The Centre for Australian Weather and Climate Research

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Measurements of Soil-Atmosphere Exchange of CH_4, CO, N_2O and NO_x in the Semi-arid Mallee System in Southeastern Australia

I.E. Galbally, C.P. Meyer, Y-P. Wang, W.V. Kirstine, C.J. Smith, and I.A. Weeks.

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Distribution list

Chief	1
Authors	1
Library	1

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Contents

ABSTRACT

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A 12-month study (involving 5 measurement periods) of the influence of land use on the soil-atmosphere exchange of methane, carbon monoxide, nitrous oxide and odd nitrogen oxides in the semi-arid (275 mm annual rainfall) Mallee system of north-western Victoria, Australia, is reported. The measurements were conducted on two adjacent sites of the same soil type, where one site was pristine vegetation and the other site had been cleared and farmed with cropping and sheep grazing for approximately 65 years. A wheat crop was grown and harvested on the farmland during the year and this site is subsequently described as Wheat. This study was undertaken because of the paucity of information on soil-atmosphere exchange of trace gases in semi-arid and arid zones.

The site and the measurement techniques are presented in this technical report. The full set of measurements and supporting data from the study on meteorology, soil properties, nutrients and moisture, the trace gas exchange rates and some simple statistical summaries of the observations are included. These data have been used as inputs for the estimation of nitrous oxide emissions from agriculture for the Australian National Greenhouse Gas Inventory. This report is intended as a record of the observations.

1. INTRODUCTION

Human changes to the Earth's biosphere have profoundly influenced the concentrations of greenhouse and other trace gases in the Earth's atmosphere (Brasseur *et al*. 2003). The atmospheric consequences of several changes to the biosphere, including deforestation and the expansion of ruminant animal numbers, are well quantified (Henderson-Sellers *et al*. 1993). The soil-atmosphere trace gas exchange from semi-arid and arid regions is poorly understood, as are the effects on trace gas exchange of the loss of vegetation and soil organic matter from unsustainable use of these regions (Castaldi *et al*. 2006, Galbally *et al*. 2008). This paper focuses on the soil-atmosphere exchange of CH_4, CO, N_2O and NO_x in a semi-arid 'mallee' region of south-eastern Australia, and the effects of land use change on these trace gas emissions.

The term 'mallee' is commonly used to describe both (1) a type of mediterranean ecosystem prevalent in southern Australia or the region in which it occurs, and (2) a type of eucalyptus species of scrub found in those regions. The climatic conditions in the Mallee are typical of other Mediterranean-type shrublands of the world, with variable annual rainfall, mild to hot summers and cool winters (DiCastri 1981). In the Mallee district of western Victoria, the native forest is dominated by mallee woodlands. From 1869 to 1972, 2.3 Mha of mallee forest were cleared. Subsequent to 1972, the rate of forest clearing in freehold and public land slowed down considerably (Woodgate & Black 1988). The Mallee was chosen for this study because it is one of the few regions of Victoria (indeed one of the few semi-arid regions in the world) that contains large areas of relatively unmodified natural vegetation. It is also an area where extensive clearing is still possible. In this paper, the further distinction will be made between the Mallee district which covers all of the area of the original mallee ecosystems (both cleared and undisturbed) and the unattached term Mallee that will be used to describe the undisturbed Mallee site where the measurements were made. The vegetation will be described with the lower case term mallee.

This study was a 12-month study, involving 5 measurement periods, of trace gas emissions from, and uptake by, undisturbed natural and cleared farmland Mallee soils. The objectives were two-fold: (1) To determine both the rates of, and the processes controlling, CH_4, CO, N_2O, and NO_x biosphere-atmosphere exchange of a common semi-arid zone soil type, and (2) to investigate the effect of land use change from the natural mallee vegetation to a combination of wheat/fallow/sheep rotational farming on this soil-atmosphere trace gas exchange. A summary of the project (without the detailed data) was previously presented (Galbally *et al*. 1996).

The gas exchange measurements have been reprocessed in the preparation of this report to identify and remove a few errors that arose in the initial manual transcription of the data and subsequently as a result of a change in file format.

2. MATERIALS AND METHODS

2.1 Site

This study was conducted in the Sunset country about 70 km west-southwest of Mildura, a regional centre in northwest Victoria, Australia, on two sites of the same soil type. One site was located in a nature reserve administered by the Department of Conservation and Environment, while the other site, approximately 2 km away, was on privately-owned farmland. The sites were located at 34° 29′ 38″S, 141° 24′ 36″ E, and 73 metres above sea level. Both sites were located in the Woorinen land system type, having an east-west Mallee dunefield consisting of Calcarosols with a sandy A-horizon underlain at 20-30 cm by sandy clay (McKenzie et al. 2004). Of this system, 84% of the land area was freehold and had been cleared for agriculture.

The vegetation on the Mallee site consisted of *Eucalyptus incrassata*, *E. dumosa*, and *E. oleosa* (giving a canopy cover of approximately 50%) with an understorey of *Triodia spp*. and annual herbs. The site was estimated to be unburnt for at least 90 years. The undisturbed ground was covered by a crust of lichens and mosses, which disintegrated when walked upon to be replaced by the loose sand from beneath. The Mallee site (of 0.25 ha) was fenced to facilitate the experiment and to provide protection against accidental intrusion of domestic grazing animals. One side of the fenced area had a gate. The five field measurement periods utilized the field site progressively from the gate to the opposite corner, so that each time flux measurements were made on undisturbed ground. Walkways were marked with stakes to minimise accidental disturbance. Six plots (0.8 m x 0.8 m chamber bases) were set up for each experiment. Two plots were placed close to the bases of trees; two were under, but near, the periphery of the canopy; and two were in the open. Subterranean termites were active in the Mallee site, as observed by the presence of narrow (several mm wide) galleries across the site just below the soil surface, which were revealed when the roofs collapsed following rainfall events.

The farmland site was on a parallel sand dune in a regularly cropped wheat field, and is subsequently called the Wheat site. The land had been released by the government for purchase for farming in 1927. Thus, the farmed land had been cultivated for more than 60 years – in recent years on the standard 3-year cycle of crop, grazed stubble and long fallow. Superphosphate, sometimes with small amounts of nitrogen (5 kg ha^{-1}), was applied at sowing, and weeds were controlled using herbicides. The site being used had just been under fallow and was planted with wheat accompanied by a NPK fertiliser. The wheat cultivar was Meering – sown with a seed density of 32 lbs $acre^{-1}$ (36 kg ha^{-1}) at a depth of 6 cm. The field was approximately 1 km^2 in area. Wheat biomass measurements, taken during this study, are included in Appendix D. The locations used for the trace gas measurements during the five measurement periods were approximately 30 m in from the northern boundary of the field to minimise edge effects, and each measurement period used a location approximately 20 m west of the previous measurement period so that each time flux measurements were made on undisturbed ground. Walkways were marked with stakes to minimise accidental disturbance. Six plots (0.8 m x 0.8 m chamber bases) were set up, located randomly (by closing ones eyes and throwing markers) about a central point for each experiment. No evidence of termites was observed in the wheat field.

2.2 Chambers

Gas fluxes were measured by a static chamber method that consisted of covering an intact area of the soil surface (0.65 m^2) with a solid-walled chamber and monitoring the change in concentration of the relevant gases over the subsequent hour (Galbally *et al*. 1985). The gas flux was calculated as the initial linear rate of concentration change, after correcting for the small rates of air leakage from the chamber. Gases were sampled for CH_4, CO and N_2O at 0, 5, 15 and 50 minutes after closing, and, on separate occasions, continuously for CO_2 and NO_x. The convention in this paper is that gas uptake by the soil and plants from the atmosphere is negative, whereas gas release by the soil and plants to the atmosphere is positive.

Emission rates were calculated from the increase in the concentration inside the chamber during the time intervals following the placing of the chamber over the plot. When the chamber was sealed, the emitted gases accumulated and caused an increase in the gas concentration in the chamber air. The flux of trace gas from the soil and plants in the chamber, *F* (units: mass per unit area per unit time), was calculated using Equation (1):

$$F = \frac{\Delta C_s \cdot M_s \cdot \rho \cdot h}{M_a \cdot \Delta t'} \qquad (1)$$

where *h* is the height of the chamber; ΔC_s is the change in concentration of the trace gas in mixing ratio units; *M* is the molecular mass; the subscripts *s* and *a* refer to the trace gas and air, respectively; ρ is the density of air; and $\Delta t'$ is the leakage-corrected time interval corresponding to ΔC.

Chamber leakage was defined as the gross rate of air lost from the chamber, v_g, which was the sum of the rate of natural air leakage of the chamber and the rate at which air was purposely withdrawn from the chamber as a result of sampling (Meyer *et al*. 2001b). When there was chamber leakage, the concentrations measured by the continuous analysers were lower than the concentrations that would have occurred in a fully sealed chamber. Marynick & Marynick (1975) applied Equation (2) as a formula to calculate a time correction, which is used in Equation (1) to correct for chamber leakage.

$$\Delta t' = \frac{1 - e^{-v_g \cdot V^{-1} \cdot \Delta t}}{v_g \cdot V^{-1}} \qquad (2)$$

Δt is the difference in time between the initial and final concentrations (in s);
$\Delta t'$ is the time difference corrected for chamber leakage (in s);
v_g is the gross rate of air lost from the chamber (in $m^3\ s^{-1}$); and,
V is the volume of the chamber (in m^3).

The term, $v_g \cdot V^{-1}$, is known as the air exchange rate of the chamber. This chamber air exchange rate was measured (following some of the trace gas exchange measurements) by adding an excess of CO_2 to the chamber and observing its decrease with time.

Three chambers, with heights of 20 cm, 40 cm, and 100 cm were used. The choice of chamber used depended on the height of the vegetation on the site. The small chamber had a solid anodised aluminium construction with a perspex window in about 50% of the top of the chamber. The two larger chambers were constructed from an anodised aluminium frame with perspex sides. The larger transparent chambers were lined with teflon film and had an interior fan creating an aerodynamic resistance equivalent to a light wind. There was a 3-mm diameter hole in each chamber to ensure pressure equalisation between the inside and the outside of the chamber. Open aluminium bases were inserted to a depth of about 10 cm into the ground at each site, and left intact for the duration of the measurement period.

During each measurement period, measurements of the chamber blank or artefact fluxes were made by putting a solid anodised aluminium base under the chamber. This allowed the detection of any artefact fluxes. Indeed, with the exception of CO, the blank or artefact fluxes were very small compared with the soil-atmosphere fluxes. The artefact fluxes were: CO_2 = -0.3 ± 1.0 µg(C) m^{-2} s^{-1}; CH_4 = -0.3 ± 1.7 ng(C) m^{-2} s^{-1}; N_2O = 0.0 ± 0.3 ng(N) m^{-2} s^{-1}; and CO = 2 ± 6 ng(C) m^{-2} s^{-1}. The CO distribution was skewed with a maximum artifact of +8 ng(C) m^{-2} s^{-1}. In response, an average flux of 2 ng(C) m^{-2} s^{-1} was subtracted from all of the CO measurements.

When the wheat crop was growing, and vegetation was inside the chamber, the measurements of CO_2 exchange were an unspecified combination of plant uptake and soil respiration, and varied with the time of day due to varying solar radiation levels. In the case of the Mallee, there was little understory vegetation and the small chamber was used. This chamber was not transparent to sunlight (apart from a small window). Consequently, the Mallee fluxes were a measurement of soil respiration.

2.3 Gas Concentrations

Air samples taken from the flux chambers were analysed for CH_4, CO and N_2O using two gas chromatographs set up in an air-conditioned field laboratory located on a nearby farming property several kilometres from the two sampling sites. Air samples were dried using a semi-permeable membrane drier (Nafion, Dupont, USA) prior to injection onto the gas chromatographs.

The nitrous oxide analyses were made on a HP5890 Series 1 (Hewlett Packard, USA) gas chromatograph, fitted with an electron capture detector (ECD) that was operated at 400ºC. Sample introduction was via a 10-port Valco gas sampling valve fitted with a 3-mL gas loop held at 80ºC. The gas chromatographic separation was achieved using two 1/8 inch outside diameter packed columns containing Porapak QS, and operated at 65ºC. The two columns were arranged in a backflush arrangement. The response of the ECD was non-linear but, within the measurement range of this experiment (150-450 ppbv), a linear correction factor of 0.86 was determined using a dynamic dilution method. This was applied to the results described here.

The methane and carbon monoxide analyses were conducted on a HP5730A (Hewlett Packard, USA) gas chromatograph, fitted with a flame ionization detector (FID) and catalytic methanator. Sample air injections were made via a 6-port Valco gas sampling valve, with an unheated 8-mL sample loop, onto a 1.9 m x ¼ inch outside diameter column packed with Molecular Sieve 5A, and operated at 95ºC.

Continuous carbon dioxide measurements were made in the field using a non-dispersive infra-red gas analyser (Licor 6251, Nebraska, USA). Calibrations of both gas chromatographs and the non-dispersive infra-red gas analyser were done using a high pressure cylinder of Cape Grim air, CG151190C (#ALTH8471), that was calibrated by CSIRO (GASLAB) against their standards that are traceable to US standards (Francey *et al*. 2003).

The NO_x ($NO + NO_2$) measurements were made with a Scintrex LMA-3 luminol-based chemiluminescent NO_2 detector, and a Scintrex LNC-3 NO to NO_2 convertor (Scintrex Ltd., Toronto, Canada). The NO_x calibrations were based on a US National Bureau of Standards NO in N_2 certified standard with a concentration of 4.71 ppm. Daily calibrations of the NO_x measurement system were undertaken.

Precisions of the measurements were: methane (± 0.4%), carbon monoxide (± 20%), nitrous oxide (± 0.3%), nitric oxide and nitrogen dioxide (± 0.1 ppb) and carbon dioxide (± 0.2 ppm).

2.4 Other Measurements

Soil sampling involved taking 10 composite soil cores of 0-5 cm depth (each a composite of 3 samples) from each of the Mallee and Wheat sites at the end of each of the five measurement periods, giving a total of 100 soil samples from the experiment. See Appendices B and C. Soil analyses were conducted by standard methods (Rayment & Higginson 1992) at the Institute for Sustainable Agriculture, Department of Primary Industry, Tatura, Victoria.

Minimum and maximum temperatures, rainfall and evaporation for the period of the study were obtained from the data records of representative weather stations of the Australian Bureau of Meteorology at Meringur and Lake Cullulleraine, in the vicinity of the study site (BOM 2006). Chamber air temperature and soil temperature at 2.5 cm depth were measured using thermocouples and rainfall via a gauge during each of the measurement periods.

2.5 Artificial Watering

Ecological processes in semi-arid regions are driven by occasional rainfall events, which in normal conditions are unlikely to occur during each of the one-week measurement periods. To obtain representative trace gas exchange rates, an estimate of the transient changes in gas emissions following rainfall is required, in addition to the basal emission rates from the undisturbed soils. To accommodate this, the normal measurement protocol consisted of measuring the fluxes from four or five sample areas each day for two to three days. Then, to simulate a rainfall event, deionised water, equivalent to a 5 mm rainfall (which is the average amount falling in a typical rainfall event in this region), was applied as a fine spray to one or two of the sample plots. Fluxes of both watered and unwatered plots were measured for a further two or three days. Where rainfall had occurred just before the measurements or during the measurements, this regime was altered and no watering occurred.

The yearly average fluxes were calculated from unequal weighting of measurements on dry soil and after watering. The dry soil measurements were taken to represent two-thirds of the days of the year, and the moist soil measurements represented the balance of the days. This reflects the frequency and intensity of rainfall events and the duration of the impact of single rainfall events on soil moisture.

3. RESULTS

Five field measurement periods were chosen for the study: from March 4 to March 13, 1991; from May 24 to June 5, 1991; from July 25 to August 7,1991; from October 25 to November 6, 1991; and from January 24 to February 5, 1992. In each measurement period, samples were taken at each of the Mallee site and the farmland Wheat site. The results are presented in Appendices E and F. The site description commences with a digit that indicates the trip, i.e. 1 to 5, followed by an underscore and then another 1 or 2 digits that indicated the plot number for that trip (different plot numbers were used for Wheat and Mallee). This identifier was followed by a letter, W if the data was collected in the days following watering, and R if the data follows rain.

3.1 Environmental Conditions

During this study, the mean annual temperature was 17.5°C with extremes varying from daily minimum temperatures of nearly zero in the winter to daily maximum temperatures in the mid-forties in the summer. See Appendix A. The total annual rainfall during the year 1991 was 211 mm, with most of the precipitation occurring during the winter months. See Appendix A. Notably, the annual rate of evaporation exceeded the rate of rainfall by a factor of 10, giving a precipitation to potential evapotranspiration ratio over the period of the study equal to 0.105. Rainfall was comparable to the rate of evaporation only during the two winter months of June and July. See Appendix A.

3.2 Soil composition, nutrients and soil moisture

The average soil properties from the two sites from the five measurement periods are presented in Table 1. The wheat crop soil was slightly more alkaline, had a higher phosphorus content and lower sulphur content than the Mallee soil.

