Quantifying N_2O and CO_2 emissions from a subtropical pasture

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Abstract
Greenhouse gas emissions from a well established, unfertilized tropical grass-legume pasture were monitored over two consecutive years using high resolution automatic sampling. Nitrous oxide emissions were highest during the summer months and were highly episodic, related more to the size and distribution of rain events than WFPS alone. Mean annual emissions were significantly higher during 2008 (5.7 ± 1.0 g N_2O-N/ha/day) than 2007 (3.9 ± 0.4 and g N_2O-N/ha/day) despite receiving nearly 500 mm less rain. Mean CO_2 (28.2 ± 1.5 kg CO_2 C/ha/day) was not significantly different ($P < 0.01$) between measurement years, emissions being highly dependent on temperature. A negative correlation between CO_2 and WFPS at >70% indicated a threshold for soil conditions favouring denitrification. The use of automatic chambers for high resolution greenhouse gas sampling can greatly reduce emission estimation errors associated with temperature and WFPS changes.

Introduction
Increases in the concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the atmosphere due to human activities have long been linked to climate change. Greenhouse gas (GHG) emissions from agriculture are estimated to be about 16% of Australia's total GHG budget. This is expected to increase with intensification of agriculture over the coming decades. For these reasons full greenhouse accounting to comprehensively assess the impact of land management strategies has continued to gain momentum in recent years, aimed at ultimately developing mitigation strategies to reduce GHG emissions. Little comprehensive data exists for the processes related to GHG emissions from tropical soils and land management systems, the majority of work being associated with temperate climates or in laboratory conditions. During this experiment, GHG emissions were examined and compared between three landuses on a Haplic, Brown Dermosol as part of a larger study aimed at reducing uncertainties in GHG estimates from subtropical landscapes. In this paper N_2O and CO_2 emissions from pastures will be examined.

Methods
The study site was situated in the wet subtropical region of the Mooloolah valley; approximately 100km north of Brisbane, Queensland. Three landuses were examined; a grazed and mown tropical pasture dominated by *Setaria sphacelata,* Silverleaf Desmodium (*Desmodium uncinatum*) and White Clover (*Trifolia repens*), remnant Gallery rainforest (notophyll vine forest) and a 20 year old Lychee orchard. The greenhouse gases N_2O, CO_2 and CH_4 were measured for two full years commencing the 1st of March 2007 and finishing on the 28 February 2009. Emissions were measured from three landuses; (three chambers per plot) using an automated gas sampling system described by (Breuer *et al.* 2000) and (Kiese 2002). Briefly the system consisted of nine automated measuring chambers linked to an automated sampling control system, computer and a gas chromatograph (SRI 8610C,) housed in a weatherproof trailer at a central position on the field site. Chambers from each plot were closed for 48 minutes and open for 96 minutes, allowing for 10 individual flux measurement periods per day while minimizing any impact on the soil environment. Auxiliary sub-daily soil temperature and moisture data was collected from each landuse and a weather station was situated on the site.

Results
A total of 1928 mm rain fell at the site during the March 2007 to February 2008 measurement season, significantly (P <0.05) higher than the 1432 mm in the 2008/09 season and above the long term average of 1709 mm. Frequent heavy rainfall resulted in large and rapid changes in soil moisture content (amplitude of WFPS: 28-90%). Though rainfall was higher in the summer months no distinct wet/dayry pattern was observed, though seasonal patterns did persist over the 2 year measurement period. Temperatures ranged from a mean daily minimum of 9.0 °C during the winter to a daily maximum of 27.9 °C in the summer. The minimum hourly air temperature was -0.6 °C recorded in July 2007, while the maximum hourly temperature (38.2 °C) was recorded in February 2008.

