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Extensive grazing in contrast to mowing is climate-friendly based on the farm-scale greenhouse gas balance

Péter Koncz[a,*], Krisztina Pintér[b], János Balogh[b], Marianna Papp[a], Dóra Hidy[a], Zsolt Csintalan[b], Erik Molnár[c], Albert Szaniszló[c], Györgyi Kampfl[c], László Horváth[d], Zoltán Nagy[a,b]

[a] MTA–SZIE Plant Ecology Research Group, Szent István University, Páter K. u. 1., 2100 Gödöllő, Hungary
[b] Szent István University, Institute of Botany and Ecophysiology, Páter K. u. 1., 2100 Gödöllő, Hungary
[c] Szent István University, Department of Chemistry, Páter K. u. 1., 2100 Gödöllő, Hungary
[d] Hungarian Meteorological Service, Gilice tér 39., 1181 Budapest, Hungary

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ABSTRACT

Livestock is both threatened by and contributing to climate change. The contribution of livestock to climate change and greenhouse gas (GHG) emission greatly vary under different management regimes. A number of mitigation options comprise livestock management, although there are a lot of uncertainties as to which management regime to use for a given pedoclimatic and farming system. Therefore, we 1) tested if an extensive cattle livestock farm is a net sink or a net source for GHG (carbon–dioxide, CO_2; methane, CH_4; nitrous oxide N_2O) in Central–Eastern Europe, 2) compared the annual GHG balances between the grazed and mowed treatments of the farm 3) and investigated the role of climate variability in shaping these balances. Net ecosystem exchange of CO_2 (*NEE*) was measured with eddy covariance technique in both the grazed and mowed treatments. Estimations of lateral C fluxes were based on management data. Other GHG fluxes (CH_4, N_2O) were determined by chamber gas flux measurements technique (in case of soil) and IPCC guidelines (in case of manure decomposition and animal fermentation). Net greenhouse gas balance (*NGHG*) for the grazed treatment was 228 ± 283 g CO_2 equivalent m^{-2} $year^{-1}$ (net sink) and -475 ± 144 g CO_2 equiv. m^{-2} $year^{-1}$ (net source) for the mowed treatment. Net source activity at the mowed treatment was due to its higher herbage use intensity compared to the grazed treatment. At the farm scale the system was estimated to be a net sink for *NGHG* in a year with wet (135 g CO_2 equiv. m^{-2} $year^{-1}$), while a net source in years with dry soil moisture conditions (-267 ± 214 g CO_2 equiv. m^{-2} $year^{-1}$). We conclude that under a temperate continental climate extended extensive grazing could serve as a potential mitigation of GHG in contrast to mowing. Our study highlights the fact that livestock farming could create a net sink for GHG under proper management regimes.

1. Introduction

Livestock is not only threatened by climate change (IPCC, 2013; Nardone et al., 2010), but it also contributes to it because the share of livestock sector in total anthropogenic greenhouse gas (GHG) emission is estimated to be between 10–25% (IPCC, 2007; Schwarzer, 2012; Gerber et al., 2013). Due to climate change the frequency of drought, heat waves and other extreme weather events (e.g. sudden rainfall) increased in temperate continental climate (Bartholy and Pongracz, 2007; IPCC, 2013). Drought decreases the productivity of grasslands, which support livestock (Craine et al., 2012; Kanneganti and Kaffka, 1995; Thornton et al., 2014; Zhang et al., 2010) and heat stress lowers meat and milk yield of cattle (Gaughan, 2012; Gauly et al., 2013; Nardone et al., 2010). Concurrently, livestock farming will need to supply an expected 20% increase in food demand between 2002 and 2050 under the threats of climate change (Steinfeld et al., 2006; Foley et al., 2011). Therefore, to maintain food security livestock farming has to adapt to climate change while reducing its GHG emissions (Smith et al., 2014). Decreasing GHG (carbon–dioxide, CO_2; methane, CH_4, and nitrous oxide, N_2O) emissions of livestock systems and increasing carbon (C) sequestration of grasslands could be achieved by the

* Corresponding author.
E-mail address: pkoncz@gmail.com (P. Koncz).

