



Short-term emissions of CO₂ and N₂O in response to periodic flood irrigation with waste water in the Mezquital Valley of Mexico



B. González-Méndez ^{a,*}, R. Webster ^b, S. Fiedler ^c, E. Loza-Reyes ^b, J.M. Hernández ^d,
L.G. Ruíz-Suárez ^d, C. Siebe ^a

^a Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, C.P. 04510 México D.F., Mexico

^b Rothamsted Research, Harpenden, Hertfordshire AL5 2JQ, UK

^c Johannes Gutenberg-University Mainz, Institute for Geography, Johann-Joachim-Becher-Weg 21, 55099 Mainz, Germany

^d Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, C.P. 04510 México D.F., Mexico

HIGHLIGHTS

- Soil irrigated with untreated sewage water emits much CO₂ and N₂O.
- The gases were measured frequently in static chambers.
- The repeated measurements were tested by antedependence.
- Autocorrelated effects of irrigation were estimated by REML.
- Significant short-term emissions of CO₂ and N₂O followed each irrigation.

ARTICLE INFO

Article history:

Received 3 March 2014

Received in revised form

26 October 2014

Accepted 30 October 2014

Available online 31 October 2014

Keywords:

Sewage effluent

Nitrous oxide

Carbon dioxide

Mexico

Static chambers

REML

ABSTRACT

Irrigation with waste water adds labile carbon and nitrogen compounds to the soil, and when applied by flooding it rapidly changes the soil's atmosphere and redox potential. In the Mezquital Valley more than 90 000 ha is irrigated with waste water from Mexico City, and enhanced emissions of CO₂ and N₂O follow each flooding. We measured the emissions of these two gases from a field irrigated periodically with waste water and under three crops, namely alfalfa, rye-grass and maize, using static chambers for 21 months. We also measured emissions from a field growing rain-fed maize before and shortly after two rain events. The data from repeated measurements from the same chambers are correlated in time, and so we modelled the ante-dependence and fitted the models by residual maximum likelihood (REML). The emissions of both CO₂ and N₂O increased rapidly in response to flood irrigation with peaks up to 448 mg C m⁻² hour⁻¹ for CO₂ and 2.98 mg N m⁻² hour⁻¹ for N₂O under maize. Emissions peaked in particular irrigation events either as the infiltrating water replaced the gas from air-filled pores or several days after irrigation as excess nitrogen and fresh sources of carbon were mineralized. Processes operating during the few days during and immediately after irrigation seem to determine the dynamics of gaseous production in this agricultural ecosystem.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Animal manures, sewage sludge and similar waste materials contain large quantities of labile organic compounds, and when used as agricultural fertilizers they enrich the soil in carbon (C) and nitrogen (N). The same happens when untreated sewage water is used for irrigation. Most of that C and N is readily oxidized to CO₂

and N₂O, which are then released into the atmosphere. Both gases contribute significantly to global warming.

Much of our current knowledge about gaseous emissions from agriculture comes either from regions with a temperate climate, in which large amounts of mineral fertilizers are applied, or from flooded paddy soils (Zou et al., 2009; Kim et al., 2010). Much less is known about emissions from soil irrigated with sewage water, a practice that is increasing around the world, especially in arid and semiarid regions where water is scarce (Qadir et al., 2010). Xue et al. (2012) recognized that irrigation with untreated waste water increases the emissions of both CO₂ and N₂O and so enhance the greenhouse effect.

* Corresponding author.

E-mail address: blancagzm@gmail.com (B. González-Méndez).

As mentioned above, untreated sewage water typically contains large quantities of labile C and N, and irrigation with it, especially flood irrigation, produces an oxygen deficit in the soil and promotes the generation of N₂O. Nitrous oxide is generated in soil by microbially mediated nitrification in aerobic conditions and by denitrification in anaerobic ones. The latter can be rapid if there is an excess of N and abundant carbon to provide the energy (Kim et al., 2010). The recent paper by Zhang et al. (2014) reports that simultaneous addition of phosphorus (P), which is also abundant in untreated sewage, can mitigate the production and release of N₂O, however.

Carbon dioxide is produced in the rhizosphere by respiration of organisms, particularly when the soil is moist and the air temperature is close to 20 °C or by oxidation of methane.

The Mezquital Valley in central Mexico is the largest single block of land in the world where waste water is used to irrigate maize, fodder crops and vegetables (Siebe and Fischer, 1996). Irrigation with waste water from Mexico City started more than a century ago, and the practice has added excessive amounts of plant nutrients. Siebe (1998) found that irrigation with waste water has added 527 kg N, 227 kg P and 781 kg K per ha every year to land growing alfalfa. These amounts exceed by 1.5–8 times the uptake by the crop. The fate of the excess N is of particular concern because it could be leached as nitrate into the aquifer or be emitted as N₂O into the atmosphere or both.