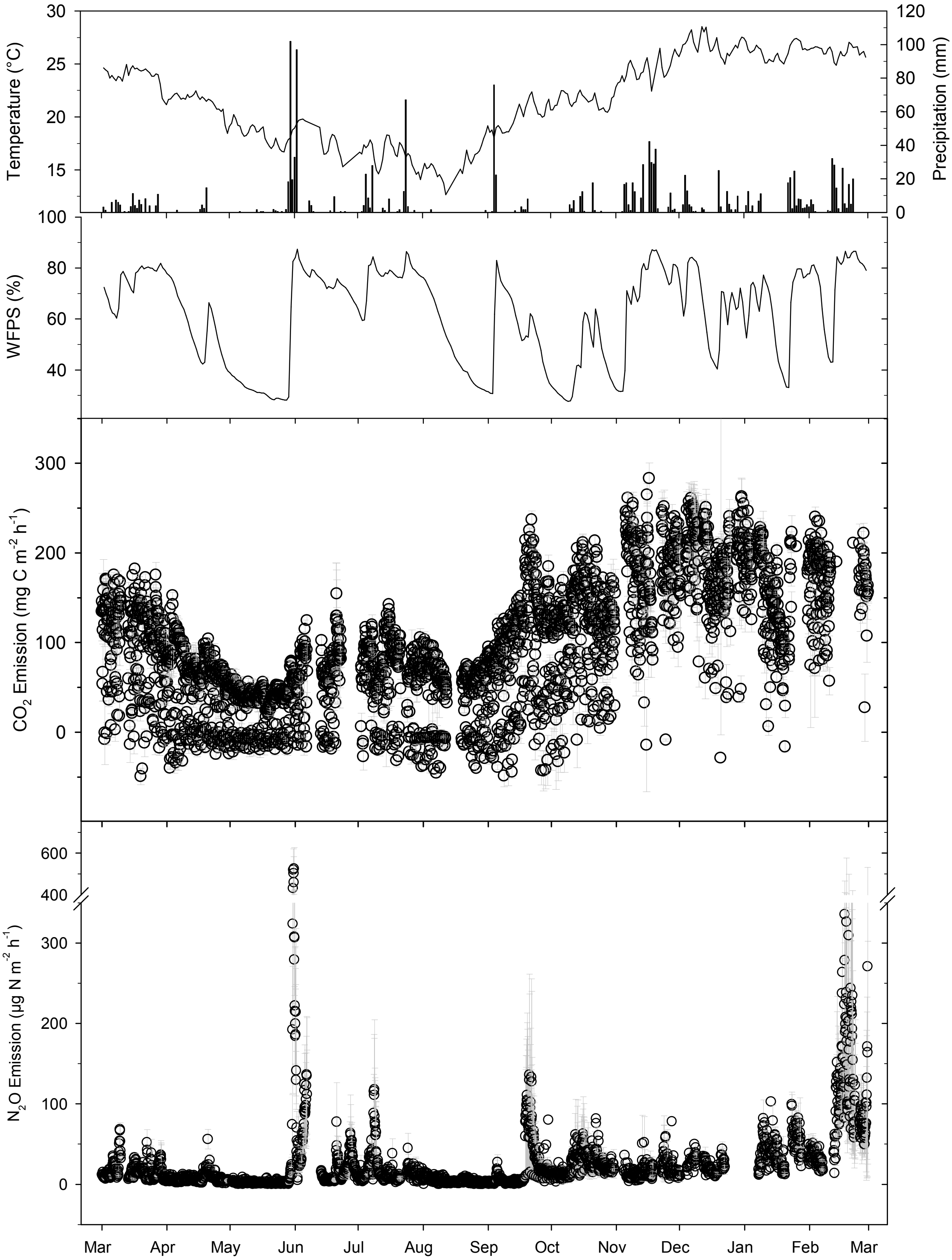

Figure 1. Hourly means of soil temperature (5 cm), water-filled pore space (WFPS), mean CO_2- emission rates (N = 3), N_2O-emission rates (N = 3) and daily precipitation for pasture (March 2008 February 2009).