During one measurement period (May 1991), soil cores from the surface to 1-m depth were taken. Results of the analysis of these core samples are presented in Table 2.

Variations in major soil nutrients and soil moisture over the period of this study are presented in Figure 1 (a) and (b) for the Mallee and the Wheat sites. Between the May/June and July/August measurement periods there was, at both sites, a substantial increase in soil moisture content and a decrease in total ($NH_4^+ + NO_3^-$) soil inorganic N concentration.

Table 1. Means and standard deviations of soil properties sampled at 0–5 cm depth for the Mallee and Wheat sites from five sets of samples over the period March 1991 to February 1992. The numbers in parentheses are standard deviations followed by the number of samples analysed.

Soil Property	Mallee	Wheat
Bulk density g cm^{-3}	**1.42**	**1.38**
	(0.19, 40)	(0.09, 40)
pH	**6.97**	**7.41**
	(0.24, 50)	(0.17, 50)
Oxidisable carbon (%)	**0.68**	**0.61**
	(0.42, 50)	(0.17, 50)
Total N (%)	**0.05**	**0.06**
	(0.03, 50)	(0.02, 50)
Inorganic N (μg g^{-1})	**4.5**	**8.4**
	(2.2, 50)	(4.5, 49)
Olsen-P (μg g^{-1})	**2.48**	**7.94**
	(2.93, 50)	(4.69, 50)
HCO_3-P (μg g^{-1})	**18.9**	**31.0**
	(15.0, 50)	(12.5, 50)
CDP-S (μg g^{-1})	**0.83**	**0.18**
	(2.35, 50)	(0.26, 50)
Coarse sand (%)	**68.7**	**64.6**
(0 – 0.2 mm)	(6.9, 10)	(0.9, 10)
Fine sand (%)	**25.9**	**27.2**
(0.2 – 0.02 mm)	(6.9, 10)	(1.0, 10)
Silt (%)	**1.6**	**1.5**
(0.02 – 0.002 mm)	(0.5, 10)	(0.4, 10)
Clay (%)	**3.8**	**6.7**
(< 0.002 mm)	(1.1, 10)	(0.2,10)

Table 2. Soil properties sampled at various depths between the surface and 100 cm at the Mallee and Wheat sites on May 28-29, 1991.

Depth (cm)	0-10	0-10	10-20	10-20	20-30	20-30	30-50	30-50	50-100	50-100
Land use	Mallee	Wheat	Mallee	Wheat	Mallee	Wheat	Mallee	Wheat	Mallee	Wheat
% moisture	0.819	2.289	1.239	5.060	1.225	7.201	1.256	13.030	2.811	13.940
pH	7.25	7.73	6.81	7.47	7.00	8.68	7.16	9.66	8.02	9.82
NH_4^+-N (μg g^{-1})	2.34	3.14	1.85	1.73	1.83	2.57	1.86	3.25	1.83	3.14
NO_3^--N (μg g^{-1})	0.36	17.55	0.74	17.52	0.45	8.70	0.35	4.42	1.02	12.45
Total N (%)	0.05	0.08	0.04	0.08	0.04	0.07	0.04	0.08	0.04	0.05
Oxidisable carbon (%)	0.2	0.7	0.2	0.5	0.2	0.8	0.1	0.9	0.1	0.3
Olsen-P (μg g^{-1})	2.7	10.1	2.3	4.4	1.1	4.9	1.3	3.8	1.6	1.8
HCO_3-P (μg g^{-1})	8.5	25.0	27.5	16.0	24.5	78.0	46.5	42.5	6.5	31.5
CDP-S (μg g^{-1})	<0.1	<0.1	0.5	0.8	<0.1	<0.1	<0.1	11.1	8.4	43.6

3.3 Field Conditions

The first measurement period was from the 4th to the 13th of March, 1991. During this time, the average daily maximum and minimum air temperatures were 30°C and 15°C, respectively. The daytime soil surface temperature was commonly 60°C. There had been no rainfall during the preceding month, and only about 0.2 mm of rain fell during the measurement period. The soil water content was 0.6% in the Mallee and 0.8% in the wheat field. Total-N, NH_4^+-N and total organic carbon were similar at the two sites. As would be expected, phosphorus was twice as abundant, and NO_3^--N was a factor of three higher in the Wheat site, as compared to the Mallee. Conversely, sulphur concentrations were 7-fold higher in the Mallee than the Wheat field – a reflection of the limited supply of S and the removal of S in the harvesting of the wheat. The Wheat field was in the last stages of a long fallow.

The second measurement period was from May 24 to June 5, 1991. The average daily maximum and minimum air temperatures were 19°C and 9°C, respectively. The previous rain was the 20 mm that preceded sowing in April. However, the season broke soon after the commencement of measurements in the Mallee, with intermittent showers delivering approximately 14 mm over the period from late on June 1 to June 4. Soil moisture in the Wheat field was 2% and twice that of the Mallee. The lower moisture content in the Mallee reflects the deeper infiltration of soil water. There was an increase in soil phosphorus, as a result of fertiliser application. Otherwise, there was little change in soil characteristics in the Wheat field since the previous sampling period. In the Mallee, NO_3^--N, NH_4^+-N and sulphur concentrations had declined during the autumn, while extractable phosphorus concentrations had increased. The wheat crop was sown four weeks earlier and the wheat seedlings were 10 cm high. The flux measurements in the Wheat field were conducted in cool, dry, sunny weather. Because of the rain, the watering treatment was not applied to the Mallee sample sites during this measurement period.

The third measurement period was from July 25 to August 7, 1991. The average daily maximum and minimum air temperatures were 17°C and 7°C, respectively. Most of the annual rain fell between June and August, and the soil was at its wettest for the year, reaching an average gravimetric moisture content in the top 5 cm of 8.8% in the Wheat field and 3.8% in the Mallee. About 6 mm of rain fell during the whole measurement period in several small amounts. The total inorganic nitrogen content of the soil was 7.8 $\mu g\ g^{-1}$ in the Wheat field and 4 $\mu g\ g^{-1}$ in the Mallee. The total inorganic nitrogen content of the Wheat field was much lower than those measured in the previous two measurement periods, most probably as a result of crop nitrate uptake. The inorganic nitrogen content in the soil of the Mallee site changed little throughout the year. Ground vegetation was revitalised in the Mallee as a result of the increased soil water availability. The wheat crop was vigorously growing. The crop development was between stem extension and spikelet initiation, and the canopy leaf area index was about 2.

The fourth measurement period was from October 25 to November 6, 1991. The average maximum and minimum daily air temperatures were 26°C and 12°C, respectively. Only about 0.5 mm of rain had fallen during October, but 11 mm was recorded over the three days at the end of the measurement period. 7.4 mm of this rainfall was recorded during the night between November 3 and 4 and all subsequent Mallee measurements are regarded as watered. The gravimetric soil moisture content was about 4.3% in the wheat field, and 3.3% in the Mallee. The soil inorganic nitrogen was 5.8 $\mu g\ g^{-1}$ at the Wheat site and 4.8 $\mu g\ g^{-1}$ at the Mallee site.

There was a significantly larger phosphorus content in the Mallee. The ground vegetation at the Mallee site, such as mosses and lichens, appeared dead. This measurement period was just before the harvest of the wheat crop. The crop yield at harvest was about 1300 kg ha^{-1} with a protein content of 11.0-11.6%.

The final measurement period was from January 24 to February 5, 1992. The average maximum air temperature was 31°C, and the average minimum air temperature was 17°C. About 8 mm of rain fell during the month prior to this measurement period, and a further 10 mm of rain fell overnight between the 3^{rd} and 4^{th} of February. All subsequent flux measurements in this period are considered watered. The gravimetric soil moisture content was 4.7% in the Wheat field and 3.7% in the Mallee. Both the inorganic nitrogen and phosphorus levels had decreased at both sites since the previous measurement period. The ground vegetation in the Mallee appeared dead, and leaf shedding of the forest canopy was the highest observed. The wheat crop harvest had left stubble covering part of the soil surface.

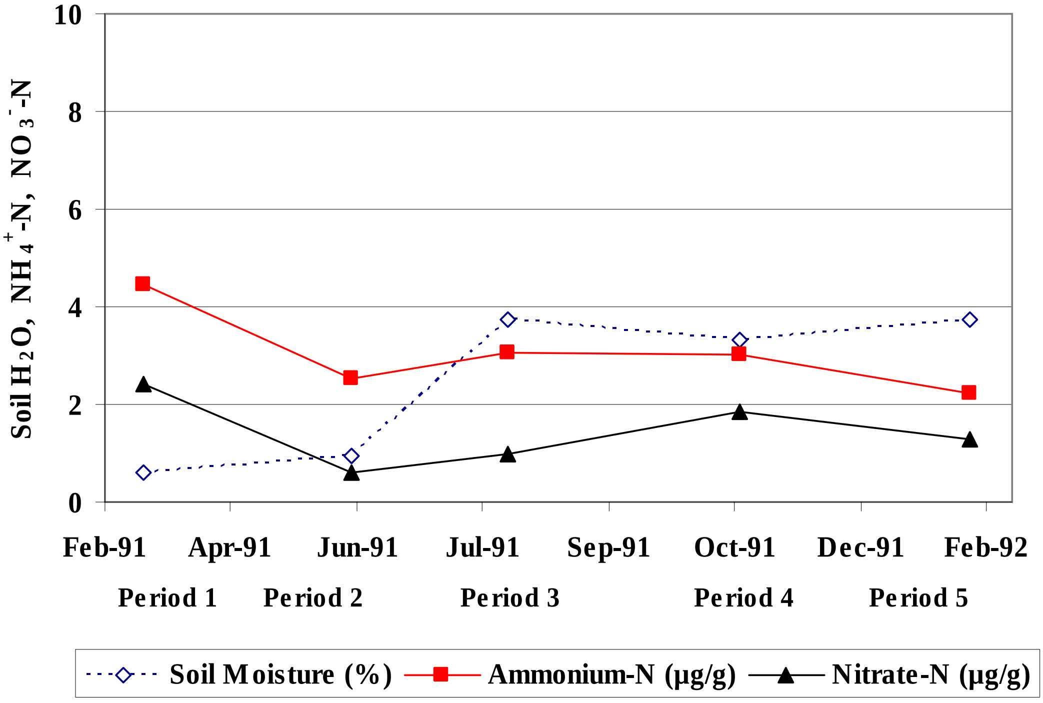

Figure 1 (a). Variation in the means of selected soil properties of the Mallee site during this study.

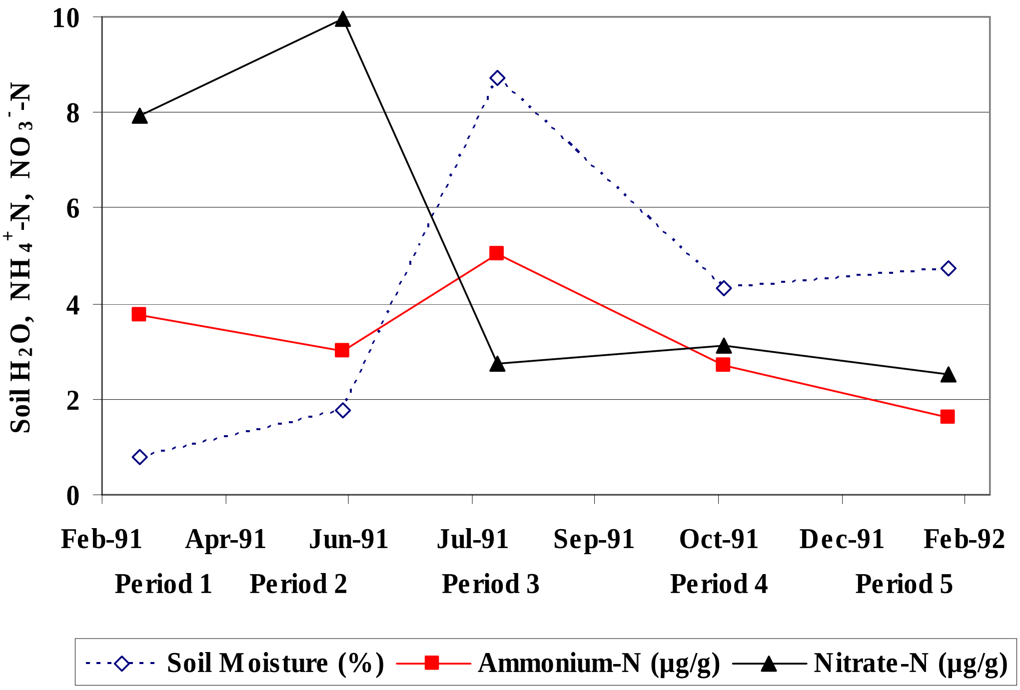

Figure 1 (b). Variation in the means of selected soil properties of the Wheat site during this study.

3.4 Carbon cycling

The balance of the carbon in above-ground plus below-ground biomass was determined for each site and presented in Table 3 (a) along with the sources of the data. The input to biomass C is net primary productivity and the loss occurs via biomass harvest and soil plus root respiration.

The rates of carbon turnover in these systems are much lower than those in temperate systems, and are driven primarily by the low rainfall and semi-arid nature of the environment at this site. The soil plus root respiration rates are consistent with other observations in semi-arid regions, summarised by Zepp *et al*. (1996).

Litterfall represents an internal recycling in this framework. The litterfall for the Mallee system was much lower than would be expected, given the estimated NPP. In a mature system, the amount of photosynthetic carbon allocated below-ground can be twice as much as the above-ground litter fall (Nadelhoffer & Raich 1992).

The carbon cycle of the wheat crop is more complex than that of the Mallee. The CO_2 exchange measurements, made in this study, underestimated the carbon uptake during crop growth (June to October) because the semitransparent chamber allowed one-half to two-thirds of the incoming sunlight to get through (Galbally *et al*. 1987). The measurements in February/March, October/November and January/February represent soil respiration because the wheat crop was not yet planted during February/March and was in senescence by October. The average of these three measurement periods gives a soil respiration of 308 g(C) m^{-2} y^{-1}, similar to that observed in the Mallee.

The estimate of total net carbon dioxide exchange between the cleared land and the atmosphere depends on the history of land use (Harmon *et al*. 1990). The soil carbon pool is several times larger than the plant carbon pool and responds to disturbance, such as land use change, at a much slower rate than plant carbon. The carbon density estimated in the top 1 metre of virgin mallee soil was 9620 g(C) m^{-2}; and in the farmland, converted from the mallee forest 67 years earlier, it was 7600 g(C) m^{-2} (C.J. Smith, pers. comm.). This difference is consistent with the data from nearby sites (Russell & Williams 1982; Webb 2002; Skjemstad & Spouncer 2003). The 0-5 cm soil cores showed 10% less oxidisable carbon in the soil in the Wheat versus the Mallee; but, due to the variability of observations, the difference is not statistically significant at the 5% level. As shown in the simple model simulation in Wang *et al*. (1997), the mallee forest soil after clearing and conversion to wheat cropping loses 21% of its carbon at 67 years, and will not reach its new equilibrium state until 270 years after clearing, when by then 26% of soil carbon will be lost. For the mallee forest converted to farmland in the late 1920s, the simulation by the simple model (Wang *et al*. 1997) indicates that the soil is still losing its carbon at a rate of 13 g(C) m^{-2} $year^{-1}$. This loss is small compared with the total annual carbon turnover in the farmland.

In perspective, compared with the NPP and soil plus plant respiration, the annual CH_4 uptake and the annual CO release represent 0.04% and approximately 0.1%, respectively, of the carbon being cycled. We argue subsequently that the annual emission of CO from the ecosystem is controlled by the C flux through the system.

Table 3 (a). The carbon balance for the Mallee and Wheat systems.

	Mallee	Wheat	References
INPUTS	$g(C)\ m^{-2}\ y^{-1}$	$g(C)\ m^{-2}\ y^{-1}$	
Net Primary Productivity	267	382	This study; Grierson *et al*. (1992)
Litterfall	46	-	Vadala (1991)
OUTPUTS	$g(C)\ m^{-2}\ y^{-1}$	$g(C)\ m^{-2}\ y^{-1}$	
Harvest (grain)	-	130	This study
Soil-root respiration	310	308	This study
RESERVOIRS	$g(C)\ m^{-2}$	$g(C)\ m^{-2}$	
Above-ground biomass	1800	294	This study
Below-ground biomass	450	88	Burrow *et al*. (2000); O'Leary *et al*. (1985)
Soil organic matter (0-100 cm)	9620	7600	This study

Table 3 (b). The nitrogen balance for the Mallee and Wheat systems.

