20	0.015	0.045	33
		K^+	Spherical	15	0.006	0.017	35
KY31	7-1-09 to 12-1-09	NO_3^- N	Spherical	39	0.22	0.47	47
		$PO4^{-3}$- P	Spherical	25	0.0004	0.0012	33
		SO_4^{-2}- S	Spherical	21	0.8	1.55	52
		K^+	Spherical	20	1.80E+04	29000	62
	12-2-09 to 4-8-10	NO_3^- N	Spherical	45	0.1	0.22	45
		$PO4^{-3}$- P	Spherical	30	0.0008	0.0021	38
		SO_4^{-2}- S	Spherical	20	0.01	0.151	7
		K^+	Spherical	40	0.07	0.11	64
NE	7-1-09 to 12-1-09	NO_3^- N	Gaussian	100	0.6	1.1	55
		$PO4^{-3}$- P	Spherical	35	0.0015	0.0021	71
		SO_4^{-2}- S	Spherical	40	1.4	3.9	36
		K^+	Spherical	25	20000	39000	51
	12-2-09 to 4-8-10	NO_3^- N	Nugget effect				
		$PO4^{-3}$- P	Spherical	60	0.0001	0.0002	50
		SO_4^{-2}- S	Nugget effect				
		K^+	Nugget effect				

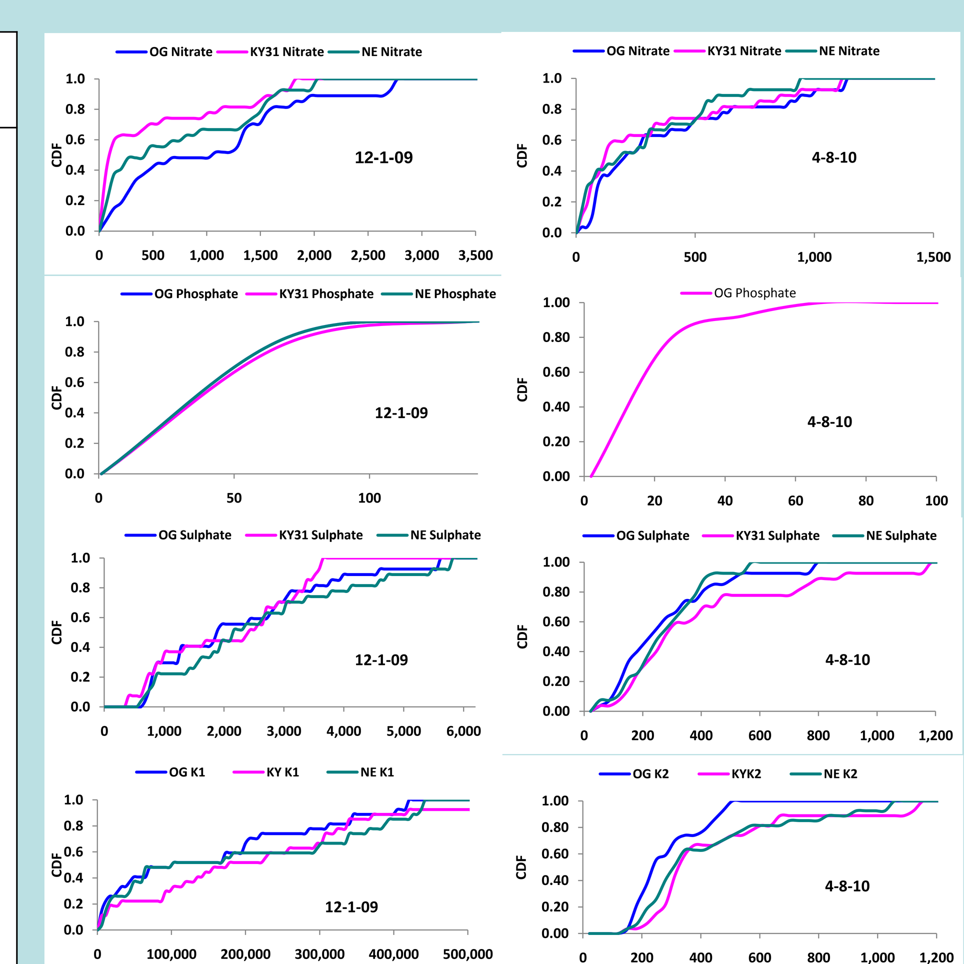

Figure 4. Cumulative distribution function for the nutrient leaching under different grasses during the two studied periods.

