CARBON BALANCE OF A GRAZED GRASSLAND IN BELGIUM

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INTRODUCTION

By emitting about 20% of total greenhouse gases (GHG), livestock production systems widely contribute to climate change (Steinfield et al., 2006). Since agricultural management is one of the key drivers of GHG fluxes (Soussana et al., 2007), there is considerable potential to reduce emissions.

Livestock production systems, primarily based on ruminants, are intimately linked to grasslands. Indeed, most of the grasslands in Europe are used to provide ruminants with fodder, either directly in the field during grazing season, or as hay or silage during the winter (Flechard et al., 2007). Of the three GHG that are exchanged by grasslands, carbon dioxide (CO_2) is exchanged with the soil and vegetation, nitrous oxide (N_2O) is exchanged with the soil and methane (CH_4) is emitted by livestock at grazing and can be exchanged with the soil (Soussana et al., 2007). So, grasslands can play an important role in reducing emissions, for example by sequestrating carbon (C) in soils.

There are only few studies that measured GHG fluxes at field scale (Soussana et al., 2007; Schulze et al., 2009). In Belgium, that kind of research has not been made yet and many uncertainties still remain on GHG balance of grasslands. This paper presents the C budget of a grassland grazed by the 'Blanc Bleu Belge' breed of cattle. This work is the core of a project funded by the DGARNE (Direction Générale Opérationnelle de l'Agriculture, des Ressources naturelles et de L'Environnement - Walloon Region) whose objectives are *i)* to assess carbon and GHG balance of the grassland, *ii)* to propose mitigation scenarios in order to improve the GHG balance and thus contribute to the sustainability of this kind of livestock production systems in the Walloon Region.

MATERIAL AND METHODS

Site description

The site is located at Dorinne in the Belgian Condroz (50° 18' 44" N; 4° 58' 07" E; 248 m asl.). The region is characterized by a temperate oceanic climate. The mean annual temperature is 10°C and the annual precipitation is 800 mm. The site is permanent grassland of ca. 4.2 ha with a moderate slope of 1 to 2 %.

Grassland management

The plot was subjected to intensive management. A detailed list of management activities is given in Table 1. In 2010, the paddock was rotationally grazed from 12 June to 22 November by Belgian Blue heifers sometimes with a Taurus of the same breed. Rotation between grazing and non grazing periods depended on the herbage growth and its consumption by cattle and was influenced by climatic conditions. Also, complementary feeding had to be distributed during grazing because of insufficient grass development. In 2011, the grazing season started on 2 April since the weather was warm. The farmer removed the cows one month later.

Table 1: List of management activities from the 12th of May 2010 to 12th of May 2011 at Dorinne grassland site. $C_{NBP,import}$ is the C imported through manure and/or slurry application, $C_{NBP,export}$ the C exported through mowing, $C_{NBP,complement}$ the C imported as complementary feeding.

Date	Type	$C_{NBP,import}$ (g C m^{-2})	$C_{NBP,export}$ (g C m^{-2})	$C_{NBP,complement}$ (g C m^{-2})
3-6 Jun-10	Cut-harvest		**113 ± 11**	
10-Jun-10	Fertilisation: 24/0/0 + Se			
12-Jun-11-Jul-10	Complementary feeding			**-17 ± 0.9**
31-Jul-21-Aug-10	Complementary feeding			**-20 ± 1.3**
7-Sep-22-Nov-10	Complementary feeding			**-66 ± 2.7**
20-Feb-11	Fertilisation: compost	**-91 ± 2**		
9-Mar-11	Fertilisation: 18/5/5 + Mg			
22-Mar-11	Liming: CaO			

Carbon budget establishment

Throughout this paper, we adopted the micrometeorological convention that fluxes from the biosphere are positive and that fluxes to the biosphere are negative. Net Biome Productivity (NBP), which took into account C imports and exports, was defined as:

$$NBP = NEE + C_{NBP,CH4} + C_{NBP,export} + C_{NBP,import} + C_{NBP,complement} + C_{NBP,lw} + C_{NBP,leach} \quad (1)$$

Where NEE is the Net Ecosystem Exchange of CO_2 and $C_{NBP,CH4}$ is the C lost through CH_4 emissions by grazing cattle. $C_{NBP,export}$ is the C exported through mowing, $C_{NBP,import}$ the C imported through manure and/or slurry application, $C_{NBP,complement}$ the C import as complementary feeding, $C_{NBP,lw}$ the C accumulated trough animal live weight gain and $C_{NBP,leach}$ the C lost through dissolved organic/inorganic C leaching.

Carbon dioxide flux measurements

Turbulent fluxes have been measured using the eddy covariance method since 12 May 2010. The system consisted of a fast response three dimensional sonic anemometer coupled with a fast infrared gas analyzer measuring CO_2 fluxes. Data were sampled at a rate of 10 Hz. Supporting measurements included air temperature and relative humidity, soil temperature and moisture, global and net radiation, atmospheric pressure and rainfall.

