Soil Gas Diffusivity and Air-filled Porosity and Their Spatial Patterns in Crop and Grass Systems

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1. Introduction

- Soil gas diffusivity and air-filled porosity are important indicators of soil structure and soil aeration status.
- Soil gas diffusivity is an important characteristic for roots and microbial respiration and gas exchanges with atmosphere.
- Land use affects soil gas diffusivity and air-filled porosity.
- Soil gas diffusivity and air-filled porosity exhibit high variation in space and their spatial patterns in crop and grass land-use systems have not been investigated.

Objectives

- Quantify soil gas diffusivity and air-filled porosity in crop and grass systems
- Characterize their spatial patterns in crop and grass systems

2. Methods and Materials

- The research site (75m x 55m) had two established land-use systems (Fig. 1a) on Bluegrass-Maury silt loam (typic paleudalf) soil with 2-6 % slope.
- Sixty undisturbed soil cores (342 cm^3) were taken at 4 - 10 cm depth from four transects with 1 m and 5 m distance separations (Fig. 1a).
- Oxygen diffusivity was measured in the lab using a chamber (Fig. 1b) similar to that described by Rolston (1986) with O_2 measurements taken at 30-min intervals.
- The gas diffusion coefficient was estimated for soil samples at -0.1, -0.5, -1.0, -3.3, and -10.0 m of soil water pressure heads, which were controlled using a pressure plate apparatus.
- Soil gas diffusion coefficient is reported at a reference air temperature (20 ºC).
- Soil gas diffusivity is reported as oxygen diffusion coefficient in soil relative to diffusion coefficient of oxygen in air (12.18 cm^2 min^{-1}).
- Air-filled porosity was estimated from total porosity and volumetric water content at each matric potential.
- Semivariogram (Eqn. 1) analysis was used to quantify the continuity and the spatial behavior of gas diffusivity and air-filled porosity across the field.

$$\gamma(h) = \frac{1}{2N(h)}\sum_{i=1}^{N(h)}[A_i(x_i) - A_i(x_i + h)]^2 \qquad (1)$$

where $\gamma(h)$ refers to semivariance, N to number of pairs of a variable A_i at location x_i and separated by lag distance h.

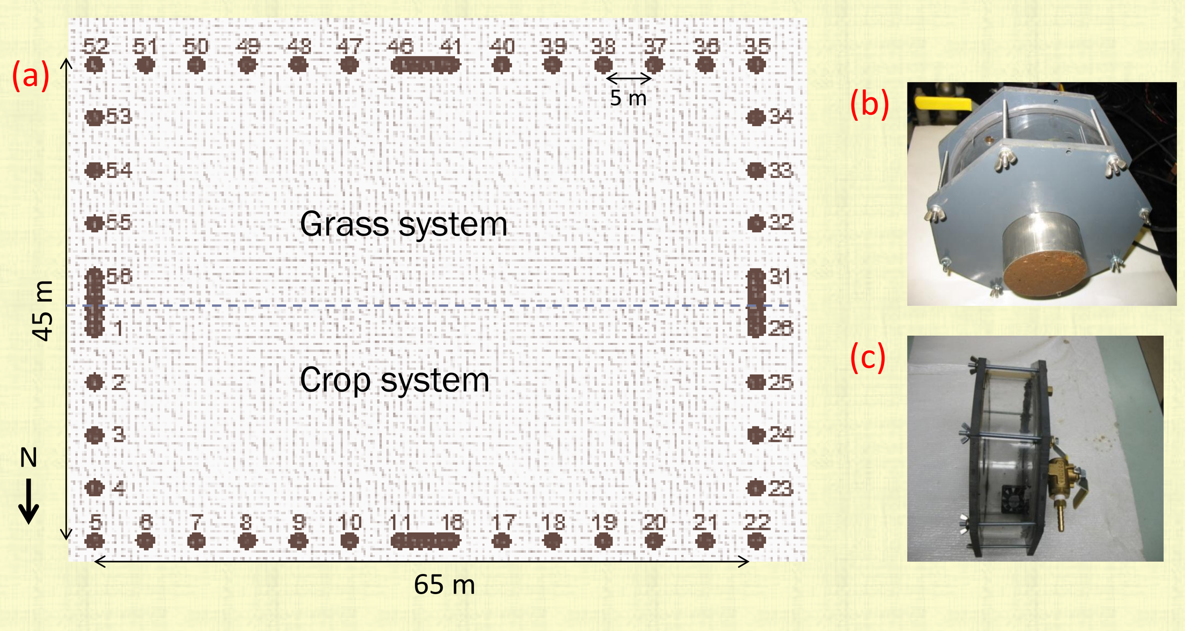

Fig. 1: Study site showing the two land-use systems (crop and grass) and 60 sampling points along four transects (a), a gas diffusion chamber (b,c).

