Spatial and Temporal Patterns of CO_2 Flux in Crop and Grass Systems

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1. Introduction

- Carbon dioxide flux from soil is an important component of the soil carbon cycle.
- Soil respiration exhibits high variation in space and time.
- Significant spatial variability contributes to the lack of understanding of CO_2 flux.
- Assessing the space-time behavior of soil respiration in different land-use systems requires quantifying the variability structure and its dynamics.

Objectives

- Quantify soil respiration in crop and grass systems.
- Characterize spatial and temporal patterns of CO_2 flux in crop and grass systems.

2. Methods and Materials

- *In situ* CO_2 flux was measured 22 times (June 2010 to June 2011) in two-week intervals at 60 locations (Fig. 1a) distributed in crop and grass systems.
- Spatially nested approach with 1 m and 5 m sampling intervals (Fig. 1a).
- Bluegrass-Maury silt loam (typic paleudalf) (2-6% slope) soil.
- Annual precipitation 976 mm in 2010 and 1677 mm in 2011; and average air temperature 13.2 ºC in 2010 and 13.6 ºC in 2011.
- A closed chamber method was used in combination with a photoacoustic environmental gas monitor (Fig. 1b and c) to measure soil respiration.
- CO_2 flux was adjusted based on the linear relation of CO_2 flux over time to remove the daily temporal trend of CO_2 flux.
- Semivariogram (Eqn. 1) analysis was used to quantify spatial and temporal variability.

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

where $\gamma(h)$ refers to semivariance, N to number of pairs of CO_2 flux A_i at location x_i and separated by lag distance h.

- Semivariogram parameters, nugget, sill, and range, were used to quantify and compare the spatial and temporal behaviors in crop and grass systems.

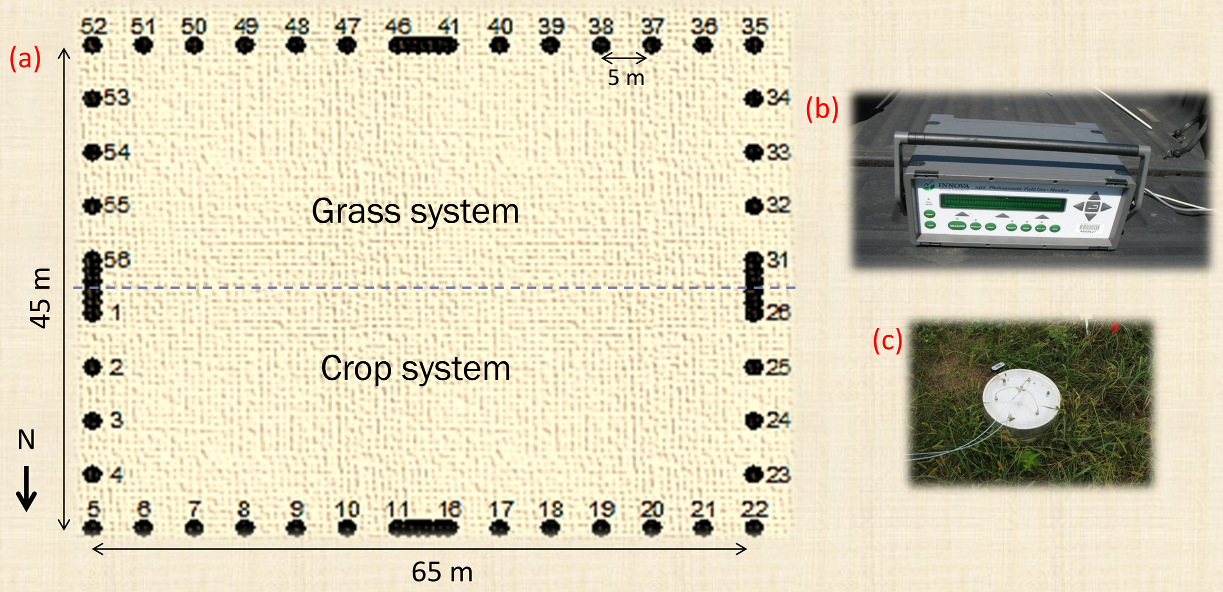

Fig. 1: Study site showing two land-use systems (crop and grass) and 60 sampling points along four transects (a), a gas monitor (b), and a collar with a chamber (c).

