Does Increasing Soil Organic Carbon in Sandy Soils Increase Soil Nitrous Oxide Emissions from Grain Production?

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Key messages

- Crop production is often a source of greenhouse gas (GHG) emissions including nitrous oxide (N_2O).
- Increasing organic carbon (C) in the surface soil increased N_2O emissions from a cropped soil in the Western Australian grainbelt, however, losses were low by international standards.
- Greatest N_2O emissions occurred in response to summer-autumn rainfall events.

Aim

To investigate if increasing soil organic carbon (SOC) increases N_2O emissions.

Background

Crop production is often a source of GHG emissions including N_2O, which is almost 300-times more potent than carbon dioxide (CO_2), as well as a sink for CO_2 via soil C sequestration. Understanding the interactions between SOC and N fertiliser, and its influence on GHG emissions and crop yield is critical when assessing the effectiveness of soil C sequestration to abate GHG emissions from the agricultural land sector.

The effect of increasing SOC via tillage practises on GHG emissions varies depending on soil type. A review of international studies showed for a well-aerated soil (e.g. sands), increasing soil C abated soil GHG emissions via soil C sequestration plus decreased soil N_2O emissions. Increasing SOC by the same amount in poorly aerated soils (e.g. clay) was less effective at abating GHG emissions, as increased soil N_2O emissions from the poorly aerated soil offset soil C sequestration. These findings were mainly derived from agricultural systems in the Northern Hemisphere, and their applicability to southern Australian cropping systems is unknown.

Experimental Approach

We are investigating if increasing SOC alters soil N_2O emissions at the Liebe Group's Long Term Research Site at Buntine (Table 1). The site was established in 2003, and includes a variety of replicated treatments aimed to alter SOC. The current study is utilising field plots that have either been tilled annually with or without the addition of organic matter (OM) every three years. In May 2011, the OM+tillage plots contained 1.2% C in the surface 100mm, while the Tillage treatment contained 0.5% C. Two blocks (Tillage, OM+tillage) have been divided into six plots, with half the plots in each block receiving no nitrogen (N) fertiliser and the remaining plots receiving N fertiliser (100 kg N/ha as urea in 2013 and 2014).

Soil N_2O emissions will be measured for approximately 2.5 years, and commenced 6 June 2012 following seeding. Fluxes are measured using soil chambers (one per plot) connected to a fully automated system that measures N_2O emissions using gas chromatography. Chambers (500mm x 500mm in area) made of clear perspex are placed on metal bases inserted into the ground. The chamber height is progressively increased to accommodate crop growth, with a minimum height of 150mm and a maximum height of 900mm. Four bases are located in each treatment plot to enable the chambers to be moved to a new position every week so as to minimise the effect of chambers on soil properties and plant growth. In addition, grain yield is estimated at harvest each year by collecting hand-cuts collected from each treatment.

Property	Long Term Research Site, Buntine
Experimental design	2 OM treatments x 2 N fertiliser rates x 3 replicates
Treatments	*OM treatments:* 1. Tillage only (annual tillage using offset disks) 2. OM+tillage (OM applied every 3 years, last applied 2012 at rate of 20 t/ha; annual tillage using offset disks) *Nitrogen fertiliser treatments* 1. No N fertiliser 2. N fertiliser (100 kg N/ha applied 4 weeks after seeding)
Plot size	10.5m x 3.6m
Soil type	Deep Yellow Sand (Basic Regolithic Yellow-Orthic Tenosol)
Sowing date	06/05/2014
Seeding rate	100 kg/ha oats (cv. Brusher)
Fertiliser	03/06/2014: 214 kg/ha as urea
Paddock rotation	2011 wheat, 2012 canola, 2013 barley
Herbicides	03/04/2014: 1 L/ha Glyphosate, 300 mL/ha Ester 680, 100 mL/ha Garlon 06/15/2014: 0.5 L/ha Diuron, 0.5 L/ha Dual Gold 30/06/2014: 2 L/ha SpraySeed, 500 g/ha Diuron, 140 g/ha Cadance, 1.5 L/ha Precept, 1 L/ha Hasten
Harvest date	04/11/2014
Growing Season Rainfall	185mm

Results

Hourly N_2O fluxes ranged from -9 to 108 µg N_2O -N/m^2/h in the first two years of the study (7 June 2012–7 June 2014). Losses appeared to be greater from the OM+tillage treatment, especially in response to summer-autumn rainfall (Figure 1). The total amount of N_2O emitted during the first two years of the study varied in response to both the OM treatment and the application of N fertiliser. Consequently, total N_2O losses after two years were ranked: OM+tillage, plus N fertiliser (143 g N_2O-N/ha) > OM+tillage, no N fertiliser (203 g N_2O-N/ha) > Tillage, plus N fertiliser (42 g N_2O-N/ha) = Tillage, no N fertiliser (11 g N_2O-N/ha) (Figure 1). The proportion of N fertiliser emitted as N_2O, after correction for the 'background' emission (no N fertiliser applied), was 0.1% for the OM+tillage treatment. An emission factor for the Tillage treatment was not calculated as the annual N_2O emission did not differ between the plus and no N fertiliser treatments.

