Effect of grassland renovation on the greenhouse gas budget of an intensive forage production system

C Ammann, J Leifeld, M Jocher, A Neftel, J Fuhrer
Agroscope ART, Zürich, Switzerland *Email:christof.ammann@art.admin.ch*

Introduction European grasslands used for animal grazing and forage production are usually considered as a net carbon sink on average (e.g. Soussana *et al.*, 2007). This carbon sequestration effect can be counteracted by the emission of methane (by grazing ruminants) and N_2O depending on the management and fertilisation intensity. In addition it has to be taken into account that intensive forage production grasslands are often subject to periodic renovation activities, including ploughing and reseeding, in order to maintain an optimum plant composition and high harvest yields. But grassland renovation represents a major disturbance of the perennial grass ecosystem that can lead to enhanced greenhouse gas emissions (e.g. Velthof *et al.*, 2010) . In the present study we investigated the greenhouse gas (GHG) budget of an intensively managed grassland field in Central Europe several years before and after a renovation was carried out.

Material and Methods Within the framework of the European flux network projects GreenGrass, CarboEurope and NitroEurope we have measured the GHG exchange and the carbon cycle on the field scale at the intensive grassland site Oensingen during 9 years (2002-2010). The site is located on the Swiss Central Plateau. The soil is classified as Eutri-Stagnic Cambisol developed on clayey alluvial deposits with clay contents between 42% and 44%. The vegetation is a grass-clover mixture dominated by *Lollium perenne* and *Trifolium repens*. The field was subjected to intensive management over the entire observation period with an average nitrogen input of 230 kg N ha^{-1} y^{-1} as mineral and organic fertiliser and 4–5 harvests (hay or silage) per year. Within the measurement period, one grassland renovation was performed at the end of the sixth year. The field was ploughed (to ca. 20 cm depth) in December 2007 and was reseeded in the following spring (May 2008). The total carbon budget (sequestration or loss) of the grassland soil corresponds to the net biome productivity (NBP) and was assessed by continuous measurement of the ecosystem CO_2 exchange using an eddy covariance system and by analysing the carbon import by manure application and the carbon export by harvest biomass removal (see Ammann *et al.*, 2007). N_2O fluxes were measured using stainless steel static chambers (side length: 300 mm, height: 250 mm). Up to eight chambers were automatically operated in the field and provided flux measurements at a regular interval of typically two hours (Flechard *et al.*, 2005). For the present study the emission data of all available chambers were averaged.

Results In the 6 years before the renovation, the annual carbon budget resulting from the summation of the individual carbon fluxes (net CO_2 exchange, import by manure, removal by harvest) was generally positive indicating a carbon accumulation (sequestration) in the grassland soil of about 100 g C ha^{-1} y^{-1} on average (Ammann *et al.*, 2009). Yet a considerable year-to-year variability could be observed showing a correlation with the harvest yield but also with soil moisture conditions. Years with high productivity (2002, 2004, 2007) showed highest carbon accumulation, while the year 2003 with extreme temperature and drought conditions showed an almost neutral carbon budget. Before the renovation, an average N_2O emission of about 1.5 kg N ha^{-1} y^{-1} was observed with annual values up to 2.6 kg N ha^{-1} y^{-1} (Ammann *et al.*, 2009), mainly as a result of large emission pulses following fertiliser applications (see Flechard *et al.*, 2005). In the other periods (cold season or growing phases) generally small fluxes in both directions, emission or deposition, were recorded.
In the 3 years following the renovation, large differences to the previous years were found. The carbon budget changed its sign from sequestration to carbon loss (-130 g C ha^{-1} y^{-1} on average). This was partly due to considerable respiration losses during the fallow phase (January-Mai 2008) between ploughing and reseeding, but the net carbon loss, although smaller, continued in the following two years (2009, 2010). In addition to this effect, the N_2O emission was also considerably enhanced after the renovation. On average it was about 3 times larger than before the renovation.

Conclusions Renovation (ploughing and reseeding) of an intensively managed permanent grassland field had a large impact on the carbon budget (CO_2 uptake/loss) as well as on the soil N_2O emission. It changed the grassland from a net carbon sink to a carbon source (for the following three years) and approximately tripled the annual N_2O emissions. It can be concluded that grassland renovation has a considerable potential for GHG emission that may offset the net carbon sink activity of grassland in undisturbed periods.

References.

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