	Mallee	Wheat	References
INPUTS	$g(N)\ m^{-2}\ y^{-1}$	$g(N)\ m^{-2}\ y^{-1}$	
Wet/dry deposition	0.2	0.2	Meyer *et al*. (2001a)
Fertilizer	–	0.5	This study
Litterfall	0.23		Baker & Attiwill (1981)
Mineralization	0.2	1.3	This study
Fixation	0.5	–	Rogers *et al*. (1966); Smith *et al*. (1990); Peterjohn & Schlesinger (1990)
OUTPUTS	$g(N)\ m^{-2}\ y^{-1}$	$g(N)\ m^{-2}\ y^{-1}$	
Plant uptake	2.7	2.5	This study
Leaching	0	0	Estimate
Gaseous loss	~ 0.12	~ 0.12	Estimate of N_2O and NO_x only
RESERVOIRS	$g(N)\ m^{-2}$	$g(N)\ m^{-2}$	
Soil inorganic N	6.9	6	This study

3.5 Nitrogen cycling

The annual balance of the soil inorganic nitrogen content is determined for each site. The inputs to soil inorganic N are nitrogen fixation by free living organisms, mineralisation of litter and soil organic material, and dry and wet deposition of inorganic nitrogen including fertilizer. The losses are plant uptake of N, denitrification and gaseous nitrogen loss, and leaching. The N balances for the Mallee and Wheat systems are given in **Table** 3 (b).

In the Mallee system, the inorganic N content of the top 100 cm of soil is 6.9 g (N) m^{-2}. Nitrogen fixation may contribute 0.5 g(N) m^{-2} y^{-1} (range 0.05 – 10 g(N) m^{-2} y^{-1}) in such a natural semi-arid system (Rogers *et al*. 1966; Smith *et al*. 1990; Peterjohn & Schlesinger 1990). The combined wet and dry deposition of inorganic nitrogen in remote/rural Australia is 0.2 g(N) m^{-2} y^{-1} (Meyer *et al*. 2001). The nitrogen return to the soil through above-ground fine litterfall is estimated to be 0.23 g (N) m^{-2} y^{-1} using the mean nitrogen content of litterfall material of 4.9 g(N) kg^{-1} (Baker & Attiwill 1981) and the litterfall rate given previously. The bulk of this nitrogen in the litter will subsequently be mineralised during litter decomposition (Adams *et al*. 1989). The soil plus root plus litter respiration (decomposition of organic material) will release N. Using the observed respiration rate given above, and the N:C ratio in topsoil of 0.074, it is estimated that 23 g (N) m^{-2} y^{-1} of N potentially could have been released into the soil from mineralization. Due to the high potential evaporation to precipitation ratio, leaching rarely occurs in these soils. N loss via ammonia volatilization and denitrification to N_2 cannot be calculated from the information available. Assuming that 40% of NPP is allocated above ground (Grierson *et al*. 1992), and equal amount of aboveground NPP is then allocated to leaf and woody tissue with a C:N ratio of 1:25 for leaf and 1:100 for woody tissue, we estimated the N uptake for above ground NPP production is 2.7 g(N) m^{-2} y^{-1}. We suggest that the difference between N release by soil respiration and N uptake due to plant growth is within the uncertainty estimates.

In spite of the extraordinarily low N inputs from fixation and deposition, there is a sufficient standing supply of inorganic N within the top 50 cm of soil for a year's plant growth and also the emissions of N_2O of 0.02 g (N) m^{-2} y^{-1} and NO_x of perhaps 0.1 g (N) m^{-2} y^{-1} (based on extrapolation from the one trip to the year). The amount of N lost via these two gases makes up a significant fraction of the estimated inputs of N via nitrogen fixation by free living organisms and dry and wet deposition; and thus the release of N_2O and NO_x from these systems may be tightly controlled by the inputs of N to the system.

In the wheat crop, there are six key nitrogen-cycling terms, namely inputs of: inorganic nitrogen fertiliser addition, mineralisation of soil organic matter, dry and wet deposition of inorganic nitrogen, and losses by plant uptake and harvesting, denitrification and gaseous nitrogen loss, and leaching. The fertiliser input was 0.5 g(N) m^{-2} y^{-1}. The loss of organic matter from the soil is probably through oxidation and is associated with a release of mineralized nitrogen into the soil. The amount of nitrogen released from this farmland soil carbon loss is estimated from soil C loss and the C:N ratio (**Table** 1) to be 1.3 g (N) m^{-2} y^{-1}. The N content of the wheat harvested (wheat yield 1375 kg ha^{-1}, 11-11.6% protein content and a nitrogen content of protein of 1g N/6.25 g protein) is 2.5 g (N) m^{-2} y^{-1}. As in the Mallee, leaching rarely occurs in these semi-arid soils. In the top 50 cm of soil in the wheat field, there is about 54 kg (N) m^{-2} total fixed N, and 6.0 g (N) m^{-2} total inorganic N. This quantity of inorganic N is comparable with the N uptake of the wheat during the growing season; hence, the variation in soil inorganic N in the wheat is most probably driven by the plant uptake.

A comparison between the data from the two experimental sites demonstrates the difficulty in quantifying the effects of land use changes on soil nutrient cycling. As indicated by both the soil respiration rates and the other gas species, the seasonal changes were far greater than the differences between the Mallee and Wheat sites.

3.6 Trace Gas Exchange Measurements

3.6.1 CH_4

During the five measurement periods, there were 101 measurements of CH_4 exchange at the Wheat site and 104 observations at the Mallee site. As shown in Figure 2, there was soil uptake of CH_4 in more than 98% of the measurements for the wheat crop, and approximately 80% of the measurements for the Mallee site. The balance of the measurements (5% of Wheat and 20% of Mallee) indicated soil emission of CH_4. The median rates of soil uptake of CH_4, over the whole data set, were -4 ng(C) m^{-2} s^{-1} for the Mallee and -6 ng(C) m^{-2} s^{-1} for the Wheat. The observations from both sites were in the range -17 ng(C) m^{-2} s^{-1} (uptake) to +13 ng(C) m^{-2} s^{-1} (release) of CH_4.

The effect of watering on CH_4 uptake, by the application of 5 mm of water to some of the field sites, was not statistically significant, with the results from 21 paired observations over the five measurement periods before and after watering being uptakes of -3.9 ± 0.7 ng(C) m^{-2} s^{-1} and -2.9 ± 0.7 ng(C) m^{-2} s^{-1} (mean ± standard error), respectively. Thus, watering had no significant effect on CH_4 uptake rates in this study.

Both sites showed a seasonal cycle of CH_4 exchange, with the smallest uptake rates (or in some cases CH_4 emissions) in the hottest months and the largest uptake rates in the cooler months. This implies an either accidental or causal link between CH_4 exchange and temperature.

There is a shift from uptake to emissions of CH_4 from the Mallee site in January and early February (summer), compared to other seasons as shown in Table 4.

3.6.2 CO

During the five measurement periods, there were 93 measurements of CO exchange at the Wheat site and 78 observations at the Mallee site. As shown in Figure 3, there was emission of CO in about 60% of the measurements for the wheat crop, and approximately 70% of the measurements for the Mallee site. The balance of the measurements indicated soil uptake of CO. The median rates of soil emission of CO, over the whole data set, were 3.1 ng(C) m^{-2} s^{-1} for the Mallee and 2.6 ng(C) m^{-2} s^{-1} for the Wheat. The observations from both sites were in the range -4 ng(C) m^{-2} s^{-1} (uptake) to +70 ng(C) m^{-2} s^{-1} (emission) of CO. Subsequently, there was an indication of CO uptake in the June measurements, but we were unable to quantify it due to the very low CO concentration in the ambient air and a lack of sensitivity in the CO measurements. CO exchange measurements were not made for the Mallee during the third measurement period due to the small and erratic CO exchange measurements obtained on the first day. In retrospect, these CO exchange rates may have been real and reasonable.

Carbon monoxide emissions were highest in summer and in autumn when the soil temperature was extremely high, see Table 4.

The highest CO emissions occurred with the Wheat field immediately before harvest and two months after harvest. The Mallee emissions of CO were higher than the Wheat field in the initial two measurement periods when there was bare soil in the Wheat field, and surface litter in the Mallee site.

The effect of watering on CO emissions was not statistically significant. The results from more than 40 observations over the five measurement periods, before and after watering, gave emissions of 15 ± 3 ng(C) m^{-2} s^{-1} and 6.6 ± 1.7 ng(C) m^{-2} s^{-1} (mean ± standard error), respectively.

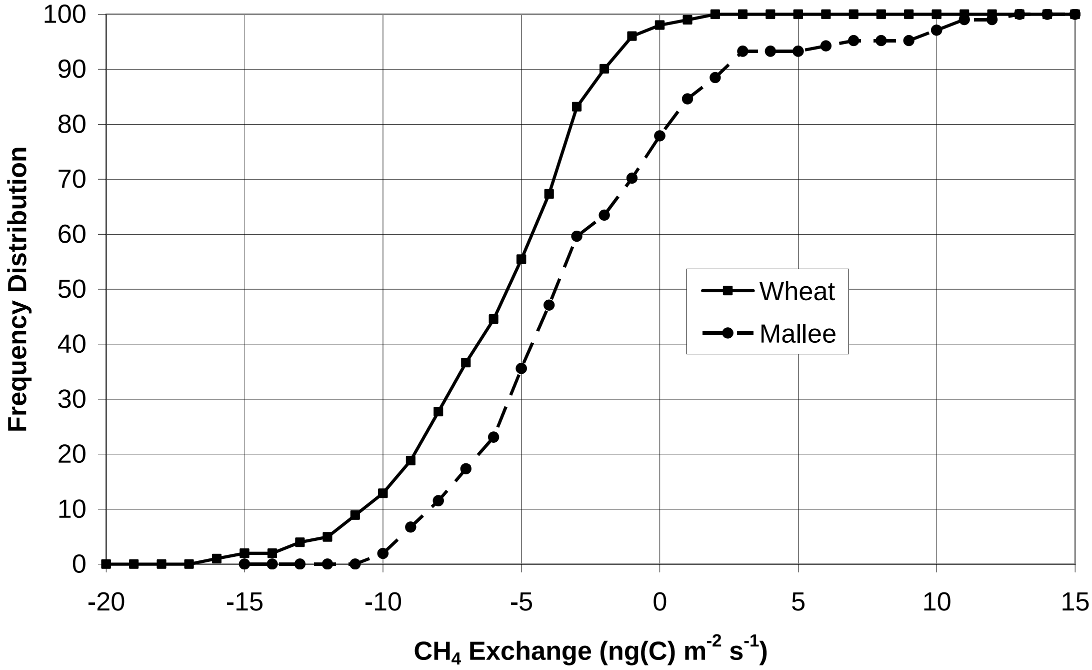

Figure 2. The cumulative frequency distribution of methane uptake by the soils under wheat cropping and Mallee.

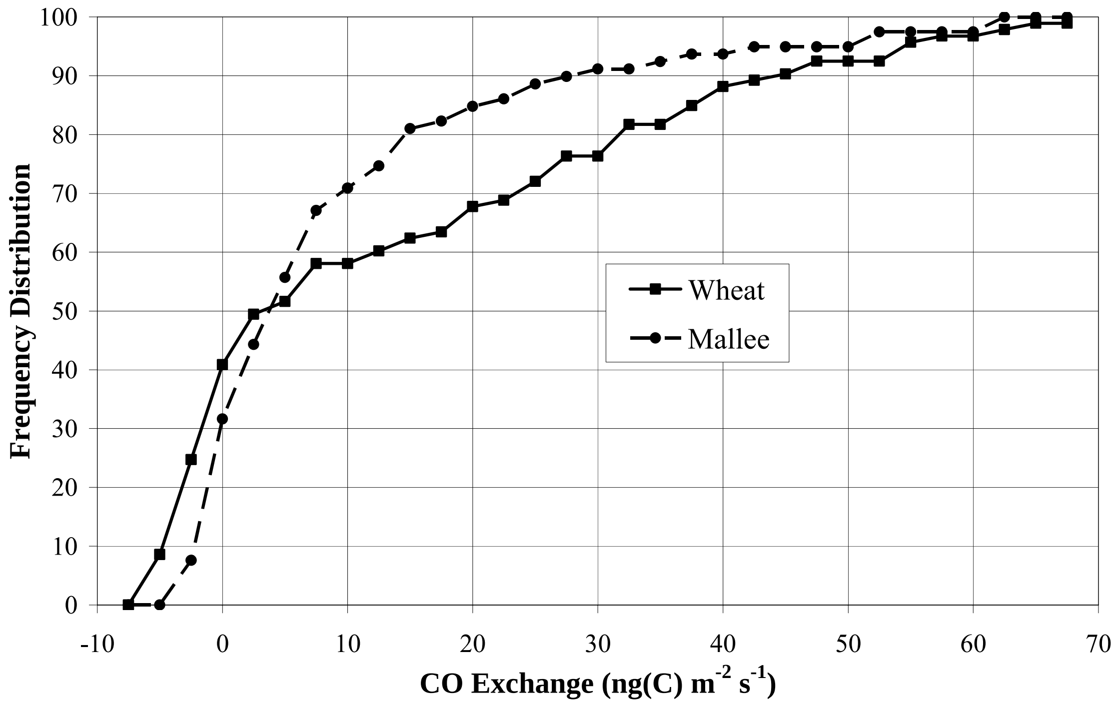

Figure 3. The cumulative frequency distribution of carbon monoxide emissions by the soils under wheat cropping and Mallee.

3.6.3 N_2O and NO_x

During the five measurement periods, there were 101 nitrous oxide emission measurements from the Wheat crop and 102 emission measurements from the Mallee. The cumulative frequency distributions of these two data sets are shown in Figure 4. As can be seen from the distribution, the highest 5% of the observations (those greater than the 95 percentile) are around 10 times or more than the median emissions. These high emissions correspond to the few rain events, and over the year contribute around half of the total emissions. Seventy to 80 percent of the observations were near zero, at less than 0.5 ng(N) m^{-2} s^{-1}. Twenty-four chamber blank values were measured, and these gave a 10-90% spread of ± 0.3 ng m^{-2} s^{-1}. Therefore, the scatter of observations around zero in the field measurements is dominated by measurement uncertainty.

NO_x exchange measurements were made only during the 5th measurement period. There were 17 measurements from the Wheat and 15 measurements from the Mallee. The frequency distributions are presented in Figure 5. For both sites, around two-thirds of the measurements are less than 1 ng(N) m^{-2} s^{-1}. There is a strong influence of soil moisture on the higher NO_x emissions.

The seasonal variation in the N_2O emissions shows highest N_2O fluxes from the Wheat during measurement period 3 (winter), and from the Mallee in measurement period 1 (late summer/early autumn). An examination of soil and the other environmental variables indicates that the distinguishing feature of the winter Wheat measurements was that the soil moisture was, on average, 8.7% – around twice that observed in the Mallee, and twice that observed in the Wheat on other occasions. In these sandy soils, the water holding capacity is about 12% (McKenzie et al. 2004), and 8.7% represents a high soil moisture content. The Wheat field was underlain by a hard compacted layer (presumably due to prolonged cultivation), and so less drainage occurred than in the Mallee. There is inadequate evidence to attribute these peak N_2O emissions to nitrification and denitrification.

The peak N_2O emissions in the Mallee that occurred in measurement period 1, were at very low soil moisture conditions (0.6%), and soil surface temperatures exceeding 40°C. These emissions can presumably only be due to nitrification.

The effect of watering on N_2O and NO_x emissions was statistically significant, with emissions generally an order of magnitude higher on the day following watering and decreasing thereafter, see Table 4.

For the Wheat, the highest N_2O emissions occurred when there was CO_2 uptake in the chamber (winter – period 3) and when a weak negative relationship (r^2 = 0.2) occurred between N_2O emissions and CO_2 uptake with a slope of -5 x 10^{-5}. Similarly, these highest N_2O emissions occurred when there was CH_4 uptake of around -5 ng(C) m^{-2} s^{-1}, with lower N_2O emissions at higher and lower CH_4 exchange.

For the Mallee, N_2O emissions were unrelated to CH_4 exchange. There was no enhancement of N_2O emissions when CH_4 emissions occur. The highest N_2O emissions of Wheat occurred at temperatures of 10-20°C (the winter period), with lower emissions at higher temperatures. The N_2O emissions for the Mallee showed a weak increase with temperature (r^2 = 0.12), increasing 0.02 ng(N) m^{-2} s^{-1} per °C temperature rise.

The key feature that separated the high N_2O emissions (Wheat in measurement period 3) from the lower N_2O emissions (that is, the Mallee in measurement period 3 (winter), and both sites on the other four trips) was the high soil moisture content. The soil moisture content was 8.7% in the Wheat during measurement period 3 (winter), and never exceeded 4.7% at either site on any other occasions. The field capacity of these sandy soils was around 12% (McKenzie *et al*. 2004). During this measurement period, there was active growth of the wheat, and presumably carbon root exudates into the soil. It is possible that, during this period, denitrification was driving the N_2O emissions from the Wheat.

4. EPILOGUE

These data on trace gas exchange have been used as inputs for the estimation of nitrous oxide emissions from agriculture for the Australian National Greenhouse Gas Inventory. This utilization has been in Inventory Workbooks and Reports (e.g. Galbally *et al*. 1994) and subsequent publications see http://www.greenhouse.gov.au/inventory/index.html and in scientific papers focused on the Australian inventory (e.g. Galbally *et al*. 2005).

