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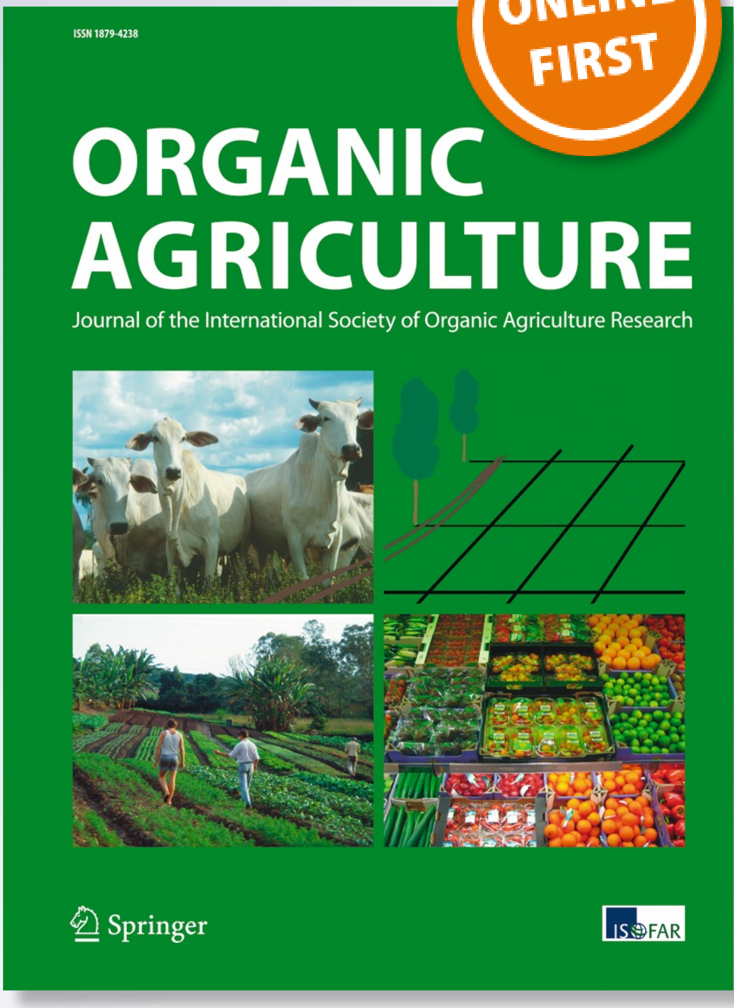

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Measurement methods on pastures and their use in environmental life-cycle assessment

Magdalena Ohm · Maximilian Schüler · Sylvia Warnecke · Hans Marten Paulsen · Gerold Rahmann

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Abstract Grassland agriculture plays an important role for livestock production and land management throughout the world. It is challenging to estimate the available feed on pasture plots. For this study, a rising plate meter was calibrated in swards of the organic experimental station of Trenthorst in northern Germany to calculate grazing intake of cattle and to determine biomass regrowth. A LCA-model (FARM) that was used to calculate the global warming potential (GWP) of milk of the station showed that substituting grass silage by grazing reduces the GWP per kilogram energy-corrected milk by 1.5 %. High differences of dry matter intake that were found between the plots indicate a potential for improving the grazing management and hence for further reducing the GWP of milk production.

Keywords Grazing intake · Dairy · Global warming potential · LCA

Introduction

A total of 70 % of the world's agricultural area is covered by grassland (FAO 2008). It is an important and energy extensive feed source for livestock. Good pasture management is required to maintain its productivity. Due to the selective grazing behaviour of dairy cows (Vallentine 2001), site and management-related sward variability (Correll et al. 2003) and herbage regrowth during grazing bouts, it is difficult to estimate pasture yield or pasture intake (McNaughton et al. 1996, Walters and Evans 1979, Macoon et al. 2003; Smit et al. 2005). A proper estimation of feed intake of animals on grassland enables the farmer to appropriately manage his pastures. This is the basis to increase grazing intake and feed quality. Studies on greenhouse gas emissions of dairy systems with and without pasture access revealed higher energy intensity of confinement systems using conserved feedstuff (O'Brien et al. 2012). Substitution of conserved forage by efficient grazing management and improved grassland management might be an important key to reduce energy demand in feed production, subsequently reducing GWP of milk production. This paper presents a fast and easy-to-use method to estimate herbage intake without exclosure cages. The collected data are used to describe material flows from grassland. Subsequently, environmental impacts of an improved grazing management based on the whole farm process are calculated with a flow model FARM (flow analysis and resource management) that is designed to conduct life-cycle assessments (LCA) of farm products.

