GREENHOUSE GAS BUDGET OF NEWLY ESTABLISHED GRASSLANDS

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ABSTRACT

A field experiment on the Swiss Plateau was designed to measure the greenhouse gas (GHG) budget of two parallel fields after conversion from arable crop rotation to cut grassland and managed either intensively or extensively. Measurements of N_2O fluxes with chambers and of CO_2 with eddy flux towers were complemented by estimates of C-imports (organic fertilizers) and C-exports (yield). The results indicate that newly established grassland plots act as a net GHG sink when management intensity (fertilization and cutting) is high, while conversion to extensive grasslands leads to an initial net loss of GHG.

INTRODUCTION

Conversion of arable land to permanent grassland has been suggested as a possible measure to improve the greenhouse gas (GHG) balance of agricultural land in Switzerland, and thus to contribute to the national GHG reduction commitment under the Kyoto protocol [*Leifeld et al*., 2004]. This positive effect is thought to result from a reduction in the loss of soil carbon (C) in the absence of soil tillage, while at the same time high C input is maintained through plant fixation. But the improvement of the C balance at the field scale must be corrected for any change in net fluxes of other GHGs due to management, mainly nitrous oxide (N_2O) when fertilizers are applied, and methane when grazing by ruminants occurs. Therefore, the overall GHG balance is subject to the influence of the type and intensity of management, and the grassland may be a net source or a net sink of GHGs. The aim of the present study was to quantify the full GHG budget of permanent grassland after conversion from arable land, and to compare two levels of management intensity, i.e. intensive vs. extensive.

EXPERIMENTAL SITE AND METHODS

A multi-year ‘Kyoto’ field experiment on the Swiss Central Plateau (7°44' E, 47°17' N, 450 m above sea level) was designed to measure the full GHG budget of two parallel fields established in 2001 on the same plot, which was previously used for arable crop rotations. The soil is classified as Eutri-Stagnic Cambisol. Average soil organic carbon contents in the upper 30 cm were 28-29 g kg^{-1} dry soil (for three depth layers) at the beginning of the experiment and were not significantly different between fields. The ‘intensive’ field INT was cut 4-5 times each year and fertilized with both organic and inorganic fertilizers after each cut (total N input: 200 kg N ha^{-1} yr^{-1}). The ‘extensive’ plot EXT was cut 3 times annually and received no fertilizers. The annual balance of C was determined from 2002-2004 based on measured net ecosystem CO_2 exchange (eddy flux), C inputs via organic fertilizer application, and C export via harvesting. The balance of N_2O was determined from year-round measurements with both manual and automatic static chambers. In the absence of grazing, net CH_4 fluxes were ignored. CH_4 uptake by soils was found to be negligible.

RESULTS

Cumulative N_2O fluxes (Fig. 1) show for the INT field the relative contributions of background and trigger events, while for the EXT field no such distinction is made. Flux integration over 2.5 years yielded a cumulated emission of +4.7 kg N_2O-N ha^{-1} for the intensively-managed field, equivalent to an average emission factor of 1.1%, and a small net sink activity of –0.4 kg N_2O-N ha^{-1} for the unfertilized system. In 2003 and 2004 emission peaks generally did not last as long as in 2002 or were of lesser magnitude, for comparable fertilization levels. Annual emission factors reflect this fact with a value of 1.9% in 2002 compared with 0.8% and 0.6% in 2003 and 2004, respectively. The overall EF of 1.1% is close to the 1.25 ±1% IPCC default value for fertilized grassland (IPCC, 1996). Net uptake of N_2O and sub-ambient soil N_2O concentrations were frequently measured on both fields, even during the dry summer of 2003.