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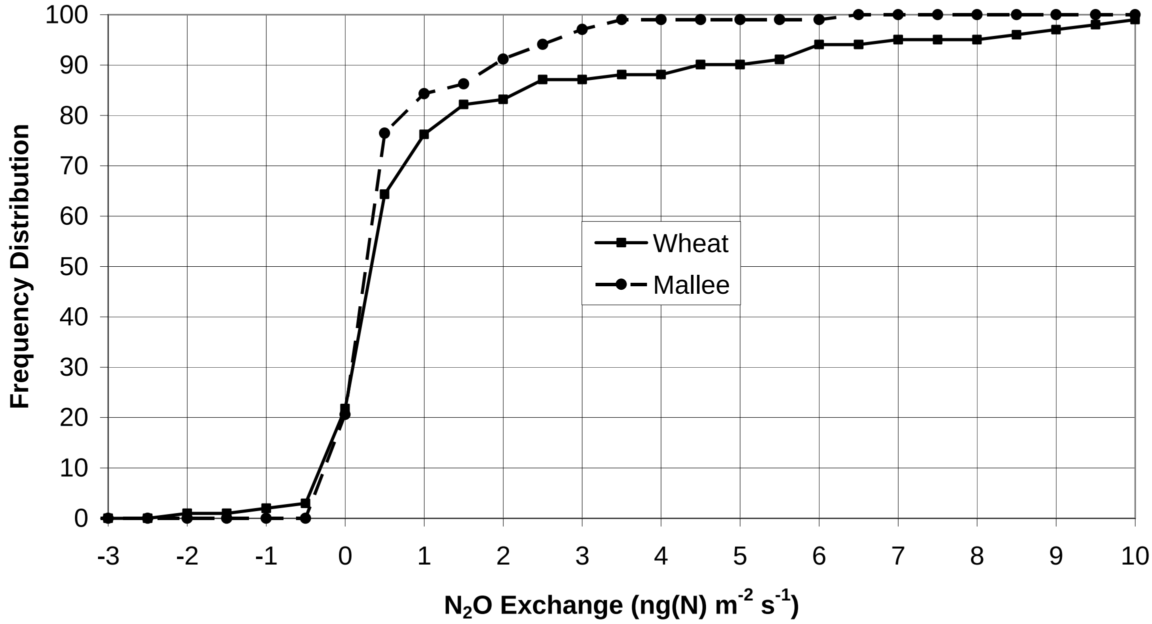

Figure 4. The cumulative frequency distribution of nitrous oxide emissions by the soils under wheat cropping and Mallee.

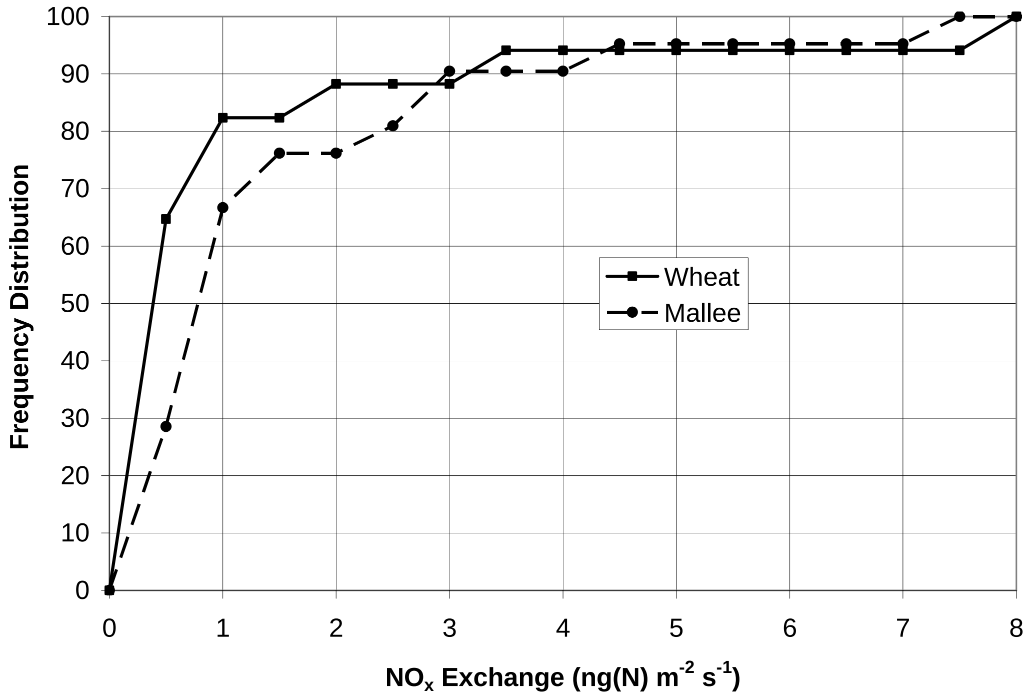

Figure 5. The cumulative frequency distribution of NO_x emissions by the soils under wheat cropping and Mallee.

Table 4. A summary of the average trace gas exchange from the Mallee and the Wheat sites over the 5 measurement periods of this study. Quantities in parentheses are standard errors.

	Condition	Number	CO_2 (μgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
PERIOD 1							
Wheat	unwatered	12	6.76 (1.31)	-3.94 (0.64)	0.28 (0.97)	0.37 (0.44)	–
	watered	4	17.42 (3.51)	-5.56 (0.44)	1.68 (1.57)	1.18 (0.61)	–
Mallee	unwatered	14	9.62 (1.35)	-2.40 (0.88)	5.70 (1.35)	1.62 (0.23)	–
	watered	5	27.81 (5.41)	-0.49 (0.59)	10.75 (5.10)	2.61 (1.01)	–
PERIOD 2							
Wheat	unwatered	15	2.01 (0.19)	-7.26 (0.27)	-3.53 (0.48)	0.03 (0.04)	–
	watered	5	9.04 (0.69)	-7.70 (0.44)	-2.86 (1.57)	0.47 (0.61)	–
Mallee	unwatered	6	4.87 (0.60)	-3.76 (0.23)	-1.05 (0.90)	-0.11 (0.15)	
	watered (rain)	12	10.81 (1.81)	-3.06 (0.44)	-0.54 (0.50)	0.28 (0.13)	–
PERIOD 3							
Wheat	unwatered	20	-28.40 (6.95)	-4.51 (0.76)	-1.59 (1.07)	4.56 (0.97)	–
	watered	4	-43.47 (9.88)	-3.77 (0.76)	no data	5.53 (0.69)	–
Mallee	unwatered	22	5.55 (0.59)	-7.04 (0.42)	no data	0.27 (0.12)	–
	watered	4	9.65 (2.28)	-5.59 (0.78)	no data	0.14 (0.05)	–

Table 4. A summary of the average trace gas exchange from the Mallee and the Wheat sites over the 5 measurement periods of this study. Quantities in parentheses are standard errors.

	Condition	Number	CO_2 (μgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
PERIOD 4							
Wheat	unwatered	19	9.93 (0.84)	-10.32 (0.74)	31.55 (3.87)	0.22 (0.12)	–
	watered	4	23.32 (3.80)	-8.66 (1.15)	28.71 (3.69)	0.85 (0.21)	–
Mallee	unwatered	10	8.51 (1.01)	-5.92 (0.76)	8.36 (2.89)	0.09 (0.03)	–
	watered	13	21.53 (1.64)	-4.72 (0.58)	0.19 (0.62)	0.22 (0.02)	–
PERIOD 5							
Wheat	unwatered	15	3.02 (0.22)	-3.10 (0.25)	37.72 (4.08)	0.04 (0.02)	0.45 (0.11)
	watered	4	7.62 (2.20)	-2.89 (0.51)	10.46 (2.94)	0.28 (0.18)	1.63 (0.70)
Mallee	unwatered	12	6.26 (0.54)	3.12 (1.24)	32.01 (5.28)	-0.03 (0.69)	1.33 (0.60)
	watered	8	44.89 (5.35)	5.01 (0.26)	13.64 (6.23)	0.90 (0.30)	0.92 (0.84)

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APPENDIX A – METEOROLOGICAL DATA

Table A1. Meterological data measured in the vicinity of the sites of this study over the 5 measurement periods of this study (BOM 2006).

The information on these Bureau of Meteorology sites are:

Station: 76134, LAKE CULLULLERAINE, Latitude-34.2744, Longitude 141.5875

Station: 76029, MERINGUR, Latitude -34.3894, Longitude 141.335.

Station: 76031, MILDURA AIRPORT, Latitude -34.2306, Longitude 142.0839

Station: 47016, LAKE VICTORIA STORAGE, Latitude -34.0398, Longitude 141.2652

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
01-Jan-91	0	0	14.8	39.6	21
02-Jan-91	0	0	10.4	38	24.5
03-Jan-91	0	0	17.6	39.5	28.9
04-Jan-91	7	1	13.4	27	19
05-Jan-91	16.2	25.2	7.8	21	12.5
06-Jan-91	1.4	0	4	22.5	11.5
07-Jan-91	0	0	6.2	28	14
08-Jan-91	0	0	6.6	29.5	14.5
09-Jan-91	0	0	8.4	32.5	16
10-Jan-91	0	0	8	39.5	21.5
11-Jan-91	0	0	12	42	23
12-Jan-91	0	0	15.2	29.5	16
13-Jan-91	0	0	7.6	36.5	17.5
14-Jan-91	0	0	10	42.5	23
15-Jan-91	0	0	14	34.5	23.5
16-Jan-91	0	0	12.6	32.5	16
17-Jan-91	0	0	9.2	31.5	15.5
18-Jan-91	0	0	10.8	30	18.5
19-Jan-91	0	0	7	35.5	17.5
20-Jan-91	0	0	11.6	32.5	18.5
21-Jan-91	0.4	0.4	7.6	36	19.5
22-Jan-91	0	0	8.6	27.5	21.5
23-Jan-91	16.4	6.6	2.4	23.5	20.5
24-Jan-91	20.8	62.2	2.8	29.5	19.5
25-Jan-91	0	0	8	29	18
26-Jan-91	0	0	8.2	28	16.5
27-Jan-91	0	0	9.6	27.5	15
28-Jan-91	0	0	9.4	27.5	14.5

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
29-Jan-91	0	0	9.8	27	14.5
30-Jan-91	0	0	9.6	29.8	13.8
31-Jan-91	0	0	11.8	31.2	15.6
01-Feb-91	0	0	6.4	32.5	15.3
02-Feb-91	0	0	9	35.5	14.8
03-Feb-91	0	0	9.2	37	18.4
04-Feb-91	0	0	12.6	40.4	18.6
05-Feb-91	0	0	11	35	19.5
06-Feb-91	0	0	13.4	33.5	18.5
07-Feb-91	0	0	9.2	32.8	17.4
08-Feb-91	0	0	13.8	29.4	14.8
09-Feb-91	0	0	7.6	32.6	17.5
10-Feb-91	0	0	12	28.8	13
11-Feb-91	0	0	8	30.4	13
12-Feb-91	0	0	7.6	35.1	15.5
13-Feb-91	0	0	10.2	39	16.4
14-Feb-91	0	0	10.8	31.8	18.2
15-Feb-91	0	0	11.6	25.5	14.4
16-Feb-91	0	0	7.2	25.5	10.7
17-Feb-91	0	0	8	28.6	11
18-Feb-91	0	0	7.4	36	14.4
19-Feb-91	0	0	11.6	30.2	15.5
20-Feb-91	0	0	9.2	30	13.4
21-Feb-91	0	0	7.4	29.8	12.9
22-Feb-91	0	0	8	33.5	17.4
23-Feb-91	0	0	8.6	32	15
24-Feb-91	0	0	9	36	12.5
25-Feb-91	0	0	8.4	38.9	18.5
26-Feb-91	0	0	12.2	36	21.5
27-Feb-91	0	0	15	30.8	16
28-Feb-91	0	0	7.8	31.5	15.4
01-Mar-91	0	0	9	24	12.9
02-Mar-91	0	0	8.8	26	11.4
03-Mar-91	0	0	7.8	32	11.4
04-Mar-91	0	0	6.4	35	13.5
05-Mar-91	0	0	11	30	16.6
06-Mar-91	0	0	5.6	37	16.7
07-Mar-91	0	0	10.2	36.9	23.5
08-Mar-91	0	0	12.8	36	18.9
09-Mar-91	1	0.4	13.6	27	17.5
10-Mar-91	0	0	7.2	24.5	10.5
11-Mar-91	0	0	6.2	24.7	10
12-Mar-91	0	0	5.8	23.4	9
13-Mar-91	0	0	6.6	26.3	9.8
14-Mar-91	0	0	6.4	29	10.7

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
15-Mar-91	0	0	6.4	30	10.7
16-Mar-91	0	0	7.8	28	10.5
17-Mar-91	0	0	6.8	34.5	12.4
18-Mar-91	0	0	10.8	36	18.8
19-Mar-91	0	0	9.2	25.5	16.4
20-Mar-91	0	0	6.8	23.5	13.1
21-Mar-91	0	0	6.4	21.8	11.5
22-Mar-91	0	0	5.4	22	8.8
23-Mar-91	0	0	4.6	23	7.5
24-Mar-91	0	0	5	25.5	8.5
25-Mar-91	0	0	5.4	30.8	16.4
26-Mar-91	1.8	2	9.6	22.8	17.3
27-Mar-91	0	0	4	24.2	10
28-Mar-91	0	0	4.8	28.5	12.4
29-Mar-91	0	0	5.4	26.2	17
30-Mar-91	0	0	6.4	24.5	17
31-Mar-91	0	0	5	25	14.5
01-Apr-91	0	0	7.8	21.2	16
02-Apr-91	0	0	3.4	20.6	6.5
03-Apr-91	0	0	5	23	9
04-Apr-91	0	0	4.2	25.5	11
05-Apr-91	0	0	5.4	26	9.5
06-Apr-91	0	0	4.2	29.5	11
07-Apr-91	0	0	3.8	26.2	12
08-Apr-91	0	0	4.6	30.6	12.5
09-Apr-91	0	0	6.6	31	15.8
10-Apr-91	0	0	6.8	32	16
11-Apr-91	0	0	6	31	16.5
12-Apr-91	0	0	7.2	29	19.8
13-Apr-91	0	0	6	24.5	16
14-Apr-91	9.2	6.2	3.8	19.9	14
15-Apr-91	0	0.2	3	20	10.5
16-Apr-91	0	0	2.4	20.7	9.7
17-Apr-91	0	0	2.4	21.3	8.3
18-Apr-91	0	0	2.4	21.5	9.5
19-Apr-91	0	0	2.4	23.5	11.7
20-Apr-91	0	0	2.6	25.5	14.7
21-Apr-91	0	0	4.2	25.5	16.5
22-Apr-91	0	0	5.8	18.1	0.5
23-Apr-91	0	0	2.4	20.6	6.4
24-Apr-91	0	0	3.6	22.5	12.4
25-Apr-91	4.4	4.4	4.6	15.5	10.5
26-Apr-91	9.8	3.2	0.8	19.5	8.5
27-Apr-91	0	0	2.4	18	8
28-Apr-91	0	0	3	18.4	6

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
29-Apr-91	0	0	3.2	17.5	6.7
30-Apr-91	0	0	1.2	21.6	10.4
01-May-91	0	0	1.6	23.9	14.1
02-May-91	0	0	4	18.5	11
03-May-91	0	0	3	17	7.4
04-May-91	0	0	2	19	4
05-May-91	0	0	2.2	21.6	4
06-May-91	0	0	3.2	23.1	11.8
07-May-91	0	0	2	22.1	11
08-May-91	0	0	3.6	18.8	10.4
09-May-91	0	0	2.8	16.4	5.4
10-May-91	0	0	4	17	6.6
11-May-91	0	0	3.2	17.2	9.5
12-May-91	0	0	2	16.6	7.5
13-May-91	0	0	2.6	16.4	5
14-May-91	0	0	2.8	17.1	3.8
15-May-91	0	0	1.2	16.8	3.3
16-May-91	0	0	2.4	17	4.4
17-May-91	0	0	1.8	18.5	5
18-May-91	0	0	1.4	18	4
19-May-91	0	0	1.8	21	5.6
20-May-91	0	0	1.8	20.4	7.5
21-May-91	0	0	2.6	22	8
22-May-91	0	0	4.4	17.1	5.5
23-May-91	0	0	0.6	18.5	7
24-May-91	0	0	0.8	19	8
25-May-91	0	0	1.4	21.2	8.6
26-May-91	0	0	1.6	19.6	9.7
27-May-91	0	0	2.2	14.6	9.5
28-May-91	0	0	0.6	17.9	4.8
29-May-91	0	0	1.2	19.9	4.5
30-May-91	0	0	2	19.6	7.2
31-May-91	0	0	3	19.2	11.4
01-Jun-91	0	0	3.4	22.3	13
02-Jun-91	0	1.4	3.8	18.1	14.1
03-Jun-91	14.4	11	1.6	18.2	11.7
04-Jun-91	0	1.4	1	18.3	8
05-Jun-91	0	0	1.8	17.2	8.3
06-Jun-91	7.8	11.2	2.8	16.9	11.5
07-Jun-91	6	0	1.2	15.7	9.1
08-Jun-91	0.8	0	2	15.1	6.8
09-Jun-91	0	1.8	1.2	15.5	
10-Jun-91	1.2	0	2.4	16	10
11-Jun-91	2.2	3.4	0.8	14.5	9
12-Jun-91	3.6	0	1	15.5	8