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Material and methods

Data were collected on the experimental station of the Thünen-Institute of Organic Farming, Trenthorst in Northern Germany (53° 46′ N, 10° 30′ E; 10–43 m asl). For the dairy branch of the station, an area of

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37 ha is used as permanent grassland for grazing and for producing silage and hay. The farm converted from conventional to organic farming in 2001. Mean annual precipitation is 706 mm and mean annual temperature is 8.8 °C (1978–2007). In 2012, precipitation was as low as 534 mm, which is 34 % lower than average. The soils of the permanent grassland are characterized as Cambisols and Luvisols. On the grassland, a mixture of grass, legumes (mostly Trifolium repens) and herbaceous plants is growing in different proportions. In 2012, the dairy cows (Black Holstein and Red Holstein dual purpose breed) grazed approximately 7 hours a day from 24th of April until 7th of October. The permanent grassland is divided into 13 plots (mean size 2.66 ha) and managed by rotational grazing with a duration of 2–10 days per plot. The plots differ in their sward characteristics due to management and drainage. Besides, sward characteristics were not the only decision factor for the pasture management on the research farm. Low biomass intake was caused, e.g., by delayed grazing or long-lasting grazing periods. Therefore at some plots, the grazing efficiency was below the plot's potential. To estimate the pasture intake on a dry matter basis, the following equation (1) was used: (biomass before grazing−biomass after grazing)+(daily growth rate×days of grazing). The biomass before and after grazing was measured at four representative GPS-located points per pasture plot (Fig. 1, left). The biomass was determined directly by cutting 0.5 m×1 m to 1 cm above ground level, which took around 20 min per plot. The dry matter (DM) yield was determined by drying the biomass (24 h, 60 °C).

The average daily growth rate was calculated on the basis of weekly measurements at all ungrazed plots with

Table 1 Global warming potential (100 a) of grass silage for different yield levels in the experimental farm Trenthorst in 2011 (left) and for the mean yield of the years 2005, 2008, and 2009 (right)

Emission source	Grass silage 17.5 t ha^{-1} [g CO_2eq. kg^{-1} DM]	Grass silage 26.5 t ha^{-1} [g CO_2eq. kg^{-1} DM]
Supply chain[a]	11.8	8.8
Transports of silage film, lime and fuel to farm	0.3	0.2
Fuel combustion from fieldwork	89.4	66.4
Direct emissions from soil	226	218.5
Combustion of silage film	$5.96*10^{-6}$	$5.9*10^{-6}$
Sum	327.6	293.9

[a] The environmental burdens of all upstream products have been calculated with datasets from the EcoInvent v2.2 database

a rising plate meter (FARMWORKS). It measures the compressed height of the pasture: the plate of the meter lowers from top to bottom until enough plant material carries the plate's weight. The instrument was calibrated to the farm conditions of the permanent grassland in Trenthorst. There was a linear relationship between DM (in kilogram per ha) yield and compressed sward height H (in centimeter) with the function: DM=100.41×H+1 (r^2=0.75, n=396). This function was used to calculate the dry matter yield by the sward height measurements. The sward height was measured every 10 steps while the plots were crossed in zigzag (Fig. 1, right). Time needed per plot was around 12 min. For every crossing line, the mean height was recorded. Both methods (four-point

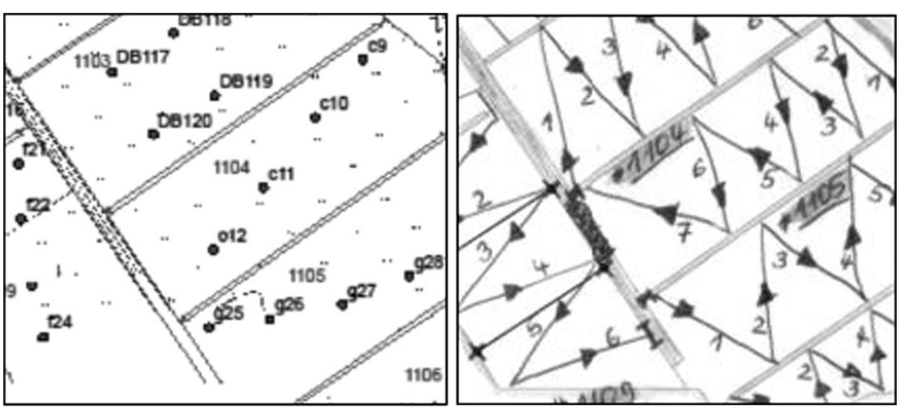

Fig. 1 GPS-located sample points (*left*) were used to measure the difference before and after grazing and weekly zigzag plate meter measurements (*right*) were used to estimate the daily growth rates