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implementation of several management techniques (Bellarby et al., 2013; Herrero et al., 2016; Ripple et al., 2014; Smith et al., 2008; Soussana, 2008; Soussana et al., 2010). Management and climate variability have an integrated effect on shaping the GHG balances of grasslands and grassland-based farming systems.

Improper grazing management such as over or under grazing (Smith et al., 2008; Wang et al., 2011), degradation due to livestock expansion (Zhang et al., 2011) or intensification (Smith et al., 2008) led to a net loss of C from the ecosystem. On the other hand, improved grazing management (e.g. optimized grazing intensity, introduction of legumes, fertilization) of grasslands was found to increase C sequestration (Smith et al., 2008; Soussana et al., 2010; Oates and Jackson, 2014). In general, grasslands were observed to be net sinks for CO_2 (Oliphant, 2012) but grazing was found to have a positive, negative or no impact on net ecosytem exchange (*NEE*) of grasslands (Luo et al., 2014). *NEE* was observed to vary between 2394 g CO_2 m^{-2} $year^{-1}$ (net sink) and −1342 g CO_2 m^{-2} $year^{-1}$ (net source), with a mean of 255 ± 521 g CO_2 m^{-2} $year^{-1}$ for extensive and 700 ± 717 g CO_2 m^{-2} for intensive grazing (Gilmanov et al., 2010). Mowed areas were also found to act as net sinks (−476 ± 51, Senapati et al., 2014; 313 ± 145 g C m^{-2} $year^{-1}$, Soussana et al., 2007) or net sources (18 ± 49 g C m^{-2} $year^{-1}$) (Wohlfahrt et al., 2008) for C in terms of *NEE*. Besides the management regime, climatic factors also affect C balance. Net sink/source activity in dry grasslands highly depends on climatic factors especially on the amount of precipitation (Jaksic et al., 2006; Nagy et al., 2007). However, it is not easy to separate the effects of climate from those of management in grasslands due to their interactions (Reichstein et al., 2013; Senapati et al., 2014). For example high net C sink activity of grasslands can be observed under high precipitation conditions in temperate, dry climate, which can also be due to the interaction with high rates of fertilization (Senapati et al., 2014; Soussana et al., 2010). Climate is expected to change rapidly in Central–Eastern Europe with more frequent heat waves and drought especially during spring and summer periods (Bartholy and Pongrácz, 2008). Droughts were observed to turn grasslands into net C sources at temperate (Nagy et al., 2007; Soussana et al., 2010) rather than in wet, cold climate (Mudge et al., 2011), thus climate change is expected to negatively impact C uptake of grazed grasslands in dry, continental climate.

Besides CO_2 fluxes lateral C and methane-C fluxes affect the total accumulation of carbon for a given system i.e. the net ecosystem carbon balance (*NECB*) (Chapin et al., 2006). Depending on management intensities C is exported from the mown areas and imported to the corral/feeding system and exported from the farm in the form of animal products and manure (Fig. 1). *NECB* of mown areas was found to be lower compared to the grazed treatment (Senapati et al. 2014) but the mown areas were also turned into a net source in terms of *NECB* due to the large amounts of hay removed (Haszpra et al., 2010; Oates and Jackson, 2014; Skinner, 2008). *NECB* only consists of C fluxes, while it does not express the greenhouse gas balance.