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
13-Jun-91	0	1.2	0	16.5	7.5
14-Jun-91	0	0	1.4	14.5	5
15-Jun-91	1.6	2.4	1	17.5	7
16-Jun-91	0.6	0	1.2	19	11.5
17-Jun-91	0	0	1.2	18.5	9
18-Jun-91	0	0	1.4	15	9.5
19-Jun-91	0	0	1	15	9.5
20-Jun-91	1.4	0.8	0	15.5	11
21-Jun-91	0	0.2	0.8	19.5	10
22-Jun-91	0	0	1.2	17	
23-Jun-91	0	0	1.6	18	
24-Jun-91	0	1.2	2.6	22.5	14.5
25-Jun-91	0	0	1.8	26.5	13
26-Jun-91	0	0	2.6	18	11.5
27-Jun-91	0	0	2.6	18.5	9.5
28-Jun-91	0	0.4	4	15	12.9
29-Jun-91	7.4	6.6	1	16	9
30-Jun-91	0	0	2.8	16	7.5
01-Jul-91	0	0.8	0.4	17	9
02-Jul-91	0	0	0.8	15.5	7
03-Jul-91	0	0	1	15.5	10
04-Jul-91	0	0	2.2	15.8	10
05-Jul-91	18.6	17.2	1.7	14.5	8.4
06-Jul-91	0	0	2.4	15	6.5
07-Jul-91	0	0	2.2	13.5	6.5
08-Jul-91	8.4	10	1	10.4	8.4
09-Jul-91	12	13.8	1.4	13.3	7.6
10-Jul-91	2	4.4	1.8	13	6.8
11-Jul-91	0	0	1	13.5	4.5
12-Jul-91	0	0	1	14.5	5.2
13-Jul-91	0	0	1.2	14	5
14-Jul-91	0	0	1.4	15.5	6
15-Jul-91	0	0	1.4	13.5	7
16-Jul-91	0	0	1.8	13	3.8
17-Jul-91	0	0	1.2	14	6
18-Jul-91	0	0	2.4	17.8	7
19-Jul-91	0	0	1.4	19.8	7.8
20-Jul-91	0	0	2.6	18.2	8.5
21-Jul-91	0	0	2.4	15.5	8.5
22-Jul-91	8.5	7.4	2.2	11.8	6.5
23-Jul-91	0	0	0.4	13	2.4
24-Jul-91	0	0	1.6	13.5	4.4
25-Jul-91	0	0	1.8	13.5	6.4
26-Jul-91	0	0	1	14.5	2.4
27-Jul-91	0	1	2	16.5	4.5

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
28-Jul-91	4	2.2	1.2	15.7	7
29-Jul-91	0	0	1.8	16.5	8.1
30-Jul-91	0		1	16	8.2
31-Jul-91	1	2.2	1.8	15.9	10.4
01-Aug-91	0	0	1.2	15.8	8
02-Aug-91	0	0	2.4	16	4.4
03-Aug-91	0	0	2.6	19	10
04-Aug-91	0	0.2	2.8	18.4	8
05-Aug-91	0	0	2.8	21.5	8
06-Aug-91	0.3		3.2	16.4	9
07-Aug-91	0.5	1	2.6	17.1	9.5
08-Aug-91	0.5	0.2	2.2	15	6.5
09-Aug-91	0.2	0.6	2.8	16.5	4.8
10-Aug-91	0	0	0.6	15	6.5
11-Aug-91	0	0	0.6	16.8	6.5
12-Aug-91	0	0	1.6	19.1	10
13-Aug-91	0	0	2.4	18	7.8
14-Aug-91	1.2	0	2.8	16.4	8
15-Aug-91	0	0	2.2	16.4	10.5
16-Aug-91	0	3.2	2.2	13.6	4.1
17-Aug-91	0	0	2.2	14.5	1
18-Aug-91	0	0	2	16.3	3
19-Aug-91	0	0	2.2	19	8
20-Aug-91	1.5		5	17.5	9
21-Aug-91	0	0.6	3.2	16.5	7.5
22-Aug-91	0	0	3	19.5	7.5
23-Aug-91	0	0	3.4	15.5	10.5
24-Aug-91	0	4.4	3.2	14	3.5
25-Aug-91	0	0	2.2	15.2	4
26-Aug-91	0	0	2.2	17	6.3
27-Aug-91	0	0	2.2	16.4	10.5
28-Aug-91	1.2	4.6	3	17.4	6.2
29-Aug-91	0	0	2.6	19.5	8.8
30-Aug-91	3	7.4	4.2	16.6	6
31-Aug-91	5	4	2.4	15.5	7.6
01-Sep-91	0	0	2	16.5	3
02-Sep-91	0	0	1.8	22.1	7.8
03-Sep-91	0	0	3.2	19.4	7
04-Sep-91	0	0	3.6	24.8	4.8
05-Sep-91	0	0	3.6	29	10.7
06-Sep-91	0	0	4.4	27	7.6
07-Sep-91	0	0	4.6	26.5	9
08-Sep-91	7.4	2.2	7	19.2	13
09-Sep-91	0	0	3.8	20.5	6
10-Sep-91	2	0	4	16	12

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
11-Sep-91	4.8	2.2	3.4	18	8.4
12-Sep-91	0.6	1	2.6	15.4	8
13-Sep-91	0	0	5.6	20.5	6.5
14-Sep-91	0	0	3.2	23	8
15-Sep-91	0	0	5.6	21.5	11.5
16-Sep-91	0	0	4.8	22	9.5
17-Sep-91	1.5	2.8	6.2	17.5	8
18-Sep-91	8	4.6	5.8	20	9
19-Sep-91	0	0	2.6	17	5
20-Sep-91	0	0	3.6	20	6
21-Sep-91	0	3.8	3.8	18.5	7
22-Sep-91	0	0	4.6	18	4
23-Sep-91	0	0	2.8	20.5	4.5
24-Sep-91	0	0	3.6	20	8
25-Sep-91	0	0	2	24	11
26-Sep-91	0	0	2.4	22	9
27-Sep-91	0	0	3	24.5	7
28-Sep-91	0	0	3.6	22	9.5
29-Sep-91	0	0	3	23.6	9.4
30-Sep-91	0	0	6.8	32.6	7.4
01-Oct-91	0	0	5.6	32.6	14
02-Oct-91	0	0	5.8	27.5	14.2
03-Oct-91	0	0	10	27.7	10
04-Oct-91	0	0	4.6	30	13.6
05-Oct-91	0	0	4.8	28.5	17.8
06-Oct-91	0	0	8.6	25.2	15.5
07-Oct-91	0	0	3.6	21	9.9
08-Oct-91	0	0.8	3.2	20	10.9
09-Oct-91	0	0	6.6	21	6.4
10-Oct-91	0	0	4	23	8.5
11-Oct-91	0	0	4	25	7.9
12-Oct-91	0	0	4.6	31.5	10.5
13-Oct-91	0	0	8.4	25.5	11.5
14-Oct-91	0	0	5.2	31.3	14.5
15-Oct-91	0	0	8.6	37.5	19.5
16-Oct-91	0	0	16	26.1	10.4
17-Oct-91	0	0	5.4	20.7	6.6
18-Oct-91	0	0	6	26.5	10.4
19-Oct-91	0	0	5	28.5	17.5
20-Oct-91	0	0	8.2	33.5	18.5
21-Oct-91	0	0	9.2	26.8	17
22-Oct-91	0	0	7.8	24.1	12.5
23-Oct-91	0	0	3.8	23.5	10.4
24-Oct-91	0	0	5.8	26.9	10.8
25-Oct-91	0	0	7	23.6	10.4

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
26-Oct-91	0	0	7.4	21.6	7.5
27-Oct-91	0	0	5.8	23	6.5
28-Oct-91	0	0	5.6	26.4	10.6
29-Oct-91	0	0	5.8	28.5	15.5
30-Oct-91	0	0	8.2	35.7	18.8
31-Oct-91	0	0	10.6	25.4	9.8
01-Nov-91	0	0	9.8	25	10.9
02-Nov-91	0	0	7.2	22.5	11
03-Nov-91	0	0	5	26	19.5
04-Nov-91	8.7	10	5.2	23.8	12.3
05-Nov-91	0	0	5.8	26.1	10.6
06-Nov-91	2.8	1.2	7	27.5	15
07-Nov-91	0	1.8	6.2	23.3	11.5
08-Nov-91	0	0	8.6	21	8.2
09-Nov-91	0	0	6.4	23	7.8
10-Nov-91	0	0	7.2	22.8	8.5
11-Nov-91	0	0	6	23.6	8.5
12-Nov-91	0	0	6.6	21	15.4
13-Nov-91	0	0	5.2	25.2	11.8
14-Nov-91	0	0	7.2	26.6	13.4
15-Nov-91	0	0	8.2	27.5	16.3
16-Nov-91	0	0	9.4	26	16.5
17-Nov-91	0	0	8.4	30.4	16.5
18-Nov-91	0	0	7.6	34.6	16.5
19-Nov-91	0	0	13.8	35.6	21.6
20-Nov-91	0	0.2	12.8	24	11.5
21-Nov-91	0	0	9.6	25	9
22-Nov-91	0	0	6.4	28	10.8
23-Nov-91	0	0	7.6	32.5	15
24-Nov-91	0	0	5.6	36.6	19
25-Nov-91	0	0	12.4	35	23.8
26-Nov-91	9.6	4.2	15	27.9	15.5
27-Nov-91	0	0	10	23.6	11.5
28-Nov-91	0	0	8.6	27.4	10
29-Nov-91	0	0	11	25	12
30-Nov-91	0	0	9.2	23	11
01-Dec-91	0	0	5.6	25	14
02-Dec-91	0	0	6.6	30.2	11
03-Dec-91	0	0	6.2	25.7	16
04-Dec-91	0	0	12.2	24.5	12.9
05-Dec-91	0	0	7.2	26.7	9.9
06-Dec-91	0	0	6	30.5	11.4
07-Dec-91	0	0	8	33	15
08-Dec-91	0	0	8.2	35	15
09-Dec-91	0	0	9.6	37	17.4

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
10-Dec-91	0	0	15.8	27.8	18.5
11-Dec-91	0	0	9.6	26	10.7
12-Dec-91	0	0	8.8	29.4	13.8
13-Dec-91	0	0	10.2	27.5	17.8
14-Dec-91	0	0	4.6	32.5	19
15-Dec-91	0	0	8	24.6	17.5
16-Dec-91	0	0	9	22.6	13.5
17-Dec-91	0	0	7.8	21	11
18-Dec-91	0	0	5.4	23	7
19-Dec-91	0	0	5.6	26.6	10.5
20-Dec-91	0	0	6.4	26	11.5
21-Dec-91	0	0	8.4	25	13
22-Dec-91	0	0	8.6	28.5	12.5
23-Dec-91	0	0	9.2	30.6	12
24-Dec-91	0	0	8.6	35.5	13.6
25-Dec-91	0	0	10.2	39	19
26-Dec-91	0	0	12	40	24
27-Dec-91	0	0	13.8	34.5	25.5
28-Dec-91	0	0	11.6	34	20
29-Dec-91	0	0	10.8	33.5	19
30-Dec-91	0	0	8.8	31	19
31-Dec-91	0	0	7.2	29	17
01-Jan-92	0	0	10.6	27.5	16
02-Jan-92	0	0	9.6	30	13.8
03-Jan-92	0	0	7.6	33	16
04-Jan-92	0	0	9.8	25.5	14
05-Jan-92	0	0	9	25.1	11
06-Jan-92	0	0	8	25.4	12
07-Jan-92	0	0	8.8	23	13.1
08-Jan-92	0	0	6.2	22.2	13.2
09-Jan-92	0	0.6	6.8	23.3	12.6
10-Jan-92	3.6	10	6.6	27.5	12.3
11-Jan-92	0	0	6	28	13.5
12-Jan-92	0	0	7.8	28.5	12.5
13-Jan-92	0	0	10.4	30.4	12.8
14-Jan-92	0	0	12.4	27	15.6
15-Jan-92	0	0	8	29.4	13
16-Jan-92	0	0	11.8	25.6	14.8
17-Jan-92	0	0	9	25.8	10.7
18-Jan-92	0	0	7.2	30.2	12.1
19-Jan-92	0	0	8.6	36.4	14.4
20-Jan-92	0	0	10.6	42.3	21.4
21-Jan-92	0	0	15	37.4	20.5
22-Jan-92	0	0	10.6	38.4	21.8
23-Jan-92	0	0	8.6	28.5	20.1

Location	Lake Cullulleraine	Meringur	Mildura	Lake Victoria Storage	
Date	Rainfall (mm/day)	Rainfall (mm/day)	Pan Evaporation (mm/day)	Maximum Temp.(°C)	Minimum Temp.(°C)
24-Jan-92	0	0	5	29.5	16
25-Jan-92	0	0	9.8	28	15
26-Jan-92	0	0	9.8	27.5	14
27-Jan-92	0	0	8	28.8	13.5
28-Jan-92	0	0	8.8	27.7	14.5
29-Jan-92	0	0	9.4	29.1	14.2
30-Jan-92	0	0	8	32.1	15.8
31-Jan-92	0	0	8.2	35	17.8
01-Feb-92	0	0	10.2	33	20
02-Feb-92	0	0	9	35.5	20.4
03-Feb-92	0	0	8	37.5	20.9
04-Feb-92	1.2	4	9.4	31	20.2
05-Feb-92	2.8	0.8	5.2	33	19.6
06-Feb-92	3	8	3	28.5	19.5
07-Feb-92	0	0	9	29.5	15
08-Feb-92	0	0	8.4	32	15
09-Feb-92	0	0	8	33.5	16.5
10-Feb-92	0	0	9.8	32.5	21
11-Feb-92	0	0	9.2	34	22
12-Feb-92	17.2	5.2	7.4	31	19.5
13-Feb-92	0	0	9	29	14.5
14-Feb-92	0	0	8.8	29.5	13.5
15-Feb-92	0	0	6.8	31	14.5
16-Feb-92	0	0	7.6	36	17
17-Feb-92	0	0	10.4	36.5	24
18-Feb-92	0	0	15	34.5	22
19-Feb-92	0	0	10.4	31.5	18.5
20-Feb-92	0	0	10.6	28.5	13.5
21-Feb-92	0	0	8	31.5	14.5
22-Feb-92	0	0	7.2	31.5	19
23-Feb-92	0	0	12	25	16
24-Feb-92	0	0	6.8	24	12
25-Feb-92	0	0	9.2	26.5	11.5
26-Feb-92	0	0	10.6	28	13
27-Feb-92	0	0	8	31	15.5
28-Feb-92	0	0	10	29.5	16.5
29-Feb-92	0	0	8.6	28.5	21

APPENDIX B – SOIL ANALYSES

Table A2. Soil Analyses from the Mallee and the Wheat sites over the 5 measurement periods of this study.

