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Research Paper

Rotational and continuous grazing does not affect the total net ecosystem exchange of a pasture grazed by cattle but modifies CO_2 exchange dynamics

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ABSTRACT

Grassland carbon budgets are known to be greatly dependent on management. In particular, grazing is known to directly affect CO_2 exchange through consumption by plants, cattle respiration, natural fertilisation through excreta, and soil compaction. This study investigates the impact of two grazing methods on the net ecosystem exchange (NEE) dynamics and carbon balance, by measuring CO_2 fluxes using eddy covariance in two adjacent pastures located in southern Belgium during a complete grazing season. Rotational (RG) grazing consists of an alternation of rest periods and short high stock density grazing periods. Continuous grazing (CG) consists of uninterrupted grazing with variable stocking rates. To our knowledge, this is the first study to assess the impact of these grazing methods on total net ecosystem exchange and CO_2 exchange dynamics using eddy covariance. The results showed that NEE dynamics were greatly impacted by the grazing method. Following grazing events on the RG parcel, net CO_2 uptake on the RG parcel was reduced compared to the CG parcel. During the following rest periods, this phenomenon progressively shifted towards a higher assimilation for the RG treatment. This behaviour was attributed to sharp biomass changes in the RG treatment and therefore sharp changes in plant photosynthetic capacity. We found that differences in gross primary productivity at high radiation were strongly correlated to differences in standing biomass. In terms of carbon budgets, no significant difference was observed between the two treatments, neither in cumulative NEE, or in terms of estimated biomass production. The results of our study suggest that we should not expect major benefits in terms of CO_2 uptake from rotational grazing management when compared to continuous grazing management in intensively managed temperate pastures.

1. Introduction

Livestock total greenhouse gas (GHG) emissions represent 14.5% of all anthropogenic GHG emissions (IPCC, 2014), among which cattle production represents 41% of the sector's emissions (Gerber et al., 2013). Therefore, there is a strong need to find and evaluate levers to mitigate these GHG emissions. During the last decade, several studies suggested that grasslands could act as important carbon (C) sinks (Klumpp et al., 2011; Mudge et al., 2011; Peichl et al., 2011; Rutledge et al., 2015; Soussana et al., 2007, 2010) with a notable site to site variability depending on several factors, such as pedoclimatic conditions and management practices. Maintaining and increasing the C sink activity of grasslands by improving their management has been identified as a lever to reduce the sector's GHG emissions (Pellerin et al., 2013; Soussana and Lemaire, 2014).

Grassland C balance and net ecosystem exchange are known to be greatly impacted by management (Smith, 2014; Soussana and Lemaire, 2014). The annual net carbon dioxide ecosystem exchange (annual NEE) is known to be directly impacted by grazing intensity through cattle respiration and indirectly through biomass consumption, natural fertilisation in the form of excreta, and soil compaction (Felber et al., 2016b, 2016a; JérÔme et al., 2014; Rong et al., 2017). The fertilisation rate also affects grassland carbon balance and carbon dioxide (CO_2) flux dynamics (Allard et al., 2007; Ammann et al., 2007; Klumpp et al., 2011; Skinner, 2013). Several studies assessing CO_2 fluxes and total C balance in rotational grazing (Campbell et al., 2015; Felber et al., 2016b; Mudge et al., 2011; Peichl et al., 2011; Rutledge et al., 2015), continuous grazing systems (Allard et al., 2007; Gourlez de la Motte et al., 2016; Klumpp et al., 2011) or both (Soussana et al., 2007) have been carried out. In those studies, grazing impacts on CO_2 exchanges

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were not easy to discern as they were blurred by CO2 flux responses to meteorological variables. Studies comparing CO_2 and C exchanges of both grazing methods in similar pedoclimatic conditions are very scarce (Chan et al., 2010; Cowie et al., 2013; Sanderman et al., 2015). These cited studies investigated the impact of rotational and continuous grazing by comparing direct soil organic carbon (SOC) measurements in different pastures. However, the lack of exactly similar management (stocking rates, fertilization etc.), pedoclimatic conditions and inherent SOC random variability between the investigated farms made differences difficult to analyze.

This research investigates the impact of two conventional cattle grazing methods on the CO_2 flux dynamics and its implication for the C balance. The first method, continuous grazing (CG), consists of uninterrupted grazing with variable stocking rates. It favours the ingestion of growing biomass thereby maintaining a relatively low standing biomass on the field during the whole grazing season. When well managed this method maintains a relatively stable grass height in the field by adjusting the stocking density to forage mass. This common system is not labour intensive and is well adapted to humid grasslands where grass production remains steady. The second method, rotational grazing (RG, also known as multi paddock grazing), consists of an alternation of short grazing periods (around 5 days) with high stocking densities and rest periods. During grazing periods, the forage mass accumulated during the preceding rest period is quickly eaten by the cattle leading to a rapid grass height shortening. This grazing system is commonly used in cattle production and has several advantages. First, it is very easy to keep an ungrazed paddock for harvest and therefore reduce forage loss. It is also easier to adapt the rotations to grass growth and maintain high productivity as well as good animal nutrition. It also facilitates operations such as fertilisation after grazing, scattering of livestock droppings, and the harvest of uneaten biomass because of cattle rejections, flowering etc. On the other hand, rotational grazing requires more workforce than continuous grazing, a good soil carrying capacity, and more drinking infrastructure across paddocks.