3. Results

3.1 Field observations of CO_2 flux

- CO_2 flux varied between 0.0 and 36.7 mg CO_2 m^{-2} min^{-1} among all sampling locations during the study period.
- Soil respiration was the highest during the warm-moist season and lower during the warm-dry or cool-wet season (Fig. 2).
- Soil respiration was slightly higher in the grass system than in the crop system.

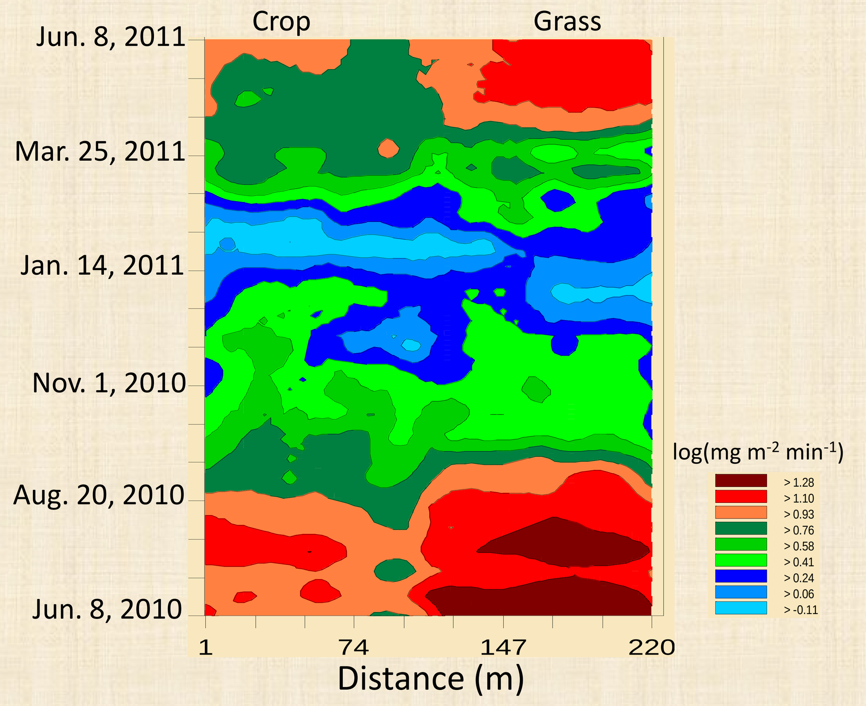

Fig. 2: Distributions of $\log_{10}$-transformed CO_2 fluxes in space and time in crop and grass systems.

3.2. Spatial behavior of CO_2 flux in time

- Soil respiration showed high variation with space in both land-use systems (Fig. 2).
- CVs of log-transformed CO_2 flux proceeded at lower levels during warm-moist months than in the warm-dry or cold-wet season in both land-use systems (Fig. 3).
- Carbon dioxide fluxes were more variable in the crop system than in the grass system.