- Leached nutrient semi-variogram parameters (Table 1) showed moderate to weak spatial structure with a noticeably high nugget effect, and exhibited short to moderate spatial correlation range of (20 to 40m).
- The pure nugget effect and the weak spatial structure observed for leached potassium, sulfate and Nitrate under OG and NE grass treatments indicated highly heterogeneous flow processes.
- Cumulative distribution function (CDF) (Fig. 4) and Kolmogorov-Smirnov (K-S) test for the spatial patterns of nutrient leaching indicated that leaching patterns of nitrate, phosphate, and potassium were significantly different under the OG grass treatment. The CDF and PDF analysis showed irregular and highly variable nutrient leaching patterns across the space.

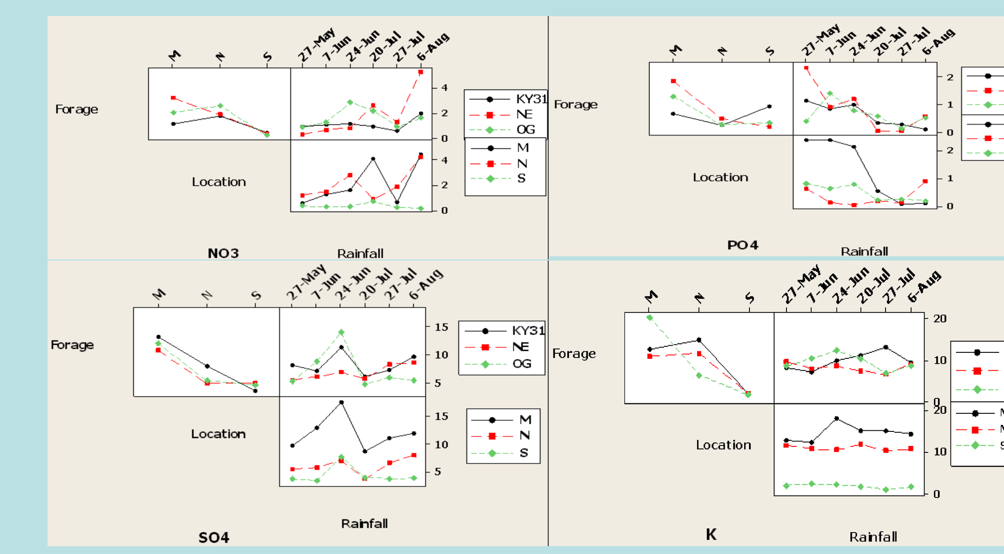

Figure 5. Interaction plot for soil solution chemistry (mg/L) as affected by grass cover, location, and rain event date.

Soil solution chemistry (Fig. 5) from tension lysimeter samples as affected by forage type, location, and rainfall date showed that shallow ground water is potentially vulnerable to contamination in the middle location of all forage treatments. GLM analysis indicated that the concentration of NO_3^-, SO_4^{2-}, and PO_4^{3-} was significantly affected by the location and the amount of rainfall, while the potassium concentration was significantly affected by the topographic location.

CONCLUSIONS

- Significant differences in spatial and temporal nutrient leaching were observed under different forage species indicating an effect of the forage type on the nutrient leaching potential.
- There is potential vulnerability for shallow ground water contamination under the sinkhole area for all forage treatments specially in wet seasons.
- Endophyte infection seems to slow mineralization rates and reduce the nitrate leaching fluxes.
- The highly variable leaching patterns under different grass treatments and its log normal distribution indicate quasi-preferential flow paths and strongly heterogeneous flux rates.

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