3. Results

3.1. Quantifying gas diffusivity and air-filled porosity

- Soil relative gas diffusivity was higher in the grass system than in the crop system at all five soil matric potentials.
- Relative gas diffusivity and air filled porosity increased with decreasing soil matric potential in crop and grass systems.
- Geometric mean of air-filled porosity in the grass system was higher than in the crop system at all matric potentials except at -0.1 m (Fig. 2).
- At the same air-filled porosity, grass system exhibited higher relative gas diffusivity than crop system (Fig. 3).

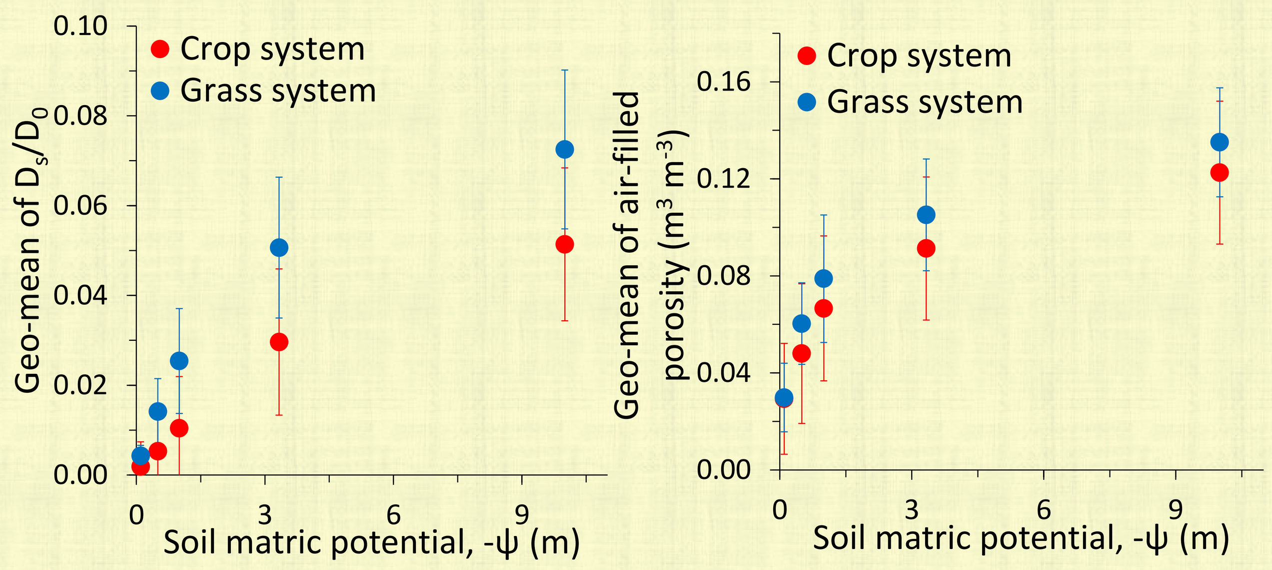

Fig. 2: Geometric means of relative gas diffusivity and air-filled porosity in crop and grass systems at different soil matric potentials. Bars indicate standard deviation.