The main objectives of this study are to assess the impact of these two grazing methods on CO_2 flux dynamics as well as implications for the C balances. For this, a full grazing season (14th April to 17th November) monitoring of CO_2 turbulent fluxes using the eddy covariance (EC) method was performed simultaneously over two adjacent pastures managed according to these two grazing methods.

2. Material and methods

2.1. Site description and grassland management

This research was performed at the Dorinne Terrestrial Observatory (DTO) (50° 18′ 44″ N; 4° 58′ 07″ E) in southern Belgium. The mean air temperature is 10 °C and annual precipitation is 847 mm. Briefly, the site consists of two adjacent intensive permanent grasslands both similarly managed by the same farmer before the experiment (Fig. 1). The carbon balance and management of one of the pastures has been described in detail in a preceding paper (Gourlez de la Motte et al. (2016)), the second one has been added and fully equipped for the present experiment. Both pastures have been grazed by Belgian Blue cattle and fertilised using organic and mineral fertilisers for more than 40 years. According to the farmer there has been no vegetation restoration for more than 40 years. The grassland species composition is mainly grasses, with legumes and other species. The dominant species are perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). The main wind directions are south-west and north-east. The site used for this study is part of a commercial farm so that stocking rates, fertilization rates and other management practices are, as much as possible, representative of the common practices in beef cattle farms around the region.

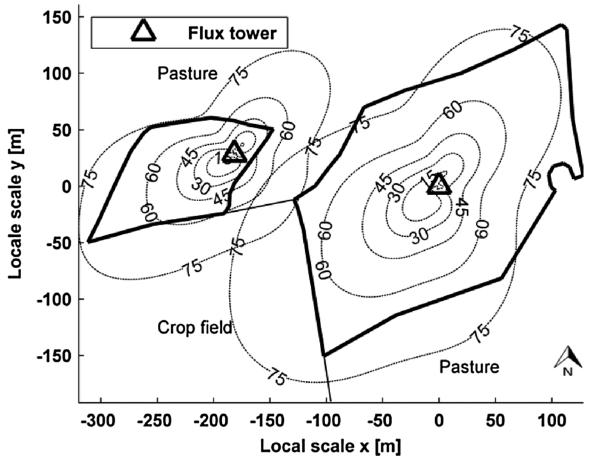

Fig. 1. Plan of the measurement site with both the rotational grazing parcel (RG) and the continuous grazing parcel (CG). Cumulative footprint contributions for the whole measurement season are illustrated by the dashed lines. Contribution levels are given in the labels for each line.

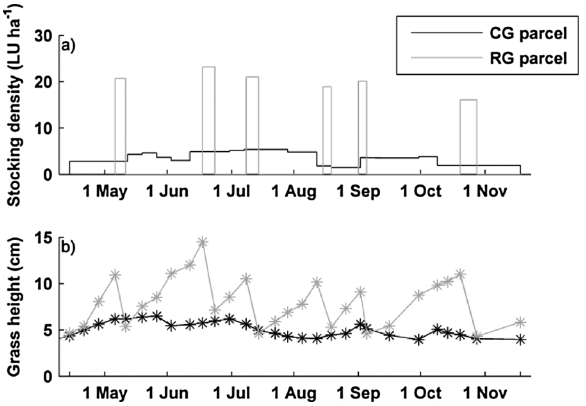

Fig. 2. Cattle stocking density (a) and herbage height (b) throughout the grazing season in the CG and RG parcels. A stocking density of zero designates rest periods.

The continuous grazing treatment (labelled “CG”) was operated on a 4.2 ha pasture. The pasture was fertilised in March 2015 with 7 kg N ha^{-1} just before the beginning of the experiment. The field was continuously grazed from 14th April 2015 to 17th November 2015 (220 days) with a varying stocking rate depending on forage availability and weather conditions (Fig. 2). The annual stocking rate was 2.1 LU ha^{-1}.

In order to simulate rotational grazing (labelled “RG”), a plot of 1 ha was delimited within a bigger pasture for the purpose of the experiment (Fig. 1). The field was grazed with an alternation of high stocking density periods and rest periods (Fig. 2). A total of six grazing periods, each an average of six days with a stocking density of 19.3 LU ha^{-1} were carried out, leading to 36 days of grazing and an average annual stocking rate of 1.9 LU ha^{-1}. The cattle were confined in the parcel when grass height was between 10 and 15 cm. The stocking densities and grazing duration were adapted, so that similar stocking rates were obtained for both treatments with stocking densities and grazing durations in agreement with common practices in the region.

Throughout the paper, all variables labelled “RG” concern the rotational grazing treatment and all variables labelled “CG” concern the continuous grazing. Differences between the two treatments are always calculated as RG–CG and labelled using the symbol “Δ”. The reference unit used for calculating LU is the grazing equivalent of one 600 kg liveweight (LW) adult dairy cow producing 3000 kg of milk annually, without additional concentrated feed (Eurostat, 2013). Breeding bulls and suckler cows correspond to 1 LU, and heifers and calves to 0.6 and 0.4 LU, respectively.