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Methane balance of an intensively grazed pasture and estimation of the enteric methane emissions from cattle

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ABSTRACT

The methane turbulent fluxes of an intensively grazed pasture were measured continuously from June 2012 to December 2013 at the Dorinne Terrestrial Observatory (DTO) in Belgium. During grazing periods, the fluxes were dominated by enteric fermentation and were found to be strongly related to cow stocking density. In 2013, total emission from the pasture was found between 9 and 11 g CH_4 m^{-2}, 97% of which being emitted during grazing periods. Emission per LU (livestock unit) was estimated in a non-invasive way by integrating eddy covariance fluxes over large periods and by assuming a homogeneous average cattle disposition on the pasture.

This estimate was compared to the one obtained during confinement periods, where cows were confined in a small part of the pasture. The emission per LU varied between 104 and 134 g CH_4 LU^{-1} day^{-1} (13 and 17 g CH_4 kg DMI^{-1}), depending on the dataset and the computation method used. Diel course was characterized by two emission peaks, one in the morning and a larger one in the afternoon. For rest periods (no cattle on the pasture), small emissions were observed (median and mean values of 0.5 and 1.5 mg CH_4 m^{-2} day^{-1}, respectively).

1. Introduction

Between 1750 and 2014, the atmospheric methane dry molar fraction rose from 0.722 to 1.8 µmol mol^{-1} (NOAA, 2014; Macfarling Meure et al., 2006). This radical increase in methane concentration accounted for almost 30% of the total greenhouse gas (GHG) radiative forcing of all well-mixed GHG over the period from 1750 to 2011 (Myhre et al., 2013). The accurate monitoring of ecosystem CH_4 fluxes and balances is therefore of crucial importance.

About 50% of all sources of terrestrial methane are thought to be linked to human activities, with the husbandry of domestic ruminants representing 25% of this amount (Ghosh et al., 2015). Grazed grassland is therefore one of the most important ecosystems in terms of methane exchange. Its methane budget comprises two main components: first, ruminants present on pasture produce methane when digesting grass; and second, soil bacterial communities that can either produce or consume methane, depending on the soil's physical and biological conditions (Smith et al., 2003).

Monitoring these fluxes is usually conducted separately for grasslands and for animals, soil emissions being measured using chambers or micro-meteorological techniques on ungrazed grasslands (Oertel et al., 2016) and cattle emission using metabolic chambers or a tracer method (typically involving SF_6) (Storm et al., 2012). Such separated monitoring can lead to biases as it doesn't take into account the interaction between grasslands and animals during grazing. Moreover, metabolic chambers or tracers are typically applied to a limited number of cows while important emission differences may appear among individuals. Finally, the tracer technique, which has often the advantage to be applied with "in-situ" conditions, has a limited duration, typically a couple of days, and does not allow studies of emission diel cycle. The presence of equipment (saddle, bottles, hoses...) can also affect the behavior of the animals during these short measuring periods. The use of the eddy covariance (EC) method over pastured ecosystems can overcome some of these limitations (Mcginn, 2013).

EC is a micrometeorological technique adapted to the continuous measurement of tracer fluxes over ecosystems.

It measures fluxes originating from a zone (footprint area) situated mostly upwind of the measurement point and has the advantage of integrating all the exchange processes at work in the footprint, thus providing the net methane exchange of the ecosys-

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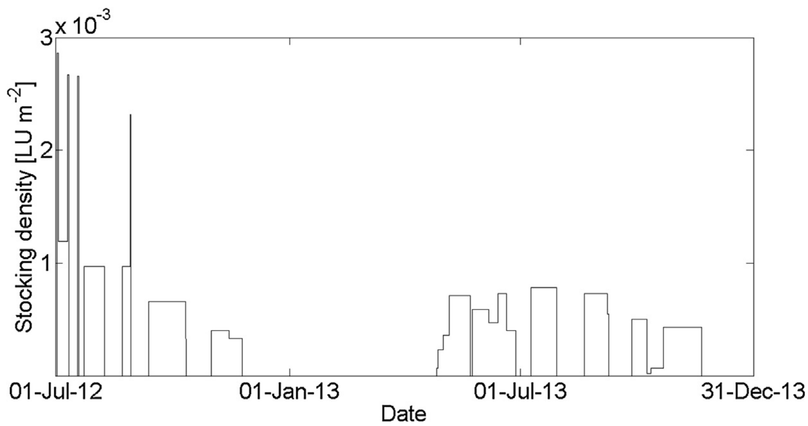

Fig. 1. Stocking density evolution throughout the measuring period; the periods with stocking densities above 15.10^{-4} LU m^{-2} correspond to confinement periods.

tem. Its drawbacks include its inability to detect the origin of fluxes or to disentangle simultaneous incoming and outgoing fluxes. Soil and cattle respective contributions to the net methane exchange can however be identified by separating rest periods (without cattle on the pasture), when only soil fluxes are operating, from grazing periods, when cow emissions are dominating the exchanges. In this latter situation, the EC technique has the advantage to provide flux estimates from the whole herd, over long periods and with high time resolution. However, in the absence of information on cow location and activity, the interpretation of the measured flux is challenging because cows constitute punctual, moving and intermittent sources. Many teams working on grazed ecosystems methane exchanges are presently facing this challenge (Baldocchi et al., 2012; Dengel et al., 2011; Tallec et al., 2012).