N_2O and CO_2 emissions from soils

Despite data loss from leaks due to livestock and rodent activity, issues with the gas chromatograph due to high humidity and even the inundation of the chambers during a flood event, over 70 000, individual, real time gas concentration measurements were taken for each gas over the duration of the experiment.

The use of the automatic chambers allowed for the high temporal variability of fluxes to be fully accounted (Fig.1). Emissions varied on a daily, seasonal and yearly basis driven chiefly by changes in WFPS and temperature. Nitrous oxide fluxes were highly episodic with 48% of emissions occurring in just 16% of measurement days. Mean N_2O fluxes for 2008 were 5.7 ± 1.0 g N_2O-N/ha/day, significantly ($P < 0.01$) higher than 2007 (3.9 ± 0.4 g N_2O-N/ha/day). Emissions were highest during the summer with the highest daily flux of 94.2 g N_2O-N/ha/day occurring on the 18th February 2009. The highest individual chamber flux also occurred on this day (197.8 g N_2O-N/ha/day). Lowest emissions were recorded during the spring and winter. Detailed correlation analysis revealed a close relationship between WFPS and magnitude of N_2O emissions for autumn ($r = 0.52$, $P < 0.01$), winter ($r = 0.65$, $P < 0.01$) and summer ($r = 0.39$, $P < 0.01$). Mean nightly CO_2 fluxes (28.2 ± 1.5 kg CO_2- C/ha/day) were not significantly different ($P < 0.01$) between measurement years. Emission were highly significantly correlated ($r = 0.73$, $P < 0.01$) with temperature; highest fluxes (58.1 kg CO_2-C/ha/day) occurring in late spring and early summer when maximum temperatures occurred. CO_2 and WFPS were less correlated ($r = 0.33$, $P < 0.01$) and in spring and summer negative correlations ($r = -0.25$, $P < 0.01$ and $r = -0.37$, $P < 0.01$ respectively) occurred as increasing WFPS (> 70%) inhibited O_2 availability in the soil.

Table 1. Mean annual emissions for CO_2 (t C/ha/y) and N_2O (g N/ha/y).

Gas	2007			2008		
	Mean	N	CV%	Mean	N	CV%
CO_2	11.2 ± 0.4	3	5.7	10.7± 0.4	3	6.3
N_2O	1504.7 ± 126.7	3	14.3	2148.6 ± 273.1	3	22.0

Discussion

Nitrous oxide emissions measured over the study period were twice as high as maximum values generally quoted in the literature (Dalal 2003; Denmead *et al.* 2000), and were highly episodic; responding more to individual rain events than to general trends in WFPS. Rainfall and subsequent WFPS, though playing a critical role; was less an influencing factor than the distribution and length of individual rainfall events. This was highlighted by emissions from 2007 being significantly lower than 2008, despite receiving almost 500 mm more rainfall. Carbon dioxide dynamics provide a good representation of microbial activity in the soil. Emissions continued at WFPS values well below 40% indicating microbial processes such as mineralization were less affected by low moisture. At values greater than 70% WFPS CO_2 emissions were inhibited by lack of available O_2, creating soil conditions that favour denitrification. High moisture and legume component (which can fix up to 200 kg N/ha/y as stated by Peoples and Baldock, 2001) and a fine textured soil contributed to the comparably higher emissions on this site. In addition, traditional manual sampling is generally carried out on a weekly or fortnightly basis, leaving the potential to completely miss these large temporal events subsequently underestimation of annual totals.

Conclusion

When considering the cost in equipment and time resources required to attain even one tenth of measured samples manually; the benefits of the automated system are clear. The combination of a fine textured soil, high soil moistures and temperatures and readily available N from legumes contributed to substantial N_2O emissions in the tropical pasture-legume system. The use of automatic chambers for high resolution greenhouse gas sampling can greatly reduce emission estimation errors associated with temperature and WFPS changes. However as legume content and distribution in long term pastures can change with time of year, rainfall, frost and grazing pressures, N_2O fluxes related to legume residues are likely to be just as variable in space as time.

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