Ecosystem CO_2 Exchange in a Mixed-Grass Prairie

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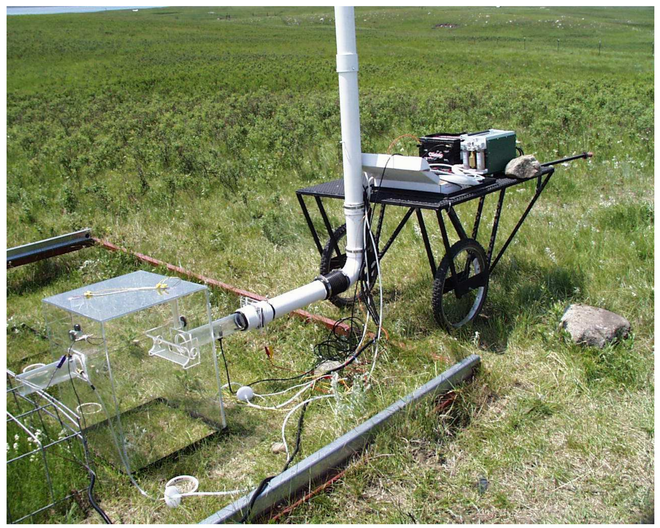
Research Problem and Objectives

- Problem–*Quantifying ecosystem carbon exchange:*
  - Provides basis for modeling biomass production;
  - Provides site/scenario specific dataset for the evaluation of ecosystem functioning.
- Objectives– *Daily net ecosystem CO_2 exchange rate:*
  - What were the seasonal trends?
  - What was the effect of grazing intensity?
  - What was the effect of drought?

Field Measurements

- Drought treatment was imposed using a set of automatic rain-out-shelters.
- Canopy photosynthesis was measured using a plastic chamber (44.5 cm long × 44.5 cm wide × 60 cm high) attached to a LI-6400 Photosynthesis System.
- Nighttime soil respiration was measured using a 6400-09 Soil CO_2 Flux Chamber attached to a LI-6400 Photosynthesis System.

Measuring Canopy CO_2 flux



Sample Data of Photosynthesis and Respiration

Gross canopy photosynthesis (μmol CO_2 m^{-2} s^{-1}) was calculated by $GPh_i = \frac{J_i\alpha + P_m - \sqrt{(\alpha J_i + P_m)^2 - 4\theta\alpha J_i P_m}}{2\theta}$, where J_i is the photosynthetic photon flux density (PPFD) (μmol photon m^{-2} s^{-1}) of hour i ($i = 1, 2, ..., 24$) within a day; α is the photosynthetic efficiency; P_m is the maximum photosynthesis (μmol CO_2 m^{-2} s^{-1}); and θ is the photosynthesis sharpness parameter (Figure 1). Soil respiration rate for hour i of a day, R_i (μmol CO_2 m^{-2} s^{-1}), was calculated using an empirical sin function:

$$R_i = (\frac{R_x - R_n}{2}) \times (-1.01) \times sin(\frac{\pi}{24} \times 2.08 \times (i - t_m) + 1.45) + R_n + (\frac{R_x - R_n}{2}),$$

where R_x is the maximum soil respiration rate (μmol CO_2 m^{-2} s^{-1}); R_n is the minimum soil respiration rate (μmol CO_2 m^{-2} s^{-1}); t_m is a factor determining diurnal peak of soil respiration; and $t_m = 3.5 \Leftrightarrow$ soil respiration peaks at 3:30 pm (Figure 2).

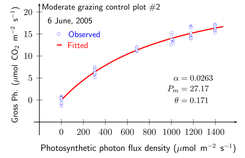


Figure 1: A sample photosynthesis-light curve.

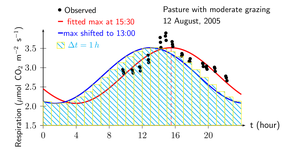


Figure 2: Soil respiration: observed vs. fitted.

Results

Table 1: Daily net ecosystem CO_2 exchange of grasslands (mol CO_2 m^{-2} day^{-1}).

Source	*M*	*GI*	*SD*	*M* ∗ *GI*	*M* ∗ *SD*	*GI* ∗ *SD*	*M* ∗ *GI* ∗ *SD*
2004	0.062	0.492	**0.043**	**0.012**	0.642	0.426	0.771
2005		0.669	0.852			0.32	

- The 3 factors are defined as GI: Grazing intensity; SD: Simulated drought; M: Month.
- The effect of "Month" was not evaluated in 2005, because the measurements were occasionally interrupted due to adverse weather conditions.

Table 2: Daily net ecosystem CO_2 exchange of grasslands (mol CO_2 m^{-2} day^{-1}).

Treatment	2004 (*2nd year of drought*)	2005 (*drought removed*)
Average rainfall	**0.33a**	0.08*a*
Natural rainfall	0.22*ab*	0.08*a*
Drought	**0.14b**	0.05*a*

- Numbers with different letters in a same column are statistically different at $p = 0.05$.
- Average rainfall: Long-term average rainfall.
  Drought: 75% of long-term average rainfall.

Effects of Grazing and Month

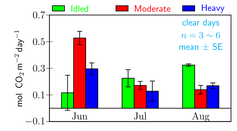


Figure 3: Daily net ecosystem CO_2 exchange (2004).

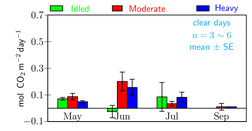


Figure 4: Daily net ecosystem CO_2 exchange (2005).

Daily CO_2 Exchange

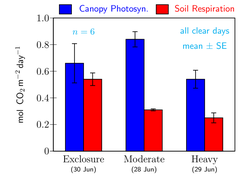


Figure 5: Daily photosynthesis & soil respiration (2004).

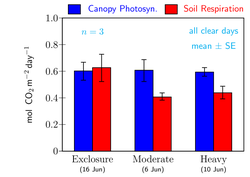


Figure 6: Daily photosynthesis & soil respiration (2005).

Conclusions

1. Effect of Season
   - Overall, the net ecosystem CO_2 exchange rate showed an increasing-then-decreasing seasonal trend that peaked in June.
   - However, in the idled land (no-grazing), the more positive net CO_2 gain shifted to later months (to August in 2004 and July in 2005).
2. Effect of Drought
   - In 2004, the estimated daily net CO_2 exchange in the Missouri Coteau grasslands was affected by drought stress, with drought treatment (75% of the average rainfall) causing a 58% reduction in net daily CO_2 exchange compared with the average rainfall treatment.
   - In 2005, with the removal of the drought treatment, the net ecosystem CO_2 exchange rate was similar for the field plots that had experienced different drought treatments in the previous two years.
3. Effect of Grazing
   - The main effect of grazing intensity on ecosystem CO_2 exchange was not significant for the whole grazing season;
   - However, in June, when the grassland plants were most active in physiology, the moderately grazed grassland showed a more positive net CO_2 gain than did the idled land, for which ecosystem respiration can be comparable to the increase in photosynthesis.

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