The net greenhouse gas balance (*NGHG*) consists of the total greenhouse gas fluxes (CO_2, CH_4 and N_2O) for a given system (Fig. 1) in CO_2 equivalent, which takes into account the global warming potential (GWP) of the different gases (Soussana et al., 2010). When considering *NGHG* the mowed sites were found to act as net sources (Soussana et al., 2010) but the grazed sites functioned as net carbon sinks (Chang et al., 2015; Soussana et al., 2010), net sources (Levy et al., 2007) or neutral to total net GHG (Schulze et al., 2009). CH_4 and N_2O emissions of the farm depend on livestock management practices and the climate. CH_4 emissions due to enteric fermentation of cattle varies between 27 and 128 kg CH_4 kg $head^{-1}$ $year^{-1}$ (IPCC 2006a) depending on the type of animals, feeding and breeding practices (Smith et al., 2008). CH_4 emissions due to manure decomposition could vary between 1 and 112 kg CH_4 kg $head^{-1}$ depending on the interaction between manure management (storage) and climate (e.g. differences in emissions in wet and warm vs. cool and dry weather conditions) (IPCC 2006a). Soil CH_4 and N_2O fluxes are affected by climatic factors and management regimes through the changes of abiotic (soil temperature, soil water content, pH, aeration of soil) and

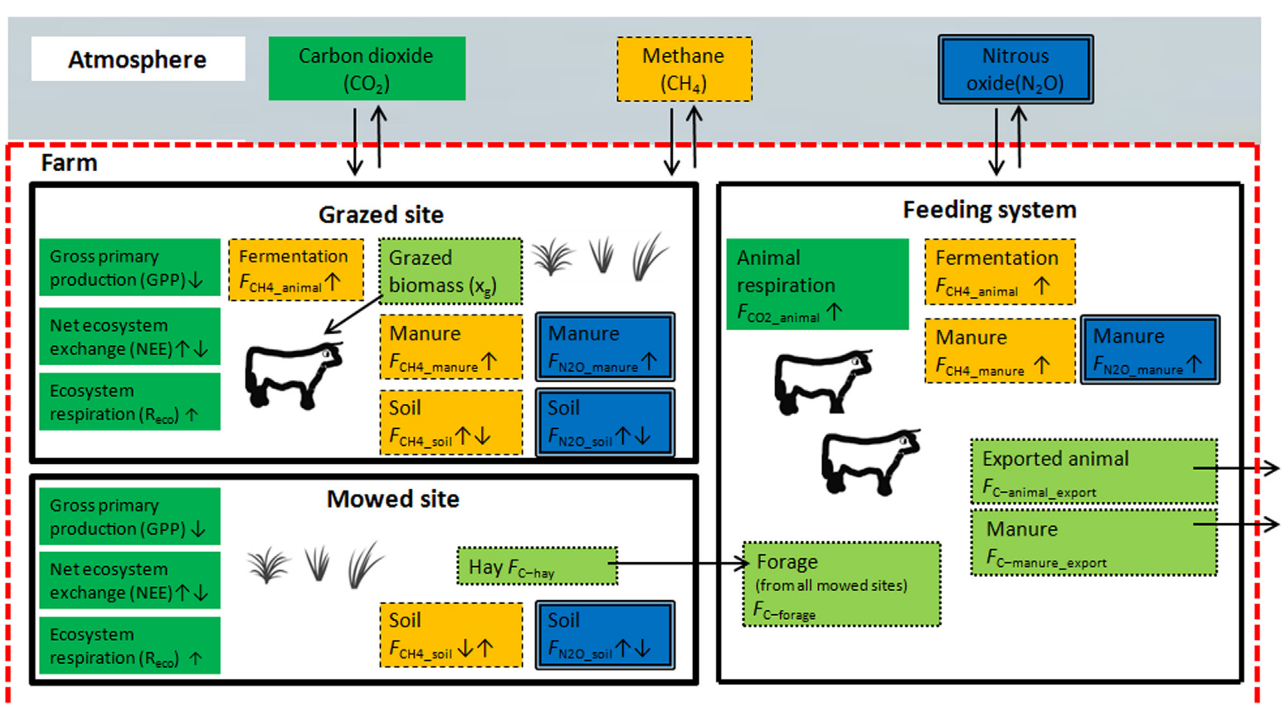

Fig. 1. Illustration of the farm–scale carbon and greenhouse gas fluxes. Arrows pointing up (to the atmosphere) and lateral directions (right) represent net sources, while arrows pointing down represent net sinks to the ecosystem.