Period 1

Sample	Bulk density (g cm^{-3})	pH	Gravimetric soil moisture (%)	NH_4_N (µg g^{-1})	NO_3_N (µg g^{-1})	Total N (%)	Oxidisable carbon (%)	Olsen-P (µg g^{-1})	HCO_3-P (µg g^{-1})	CDP-S (µg g^{-1})
Mallee										
1	1.315	6.95	0.398	5.51	4.62	0.06	0.30	1.60	6.00	0.10
2	1.379	6.89	0.355	4.13	1.78	0.05	0.30	2.40	9.00	0.20
3	1.467	6.86	0.452	6.06	3.54	0.11	0.70	1.60	18.50	14.50
4	1.316	7.35	0.591	4.59	3.32	0.08	0.60	1.40	5.50	3.00
5	1.376	7.24	0.490	3.89	0.89	0.05	0.60	1.50	4.00	0.10
6	1.262	7.19	1.204	6.25	5.92	0.17	2.80	5.10	20.00	6.50
7	1.399	7.31	0.488	3.12	1.91	0.06	0.40	1.80	9.00	3.87
8	1.353	7.06	0.700	3.72	0.44	0.06	0.50	1.90	1.00	0.30
9	1.427	6.89	0.603	3.62	0.51	0.05	0.70	1.40	4.00	1.00
10	1.428	6.70	0.552	3.70	1.02	0.06	0.50	3.80	2.50	2.20
Wheat										
1	1.522	7.32	0.752	3.00	4.09	0.07	0.40	7.00	16.50	0.20
2	1.520	7.35	0.731	3.20	6.01	0.06	0.40	5.40	20.00	0.10
3	1.399	7.50	0.764	3.87	7.24	0.03	0.40	2.80	17.50	0.10
4	1.467	7.43	0.842	3.92	6.38	0.03	0.40	3.00	15.50	0.50
5	1.508	7.38	0.807	4.18	18.37	0.07	0.50	3.10	17.00	0.50
6	1.485	7.46	0.756	3.50	5.94	0.06	0.50	4.70	15.50	0.20
7	1.502	7.55	0.722	3.81	4.95	0.09	0.50	4.10	24.00	0.40
8	1.451	7.57	0.894	4.42	5.94	0.10	0.50	2.32	27.50	0.10
9	1.529	7.47	0.826			0.05	0.50	4.20	34.50	0.30
10	1.520	7.37	0.945	4.00	12.58	0.06	0.60	4.80	23.00	1.80

Table A2. Soil Analyses from the Mallee and the Wheat sites over the 5 measurement periods of this study. Cdt

Period 2

Sample	Bulk density (g cm^{-3})	pH	Gravimetric soil moisture (%)	NH_4_N (µg g^{-1})	NO_3_N (µg g^{-1})	Total N (%)	Oxidisable carbon (%)	Olsen-P (µg g^{-1})	HCO_3-P (µg g^{-1})	CDP-S (µg g^{-1})
Mallee										
1	1.54	7.12	0.78	3.55	0.54	0.05	0.20	5.10	26.00	0.10
2	1.43	7.00	0.77	2.93	0.55	0.05	0.20	7.50	64.50	0.10
3	1.49	7.35	0.72	2.36	0.37	0.06	0.20	5.10	21.50	0.10
4	1.48	6.92	0.82	2.35	0.36	0.06	0.40	4.10	32.00	0.10
5	1.38	7.02	0.80	3.48	0.63	0.06	0.40	4.50	16.00	0.10
6	1.31	6.90	1.19	2.07	0.64	0.08	0.70	4.80	13.50	0.10
7	1.39	7.12	1.00	1.98	0.36	0.05	0.40	10.80	30.00	0.10
8	1.34	7.22	1.10	2.21	0.18	0.06	0.30	1.90	37.50	0.10
9	1.37	7.40	1.07	2.35	1.20	0.07	0.50	5.50	25.00	0.10
10	1.35	7.05	1.17	1.98	1.17	0.08	0.90	4.90	24.50	0.10
Wheat										
1	1.33	7.81	1.82	2.42	5.99	0.09	0.60	12.60	26.50	0.10
2	1.36	7.64	1.71	3.13	7.05	0.09	0.60	18.50	49.50	0.10
3	1.39	7.53	2.05	2.53	19.95	0.08	0.40	25.70	56.50	0.30
4	1.25	7.78	1.90	3.14	11.33	0.08	0.50	12.00	31.50	0.10
5	1.29	7.93	1.89	3.01	6.35	0.08	0.50	17.30	41.00	0.60
6	1.36	7.44	1.72	2.78	7.69	0.08	0.50	9.50	39.50	0.10
7	1.43	7.56	1.85	4.16	13.16	0.09	0.60	17.20	58.50	0.10
8	1.29	7.76	1.68	3.28	8.99	0.09	0.50	13.10	61.50	0.10
9	1.23	7.50	1.56	3.08	9.08	0.08	0.50	15.70	50.50	0.10
10	1.35	7.56	1.61	2.70	9.88	0.07	0.60	10.90	45.00	0.10

Table A2. Soil Analyses from the Mallee and the Wheat sites over the 5 measurement periods of this study. Cdt

Period 3

Sample	Bulk density (g cm^{-3})	pH	Gravimetric soil moisture (%)	NH_4_N (µg g^{-1})	NO_3_N (µg g^{-1})	Total N (%)	Oxidisable carbon (%)	Olsen-P (µg g^{-1})	HCO_3-P (µg g^{-1})	CDP-S (µg g^{-1})
Wheat										
Site 1		7.39	8.68	4.48	8.23	0.06	1.00	8.40	36.30	0.10
Site 1		7.27	7.96	4.52	1.96	0.07	1.00	8.20	31.30	0.10
Site 2		7.38	8.30	4.51	2.40	0.05	1.00	7.70	32.80	0.10
Site 2		7.47	9.44	5.47	3.53	0.05	0.90	9.30	39.30	0.10
Site 3		7.24	8.28	4.53	2.01	0.05	0.90	8.80	36.60	0.10
Site 3		7.13	8.79	5.29	1.39	0.01	0.90	5.80	38.30	0.10
Site 4		7.38	10.83	6.39	1.52	0.04	0.80	5.10	27.30	0.10
Site 4		7.36	10.09	5.98	3.09	0.06	0.90	8.90	49.30	0.10
Site 11		7.48	7.01	4.50	1.63	0.05	0.80	10.00	26.80	0.10
Site 11		7.50	7.89	4.70	1.71	0.05	0.90	6.10	55.30	0.10
Mallee										
Site 5		6.78	6.06	2.62	1.08	0.03	0.80	2.30	16.80	0.10
Site 5		6.93	4.61	2.94	0.77	0.04	1.00	1.70	13.30	0.10
Site 6		6.90	2.96	3.11	0.94	0.05	1.20	1.60	8.80	0.10
Site 6		6.84	3.64	2.86	1.78	0.04	1.00	1.60	8.30	0.10
Site 8		6.94	4.53	3.02	1.05	0.04	1.00	1.80	9.30	0.10
Site 8		6.91	3.70	2.58	0.79	0.04	0.90	1.60	18.80	0.10
Site 9		7.05	3.40	3.02	1.08	0.06	1.20	2.20	27.80	0.10
Site 9		6.94	4.59	3.98	1.13	0.04	0.90	1.90	17.80	0.10
Site 10		6.56	2.12	3.13	0.61	0.06	1.10	2.20	17.80	0.10
Site 10		6.64	1.86	3.34	0.57	0.05	1.10	1.50	15.80	0.10

Table A2. Soil Analyses from the Mallee and the Wheat sites over the 5 measurement periods of this study. Cdt

Period 4

Wheat

Sample	Bulk density (g cm^{-3})	pH	Gravimetric soil moisture (%)	NH_4_N ($\mu g\ g^{-1}$)	NO_3_N ($\mu g\ g^{-1}$)	Total N (%)	Oxidisable carbon (%)	Olsen-P ($\mu g\ g^{-1}$)	HCO_3-P ($\mu g\ g^{-1}$)	CDP-S ($\mu g\ g^{-1}$)
Site 1	1.25	7.23	4.21	2.89	4.14	0.06	0.60	7.80	28.80	0.10
Site 1	1.28	7.25	3.24	2.33	3.21	0.05	0.50	7.00	44.80	0.10
Site 2	1.38	7.30	4.89	3.25	4.55	0.06	0.50	6.30	16.30	0.10
Site 2	1.31	7.22	4.56	2.77	2.66	0.06	0.60	6.70	24.80	0.10
Site 3	1.25	7.34	3.67	2.62	2.69	0.06	0.80	7.40	32.30	0.10
Site 3	1.28	7.31	4.23	2.52	2.86	0.06	0.60	6.80	29.80	0.10
Site 4	1.31	7.38	5.16	2.72	2.55	0.05	0.60	6.10	30.30	0.10
Site 4	1.30	7.25	4.18	2.39	3.61	0.07	0.50	6.40	27.30	0.10
Site 5	1.33	7.30	4.60	3.03	2.06	0.07	0.60	4.90	34.80	0.10
Site 5	1.29	7.16	4.53	2.54	2.96	0.07	0.60	5.30	16.30	0.10
Mallee										
Site 11	1.41	7.12	3.71	3.17	2.53	0.07	0.80	2.50	38.80	0.40
Site 11	1.39	6.69	3.94	3.84	5.32	0.14	1.80	4.50	55.80	5.30
Site 10	1.56	6.74	3.61	3.05	0.79	0.04	0.40	2.10	27.80	0.10
Site 10	1.57	6.98	2.87	2.63	0.99	0.03	0.30	1.20	19.80	0.10
Site 9	1.51	6.67	3.83	3.73	1.33	0.04	0.60	1.90	21.30	0.10
Site 9	1.51	6.80	3.20	2.40	0.96	0.04	0.60	2.30	25.30	0.10
Site 8	1.42	6.97	2.96	2.69	0.65	0.04	0.50	1.80	45.80	0.10
Site 8	1.37	6.94	2.74	2.63	1.10	0.03	0.40	1.80	32.80	0.10
Site 6	1.41	7.29	3.53	2.87	2.49	0.05	0.70	2.10	26.80	0.10
Site 6	1.36	7.03	2.80	3.19	2.25	0.05	0.50	1.50	6.80	0.10

Table A2. Soil Analyses from the Mallee and the Wheat sites over the 5 measurement periods of this study. Cdt

Period 5

Sample	Bulk density ($g\ cm^{-3}$)	pH	Gravimetric soil moisture (%)	NH_4_N ($\mu g\ g^{-1}$)	NO_3_N ($\mu g\ g^{-1}$)	Total N (%)	Oxidisable carbon (%)	Olsen-P ($\mu g\ g^{-1}$)	HCO_3-P ($\mu g\ g^{-1}$)	CDP-S ($\mu g\ g^{-1}$)
Wheat										
Site 1	1.39	7.39	5.31	1.78	2.65	0.05	0.50	2.90	17.90	0.10
Site 1	1.37	7.39	5.87	1.42	0.49	0.05	0.60	3.10	19.90	0.10
Site 2	1.38	7.35	3.70	1.74	4.05	0.05	0.60	4.70	16.90	0.10
Site 2	1.41	7.33	4.30	1.66	1.82	0.05	0.40	11.90	32.40	0.10
Site 3	1.41	7.28	5.38	1.39	0.63	0.05	0.50	9.30	28.90	0.10
Site 3	1.39	7.13	4.79	1.64	2.93	0.06	0.70	11.50	32.40	0.10
Site 4	1.47	7.40	4.32	1.80	3.70	0.04	0.60	4.90	18.40	0.10
Site 4	1.39	7.28	3.79	1.68	3.22	0.04	0.50	5.20	21.40	0.10
Site 5	1.51	7.36	5.36	1.51	1.77	0.04	0.60	2.40	13.90	0.10
Site 5	1.45	7.35	4.58	1.56	4.04	0.04	0.60	4.40	17.90	0.10
Mallee										
Site 6	1.59	6.54	3.74	2.44	1.64	0.04	0.90	1.40	11.40	0.10
Site 6	1.62	6.72	3.38	1.83	0.79	0.03	0.60	0.40	12.90	0.10
Site 8	0.43	6.97	3.08	2.12	1.91	0.04	0.60	2.30	12.90	0.10
Site 8	1.29	7.11	4.28	4.43	4.65	0.05	0.60	0.70	9.90	0.10
Site 9	1.62	6.68	3.67	2.12	0.87	0.02	0.40	0.50	12.90	0.10
Site 9	1.50	7.00	3.78	1.84	1.60	0.02	0.50	0.80	11.40	0.10
Site 10	1.65	7.15	3.93	1.91	0.41	0.02	0.40	0.50	12.40	0.10
Site 10	1.59	6.82	4.07	1.87	0.34	0.02	0.50	0.70	9.90	0.10
Site 11	1.50	7.19	0.35	1.98	0.54	0.03	0.50	0.10	11.90	0.10
Site 11	1.55	7.05	0.30	1.76	0.16	0.03	0.60	0.00	12.40	0.10

APPENDIX C – SOIL PHYSICAL PROPERTIES

Table A3. Soil Physical Properties for the Mallee and the Wheat sites measured in measurement period 1 of this study.

Sample	Bulk density (g cm^{-3})	pH	coarse sand 0-0.2 mm (%)	fine sand 0.2-0.02 mm (%)	Silt 0.02-0.002 mm (%)	Clay < 0.002 mm (%)
Mallee						
1	1.315	6.95	52.50	43.00	1.00	3.50
2	1.379	6.89	76.50	18.50	1.50	3.50
3	1.467	6.86	66.00	28.00	2.00	4.00
4	1.316	7.35	68.00	26.00	1.00	5.00
5	1.376	7.24	72.00	23.00	2.50	2.50
6	1.262	7.19	65.00	27.00	1.50	6.50
7	1.399	7.31	76.50	19.00	1.50	3.00
8	1.353	7.06	72.00	24.00	1.00	3.00
9	1.427	6.89	64.00	31.00	1.50	3.50
10	1.428	6.70	74.00	20.00	2.50	3.50
Wheat						
1	1.522	7.32	69.50	22.00	1.50	7.00
2	1.520	7.35	66.50	25.50	0.50	7.50
3	1.399	7.50	69.00	22.50	1.50	7.00
4	1.467	7.43	60.00	31.00	3.00	6.00
5	1.508	7.38	64.00	27.00	3.50	5.50
6	1.485	7.46	64.00	29.00	0.00	7.00
7	1.502	7.55	65.00	29.00	0.00	6.00
8	1.451	7.57	61.50	32.00	0.50	6.00
9	1.529	7.47	62.50	28.00	2.00	7.50
10	1.520	7.37	64.00	26.50	2.00	7.50

APPENDIX D – WHEAT BIOMASS MEASUREMENTS

Table A4. Wheat biomass final data summary (g m^{-2}).

Plot	Leaf	Root	Heads	Grain	Total	Grain/Head	Above ground Biomass	Above ground stubble Biomass
1	63.04	10.5	320.38	230.77	642	0.720	631.5	400.73
2	35.47	9.54	346.59	249.65	639.21	0.720	629.67	380.02
3	45.08	9	269.61	194.2	545.7	0.720	536.7	342.50
4	41.33	9.45	268.73	193.57	558.4	0.720	548.95	355.38
5	36.59	8.81	269.16	193.88	539.18	0.720	530.37	336.49
6	43.39	9.42	313.34	225.7	602.08	0.720	592.66	366.96
	44.15					Average	**578.3**	**363.7**

APPENDIX E - TRACE GAS EXCHANGE MEASUREMENTS FOR MALLEE

Table A5. Trace Gas Exchange Measurements for the Mallee sites measured over the 5 measurement periods of this study.

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (µgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
1	25	07-Mar-91	10:47:30	1_Blank	374	2.71	35.6	38.3		1.00	0.00	-0.40	1.17		
2	30	03-Jun-91	12:02:00	2_Blank	180	1.88	18.8	27.0	18.2	0.31	0.00	-0.33	0.09		
2	43	05-Jun-91	16:39:00	2_Blank	180	1.08	20.0	25.0		0.15	0.00	-0.55	0.03		
4	42	05-Nov-91	09:02:18	4_S_Blank	141	0.65	21.3	37.9	21.3	0.72	-0.30	0.01	0.37		
4	47	05-Nov-91	16:23:40	4_S_Blank	141	0.81	27.9	38.6	35.0	0.75	-0.10	0.00	0.00		
4	52	06-Nov-91	14:57:45	4_S_Blank	141	2.29	20.0	20.0	20.0	0.72	-0.16	0.15	0.21		
5	32	31-Jan-92	16:45:45	5_M_Blank	353	1.38	39.6	43.0	55.0	0.95	0.00	0.44	-0.05		
5	38	01-Feb-92	17:05:05	5_M_Blank	353	0.98	20.0	20.0	20.0	0.99	-0.31	0.21	-0.03		
5	41	03-Feb-92	14:01:33	5_L_Blank	600	0.88	40.1	46.0	45.8	0.90	-0.10	-0.33	-0.76		
5	55	05-Feb-92	16:02:24	5_L_Blank	600	0.25	32.8	34.3	35.6	0.75	0.15	0.07	-0.05		0.42
5	33	01-Feb-92	9:51:50	5_M_Blank	353	1.07	27.2	44.4	33.0	0.52	0.00	0.14	-0.26		
4	1	24-Oct-91	13:45:00	4_L_Blank Caravan	640	0.00	20.0	20.0	20.0	1.80	0.00	0.00	0.00		
4	2	24-Oct-91	15:26:00	4_L_Blank Caravan	640	0.00	20.0	20.0	20.0	1.80	0.00	-7.97	0.00		
5	1	23-Jan-92	13:26:55	5_S_Blank Caravan	141	1.18	27.7	32.6	27.8	0.91	-0.04	0.69	-0.05		
5	2	23-Jan-92	15:32:31	5_S_Blank Caravan	141	0.89	29.1	34.3	29.1	0.73	-0.11	0.44	-0.30		
5	3	23-Jan-92	17:13:15	5_S_Blank Caravan	141	0.99	27.1	29.1	27.0	0.70	0.07	0.03	-0.39		
1	10	04-Mar-91	10:24:40	1_3	374	1.58	29.0	36.4	24.6	0.73	8.41	-1.86	0.24	2.63	
1	11	04-Mar-91	11:43:47	1_2	374	1.89	36.0	41.1		0.80	8.28	-3.32	1.67	0.82	