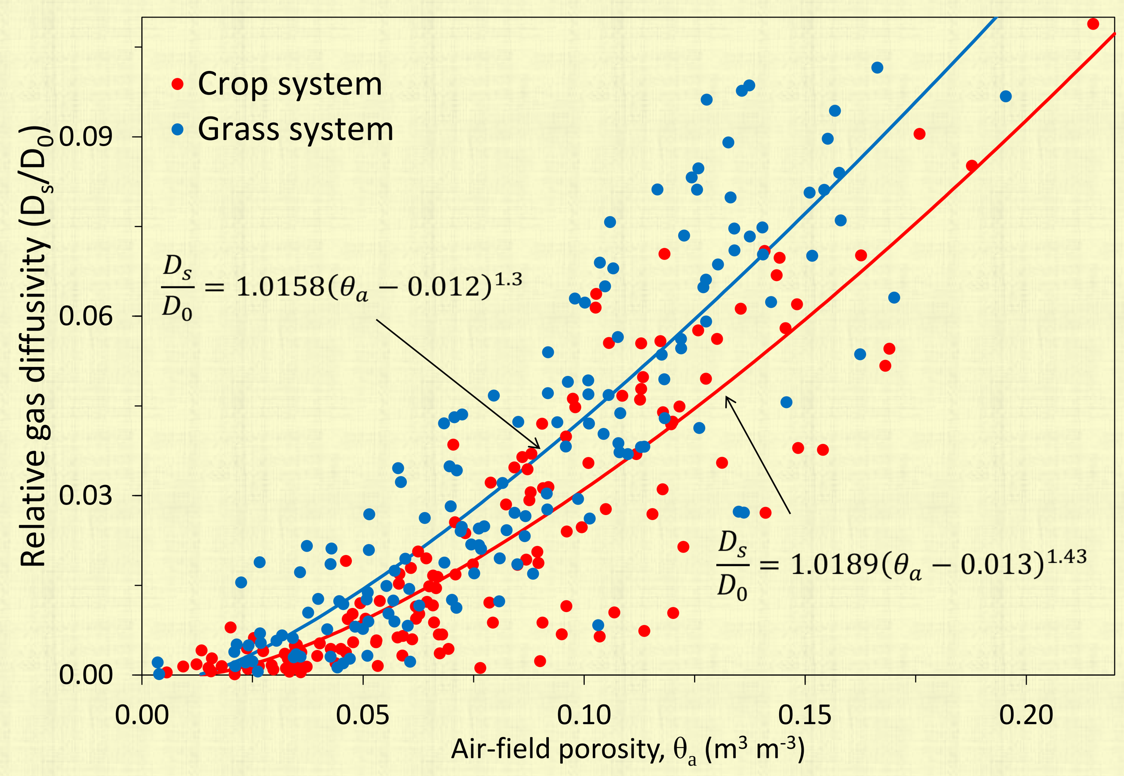

Fig. 3: Relative gas diffusivity as a function of air-filled porosity θ_a in crop and grass systems measured at five soil water matric potentials: -0.1, -0.5, -1.0, -3.3, and -10 m.

3.2. Spatial behavior of gas diffusivity and air-filled porosity

- CVs of relative gas diffusivity and air-filled porosity were higher in the crop system than in the grass system (Fig. 4).
- Spatial variation of relative gas diffusivity and air-filled porosity decreased as soil matric potentials decreased.