CO_2 flux computation was performed using the EDDYFLUX (EDDY Software, Jena, Germany) software package and the 10 Hz time series data. All the computation and correction procedures were the standard procedures defined in the context of the EUROFLUX - CARBOEUROFLUX - CarboEurope IP networks (Aubinet et al., 2012). NEE was finally computed half hourly as the sum of the turbulent flux and of a storage term deduced from the CO_2 concentration rate of change.
The turbulent fluxes were scrutinized using a stationary test (Aubinet et al., 2012) with a selection criterion of 30%. Data were separated between night and day thanks to a Photosynthetically Photon Flux Density (PPFD) criterion, using a threshold of 5 µmol m^{-2} s^{-1}, cross-checked against sunrise and sunset local time. In order to avoid night CO_2 flux underestimation (Aubinet et al., 2012), we filtered CO_2 fluxes taken under low turbulence conditions. A critical threshold of friction velocity (u_*) was determined using available night time data. It was fixed to 0.13 m s^{-1} so that night time measurements with u_* below this value were systematically discarded.
To estimate the annual grassland NEE, a continuous flux time series was required, which was obtained by filling the data gaps due to system failures, power cuts or bad quality data removal. Gap filling procedures were applied on fluxes and meteorological data (Reichstein et al., 2005).

Methane flux estimation

To estimate $C_{NBP,CH4}$ we considered that 1 kg of dry matter intake (DMI) corresponded to 0.0198 kg of CH_4 (Lassey, 2007).
Grazing animals DMI (kg DM ha^{-1}) was measured by the method of difference of Macoon et al. (2003) which is a direct method based on the herbage mass measurement. It implies the knowledge of herbage mass before and after the grazing period. As grazing periods at Dorinne were longer than one or two days, the grass re-growth had to be taken into account.
Herbage mass was inferred from the mean canopy height through an allometric relation fitted to the site. Mean canopy height was determined manually by measuring the centre height of a light-weight plate of 0.25 m^2 dropped onto the canopy at about 60 points on the field.

RESULTS

The data discussed in this study cover one complete year of measurements from 12 May 2010 to 12 May 2011.

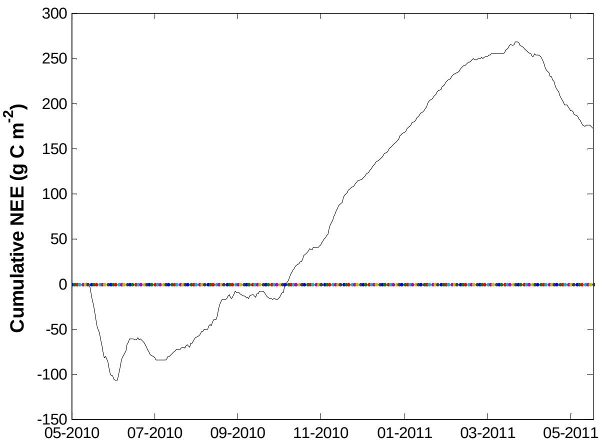

Figure 1: Cumulative Net Ecosystem Exchange (NEE) at Dorinne grassland site. Cumulative fluxes are presented over one year of measurements.

Figure 1 shows the cumulated NEE measured at Dorinne by eddy covariance since the beginning of the experiment. The active vegetation growth period in spring 2010 was characterized by a high accumulation of C in the system, mainly as plant biomass: fluxes were dominated by photosynthesis. Cutting induced an abrupt decline of NEE in early June. Moreover, in July, dry conditions precluded C accumulation. From August, lower temperatures and radiation reduced assimilation and net fluxes were dominated by respiration until March 2011. Since then, assimilation increased and the ecosystem shifted into a CO_2 sink. After one year of measurements, the grassland behaved as a net CO_2 source of 172 ± 94 g C m^{-2} $year^{-1}$ (endpoint of the curve in Figure 1).

Flux-partitioning approach based on night time data was followed to separate NEE into its two components Total Ecosystem Respiration (TER) and Gross primary Productivity (GPP) (Reichstein et al., 2005). The annual values were 2440 and -2268 g C m^{-2} $year^{-1}$ respectively. It is remarkable that NEE accounted for less than 10% of these fluxes. As a consequence, a small variation of either TER or GPP due to different climatic conditions could either strongly increase the net carbon emission or shift the grassland into a net carbon sink.

The grassland NBP was calculated from NEE by taking imports and export of organic C and losses of carbon as CH_4 into account (see Eq. 1). The contribution of $C_{NBP,CH4}$ to NBP was small as it was 12 ± 1 g C m^{-2} $year^{-1}$. It represented 3.5% of the C intake (C_{intake}) by cattle at grazing. The balance between $C_{NBP,import}$ and $C_{NBP,export}$ did not create a large departure of NBP from NEE, which is not the case of $C_{NBP,complement}$ (Table 1). NBP was finally estimated at 102 ± 95 g C m^{-2} $year^{-1}$. Note that, as in Soussana et al. (2007), $C_{NBP,leach}$ and $C_{NBP,lw}$ were neglected.

CONCLUSIONS

This article presented the carbon budget, based on measurements at the field scale, of a Belgian grassland grazed by the 'Blanc Bleu Belge' breed of cattle. The site behaved as a net source of C (NBP = 102 ± 95 g C m^{-2} $year^{-1}$) after one year of measurements. It is however premature to conclude about the sink or source behaviour of the plot because *i)* the NBP value is very close to its uncertainty, *ii)* it was obtained under particular climate conditions, characterised by drought during summer 2010 and spring 2011 and *iii)* it is a small fraction of TER and GPP so that a small relative change in one of these fluxes may strongly modify the net budget. To conclude on the average C budget of this ecosystem, long term measurements are necessary.

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