Available online at www.sciencedirect.com

SCIENCE DIRECT®

Agriculture, Ecosystems and Environment 112 (2006) 200–206

Agriculture Ecosystems & Environment

www.elsevier.com/locate/agee

Nitrous oxide emissions from organic and conventional crop rotations in five European countries

Søren O. Petersen[a,*], Kristiina Regina[b], Alfred Pöllinger[c], Elisabeth Rigler[d], Laura Valli[e], Sirwan Yamulki[f], Martti Esala[b], Claudio Fabbri[e], Eija Syväsalo[b], Finn P. Vinther[a]

[a] *Danish Institute of Agricultural Sciences, DK-8830 Tjele, Denmark*
[b] *Agrifood Research Finland (MTT), FIN-31600 Jokioinen, Finland*
[c] *Federal Research Institute for Agriculture in Alpine Regions (BAL), A-8952 Irdning, Austria*
[d] *Institute for Landscape Development, Recreation and Conservation Planning (ILEN), University for Agriculture, A-1190 Vienna, Austria*
[e] *Research Centre for Animal Production (CRPA spa), I-42100 Reggio Emilia, Italy*
[f] *Institute of Grassland and Environmental Research (IGER), North Wyke, Okehampton EX20 2SB, UK*

Available online 13 October 2005

Abstract

Nitrous oxide (N_2O) emissions from agriculture are currently estimated from N inputs using emission factors, and little is known about the importance of regional or management-related differences. This paper summarizes the results of a study in which N_2O emission rates were recorded on 15–26 occasions during a 12-month period in organic and conventional dairy crop rotations in five European countries (Austria, Denmark, Finland, Italy, UK). A common methodology based on static chambers was used for N_2O flux measurements, and N_2O data were compiled together with information about N inputs (from fertilizers, N_2 fixation, atmospheric deposition and excretal returns), crop rotations and soil properties. Organic rotations received only manure as N fertilizer, while manure accounted for 0–100% of fertilizer N in conventional rotations. A linear regression model was used to examine effects of location, system and crop category on N_2O emissions, while a second model examined effects of soil properties. Nitrous oxide emissions were higher from conventional than from organic crop rotations except in Austria and, according to the statistical analysis, the differences between locations and crop categories were significant. Ammonium was significantly related to N_2O emissions, although this effect was dominated by observations from a grazing system. Despite the limited number of samplings, annual emissions were estimated by interpolation. Across the two systems and five locations there was a significant relationship between total N inputs and N_2O emissions at the crop rotation level which indicated that annually $1.6 \pm 0.2\%$ (mean ± standard error) of total N inputs were lost as N_2O, while there was a background emission of 1.4 ± 0.3 kg N_2O-N ha^{-1} $year^{-1}$. Although this measurement program emphasized system effects at the expense of high temporal resolution, the results indicate that N input is a significant determinant for N_2O emissions from agricultural soils.

Keywords: Nitrous oxide; Crop rotations; Soil properties

1. Introduction

Currently, the dependency of nitrous oxide (N_2O) emissions from agriculture on regional differences or management is not known (Freibauer and Kaltschmitt, 2000), and emissions are calculated from N inputs and emission factors (IPCC, 1997). Based on this approach, agriculture is estimated to contribute 65% of total anthropogenic N_2O emissions within EU15 (European Environment Agency, 2001a). Almost 90% of these emissions are derived from N inputs to agricultural land in the form of fertilizers, manure, leguminous crops and crop residues.

Nitrous oxide emissions are not only derived from recent inputs of N, but also contain emissions derived from

* Corresponding author. Tel.: +45 8999 1723; fax: +45 8999 1619.
E-mail address: soren.o.petersen@agrsci.dk (S.O. Petersen).

0167-8809/$ – see front matter
doi:10.1016/j.agee.2005.08.021

turnover of soil organic N. This so-called background emission is in the order of 1 kg N_2O-N ha^{-1} $year^{-1}$ (Bouwman, 1996), but in practice it will depend on soil characteristics and prehistory, including the position in a crop rotation. For example, Eriksen (2001) found that NO_3^- leaching was reduced by more than 50% between the first and third year after plowing of a pasture, indicating that gross N transformations and, presumably, N_2O production, decreased over time. A variable background emission of N_2O will complicate the interpretation of emissions measured at the field level.

