



# Water availability and abundance of microbial groups are key determinants of greenhouse gas fluxes in a dryland forest ecosystem



Catarina S.C. Martins, Loïc Nazaries, Catriona A. Macdonald, Ian C. Anderson, Brajesh K. Singh\*

Hawkesbury Institute for the Environment, University of Western Sydney, Penrith South DC, NSW 2751, Australia

## ARTICLE INFO

### Article history:

Received 27 January 2015

Received in revised form

6 March 2015

Accepted 12 March 2015

Available online 27 March 2015

### Keywords:

GHG emissions

Management practices

Ammonia oxidizers

N<sub>2</sub>O-reducing bacteria

Methanotrophs

Bacteria

## ABSTRACT

Forests are considered key biomes that could contribute to minimising global warming as they sequester carbon (C) and contribute to mitigate emissions of the potent greenhouse gases (GHG) including nitrous oxide (N<sub>2</sub>O), methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). Management practices are prevalent in forestry, particularly in dryland ecosystems, known to be water and nitrogen (N) limited. Irrigation and fertilisation are thus routinely applied to increase the yield of forest products. However, the contribution of forest management practices to current GHG budgets and consequently to soil net global warming potential (GWP) is still largely unaccounted for, particularly in dryland ecosystems. We quantified the long-term effect (six years) of irrigation and fertilisation and the impact of land-use change, from grassland to a *Eucalyptus* plantation on N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> emissions and soil net GWP, within a dryland ecosystem. To identify biotic and abiotic drivers of GHG emissions, we explored the relationship of N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> fluxes with soil abiotic characteristics and abundance of ammonia-oxidizers, N<sub>2</sub>O-reducing bacteria, methanotrophs and total soil bacteria. Our results show that GHG emissions, particularly N<sub>2</sub>O and CO<sub>2</sub> are constrained by water availability and both N<sub>2</sub>O and CH<sub>4</sub> are constrained by N availability in the soil. We also provide evidence of functional microbial groups being key players in driving GHG emissions. Our findings illustrate that GHG emission budgets can be affected by forest management practices and provide a better mechanistic understanding for future mitigation options.

© 2015 Elsevier Ltd. All rights reserved.

## 1. Introduction

Intensive anthropogenic disturbances in terrestrial ecosystems are rapidly increasing concentrations of N<sub>2</sub>O, CH<sub>4</sub> and CO<sub>2</sub> gases released to the atmosphere, which directly affects global surface temperatures (IPCC, 2013). Soils are important sources and sinks of these three potent GHGs, with approximately 70% and 35% of the total N<sub>2</sub>O and CH<sub>4</sub> emitted to the atmosphere from soils (Smith et al., 2003). In addition the complex terrestrial global C cycle is characterised by an annual emission of 120 Gigatons of CO<sub>2</sub>, 50% of which is contributed by soil respiration (IPCC, 2013). Although both N<sub>2</sub>O and CH<sub>4</sub> have lower concentrations in the atmosphere compared to CO<sub>2</sub>, their GWP is 298 times and 34 times higher respectively, than that of CO<sub>2</sub> over a 100-year time horizon (IPCC, 2013). This makes them two of the most important non-CO<sub>2</sub> GHGs to include in future mitigation options.

Human activities can directly change GHG fluxes and alter how terrestrial ecosystems influence the climate and future GHG emission budgets. Dryland ecosystems (hyper-arid, arid, semi-arid and dry sub-humid ecosystems) are particularly important and cover about 41% of Earth's terrestrial surface (Millennium Ecosystem Assessment, 2005). They are expected to expand further by 10% globally under predicted climate change (Feng and Fu, 2013). These ecosystems are characterized by extremely low availability of soil water and nutrients, resulting from low precipitation and high evaporation (Delgado-Baquerizo et al., 2013) and hence, are considered to be highly vulnerable ecosystems. The expected expansion of dryland ecosystems not only impact human populations but can also affect current GHG fluxes from these ecosystems and further contribute to increasing GHG emissions into the atmosphere. In fact, even though studies in arid-zone soils are rare, both CH<sub>4</sub> oxidation (Dalal et al., 2008) as well as N<sub>2</sub>O emissions are reported, the latter occurring mostly after summer rainfall (Barton et al., 2013). However, the mechanisms and drivers

\* Corresponding author.