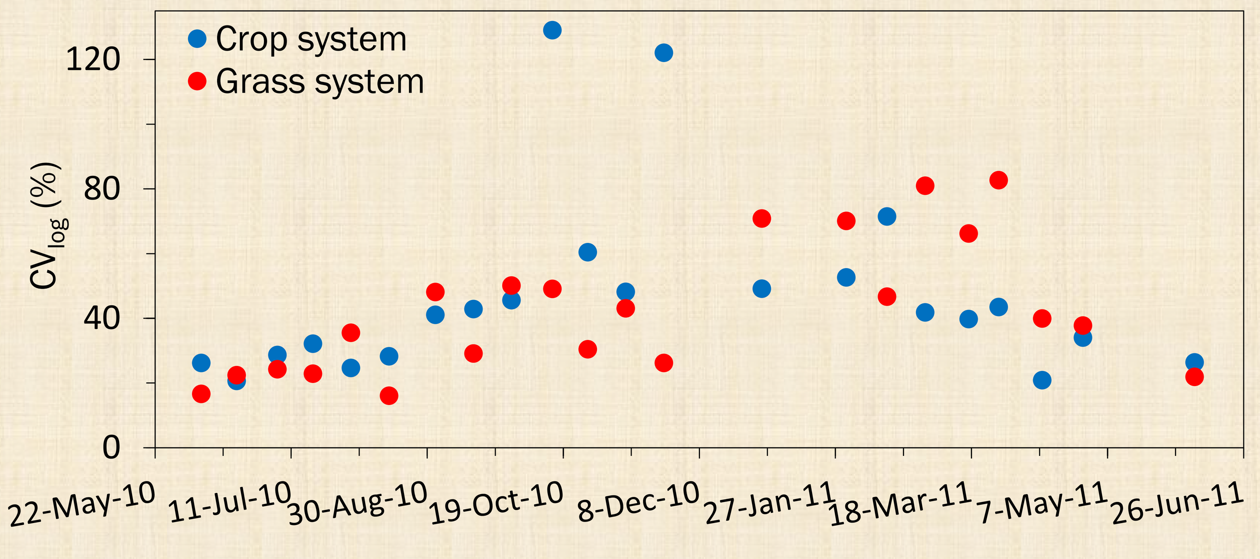

Fig. 3: Distribution of coefficient of variation of CO_2 flux with time in crop and grass systems.

- Spatial nugget semivariance was relatively higher during colder months than warmer months in both land-use systems (Fig. 4a).
- Spatial nugget-sill ratio was moderate and similar in both land-use systems (Fig. 4b).
- Spatial correlation lengths of CO_2 flux were generally longer in the grass system (average of 33 m) than in the crop system (average of 23 m) (Fig. 4c).
- CO_2 fluxes in the grass system exhibited higher spatial dependency than in the crop system, which was evident from the higher and more homogeneous flux observed in the grass system.