The agricultural area within EU15 that is cultivated by organic farming practices has increased exponentially to a level of 2.5% in 1999 (European Environment Agency, 2001b). Organic farming is characterized by a relatively high reliance on internal N cycling. The lower import of N should reduce the potential for N_2O emissions according to the IPCC methodology, but higher organic inputs and N turnover rates may have the opposite effect. It is therefore relevant to consider if there are systematic differences between organic and conventional farming with respect to N_2O emissions.

This paper summarizes the main findings of a measurement program that was conducted to obtain region- and management-specific estimates of N_2O emissions from organic and conventional dairy crop rotations across Europe. Details of the measurement results from individual locations will be reported separately.

2. Materials and methods

2.1. Experimental sites

The study included measurements in five different locations representing the major cattle producing regions within EU15, as well as the main climatic zones. The geographical locations were Southern Finland (60°49′N, 23°30′E), Western Denmark (55°52′N, 9°34′E), Southwest England (50°42′N, 4°52′W), Central Austria (47°40′N, 13°05′E) and Northern Italy (44°41′N, 10°35′E). In Finland, Denmark, Austria and Italy, N_2O emissions from high intensity (henceforth 'conventional') and low intensity (henceforth 'organic') arable crop rotations were investigated, while at the UK site grazed pastures under organic and conventional management were monitored.

The sites used for the monitoring programs were either experimental crop rotations or local farms. In this paragraph, the systems are characterized in terms of management and intensity. In Austria, N_2O monitoring took place in two crop rotations from a field experiment initiated in 2000. The rotations corresponded to 1.0 livestock unit (LSU) ha^{-1} (organic) and 1.8 LSU ha^{-1} (conventional), and manure management represented a tie-stall system with both slurry (mixture of faeces and urine, with some bedding material) and solid manure. In Denmark, an organic crop rotation receiving two levels (0.7 and 1.4 LSU ha^{-1}) of cattle slurry was used for N_2O monitoring; the treatments had been applied since 1994. In Finland, monitoring took place in experimental crop rotations under organic and conventional management, which were established in 1990. The level of fertilization in the organic rotation corresponded to 0.5 LSU ha^{-1}, while the conventional system received only mineral fertilizer. The monitoring program in Italy was carried out near Reggio Emilia on two farms which produce milk for parmesan cheese production. Livestock densities were 1.5 and 2.3 LSU ha^{-1} on the organic and conventional farm, respectively. The organic farm was converted to this production system in 1986. In the UK, permanent pastures grazed by 1.0 (organic) or 2.4 LSU ha^{-1} (conventional) between mid April and late October were used for N_2O monitoring. On the organic farm, the field selected was grazed in three weekly intervals; grazing was restricted to night time. On the conventional farm, the field was part of a four-block rotation grazed both day and night.

2.2. Background information

Soil and air temperature and precipitation was recorded as part of the measurement programs, either by equipment installed on the site or by an existing weather station. Long-term temperature and precipitation means were obtained for reference.

The soils used for the program represented a range of soil types, i.e., silt loam (Austria), loamy sand (Denmark), clay (Finland), fine silty loam (Italy) and loam (UK). Soil carbon and nitrogen stocks were determined at the field/plot scale. The C:N ratios of the soil in Finland was higher (around 16) than at the other locations (10–13), possibly due to a better protection of soil organic matter in the clayey soil at this site (Christensen, 1992). All soils were neutral to slightly acidic, and there were no consistent differences between management practices. The electrical conductivity (EC) was recorded during autumn 2002 as an indicator for nutrient availability (Smith and Doran, 1996). The soils were all non-saline, although EC in some of the crops at the Italian site was in a range (0.6–0.8 dS m^{-1}) that may have stimulated losses of N_2O (Weier et al., 1993).

2.3. Crop rotations

Nitrous oxide was monitored during 12-month periods which included the growth season of 2002. Table 1 shows the crops grown in 2002. All arable rotations contained grass, small-grain crops and N_2 fixing crops.

2.4. Nitrogen inputs

The data on N inputs are given in Section 3. Nitrogen applied in manure and fertilizers were recorded at each