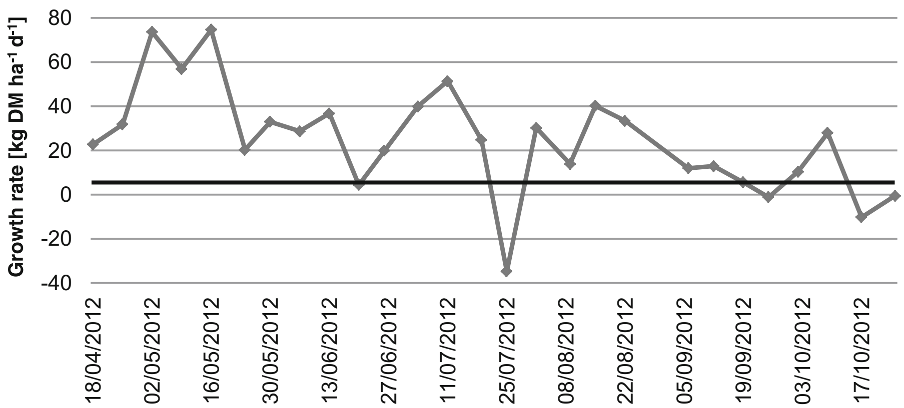

Fig. 2 Daily growth rate of dry matter on ungrazed plots in 2012

cutting and zigzag measurement with rising plate meter) showed similar results when yield estimation per plot was compared (Ohm et al. 2013). The LCA-FARM model was developed to calculate the environmental performance of milk production (Schüler and Paulsen 2012). The input data were obtained from the actual farming conditions on the experimental station. The parameters used were field work, crop yields, amount of manure, herd size, milk yields, feed intake and feeding regime, which includes the grazing management. Greenhouse gas emissions were calculated according to the emission factors specified in IPCC (2006) and Rösemann et al. (2011). The global warming potential (GWP) connected with grass silage production at Trenthorst depends on the total yield (Table 1). In 2011, grass silage yield was very low (17.5 t ha^{-1} DM) and the GWP (100 a) was 327.6 g CO_2 eq. per kilogram DM. Yields around 26.5 t ha^{-1} DM (mean of the years 2005, 2008, 2009) are more representative for the location and had a GWP of 293.9 g CO_2 eq. per kilogram DM. Climate effects of improved grazing are calculated by substituting grass silage with increased grazing intake.

Results

For calculating grazing intake, the biomass difference before and after grazing was added to the biomass gain calculated by daily growth rates. The daily growth varied widely during the grazing season. The maximum was in spring with more than 70 kg DM ha^{-1} (Fig. 2). The mean daily growth rate was around 25 kg DM ha^{-1}. It also shows some negative values which can be attributed to dry periods when the grass went limp.

Both the dry matter yields from direct cuttings and the estimated yield from growth rates (Eq. 1) show variations between the plots (Fig. 3). The sum

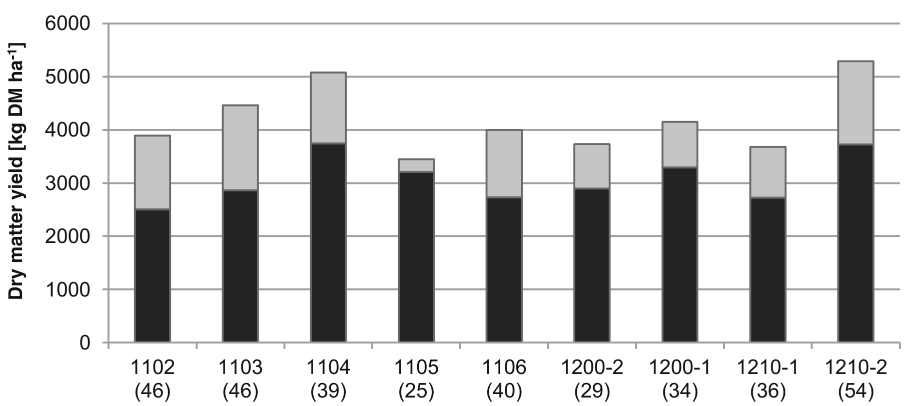

Fig. 3 Dry matter yields of the grazed pasture plots calculated by the difference before and after grazing (*black*) and daily growth rate (*grey*) in 2012. *In brackets*: number of grazing days