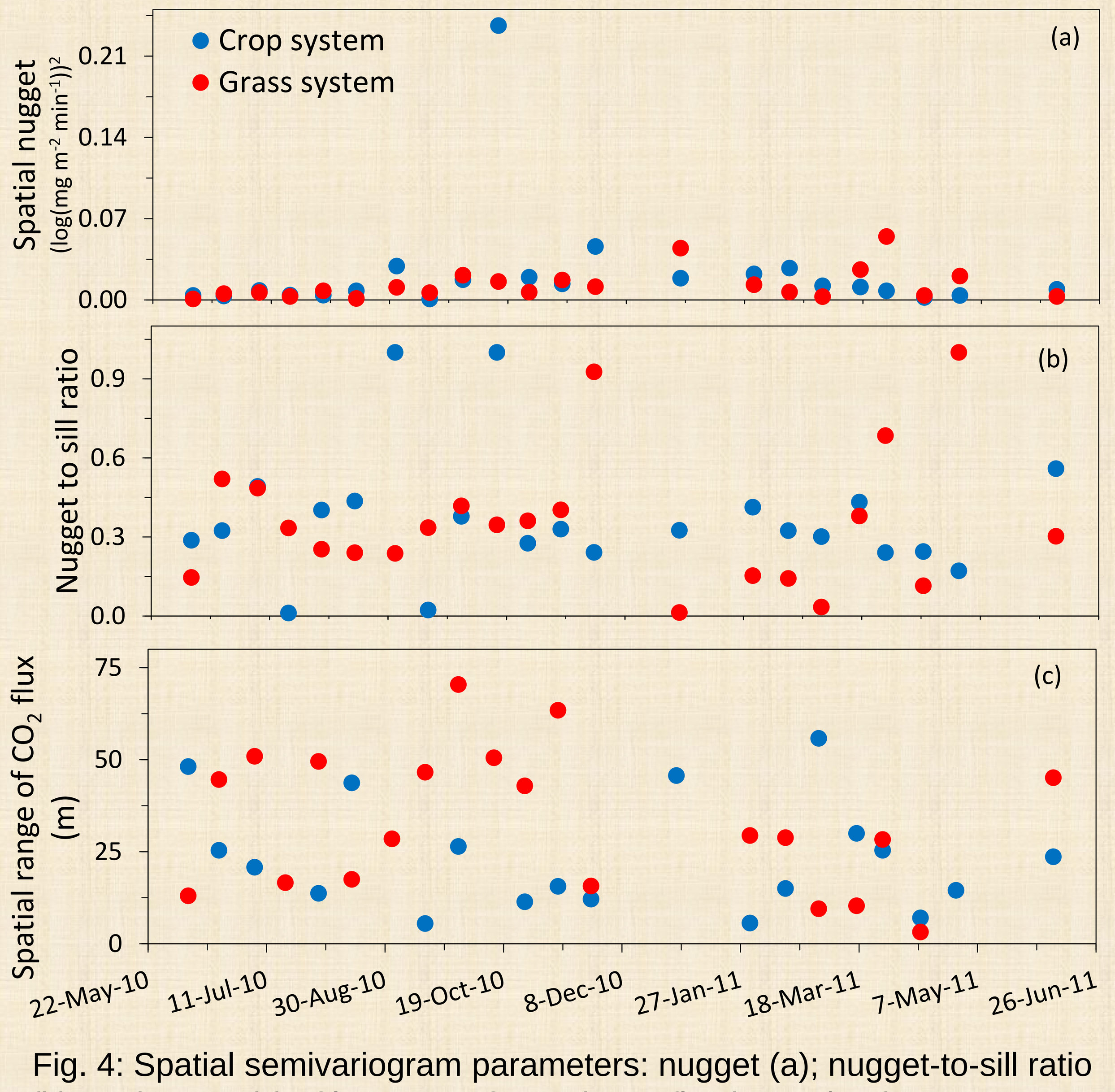

Fig. 4: Spatial semivariogram parameters: nugget (a); nugget-to-sill ratio (b); and range (c) of $\log_{10}$-transformed CO_2 flux in two land-use systems.

3.3. Temporal behavior of CO_2 flux in space

- Soil respiration exhibited high temporal variation in both land-use systems (Fig. 2).
- Under the same climatic conditions, the temporal variability of CO_2 flux slightly differed in the crop system relative to the grass system with higher CVs in the grass system (Fig. 5).
- The CVs were higher under both land-use systems in the temporal domain than in the spatial domain.

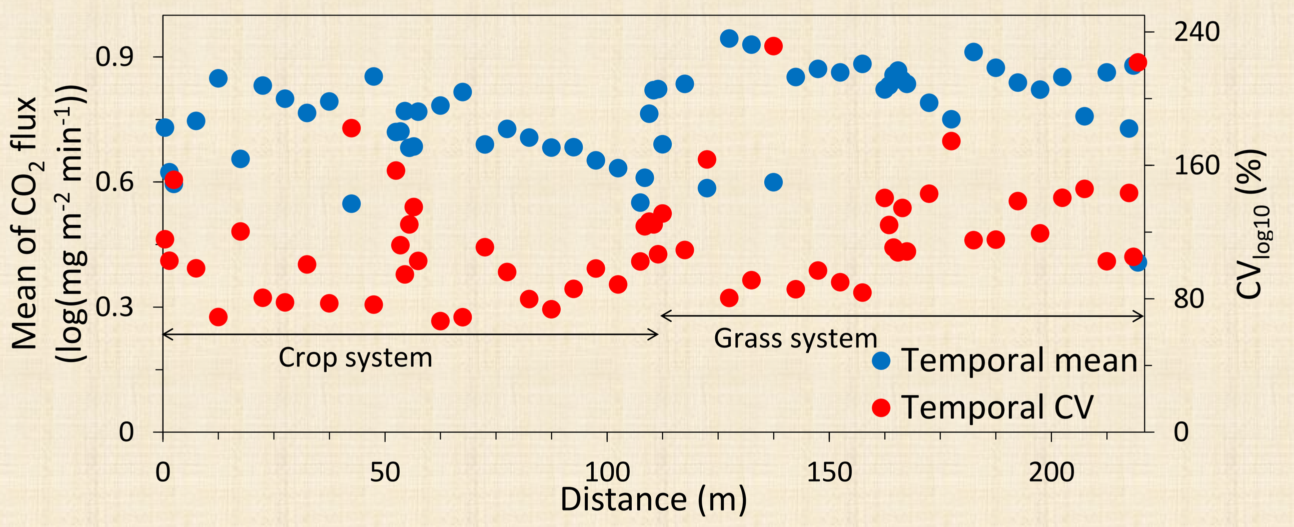

Fig. 5: Temporal mean and coefficient of variation of CO_2 flux in crop and grass systems.

- Temporal nugget semivariance was higher and more variable in the crop system than in the grass system (Fig. 6a).
- Temporal nugget-sill ratio was relatively small in both land-use systems but higher and more variable in the crop system.
- The two land-use systems had long temporal correlation lengths (ranges) (Fig. 6b) and the grass system had a longer mean temporal range than the crop system.
- Higher and more homogeneous CO_2 fluxes in the grass system relative to the crop system explain the longer temporal correlation lengths of soil respiration in the grass system.