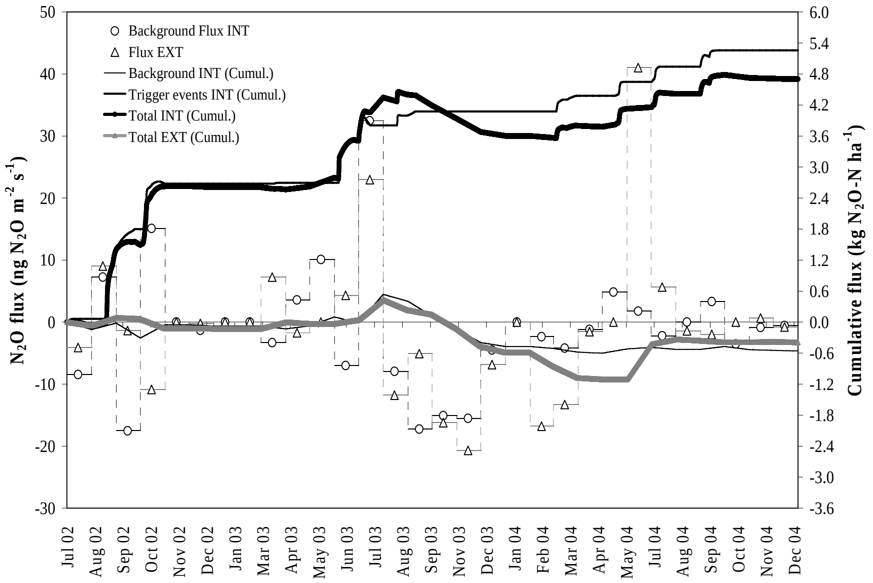

Fig. 1. Monthly mean background N_2O fluxes (dashed) and cumulative budgets (solid) Jul 2002 to Dec 2004.

For the INT field a distinction is made between background fluxes and emission peaks, which follow trigger events.

Averaged over the initial 3 years (2002-2004), the intensive field exhibited a rate of C sequestration of –1.5 (± 1.3) t ha^{-1} yr^{-1}), compared to a net C loss of +0.5 (+1.3/-1.1) t ha^{-1} yr^{-1} of the extensive field (not significantly different from 0).

The total net GHG forcing effect was calculated using the different global warming potentials (100 yr) of N_2O and CO_2. On the INT field, the GWP effect due to C sequestration (-5.5 ± 4.8 t CO_2 eq ha^{-1} y^{-1}) is offset by 16% by N_2O emissions due to fertilizer applications. The GHG budget in t CO_2 eq ha^{-1} yr^{-1} was –4.6 and 1.7 for the INT and EXT, respectively.

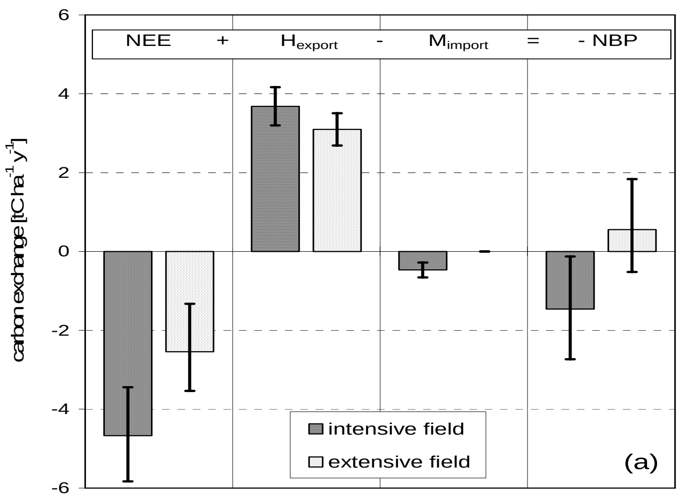

Fig. 2. Average C- budget for the whole 3-year period, (a) absolute budget components for extensive and intensive field with individual uncertainty range, (b) difference between components of the two fields with differential uncertainty range.

DISCUSSION

The results confirm that newly established grassland could act as an important net GHG sink when management intensity is high, i.e. when high net primary productivity (NPP) is maintained by fertilization, while conversion to extensive grasslands leads to an initial net loss of GHG. This positive effect in the INT field occurred in spite of N_2O emissions due to fertilizer application. While NPP remained only slightly lower than in the intensive field, the net loss of C could be caused by higher CO_2 production rate in the uppermost 10 cm of the soil of the extensive field, as measured under standardized laboratory conditions, thus indicating higher potential rates of SOC decomposition. Consequently, conversion of arable land to grassland with the aim to increase C sequestration can be misleading because of possibly transitory losses of soil C during the initial years.

REFERENCE

Leifeld, J., Bassin, S., and Fuhrer, J. (2003), Carbon stocks and carbon sequestration potentials in agricultural soils in Switzerland. *Schriftenreihe der FAL no. 44,* Zurich-Reckenholz, Switzerland.