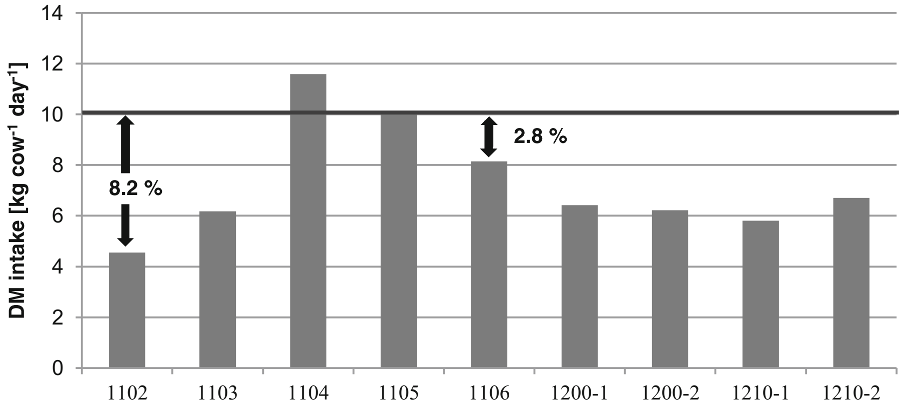

Fig. 4 Daily dry matter (DM) intake per cow at the pasture plots in 2012. The percentage shows the reduction potential of global warming per kg ECM [%] by increasing the DM intake by grazing to 10 kg per cow per day

of both values is the basis to calculate the DM intake per cow and plot. This is the parameter for the LCA.

In detail, the dry matter intake per cow and day was calculated by the dry matter yield per plot, number of animals and days of grazing (Fig. 4). High differences occurred between the plots.

Discussion

The considerable differences in DM intake that were found between the plots (Fig. 4) might on the one hand be caused by sward composition and soil site differences. On the other hand, they could be attributed to improper grazing management decisions because those can lead to a low DM intake per cow. The DM intake decreases if the biomass on the pasture becomes too short (because then the cows need more time to find enough feed) or if the biomass on the pasture becomes too old (a high fiber content results both in less palatability and in a long digestion time (Klapp 1971)). High differences in feed offer between plots might indicate a potential for improvement of pasture management. If improved management decisions could increase the dry matter intake of the dairy cows during grazing by 1 kg dry matter per day, equivalently less grass silage would have to be fed for the same milk yield. Substituting grass silage by improving grazing management reduces GWP per kilogram energy-corrected milk (ECM). This is the potential of an improved grazing management to reduce the GWP of milk. Calculating the LCA for the experimental station results in (a) GWP of 293.9 g CO_2 eq. per kilogram grass silage DM (Table 1) and (b) 1 kg CO_2 eq. per kilogram ECM. At daily milk yields of 20 kg ECM per cow and day, the GWP can be reduced by 14.7 g CO_2 eq. per kilogram ECM (=1.5 %) by substituting 1 kg DM grass silage by 1 kg DM intake from pasture. At the pasture plot with the lowest DM intake (plot 1102, Fig. 4), the GWP of milk production could even be reduced by 8.2 % if daily DM intake during the grazing period could be more than doubled from 4.6 to 10 kg. The fast and practical measurements with a rising plate meter allow estimating the variable feed offer at pasture plots. These data offer chances to improve grazing and pasture management (as they are commonly used for in New Zealand (Lile et al. 2001)) and are also useful for calculations of DM intake per cow which can be used for LCA. Improvements could be achieved in an intensified rotational grazing system by offering high quality pasture (green and leafy, pre ear emergence) and subsequently leaving an even sward height after grazing (Vallentine 2001).

If pasture management is improved, it is possible to substitute other roughage with grazing intake, hence improving the overall system efficiency and reducing environmental impacts such as global warming from milk production. The range of improvement depends on (a) the current farm and site specific performance, (b) the yield potential and food quality of the pasture site itself and (c) feeding management options within the farm. Further reductions can be achieved by improving feeding management and feed quality.

Conclusion

Measurements of the variable feed offer at pasture plots with a rising plate meter provide a data basis to indicate necessary improvements of grazing and pasture management. Calculating grazing intake by the use of regrowth values of biomass of temporarily ungrazed pastures might be a practical and fast alternative to measurements with exclosure cages. On the explored pasture plots, high differences in the dry matter intake of the cows between plots were found, and might indicate a potential for the improvement of pasture management. This could be achieved by optimizing pasture yields, e.g. by sward improvements and grazing management. From the study, it cannot be concluded that pasture-based systems perform better than other systems, but that a well-run pasture provides a great opportunity to avoid GHG emissions.

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