E-mail address: [b.singh@uws.edu.au](mailto:b.singh@uws.edu.au) (B.K. Singh).

of GHG production and consumption in dryland ecosystems are not fully understood.

Nitrous oxide is emitted from terrestrial ecosystems through a combination of microbial processes, mostly nitrification-mediated pathways (nitrifier nitrification and/or nitrifier denitrification) and denitrification (Baggs, 2011). Nitrification-mediated pathways are facilitated by ammonia-oxidizing archaea (AOA) and ammonia-oxidizing bacteria (AOB) by aerobic oxidation of ammonia ( $\text{NH}_4^+$ ) but this can also occur through the reduction of nitrite ( $\text{NO}_2^-$ ) by relevant AOB (Kool et al., 2010). Denitrifying microorganisms can also generate  $\text{N}_2\text{O}$  as an intermediate or as an end product of the anaerobic respiratory pathway by reducing nitrate ( $\text{NO}_3^-$ ) or  $\text{NO}_2^-$  (Baggs, 2011). More recently, work has demonstrated a  $\text{N}_2\text{O}$  sink capacity for soils via the activity of  $\text{N}_2\text{O}$ -reducing microorganisms (Jones et al., 2014). Methane production occurs through the anaerobic process methanogenesis by methanogenic archaea. It is consumed mostly through the aerobic process methanotrophy by methanotrophic bacteria, with forests known to be dominated by  $\text{CH}_4$ -oxidising microorganisms (Le Mer and Roger, 2001). Carbon dioxide is emitted through soil respiration, a combination of root, microbial and faunal respiration, and decomposition (Rastogi et al., 2002; Singh et al., 2010). All of these GHG-producing processes are primarily controlled by substrate availability, such as mineral N and labile C as well as by soil physico-chemical factors, such as pH, soil moisture, temperature and diffusivity (Dalal and Allen, 2008). These factors regulate microbial enzymatic expression which is ultimately responsible for the production and consumption of these gases (Spiro, 2012).

Forestry plantations routinely use fertilisation (N, P and K) and irrigation practices to maximise wood production by shortening rotation times. This is intended to overcome nutrient and water deficiencies that are common in many Australian, and other dryland soils. Furthermore, changes in land-use are occurring continuously, with conversion of native woodland to grazed pastures as well as conversion of pasture to forest plantations. The latter known to improve  $\text{CH}_4$  consumption rates, reduce  $\text{N}_2\text{O}$  emissions from soil and increase C sequestration (Dalal et al., 2008; Allen et al., 2009; Livesley et al., 2009). As a consequence, some studies have addressed the impact of land-use change on GHG fluxes in Australian soils (Livesley et al., 2009; Grover et al., 2012) but much less is known about how fertilisation and irrigation affect GHG emissions from nutrient poor soils and how they alter functional microbial groups responsible for these emissions (Hu et al., 2015).

Because microbial communities play a central role in the production and mitigation of all GHGs, it is essential to understand how key functional microbial groups will respond to management practices and land-use change in order to improve the prediction of total GHG fluxes under current and future forestry management practices. In fact, knowledge of responses of GHG fluxes and their biotic drivers are practically sparse in dryland forests, with recent evidence drawing attention to the great importance of water and N availability in the net primary production and biological activity in dryland forest ecosystems (Austin et al., 2004; Delgado-Baquerizo et al., 2013). Field studies of forest fertilisation have mostly taken place in temperate and boreal forest ecosystems in the Northern Hemisphere (Levy-Booth et al., 2014) where water and nutrient limitation is less likely. Studies that link soil characteristics and N and C cycling dynamics to microbial functional dynamics are, therefore, essential for identifying the key environmental drivers of GHG fluxes in dryland forest ecosystems, and particularly to incorporate biological factors into predictive models to improve the accuracy of GHG emissions projections. This study aimed at quantifying the long-term (six years) effect of fertilisation and irrigation on  $\text{N}_2\text{O}$ ,  $\text{CH}_4$  and  $\text{CO}_2$  emissions in a *Eucalyptus* plantation, and the impact of land-use change from grassland to forest, within a dry

sub-humid ecosystem. We further identified key environmental drivers within microbial and abiotic variables from soil. In addressing these aims we hypothesized that water addition and fertilisation would favour  $\text{N}_2\text{O}$ ,  $\text{CH}_4$  and  $\text{CO}_2$  emissions by increasing nutrient and water availability to soil microbial communities and that land-use change would help mitigate GHG emissions.