Emissions of greenhouse gases from soil in the field vary greatly both in space and time. Variation in space arises from the heterogeneity of aerobic and anaerobic microsites at several spatial scales, i.e. within soil aggregates, variation from one horizon to another, and laterally on scales from a few centimetres to many metres (Stevens et al., 1998) and includes 'hot spots'—locally concentrated small zones of emissions. Fluxes in time can vary similarly. Frequent wetting and drying and also fertilizing trigger emission pulses over a few hours to days ('hot moments'), and these pulses can dominate annual fluxes at any one place (McClain et al., 2003).

In temperate regions, the emissions of CO₂ and N₂O are affected by the annual cycle of weather, drying and wetting of shorter duration, and tillage. In the Mezquital Valley seasonal variation in temperature is less important (5–6 °C), but flood irrigation creates temporary anoxic conditions, and we therefore expect emissions to vary in time as the topsoil is saturated with water and dries again between irrigation events. We need to understand and measure these effects so that we can take practical steps to diminish emissions within individual fields.

The method using static closed chambers is the most popular for measuring emissions of gases. For studies *in situ* of the temporal variation in the emissions, numerous measurements are made from the same chambers, i.e. on the same sampling units, and so are likely to be correlated in time. These correlations are likely to weaken as the time intervals lengthen. Further, technical failures and unforeseen changes in circumstances during sampling lead to lack of balance in the design. It was to deal with precisely such situations that Patterson and Thompson (1971) devised the analytical method of residual (or restricted) maximum likelihood (REML).

The weakening correlation between repeated measurements as the length of time (and number of time intervals) between the measurements increases can be described quantitatively by an ante-dependence analysis (Gabriel, 1962). It provides information about how many preceding measurements contain information about the current one (Webster and Payne, 2002). As far as we know, neither REML nor ante-dependence analysis have been used to study sequential measurements of gas emissions from agricultural soil in the field, and for this reason we describe the analysis in some detail.

The principal objective of the research was to discover how gaseous emissions respond in the short term to flooding with waste water rich in N and C and to rain and to estimate the rates of emissions as they change in time.

2. Materials and methods

2.1. Experimental sites

This research was done in the Mezquital Valley of Central Mexico, where most of the land is irrigated, but where some is farmed with rain alone. The climate there is semiarid with an average annual precipitation varying from 500 to 600 mm and a mean annual temperature between 15 and 17 °C. The difference between the mean summer and the mean winter temperature is 5–6 °C. Most of the rain falls from June to September in short spells during any one of which there is no more than 40 mm (Fernández-Luqueño et al., 2010). Irrigation is done by flooding with raw waste water from Mexico City. The mean application rates of the water vary between 1500 and 2200 mm per year depending on crop and soil type. Between 170 and 210 mm is typically applied on each occasion. Our most up-to-date information on the content of the irrigation water from our measurements at Las Palmas ranch in 2012 are as follows: 81.0 (±5.3) mg litre⁻¹ total carbon, 49.6 (±1.5) mg litre⁻¹ dissolved organic carbon and 5.3 (±4.3) mg litre⁻¹ total nitrogen.

We selected two plots: one at Rancho Las Palmas (municipality of Tlahuelilpan, 200°7' N, 991°3' W), irrigated with raw waste water, and a rain-fed plot growing maize at El Tigre (municipality of Tetepango, 200°4' N, 990°9' W).

The Las Palmas plot covers 2.43 ha with a gentle slope of 0.5° It grows alfalfa, rye-grass and maize in rotation (Table 1). It is irrigated at approximately 30-day intervals, with about 180–200 mm of water on each occasion. The soil is a Haplic Phaeozem with a mollic A horizon more than 50 cm thick covering several strata of dense and compact volcanic tuff locally known as 'tepetate'. The soil's texture ranges from a silt loam at the top of the field to clay loam to silty clay loam at the bottom. The plot had been graded to allow water to flow uniformly from the inlet to the outlet of the field. This created thinner soil at the inlet and thicker soil towards the outlet. We chose three sampling locations:

- (1) near the inlet on soil 50 cm deep,
- (2) near the middle of the field on soil 53 cm deep, and
- (3) near the outlet with soil 160 cm deep.

We chose this design because we expected emissions to differ as the water flows more rapidly over the upper part of the field and stagnates towards the lower part. As it happened we found no significant differences between positions, see below. We monitored five irrigation events of alfalfa. The following crops of rye-grass and

Table 1
Crop rotation and land management at Las Palmas.

Time	Crop and management	Sampling and irrigation	Fertilization
January to July 2008	Alfalfa	5	Nil
Early August	Tillage	Removal of chambers	Nil
August 2008 to February 2009	Rye-grass	4	Nil
March–April 2009	Fallow and tillage	Removal of chambers	Nil
May to September 2009	Maize	4	100 kg N ha ⁻¹

Download English Version:

<https://daneshyari.com/en/article/6338601>

Download Persian Version:

<https://daneshyari.com/article/6338601>

[Daneshyari.com](https://daneshyari.com)