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (µgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
1	12	04-Mar-91	13:11:00	1_5	374	1.94	35.5	40.5	53.4	0.82	9.23	-4.36	0.95	6.48	
1	13	04-Mar-91	14:32:30	1_1	374	1.80	38.1	51.4		0.78	3.08	1.27	2.36	5.33	
1	14	04-Mar-91	16:08:00	1_3	374	1.57	37.9	55.0	53.9	0.73	21.33	-9.28	0.67	7.48	
1	15	05-Mar-91	10:11:00	1_3W	374	1.08	22.4	26.3	28.9	0.61	41.74	-0.66	2.39	5.03	
1	16	05-Mar-91	11:41:00	1_2	374	1.08	28.3	35.4		0.61	5.45	-3.77	1.55	1.67	
1	17	05-Mar-91	13:05:45	1_5	374	0.95	31.5	39.8	37.9	0.58	6.13	-5.60	0.97	5.93	
1	18	05-Mar-91	14:40:00	1_1	374	0.90	32.2	47.5	56.9	0.57	11.49	0.54	2.94	13.26	
1	19	05-Mar-91	16:11:30	1_3W	374	0.73	37.7	51.3	51.3	0.53	38.23	-2.44	6.15	29.91	
1	20	06-Mar-91	10:24:30	1_3W	374	1.09	32.0	40.0	36.8	0.61	13.24	0.10	0.49	3.28	
1	21	06-Mar-91	12:18:10	1_2	374	1.41	36.0	43.0	46.0	0.69	5.56	-0.70	1.54	0.12	
1	22	06-Mar-91	14:00:00	1_5	374	2.11	39.2	46.6	50.5	0.86	12.03	-6.66	3.07	8.11	
1	23	06-Mar-91	15:28:30	1_1	374	2.34	40.5	53.5	50.1	0.91	15.23	0.16	1.44	7.51	
1	24	06-Mar-91	16:57:30	1_3W	374	1.81	39.3	50.0		0.78	26.25	1.15	3.12	12.60	
1	26	07-Mar-91	12:15:00	1_2	374	2.61	38.9	42.0	51.7	0.98	4.97	0.33		-4.03	
1	27	07-Mar-91	13:57:30	1_5	374	2.29	41.0	46.5	54.9	0.90	7.77	-2.37	2.24	11.73	
1	28	07-Mar-91	15:21:30	1_1	374	1.85	41.5	54.9	51.3	0.79	15.67	2.04	1.44	12.80	
1	29	07-Mar-91	17:06:20	1_3W	374	1.42	41.6	55.1		0.69	19.60	-0.61	0.89	2.94	
2	24	31-May-91	11:37:00	2_6	146	2.17	22.4	28.9	23.2	0.38	2.74	-3.53	-0.34	3.29	
2	25	31-May-91	12:54:06	2_10	147	1.88	22.8	28.8	24.4	0.36	3.85	-3.19	-0.27	-1.00	
2	26	31-May-91	14:48:10	2_8	151	1.38	22.1	24.5	22.6	0.39	5.27	-4.49	-0.33	-1.77	
2	27	01-Jun-91	13:12:20	2_8	151	1.85	23.1	24.3		0.36	5.34	-4.40	-0.01	-2.22	
2	28	01-Jun-91	14:29:40	2_10	147	1.29	22.2	22.7		0.39	4.91	-3.27	0.42	-1.88	
2	29	01-Jun-91	16:18:50	2_6	146	0.74	21.1	21.1		0.53	7.11	-3.65		-2.71	
2	31	03-Jun-91	13:49:50	2_8R	151	1.45	20.0	23.2	20.3	0.17	9.58	-0.87	0.14	-0.03	
2	32	03-Jun-91	14:57:40	2_6R	146	1.51	21.0	21.3	19.8	0.27	22.23	-2.80	0.19	0.98	
2	33	03-Jun-91	16:56:30	2_10R	147	0.60	14.0	16.0	18.9	0.09	10.90	-2.24	1.55	0.53	
2	34	04-Jun-91	10:54:40	2_8R	151	0.62	17.7	20.0	16.5	0.17	3.10	-1.82	-0.07	0.67	

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed ($m\ s^{-1}$)	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 ($\mu gC\ m^{-2}\ s^{-1}$)	CH_4 ($ngC\ m^{-2}\ s^{-1}$)	N_2O ($ngN\ m^{-2}\ s^{-1}$)	CO ($ngC\ m^{-2}\ s^{-1}$)	NO_x ($ngN\ m^{-2}\ s^{-1}$)
2	35	04-Jun-91	12:06:30	2_10R	147	0.52	18.6	22.8		0.19	5.32	-1.67	0.19	2.54	
2	36	04-Jun-91	14:09:20	2_6R	146	0.52	20.9	23.6	20.8	0.25	8.46	-1.70	0.28	-0.29	
2	37	04-Jun-91	15:59:20	2_9R	146	0.25	19.4	17.4	19.2	0.43	17.48	-4.73	0.26	-2.87	
2	38	04-Jun-91	17:20:00	2_5R	179	0.00	20.0	25.0		0.23				-2.00	
2	39	05-Jun-91	10:31:09	2_8R	151	1.55	15.5	15.1	13.3	0.26	4.29	-4.20	0.07	-1.94	
2	40	05-Jun-91	11:40:31	2_10R	147	1.73	19.3	20.1	16.2	0.24	5.72	-3.46	-0.03	-0.56	
2	41	05-Jun-91	13:27:28	2_6R	146	1.21	18.6	19.7	17.3	0.29	15.42	-4.71	0.06	-2.20	
2	42	05-Jun-91	15:05:00	2_9R	146	0.98	17.9	18.4	17.0	0.39	16.45	-5.44	0.48	-2.77	
3	25	01-Aug-91	15:06:14	3_5	116	0.96	14.9	14.7	18.9	0.17	2.93	-7.03	0.08		
3	26	01-Aug-91	16:10:55	3_6	123	0.45	13.4	13.7	16.3	0.13	3.68	-3.99	0.44		
3	27	02-Aug-91	10:06:01	3_9	117	1.52	14.5	12.6	13.3	0.21	1.78	-5.77	0.10		
3	28	02-Aug-91	11:14:41	3_8	120	1.64	17.4	14.8	18.1	0.22	1.23	-6.65	0.06		
3	29	02-Aug-91	12:30:30	3_6	123	1.60	18.9	25.1	22.3	0.21	4.22	-5.13	0.34		
3	30	02-Aug-91	15:30:30	3_10	321	1.56	17.0	18.5	20.6	0.73	4.56	-10.40	2.51		
3	31	02-Aug-91	16:48:20	3_5	116	0.87	13.0	13.3	16.3	0.16	4.14	-8.42	-0.02		
3	32	03-Aug-91	10:42:20	3_9	117	1.42	20.6	17.9	19.6	0.20	8.16	-5.78	0.03		
3	33	03-Aug-91	12:00:00	3_8	120	1.15	23.2	21.9	25.1	0.18	3.16	-5.62	0.05		
3	34	03-Aug-91	14:23:06	3_5	116	1.07	21.2	20.8	25.4	0.18	7.64	-7.52	-0.07		
3	35	03-Aug-91	16:33:49	3_6	123	0.66	16.4	17.3	20.2	0.15	7.68	-4.10	0.19		
3	36	05-Aug-91	10:30:20	3_9	117	2.18	17.3	18.1	15.8	0.25	6.11	-7.62	-0.06		
3	37	05-Aug-91	11:43:40	3_8	120	2.69	19.4	20.4	18.4	0.29	6.24	-8.41	0.12		
3	38	05-Aug-91	12:54:08	3_5	116	3.31	12.0	12.0	15.0	0.33	8.29	-10.08	0.02		
3	39	05-Aug-91	14:54:11	3_10	321	2.92	11.9	12.7	15.5	1.05	12.28	-6.11	0.62		
3	40	05-Aug-91	16:18:46	3_6W	123	1.98	11.8	12.1	13.1	0.24	12.06	-3.63	0.21		
3	41	06-Aug-91	9:46:20	3_9	117	1.82	15.1	14.3	14.2	0.23	4.01	-6.64	0.02		
3	42	06-Aug-91	11:09:56	3_8	120	1.79	14.8	15.0	15.9	0.23	3.43	-5.58	0.02		
3	43	06-Aug-91	12:29:00	3_5W	116	1.72	16.1	16.9	17.4	0.22	3.95	-6.36	0.02		

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3	44	06-Aug-91	14:45:20	3_10	321	1.80	16.7	17.7	18.4	0.78	3.75	-7.98	0.86		
3	45	06-Aug-91	16:04:30	3_6	123	1.79	15.5	17.1	17.4	0.23	8.75	-3.91	0.21		
3	46	07-Aug-91	10:04:56	3_9	117	2.80	14.7	18.1	14.5	0.30	4.85	-8.75	0.01		
3	47	07-Aug-91	11:14:50	3_8	120	3.14	15.3	17.0	16.4	0.32	5.40	-9.81	0.14		
3	48	07-Aug-91	12:26:06	3_5W	116	2.82	15.0	15.9	16.1	0.30	8.24	-7.20	0.09		
3	49	07-Aug-91	14:05:00	3_10	321	2.26	13.5	14.7	15.4	0.89	9.80	-9.61	0.26		
3	50	07-Aug-91	15:15:24	3_6W	123	2.24	12.1	13.2	13.0	0.26	14.33	-5.15	0.22		
4	27	01-Nov-91	09:50:24	4_9	115	0.98	23.8	36.6	35.6	0.17	3.60	-3.81	0.12	6.82	
4	28	01-Nov-91	11:32:48	4_8	128	0.85	28.1	45.5	33.1	0.16	6.95	-4.99	0.06	21.27	
4	29	01-Nov-91	13:01:17	4_11	126	0.90	31.1	40.1	40.0	0.83	9.22	-9.11	0.20	23.35	
4	30	01-Nov-91	14:54:05	4_6	122	0.82	30.4	34.9	43.1	0.84	8.86	-3.46	0.23	8.16	
4	31	01-Nov-91	16:38:20	4_10	126	0.67	28.1	38.3	40.4	0.81	8.72				
4	32	02-Nov-91	09:43:30	4_9	115	1.36	23.7	25.1	24.3	0.20	5.49	-5.28	-0.02	-0.16	
4	33	02-Nov-91	11:19:49	4_8	128	0.60	25.2	28.2	26.4	0.79	5.85	-5.28	0.05	4.85	
4	34	02-Nov-91	12:46:42	4_11	126	0.84	24.5	27.3	26.9	0.82	9.72	-8.09	0.05	5.87	
4	35	02-Nov-91	14:25:48	4_6	122	0.38	21.9	21.6	24.0	0.81	13.96	-4.08	0.08	7.45	
4	36	02-Nov-91	15:56:36	4_10	126	0.80	20.0	20.0	20.0	0.82	12.76	-9.22	0.08	-2.34	
4	37	04-Nov-91	09:27:27	4_9W	115	14.25	21.5	21.9	22.2	0.45	12.80	-1.88	0.37	-0.36	
4	38	04-Nov-91	11:01:16	4_8W	128	16.67	20.0	20.0	20.0	1.10	17.71	-4.36	0.29	2.89	
4	39	04-Nov-91	12:33:20	4_11W	126	1.68	22.5	27.6	24.0	0.88	31.79	-5.63	0.36	-1.43	
4	40	04-Nov-91	14:05:54	4_6W	122	1.59	23.8	27.9	26.2	0.90	25.04	-1.71	0.23	-1.32	
4	41	04-Nov-91	15:33:30	4_10W	126	1.59	23.6	30.0	27.3	0.88	21.61	-4.66	0.19	-2.53	
4	43	05-Nov-91	10:32:50	4_8W	128	0.61	25.4	37.5	27.1	0.79	14.45	-3.23	0.13	0.44	
4	44	05-Nov-91	12:05:20	4_11W	126	0.75	28.7	34.9	34.0	0.82	26.78	-7.17	0.24	-1.77	
4	45	05-Nov-91	13:41:50	4_6W	122	0.79	29.8	38.0	35.5	0.84	22.14	-1.93	0.16	0.26	
4	46	05-Nov-91	15:05:30	4_10W	126	1.00	28.8	37.6	36.1	0.83	22.60	-6.39	0.15	-0.45	
4	48	06-Nov-91	08:52:23	4_9W	115	1.67	16.9	18.5	16.9	0.94	15.37	-5.36	0.23	0.36	

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4	49	06-Nov-91	10:25:50	4_8W	128	2.30	20.0	21.2	18.8	0.91	16.48	-5.75	0.20	6.15	
4	50	06-Nov-91	11:56:00	4_11W	126	7.47	26.7	29.5	25.4	1.12	29.59	-8.55	0.13	0.29	
4	51	06-Nov-91	13:29:37	4_10W	126	2.10	20.0	20.0	20.0	0.91	23.56	-4.69	0.19	-0.11	
5	28	31-Jan-92	10:21:49	5_8	132	1.12	30.9	37.5	37.0	0.81	4.55	-0.47	-0.02	18.73	0.58
5	29	31-Jan-92	11:36:48	5_9	137	1.09	36.7	42.1	46.1	0.79	5.05	0.57	-0.03	19.11	0.59
5	30	31-Jan-92	13:25:33	5_10	120	1.13	40.7	56.3	54.8	0.87	4.88	10.43	-0.01	37.44	0.26
5	31	31-Jan-92	14:50:35	5_6	138	0.99	41.7	57.9	56.9	0.77	7.03	2.72	-0.13	60.04	0.69
5	34	01-Feb-92	11:15:00	5_8	132	1.14	33.1	40.7	43.6	0.18	4.23	-0.28	-0.08	24.43	
5	35	01-Feb-92	12:43:36	5_9	137	0.96	38.5	50.6	52.2	0.78	5.09	1.04	-0.01	51.55	0.38
5	36	01-Feb-92	14:11:10	5_10	120	0.94	40.6	56.7	55.9	0.86	4.43	9.36	-0.05	41.46	0.09
5	37	01-Feb-92	15:27:00	5_6	138	0.89	41.7	57.2	57.5	0.76	6.56	2.69	-0.02	60.28	0.71
5	39	03-Feb-92	11:15:26	5_8	132	0.85	38.8	46.4	44.2	0.79	6.77	-0.93	0.00	34.69	0.37
5	40	03-Feb-92	12:30:20	5_9	137	0.81	36.1	41.7	44.8	0.77	7.86	-0.36	-0.12	12.21	0.31
5	42	03-Feb-92	15:44:00	5_10	120	0.96	39.6	47.4	48.2	0.86	9.81	9.96	0.08	11.43	
5	43	03-Feb-92	17:28:10	5_6	138	1.91	35.8	43.4	47.0	0.84	8.84	2.72	-0.01	12.78	0.37
5	44	04-Feb-92	10:45:10	5_8W	132	0.66	21.2	22.8	25.5	0.78	68.52	0.18	0.85	14.41	7.03
5	45	04-Feb-92	12:09:50	5_9W	137	0.86	26.9	30.1	30.8	0.77	65.28	1.47	1.64	50.06	1.37
5	46	04-Feb-92	13:34:00	5_10W	120	1.00	30.6	37.9	35.3	0.86	39.02				0.76
5	47	04-Feb-92	14:04:00	5_6W	138	0.86	31.6	40.9	36.3	0.76	58.21				2.95
5	48	04-Feb-92	14:34:00	5_11W	134	0.68	33.0	41.4	37.0	0.77	28.35				2.60
5	49	04-Feb-92	15:01:00	5_10W	120	0.66	34.1	42.5	37.9	0.84	48.80	10.74	0.77	25.66	0.75
5	50	04-Feb-92	16:33:00	5_9W	137	0.64	34.7	42.7	37.8	0.75	70.16	6.81	2.66	16.20	4.02
5	51	05-Feb-92	10:31:00	5_8W	132	1.04	29.7	30.8	28.5	0.81	29.29	0.72	0.26	-2.65	1.06
5	52	05-Feb-92	11:48:00	5_9W	137	1.21	35.6	38.1	36.3	0.79	29.35	2.22	0.37	3.99	0.85
5	53	05-Feb-92	13:10:09	5_10W	120	0.88	39.2	43.5	42.2	0.86	29.17	12.60	0.27	2.69	0.66
5	54	05-Feb-92	14:31:32	5_6W	138	1.14	34.0	36.8	37.8	0.78	27.63	5.32	0.38	-1.21	2.45

APPENDIX F - TRACE GAS EXCHANGE MEASUREMENTS FOR WHEAT

Table A6. Trace Gas Exchange Measurements for the Wheat sites measured over the 5 measurement periods of this study.