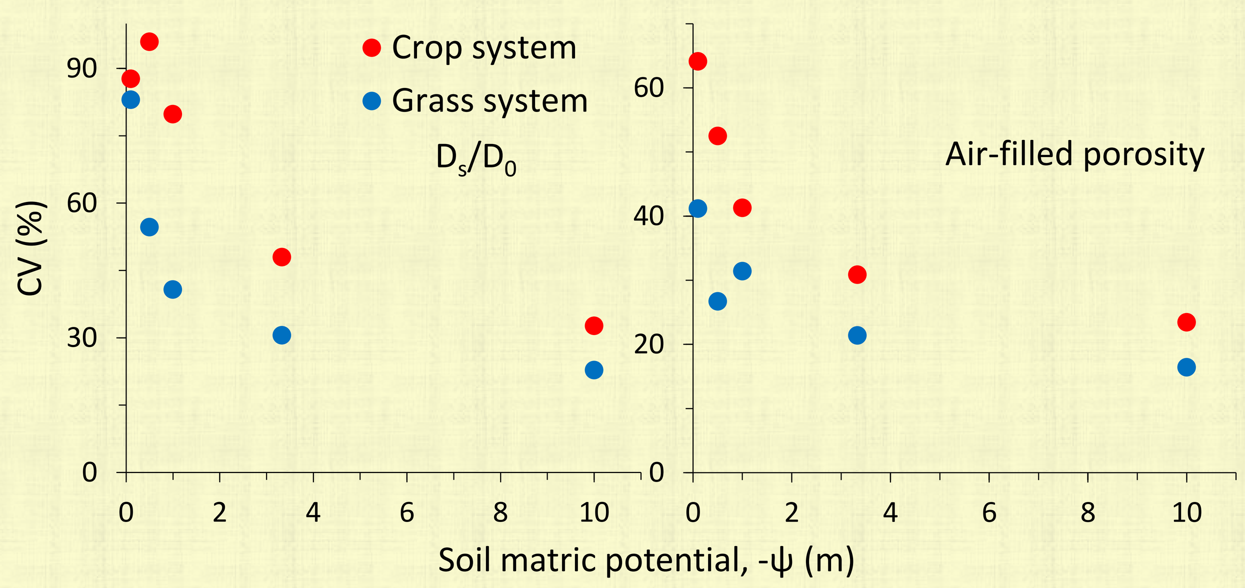

Fig. 4: Spatial coefficient of variation (CV) of relative gas diffusivity and air-filled porosity in crop and grass systems at different soil matric potentials.

- Spatial variability of relative gas diffusivity was structured at all soil matric potentials in both crop and grass systems.
- Nugget semivariance of relative gas diffusivity was low at all matric potentials in both land-use systems (Table 1).
- Nugget-to-sill ratio of relative gas diffusivity was lower in the crop system than in the grass system.
- Range of relative gas diffusivity was longer in the grass system than in the crop system at all matric potentials which was evident from the higher and more homogeneous relative gas diffusivity in the grass system.
- Soil in the grass system had larger pores and less tortuous pore paths than in the crop system which caused higher spatial dependency of gas diffusivity in the grass system.

Table 1: Semivariogram parameters of relative gas diffusion coefficients in crop and grass systems at different soil matric potentials.

	Crop system			Grass system		
Ψ (m)	Range (m)	Nugget	Nugget-to-sill ratio	Range (m)	Nugget	Nugget-to-sill ratio
-0.1	4.7	0.0	0.00	22.5	4×10^{-5}	0.34
-0.5	6.4	0.0	0.00	7.0	3.6×10^{-5}	0.39
-1.0	4.4	0.0	0.00	30.4	1.2×10^{-5}	0.07
-3.3	8.1	0.0	0.00	12.7	0.0	0.00
-10.0	8.0	1×10^{-4}	0.44	15.3	2×10^{-4}	0.67

- Spatial variability of air-filled porosity was structured at all matric potentials in the crop and grass systems except at -1.0 and -0.1 m in the grass system.
- Nugget semivariance of air-filled porosity was low in both land-use systems (Table 2).
- Nugget-to-sill ratio was higher in the grass system than in the crop system at all matric potentials except at -0.5 and -10 m.
- Correlation length of air-filled porosity varied with matric potential in both land-use systems but it was longer in the crop system except at -3.3 m matric potential.

Table 2: Semivariogram parameters of air-filled porosity in crop and grass systems at different soil matric potentials.

	Crop system			Grass system		
Ψ (m)	Range (m)	Nugget (m^3 m^{-3})^2	Nugget-to - sill ratio	Range (m)	Nugget (m^3 m^{-3})^2	Nugget-to - sill ratio
-0.1	17.5	2×10^{-4}	0.55	-	2×10^{-4}	1.00
-0.5	12.8	4×10^{-4}	0.60	5.3	0.0	0.00
-1.0	16.1	3×10^{-4}	0.37	-	5×10^{-4}	1.00
-3.3	11.7	3×10^{-4}	0.38	13.0	3×10^{-4}	0.61
-10.0	16.8	4×10^{-4}	0.43	7.1	2×10^{-4}	0.43

4. Conclusions

- The grass system had generally higher spatial dependency of soil gas diffusivity but lower spatial dependency of air-filled porosity than the crop system.
- The pore size distribution and geometry affected the field scale spatial behavior of gas diffusivity and air-filled porosity.
- Spatial processes should be considered when soil gas diffusivity is predicted from air-filled porosity.

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Reference

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