## 2. Materials and methods

### 2.1. Field site description

The experimental field study is situated at the Hawkesbury Forest Experiment (HFE) site (33°36'40"S, 150°44'26.5"E), Richmond, NSW, Australia. The field site where the experiment was established covers 5 ha and was a paddock which had been converted from native pasture grasses more than a decade earlier. The soil, a sandy loam formed on alluvial deposits is classified as Chromosol within the Clarendon formation. It is characterized by low organic matter content (0.7%) and low N (<1 mg kg<sup>-1</sup>) and P (8 mg kg<sup>-1</sup>) concentrations. Full soil characteristics and climate description are described in Barton et al. (2010). With a precipitation/evapotranspiration ratio of 0.6, the site is classified as a dry sub-humid environment under UNEP classification (Millennium Ecosystem Assessment, 2005).

A plantation of Sydney blue gum (*Eucalyptus saligna* Sm.) consisting of 1000 trees ha<sup>-1</sup> was established in April 2007. Three different management practices, namely irrigation (I), solid fertilisation (F) and irrigation × liquid fertilisation (IF), were initiated together with a control treatment (C) which received no irrigation or fertilisation. Four experimental plots (38.5 m × 41.6 m) were replicated in a randomized block design and all trees were initially supplied with 50 g diammonium phosphate (DAP) starter blend (N 15.3%, P 8.0%, K 16.0%, S 7.7%, Ca 0.3%) to promote tree establishment. The first fertilisation event in F and IF was undertaken in January 2008 as a solid N fertiliser (N 20.6%, P 3.0%, K 7.5%, S 3.8%, Ca 4.4%) at a rate of 25 kg N ha<sup>-1</sup> yr<sup>-1</sup>. In October 2008, solid N fertiliser (N 21.6%, P 8.1%, K 12.0%, S 0.6%) was applied uniformly to F, and IF started with the addition of a complete liquid fertiliser (N 20.8%, P 7.9%, K 15.6%) plus liquid N fertiliser (urea-N 46%). Both treatments were at a rate of 150 kg N ha<sup>-1</sup> yr<sup>-1</sup> and 55 kg P ha<sup>-1</sup> yr<sup>-1</sup>. In I, grey water (pH 8.8, total N 0.6 mg/L, total P 3.0 mg/L) has been supplied since the establishment of the field site at a rate of 7–20 mm every 4 days, according to season and precipitation events. The irrigation rate applied to IF was the same as to I. The irrigation treatments were applied all year round, while the fertilisation treatments occur only during the growing season. In total, 16 field plots comprising 4 different experimental treatments were considered in this study, together with 4 areas of grassland (G) surrounding the forest plots in order to assess the effect of afforestation.

### 2.2. Greenhouse gas flux measurement

Greenhouse gas fluxes ( $\text{N}_2\text{O}$ ,  $\text{CH}_4$  and  $\text{CO}_2$ ) were measured seasonally, every twelve weeks, from the beginning of May 2013 to the end of January 2014 using a static chamber technique. All sampling activities were carried out after 4 weeks of solid fertiliser application in order to avoid potential short-term effects on flux rates and microbial communities. Three polyvinyl chloride chamber anchors (diameter = 24 cm, height = 21 cm) were inserted 10 cm into the soil in each plot, between trees favouring litter areas when possible. Chamber anchors were installed 24 h before measurements were taken in order to minimise soil disturbance impact on GHG fluxes. Air samples (20 ml) were taken from the headspace (headspace volume = 4976 cm<sup>3</sup>) after 0, 20, 40 and 60 min using a

Download English Version:

<https://daneshyari.com/en/article/2024515>

Download Persian Version:

<https://daneshyari.com/article/2024515>

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