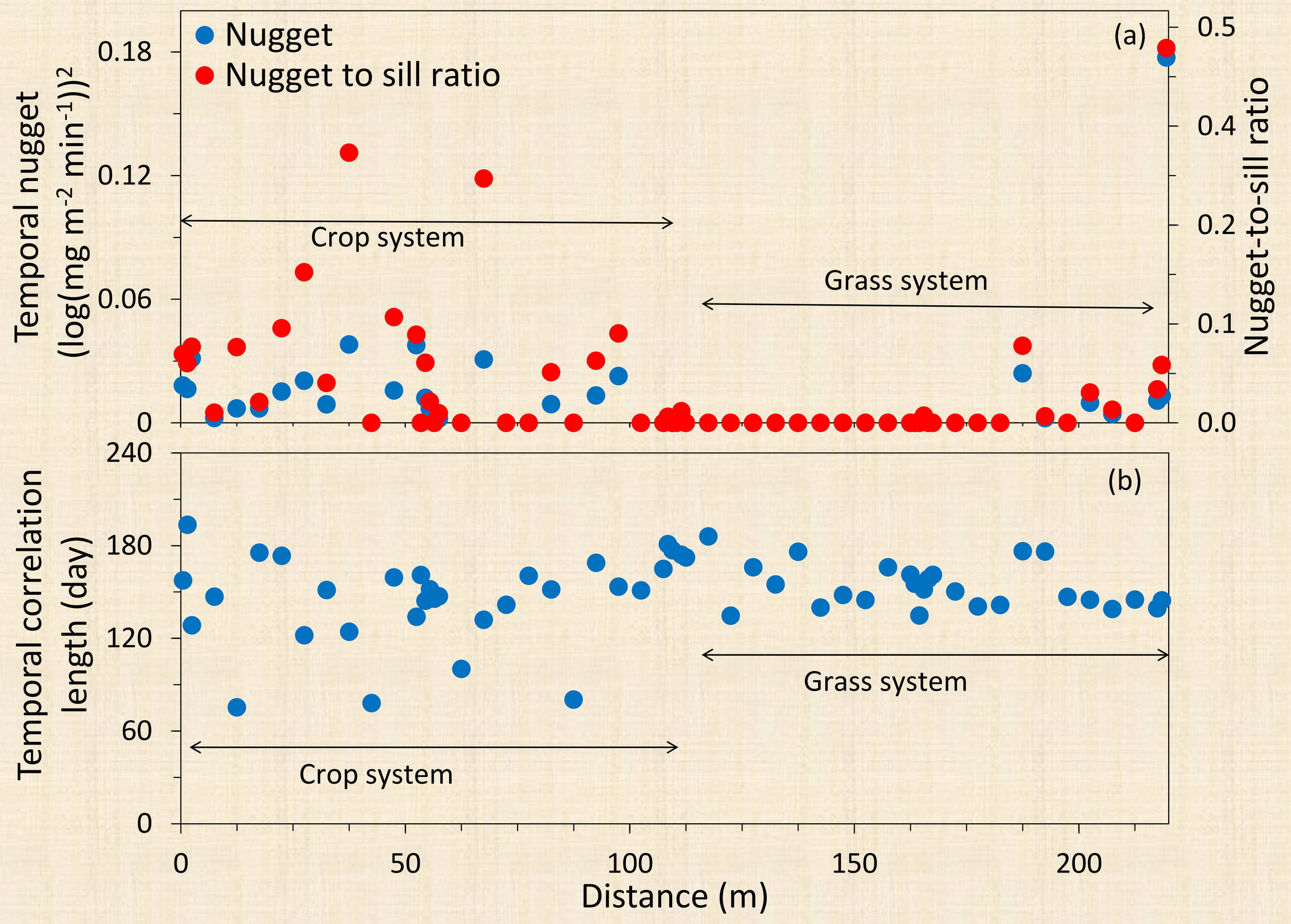

Fig. 6: Temporal semivariogram parameters: nugget and nugget-to-sill ratio (a) and range (b) of $\log_{10}$-transformed CO_2 fluxes in crop and grass systems.

4. Conclusions

- Soil respiration exhibited structured spatial and temporal variability with longer spatial and temporal correlation lengths in the grass system.
- Land-use affects small scale spatial and temporal variability dynamics of soil respiration. These dynamics should be taken into account for experiment design, spatial and temporal associations with other variables, geostatistical mapping, carbon loss prediction, and data interpretation.

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