Impact of grazing on carbon dioxide flux exchanges in an intensively managed grassland

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1. OBJECTIVES
To analyze grazing impact on carbon dioxide (CO2) fluxes (F) measured by eddy covariance over a Belgian meadow,
To look at both long-term and short-term grazing impact.

2. EXPERIMENTAL SITE
- **Situation**: Belgium, Domine Terrestrial Observatory (DTO), 15°0’18”N; 4°58’07”E; 248 m asl.
- **Climate**: temperate oceanic (TA: 10°C; PPT: 800 mm).
- **Type**: permanent grassland.
- **Surface**: 4.2 ha.
- **Slope**: moderate (1 to 2 %).
- **Ruminant livestock system**: intensive (= 2 LU ha⁻¹).
- **Breed of cattle**: Belgian Blue.

3. METHODS

3.1 Long- and short-term effects of grazing
- **Long-term effects**: > biomass consumption by cattle and from cattle effluents modifying assimilation and respiration fluxes.
  This could only be quantified by comparing fluxes before and after grazing periods.
- **Short-term effects**: > livestock CO2 emissions (F\text{CO}_2\text{,livestock}) that are part of Total Ecosystem Respiration (TER) and should be measured in its presence in the field.

3.2 Datasets
- **Dataset I**: long-term effects \(\rightarrow\) 2 complete years of eddy covariance measurements made at the DTO (only data from the growing seasons).
- **Dataset II**: short-term effects \(\rightarrow\) livestock confinement experiments.

4. RESULTS

4.1 Long-term effects
Figure 2: Response of a) accumulated carbon dioxide flux (\(F\text{CO}_2\)) and b) \(\Delta GPP\) (difference between the last and first 5-day window regression parameters for grazing and non-grazing periods as grazing intensity.

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**Analysis:**
1) **Figure 2a**: cumulated \(F\text{CO}_2\) ↑ with grazing intensity but the trend was not significant.
2) **Figure 2b**: gross photosynthetic capacity ↓ significantly with grazing intensity, suggesting that the presence of cattle affected grass assimilation capacity.
3) **Figure 2c**: no significant impact of grazing intensity on \(R_{\text{ הד}}\).

**Conclusion:**
1) Response blurred by responses to climatic variables: radiation, soil temperature, drought. This suggested that the grazing cycle effects on \(F\text{CO}_2\) are not dramatic at the ecosystem scale.
2) Decreases during grazing periods: > aboveground biomass ↓ due to defoliation by grazing \(\rightarrow\) plant assimilation ↓
   - Increases during non-grazing periods: > biomass re-growth.
   - Significant impact of grazing intensity: \(\Delta GPP_{\text{max}}\) ↓ by 0.08 µmol m⁻² s⁻¹ for each LU ha⁻¹ day⁻¹.
3) No significant \(R_{\text{כד}}\) response to grazing intensity due to the combination of contradictory effects: ↓ autotrophic plant respiration and ↑ heterotrophic respiration.

4.3 Short-term effects
- **Analyzing and comparing CO2 fluxes between grazing and non-grazing periods** \(\rightarrow\) dataset I divided into different intervals corresponding to grazing or non-grazing periods:
  1) Response of cumulated gap-filled \(F\text{CO}_2\) calculated for each period to grazing intensity.
  2) Response of the differences between parameters of interest of the last and first 5-day windows in each grazing or non-grazing period to grazing intensity. Parameters of interest were obtained by fitting a 5-day window \(F\text{CO}_2\) - PPFD relationship on daytime eddy covariance measurements.

3.4 Short-term effects
- **Confinement experiment = 2 successive days**:
  1) Cattle day: cattle (≈ 26 LU ha⁻¹) confined in the main wind direction area of the eddy covariance set up (1.76 ha, Figure 1),
  2) No-cattle day: removed from it.
- **3 independent estimations of \(F\text{CO}_2\text{,livestock}\)**:
  1) > nighttime eddy covariance measurements (\(F\text{CO}_2\text{,night}\)),
  2) > daytime eddy covariance measurements (\(F\text{CO}_2\text{,day}\)),
  3) Comparison of filtered half-hourly \(F\text{CO}_2\text{,measurements made at 24h interval.}

- **Similar environmental conditions**:
  - Air temperature within 3°C,
  - Wind speed within 3 m s⁻¹,
  - Radiation within 75 µmol m⁻² s⁻¹,
  - Wind direction within confinement area.
- **Carbon intake measurements**:
  \(F\text{CO}_2\text{,livestock} = \text{OMD} \times \text{C intake} - F\text{CH}_4\text{,c} - F\text{product}\)
  - OMD (%) = organic matter digestibility,
  - C intake (kg C ha⁻¹ d⁻¹) = carbon intake,
  - \(F\text{CH}_4\text{,c} = \text{kg C ha⁻¹ d}^{-1}\) = lost through methane (\(\text{CH}_4\)) emissions,
  - \(F\text{product} = \text{kg C ha⁻¹ d}^{-1}\) = the lateral organic C fluxes exported as meat.

4.2 Short-term effects

Figure 3: a) Nocturnal CO2 flux evolution, and to discriminate CO2 flux response to radiation over the two successive days with or without cattle confinement in experiments if not III. Above grazing stocking rate for the cattle was 27 LU ha⁻¹. Dataset II was filtered for u and v wind, and environmental conditions were equivalent over the two successive days. Errors bars are the random error of measurement.

**Analysis:**
**Table 1:** results of the confinement experiments.

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<thead>
<tr>
<th></th>
<th>F\text{CO}_2\text{,livestock}</th>
<th>C intake measurements</th>
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<tbody>
<tr>
<td>No cattle</td>
<td>1.67 ± 4.26</td>
<td>0.62 ± 2.28</td>
</tr>
<tr>
<td>C cattle</td>
<td>1.37 ± 4.26</td>
<td>0.62 ± 2.28</td>
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**Conclusion:**
- Confinement experiments allowed us to evaluate \(F\text{CO}_2\text{,livestock}\) directly and to distinguish them from other fluxes.
- Confinement experiments gave reliable results.
- Not possible under normal cattle management because emissions are too small and masked by flux responses to climatic factors.