In this study, our objectives were therefore: (i) to evaluate the feasibility of estimating animal methane emissions in the field on the basis of eddy covariance measurements and of simple hypotheses on cattle dispersion and (ii) to provide an estimate of the methane net emission by an intensively grazed pasture in Belgium.

2. Material and methods

2.1. Site description and cattle management

The study was performed at the Dorinne Terrestrial Observatory (DTO), a pasture situated at Dorinne, in Condroz region, in Belgium (location: 50° 18′ 44.00″ N; 4° 58′ 7.00″ E; 248 m asl.). The site has a gentle SW-NE slope varying between 0 and 5% along this transect and averaging to 1–2%. According to the FAO classification system, the pasture is dominated by colluvic regosols (DGARNE, 2015). More details about the site are given by Jérôme et al. (2014) and Gourlez De La Motte et al. (2016).

The pasture covers 4.2 ha and is intensively grazed by Belgian Blue cattle, following regional common practices for a cow-calf operation system. The cattle graze from mid-April to mid-November (growing season) at varying stocking densities (Fig. 1), with a mean density of 2.3 10^{-4} livestock units (LU) m^{-2} in 2013. At the beginning of the season (May, June) the herd consists of up to 30 cows, accompanied by their calves and a bull. During this period calves' diet is supplemented with concentrates. After weaning (July), only the adults remain on the pasture. Cattle density is estimated by considering that a breeding bull (1300 kg) or a suckler cow (600–900 kg) represents 1 LU, whereas a heifer (400–600 kg) and a calf (100–200 kg) represent 0.6 and 0.4 LU, respectively.

The measuring mast was placed at the center of the pasture (Fig. 2), which is totally surrounded by other pastures except in the south-west (main wind direction) where it is bordered by a crop.

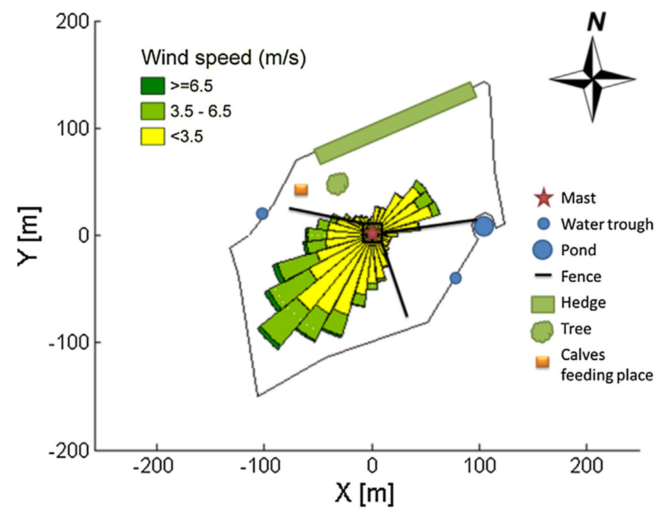

Fig. 2. Schematic view of the pasture. During confinement periods, gates in internal fences were closed and the cattle were confined to the south-western part of the pasture.

There are two drinking troughs shared with adjacent pastures at the edge of the pasture. During the monitoring study, the studied herd and the neighboring herd often gathered at the north-western drinking trough, but little social activity was observed at the south-eastern trough. There was a fenced pond 100 m east of the mast. In the northern part of the pasture lie a hedgerow and a tree under which the cattle often repose. A calf creep-feeder was placed near the tree and was filled when calves were on the pasture.

The measurements were performed from June 2012 to December 2013. During this period, the farmer adjusted stocking density to grass availability, which led to an alternation of rest and free-ranging periods during which the herd was spread in the pasture. In addition, four one day confinement periods were established during which the cattle were confined to about a third of the pasture (1.7 ha), roughly covering the flux source area (footprint) in the main wind direction (Jérôme et al., 2014). This allowed stocking density in the footprint to be more homogeneous. Free-ranging and confinement periods were regrouped under the term 'grazing periods'.

2.2. Instrumentation

2.2.1. Eddy-covariance and meteorology

Methane fluxes exchanged in the pasture were measured continuously using a fast CH_4 analyzer (PICARRO G2311-f, PICARRO