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (µgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
1	41	12-Mar-91	14:47:30	1_Blank	374	2.52	22.9	32.7		0.96	-4.57	-0.96	0.28		
4	21	29-Oct-91	16:22:21	4_L_Blank	640	1.39	31.1	34.0	33.1	0.21	-1.40	0.11	0.19		
5	7	24-Jan-92	16:42:50	5_S_Blank	141	2.09	33.3	39.8	47.8	0.84	0.12	-0.17	-0.14		0.09
5	11	25-Jan-92	15:00:00	5_S_Blank	141	2.41	32.1	39.2	48.7	0.86	-0.03	-0.26	-0.08		0.02
5	16	27-Jan-92	15:43:45	5_S_Blank	141	2.51	32.5	39.6	47.3	0.87	-0.07	0.33	-0.13		0.13
5	21	28-Jan-92	14:45:07	5_S_Blank	141	2.55	31.5	38.6	46.6	0.87	0.18	0.16	-0.10		
5	26	29-Jan-92	14:32:20	5_S_Blank	141	1.44	34.3	41.2	45.8	0.76	0.22	0.23	-0.14		0.37
2	14	28-May-91	14:46:00	2_Blank	180	1.29	22.3	28.5	22.3	0.28	0.08	-0.06	-0.14		
1	30	08-Mar-91	11:08:30	1_7	374	4.04	33.3	41.6		1.32	3.48	1.24	2.59	-1.54	
1	31	08-Mar-91	12:19:30	1_9	374	5.17	35.1	43.3	44.3	1.55	8.47	-3.90	0.09	1.13	
1	32	08-Mar-91	13:58:00	1_8	374	3.66	39.0	47.9	53.9	1.23	6.12	-7.83	0.91	6.89	
1	33	08-Mar-91	15:26:40	1_6	374	8.81	39.4	49.4	53.8	1.55	6.29	-3.47	2.80	4.98	
1	34	09-Mar-91	10:37:00	1_7	374	6.68	19.9	23.9	27.9	1.55	19.49	-6.15	1.19	-3.70	
1	35	09-Mar-91	12:02:40	1_9	374	28.44	21.2	24.4	24.7	1.55	8.41	-4.84	-1.51	0.16	
1	36	09-Mar-91	13:39:30	1_8	374	7.09	23.8	30.1	37.7	1.55	5.13	-3.04	-0.88	-4.97	
1	37	09-Mar-91	15:27:10	1_6	374	7.16	24.8	37.8	35.0	1.55	8.86	-2.39	0.25	0.12	
1	38	12-Mar-91	10:22:30	1_7	374	3.50	16.3	24.7	24.7	1.19	5.40	-4.22	-2.44	1.45	
1	39	12-Mar-91	11:44:30	1_9W	374	2.92	19.1	26.8	35.8	1.05	25.16	-5.78	0.53	-0.81	
1	40	12-Mar-91	13:06:30	1_8	374	2.61	20.5	36.9	39.4	0.98	2.70	-2.84	1.07	-2.31	
1	42	12-Mar-91	16:21:30	1_6W	374	2.57	24.6	38.6	41.8	0.97	21.54	-4.43	2.57	2.61	
1	43	13-Mar-91	10:23:15	1_7	374	3.15	18.9	21.0	32.3	1.11	3.87	-5.33	0.45	-0.58	

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (µgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
1	44	13-Mar-91	11:37:20	1_9W	374	2.35	21.4	31.6	40.1	0.91	12.04	-5.50	-0.16	-0.79	
1	45	13-Mar-91	12:57:30	1_8	374	2.65	24.1	36.2	41.3	0.99	2.93	-4.51	-0.03	1.77	
1	46	13-Mar-91	15:40:20	1_6W	374	2.65	28.2	37.8	39.3	0.99	10.96	-6.53	1.80	5.72	
2	1	24-May-91	17:17:00	2_4	140	0.38	20.0	25.0		0.25		-5.87	0.06	-6.03	
2	2	25-May-91	10:47:00	2_4	140	2.98	20.0	25.0		0.44		-5.88	0.05	-0.36	
2	3	25-May-91	12:12:00	2_3	149	2.57	20.0	25.0	28.4	0.41		-8.29	0.35	-1.58	
2	4	25-May-91	14:02:00	2_4	140	2.75	21.8	29.0		0.42	4.08				
2	5	25-May-91	14:46:00	2_1	135	2.65	21.4	26.9	27.9	0.41	2.57	-8.02	0.12	-1.99	
2	6	25-May-91	16:12:00	2_2	143	2.14	20.2	23.1		0.38	1.75	-9.06		-3.34	
2	7	25-May-91	17:03:00	2_3	149	0.73	16.5	15.8	19.8	0.28	2.56				
2	8	27-May-91	10:51:25	2_4	140	1.60	14.1	17.3	15.9	0.34	1.74	-5.69	-0.09	-3.26	
2	9	27-May-91	12:10:59	2_3	149	1.55	14.8	18.2	16.6	0.34	1.61	-7.37	0.06	-5.80	
2	10	27-May-91	14:00:30	2_1	135	2.39	14.4	17.2	16.4	0.35	1.73	-7.41	0.04	-5.83	
2	11	27-May-91	15:39:15	2_2	143	2.14	13.8	15.3	15.6	0.44	1.23	-6.91	-0.17	-5.14	
2	12	28-May-91	10:05:50	2_4	140	0.80	20.1	19.1	14.9	0.28	1.74	-6.60	0.02	-6.44	
2	13	28-May-91	11:19:00	2_3	149	1.30	18.7	26.2	25.9	0.32	2.27	-7.19	0.01	-2.24	
2	13.5	28-May-91	13:01:42	2_1	135	1.30	22.3	28.5	25.9	0.32	1.78				
2	15	28-May-91	16:00:00	2_2	143	0.40	18.9	19.7	18.8	0.40	1.53	-7.32	0.14	-3.90	
2	16	29-May-91	10:12:00	2_4W	140	2.39	16.1	17.4	14.5	0.38	9.42	-5.67	0.32	2.17	
2	17	29-May-91	11:47:00	2_3	149	2.60	21.7	24.6	21.9	0.36		-7.07	0.03	-0.44	
2	18	29-May-91	13:45:30	2_1W	135	2.82	21.7	24.6	21.9	0.43	11.21	-9.10	0.65	-5.64	
2	19	29-May-91	15:23:00	2_2	143	2.93	20.3	21.9	22.8	0.97	1.25	-6.82	0.13	-3.79	
2	19.5	29-May-91	17:05:12	2_4W	140	2.93	14.4	13.3	15.8	0.70	9.49				
2	20	30-May-91	10:51:10	2_4W	140	3.45	21.4	23.6	18.4	0.47	7.30	-6.66	0.49	-2.08	
2	21	30-May-91	12:13:00	2_3	149	4.83	22.4	27.6	20.8	0.69	2.76	-9.64	-0.27	-2.88	
2	22	30-May-91	14:42:00	2_1W	135	3.77	20.8	23.7	21.2	0.45	7.80	-9.36	0.42	-5.89	
2	23	30-May-91	16:32:40	2_2	143	1.75	17.5	17.2	18.3	0.55	1.50	-7.06	0.01	-3.48	

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (μgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
3	1	25-Jul-91	14:12:45	3_4	328	0.00	20.0	20.0	20.0	0.35		-3.04	0.45	-1.64	
3	2	25-Jul-91	15:57:30	3_3	331	0.00	20.0	20.0	20.0	0.35		0.51	0.40	-3.21	
3	3	26-Jul-91	10:58:19	3_4	328	0.00	20.0	20.0	20.0	0.35		-3.88	0.72	-5.46	
3	4	26-Jul-91	12:12:30	3_3	331	1.50	13.2	23.9	15.6	0.71	-84.96	-0.97	0.55	-2.89	
3	5	26-Jul-91	13:42:08	3_2	335	1.44	16.9	20.7	17.8	0.70	-64.95	-1.88	0.79	-3.80	
3	6	26-Jul-91	15:21:00	3_11	329	1.12	15.3	17.8	14.8	0.62	-28.11	-7.76	0.99	12.27	
3	7	27-Jul-91	10:14:30	3_4	328	1.88	9.6	11.8	10.1	0.80	-12.40	-6.73	1.35	-4.83	
3	8	27-Jul-91	11:27:00	3_3	331	2.26	12.5	15.3	12.4	0.89		-0.09	0.47	0.12	
3	9	27-Jul-91	12:58:00	3_2	335	2.65	15.2	20.2	14.3	0.99	-40.85	-5.21	1.62	-0.56	
3	10	27-Jul-91	14:33:15	3_11	329	2.65	15.2	17.6	14.3	0.99	-20.80	-4.03	2.66	-3.25	
3	11	27-Jul-91	15:57:30	3_1	323	1.69	16.3	17.6	13.9	0.76	-28.39	-13.88	1.49	-3.58	
3	12	29-Jul-91	12:32:20	3_4	328	2.09	15.8	20.6	15.6	0.85	-17.64	-5.22	6.30	0.03	
3	13	29-Jul-91	14:00:28	3_3	331	2.04	17.5	23.2	17.1	0.84	-51.68	-5.15	10.90	-2.35	
3	14	29-Jul-91	15:17:30	3_2	335	1.33	16.5	20.5	16.3	0.67	-15.42	-3.44	4.93	-2.69	
3	15	29-Jul-91	17:16:20	3_11	329	0.26	13.6	13.4	14.4	0.41	23.61	-4.45	11.97	-2.00	
3	16	30-Jul-91	10:20:30	3_4W	328	0.91	15.4	18.7	13.7	0.57	-57.69	-5.31	6.73		
3	17	30-Jul-91	11:43:55	3_3	331	1.07	17.9	21.8	15.7	0.61	-54.91	-3.63	9.80		
3	18	30-Jul-91	13:02:48	3_2W	335	1.67	17.8	22.0	16.8	0.75	-54.23	-4.22	4.92		
3	19	30-Jul-91	15:03:06	3_11	329	1.54	16.3	17.9	16.0	0.72	-40.99	-4.67	10.21		
3	20	30-Jul-91	16:15:04	3_1	323	0.90	15.8	16.3	14.4	0.57	4.50	-9.15	6.74		
3	21	31-Jul-91	10:34:52	3_4W	328	1.78	13.8	16.3	13.6	0.78	-47.42	-3.84	3.88		
3	22	31-Jul-91	12:08:26	3_3	331	1.94	14.0	15.2	14.4	0.82	-26.14	-2.96	7.83		
3	23	31-Jul-91	15:14:06	3_2W	335	2.67	12.8	13.6	14.0	0.99	-14.54	-1.69	6.58		
3	24	31-Jul-91	16:46:31	3_11	329	2.66	11.9	12.4	12.7	0.99	4.70		11.07		
4	3	25-Oct-91	10:57:53	4_1	619	1.37	26.9	44.3	37.6	1.80	17.23	-8.99	0.60	61.96	
4	4	25-Oct-91	12:26:17	4_2	630	1.79	25.8	43.0	38.6	1.80	16.09	-11.19	0.27	53.18	
4	5	25-Oct-91	13:54:21	4_3	617	0.25	25.9	37.3	38.1	1.28	14.06	-8.57	-0.03	15.90	

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (µgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
4	6	25-Oct-91	15:41:06	4_4	625	2.67	24.1	35.8	34.9	1.72	15.61	-15.41	1.10	12.34	
4	7	25-Oct-91	17:35:50	4_5	623	2.23	20.0	26.1	26.1	1.80	12.72	-10.88	0.14	6.85	
4	8	27-Oct-91	09:15:54	4_1	619	1.85	20.2	32.9	27.5	2.61	6.24	-1.25	1.55	6.54	
4	9	27-Oct-91	11:23:45	4_3	617	1.50	25.5	36.7	38.2	1.83	9.76	-12.00	0.31	24.85	
4	10	27-Oct-91	13:01:52	4_4	625	1.69	28.1	41.7	41.9	0.52	8.33	-10.39	0.01	36.23	
4	11	27-Oct-91	14:52:25	4_5	623	1.62	27.7	41.0	39.3	0.53	8.54	-7.82	0.40	47.21	
4	12	28-Oct-91	09:40:40	4_1	619	1.41	26.0	38.4	31.4	0.40	6.26	-9.89	0.29	24.05	
4	13	28-Oct-91	11:30:47	4_3	617	1.19	30.0	41.1	39.8	0.63	6.51	-8.06	0.30	37.53	
4	14	28-Oct-91	13:17:00	4_4	625	1.18	32.6	46.1	43.4	0.57	6.92	-11.70	0.21	47.01	
4	15	28-Oct-91	15:12:18	4_5	623	1.15	30.3	42.3	38.9	0.56	10.26	-8.60	0.59	39.96	
4	16	28-Oct-91	16:48:00	4_2	630	0.80	27.4	36.7	34.0	1.29	7.80	-16.93	-0.54	18.99	
4	17	29-Oct-91	09:52:00	4_1W	619	2.31	33.0	42.2	37.2	0.64	24.27	-6.05	1.42	31.99	
4	18	29-Oct-91	11:32:40	4_3	617	2.41	32.0	40.1	36.6	0.79	10.41	-13.09	0.16	25.16	
4	19	29-Oct-91	13:06:12	4_4W	625	1.34	32.1	37.5	36.3	0.38	28.94	-8.66	0.43	23.41	
4	20	29-Oct-91	14:38:06	4_5	623	1.90	33.1	40.6	36.5	0.63	9.78	-10.95	-0.07	30.04	
4	22	30-Oct-91	09:58:28	4_1W	619	2.24	36.1	45.0	39.2	0.74	12.32	-8.26	0.83	21.89	
4	23	30-Oct-91	11:42:22	4_3	617	2.72	38.8	48.4	46.6	1.41	4.21	-10.87	0.08	53.12	
4	24	30-Oct-91	13:16:26	4_4W	625	2.34	39.2	49.6	49.1	1.10	27.76	-11.66	0.71	37.53	
4	25	30-Oct-91	14:53:40	4_5	623	4.06	33.6	47.9	46.2	2.01	8.19	-11.05	-0.55	44.89	
4	26	30-Oct-91	16:31:30	4_2	630	4.74	25.9	36.4	37.1	1.47	9.74	-8.52	-0.56	13.64	
5	4	24-Jan-92	10:32:46	5_1	120	1.65	27.9	38.7	35.5	0.22	2.57	-1.60	-0.06	19.67	
5	5	24-Jan-02	12:23:37	5_2	120	2.13	32.0	47.0	45.1	0.94	2.00	-3.89	0.19	30.76	0.55
5	6	24-Jan-92	14:26:53	5_3	132	2.03	33.7	48.4	49.0	0.88	2.87	-1.06	-0.03	41.99	0.46
5	8	25-Jan-92	10:10:20	5_3	132	2.21	25.2	34.4	33.1	0.89	3.84	-2.44	0.17	32.06	0.14
5	9	25-Jan-92	11:49:40	5_2	120	2.40	28.8	42.1	42.4	0.96	3.17	-4.04	0.05	30.94	0.18
5	10	25-Jan-92	13:26:20	5_3	132	2.24	31.7	46.1	49.5	0.89	3.67	-3.49	-0.05	69.49	0.23
5	12	25-Jan-92	16:43:20	5_4	124	2.68	31.3	44.0	45.3	0.96	5.26	-4.34	-0.01	26.16	0.21

Period	Static number	Date	Time Chamber Closed	Site	Chamber volume (L)	Wind Speed (m s^{-1})	Air Temp. (°C)	Chamber Temp. (°C)	Soil Temp. (°C)	Air Exchange Rate	CO_2 (µgC m^{-2} s^{-1})	CH_4 (ngC m^{-2} s^{-1})	N_2O (ngN m^{-2} s^{-1})	CO (ngC m^{-2} s^{-1})	NO_x (ngN m^{-2} s^{-1})
5	13	27-Jan-92	10:50:45	5_1	120	1.48	26.7	39.3	36.2	0.90	2.02	-2.07	-0.05	35.49	0.30
5	14	27-Jan-92	12:33:06	5_2	120	1.36	30.2	46.1	44.1	0.89	3.10	-3.24	0.14	35.52	0.48
5	15	27-Jan-92	14:15:25	5_3	132	2.36	32.0	46.4	47.9	0.90	3.14	-3.29	0.14	62.87	0.49
5	17	27-Jan-92	17:20:50	5_4	124	2.42	32.2	42.3	43.8	0.94	3.36	-2.80	0.12	18.58	
5	18	28-Jan-92	10:06:00	5_1W	120	2.18	23.0	30.3	30.7	0.95	3.17	-1.73	0.16	5.47	1.63
5	19	28-Jan-92	11:36:15	5_2	120	2.32	27.3	39.5	37.8	0.96	2.44	-3.08	0.00	25.31	0.51
5	20	28-Jan-92	13:08:33	5_3	132	2.56	30.0	43.4	43.9	0.91	2.17	-3.50	-0.07	53.23	0.48
5	22	28-Jan-92	16:15:10	5_4W	124	2.88	31.5	43.1	44.5	0.98	13.65	-3.07	0.78	13.10	7.99
5	23	29-Jan-92	10:11:12	5_1W	120	2.22	23.4	31.4	30.8	0.95	7.36	-2.56	-0.05	5.74	0.77
5	24	29-Jan-92	11:36:00	5_2	120	2.17	27.8	39.4	37.7	0.95	3.18	-4.55	0.02	27.05	0.20
5	25	29-Jan-92	12:57:20	5_3	132	1.57	31.7	44.3	43.5	0.84	2.56	-3.17	0.00	56.66	0.23
5	27	29-Jan-92	16:09:50	5_4W	124	1.95	34.2	45.0	45.1	0.91	6.28	-4.19	0.23	17.52	3.15

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