Comments

Increasing soil C contents in the surface soil appears to increase the risk of N_2O emissions from a cropped soil in the Western Australian grainbelt. Annual N_2O emissions were 20-times greater from the OM+tillage treatment than the Tillage treatment in the absence of N fertiliser, and almost 10-times greater when N fertiliser was applied. This finding is not unexpected as increasing soil C is known to increase the size of soil microbial biomass, including the microorganisms responsible for N_2O emissions.

Despite N_2O emissions increasing in response to the OM additions, the range of annual N_2O emission at the present study site (0–0.27 kg N_2O-N/ha/yr) are conservative in comparison to values reported for other cropped sites in Australia and overseas. Globally, and across a variety of climatic regions, annual N_2O losses from cropped mineral soils have ranged from 0.3 to 16.8 kg N_2O-N/ha/yr. The annual N_2O emission reported for Buntine is also within the range of values that have been reported for other cropped soils in the Western Australian grainbelt (Table 2).

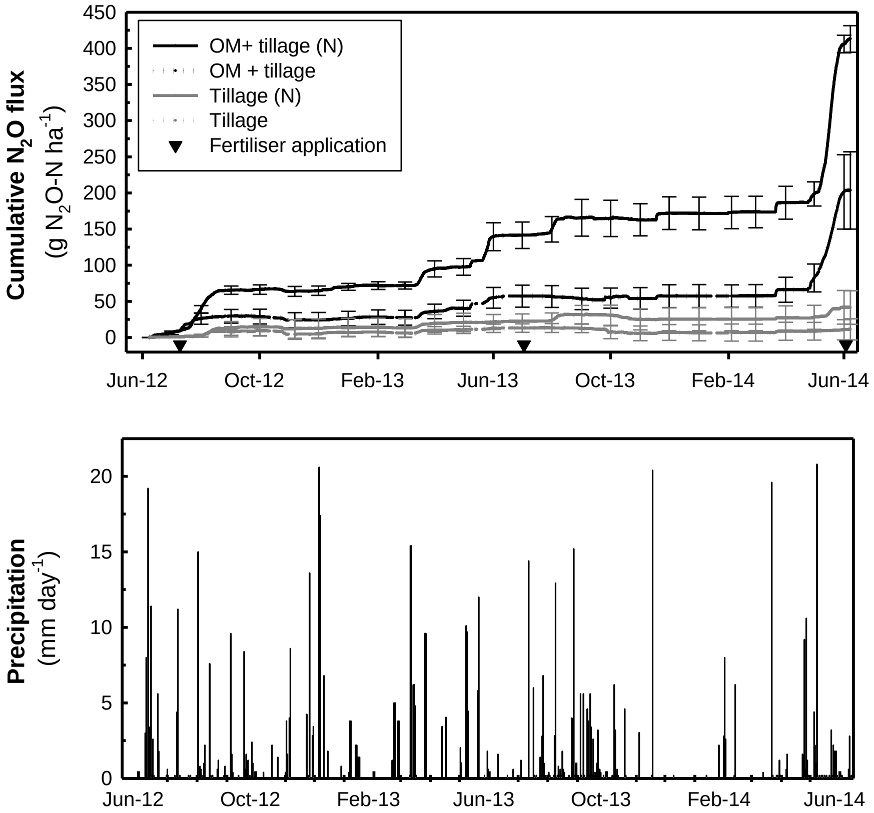

Figure 1. Cumulative N_2O emissions for each OM treatment (a) and daily precipitation (b) after two years of investigations at the Long Term Research Site, Buntine. (7 June 2012 – 14 June 2014). Cumulative N_2O fluxes represent means (± standard errors) of three replicates. The triangle indicates the timing of N fertiliser applications.

Table 2. Annual N_2O emissions from cropped soils in Western Australia.

Location, year	Crop	N application (kg N ha/yr)	Annual N_2O emission (kg N ha/yr)	Emission Factor (%)
Cunderdin, 2005	Wheat	0	0.09	0.02
		100	0.11	
Cunderdin, 2006	Wheat	0	0.07	0.02
		75	0.09	
Cunderdin, 2007	Canola	0	0.08	0.06
		75	0.13	
Cunderdin, 2008	Lupin	0	0.13	NA*
Wongan Hills, 2009	Lupin	0	0.04	NA
	Wheat	75	0.06	
Wongan Hills, 2010	Wheat	20	0.06	NA
	Wheat	50	0.07	

*Not applicable

The N_2O emission factor for the application of N fertiliser to land for the OM+tillage treatment (0.1%) was less than the both the international default value (1.0%) and the value used by the Australian Government for dryland agriculture (0.3%), but slightly greater than values previously reported for the Western Australian grainbelt (Table 2).

Largest hourly N_2O emissions occurred in response to summer-autumn rainfall events. This is consistent with previous observations in the central grainbelt, where a large proportion of annual N_2O emissions occurred between crop growing seasons, when the soil was fallow, and in response to soil wetting following summer–autumn rainfall. Elevated N_2O emissions following summer-autumn rainfall have been attributed to the rapid release of readily decomposable OM to viable microorganisms following wetting of dry soil. These substrates can be derived from non-living organic matter already present in the soil, and from the death of microorganisms due to rapid changes in water potential.

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